The Institution of Engineers of Kenya
Founded 1972
IEK

Engineering in KENYA

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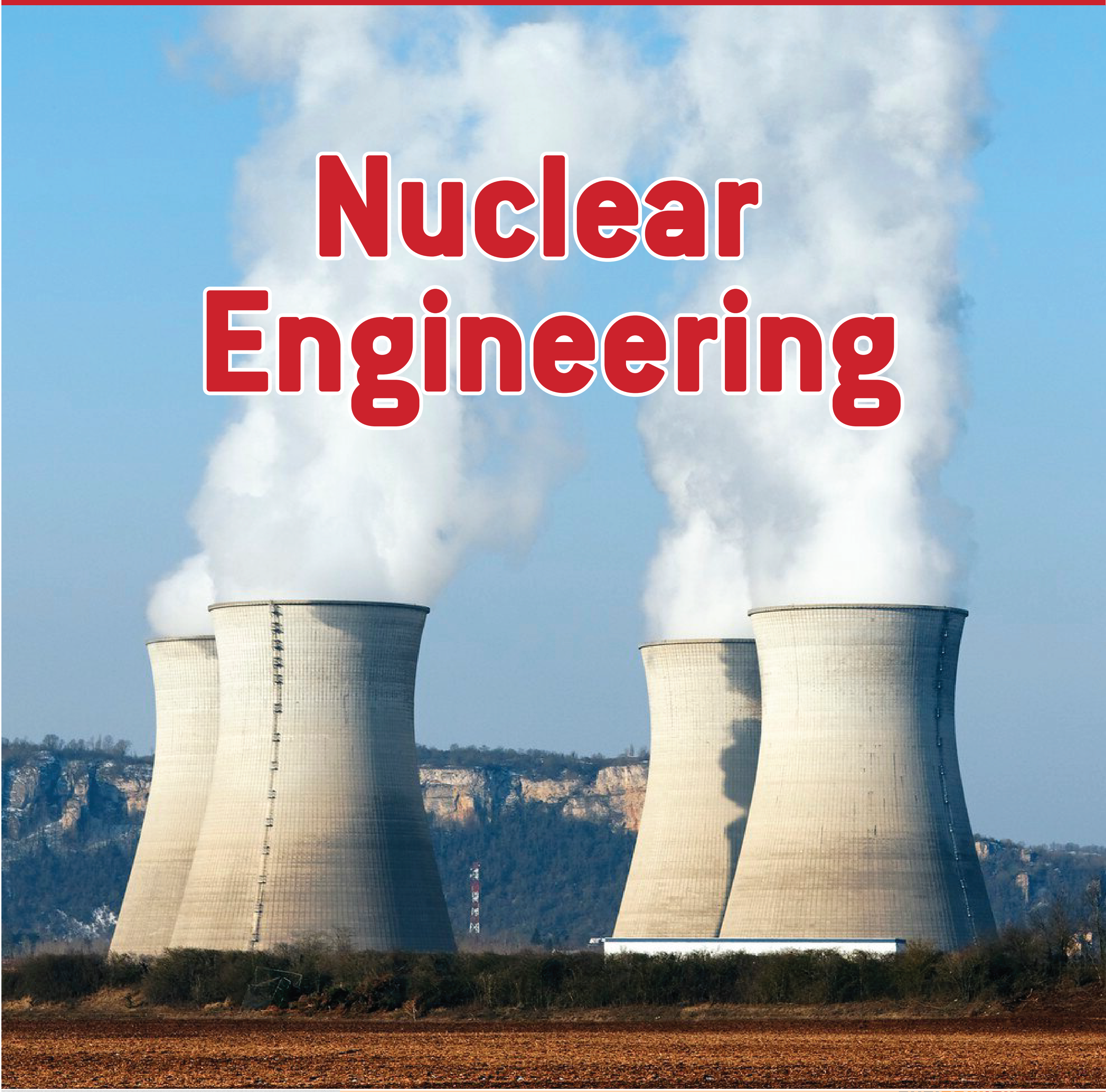
Nuclear Engineering



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Wasini/Mkwiro Solar Mini Grid Kwale County
737 Kilowatts per hour
The project was commission by
H.E. President William Ruto
on 02/11/2023

REREC
Rural Electrification and Renewable Energy Corporation

Mini-grid sites, generation capacity and estimated number of customers

No	Mini Grid Site Name:	County:	Constituency	Plant Capacity (kWp)	No. of Customer Connections
1	Takawiri	Homa Bay	Suba North	207.36	415
2	Ngodhe	Homa Bay	Suba North	149.04	223
3	Mageta	Siaya	Bondo	801.9	1744
4	Wasini/Mkwiro	Kwale	Lunga Lunga	737.1	625
5	Kerio	Turkana	Turkana South	58.32	227
6	Kaeris	Turkana	Turkana North	58.32	186
7	Dabel	Marsabit	Moyale	58.32	613

The projects are serving in excess of **3,950** customers and provide other socio-economic benefits to communities living in these areas in education, health, entrepreneurship, employment, communication, water pumping and food preservation.

WEBSITE: www.rerec.co.ke
ADDRESS: Kawi House, Off Red Cross Road, South C
PHONE: (+254) 709 193 000 / 3600
EMAIL: info@rerec.co.ke

RERECKenya @RERECMashinani @rerec_kenya @RERECMashinani

In this Issue

Engineering in KENYA

Call for Papers

Engineering in Kenya Magazine - Issue 016

The Institution of Engineers of Kenya (IEK) publishes Engineering in Kenya magazine, whose target audience includes engineering professionals, practitioners, policymakers, researchers, educators and other stakeholders in engineering and related fields. The publication is distributed to its target readers free of charge through hard and soft copies.

IEK invites you to contribute articles for our next and future editions. Articles should reach the Editor not later than 20th March, 2024 for our next issue, whose theme shall be "Trade in Services" and related sub-themes, across all engineering disciplines. An article can range from engineering projects to processes, machinery, management, innovation, news and academic research.

The articles must be well researched and written to appeal to our high-end readers in Kenya and beyond. The IEK Editorial Board reserves the right to edit and publish all articles submitted, in line with standing editorial policy. All articles should be in Word document format, 500-700 words, font type Times New Roman and font size 12.

Send your article today, and get a chance to feature in the magazine!

Send your article to:
editor@iekenya.org

Eng. Prof. Lawrence Gumbe

Message from the Editor

Nuclear engineering is the engineering discipline concerned with the design, development and operation of systems that make use of the energy released by nuclear processes. Nuclear engineering is used in electricity generation, agriculture (plant breeding, fertiliser production, pest control), food preservation through irradiation, smoke detection, production of non- stick kitchenware, non-destructive testing of materials, carbon dating in archaeology, instrumentation and inspection in industry and diagnosis and therapy in medicine.

Nuclear power is an important low-emission source of electricity, providing about 10% of global electricity generation. For those countries where it is accepted, it can complement renewables in reducing power sector emissions while also contributing to electricity security as a dispatchable power source. It is also an option for producing low-emission heat and hydrogen.

The Nuclear Power and Energy Agency (NuPEA) is a State Corporation in Kenya established under the Energy Act 2019. It is charged with the responsibility of promoting and implementing Kenya's Nuclear Power Programme, carrying out research and development for the energy sector.

Towards attainment of its mandate, the Nuclear Power and Energy Agency, NuPEA, shall develop policies and legislation, undertake public education and awareness, identify suitable sites for the construction of Nuclear Power Plants; carry out research, development and innovation on energy technologies as well as capacity building for the energy sector.

NuPEA is currently in the process of undertaking siting studies to identify suitable locations for nuclear power plants in Kenya and developing the legislative and regulatory framework for a nuclear power programme. Indeed, the Nuclear Regulatory Bill that will transform the Radiation Protection Board (RPB) into the regulator is currently before Parliament.

NuPEA has facilitated training of more than two dozen Kenyans in Nuclear Power Engineering in South Korea. Seven others have studied for the Diploma in Nuclear Law in Montpellier, France. This is all part of a comprehensive capacity building programme for the Nuclear Power Programme. Further, NuPEA is undertaking stakeholder involvement, public awareness and sensitization.

In the future outlook, plans are ongoing towards construction of a research reactor at Konza Technopolis, which will be used for training and production of medical radioisotopes for therapy of cancer and other diseases.

Kenya Nuclear Regulatory Authority (KNRA) is a public entity established under Section 5 of the Nuclear Regulatory Act No. 29 of 2019, which commenced on 10th January 2020, to provide protection of persons, property and the environment against the harmful effects of ionizing and non-ionizing radiation through the establishment of a system of regulatory control.

Electricity consumption in Kenya is about 160 kWh/capita. The country's Vision 2030 wishes to transform it into a middle income economy by the year 2030. This implies that electricity consumption should rise to about 4,345 kWh/capita. Kenya currently generates electricity through hydropower, geothermal power, thermal power and renewable sources, mainly, solar and wind.

The current generation capacity is about 3,300 MW. The projected Vision 2030 installed capacity is 60,531MW. A 2016 study indicated that a judicious Vision 2030 generation source mix would be: geothermal at 26%; nuclear at 19%; coal at 13 %; liquefied natural gas (LNG) at 11%; thermal at 9%; wind at 9%; hydropower at 5%; imports at 5 %; and solar at 3%.

Nuclear engineering is important to many sectors of an industrialising Kenya. The country cannot ignore it.

Development of nuclear engineering in Kenya will require investment in infrastructure, education and human resource development, and political will.

Picture: Courtesy

Message from the President

Eng. Erick Ohaga, CE, FIEK, MKIM, AMCIARB (UK)

Welcome to the 15th Edition of the *Engineering in Kenya Magazine*. The Institution of Engineers of Kenya sends warm wishes to all as we embark on the new year filled with numerous planned activities.

The Institution of Engineers of Kenya (IEK), in collaboration with Engineers Board of Kenya (EBK), successfully organized its 30th IEK Annual International Convention, themed "Engineering a new world", from November 14th to 17th, 2023. During the same period, Kenya represented by IEK hosted the 18th World Council of Civil Engineers (WCCE) General Assembly. Over 4,000 delegates were in attendance.

The Deputy President of the Republic of Kenya, Hon. Rigathi Gachagua, set the tone for the convention at the official opening as the chief guest. In his opening statements, he emphasized the crucial contribution of qualified professional engineers. The Cabinet Secretary for the Ministry of Roads and Transport, Hon. Kipchumba Murkomen as well as Eng. Joseph M. Mbugua, the Principal Secretary for Roads alongside other Principal secretaries and political leaders were present. The convention attracted delegates from the global stage, led by Presidents from equivalent professional engineering institutions around the world.

IEK has been a cornerstone of the engineering community, contributing significantly to the growth and development of the profession. As we approach the upcoming 2024 IEK Council Elections, I urge Corporate and Fellow members to consider vying for positions within the Council. Serving on the IEK Council not only provides an avenue for giving back to the profession, but also offers a platform to collaborate with like-minded individuals who share a common goal of promoting excellence in engineering. The strength of our institution lies in the diversity of talents, experiences, and perspectives that our members bring. Actively participating in the Council offers you have the opportunity to shape the future direction of IEK, influence policy decisions, and contribute to the advancement of engineering in our great nation.

This issue of the *Engineering in Kenya* magazine dedicated to *Nuclear Engineering* is a field of paramount importance for our nation's sustainable energy future. The challenges of the 21st century require inventive solutions, and nuclear engineering shows great potential in meeting our nation's expanding energy requirements. It is essential for engineers to continue playing an active role in shaping the narrative and promoting a holistic comprehension of the advantages and challenges associated with nuclear energy.

In a global landscape marked by escalating energy challenges and a scarcity of viable energy resources, the adoption of nuclear energy holds promise for mitigating and resolving power shortage issues. It's dependable and uninterrupted power generation capabilities position nuclear energy as a reliable solution. This form of energy offers a consistent power supply, minimizing reliance on unpredictable weather conditions. To fully harness the potential of nuclear power, it is essential to have proficient and skilled personnel. The Institution of Engineers of Kenya aims to facilitate partnerships with nuclear agencies, establishing programs dedicated to enhancing the expertise of engineers in nuclear engineering. These initiatives will emphasize skill development and continuous learning.

Kenya, with its vision for economic development and environmental sustainability, recognizes the immense potential that nuclear energy holds. Our commitment to advancing nuclear technology is not just about embracing a new form of energy but also about empowering our engineers and scientists to take the lead in developing cutting-edge solutions. It is about fostering a culture of research, innovation, and collaboration that positions Kenya as a regional leader in nuclear engineering.

As Kenya advances towards its goal of having a nuclear power plant, the role of engineers cannot be overstated. The implementation of a nuclear power plant necessitates cutting-edge technological solutions. Engineers are at the forefront of adopting innovative reactor designs, advanced control systems, and safety features that align with international standards. Continuous research and development initiatives actively contribute to the ongoing enhancement of nuclear technology, guaranteeing that Kenya maintains a leading position in the secure and effective generation of nuclear power.

Kenya has made significant strides in deploying the first nuclear power plant following the evaluation published by the International Atomic Energy Agency (IAEA). This follows intense analysis of the development of the key infrastructure issues. The evaluation has promoted Kenya to Phase II of the IAEA's milestone approach.

In this issue, you will find insightful articles and interviews highlighting the strides Kenya has made in the field of nuclear engineering. I encourage every reader to delve into the pages of this magazine, absorb the knowledge, and actively participate in the discussions related to nuclear engineering.

I thank the Engineers Board of Kenya, our major stakeholder for the continued support and collaboration, as well as all our contributors and sponsors whose content ensures our members stay well-informed.

30th IEK Annual International Convention

The Institution of Engineers of Kenya (IEK) in collaboration with the Engineers Board of Kenya (EBK) hosted the 30th Annual International Convention from November 14th to 17th, 2023. The Convention was held in conjunction with the 18th Assembly of the World Council of Civil Engineers (WCCE). Over 4,000 delegates exchanged knowledge, on global trends Engineering Innovation, Research and Policy.

The Deputy President of the Republic of Kenya, Hon. Rigathi Gachagua, graced the opening ceremony where the Cabinet Secretary for the Ministry of Roads & Transport, Hon. Kipchumba Murkomen also made remarks. Newly inaugurated World Federation of Engineering Organization (WFEO) President, Eng. Mustafa Shehu, made his first oversees official visit in attendance.

After the official opening, the Deputy President, Hon. Rigathi Gachagua, joins Engineers Board of Kenya led by Eng. Erastus Mwongera and IEK Council led by Eng. Eric Ohaga. Also present, Roads & Transport CS Hon. Kipchumba Murkomen and PS Roads Eng. Joseph Mbugua.

Roads and Transport CS Kipchumba Murkomen gives remarks at the opening ceremony of 30th IEK Annual International Convention. Over 4,000 local and International delegates attended

L-R: Deputy President of the Republic of Kenya Rigathi Gachagua, IEK President Eng. Erick Ohaga, WFEO President Eng. Mustafa Shehu and WCCE President Ing. Jorge Emilio Abramian follow proceedings.

Convention organizers led by IEK President Eng. Erick Ohaga and Chairman Engineers Board of Kenya Eng. Erastus Mwongera lead tree planting exercise on 13th November 2023, the National Tree Planting Day.

Eng. Margaret Ogai, Registrar/CEO Engineers Board of Kenya, makes remarks on mentorship for girls and women in STEM during the Women Engineers Summit on the 14th November 2023. She was flanked by past WEC chairpersons (LR) Eng. Grace Kagondu, Eng. Rosemary Kung'u, Eng. Christine Ogut and current chair Eng. Flora Kamanja.

Delegates follow proceedings.

Message from the Honorary Secretary

Eng. Shammah Kiteme, CE, MIEK

Kenya gave herself the goal of establishing a nuclear power plant as part of expanding power generation capacity. Since then there have been steps undertaken to build the capacity and meet the stringent international requirements to be able to acquire the technology and operate a nuclear power plant.

There is demand for power in Kenya and this is growing. The recent national power black outs point to the need for stability of the grid that will guarantee that businesses can trust the utility provider to provide power uninterrupted. Currently, businesses have to invest heavily in power back up systems due to frequent power black outs.

With the current mix of geothermal, hydro power generation, thermal, wind and solar the addition of nuclear power generation promises to add to the diversification of the energy sources for the country.

Nuclear power plants are complex and engage a lot of engineers to construct and operate. So this presents opportunities for engineers. They also provide a fairly stable power compared to other sources as along as fuel for the reactors is available. On the other hand, they provide a challenge of safe operation which calls for a high degree of skills and preparedness to run them.

Nuclear power plants provide a challenge for managing the nuclear waste that will be generated from the reactors.

In the wake of these realities, a number of countries that have been operating nuclear power plants have opted to shut them down. This is especially after the fukushima daichi power plant meltdown occasioned by the earthquake and subsequent tsunami that his japan in 2011.

Germany has also switched off a number of her nuclear power plants as a result of the events in Japan. Another problem with nuclear power plants is in times of war they pose a great risk. The war in Ukraine has exposed the Zaporizhzhia nuclear power plant to such a situation where if hit with an ammunition and meltdown happens leading to a nuclear accident, it would be catastrophic. On March 4 2022, the plant was shelled underscoring the danger Russia-Ukraine war posed to the nuclear power plant.

All these realities must inform the country as we pursue the nuclear technology.

The advantages must outweigh the disadvantages and the Nuclear Power Energy Agency (NuPEA) has to lead these efforts to deliver the Kenyan dream safely and successfully.

We have many of our members taking lead in this effort and we are sure that their careful planning will lead to this dream coming true.

Several other ways we use nuclear technology include in medicine where brachytherapy is used to treat cancer. This technology continues to be used in medicine in a branch of medicine called Nuclear Medicine. This area will continue to dominate our conversations particularly so as cancer has emerged as the second leading non-communicable disease causing death globally. In a study done by World Health Organisation (WHO) cancer emerged second to cardiovascular diseases in causing deaths from 1990 – 2021.

Whether in nuclear power generation, nuclear medicine or other applications of nuclear technology, engineers will be involved and at the forefront.

This issue of Engineering in Kenya magazine therefore brings to fore nuclear technology as a critical part of our lives now and in the future. I now invite you to interact with wonderful content that will inform, educate and entertain you our reader in this issue of Engineering in Kenya Magazine.

ENGINEERING PARTNERSHIPS CONVENTION | 2024

The 5th Engineering Partnerships Convention

Engineering@60: Reflections, Response, Resetting

As Kenya celebrates 60 years of independence, engineering has not been left out. It has been through 60 years of thoughtful, pioneering, insightful, exciting, dynamic and progressive delivery of infrastructure, processes and systems.

There is need to take stock, reflect and celebrate the achievements. Respond to the emerging trends, reset to address current national and global challenges, and look forward to the next 60 years of engineering being at the heart of innovation, infrastructure development and technological advancements.

The 5th EPC 2024 themed ***"Engineering@60: Reflections, Response, Resetting"*** aims to provide a comprehensive platform for engineers, scientists, innovators, and stakeholders to engage in meaningful discussions, knowledge exchange, and envision the future of engineering. The Convention will be held on **7th – 10th May 2024 at Dedan Kimathi University of Technology, Nyeri County**. The Convention seeks to achieve the following objectives:

i. Showcase Kenya's engineering innovations;
ii. Reflect: Celebrate and honor the accomplishments and milestones in engineering over the past 60 years;
iii. Respond: Address the current global challenges and explore how engineering can contribute to solving them;
iv. Reset: Strategize for the future, setting new goals and directions for the engineering field; and
v. Collaboration: Foster collaboration and networking among professionals, innovators, researchers, policy makers, academia and organizations.

The 5th EPC is unique as it will for the first time incorporate an **Innovation Fair** themed "***Engineering the Future: Sustainable Innovations for a Connected World."*** The aim of the Innovation Fair is to provide a platform that showcases creativity, ingenuity, and technological advancements made in engineering by inventors, entrepreneurs, researchers, and innovators to display their cutting-edge ideas, products, and solutions. The primary objectives of the Innovation Fair are as follows:

i. Foster Innovation: Encourage and promote a culture of innovation among individuals and organizations.
ii. Knowledge Sharing: Facilitate the exchange of ideas, best practices, and knowledge among participants.
iii. Collaboration: Create networking opportunities for potential collaborators, investors, and partners.
iv. Public Awareness: Raise awareness about the importance of innovation in addressing contemporary challenges.

EPC 2024 will be exciting, innovative and informative. Join us for the plenary sessions, technical sessions, workshops & tutorials, panel discussions, innovation fair, and networking opportunities.

Ministry of Roads and Transport

Key Activities

Plenary Sessions

Renowned speakers to reflect on engineering achievements and challenges.

Technical Sessions

Presentations and discussions on cutting-edge research and innovations.

Workshops & Tutorials

Hands-on sessions on emerging technologies and skills.

Panel Discussions

Engage in debates on critical issues and future trends in engineering.

Innovation Fair

Showcase innovative engineering solutions, products, and projects.

Networking Opportunities

Facilitate connections and collaborations among attendees.

Event Details

The event details are as follows: -

7th - 10th May 2024

Nyeri County

Charges	Virtual - Kshs. 10,000 | Physical - Kshs. 50,000
Exhibition Tent	Kshs 200,000 for a 3x3 Booth

NUCLEAR ENERGY IN KENYA

An Interview with
CS. Justus Wabuyabo

Chief Executive Officer,
Nuclear Power & Energy Agency

Nuclear Engineering and Technology:

1 ***Could you elaborate on the technological advancements and innovations in nuclear engineering that are relevant to Kenya's energy needs?***

Nuclear technology has continued to advance since its inception in the peaceful civilian uses. The advancement is to enhance nuclear safety, efficiency and sustainability of the nuclear technology. Globally, engineers are working on next-generation reactor designs that aim to improve safety, reduce nuclear waste, and enhance overall efficiency. Concepts like small modular reactors (SMRs), thorium reactors, and fast breeder reactors are being explored for their potential advantages. These SMRs have inherent passive safety features that utilize gravity to prevent any unlikely event that may lead to a radiological release hence making them even safer and cheaper to run and fits in smaller electric grid. In this context, Kenya is aiming to satisfy her energy demand through nuclear technology and therefore going for the safest and reliable technology is the goal for the Nuclear power and Energy Agency. Therefore, this advancement presents a chance for the Kenya engineering fraternity to join the global engineers to develop better nuclear technologies.

2 ***What safety measures and protocols are being implemented to ensure the safe and responsible utilization of nuclear energy in Kenya?***

Kenya is a member state of the International Atomic Energy Agency (IAEA) which provides internationally accepted guidelines for safe and peaceful utilization of nuclear energy worldwide. Kenya leverages on the high level expertise of the IAEA and follows the guidelines for safe deployment of nuclear power plants. The country also abides by international agreements on safety and safeguards to ensure safety of nuclear materials.

Kenya is a signatory to a number of a number of treaties and conventions such as the Pelindaba treaty, Treaty on Nonproliferation of nuclear materials (NPT), Bamako convention among others. Other treaties that the country is in the process of signing include convention on nuclear safety, convention on nuclear liability among others.

Education and Training in Nuclear Engineering:

3 ***What efforts are being made to promote education and training in nuclear engineering within Kenya, both in academic institutions and through professional development programs?***

Currently, the Agency runs a campaign in schools for the promotion of Science, Technology, Engineering, Mathematics (STEM) subjects in both primary and secondary levels. The Agency has also collaborated with local and international universities to train Kenyans in nuclear science and technology. Through these programs a number of Kenyans have been trained in the Republic of South Korea, China, Russia and USA in nuclear engineering. In local universities, the country in collaboration with universities such as the University of Nairobi, Kenyatta University is developing undergraduate and graduate programs on nuclear engineering, nuclear science and technology to train young Kenyans in the fields of nuclear engineering. The Agency also runs a program for young engineers where they are attached to engineering firms for professional growth. The establishment of the Kenya Advance Institute of Science and Technology (KAIST) at Konza Techno polis will be the model Kenyan institute that will be offering nuclear engineering and ensure that the country has built the necessary human capital to safely and effectively run the nuclear power plant and the research reactor.

4 ***How is the Nuclear Power and Energy Agency collaborating with local and international partners to enhance expertise and skills in nuclear engineering among Kenyan professionals?***

NuPEA has collaborated with international partners such as the IAEA, USA, China, South Korea and Russia in areas of capacity building for professional development in the areas of nuclear science and technology. A number of Kenyans have been trained on short term, fellowships and long term courses that are run in these countries.

Community Engagement and Public Perception:

5 ***How is the Nuclear Power and Energy Agency addressing public concerns and perceptions about nuclear energy, ensuring transparency and fostering community engagement?***

In carrying out its stakeholder engagement and public education activities to increase awareness of the nuclear power programme, the Agency has undertaken Conferences in Kenya such as, The National Energy Conference 2014; Third Regional Conference on Energy and Nuclear Power in Africa, 2015; Kenya Nuclear Energy Week & Regional Conference; International Conference on nuclear energy, 2017; African Business Platform 2019, Nuclear Students Ambassadors Programme and Mentorship 2021, Essay Contests 2020 and 2023.

The Agency has undertaken extensive engagement with the concerned stakeholders during the Strategic Environmental Assessment (SESA) of Kenya's nuclear power programme, and enactment of the Nuclear Regulatory Act 2019. Further the Agency established a project coordinating office in Mombasa County, to undertake structured stakeholder engagements and siting activities. The engagements are specific to the Coastal region, with a focus on the host community. This is to ensure that the stakeholders' interests, expectations and concerns are factored into the decision-making process.

Additionally, the Agency engages the public through social media as well as mainstream media to inform/ educate the public of the facts and demystify the myths behind peaceful application of nuclear technology. So far the public is getting a better understanding of peaceful application of nuclear technology in the country and this is playing a significant role in the acceptance of the programme.

6 *What outreach programs or educational initiatives are being conducted to inform and involve the public in discussions about nuclear engineering's role in Kenya's energy future?*

NuPEA is currently engaging educational institutions in championing for the uptake of STEM subjects in primary and secondary schools. The Agency has an ongoing program of identifying and training student ambassadors for the STEM subjects and the nuclear power program.

The Agency has also previously participated in various forums, including science and engineering fairs, school talks, and supporting organizations such as Women in Nuclear, which encourages girls to engage in STEM subjects, and Kenya Network for Nuclear Education Science and Technology (KEN-NEST) under AFRA-NEST whose role is to have a network of institutions offering education in nuclear science and technology, thus it is supporting researchers in tertiary institutions. The overall goal of these efforts is to actively involve students in pursuing STEM subjects, ultimately leading to advancements in nuclear technology.

Future Outlook and Sustainability:

7 *What is the long-term vision for nuclear energy in Kenya, and how does it align with the country's sustainable development goals?*

Kenya's long term vision for nuclear is to produce baseload power from nuclear power as per the Least Cost Power Development Plan (LCPDP). The LCPDP projects that Nuclear power will be injected in the electric grid by 2032 at a capacity of 1000MWe and followed incrementally in subsequent years as the energy demand grows.

Kenya's nuclear power program aligns itself with 9 of the 17 sustainable development goals which include zero hunger through nuclear technology, good health and wellbeing, clean water and sanitation, affordable and clean energy, industry innovation and infrastructure, climate action through reduction of greenhouse gas emissions, Life below water, Life on land and partnership for the goals.

Kenya's vision 2030 identifies energy as an enabler to its achievement. Nuclear power has been identified as affordable and reliable source of baseload energy that will be used to power the flagship projects in the Vision 2030 blueprint.

8 *Could you discuss potential collaborations or partnerships aimed at advancing nuclear engineering research and application for sustainable energy in Kenya?*

NuPEA is looking out to collaborate with other institutions to enhance professional development in all relevant areas of the nuclear field. The Agency is therefore looking out to collaborate with professional bodies/ societies such as the Institution of Engineers of Kenya, Law Society of Kenya, ICPAK, Geological Society of Kenya among others. These collaborations are aimed at dissemination of information and sharing of knowledge and expertise for mutual growth.

In addition, Kenyatta University in collaboration with the Kenya Nuclear Regulatory Authority hosts a Postgraduate Educational Course (PGEC) on Radiation Protection and the Safety of Radiation Sources for African English-speaking Countries. NuPEA is a key stakeholder in this program and

NuPEA Chairman Mr Ezra Odhiambo (L), Energy PS Mr Alex Wachira (2nd L) NuPEA CEO CS Justus Wabuyabo (2nd R) and Energy and Petroleum CS Mr Davis Chirchir pose for a photo after signing the Performance Contract for the FY2023/24 between NuPEA and the Ministry of Energy and Petroleum at Kawi Complex.

NUCLEAR SCIENCE AND TECHNOLOGY FOR DEVELOPMENT

By EiK Correspondent

Nuclear

When the term "nuclear" is mentioned, what comes to your mind? For some, Nuclear Engineering conjures images of apocalyptic scenarios, a world-ending technology. Other, however, view it as a sophisticated technology, exclusive to superpower nations. It's crucial to challenge the notion that nuclear science is dispensable or distant from our everyday lives. In reality, nuclear science is intricately woven into the fabric of our daily existence. Nuclear Science is synonymous with Radioactivity, a phenomenon that encompasses both natural and man-made aspects. It is a constant presence in our environment.

But what exactly does the term 'nuclear science and technology' encompass? It refers to the principles and wide-ranging applications of nuclear energy and radiation. These technologies are not just limited to power generation; they extend their benefits to fields as diverse as medicine, industry, and agriculture, profoundly impacting various aspects of modern life.

History

The historical development of nuclear science and technology is a tale of groundbreaking discoveries and transformative applications, shaping the world as we know it today.

The development of atomic radiation, atomic change, and nuclear fission spanned from 1895 to 1945, with significant advancements occurring in the final six years of this period. Between 1939 and 1945, the majority of this development was concentrated on the atomic bomb, an aspect that unfortunately dominates public perception of nuclear science. However, post-1945, the focus shifted to harnessing nuclear energy for beneficial purposes. Efforts were directed towards utilizing this energy in a controlled manner for naval propulsion and electricity generation. Since 1956, the emphasis has been on the technological advancement of reliable nuclear power plants, marking a significant shift in the application and perception of nuclear technology.

Current State of Technology:

Breakthroughs in computing, engineering, and physics in recent decades have greatly increased the contribution of nuclear science and technology in areas as diverse as healthcare, energy, and environmental protection. The growing versatility of nuclear applications is helping countries to tackle a host of existing and emerging challenges.

Three generations of nuclear power systems, derived from designs originally developed for naval use beginning in the late 1940s, are operating worldwide today. Improved designs of nuclear power reactors are constantly being developed internationally. The first so-called Generation III advanced reactors have been operating in Japan since 1996. These have now evolved further. Newer advanced reactors now being built have simpler designs which are intended to reduce capital cost. They are more fuel efficient and are inherently safer. Many new designs are small – up to 300 MWe.

At COP28, a major highlight was the focus on technological innovation, particularly in enhancing nuclear safety and reducing the high investment costs typically associated with the construction and operation of nuclear power plants. A significant development in this area is the active participation and support of prominent industry leaders, such as Bill Gates, Chairman of TerraPower. TerraPower, NuScale Power, and other companies are leading the development of Small Modular Reactors (SMRs), an innovative technology that stands to revolutionize the nuclear energy industry. The push for SMRs, noted for their compact size and modular design, addresses many of the traditional challenges in nuclear power adoption, such as the need for substantial initial capital and complex construction processes.

Applications Beyond Power Generation

Medicine: In medicine, nuclear technology has become indispensable. It's used in high-dose radiation therapy for cancer treatment, in sophisticated diagnostic imaging techniques like PET and CT scans, and in the application of radioisotopes for a range of diagnostics.

Nuclear technology is making a profound impact in agriculture, a sector where its contributions are particularly noteworthy. At the forefront of this agricultural revolution is mutation breeding, a process that utilizes radiation to modify plant genetics. This innovative technique has facilitated the creation of crop varieties more resilient to the challenges brought on by climate change. These new strains are better equipped to endure extreme weather conditions, pests, diseases, and they require fewer chemical inputs such as pesticides and fertilizers. This not only enhances crop yield but also contributes to a reduced agricultural carbon footprint.

In Kenya, a standout example of this progress is seen in the work of Prof. Mirium Kinyua, who has effectively employed nuclear techniques to transform wheat farming. Her pioneering efforts have led to the development of a wheat variety that is both high-yielding and drought-resistant. This breakthrough is particularly beneficial for small farming families, allowing them to cultivate productive harvests on land previously considered unsuitable for wheat farming. The impact of this innovation extends beyond agricultural advancements, offering significant social and economic benefits to the region.

Industry: The industrial applications of nuclear technology are vast, ranging from non-destructive material testing and analysis, like radiography, to quality control in manufacturing and the use of radioactive isotopes in various gauging applications such as checking integrity of pipeline welds.

Environmental Applications: In environmental management, nuclear technology aids in tracing pollutants, studying climate change patterns, and radioactive dating, providing valuable insights into the history and dynamics of our planet.

Sterilization: Lastly, the sterilization of medical equipment using gamma radiation underscores the critical role of nuclear technology in healthcare safety and hygiene.

In summary, the journey of nuclear science and technology from its early 20th-Century origins to the present day is marked by constant innovation and expansion into various fields. From powering nations and exploring the Cosmos to fighting cancer and preserving food, its impact is both profound and pervasive.

Safety and Regulation

A human activity that involves both hazards and benefits calls for a strict legal framework with more of prohibition than regulation. Thus, a basic feature of nuclear energy legislation is its dual focus on risks and benefits.

As is well known, nuclear energy poses special risks to the health and safety of persons and to the environment, risks that must be carefully managed. However, as already demonstrated nuclear material and technology also hold the promise of significant benefits in a variety of fields, from medicine and agriculture to electricity production and industry.

Therefore, the primary objective of this framework is to ensure that all activities related to nuclear energy and ionizing radiation are conducted in a way that:

a. Adequately Protects Individuals: Ensuring the safety and health of people is a paramount concern. The framework establishes regulations and guidelines to minimize risks associated with nuclear energy and ionizing radiation.

b. Safeguards Property: It includes measures to protect properties from potential damage or contamination due to nuclear activities, ensuring that these activities do not adversely affect assets.

c. Cares for the Environment: The framework prioritizes environmental protection, mandating that all nuclear and radiation-related activities are carried out in a manner that mitigates environmental impact and promotes sustainability.

The Nuclear Regulatory Act, No. 29 of 2019, establishes a comprehensive framework for the regulation of the safe, secure, and peaceful utilization of atomic energy and nuclear technology in Kenya. The Kenya Nuclear Regulatory Authority is designated as the competent authority responsible for overseeing and enforcing this framework.

International aspects of nuclear science and technology

Nuclear energy, due to its inherent risks of radiological contamination, stands out among human activities for its potential to cause cross-border damage. This has led to the development of an international law framework specific to nuclear energy, shaped both regionally and globally through bilateral and multilateral instruments.

International Atomic Energy Agency (IAEA)

The IAEA helps countries to take full advantage of nuclear science and technology

To improve the lives of their people and care for the environment. The Agency is uniquely equipped to assist countries in building their capacity, knowledge and expertise, as well as in tapping into the latest developments in nuclear applications

Empowering Mashinani:

Launch of Nyanza Branch Signals Growth, Opportunity for IEK.

By EiK Correspondent

The Institution of Engineers of Kenya (IEK) launched its 8th branch in December 2023 in Nyanza Region, a significant milestone. The branch was curved out of the larger Western Branch. The launch marks a pivotal moment in IEK's journey towards empowering engineers and fostering growth in Kenya's engineering landscape.

The launch of the Nyanza Branch, presided over by the 1st Vice President of IEK Eng. Grace Kagondu, represents a strategic step in the institution's journey to decentralize services and extend professional training and opportunities across the country. The branch joins the already existing branches: Capital Branch, North Eastern Branch, South Rift Branch, Coast Branch, North Rift Branch, Western Branch, and Central Branch. The branches ensure that engineers in every corner of Kenya have access to resources and support necessary for their professional growth and development.

On the occasion of the launch, IEK hosted a Professional Interview Preparation seminar—a testament to the institution's dedication to equipping graduate engineers with the essential skills needed for a successful transition into the realm of professional engineering. Reflecting on past initiatives, IEK's commitment to fostering expertise has been evident through various training programs, including the Solar T2 training, AutoCAD and Civil 3D training, and Project Management Professional Training, among others. These programs have been pivotal in elevating the capabilities of engineers across diverse disciplines.

The decision to establish the Nyanza Branch was a purposeful one. Recognizing the significant number of engineers in the Western and Nyanza counties, IEK strategically split the Western Branch and incorporated the Nyanza region to create a more vibrant and accommodative space. This move aims to not only bridge geographical gaps but also to provide equal opportunities for engineers in the region, ensuring they have access to the same professional growth and networking prospects as their counterparts in other parts of the country.

The Nyanza Branch launch aligns seamlessly with IEK's core pillars: welfare and membership, policy and advocacy, and the creation of opportunities for engineers. By extending its footprint into Nyanza, IEK is poised to further its mission of fostering a thriving community of engineers dedicated to excellence and innovation.

This expansion represents more than just the inauguration of a new branch; it symbolizes a collective commitment to nurturing talent, fostering collaboration, and propelling the engineering profession forward. The IEK's vision for a more vibrant and inclusive engineering community is now more attainable with the establishment of the Nyanza Branch.

As IEK's footprint continues to expand, the institution remains steadfast in its dedication to empowering engineers, advocating for their interests, and creating an environment ripe with opportunities for professional development and growth.

The inauguration of the Nyanza Branch stands as a testament to IEK's unwavering commitment to shaping a brighter future for the engineering profession in Kenya. Together, let us embrace this milestone and stride forward into a future where innovation, collaboration, and excellence define the engineering landscape in Nyanza and beyond.

Eng. Margaret Ogai, the Registrar/CEO EBK joins IEK Council Members and Nyanza Branch officials to cut the cake marking launch of the IEK Nyanza Branch in December 2023.

The Evolution of Nuclear Energy

By EiK Correspondent

Through intense research and innovation spanning more than a century, not only have we been able to obtain the said enormous amount of energy, but we have harnessed in for use in agriculture, space and naval exploration, forensics, medical research and treatment and energy production. The earlier research and application of nuclear energy focused mainly on nuclear weaponry. After the World War II, nuclear energy has mainly followed a more peaceful trajectory.

Discovery of Nuclear Fission

It was not until the 1930s, that Rutherford's wish came true, with the discovery and demonstration of nuclear fission. This discovery was the cumulative theoretical and experimental contribution and international collaboration of Scientists **Enrico Fermi, Niels Bohr, Otto R. Frisch, Albert Einstein, Lise Meitner, Otto Hahn and Fritz Strassman** among other notable names. Fermi's experiments demonstrated that neutrons could be split into atoms. Hahn and Strassman experimentally proved fission.

Meitner employed Einstein's theory to demonstrate that the lost mass post fission transformed into energy, thereby proving the occurrence of fission and confirming Einstein's work. This would form the foundation in nuclear energy exploration, innovation and developments of later decades.

Nuclear Energy in Warfare (1940s)

Once word spread on nuclear fission and the possibility of a self-sustaining nuclear reaction, scientists took a fervent interest in the application of nuclear energy in nuclear weaponry. The world was on the verge of the second war, and nuclear energy promised a strategic advantage in the conflict. November 1942 in the University of Chicago, a team led by Fermi built the first nuclear reactor, aptly named the Chicago Pile-1. The Chicago Pile-1 was made up uranium placed in a pile of graphite, with cadmium control rods. It reached criticality on 2 December 1942, thus ushering the world into the Nuclear Age.

Physicist and Army Lt. General **Robert Oppenheimer** played pivotal roles in developing the first atomic bomb under the Manhattan Project. This is the first and last time nuclear weaponry of such magnitude was deployed in war.

Atoms for Peace

The post-World War II ushered in an era that strove to use nuclear energy for peaceful exploits and the betterment of human society. Research into weaponry persisted on either side of the 'iron curtain', through which scientists gained critical knowledge and better understanding of nuclear energy. It soon became apparent that nuclear energy had applications that went far beyond the realms of weaponry. of great interest was the fact that the heat that the process produced could be harnessed for direct use or in generating electricity.

First Nuclear Power Plants (1950s-1960s)

By the 1950s, interest in nuclear energy for commercial purposes had peaked. With the USA's Congress' go ahead, the Experimental Breeder Reactor I (EBL-1) was built and successfully produced electricity in 1951. Though the electricity produced was negligible, this success heralded a shift in nuclear energy research which now mainly focused on electricity generation. Backed by **President Eisenhower's** "Atoms for Peace" program, this period saw a nuclear power revolution that set the stage for the rise of diverse reactor technologies.

By 1957, USA's first nuclear power plant for generating electricity in Pennsylvania was already running. The plant mainly used light water reactors which required ordinary water for cooling down the core during the chain reaction. This was the most preferred design for power plants at the time.

Admiral Hyman Rickover spearheaded the development of the Pressurized Water Reactors (PWR) whose design was widely replicated in the future reactors. The simple, compact design was especially useful in naval application.

In the early 1960s, General Electric developed the Boiling Water Reactors (BWR). They have since become the second most-preferred reactor type, with the first position being held firmly by the PWRS.

Across the pond, Britain successfully launched the world's first commercial nuclear power station in August 1956. This plant at Calder Hall played two major roles: to generate electricity and produce plutonium-239.

In the Soviet Union, work on nuclear power was just as impassioned. The city of Obninsk became the epicenter of nuclear power research, as it housed The Institute of Physics and Power Engineering (FEI) which was dedicated to developing nuclear power technology. The existing graphite-moderated channel-type plutonium production reactors were tweaked and reoriented it for electricity generation.

In 1954, the FEI delivered a historic milestone: the world's first nuclear power plant to generate electricity for a power grid. The reactor's design required water for cooling down and was moderated using graphite.

In the following year, FEI also worked on Fast Breeder Reactors (FBRs) and lead-bismuth reactors for naval use. The first of these FBRs was christened BR-1. BR-1 in itself produced no power, but paved way for the coming online of BR-5 in 1959.

The BR-5 contributed significantly to the conceptualization of sodium-cooled FBRs. The BR-5 has since graduated to the BR-10 whose current application includes testing fuel endurance and providing isotopes.

Nuclear Power Golden Era

The 1960s and 1970s were golden era of nuclear power generation and expansion. Once nuclear energy has been proven to be a viable and virtually inexhaustible source of energy, the commercial sector capitalized on it.

The public warmly welcomed an energy source that promised affordable and clean power. International collaboration was at its peak with scientists remaining committed to the course of the peaceful use of the atom.

15 countries boasted of 90 nuclear units by 1970. The growth spurt in the 70s was assisted by the high fuel prices, which made nuclear power an even attractive, secure energy source. By 1980 there were 253 plants spread across 22 countries.

Nuclear Power Fluctuation

Energy demand plummeted significantly in the 1980s as more countries started focusing on energy conservation. Technological cracks started to appear in the earlier nuclear power units. This slowed production as these hitches were addressed.

Electric power utilities which had acquired nuclear plants were coming alive to the reality that it was not easy to run these plants. Concerns on the safety of these plants and the impact they had on the environment began to spread, and was heightened by the Three Mile Island nuclear plant accident.

While there were no direct casualties, this incident led to more stringent regulatory requirements, which in turn resulted in longer approval periods and therefore, longer construction times of nuclear plants. Many projects were cancelled in the aftermath of this accident. The public perception of nuclear power took another major blow in the 1986 Chernobyl Disaster, which seemed to have proved its critics right.

Dark as they may seem, there has been a silver lining these accidents. They have created an avenue for learning from past mistakes, and inspired an international collaboration in sharing expertise, best practices and developing a regulatory framework that when followed promises safer nuclear facilities.

While the Fukushima Daiichi disaster was unfortunate, for instance, it was a tough lesson on emergency preparedness that led to the development of more effective communication systems, evacuation plans that have since been implemented in other nuclear facilities' response strategies.

They have also seen to the rise of advanced reactor designs with enhanced safety features. Modern reactors incorporate passive safety systems that can automatically respond to certain types of failures without depending on active human intervention.

Current Outlook On Nuclear Power

As of May 2023, there were 436 active nuclear reactors spread across 32 countries globally. Despite its drawbacks, this number is proof that nuclear power plays a significant role in producing the world's power. The United States is the largest producer of nuclear power. France takes up almost 70% of electricity generated by nuclear power.

In Africa, South Africa has the only operational reactor in the continent, though there are expansion plans in the pipeline. In Kenya, plans are underway to start the construction of its first nuclear power plant in 2027 as the country seeks to further diversify its energy generation.

IEK President Eng. Erick Ohaga led a delegation on a courtesy call to the acting CEO and Managing Director, Kenya Airports Authority, Mr. Henry Ogoye. The meeting discussed viable opportunities of partnerships and collaboration.

Trends and Opportunities in Nuclear Energy


Picture: Courtesy

By EiK Correspondent

Trends and Opportunities in Nuclear Energy

The energy production landscape is highly dynamic and evolves more and more by the minute. With all these new changes coming into the energy sphere, nuclear power stands out as a formidable contender that constantly evolves to meet the opportunities and challenges in this field. As we explore the trends currently shaping the nuclear sector, it becomes quite apparent that innovation serves both as a driving force and an exigent necessity for sustainable development.

Generation IV Reactors and Small Modular Reactors (SMRs)

One prominent trend that currently rocks the nuclear energy landscape is the exploration of cutting-edge nuclear technologies. The focus of this exploration is particularly on Generation IV Reactors and Small Modular Reactors (SMRs). Being a stark departure from traditional nuclear technologies, these new designs promise a more sustainable nuclear future by enhancing safety, versatility and efficiency in energy production.


Picture: Courtesy

Safe Retirement of Aging Plants

Simultaneously, the industry is warming up to the idea of decommissioning aging nuclear plants, which gives rise to a trend that focuses on safe retirement as well as efficient waste management. As promising as this trend may seem, it is greatly impeded by the challenge of shutting down older facilities in a responsible and sustainable manner that will have the mildest impact possible on the environment.

This challenge is coupled with the need to devise effective strategies for dealing with nuclear waste. As the industry strives to find ways around these challenges, its commitment towards the sustainable use of nuclear energy becomes clearer than ever.

International Collaboration

No one country can take full credit for the scientific research, experiments, knowledge and expertise that went into the discovery and demonstration on nuclear fission. It took collaborative work that went beyond borders.

In the global context, this kind of collaboration has made a comeback and is swiftly becoming a dominant trend. Different countries are pooling their resources to take on common challenges in the energy sector. The synergy goes way beyond technological expertise; it also involves the institution of regulatory frameworks and mutual dedication to the advancement of nuclear energy. These collaborative efforts promote the use of safer technologies and set the stage for an internationally integrated nuclear landscape.

Emphasis on Plant Operation

The first two nuclear plant accidents, namely the *Three Mile Island* and *Chernobyl disasters*, were mainly attributed to human error. They could have been easily avoided with the right plant operations. Therefore, as much attention is being paid to design and construction of the plans, there is a general consensus that all that will come to naught if plant operations are not streamlined. Ultimately, the industry aims to achieve safety, reliability and quality to achieve operational performance.

Construction Costs

One of the major setbacks in the nuclear energy has been the frustratingly long construction process. While it is easy to see why this is necessary so that all plants meet the set safety standards and protocols, it is no secret that this length of time can be costly. A lot of attention is being put into improving current nuclear plant designs and developing new concepts. On top of that, players in the nuclear energy sector are looking to streamline construction methods and procedures. If successful, this will significantly reduce construction time and by extension, investment costs, without compromising on the quality.

Man-Machine Interface

Man-Machine Interface, also known as MMI, refers to how personnel interact with the machines or control systems in the nuclear facilities. Current MMI trends incorporates human factors engineering, which is cognizant of the capabilities and limitations of human operators. It utilizes past operational experiences and incidents to promote a safer environment while also equipping them with tools and knowledge on how to handle diverse emergency situations through training and emergency simulations.

Opportunities in Nuclear Energy

Nuclear Energy as A Clean Energy Source

As regards the opportunities in the industry, nuclear energy comes up as a vital carbon-free solution that can be instrumental in the fight against climate change. Unlike other sources of energy like fossil fuels, nuclear power generates electricity without releasing greenhouse gases into the atmosphere. This way, it provides a scalable and reliable energy option that helps attenuate global warming.

Space Exploration

Aside from its terrestrial applications, nuclear energy also avails opportunities in the exploration of space. Interest in space exploration has peaked recently, with commercial space exploration trips being a present reality.

Compact nuclear reactors are designed in such a way that they are able to power spacecraft on long space missions, providing sufficient energy for explorative space travel. This, in effect, opens new frontiers for cosmic exploration which advances better understanding of extraterrestrial phenomena.

Hybrid Energy Systems.

Another notable opportunity presented by nuclear energy is its integration with renewable sources of energy to create hybrid energy systems. By combining the fluctuating nature of renewable energy with the reliability of nuclear energy, these systems ensure a sustainable power supply. Such systems would address the challenge of sporadic energy production, which is often associated with renewable sources of energy. The synergy between the two types of energy can be harnessed to foster a well-balanced energy ecosystem.

Regulation and Policies

As the number of nuclear facilities around the world increase, so does the opportunity to take part in rational discourse on its varied applications. There is need for all players to work towards more unified policies and regulations. Safe and responsible use of nuclear energy is a global goal when it comes to the successful use of nuclear energy. There is opportunity to adhere to the licensing protocols and together reinstate the public faith in nuclear energy.

As we familiarize ourselves with these trends and opportunities, we are compelled to acknowledge the multifaceted nature of nuclear energy development. Whether through impressive technological advancements, collaborative efforts or embracing clean energy, the energy industry is gradually adapting to align with the demands and needs of a changing world. Recognizing the promising potential of nuclear energy becomes both a strategy for sustainable development and a bold step towards a planet-friendly future.

Opportunities in Nuclear Science Education

An Interview with

Eng. (Prof) Elijah Mwangi

Director, Institute of Nuclear Science and Technology and Professor of Electrical Engineering, University of Nairobi.

1 ***Kindly highlight the history of Nuclear Science and Technology at the University of Nairobi, what are some of the objectives, successes and challenges of this program and those who take part in it?***

Thank you. The discovery of radioactivity and X-rays happened over 120 years ago in the 1890s. The applications of this great power have grown over the years. Peaceful applications of nuclear technology are diverse and includes nuclear power, medical diagnostic radiography, cancer treatment, industrial radiography, security scans, food irradiation, insect sterilization, pollution monitoring, elemental analysis, carbon dating etc. Harmful effects of radiation have also been experienced including atomic bombs, nuclear weapons tests, nuclear accidents, etc. Due to the diverse, global and sometimes dangerous applications of nuclear science, it is important for every Nation to acquire all the necessary knowledge on this technology. After all, a major accident in any part of our globe finally affects everybody. Furthermore, there are areas where nuclear technology is the only available tool to solve some of our social problems. Thus, the institute was established in 1978 by the government of Kenya with support from the International Atomic Energy Agency (IAEA). This was 13 years after Kenya had been accepted as a full member of the IAEA.

Our role at the Institute is to provide a platform for acquiring the peaceful use of this knowledge through postgraduate studies and research. We are adequately equipped to carry out material and radioactivity measurements. In addition, we have equipment for air pollution measurements. Our research activities are usually multidisciplinary in approach. In fact, our facilities are used by students and staff within our university as well as from other Universities in the country and in the region.

The institute has trained most if not all of the key stakeholders in the nuclear sector in the country. Our alumni are teaching in various universities and colleges in and outside the country, others are supporting research in Europe and Asia, while others are involved with regulatory agencies in South Africa, Canada and in the USA. Locally most of the staff from Kenya Nuclear Regulatory Agency (KNRA) as well as NuPEA have actually been trained at our institute at some point in time. Our alumni are also involved in supporting the development of standards as well as providing technical support in various committees of in the nuclear science applications industry.

The main challenge faced has been related to the fear and stigma by the public when radiation and nuclear technology is mentioned. Until recently when Kenya started the journey towards the generation of electricity from nuclear sources, little was known or talked about. This is despite the institute having been in existence for over 40 years carrying out training, research and measurements. The public is not aware that there are many applications in their daily life that make use of nuclear science techniques. As a result of this fear and lack of awareness, the enrollment into the program has always been low. However, this trend is changing after Kenya announced the ambition to employ nuclear power.

2 How have global trends in nuclear energy impacted this program, are there any lessons learned or adjustments made based on the program's experience over time?

The University of Nairobi as a matter of policy is continuously benchmarking globally across its entire programs. In the nuclear field, the institute responds to these trends by regularly reviewing and updating our curriculum, fostering collaborations with industry and research institutions, and actively participating in international forums to stay abreast of global developments. Lessons learned from global experiences helps our programs make informed adjustments to better align with the evolving landscape of nuclear science applications.

As an example, since Kenya announced plans to include nuclear power in the energy mix, our program was revised to include significant optional units for students interested in the nuclear power direction. Prior to that, our program catered for the market needs of the day including radiation protection, medical applications, industrial applications, environmental monitoring and applications in agriculture.

Our students and staff are active on the global scene. Over half of our students have a significant part of their research work taken in foreign institutions in Europe and India. We have MOUs with many countries and institutions which allow exchange programmes for both staff and students. In addition, our institute is a regional hub that attracts students from many African countries due to our level of advancement in the sector.

3 Can you provide an overview of the current status of nuclear energy development in Kenya?

Kenya is in the process of developing the pre-requisite infrastructure before a nuclear power plant can be installed. This is through the milestones approach whereby a total of about 20 infrastructure issues have to be addressed. The organization currently mandated for this task is NUPEA. The infrastructure issues are developed by international community through the global regulator the IAEA. The IAEA also constantly audits the process as well as providing technical support for new countries like Kenya. Notable progress made so far is the establishment of KNRA through the nuclear regulatory act. The country has also been building capacity in various affiliate sectors including power generation, distribution, research, legal, etc. Suitable site feasibility studies have also been conducted to identify potential areas with capacity to hold a nuclear power plant. There has also been a great public awareness and stakeholder engagements. As a result of these efforts, the number of TV shows, Radio programmes and newspaper articles on nuclear science applications have grown exponentially compared to just 10 years ago. Kenya has made significant progress. The infrastructure issues have to be all addressed before the ground breaking ceremony is held. And yes everything is on track as per the schedule.

4 How is the regulatory framework for nuclear energy structured in Kenya?

The Kenya nuclear regulatory act of 2019 provides for a comprehensive framework for the regulation of safe, secure and peaceful utilization of atomic energy and nuclear technology; the production and use of radiation sources and the management of radioactive waste; The Kenya Nuclear Regulatory Authority established under this Act become the successor to the Radiation Protection Board established by the Radiation Protection Act (Cap. 243) of 1984. KNRA has an expanded mandate compared to its predecessor RPB.

5 What is your personal stand on the controversies surrounding nuclear energy, especially with regard to nuclear waste and accidents?

The debate around nuclear energy involves weighing these potential benefits against the challenges and risks associated with its use. Public perception, regulatory frameworks, and technological advancements will continue to shape the role of nuclear power in the global energy mix.

Low Greenhouse Gas Emissions: Nuclear power is a low-carbon energy source, producing minimal greenhouse gas emissions during electricity generation. This makes it a viable option for addressing climate change and reducing dependence on fossil fuels.

Energy Density and Reliability: Nuclear power plants have a high energy density, meaning they can generate a significant amount of electricity with a relatively small amount of fuel. This makes nuclear energy a reliable and consistent source of power, providing a stable base load for the electrical grid.

Advanced Safety Measures: Modern nuclear power plants incorporate advanced safety features and technologies to prevent and mitigate accidents. Improved reactor designs, redundant safety systems, and enhanced emergency response plans contribute to minimizing the risk of catastrophic events.

Technological Innovation: Ongoing research and development in nuclear technology aim to address the challenges associated with nuclear waste. Advanced reactor designs, such as molten salt reactors and small modular reactors, are being explored to improve efficiency, safety, and reduce the long-term environmental impact.

Long-Term Energy Security: Nuclear power can contribute to long-term energy security by diversifying the energy mix. Unlike finite fossil fuel resources, uranium, the primary fuel for nuclear reactors, is relatively abundant and widely distributed.

Economic Benefits: Nuclear power can create jobs and stimulate economic growth, particularly in regions where nuclear plants are located. It provides opportunities for skilled employment, and the construction and operation of nuclear facilities contribute to the local economy.

Baseload Power without Intermittency: Unlike some renewable energy sources that are intermittent, nuclear power provides a stable and continuous source of electricity. This baseload power can complement the variability of renewable sources like wind and solar, contributing to a more reliable energy grid.

6 *How does nuclear energy fit into Kenya's overall energy mix, and what role is it expected to play in the future?*

Kenya had to conduct thorough assessments, taking into account its specific energy needs, environmental considerations, and socio-economic factors when considering the incorporation of nuclear energy into its energy mix. Additionally, public engagement and transparent communication are essential to address concerns and build support for the integration of nuclear power in the country's energy strategy. Some expected benefits include:

Diversification of Energy Sources: Introducing nuclear energy would contribute to diversifying Kenya's energy mix. Relying on a variety of energy sources, including nuclear, helps to reduce dependence on a single energy type, enhancing energy security and resilience.

Energy Independence: Developing a diverse energy portfolio, including nuclear, can enhance Kenya's energy independence. By reducing reliance on imported fuels and diversifying the energy mix, the country can have more control over its energy sources and costs.

Long-term Energy Planning: Nuclear power provides a stable, long-term solution to energy demands. It can contribute to Kenya's strategic energy planning by offering a consistent source of electricity for several decades, helping to meet the country's growing energy needs as its population and economy expand.

Technological Innovation and Education: Introducing nuclear energy requires investment in technology and education. This can lead to advancements in science and technology, fostering a skilled workforce and promoting technological innovation that can have positive spillover effects in other sectors.

Addressing Energy Poverty: Nuclear power can play a role in providing reliable electricity to rural areas that may not have access to a stable power supply. This can contribute to reducing energy poverty and improving the overall quality of life for a larger segment of the population.

7 *What challenges does the nuclear energy department face in promoting nuclear energy in Kenya, and how are these challenges being addressed or mitigated?*

Kenya is proactively tailoring its approach to nuclear energy solutions based on its specific circumstances, engages in open dialogue with stakeholders, and continuously reassess strategies to address evolving challenges.

Some of the challenges and potential approaches to address them include:

Public Perception and Awareness:

Challenge: Public perception of nuclear energy can be influenced by concerns about safety, nuclear accidents, and radioactive waste.

Mitigation: Implementing comprehensive public awareness campaigns to educate the public about the safety features of modern nuclear technology, dispel myths, and address concerns. Transparency and open communication about plans and safety measures are crucial.

Regulatory Framework:

Challenge: Establishing a robust regulatory framework for nuclear energy, including safety standards, licensing procedures, and waste management regulations, can be a complex and time-consuming process.

Mitigation: Developing and strengthening regulatory institutions with the necessary expertise and independence. Engaging with international organizations and experts to ensure compliance with best practices and standards.

Financial Investment:

Challenge: Developing nuclear power infrastructure requires significant financial investment, including upfront costs for construction and long-term investment for decommissioning and waste management.

Mitigation: Exploring financing options, such as international partnerships, public-private collaborations, and financing mechanisms that spread costs over the long term. Conducting thorough economic assessments to demonstrate the long-term economic viability of nuclear energy.

Skilled Workforce:

Challenge: Developing and maintaining a skilled workforce in nuclear technology and safety can be a challenge.

Mitigation: Investing in education and training programs, collaborating with international organizations and institutions to transfer knowledge, and developing a pipeline of skilled professionals. Establishing partnerships with educational institutions to offer specialized nuclear programs.

Infrastructure Development:

Challenge: Building the necessary infrastructure for nuclear energy, including power plants, waste management facilities, and research institutions, can be resource-intensive and time-consuming.

Mitigation: Planning and phased implementation to manage costs and timelines. Collaborating with experienced international partners to leverage their expertise and support infrastructure development.

International Cooperation:

Challenge: Developing a nuclear energy program often requires collaboration with international organizations and partner countries.

Mitigation: Actively participating in international forums, engaging with organizations such as the International Atomic Energy Agency (IAEA), and establishing bilateral agreements with experienced nuclear nations. Learning from the experiences of other countries with established nuclear programs.

Political Will and Stability:

Challenge: Political support and stability are crucial for the successful implementation of a nuclear energy program.

Mitigation: Building bipartisan support, creating a legal and regulatory framework that transcends political cycles, and ensuring transparent decision-making processes. Engaging with political leaders to emphasize the long-term benefits of nuclear energy.

8 ***What are some success stories or notable achievements of students in this sector?***

Our alumni students of nuclear science are actively both locally and in the global scene. For instance, some are senior officials in South Africa nuclear regulator. Others are in IAEA safeguards and inspections. Others are engaged in research in countries such as Taiwan, Canada, USA, Canada, Poland, China, etc. Locally our former students are senior members in KNRA, NuPEA.

9 ***Are there any job creation or economic growth expectations associated with the Nuclear Science and Technology program?***

Oh Yes, the development and implementation of Nuclear Science and Technology programs are associated with job creation and economic growth. Here are some ways in which these programs can contribute to job opportunities and economic development:

Job Creation in the Nuclear Industry: Establishing nuclear power plants requires a skilled workforce for construction, operation, and maintenance. This includes engineers, technicians, scientists, and various support staff.

Research and Development Opportunities: Nuclear science and technology programs often involve research and development activities. This creates opportunities for scientists, researchers, and engineers to work on innovative projects, contributing to advancements in the field.

Education and Training Sector Growth: As the demand for skilled professionals in nuclear science and technology increases, there is a need for educational and training programs. This leads to job opportunities in academia and training institutions.

Supply Chain and Manufacturing Jobs: The nuclear industry has an extensive supply chain that includes the production of components for nuclear power plants. This can stimulate growth in the manufacturing sector, creating jobs for workers involved in producing specialized equipment.

Nuclear Safety and Regulatory Jobs: The establishment of nuclear programs necessitates robust safety measures and regulatory frameworks. This creates demand for professionals in nuclear safety, radiation protection, and regulatory compliance.

Environmental Monitoring and Management: Nuclear programs often involve environmental monitoring and management to ensure the safe handling of radioactive materials. This creates opportunities for professionals in environmental science and management.

Innovation and Entrepreneurship: Advancements in nuclear science may lead to the development of new technologies and innovations. Entrepreneurs and businesses may emerge to capitalize on these opportunities, contributing to economic growth.

International Collaboration and Consulting: Countries with established nuclear programs may offer expertise and consulting services to those developing or expanding their nuclear capabilities. This can create opportunities for professionals in international collaboration and consulting.

Waste Management Jobs: Proper disposal and management of nuclear waste are critical aspects of nuclear programs. This can lead to job opportunities in waste management, including the development of safe storage solutions and recycling technologies.

Infrastructure Development: Building and maintaining nuclear infrastructure, including research facilities and power plants, creates jobs in construction, project management, and facility maintenance.

10 *What are some of the things that stand in the way of collaborations or partnerships with international organizations or other countries in the field of nuclear energy research?*

Collaborations or partnerships in the field of nuclear energy research can face various challenges, some of which are:

Political Considerations: Nuclear energy involves sensitive technologies, and political considerations can impact collaborations. Countries may be hesitant to share certain information or technologies due to geopolitical tensions or national security concerns.

Regulatory Differences: Different countries have varying regulatory frameworks for nuclear energy. These differences in safety standards, licensing procedures, and environmental regulations can create obstacles to seamless collaborations.

Intellectual Property Concerns: Protection of intellectual property rights can be a significant hurdle in collaborations. Countries and organizations may be reluctant to share proprietary information or innovations without clear agreements on intellectual property rights.

Technology Transfer Barriers: The transfer of nuclear technology often involves complex agreements and may be subject to export control regulations. Countries may be cautious about sharing advanced nuclear technologies due to concerns about misuse or proliferation.

Resource Allocation and Funding: Limited resources and funding constraints can hinder collaborative efforts. Countries or organizations may prioritize domestic projects over international collaborations, impacting the feasibility and success of joint initiatives.

Public Perception and Acceptance: Public perception of nuclear energy varies across countries, and collaborations may face challenges if there is strong opposition or skepticism from the public. Governments and organizations may be hesitant to engage in collaborations that could be perceived negatively.

Policy Misalignment: Misalignment of national policies and priorities can pose challenges. Differences in long-term energy goals, environmental policies, or climate change strategies may hinder collaborative efforts in the nuclear energy sector.

Security Concerns: The potential dual-use nature of nuclear technology raises security concerns. Countries may be cautious about collaborating on projects that involve technologies with both civilian and military applications.

Lack of Trust: Building trust among collaborating partners is crucial. Historical issues, previous disputes, or lack of confidence in the commitment of a partner can impede the establishment of effective collaborations.

11 *How is the development of nuclear energy expected to impact the economy and sustainable development of Kenya?*

The development of nuclear energy in Kenya has the potential to impact the economy and sustainable development in several ways, although it is important to note that the actual outcomes depend on various factors including effective planning, management, and adherence to safety and environmental standards.

Some potential impacts include: Energy Security and Reliability, Economic Growth and Job Creation, Diversification of the Energy Mix, Reduced Greenhouse Gas Emissions, Technological Innovation and Knowledge Transfer, Education and Skill Development, Infrastructure Development, Long-Term Energy Planning, Enhanced International Collaboration, Social and Economic Benefits in Host Communities.

12 *What technological advancements or innovations are being explored in the development and utilization of nuclear energy in Kenya?*

Some areas of active research include:

Advanced Reactor Designs: There is ongoing research and development into advanced reactor designs, including small modular reactors (SMRs), molten salt reactors, and Generation IV reactors. These designs aim to improve safety, efficiency, and flexibility in nuclear power generation.

Nuclear Fusion Research: While nuclear fusion is still in the experimental stage, it represents a potential transformative technology for the future of nuclear energy. Research and development in nuclear fusion aim to achieve controlled fusion reactions, offering a cleaner and safer form of nuclear power.

Nuclear Fuel Cycle Innovations: Innovations in nuclear fuel cycles focus on improving fuel efficiency, reducing waste generation, and exploring advanced fuel types. This includes research into next-generation fuels and recycling technologies.

Digitalization and Artificial Intelligence (AI): The integration of digital technologies and AI in nuclear energy operations can enhance safety, efficiency, and predictive maintenance. Digital twins, advanced simulations, and AI applications are being explored for reactor monitoring and control.

Nuclear Safety Systems: Research continues to enhance safety features in nuclear power plants. This includes the development of passive safety systems, advanced emergency response technologies, and innovations in accident-tolerant fuels.

Nuclear Desalination: The coupling of nuclear power plants with desalination processes is explored in regions with water scarcity. This integration aims to provide both electricity and freshwater, addressing multiple sustainability challenges.

Hybrid Energy Systems: The integration of nuclear power with renewable energy sources, such as solar and wind, in hybrid energy systems is being explored. This approach aims to provide a reliable and flexible energy supply.

Materials Science and Advanced Manufacturing: Innovations in materials science and manufacturing technologies contribute to the development of advanced materials for reactor components. This includes materials that can withstand higher temperatures and radiation levels.

Decommissioning Technologies: As older nuclear facilities reach the end of their operational life, advancements in decommissioning technologies are important. This involves techniques for safe and efficient decommissioning and waste management.

13 *What are some research projects or initiatives the department is currently involved in?*

Nuclear fusion, radiation protection, medical diagnostics and treatment, applications in security, safety, agriculture, environmental quality and pollution studies, mining, materials characterization, nondestructive testing, energy storage solutions,

14 What opportunities are available for research, internships, or practical applications of nuclear science and technology in Kenya?

Here are some potential avenues to explore for individuals interested in engaging with nuclear science and technology in Kenya:

Kenya Nuclear Regulatory Authority (KNRA): KNRA plays a crucial role in regulating nuclear activities in Kenya. Explore the possibility of internships or research collaborations with KNRA to gain insights into regulatory frameworks, safety standards, and nuclear policy.

Government Research Institutions: Research institutions in Kenya may offer opportunities for involvement in nuclear-related research projects. Check for announcements, programs, or internship opportunities on their websites.

Collaboration with Universities: Kenyan universities with departments or institutes related to nuclear science and technology may have research opportunities or internship programs. Connect with faculty members, research centers, or nuclear science departments for potential collaborations.

International Collaborations: Kenya engages in international collaborations in the field of nuclear science. Explore opportunities for joint research projects, exchange programs, or internships facilitated by international organizations, universities, or research institutions. Training and capacity building programmes opportunities are also offered.

Energy Sector Companies: Companies involved in the energy sector, including those exploring or utilizing nuclear energy, may offer internships or research opportunities. Check for openings in engineering, research and development, or environmental science within these organizations. Including NUPEA.

Professional Associations: Professional associations related to nuclear science and technology may provide networking opportunities and information about research projects or internships. Connect with these associations to stay informed about industry events and opportunities. Including KYGN, AYGN.

International Atomic Energy Agency (IAEA): The IAEA supports member states in various aspects of nuclear science and technology. Check the IAEA website for programs, scholarships, or initiatives that individuals in Kenya can participate in.

Industry Conferences and Events: Attend conferences, seminars, and workshops related to nuclear science and technology. These events provide opportunities to network with professionals, learn about ongoing research, and discover potential internship or collaboration opportunities.

15 Does Kenya's legal framework in any capacity stand in the way of the execution, research and innovation in the nuclear energy sector? How can this be mitigated?

It is anticipated that the legal framework will be updated to provide clarity in licensing procedures, safety standards and oversight. The matter of public participation and provision of environmental impact assessment would also be given the adequate attention.

HVDC Opportunities for Achieving SDG7 for East Africa Region.

Authors: *Japheth Davies Bwire[1], Joel Nadebu Ouma[2], Samwel Opana[3].*

[1] Assistant Engineer, Kenya Power Company Kisumu, P.O Box 151-40100 Kisumu, Kenya
[2]Senior Superintending Engineer, State Department for Public Works Nairobi, P.O. Box 41191 – 00100 Nairobi, Kenya
[3]Programme Officer, Energy Planning and Modelling, AUDA-NEPAD

Email: japhethbwire@gmail.com

Introduction.

East Africa and Africa at large is characterized by dispersed loads and generation sources spanning hundreds and in some case thousands of kilometers. With electricity demand growing daily as experienced across the continent, there is urgent need for energy sector to plan and work around the clock on moving more power to the load centers. This will play a key role in attainment of Africa climate summit 2023 resolution of Increasing Africa's renewable generation capacity from 56 GW in 2022 to at least 300 GW by 2030, both to address energy poverty and to bolster the global supply of cost-effective clean energy for industry [1]. Bulk power transmission from generation stations to the load centers is transferred using high voltage network. High voltage alternating current (HVAC) has dominated the transmission of bulk power for a long time. Despite HVAC having a number of advantages some of its pitfalls which include; high power losses, relatively lower power transfer capacity and prone to stability challenges. Therefore, to urgently address the aforementioned challenges associated with HVAC, most energy sectors are opting to use HVDC lines in this era of green energy, which are site specific, and for attainment of SDG7. HVDC power lines possess many advantages over HVAC lines in economics, high power transfer capacity, system stability, reliability, control, low short circuit current levels, structural simplicity, and low line power losses [2].

A number of studies have shown that conversion of HVAC lines to HVDC lines increases the power transmission capability [2]. This fact lets the conversion HVAC to HVDC as an interesting alternative for the Transmission Expansion Planning, TEP, even more if restrictions to build new lines are more demanding. With East African countries struggling with the transfer of more power on the aging transmission infrastructure, HVDC offers a solution to the highlighted challenges. A DC transmission line has a lower visual profile than an equivalent AC line and so Contributes to a lower environmental impact. There are other environmental advantages to a DC transmission line through the electric and magnetic fields being DC instead of AC.

Different lay-outs can be applied for the considered HVDC link, such as a monopolar or bipolar system with ground return or metallic return. A bipolar system with ground return is chosen as it offers increased redundancy and allows some flexibility for future tappings/extensions. The increased redundancy is achieved because the system can still operate at 50% of its nominal rating in case of an outage of one converter or line. HVDC links not only decouple both HVAC systems such that faults in one system do not propagate to the other system, they can also provide grid support after an incident takes place. One of such support mechanism, which would be of interest, is to provide frequency control to the EAPP system. Countries with substantial amount of inertia and primary reserve can be offered to the systems by modifying the power controllers.

The paper proposes to the African energy sector to consider conversion of the existing HVAC to HVDC as opposed to developing new HVAC lines especially for interconnectors across neighboring countries. The paper highlights how this will increase the capacity thus ensuring that countries are able to share cheap RE, reduces power losses and improve reliability as they work towards attainment of SGD7 and Vision 2030/2063.

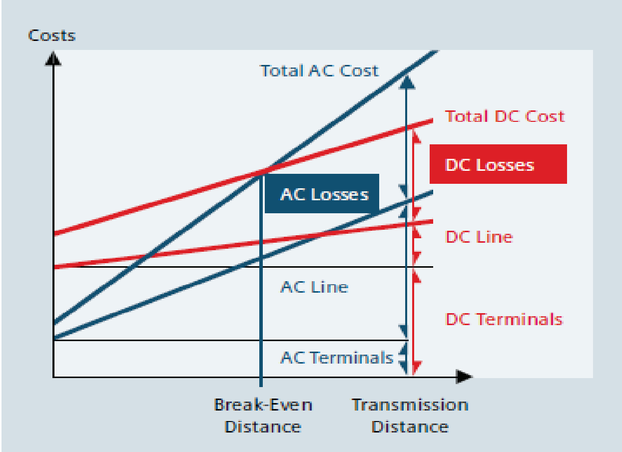

Fig.1. Comparison of Cost vs Distance between HVAC and HVDC [3].

Conversion of HVAC to HVDC Transmission Lines.

The conversion of HVAC lines to HVDC is an interesting alternative recently analyzed and currently has very few cases implemented globally. Several feasibility studies for conversion of lines describe the main aspects to take into account to increase the transmission capability. Two types of line's conversion are proposed [2]:

Table 1: proposed line conversion methods

Type A:	Type B:
Minor modifications in the structure that can be performed by changing the allowable height of the conductors with respect to ground during the conversion process.	Major modifications of structures that do not allow conductors can be located at a suitable distance from ground during the conversion process.

Type A conversion could consider hot-line work to reduce the downtime of the line. This can be a key factor to reduce the impact on the reliability of the transmission system during the conversion process. Conversion Type B may require that the line remain out of service for extended periods, thus having a greater impact on the reliability of the system. However, the increase in transmission capacity can be higher than Type A conversion.

Table 2: shows the results of expected capacity on conversion type to be used [4, 5].

HVAC AC double circuit	Rated MW	HVDC Bipolar Topology Technology	Mw Expected	Percentage Increment	Conversion Type
145kV	110	±290kV	390	255%	Type B
245kV	380	±490kV	1,330	250%	Type B
520kV	990	±840kV	3,430	246%	Type B
420kV	1,200	±400kV	2,200	83%	Type A
287kV	560	±240kV	863	54%	Type A
287kV	560	±245kV	1,762	215	Type A

The conversion of HVAC lines to HVDC reduces both the cost of investment and the Break Even Distance (BED). Conversion of lines extends the distance range in which the HVDC is less expensive than HVAC for transmission lines.

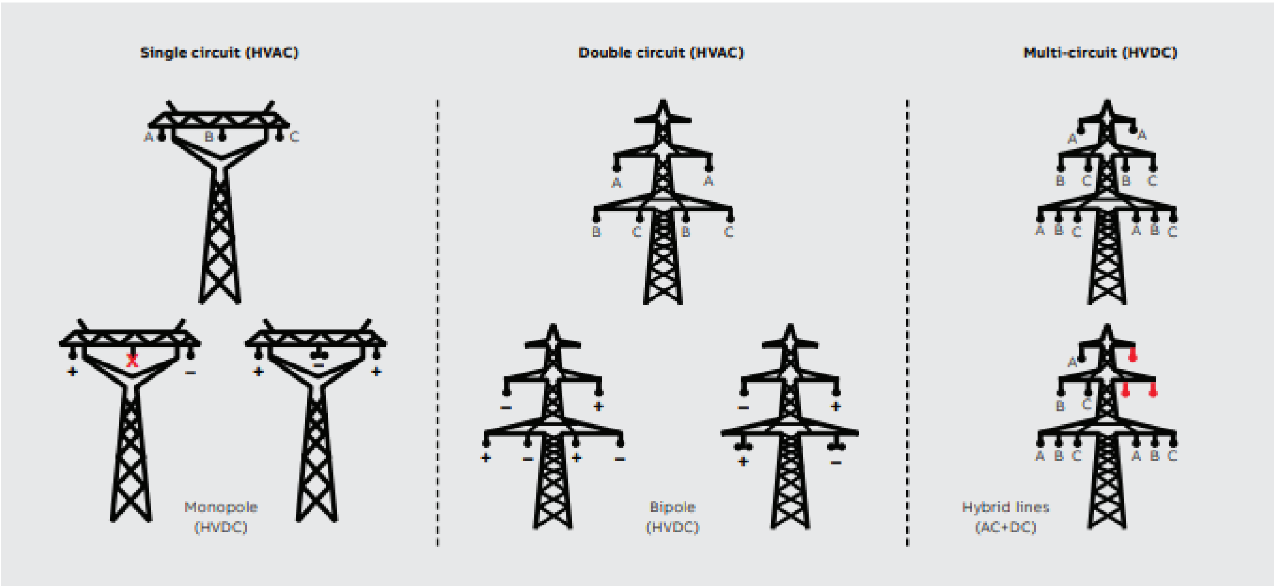

Fig2. Converting HVAC to HVDC towers

Methodology

In this study, two options were considered with the focus area on Lake Turkana Wind Power Plant (LTWP) to Suswa transmission corridor. The paper assumed that LTWP to Suswa is energized and operated at 400kV AC as designed. The methodology used two stages in each of the analyzed options: The computation of power losses from the transmitted power and the assessment of maximum transfer capacity of the transmission lines. The transfer capacities in both options were computed by carrying out the PV analysis and power losses were approximated by running load flow simulations. Modeling and simulations were done on Power System Simulator for Engineering (PSS/E) version 33 (see Fig. 3 and 4).

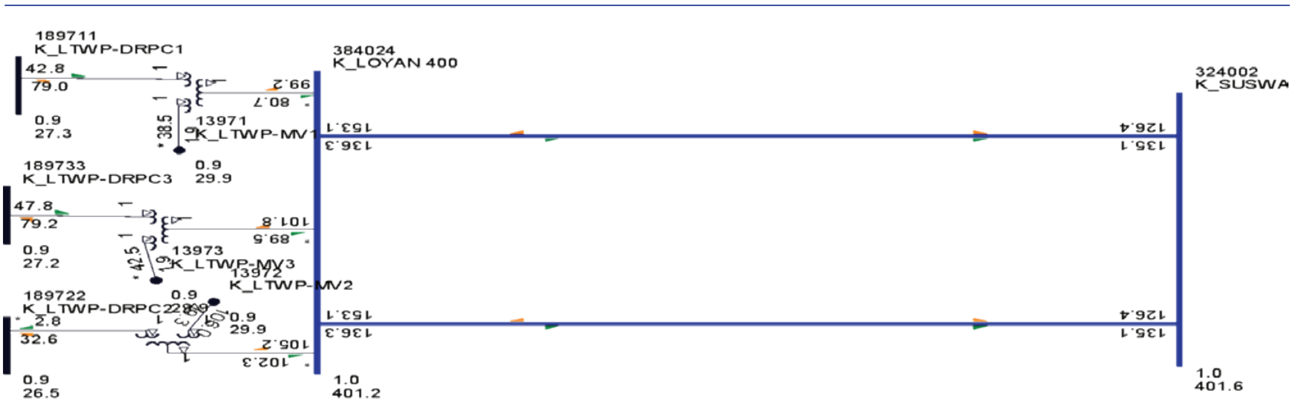

Fig. 3: HVAC for LTWP-Suswa 400kV

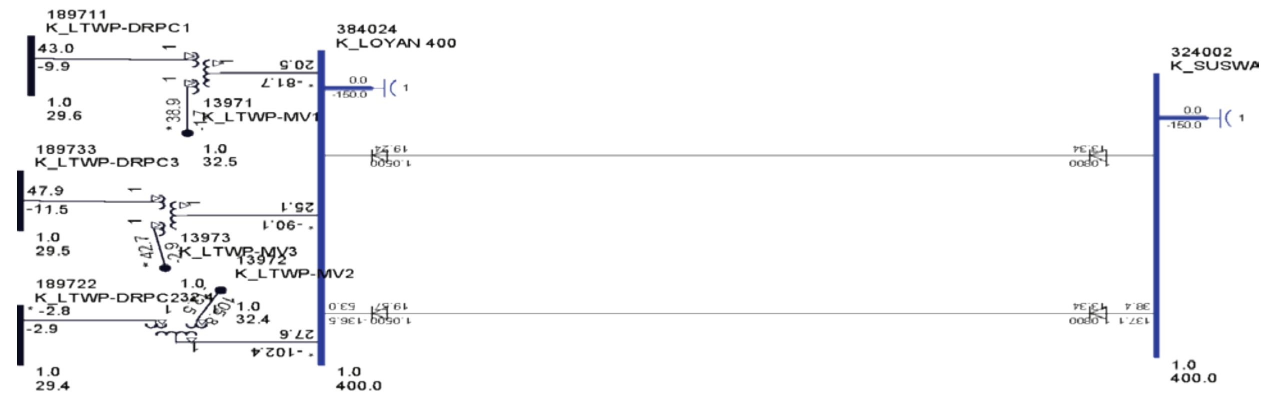

Fig. 4: HVDC for LTWP-Suswa 500kV

Results and Discussions

The load flow and maximum transfer capacities calculated for HVAC and HVDC systems are as shown in Table3. Fig.3 indicates that maximum transfer capacity calculated for LTWP-Suswa 400kV HVAC lines was 2360MW with the rated capacity of 3275.6MVA whereas the transfer capacity for the simulated LTWP-Suswa 500kV HVDC was 3000MW equivalent to the rated capacity of the lines of 3000MVA. The difference in the power carrying capabilities between HVAC and HVDC arises because the transmission capacity of HVAC operates based on its operational security (voltages at the notes) and reactive power, whereas HVDC is only limited by the thermal constraints associated with the conductor. Therefore, it can that deduced that conversion of a transmission line from HVAC to HVDC might provide improved transmission capacity and reduced transmission losses.

Table 3: shows the results of capacity increase on conversion type A to be used.

HVAC AC double circuit	Rated MW	HVDC Bipolar Topology Technology	Mw Expected	Percentage Increment	Conversion Type
400kV	2360	±500kV	3000	127.11%	Type A

Cost Analysis

A first basic cost estimation of the presented HVAC and HVDC options are presented for a direct connection between LTWP and Suswa. This paper considered investment calculation costs. Furthermore, the cost of the AC substations, which have to be built for all studied options, are not included. Therefore, the costs as given are merely to compare the different options and give not a good estimate of the final cost.

Table 4: cost comparison for HVAC VS HVDC

HVAC line (400 kV):	HVDC line (VSC - 1GW – without intermediate tapping):
Lines + compensation (400 kV double circuit)= 1.5×430 km×0.40 M$ = 258 M$ (Additional substations used for voltage control (2): 64.4 M$) Approximate total cost of double circuit =USD 322.4M	Converter stations = 2*144 M$ = 288 M$ Bipolar Lines = 430 km*0.29 M$ = 362.5 M$ Approximate total cost for bipolar converter station =USD 387.0M

Thus;

Annual cost of the power Losses

Difference in the losses between HVAC and HVDC

=4.08MW-1.1MW

=2.98MW

It is possible to establish a relationship between peak demand on a system and the average technical losses through consideration of load factors and loss load factors. Load factor (LF) is the ratio of the average demand over a period to the maximum demand within that period for the particular network and loss load factor (LLF) is the as average power losses over a period to the losses at the time of peak demand.

The formula adopted is:

$LLF = (0.3 \times LF)+(0.7\times LF\times LF)$ ……………….. (1)

As the basis for loss calculations, because the network considered is mainly transmission. Using the LLF formula stated and an assumed load factor of 0.693;

Thus:

$LLF = 0.3 \times LF + 0.7 \times LF2$

$LLF = 0.3 \times 0.694 + 0.7 \times 0.6942$

$LLF = 0.545$

Annual energy losses (kWh)

Power Losses (kW) × LLF × 8760hrs……………… (2)

Thus: $= 2980\times0.545\times8760$

$\cong 14{,}227{,}116$kWh

Using data from EPRA which indicates that the average energy cost (excluding the capacity costs) in April 2022 was 10.36kshs/kWh [6], therefore, the cost benefit on the power losses gained by implementing HVDC is:

Cost on energy losses savedzz:

$= 14{,}227{,}116\text{kWh}\times10.36\text{kshs/kWh}$

$\cong$ Ksh. 147.392M

From the analysis, it's clear that HVDC offers high power transfer capacity and lower power losses compared to HVAC even though the HVDC has high investment costs. However, the high investment cost is offset by the cost saved on the high-energy losses likely to be experienced with HVAC.

Conclusion

Based on the result of this paper with other preceding papers, the utilities within EAPP should consider the implementation of hybrid HVAC/HVDC system. By doing so, the utility company will save on cost, increase transmission efficiency and reduce socio-economic problem emanating from resettlement programs. Therefore, we recommend the use of HVDC transmission lines in evacuation of power form the isolated wind and solar generation plant which are oftentimes site specific, this will ensure reduced losses as these plants are normally far away from load center thus optimization of the green energy transition and attainment of SDG7.

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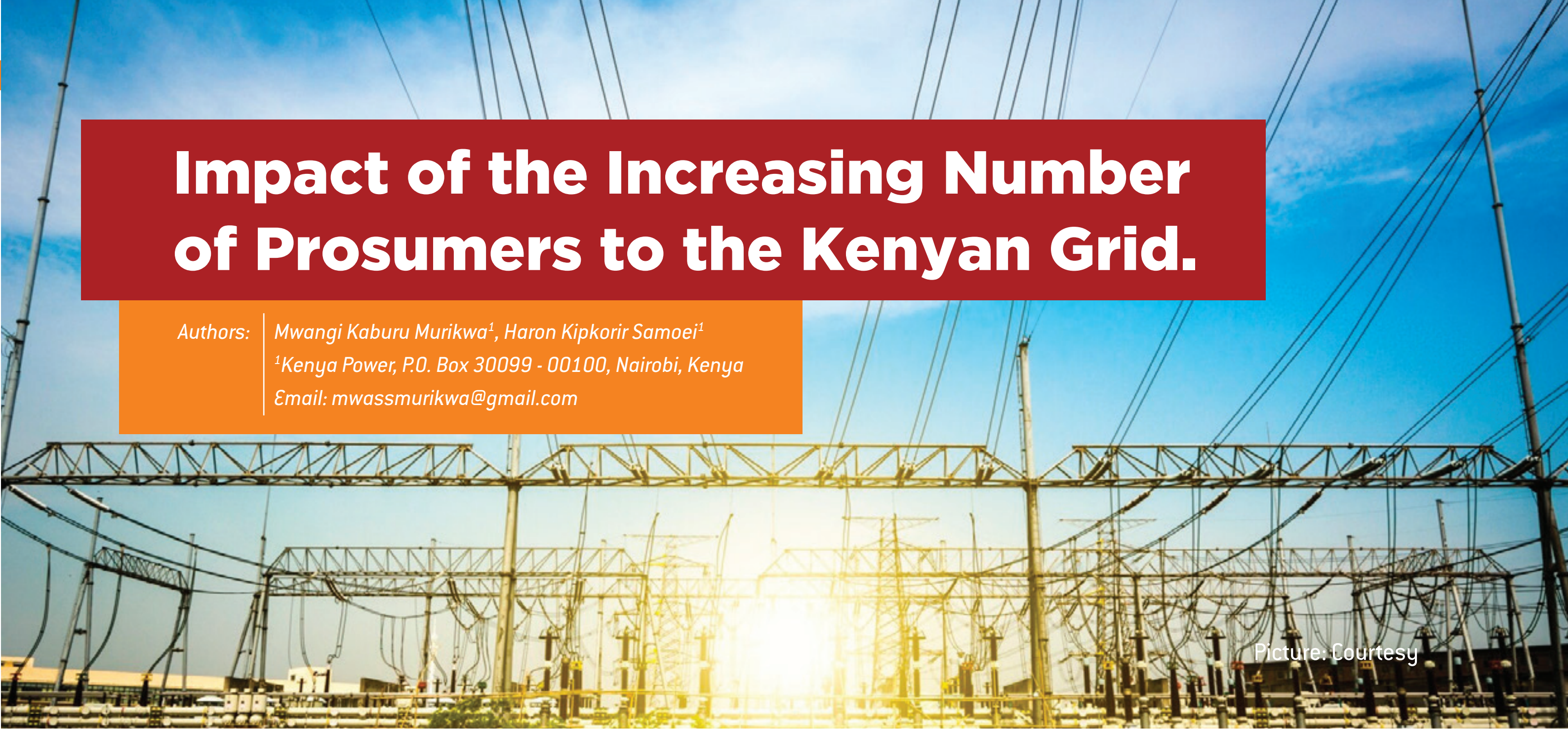
Picture: Courtesy

Impact of the Increasing Number of Prosumers to the Kenyan Grid.

Authors: Mwangi Kaburu Murikwa[1], Haron Kipkorir Samoei[1]
[1]Kenya Power, P.O. Box 30099 - 00100, Nairobi, Kenya
Email: mwassmurikwa@gmail.com



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1. Introduction

The distribution network of Kenya's electrical grid was envisioned to be passive and unidirectional where bulk power is received from the transmission network and delivered to the consumers. However, due to reducing cost of renewable energy sources and the desire for reliable power, many energy consumers are installing grid-tied captive power at their domestic or industrial sites thus turning the distribution network to an active bi-directional network.

The term prosumer is a combination of the terms producer and consumer. They are individuals who not only consume electrical energy from the grid but also produce their own energy and inject the excess generation back to the grid causing bidirectional power flow between the grid and the customer's installation.

Kenya has developed renewable energy sources to a level that about 90% of the grid's energy is from renewable energy. In the last financial year of 2022/2023, Kenya's generation mix had 45% geothermal, 19% hydro, 17% wind, 3% solar and 10% thermal energy. This is exclusive of the energy injected by prosumers into the grid since it is neither purchased nor actively measured.

Unlike traditional captive power installations where the generation was charging a battery bank, technological advancements have seen the development of grid-tied inverters that help the prosumer avoid the high cost of batteries. Additionally, investors who install and maintain rooftop solar photovoltaic (PV) system at customer's premises on behalf of the customer have catalysed this emerging trend of partial grid defection. The energy flow of three sampled prosumers is as summarised in the table below.

*Tabler SEQ Table * ARABIC 1: Energy Data of Sampled Prosumers (Source: Author)*

Name	Voltage Level (kV)	Forward Energy (+kWh)	Reverse Energy (-kWh)	Reverse Energy (%)
Prosumer - 1	Low	161,522	101,171	63%
Prosumer - 2	Medium	3,046,453	129,297	4%
Prosumer - 3	High	26,916,408	7,635,720	28%

2. Methods

The main objective of this research is to provide a better understanding of the impact of prosumers to the Kenyan grid and although there are hundreds of them on the grid, three were selected for in-depth analysis. The methodology involved identification of the key prosumers, at various voltage levels. The first prosumer selected is coupled to the grid on low voltage the second on medium voltage and the third on high voltage . They are also located in different regions of the country but the locations are withheld due to customer confidentiality. Equipment for measuring and logging data was installed/utilised for obtaining parameters such as voltage, frequency, current, power and power-quality events. Finally, the data was analysed with the aim of understanding the current and future impact of prosumers to the Kenyan grid.

3. Results

3.1 Prosumer on Low Voltage Network (230V or 400V)

Prosumer-1 is coupled to the grid at the low voltage network and is served by a three-phase 200kVA distribution transformer, which also serves domestic customers in that village. The graphs below is a 24-hour profile showing his import and export of power to the grid.

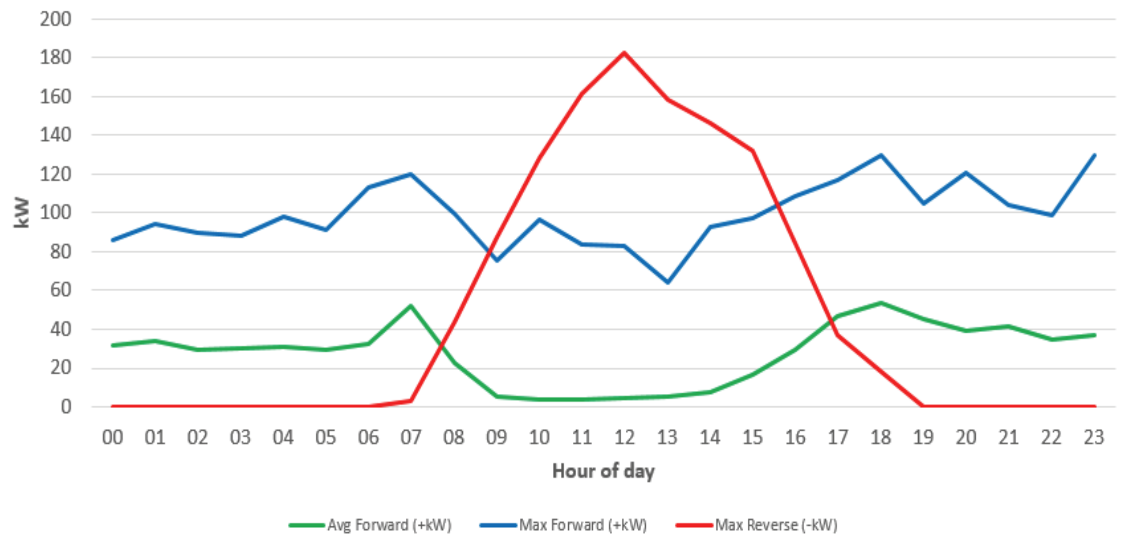

Figure 1: Import and Export Power Profile of Prosumer-1 (Source: Author)

It is observed the 200kVA step-down transformer that was designed to comfortably supply the load of at most 130kW (65% of transformer capacity) has become an overloaded step-up transformer that the prosumer uses to inject up to 183 kW (91% of the transformer's capacity) back to the grid.

3.2. Prosumer on Medium Voltage Network (11kV or 33kV)

Prosumer-2 is coupled to the grid at the medium voltage network and like majority of captive power plants; he uses solar photovoltaics (PV). He is served by a feeder, which also serves about 12,000 commercial and domestic customers. The graph below shows the load profile of the feeder and the prosumer.

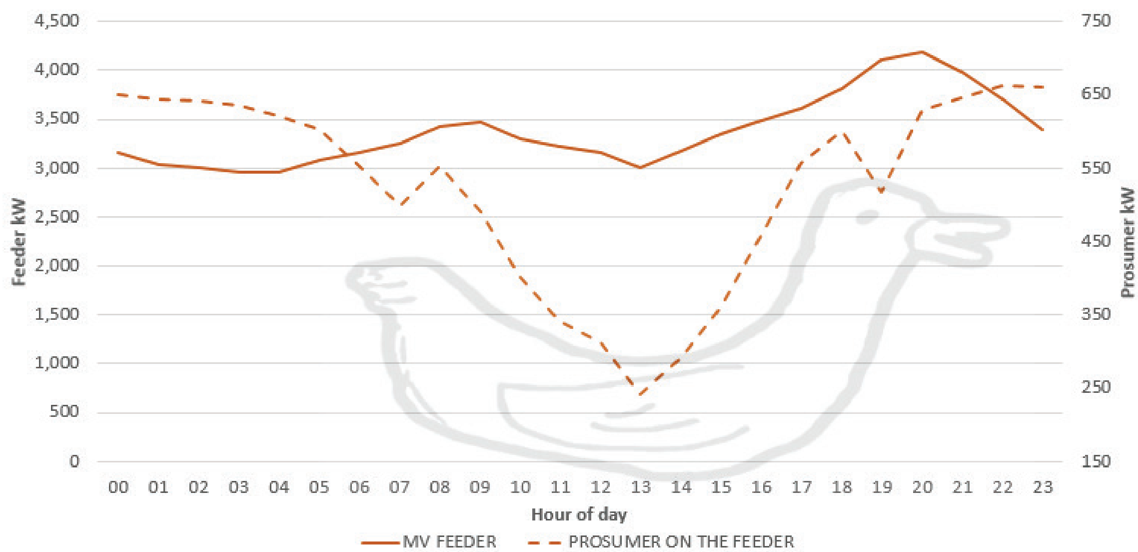

Figure 2: Load Profile of Feeder and Prosumer-2 ; Duck-Curve (Source: Author)

It is observed the two curves draw a silhouette of a duck. At night Prosumer-2 draws power from the grid but during the day, his power demand from the grid reduces (belly of the duck) upto a point at midday where the excess captive power generated is injected back to the grid causing an artificial reduction in the feeder's load (back of duck).

3.3. Prosumer on High Voltage Network (66kV, 132kV or 220kV)

The Prosumer-3 is coupled to the grid at the high voltage network, and like all other prosumers, his export power is not under the control of the S.O and can therefore affect the quality of grid power by triggering voltage spikes, dips etcetera as illustrated in the figure below.

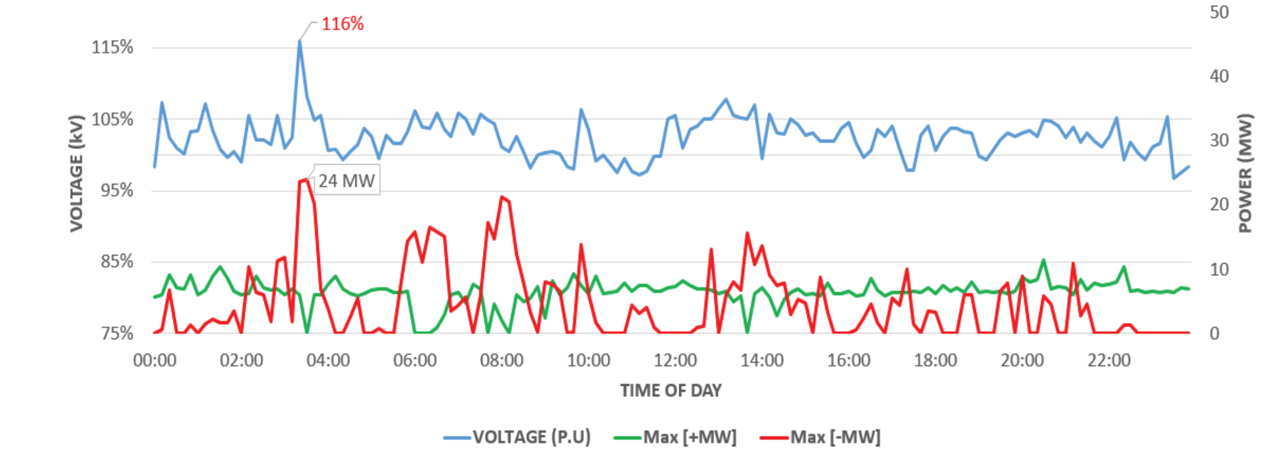

Figure 3: Relationship between Prosumer-3 Reverse Power and Grid Voltage (Source: Author)

A correlation between prosumer-3's reverse power and the grid voltage is evident where the grid voltage spikes to 116% for 2 minutes when prosumer-3 suddenly injects an un-expected 24 MW into the grid.

4. Discussion

The results in part 3 demonstrates that prosumers influence grid dynamics and affect almost all players in the energy sector as follows;

Generators - Reduced Plant Capacity Factor and Revenues

Prosumers pose a risk to the conventional power generating companies since they need to ramp down their generation during periods of high prosumer generation [4].

$$\text{Generating Plant's Capacity Factor} = \frac{\text{Actual Generation (MWh)}}{\text{Nameplate Capacity (MW)} \times \text{Time (h)}} \quad (1)$$

To maintain balance between demand and supply when prosumer is actively generating, curtailment of generation is done which effectively reduces the capacity factor of the power plants [5] and in turn reduces the revenues for the electricity generation companies.

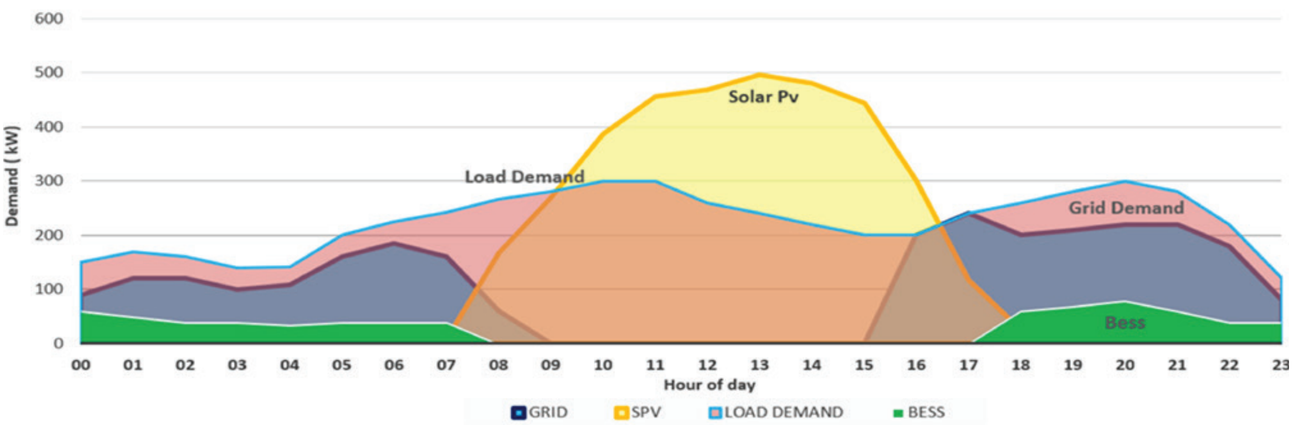

Figure 4: Forecast of Typical Load Profile and Power Supply Sources of Future Prosumers (Source: Author)

System Operator (S.O) – Grid Management and Power Quality

The task of managing power generation dispatch is entrusted to the S.O who arranges and schedules dispatches based on the prevailing electricity demand to ensure that critical grid parameters, such as voltage and frequency, remain within acceptable limits. However, the growing number of prosumers presents a significant challenge in managing the grid because he lacks visibility and control over the operations and dispatch schedules of these distributed energy sources (D.E.R).

Power quality entails supply stability and it encompasses voltage events such as dips, swells, over-voltages & under-voltages, which are characterized by magnitude and durations [6]. The variability in power injected into the grid by prosumers introduces voltage and frequency fluctuations which may pose adverse effects on the operations of electrical and electronic equipment.

Distributor & Retailer – Infrastructure constrains

The bi-directional power flow, and dumping of excess generation may introduce new dynamics in grid infrastructure, improper design of the power plant to match with the existing grid infrastructure including transformers, cables, metering devices and protection devices may lead to damage of the equipment's and further escalate the utility's operations cost.

Power Consumers – power quality

The variability in power generation from renewable introduces voltage and frequency fluctuations on the grid which may introduce adverse effects on plant operations by causing damage to equipment's, reduced productivity due to plant downtime etc.

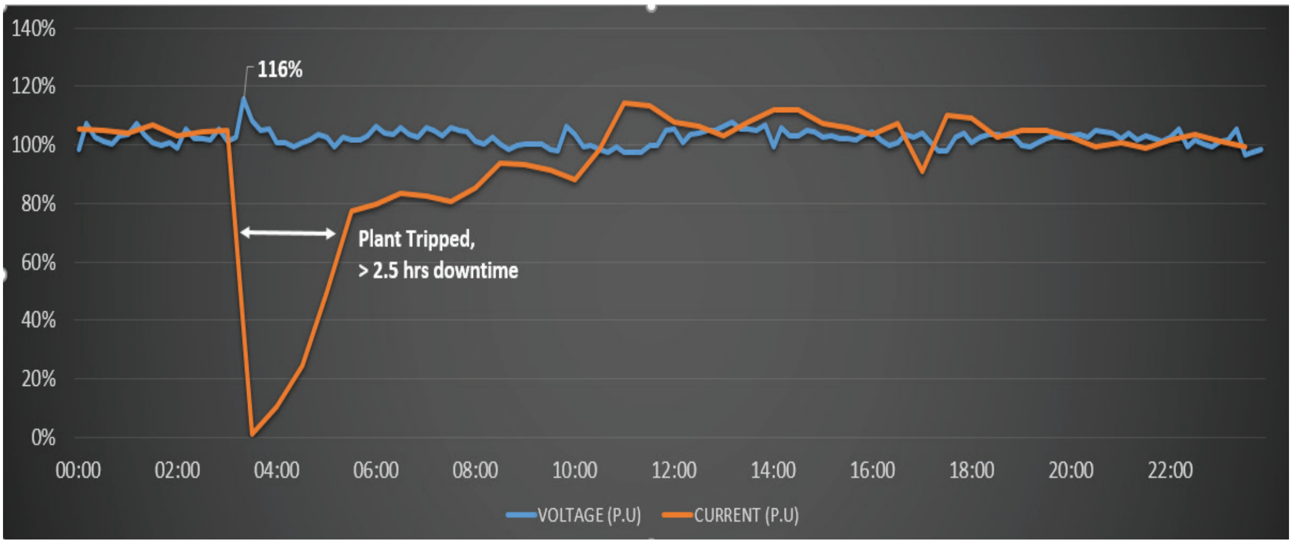

Figure 5: Impact of Voltage Fluctuations to Customer's Production (Source: Author)

5. Conclusions

Energy transition is gaining momentum and the growing number of prosumers have the potential to reshape the energy landscape. The pursuit of affordable, reliable power supply coupled with incentives such as net-metering has demonstrated the potential of influencing various aspects including grid stability, power quality, cost of electricity, revenues of energy sector stakeholders and energy accounting.

Energy sector players and policy makers therefore need to develop strategies of ensuring an optimal and coordinated integration of prosumers as part of the future energy system. This can be implemented through a multifaceted approach including technological, infrastructural and regulatory initiatives such as battery energy storage systems (BESS), smart grid distributed intelligence and tariff formulation.

Areas of further studies include; how prosumers can contribute to grid stability, utilization of grid-tie inverters for reactive power compensation and voltage regulation and how to bolster grid capacity through the aggregation and optimization of distributed energy resources.

Acknowledgement

We wish to thank the almighty God for being gracious to us and enabling us to do all that we have done, our families for their moral support and encouragement, our colleagues and friends for their insights and their contributions towards this research. We also extend our appreciation to Kenya Power for facilitating us with the resources, platform and conducive environment to conduct this work.

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Picture: Courtesy

The Nuclear Debate

Controversies Surrounding Nuclear Power

By EiK Correspondent

Nuclear energy is purported to be one of the safest sources of energy, alongside wind and solar power. It does not release toxic gases into the atmosphere that contribute to global warming, unlike the highly polluting fossil fuels. It is to a large extent clean and sustainable.

Whereas oil and natural gas often fall victim to price fluctuations and tend to be influenced by geopolitics, nuclear energy promises energy security. If there is one painful lesson the Russia-Ukraine conflict has collectively taught the world, it is the dangers of energy single source overreliance. This has revived the conversation on energy source diversification which has seen countries delay nuclear power phase out in order to address the energy deficit that came with this conflict.

Nuclear power seems to be the go-to solution to many of the world's energy problems, especially in a world where the discussion on climate change and the part fossil fuel plays in it has taken centre stage. Yet, for all its positive attributes, the use of nuclear reactors to generate electricity for civilian purposes has been marred by a lot of controversies which has impeded the global growth of nuclear power.

Nuclear Energy and Warfare

The bombings of the Japan's cities Hiroshima and Nagasaki in 1945 resulted in loss of lives and property of epic proportions. Opponents of nuclear energy feel that widespread, unregulated building of nuclear plants and access to nuclear energy could bring the world to the brink of nuclear conflicts. They also feel that it is possible for nuclear power to be diverted for purposes other than what it is intended.

Nuclear Power and Terrorism

In the current society, the threat of terrorism is constantly lurking in the air. Nuclear energy makes the possibility of detonation of a radiological device too close for comfort. Opponents also feel nuclear plants may make attractive target for terrorists. Such an attack or sabotage of nuclear facilities could have devastating effects on people and the environment.

Nuclear Power And Accidents

Accidents in nuclear plants, both man-made and inspired by acts of nature, have tested the public confidence in nuclear safety. These accidents are a strong premise upon which opponents of nuclear power cast aspersions on nuclear safety. First came the Three Mile accident where a cooling malfunction caused partial meltdown.

The Chernobyl Disaster, touted as one of the worst disasters in nuclear power generation, easily comes to mind when you assess the potential of nuclear power turning deadly in the face of accidents. The deaths, radiation sickness, and the radioactivity which crossed national frontiers chipped away at the public faith in nuclear power.

In 2011, nuclear power received yet another blow with of Japan's Fukushima disaster shaking up the nuclear industry worldwide. .

When the massive Tohoku earthquake struck in 2023, the systems at the Fukushima nuclear plant detected it and shut down the reactors and emergency generators were activated. Despite the emergency procedures activating, the quake triggered tsunami waves so high that they overwhelmed the sea wall and knocked out the emergency generators.

As if reading from the anti-nuclear activists' script, there were deaths, radioactive isotopes found their way into the atmosphere which initiated mass evacuations. Cost of cleanup has run into hundreds of billions, but it will be decades before the cleanup is complete. Residents refuse to return as they are wary of the radiation, and this has further strengthened the anti-nuclear argument.

The magnitude of these accidents and the impact they have had on people and the environment demonstrates why nuclear energy has been met with criticism.

Nuclear Power and Nuclear Waste

Safe disposal of nuclear waste is a problem that has long plagued the nuclear energy sector. Not only does the waste remain radioactive for thousands of years, but the cost of cleanup and decommission of aged reactors goes into billions of dollars, besides taking years and requiring lots of manpower. This makes it a very expensive undertaking and critics have questioned the potential of nuclear power as a clean and financially viable source of energy.

In the aftermath of the Fukushima disaster, wastewater used to cool the reactors was released into the Pacific

Ocean with the hopes that its huge volume would dilute the radioactivity. While the water is already treated to get rid of the radioactivity, critics remain wary of the effect this would have on the ocean's ecosystem and ultimately, human health.

This is just a tip of the iceberg on the debate about nuclear waste as countries grapple with safer alternatives for disposing it. Finland's solution to nuclear waste has been to bury it some 400 feet in the ground. This seems the most viable solution so far as most countries have plans in place to go the underground repository direction.

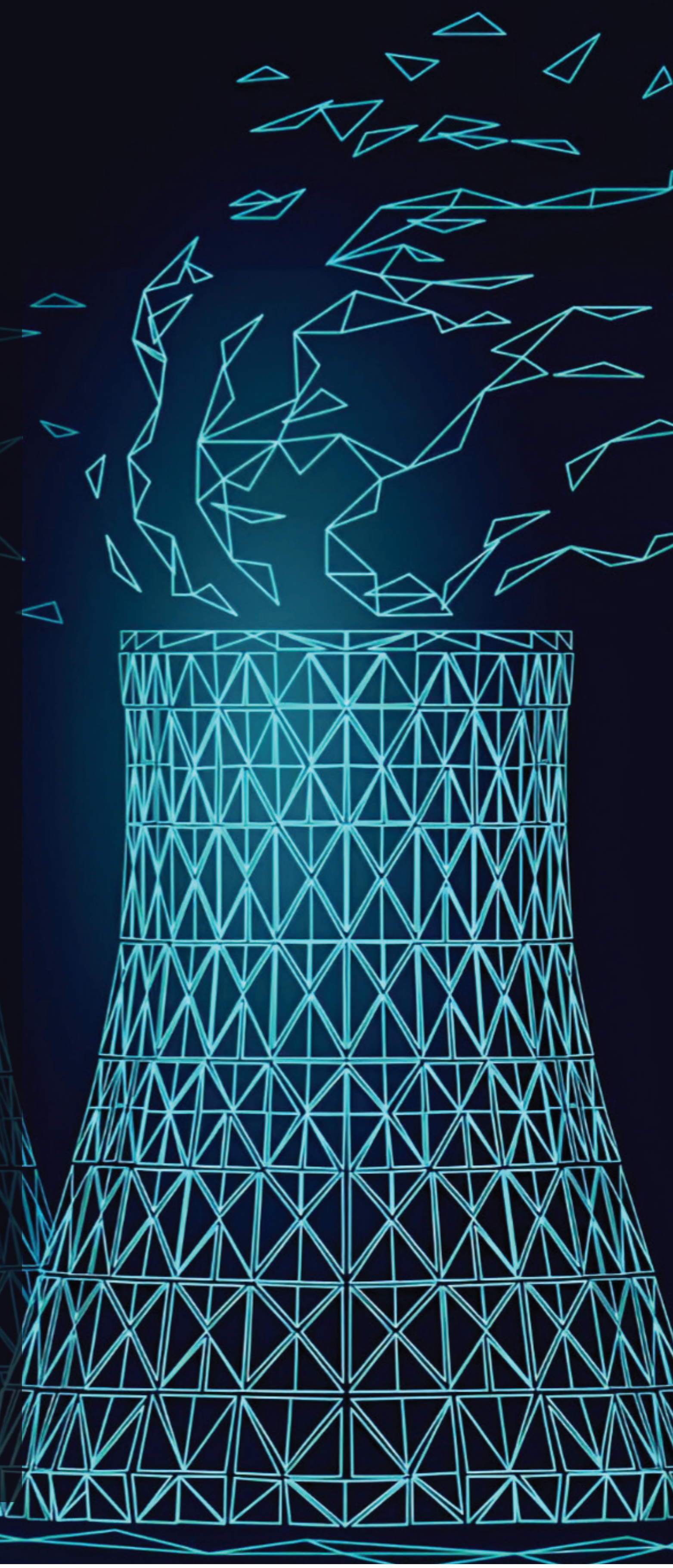
Future Outlook On the Energy Debate

Nuclear power promises reliable, consistent clean energy and seem as a viable approach for countries to meet their net-zero carbon emission targets. Nuclear proliferation, nuclear plant accidents, waste disposal, the health risks of uranium mining, process and costs of nuclear plant decommissioning are some of the problems the industry have to come to terms with. Yet, the energy crises that have followed the Russia-Ukraine conflict have made it apparent that countries, now more than ever, need to strongly think about energy source diversification.

The risks associated with nuclear power have pushed countries to the brink of nuclear power phase-out. Germany phased out the last of her reactors in April 2023, to avoid additional high level radioactive waste. Commendable progress has been made towards better nuclear waste management and disposal and more sustainable reactor designs.

As some governments make the decision to phase out their nuclear plants, others are coming alive to the potential of nuclear power in attaining energy sufficiency and autonomy. However, the kind of power nuclear energy promises comes with great responsibility.

According to the World Nuclear Association, about 60 reactors are being built around the world. Plans to build more than a hundred are in the pipeline. This goes on to show that despite these controversies, nuclear power will still be with us for a long time. Thus, the focus should go into learning from past mistakes so that power plants are more suited to handle accidents, nuclear waste is disposed in a manner that will not have adverse effects on the environment and regulations are built in place to enhance safety and accountability.



Perovskite-Based Solar Roofing Sheets.

Authors: Omondi Vincent Onyango[1], Shane Kwalanda Shitanda [2], and Weramwanja Peter (Supervisor)
[1] Mechanical Engineering, Student (5th Year), Machakos University, P.O. BOX 136 – 90100, Machakos County
[2] Mechanical Engineering, Student (5th Year), Machakos University, P.O. BOX 136 – 90100, Machakos County
[3]Mechanical Engineering Department. C.O.D, Machakos University, P.O. BOX 136 – 90100, Machakos County

Introduction

The goal of this initiative is to create perovskite-based photovoltaic-infused roofing sheets. The idea is to use sheets that incorporate photovoltaic cells that can be linked together to replace both conventional roofing sheets and solar panels made of silicon. This will enable a structurally altered roof to generate power for the building's residents. How to safely and affordably integrate the PV cells onto the roof sheets is the main difficulty. The PV cell and the sheet must both endure the weather after inclusion in order to guarantee that the solar cells are efficient for a long time and that homeowners won't need to frequently replace their roofs. The sheet's design must let light pass through while shielding the PV cells from mechanical, thermal, and chemical harm and maintaining an aesthetically pleasing appearance.

Today, Switzerland, Germany, the United States of America, and Japan are among the nations that are producing and using a small number of solar roof tiles and roofing shingles. Inverters and these tiles work together to generate electricity for the nearby electrical appliances. The amount of energy generated during certain times of the day that is more than the amount consumed by the household is put back into the local electricity grid, which results in a credit on the household's or company's bill (Zito, 2023). Perovskites are not used, nevertheless. Power generation may be much more affordable than ever thanks to perovskite solar cells' higher efficiency and simplicity of manufacture.

Problem Statement

More than 70% of the African population lives without access to sustainable, affordable, and reliable energy. This is not different in Kenya. Yet, solar energy is a year around, most abundant free naturally occurring clean energy supply that has ever existed. Despite the Kenyan government's efforts to advance its anticipated solar technology development goals in line with the Kenya Vision 2030 agenda, which calls for the development of new and renewable energy sources, there is still an excessive reliance on fossil fuels and hydropower. This project offers a roadmap for creating low-cost solar photovoltaic cells that are integrated into roofing sheets. Also, this concept takes the use of perovskites, an element with exceptional qualities that may be utilized to create solar cells and is generally accessible.

Aims and Objectives

Main Objective

- To modify the roofing sheet to incorporate perovskite solar cells in order to generate a significant solar energy source.

Specific Objectives

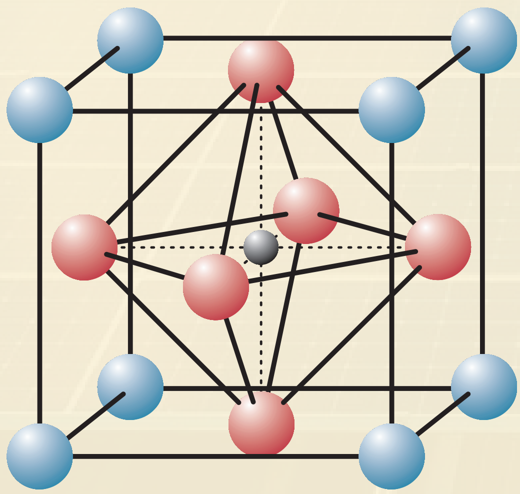
- To design roofing sheets that are integrated with solar cells.
- To produce solar roofing sheets that are easy to install.

Settings/Methods

- Perovskite solar cells are to be coated on the surface of the parent material for roofing sheets.
- PET (Polyethylene terephthalate) polyester is the best roofing sheet material because it is:
  - » Dimensionally stable, strong, stiff, and robust polymer, and absorbs very little water.
  - » Good chemical resistance
- The final step is to print the solar cells onto the desired surfaces of the PET roofing sheet.

Required Components

- Suitable elements for the ABX3 structure formation (To synthesize perovskite cells)
- Perovskite compounds, in general, have the chemical formula ABX3, where 'A' and 'B' are cations and X is an anion that links to both.



The most common elements that can be combined to form this structure are in the table below.

A	B	C
Methylammonium	Lead	Flourine
Formamidinium	Tin	Chlorine
	Germanium	Bromine
		Iodine

- An operational laboratory.
- PET material and roofing sheet processing equipment.
- Dimensions of roofing sheet=3m by 1m by 2mm.
  Volume=6*10-3 m3
  Density=1.38 g/cm3
  Mass=8.28 kg
  Price/kg=132.75ksh.
  Total price=1,100ksh.
- Perovskite cells printer/ coating equipment- Inkjet printer.
- Thin metal electrode sheets and other electrical components
- CuPc-doped Carbon and Tin Oxide used(Printed) electrodes
- Encapsulating material (Surlyn)

Expected Results & Calculations

Power yield calculations for a single perovskite solar cell with the dimensions 42cm by 20cm

Surface area for a single solar cell = 42 by 20 = 840cm^2

The formula to calculate power output (P) in watts for a solar cell is:

- P = ŋ × A × G Where:
- - P is the power output in watts per square centimetre (W).
- - ŋ is the efficiency of the perovskite solar cell, expressed as a decimal (e.g., 0.20 for 20% efficiency).
- - A is the area of the solar cell in square centimetres (cm²).
- -G is the incident sunlight intensity ranging from 1000 to 1360 watts per square meter (W/m²).
- Efficiency of a methylammonium lead Iodide based PVC ranges from 29% to 32%
- For a 42cm by 20cm cell, taking the least possible efficiencyand the least possible G;
- Power = 0.29* 1000*840/10000 = **24.36 Watts.** This is the ratting of a single perovskite solar cell.
- Our PV solar panel design contains 21 such solar cells arranged in series.
- Thus, the total rating of the perovskite solar panel = **21*24 = 504 Watts** This is the rating of the perovskite solar pannel.
- If the solar panel is to be exposed to averagely 6hrs of sunlight a day, The power produced can be calculates to be; 6hrs*504Watts = 3,024Watt-hours = **3.024 KWH per day**

Discussion

The development of solar roofing sheets based on perovskite is a possible path for integrating renewable energy sources into the built environment. While its deterioration is concerning, it is worth noting that this rate is comparable to or better than that of other developing photovoltaic technologies such as thin-film solar panels and organic solar cells.The practical integration of perovskite-based solar roofing sheets into residential and commercial structures is required to fully realise the potential of perovskite-based solar roofing sheets. Because of their flexibility and low weight, these roofing sheets are suited for a wide range of roofing constructions. To guarantee seamless integration into building designs, practical installation difficulties such as adequate sealing, connectivity, and electrical integration must be dealt with.

Advantages

- High efficiency in converting sunlight into electricity.
- Lightweight
- Faster production.
- Relatively easy to manufacture i.e simpler processes.
- Thinner solar panels
- Lower carbon footprint in terms of manufacturing.
- Cost-effective

Disadvantage

- Perovskites break down over time.
- The very best perovskites at generating energy contain lead, which is a neurotoxin; however, by encapsulating the solar cell, we are able to prevent this neurotoxin's exposure to the environment.

Conclusion

In conclusion, if this idea receives adequate support through more research, experimentation, and analysis, it may as well be a game-changer for the renewable energy sector. In comparison to conventional silicon-based solar cells, perovskites-based solar cells have better efficiency and are lighter, hence it may be feasible to generate more power than needed. The Kenyan populace would benefit greatly from having affordable, reliable energy access, and the country's economy would flourish as well. Because it integrates solar cells into roofing sheets, this project may potentially be helpful to many people. This means that solar panels and roofing sheets don't need to be installed separately during construction. Both have been blended into one, and are installed simultaneously, and the estimated cost is likewise manageable. This results in a significant cost decrease for installing solar panels and roofing sheets separately. Furthermore, as was already noted, perovskite solar cells have a typical thickness of 500 nanometers, which means that little would change regarding the dimensions and requirements of roofing sheets. The Kenyan government should embrace solar technology if it is to meet the objective of renewable energy set forth in its Vision 2030.

Acknowledgement

It is not possible to prepare a project without the assistance and encouragement of God and many people. We would like therefore, to thank the Almighty God for His guidance throughout our academics, we extend our deepest appreciation to our project supervisor, Mr. Weramwanja Peter. Your unwavering support, guidance, and mentorship have been instrumental in shaping the direction of this project. Finally, we appreciate the cooperation that each member dedicated to the production of this project.

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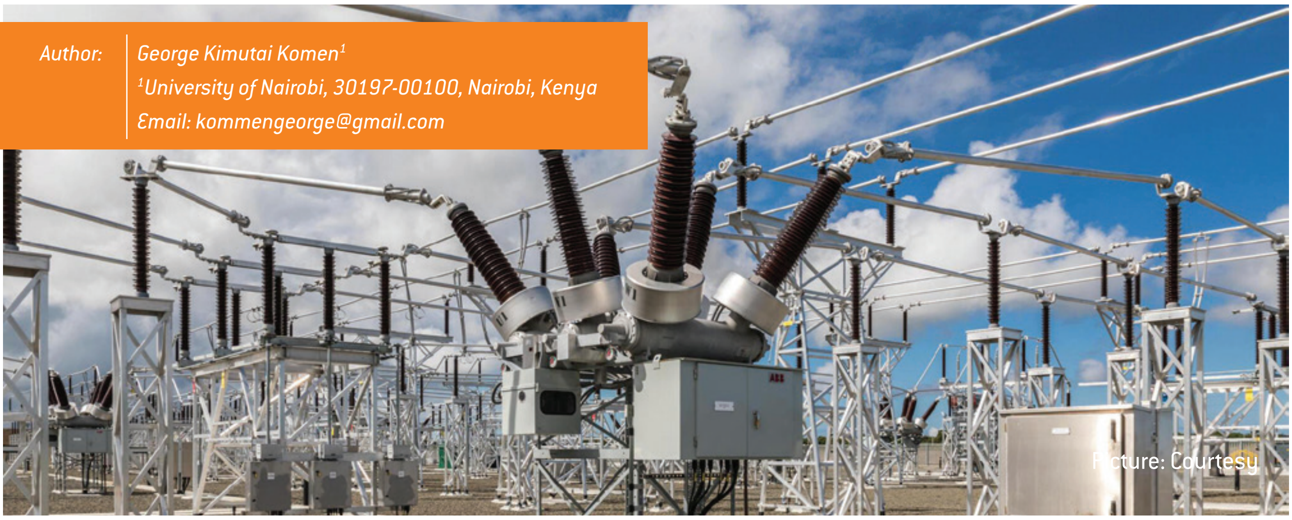
Picture: Courtesy

Comparative Tariff Assessment: Grid vs. Self-Generated Electricity in Kenya

Author: George Kimutai Komen[1]
[1]University of Nairobi, 30197-00100, Nairobi, Kenya
Email: kommengeorge@gmail.com



1. Introduction

Modern distributed technologies including flexible demand, distributed generation, energy storage, and improved power electronics are driving a huge revolution in the energy sector. This shift is taking place in tandem with broader changes in power systems, such as a rise in the use of renewable energy sources, a closer coupling of the grid, and initiatives to cut carbon emissions [1]. New possibilities for the supply and use of power are being produced by these advancements. Commercial organizations are increasingly implementing hybrid energy systems, utilizing the grid at night and solar energy during the day for a variety of uses. Due to the advancement of renewable energy technology and the demand for reliable and affordable electricity, this tendency has intensified [2]. Consumers producing their own electricity is another new trend. Industrial clients are separating themselves from the grid and putting in place their own energy strategies, frequently using solar power. Many organizations and businesses have installed solar PV systems to suit their electrical needs, including Unilever Tea Kenya, Strathmore University, Garden City Mall, Total Kenya, Mombasa International Airport, and the International Centre of Insect Physiology and Ecology (ICIPE).

The price of renewable energy dramatically dropped between 2009 and 2019. Costs for solar PV decreased by 89%, from $378/MWh to $68/MWh, while those for onshore wind decreased by 41%, from $135/MWh to $41/MWh [3]. In contrast, during this time coal and nuclear energy prices either rose or barely changed. Overall, technical improvements and the desire for less expensive and more dependable electricity are driving a change in the energy sector toward cleaner and more affordable energy sources.

With consumers increasingly shifting to renewable energy technologies (RE), which are less expensive and more dependable, the traditional electricity market structures are being challenged [4]. Although RE may have advantages, its high start-up expenditures, ongoing maintenance, and operational costs cast doubt on the viability of self-generation as an alternative to the grid [5]. Consumers may now regulate their energy output and consumption thanks to advancements in RE and energy storage technologies, but it is still unclear what this means for utilities, customers, and legislators. Understanding this new paradigm's effects on the power industry and using that knowledge to inform decisions requires research. Arguably, it is important to look into and have a better understanding of the overall notion of self-generation and grid defection given the perception of the trend as a disruptor in the energy sector.

2. Methods and Tools

The data collection process involved both primary and secondary sources capturing electricity generated, installed capacity, consumption rate, and reasons for opting for self-generation. The primary data collection process was broken into three phases. Phase I involves collecting information on energy output from businesses that had self-generation systems giving details on installed capacity, installation causes, and difficulties. The sampled self-generating systems had an installed capacity of more than 20 kW. Phase II gathered information from Engineering, Procurement, and Construction (EPC) vendors to reduce biases by capturing their viewpoints on the energy sector's capacity, costs, trends, difficulties, and incentives. In order to provide insights into the variables influencing self-generation and its effects on Kenya's energy sector, Phase III involves acquiring secondary data from EPRA, describing pricing, structural models, and changes in electricity sourcing from the national grid. The information covers tariff techniques and structures from 2013 through 2022.

The least expensive method of producing one's own electricity was determined using the LCoE methodology. The cost that results from comparing the lifetime cost of each organization to the discounted present value of the lifetime power produced indicates the point at which defecting economically makes sense. Although the tool makes comparing the competitiveness of technologies simpler, it does not take into account all project costs and financial factors. It ignores project hazards and oversimplifies project risks and discounted rates. Furthermore, it ignores distributed system efficiency advancements, which results in much higher LCOE, especially for small, efficient loads. The tool has limits in evaluating actual financial decisions, so it should be used cautiously (Hansen, 2019).

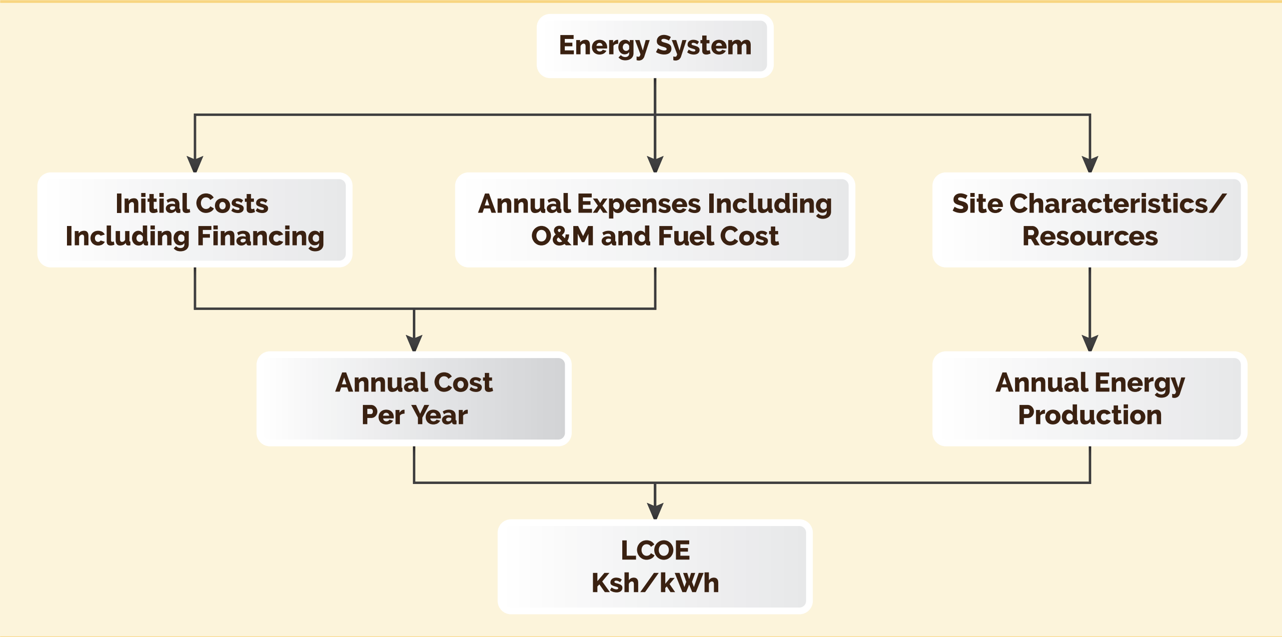


Figure 1: LCoE Concept

$$LCoE = \frac{Lifecyle\ Cost}{Lifetime\ Electricity\ Production\ (kWh)}$$

$$= \frac{\left(\frac{\sum_{t=0}^{n}(I_t + O_t + M_t + F_t)}{(1+r)^t}\right)}{\left(\frac{\sum_{t=0}^{n} E_t}{(1+r)^t}\right)}$$

Where:

LCoE: Levelised Cost of Electricity

It: Initial Capital Cost

Ot: Operation Cost,

Mt: Maintenance Cost,

Ft: Fuel Cost

Et: Total sum of Energy produced over the lifecycle

t: the plant/ system

r: discount rate (r) accounting for depreciation in value of costs and energy

3. Results

Results

From primary data, 11 companies were sampled and data collected from them. Table 1 shows the energy source with respective installed capacities, initial cost, operating hours, operating and maintenance costs (O&M) and electricity sources that include solar PVs, diesel generators, natural gas turbines.

Table 1. System variables for the surveyed companies (1 USD = Ksh 110 at the time of study)

Con-sumer	Energy Source	Installed Capacity	Initial Capital (Ksh in million)	Operating hours	Annual O&M (Ksh in million)
A	Solar PVs	1.2 MW	270	2500	1.66
	Diesel Generators	7.5 MVA	90	300	2.1
B	Solar PVs	1.67 MW	300	2500	0.3
	Diesel Generator	400 kVA	5	400	0.7
C	Solar PVs	850 kW	60	3000	0.7
	Diesel Generators	2 MVA	20	250	1.5
	Natural Gas	10kW	20	1500	1.1
D	Solar PVs	20 kW	2.1	3000	0.1
	Diesel Generators	160 kVA	0.8	500	0.3
E	Solar PVs	230 kW	23	2500	0.8
F	Solar PV	2.5 MW	270	3000	0.56
	Diesel Generators	4.32 MVA	50	600	3.2
G	Solar PVs	150 kW	15	2500	0.5
	Diesel Generators	1 MVA	10	300	1.8
H	Solar PVs	560 kW	50	3000	0.8
	Diesel Generators	1.5 MVA	20	250	1.5
I	Solar PVs	410 kW	40	2500	0.5
	Diesel Generators	2.5 MVA	30	300	1.4
J	Solar PVs	290 kW	30	2500	0.4
	Diesel Generators	500 kVA	5	200	1.1
K	Solar PVs	670 kW	70	3000	0.9

Levelised Cost of Electricity

The survey discovered that the majority of solar PV systems ran for between 2,500 and 3,000 hours annually, while diesel generators were only used for between 200 and 500 hours. Operation and maintenance (O&M) costs for solar PV systems included replacement parts, maintenance, clearing, administration, annual inspection, and security, whereas diesel generators also had fuel costs in addition to other O&M costs. Based on theoretical data, solar PV systems were projected to have a lifespan of 30 years [6], whilst diesel generators and natural gas turbines were assumed to have a lifespan of about 20 years. The discount rate taken was 7.5% and expected inflation rate was 7%. The calculated LCoE of the systems is shown in the Table 2.

Table 2: Calculated LCoE for the Surveyed Cnsumers

Con-sumer	Energy source	Life cycle cost of the system (Ksh)	Life cycle electricity produced (Ksh)	LCoE (Ksh)
A	Solar PVs	930,979,551	10,279,892.71	90.56
	Diesel Generators	433,631,018.70	9,534,232.50	45.48
B	Solar PVs	1,032,443,891	14,306,184.02	72.17
	Diesel Generator	26,837,098.88	677,989.87	39.58
C	Solar PVs	207,998,495.8	8,737,908.80	47.78
	Diesel Generators	101,227,653.70	2,118,718.33	23.80
	Natural Gas	99,344,348.48	70,623.84	70.33
D	Solar PVs	7,538,588	205,597.85	36.67
	Diesel Generators	5,179,089.26	338,994.93	15.28
E	Solar PVs	81,553,815.48	1,970,312.77	41.39
F	Solar PV	930,535,887.90	25699731.77	36.21
	Diesel Generators	250,479,589.50	10,983,435.84	22.81
G	Solar PVs	53,112,779	1,284,986.59	41.33
	Diesel Generators	55,557,502.94	1,271,231	43.70
H	Solar PVs	174,072,850	5,756,739.92	30.24
	Diesel Generators	101,227,653.70	1,589,038.75	63.70
I	Solar PVs	138,778,551.50	3,512,296.68	39.51
	Diesel Generators	147,839,457	3,178,077.50	46.52
J	Solar PVs	104,169,579.40	2,484,307.40	40.30
	Diesel Generators	28,720,404.06	423,743.67	67.78
K	Solar PVs	242,948,131	6,887,528.11	35.27

Grid Tariffs Charges

The Energy and Petroleum Regulatory Authority (EPRA) in Kenya has established tariffs and billing structures for various consumer groups over specific time periods. These consumer groups, categorized as CI 1-5, primarily consist of commercial and industrial consumers. The billing components include fixed charges, energy charges, off-peak charges, and demand charges [7]. Between 2013 and 2018, billing was based on fixed charges, demand charges, and consumed charges. Fixed charges were imposed regardless of electricity usage. However, in 2018, the billing structure shifted to be based on consumed energy, off-peak charges, and demand charges. For instance, CI1 consumers had fixed charges of Ksh 2,000.00, which later increased to Ksh 2,500.00 by 2018. CI4 consumers saw fixed charges replaced with higher consumed energy charges, starting at Ksh 7.30 and increasing to Ksh 7.80 by 2020.

Grid Defection

Many organizations opt for a hybrid strategy due to the high upfront costs of being completely off-grid, the costs of power storage devices, and the need to save money on infrastructure. Some companies also use feed-in tariffs and cheaper off-peak prices to balance their electricity costs. Despite these changes, many users still use the grid for things like controlling supply and demand imbalances, controlling voltage and frequency, and having the option to export excess electricity. Utility providers have proposed solutions like raising fixed fees and demand-based pricing in response to trends in customer desertion.

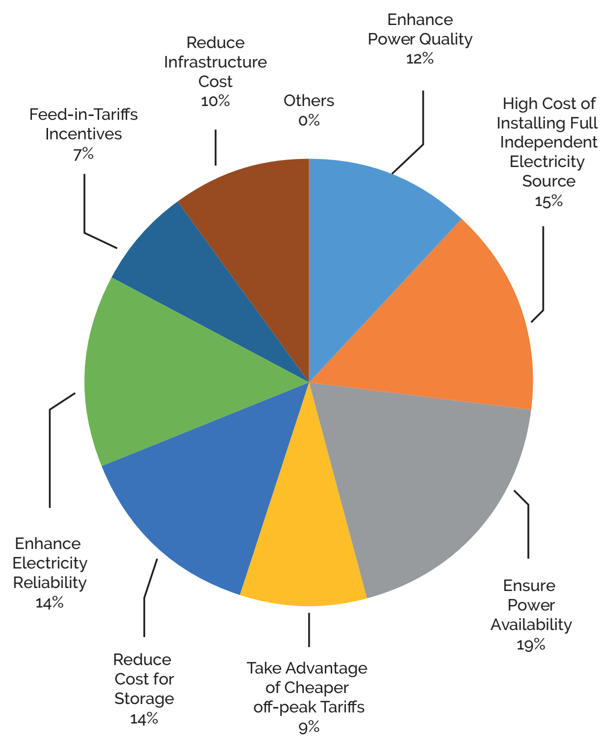


Fig. 1. Reasons for having both grid and own generated electricity

4. Discussion

Hybrid systems in industrial setups with motors drives can increase Total Harmonic Distortion (THD), has a detrimental effect on the performance of self-generated electricity, operational expenses, and equipment reliability [8]. Load sensitivity, component integration, system upkeep, and power quality are a few difficulties. Only a small percentage of respondents, who largely used net metering and FIT pricing, had agreements to deliver extra power to the grid and thought these agreements were favourable. Regulation-related problems, high rates, and lengthy negotiation processes are some of the current impediments to self-generated power, although proper policy implementation might dramatically lower the LCoE [9].

In addition to these charges, consumers face several additional fees, including fuel charges, foreign exchange rate adjustment fluctuation adjustment (FERFA), inflation adjustment (INFA), security support facility (SSF), water levy (WARMA), and various taxes and levies. These additional charges can constitute approximately 45% of the total cost of electricity, making grid electricity relatively expensive. Comparatively, Kenya Power benefits from economies of scale and density in providing electricity. However, consumers generating their own electricity do not incur these additional charges [10]. Nevertheless, self-generated electricity can have a higher LCoE when compared to grid electricity.

For certain consumer categories throughout particular time periods, EPRA in Kenya has defined tariffs and billing systems. Commercial and industrial consumers make up the majority of these CI 1–5 consumer groupings [7]. Fixed charges, energy charges, off-peak costs, and demand charges are some of the elements of the bill. Billing was based on fixed charges, demand charges, and consumption charges between 2013 and 2018. There were set fees regardless of how much electricity was used. The pricing structure changed in 2018 to be based on energy usage, off-peak fees, and demand fees.

Customers also pay for fuel, FERFA, INFA, SSF, WARMA, and other taxes and levies in addition to these expenses. Grid electricity is relatively expensive because of these extra costs, which can account for up to 45% of the overall price of electricity. Kenya Power, in contrast, makes use of economies of size and density while supplying electricity. However, these extra costs are not incurred by consumers who generate their own electricity. Compared to grid electricity, self-generated electricity may have a higher LCoE [11]. However, economic factors also play a role in the choice to keep grid connections.

5. Conclusions

The energy industry has changed significantly over the past ten years as a result of a number of variables, including dispersed generation, flexible demand, grid system liberalization, environmental concerns, and the need for reliable, affordable electricity. In order to solve challenges like power stability, economic effectiveness, environmental sustainability, and energy independence, commercial and industrial consumers in Kenya are rapidly embracing self-generated electrical systems. The study discovers, however, that the price of self-generated power varies considerably, with solar PVs costing, on average, Ksh 46.49/kWh and Gensets Ksh 40.96/kWh, frequently as a result of low capacity utilization. The price of grid power is largely steady. Despite using self-generated electricity, users still rely significantly on the grid because of blackouts and other issues. For more consumers to choose self-generation, policy implementation and utility provider support must be improved. The utilization factor should be increased, policy implementation should be improved, and more study should be done on hybrid integration systems and electrical reliability.

Acknowledgement

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Picture: Courtesy

Meeting Electricity Demand for Kenyan Island Areas and Underserved off-grid Areas Through Solar Powered Mini-grids.

Eng. Fred Ishugah

The Government of Kenya has made significant progress in energy access to her populations as compared to other Sub-Saharan countries. Despite progress made, electricity access is still low within majority of underserved areas which include Islands and specific areas of counties in Northern, Eastern and southern Counties. Kenya host a number of Islands in the Indian Ocean and Lake Victoria.

The Islands that are habitable by human settlement have unique considerations to make in addressing energy issues. Because of their locations, it is usually difficult for communities living within these Islands to fully benefit from the economies of scale that pooling energy resources compared to those within the mainland. Majority of island communities are often forced to strive to be 100% self-reliant using the resources available on the island. Currently, a number of Islands in Kenya are highly dependent on fossil fuels, and the majority spend more to access fuel compared to their adjacent mainland communities.

Renewable energy is increasingly demonstrating to be a very reliable source of supply for islands and can reduce the current energy access cost and scenario of heavy dependency on fossil fuel. Fortunately, many Islands are endowed with huge renewable energy resources that can sustainably be developed for the benefit of their economies. Some of the resources that islands can locally exploit include solar, wind, sustainable and modern use of biomass, tidal power and wave energy.

> A mini-grid is a set of small-scale electricity generators interconnected to a distribution network that supplies electricity to a small, localized group of customers. It usually operates independently from the national transmission grid.

In Kenya, solar has successfully been used at various capacities ranging from pico, solar home systems, solar powered mini-grids to large utility plants. Rural Electrification and Renewable Energy Corporation (REREC) is implementing a World Bank funded solar mini-grids under the Kenya Electricity Modernization Project (KEMP) to increase access to electricity in all areas of the country to achieve universal access to energy. This project among other deliverables entails the development of seven (7) Solar Mini-grids in islands and off-grid areas of Mageta Island, Siaya County; Ngodhe and Takawiri Islands in Homa Bay County; Mkwiro and Wasini, Kwale County, Kaeris and Kerio Market in Turkana County and Dabel Markets in Marsabit County. These mini-grids targeted 3950 connections to businesses and households that are not likely to be connected to grid electricity in the short term and medium.

The KEMP mini-grids Project represents a significant step toward improvement of the livelihoods through sustainable development, addressing energy challenges and unlocking the economic potential of the areas they are implemented. Through planning, community engagement, and proper utilization of the plant and its infrastructure, the project not only provides immediate benefits but also sets a precedent for similar initiatives in off-grid areas within the country. As areas installed with solar powered mini-grids embraces a cleaner and more reliable energy future, it stands as a beacon of sustainable development, showcasing the positive impacts that thoughtful and community-driven projects can have on local communities.

The design and implementation of the KEMP mini-grids project is a well-rounded initiative, addressing key components essential for the success and sustainability of the mini-grid. It encompassed resource assessment and design, community engagement, capacity building, mini-grid development.

The Corporation conducted a comprehensive assessment of solar energy resources to determine the feasibility and potential output of the mini-grids. Design teams ensured that the chosen location were adequate to exploit solar resources for efficient energy generation to meet the electricity demand. Community engagement were conducted along with resource assessment to raise awareness and address concerns within the local community to help build trust and support. In addition, input from the residents ensured that the project aligned with their needs and values, fostering a sense of ownership and collaboration. Capacity-building programs for non-skilled, local technicians and entrepreneurs were conducted to empower the community as well as creation of a self-sustaining model. Finally, installation of necessary infrastructure, including solar panels, energy storage systems, a backup generator, and a power distribution network was done to ensures that the system is robust, reliable, and capable of meeting the energy needs of the community.

The KEMP mini-grid project have been earmarked to have a profound impact in the following areas;

1. **Education** – Offer opportunity for increased study hours for students which, and therefore potential improved performance in the connected schools. The students can also conduct experiments and other practical's requiring electricity supply which was not possible before.

2. **Health** – Improve storage of vaccines and other drugs requiring refrigeration will lead to improved health care.

3. **Fishing** – The main economic activity in the island and areas next to water bodies is fishing, therefore, electricity connectivity will facilitate fish cold storage.

4. **Security** – Improved lighting on the streets and the centers will lead to improved security.

5. **Small enterprises** – Electricity will create an opportunity for establishment of small and micro-enterprises including welding, air-dressing among others.

6. **Quality of life** – Lighting in houses will lead to improved quality life and reduced indoor pollution because some communities were using kerosene and wood for lighting.

7. **Longer business hours** – Lighting in streets and markets will lead to longer business hours

Eng. Fred Ishugah is the General Manager, Renewable Energy Research and Development at Rural Electrification and Renewable Energy Corporation (REREC)

Picture: Courtesy

Empowering Communities:
IEK's Commitment to Corporate Social Responsibility

By EiK Correspondent

A team of IEK engineers, led by 1st Vice President Eng. Grace Muthoni Kagondu, IEK Women Engineers Committee (WEC) Chair Eng. Florah Kamanja, and IEK Capital Branch Chair Eng. Dr. Damaris Oyaro, visited the Kawangware Initiative Rescue Centre to spread the Christmas cheer and donate essentials.

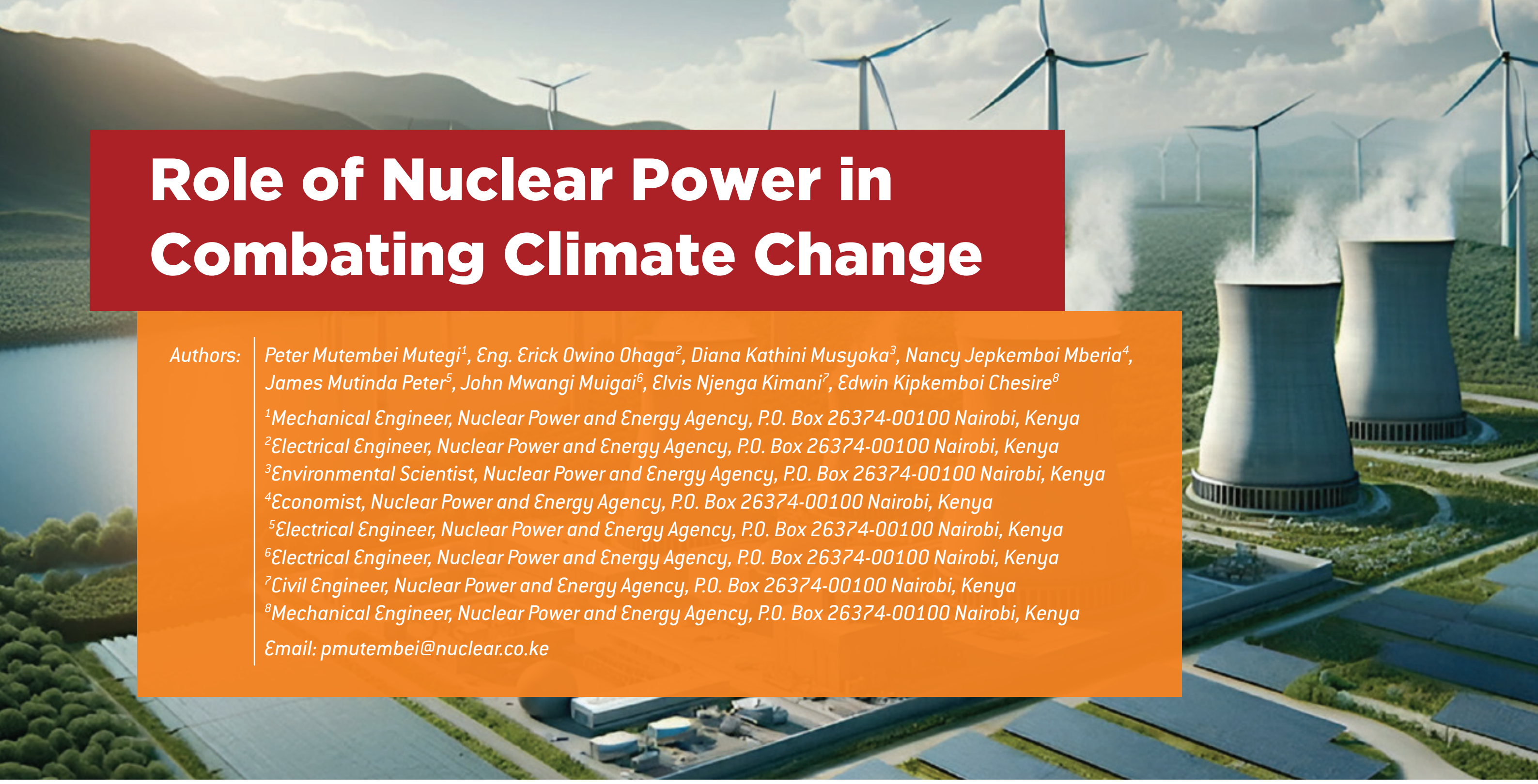
Eng. Grace Muthoni Kagondu expressed her satisfaction, saying, *"It's heartwarming to see the engineering community come together to make a difference. Our commitment goes beyond our professional duties; it extends to the well-being of the communities we serve."*

Beyond Borders: IEK's Comprehensive CSR Initiatives

The Kawangware Initiative Rescue Centre project is just one facet of IEK's broader Corporate Social Responsibility initiatives. IEK has consistently engaged in various activities aimed at community development, environmental conservation, and professional mentorship.

1. Tree Planting for a Greener Tomorrow: IEK has actively participated in tree planting activities to contribute to environmental sustainability. Recognizing the importance of a green future, IEK engineers have taken the initiative to plant trees, advocating for a healthier planet for generations to come.
2. Mentorship Programs for the Next Generation: IEK has played a pivotal role in shaping the future of engineering by providing mentorship programs for high school students, university students, and graduate engineers. These initiatives aim to nurture talent, inspire innovation, and guide aspiring engineers towards successful careers.
3. IEK engineers actively contribute to projects that address societal challenges, ensuring that engineering solutions are accessible to all.

Eng. Florah Kamanja, Chair of IEK Women Engineers Committee, emphasized the importance of empowering women in the engineering field. *"Our commitment to Corporate Social Responsibility includes initiatives that foster diversity and inclusivity. Through mentorship and support, we strive to create an environment where everyone, regardless of gender, can thrive in the engineering profession."*



Role of Nuclear Power in Combating Climate Change

Authors: Peter Mutembei Mutegi[1], Eng. Erick Owino Ohaga[2], Diana Kathini Musyoka[3], Nancy Jepkemboi Mberia[4], James Mutinda Peter[5], John Mwangi Muigai[6], Elvis Njenga Kimani[7], Edwin Kipkemboi Chesire[8]

[1]Mechanical Engineer, Nuclear Power and Energy Agency, P.O. Box 26374-00100 Nairobi, Kenya
[2]Electrical Engineer, Nuclear Power and Energy Agency, P.O. Box 26374-00100 Nairobi, Kenya
[3]Environmental Scientist, Nuclear Power and Energy Agency, P.O. Box 26374-00100 Nairobi, Kenya
[4]Economist, Nuclear Power and Energy Agency, P.O. Box 26374-00100 Nairobi, Kenya
[5]Electrical Engineer, Nuclear Power and Energy Agency, P.O. Box 26374-00100 Nairobi, Kenya
[6]Electrical Engineer, Nuclear Power and Energy Agency, P.O. Box 26374-00100 Nairobi, Kenya
[7]Civil Engineer, Nuclear Power and Energy Agency, P.O. Box 26374-00100 Nairobi, Kenya
[8]Mechanical Engineer, Nuclear Power and Energy Agency, P.O. Box 26374-00100 Nairobi, Kenya

Email: pmutembei@nuclear.co.ke

1. Introduction

Climate change is one of the most critical environmental issues the world is facing today. According to the Intergovernmental Panel on Climate Change (IPCC), the change in climate has led to the increased magnitude and frequency of extreme weather events. In Kenya during the past 50 years, surface temperatures in Nairobi have demonstrated a warming trend of more than 2.5 0C (Government of Kenya, 2018). Globally, nearly half of the increase in greenhouse gas emissions since 1990 came from increased electricity demand (International Atomic Energy Agency, 2022). In Kenya, the emissions from the energy supply (electricity generation) sector are projected to increase significantly and be the highest of all sectors from 2015 to 2030, this is largely due to projected growth in energy demand from 8,554 gigawatt-hours in 2020 to 32,914 gigawatt-hours in 2040 as development plans such as Vision 2030 are implemented (Government of Kenya, 2018). Kenya aims to achieve Vision 2030 through a low carbon, climate resilient development pathway.

Kenya is party to the Paris Agreement which intends to keep global warming below 2°C and has developed the Nationally Determined Contribution (NDC) in reducing global greenhouse gas emissions. Initially, Kenya set the NDC to 30% relative to the Business As Usual scenario by 2030. This was updated in 2020 to a target of 32% by 2030 relative to the Business As Usual scenario (Government of Kenya, 2022). The country is also developing the mid-century (2050) Long-Term Strategy for a low carbon development pathway under the Paris Agreement. In order to track and manage the national contribution to reducing global greenhouse gas emissions, the National Climate Change Action Plan (NCCAP) 2018-2022 has been developed and it aims to reduce greenhouse gas emissions from the electricity generation sector by 21.72%. The mitigation actions include increasing the share of renewables in the energy mix, majorly the geothermal sources (Government of Kenya, 2018). Currently, renewable energy sources account for approximately 75% of the country's installed capacity.

There is a need to complement the existing renewable energy sources to meet the projected energy demand while achieving low carbon development, through alternative low carbon sources such as nuclear energy. Nuclear energy reduced acceleration of global climate warming in the past four decades by preventing the release of over 60Gt CO2 after 1970. Currently, it is estimated that nuclear energy is preventing annual release of 1.2-2.4Gt CO2 emissions globally (International Atomic Energy Agency, 2022). Nuclear energy can make a significant contribution to reducing greenhouse gas emissions worldwide, and, at the same time, fulfil the increasing energy demands of a growing world population to support global sustainable development.

Nuclear energy has been identified as one of the sources to meet Kenya's future electricity demand. This offers a great opportunity for Kenya to meet its emission reduction target as it is one of the energy sources with minimal GHG emissions. Adoption of nuclear power generation not only contributes to meeting emission reduction targets in Kenya but also offers a reliable source of baseload electricity that is also resilient to climate change. The IPCC recognises that nuclear power has potential to decarbonise the global energy industry specifically in electricity generation. However, in order for nuclear energy to be expanded as a global response to climate change mitigation, there is need for greater efforts to address the safety, economics, uranium utilization, waste management, and proliferation concerns of nuclear energy use (Fischedick, 2014).

2. Methodology

The Low Emissions Analysis Platform (LEAP) is a software/ tool used for energy policy analysis and climate change mitigation assessment. The tool was used in this study to characterize national emissions of greenhouse gases and explore alternative emission reduction scenarios in Kenya's electricity supply sector. Data that was fed into the tool was obtained from the Least Cost Power Development Plan 2020 – 2040. This includes data on energy demand and generation candidates namely: hydro, biomass/biogas, wind, solar, geothermal, coal, imports, nuclear and liquefied natural gas. The study period was 20 years with the base year taken to be 2020 and optimization done from 2021 to 2040. The study period 2020 – 2040 was adopted in line with the Least Cost Power Development Plan 2020 – 2040. Three scenarios were created, all of which were compared in terms of deviation from the business as usual (BAU) case.

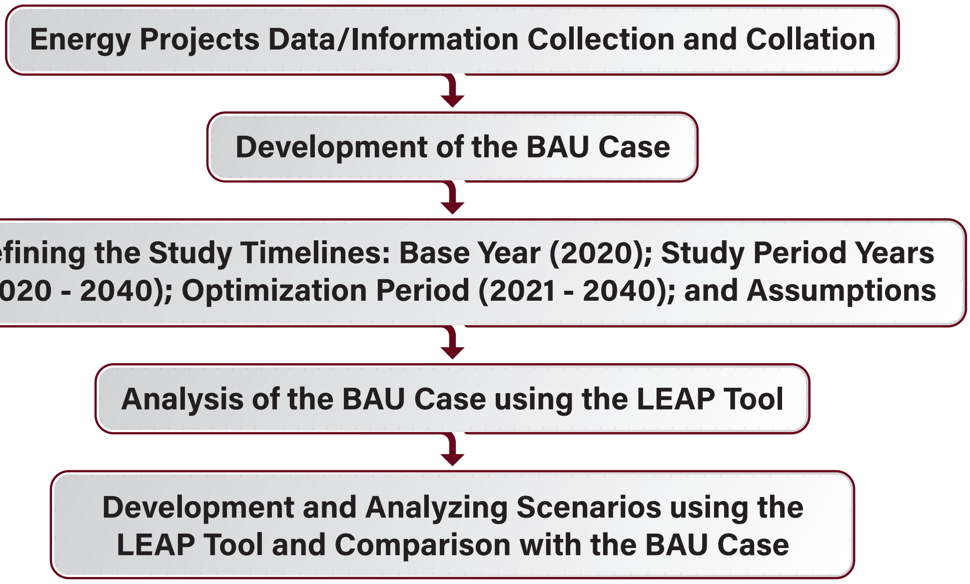


Figure 1: Summary of the methodology

The scenarios are as follows:

Table 1: Study Scenarios

Scenario	Description
1	Emissions as adapted from BAU case Versus emissions resulting from exclusion of all planned fossil-based electricity generation (coal and natural gas)
2	Emissions as adapted from BAU case Versus Emissions resulting from exclusion of planned coal-based electricity in the generation mix
3	Emissions as adapted from BAU case Versus Emissions resulting from exclusion of planned natural gas-based electricity in the generation mix

3. Results and Discussion

In the BAU case, which is the reference long term electricity generation plan, the total 20-year emissions are 17.35 million tonnes CO2 equivalent (MtCO2e). The growth in emissions is indicated in Figure 2 below.

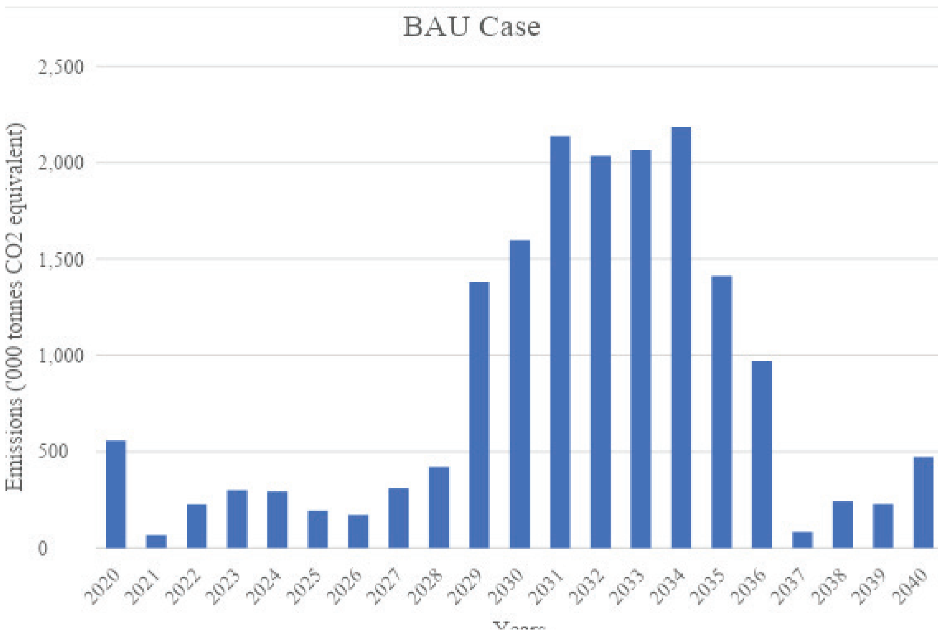


Figure 2: Business As Usual Case emission scenario

Scenario 1

The total emissions in this case are 1.76 MtC02e, which is an emission reduction of 89.87% when compared to the BAU situation. This is attributed to the removal of coal, which in the BAU model is the main source of C02 emissions. Figure 3 below illustrates the comparative examination of emissions growth.

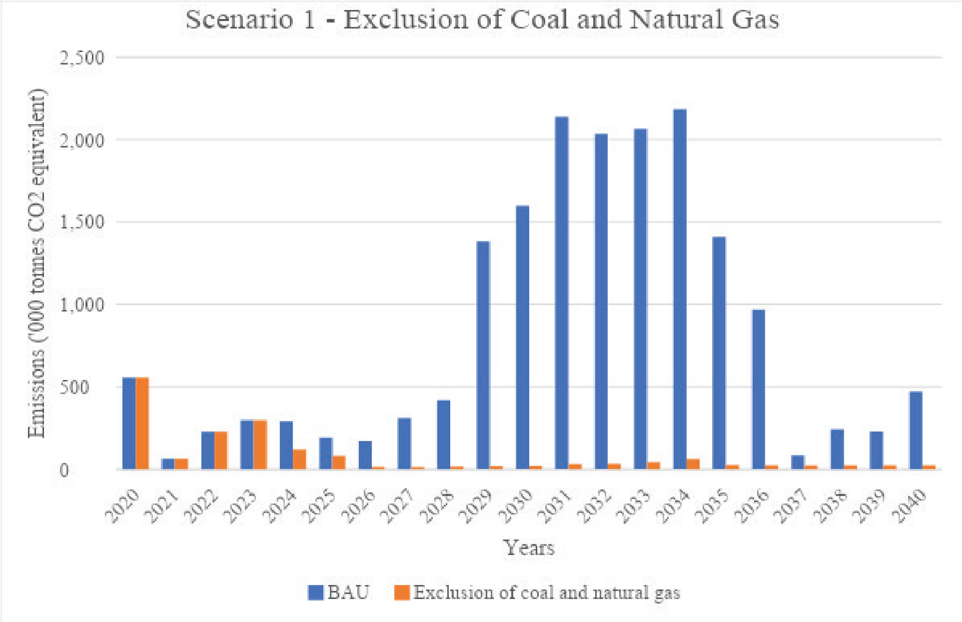


Figure 3: Scenario 1; Exclusion of Coal & Natural gas

The results also indicated that for a low carbon energy system with the removal of 981 MW of coal and 1,050 MW of natural gas, the capacity is replaced by 350 MWe of geothermal, 200 MWe of Wind, 450 MW of hydro, 160 MW of biomass and 246MWe of Solar. The total nuclear capacity is unchanged at 873.9 MW, but a capacity of 224.94 MW is brought online in 2038, instead of 2039 as in the BAU.

Scenario 2

The total emissions are 4.04 MtC02e. This is a 76.74 % emissions reduction in comparison with the BAU as illustrated in Figure 4 below. The emissions observed here are from planned natural gas generation.

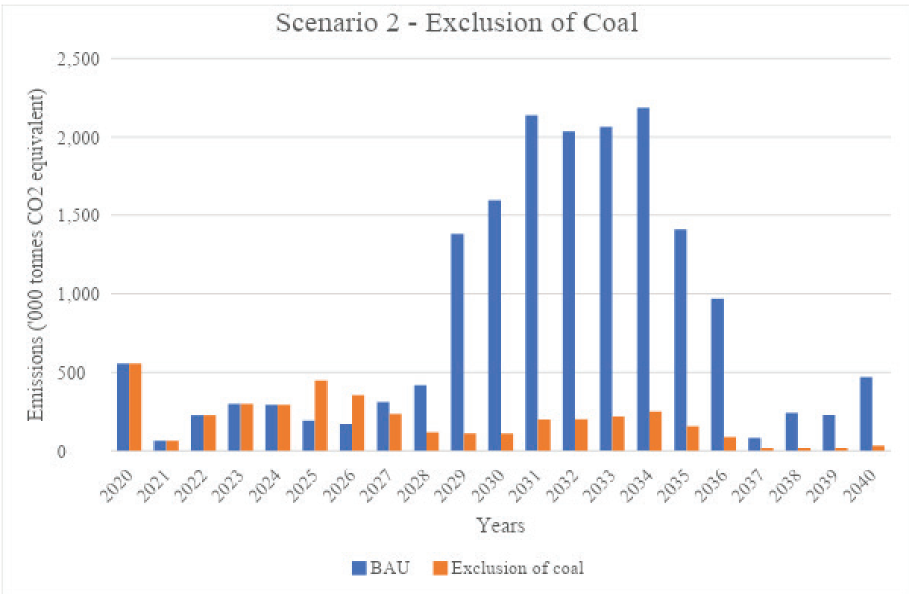


Figure 4: Scenario 2; Exclusion of Coal

Scenario 3

In this scenario the total emissions are 14.06 MtC02e. This is a 18.95% reduction in emissions growth. Compared to the BAU case this is an insignificant difference on emissions growth. This further confirms that inclusion of coal in the energy mix contributes to a significant percentage of GHG emission compared to natural gas. The growth in emissions is indicated in Figure 5.

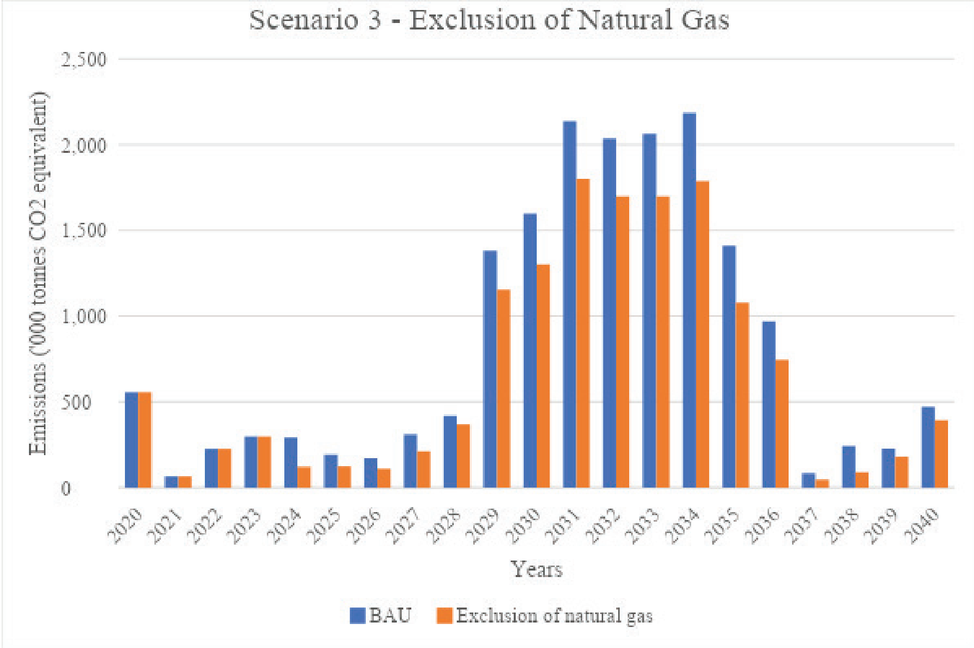


Figure 5: Scenario 3; Exclusion of Natural Gas

4. Conclusion

The assessment using the Low Emissions Analysis Platform indicates that in the future, nuclear electricity generation will play a significant role in combination with renewable sources in order to achieve a reduction in emissions in the energy sector. It is worth noting from the ongoing reactor technology assessment that, based on the forecasted nuclear generation requirements, the emerging Small Modular Reactor (SMR) technologies are expected to play a critical role. They are particularly appealing due to their novel design and desirable deployment characteristics, including: scalability, adaptability for smaller grids, modularization, suitability for cogeneration, small plant footprint, site flexibility, and load following capability. In order for nuclear energy to contribute to GHG emissions reduction in Kenya, it should be included as one of the mitigation actions in the energy sector in climate change action planning. This calls for fast-tracking the implementation of the nuclear power programme by developing the requisite infrastructure (institutional framework, human resource development, stakeholder engagement, legal and regulatory framework, research and development, technology assessment, etc.). Promotion of the coexistence of nuclear and renewable energy among the relevant stakeholders is also key, especially in research and development and policy development matters.

Acknowledgement

We take this opportunity to express our sincere gratitude to NuPEA which supported us throughout the course of this study. Of special mention are the members of the NuPEA Environmental Protection Technical Working Group for their effort. We also wish to thank the CEO, NuPEA for the moral and infrastructural support.

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IEK Membership Report

The IEK Membership Committee meets every month to consider applications for membership of the various classes received at the secretariat. The IEK Council at its 516th, 517th and 518th Council accepted the following members under various membership categories as shown below;

MEMBERSHIP CLASS	NUMBER ACCEPTED-516TH COUNCIL	NUMBER ACCEPTED-517TH COUNCIL	NUMBER ACCEPTED-518TH COUNCIL
FELLOW	-	2	2
CORPORATE	5	70	8
GRADUATE	80	60	26
GRADUATE ENGINEERING TECHNOLOGIST	3	2	2
GRADUATE ENGINEERING TECHNICIAN	7	2	-
STUDENT	8	6	3
TOTAL	**103**	**142**	**41**

During the period we had 4 member who transferred from the class of Corporate to Fellow member and 83 who transferred from Graduate to Corporate member. In addition, we had 166 Graduates, 7 Graduate Engineering Technologists, 7 Graduate Engineering Technicians and 17 Students were accepted as members.

Gender Data

Class	Male	Female	Percentage (Male)	Percentage (Female)
Fellow	4	-	100%	-
Corporate	69	14	83%	17%
Graduate	144	22	87%	13%
Graduate Engineering Technologist	6	1	86%	14%
Graduate Engineering Technician	9	-	100%	-
Student	15	2	88%	12%
TOTAL	**247**	**39**	**86%**	**14%**

Summary

Gender	No	Percentage
Male	247	86%
Female	39	14%
	286	**100%**

516TH APPROVAL

CORPORATE

S/NO.	NAME	MEMBER NO.
1	Emmanuel Ogot	M.10708
2	Gilphas Otieno Apiyo	M.13068
3	Lincon Ndwiga Muriuki	M.9942
4	Nyandusi Mogere	M.9531
5	Alphonce Odhiambo Oluoch	M.10849

517TH APPROVAL

FELLOW

S/NO.	NAME	MEMBER NO.
1	Simon Njoroge Kamunge	F.1001
2	Anthony Ooga Moire	F.1387

CORPORATE

S/NO.	NAME	MEMBER NO.
1	Abdirahim Mohamed Ibrahim	M.6571
2	Abuga Franklin Ariga	M.9293
3	Amos Oluoch Owaga	M.8933
4	Austine Silyvester Obiero Oketch	M.13156
5	Benjamin Kipruto	M.10582
6	Boaz Ochwonyo Amukhoye	M.9016
7	Byrone Ochieng Ombima	M.6318
8	Charles Ondiere Nyagaka	M.7425
9	Collins Kipkurui Kiptoo	M.9355
10	Dan Brian Munene	M.8016
11	David Makhabwa Ambetsa	M.6177
12	Dennis Kariuki Kimani	M.8537
13	Diana Chepar Rotich	M.6969
14	Dismas Kebaso Nyang'au	M.7020
15	Dominic Kibiwott Kiyeng	M.8957
16	Douglas Ngayo Ombuya	M.9399
17	Elizabeth Akinyi Dede	M.5867
18	Elly Abongo Ochieng	M.10228
19	Eric Ondara Ogao	M.10093
20	Erick Kiruja Riungu	M.10647
21	Erick Oyoto Akut	M.11411
22	Everlyne Adhiambo Nyabwa	M.8412
23	Everlyne Adhiambo Onyango	M.6609
24	George Kazungu Kingi	M.7821
25	Gerald Wachira Muchiri	M.7809
26	Gerishon Kanori Ndegwa	M.10464
27	Hassan Kahindi Mwandoro	M.8304
28	Job Gwaya Mageto	M.7838
29	Johanness Orodi Odhiambo	M.3135
30	Johnson Kamwathi Ngengi	M.10890
31	Joseph Kamau Munyua	M.9118
32	Joshua Nicholas Oyonzo	M.3669
33	Josphat Wanjohi King'uru	M.11557
34	Josephine Njeri Kamatu	M.9849
35	Judith Amondi Okore	M.9075
36	Julius Kiptoo	M.7968
37	Kepher Osano Mwambi	M.11419
38	Kevin Kiplangat Tonui	M.12082
39	Kevin Mwendwa Kimanthi	M.5052
40	Kennedy Ukeh Rayolah	M.6591
41	Kelvin Kirui Kiprotich	M.9938
42	Levis Maina Ndegwa	M.8286
43	Linus Kibet Yego	M.7453
44	Lorine Esther Awino	M.7418
45	Lynnette Muthoni Kimani	M.8005
46	Macmillan Omondi Okuku	M.9861
47	Manasse Opiata Oyier	M.12205
48	Martha Nyaguthii Kihara	M.11722
49	Martin Kimori Ngigi	M.6358
50	Martin Mati Mulandi	M.7670
51	Mary Patronila Nyawira	M.11590
52	Mercy Jepkemoi Kiptiony	M.10660
53	Mohamed Adan Bulle	M.7240
54	Monicah Nasike Atemba	M.6913
55	Oscar Odhiambo Onyango	M.11872
56	Paul Kimani Ngera	M.7688
57	Peter Kahindo Muchiri	M.6544
58	Peter Kiringa Njuguna	M.7492
59	Peter Nganga Muchiri	M.4037
60	Rashid Ouma Okode	M.9478
61	Reagan Derrick Ogonji	M.9282
62	Riaman Elias Pchumba	M.7817
63	Robert Kiplimo	M.5192
64	Samuel Gichege Thuku	M.7914
65	Samuel Muriithi Njaramba	M.5866
66	Shadrack Kieti Musyoka	M.8606
67	Susan Nkatha Mung'ori	M.7338
68	Timothy Mwenda Murithi	M.4889
69	Zachary Hamptons Odhiambo	M.8529
70	Zipporah Wangui Muriithi	M.9345

518TH APPROVAL

FELLOW

S/NO.	NAME	MEMBER NO.
1	Kariuki Muchemi	F.1713
2	Joseph Mungai Mbugua	F.3109

CORPORATE

S/NO.	NAME	MEMBER NO.
1	Eliud Muli Muendo	M.9866
2	Robinson Kamau Mwangi	M.9169
3	Victor Omondi Ogowe	M. 9511
4	Milton Ouma Otieno	M.9089
5	Pascal Mshanga Mwabonje	M.5980
6	Donald Obunga Ondiek	M.4346
7	Diana Cherop Keter	M.4903
8	Quincy Alvin Jura Onyando	M.7425

The council invites Engineers and affiliate firms to apply for membership in the various membership classes, kindly follow the link members.iekenya.org to register or scan the QR Code below to apply for membership;

The IEK condoles with family and friends of our members who have passed away in the recent past. May their souls rest in peace.

"Death is not extinguishing the light . It is putting out the lamp because the dawn has come."


Picture: Courtesy

Nuclear Power and Energy Agency (NuPEA, formerly the Kenya Nuclear Electricity Board (KNEB) is a State Corporation established in law through the Energy Act No.1 of 2019. The Agency's mandate as stipulated in Section 56(1) Act are to:

a) be the nuclear energy programme implementing organization and promote the development of nuclear electricity generation in Kenya; and

(b) carry out research, development and dissemination activities in the energy and nuclear power sector.

Vision

Provider of Safe and Sustainable Energy Solutions

Mission

To develop nuclear power, and undertake research and capacity building in the energy sector for socio-economic prosperity

Core Values

I-TEC:
Integrity
Teamwork
Excellence
Creativity
innovativeness

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