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In this Issue

Engineering in KENYA

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Call for Papers

Engineering in Kenya Magazine - Issue 021

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 February, 2025 for our next issue, whose theme shall be "Bio-medical and Healthcare Engineering" 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

The theme of this issue is ***Environmental and Climate Change Engineering.*** Environmental and climate change engineering is the use of engineering principles to address the challenges and opportunities of climate change.

As populations expand and humanity demands more of our natural resources, environmental and climate change engineers are at the forefront of developing solutions that increase the sustainability of human activities. They tackle climate change, enable the renewable energy transition, secure our water supplies, protect society from natural hazards, and redesign products to reduce waste.

Environmental engineering is important because it helps to ensure the long-term sustainability of the environment and the use of natural resources. Environmental engineers work to improve public health and the environment by:

- **Managing waste**

  Environmental engineers supervise waste management to ensure clean water and to improve recycling and waste disposal.

- **Controlling pollution**

  Environmental engineers investigate and control pollution in water, soil, and air. They also design systems to remediate contaminated sites.

- **Protecting biodiversity**

  Environmental engineers develop and promote sustainable practices to protect and restore biodiversity. This includes preserving habitats, designing wildlife corridors, and using sustainable land development practices.

- Mitigating climate change

  Environmental engineers use innovation, collaboration, and policy advocacy to help mitigate climate change.

Environmental engineers use a variety of engineering and scientific disciplines, including chemistry, biology, and soil science. They work in a variety of settings, including offices, laboratories, and in the field by:

- **Designing resilient infrastructure**

  Engineers can design buildings that are resistant to floods and other extreme weather events. They can also implement green infrastructure solutions like rain gardens and permeable pavements.

- **Managing water**

  Engineers can develop sustainable water supply systems, implement flood control measures, and promote water conservation practices.

- **Promoting sustainable agriculture**

  Engineers can develop drought-resistant crop varieties and implement precision agriculture techniques.

- **Developing clean energy technologies**

  Engineers can develop technologies that produce clean energy.

- **Implementing energy-efficient practices**

  Engineers can design processes and systems that minimize environmental impact and reduce waste generation.

- **Analyzing climate data**

  Engineers can analyze climate data to help understand how climate change is influencing the design, construction, and maintenance of various infrastructures.

Engineers can also promote circular economy principles, which involve using resources efficiently, minimizing waste, and recycling or repurposing materials.

Climate engineering also includes a number of technologies and methods that aim to intentionally alter the climate to counteract climate change. It's also known as geoengineering, solar climate intervention, or sunlight reduction methods.

Climate engineering technologies include:

- **Carbon Dioxide Removal (CDR)**

  Removing carbon from the atmosphere, for example by planting trees or building industrial-scale carbon removal infrastructure

- **Solar Radiation Modification (SRM)**

  Reflecting sunlight back into space, for example by injecting aerosols into the stratosphere or painting roofs light colours

Climate engineering has the potential to reduce and stabilize global temperatures, but it also raises ethical concerns and questions:

- **Environmental impact**

  There's a lack of research on the environmental impact of these technologies.

- **Governance**

  There's a lack of governance, which could lead to geopolitical tensions, human rights implications, and unequal distribution of harm and benefits.

- **National security**

  Climate engineering could improve national security risks, such as risks to food, energy, and water supplies.

This issue will be the last one for 2024. It contains article which we hope you will find to be educative, informative and entertaining.

We wish you are very happy new year!

Eng. Shammah Kiteme, CE, FIEK

Message from the President

Environmental and climate resilient engineering

Safe for a few climate deniers, there is a global consensus among the scientific community on the reality of climate change. Generally, it is agreed that the various human activities have resulted to climate variations. These activities have altered the composition of the atmosphere. When analyzed with similar comparable periods in the past, it is possible to draw conclusions that human activities have caused climate change.

Of all human interventions, engineering has the singular most impact on the environment. The reason is because engineers work in virtually all the aspects of the society. From agriculture to aviation, transportation and blue economy. Mining and Manufacturing among other sectors. It is for this reason that the impact of our work as engineers on the environment becomes a very pertinent conversation.

The work of engineers involve conceptualization, designing, construction, maintenance of infrastructure that should serve people. This will lead to making life bearable and meaningful to people. Whether roads and bridges, buildings and railways, airports and sea ports engineers are involved in infrastructure that enables the economy to function. In the wake of climate change, engineers must implement climate resilient engineering projects.

Resilient infrastructure means adequate engineering design built to robust metrics to withstand natural disasters of a pre-determined magnitude. The designs should be simplistic yet complex enough to allow modifications to be made over time as necessary as current conditions change. The important aspect is that designs should withstand the ever-changing climatic conditions and remain safe, reliable, functional and economical for the purposes they were designed for.

Building resilience into our infrastructure helps us adapt to the changing climate by coping with adverse effects of climate change. Our infrastructure must help us to respond to the impacts that are already happening yet at the same time prepare for future impacts. We must therefore adapt without unnecessarily losing our ability to continue to function. We must also carry out integrated design that not only helps us cope but also ensure that our activities as humans reduce the sources of Green House Gases. One way of doing this is through the deployment of sustainable energy solutions. These would help us reduce the Green House Gases emitted into the atmosphere while also enhancing the sinks and removing the capability to remove the Green House Gases in the atmosphere.

While we do this, it is also clear that we have a growing urban population. Our infrastructure must therefore respond to the need for increasing urbanization. This is important because the increasing concentration of big populations in urban areas also expose them to vulnerability to disaster impacts. Unplanned development and informal settlements expose urban populations to risk of fires that are not easy to contain because of the challenge of accessibility. These fires also affect many people and the growing risk of fires increase as urban areas grow especially in an unplanned manner. There is therefore a great need for engineers to be involved in urban planning so as to be able to advise appropriately on the suitable urban infrastructure.

The understanding that we design for people is crucial. It therefore means that we design infrastructure that factors in disaster vulnerability reduction. Our infrastructure must also respect the culture of the people we design for and when our activities disrupt the environment like in borrow pits and mining excavations, an effort at restoration is necessary. We must also be alive to the climate change mitigation measures and appropriate disaster recovery and reconstruction.

We have seen increase in tornadoes, storms and cyclones, big magnitude earthquakes have happened in a number of countries leading to serious loss of life and property. Flooding, bush fires, sinkholes, fault lines, landslides and ground subsidence are phenomenon we must think about and consider for our designs to be resilient. Volcanic eruptions, rise in groundwater, lightning strikes and rockfalls, heavy snowfalls and extreme temperatures are also other factors we must consider in our designs. While the list may not be comprehensive, there are a couple of geophysical, meteorological, hydrological, biological climatological aspects that may affect the infrastructure that we are coming up with. Our work as engineers is to make sure that we work along with scientists to develop hazard maps and other tools that will help us appropriately consider actions that our infrastructure will be subject to in their lifecycle.

We must think about siting and route selection, design and constructability of our designs. We must factor in operation and maintenance, renovation, demolition and circular economy in our engineering solutions. This therefore means that we must consider the delicate balance of the available resources so that in our application of these resources we do not disadvantage future generations. Energy, Water, mineral resources, forests, and wildlife must be delicately handled and managed so that our infrastructure design solutions handle them sustainably and facilitate their renewal and regeneration where possible.

We must plan our infrastructure to reduce risks of impacts from disasters, enhance reliability and maintain operational continuity in the face of shocks and stressors. Our infrastructure solutions must withstand time, elements and mother nature. We must plan for tomorrow today and ensure that our infrastructure can adapt to changing conditions as we minimize vulnerability. We must think about the ability to recover from disruptions and withstand future hazards. Our designs must factor in disaster avoidance, and where avoidance is impossible, we design for minimizing the impact. We must also think of mitigation and recovery from a disaster event.

As engineers it is important we think about lifecycle costs of our designs and not just initial costs. This will help us assess the cost- benefit analysis of designing for resilience considering risks and threats. We need to map out the disaster risks and identify critical infrastructure. We must also think of the interdependency of infrastructure like how transport, housing and sanitation depend on each other. Working with their relationship with the natural environment we are able to plan carefully considering their local contexts needs and vulnerabilities.

Lastly, our long-term infrastructure planning must be based on data and evidence and not guess work.

As IEK we are leading in this conversation of environmental and climate resilient engineering. We have established a climate taskforce and this edition of the EiK magazine bears testimony to this leadership. I now invite you our readers to this edition of our EiK magazine.


Road Construction

Message from the Honorary Secretary

Eng. Jacton. A. Mwembe, PE, MIEK

On this latest edition of Engineering in Kenya Magazine, under the theme of "Environmental and Climate Resilient Engineering", I want to take moment to reflect on the profound role that engineers play in shaping a sustainable future. Engineering is more than a profession; it is a calling to design and implement solutions that uplift communities, protect our environment, and transform our aspirations into reality.

Environmental engineering stands at the intersection of innovation and responsibility. It calls upon us to harness our skills, knowledge, and creativity to address the pressing environmental challenges that confront us. These includes: climate change, urbanization, deforestation, and resource scarcity. These challenges are not abstract; they are lived realities that affect millions of Kenyans every day. Yet, within these challenges lies an invitation for ingenuity, collaboration, and action.

The IEK takes this opportune time to thank all our stakeholders, and esteemed members in the broader engineering community for the various impacts and action demonstrated in responding to these issues. Our profession is not just about solving problems; it is about creating value; the value that is felt in the cleaner air we breathe, the water we conserve, the forests we restore, and the sustainable energy solutions we deploy. It is this commitment to creating meaningful impact that defines the core mission and vision of the Institution of Engineers of Kenya and the engineers it represents that we advocate for Engineering practices centered towards a more sustainable world.

This issue shade light on the most critical areas of environmental engineering, with a focus on the transformative potential of carbon credits, urban forestry, and reforestation. These topics are not only timely but also central to Kenya's ambition to achieve sustainable development and climate resilience.

Carbon credits, for instance, have emerged as a powerful mechanism to combat climate change while fostering economic growth. By creating opportunities for industries to offset their emissions through investments in renewable energy, forest conservation, and carbon capture technologies, carbon credits align environmental responsibility with economic incentive. In Kenya, projects such as the Kasigau Corridor REDD+ initiative have demonstrated the potential of carbon credits to transform landscapes and livelihoods alike.

However, the success of the carbon credit market hinges on more than just policy and investments. It requires integrity, transparency, and a commitment to equity. As engineers, we are uniquely positioned to ensure that carbon credit projects meet these standards. Engineers have the capabilities and skills to design and innovate projects that have rigorous monitoring and evaluation, providing inclusive community engagement, we can ensure that the benefits of these initiatives are distributed fairly and that their impact is sustainable in the long term.

Urban forestry and reforestation offer complementary pathways to address environmental challenges. Kenya's urban centers are growing rapidly, presenting both opportunities and risks. The creation of green spaces and the restoration of forests can help mitigate the urban heat island effect, enhance biodiversity, and provide a much-needed connection to nature for city residents. Efforts such as the Green Belt Movement have laid a strong foundation for these initiatives, and it is our responsibility to build on this momentum.

As engineers, we must lead the way in integrating nature-based solutions into urban planning. By designing cities that are not only functional but also environmentally harmonious, we can create urban environments that support both human and ecological well-being. This requires collaboration across disciplines, as well as a deep understanding of local contexts and community needs.

The challenges we face in advancing environmental engineering are significant, but they are not insurmountable. Deforestation, land-use conflicts, and gaps in technical capacity require innovative solutions and collective action. At the IEK, we are committed to fostering these solutions through partnerships, capacity building, and advocacy. We are working closely with policymakers to strengthen frameworks such as Kenya's Climate Change Act and the National Climate Change Action Plan, ensuring that they support both national and global sustainability goals.

Capacity building is another critical area of focus. To truly lead in environmental engineering, we must invest in developing local expertise. Our universities and research institutions have a vital role to play in this regard, offering specialized training and fostering a culture of innovation. The IEK is dedicated to supporting these efforts, creating opportunities for professional development and facilitating knowledge exchange within our engineering community.

The IEK council calls for various engagement and partnerships amongst the industry partners in the broader aspect that is the Government and the private sector. Public-private partnerships (PPPs) is instrumental in scaling up impactful projects such as innovative engineering projects in the renewable energy sector, water recycling and water treatment, improved agricultural mechanization amongst others. The Kenyan government under the action of various government agencies should embrace this collaborative spirit with international investors, and local communities, so as to deploy advanced technologies such as biochar, direct air capture, and conservation agriculture. These partnerships not only bring resources and expertise but also ensure that projects are designed and implemented in a way that maximizes their impact.

Environmental engineering is about stewardship. It is about recognizing that we are custodians of the earth and that the choices we make today will shape the world we leave for future generations. This responsibility is both a challenge and a privilege, and it is one that we must embrace with urgency and determination.

As I conclude, I want to extend my gratitude to every engineer who is contributing to this vital work. Your efforts, whether in the field, the lab, or the boardroom, are making a difference. You are not only solving problems but also inspiring hope—hope for a Kenya that is greener, more resilient, and more equitable.

I invite you our beloved reader to explore the articles and insights in this issue, to engage with the ideas presented, and to reflect on how we, as a profession, can continue to lead in addressing environmental challenges. Let us commit to not only being part of the solution but also to being champions of sustainability in all that we do.

Together, let us create a future we can proudly pass on—a future where engineering and environmental stewardship coexist in harmony. Wishing you an enriching reading experience as we approach the festive season. On behalf of the Institution of Engineers of Kenya, I extend my warmest wishes for a joyful Christmas and a prosperous New Year 2025!


Wind Energy

ROLE OF ENVIRONMENTAL IMPACT ASSESSMENTS (EIAs) IN INFRASTRUCTURE DEVELOPMENT.

Author

Mamo Boru Mamo, EBS
Director General - National Environment Management Authority (NEMA)

1. Could you discuss how NEMA's environmental monitoring and audit functions contribute to ongoing infrastructure projects, especially concerning activities that may risk environmental degradation?

The Environmental Management and Coordination Act (EMCA), 1999 requires that all Policies, Plans and Programs for implementation to be subjected to Strategic Environmental and Assessments (SESA) while on the other hand projects are required to be subjected to Environmental and Social Impact Assessment (ESIA) in accordance to the Environmental Management and Coordination (Impact Assessment and Audit) Regulations of 2003 and the Legal notice 31 and 32.

The National Environment Management Authority (NEMA) plays a crucial role in overseeing environmental protection in the country, particularly in relation to infrastructure projects. Infrastructural projects may be classified as low, medium or high risk depending on the scale, scope and location. NEMA's overall functions are essential for ensuring that projects are developed sustainably, minimizing risks of environmental degradation, and adhering to regulatory frameworks designed to protect natural resources and communities.

ESIA is a systematic examination conducted to determine whether or not a proposed project/ activity will have adverse social and environmental impacts. It proposes measures to optimize positive impacts and mitigation measures for the negative ones and attempts to weigh environmental effects vis a vis the economic costs and benefits of a project.

The main object of EIA as an environmental management tool is to ensure that infrastructural develop will take place while at the same time providing guarantees of a clean and healthy environment to all as enshrined in the constitution of Kenya 2010 and section 3 of EMCA 1999. EMCA also assigns responsibility to everyone including developers of safeguarding the above stated rights by putting in place sufficient and effective measures. NEMA's issuance of EIA licenses for proposed projects is not an end by itself but a means of integrating environmental considerations into infrastructural development process towards sustainable development through the conditions attached to the licenses. It is the duty of the developer of ensuring compliance during the project conception, construction, commissioning and decommissioning phases.

2. What insights from NEMA's annual State of the Environment report can you share, especially on how infrastructure development has influenced Kenya's environmental landscape? Are there any recommendations that have emerged for future project planning?

The Kenya State of Environment Reports prepared every two years in-line with EMCA (Revised 2015), 1999 provides that the development trajectory over the years have resulted in major environmental changes with several hectares of natural landscapes having been transformed by various infrastructure development projects. Many urban centers have expanded, road networks have reached new landscapes while settlement and agricultural schemes among others have also expanded as population growth continue and demand for food and livelihood opportunities escalate. The developments are bound to continue in the coming years resulting in further alternations of natural landscapes and may affect status of biodiversity and ecosystems. While developments are going to continue, from an environmental perspective they require to adopt sustainable development approaches which mainstream environmental safeguards to mitigate negative environmental impacts and green infrastructure among other environmentally friendly development models in order to guarantee a clean and healthy environment for Kenyans. NEMA has highlighted on emerging environmental scenarios regarding project planning in the following areas:

i. Projections for Urbanization and pressure on Infrastructure.

In alignment with the New Urban Agenda, Kenya's infrastructure development must prioritize sustainability, resilience, and inclusivity. As Kenya's urbanization rate is projected to increase, the pressure on infrastructure will intensify, requiring forward-looking strategies. Diversification in infrastructure planning, including the adoption of mixed-use developments, renewable energy solutions, and circular economy principles, will be critical to balancing environmental preservation with economic growth.

ii. Climate proofing on developments

This involves designing infrastructure that is resilient to climate variability, such as extreme weather events, rising temperatures, and changing precipitation patterns. Measures like improved drainage systems, energy-efficient buildings, and nature-based solutions such as urban green spaces and wetlands restoration should become standard practice.

3. How does NEMA collaborate with lead agencies and other entities to provide technical support in environmental management, especially for projects requiring EIAs?

The regulations, guidelines and rules provided under the Environmental (Impact Assessment and Audit) Regulations, 2003, mandates NEMA to collaborate with various lead agencies and other entities to provide technical support in environmental management, particularly for projects requiring Strategic Environmental and Social Assessments (SESA) and Environmental Impact Assessments (EIAs).

The Authority collaborates with such entities through:

i. Coordination and collaboration with Lead Agencies

EMCA 1999 defines Lead agencies to mean any Government ministry, department, parastatal, State Corporation or local authority, in which any law vests functions of control or management or any element of the environment or natural resources. NEMA collaborates closely with these agencies to ensure that environmental management is integrated into sector-specific projects. These agencies often provide technical expertise on environmental issues related to their areas of responsibility such as water and irrigation, infrastructure, cultural heritage and biodiversity, energy, petroleum, building and construction, forestry and wildlife sectors among others.

NEMA also collaborates with other specialized environmental organizations to provide technical expertise on specific environmental aspects to enable the authority make informed decisions regarding environmental impact assessments applications. These agencies may offer specialized knowledge in areas such as biodiversity conservation, waste management, and climate change.

ESIA and SESA reports received at NEMA are dispatched to respective relevant lead agencies to review and provide sectoral comments related regarding the project in consideration.

ii. County Environment Committee

The County Environment Committees established under section 29 of EMCA 1999 whose functions include being responsible for the proper management of the environment and development of county strategic environmental action plans among other county specific issues have representations cutting across from relevant lead agencies, civil society organizations and representation from special interest groups. These committees operational at respective county levels play a critical role in the review of environmental impact assessment reports for the proposed projects and provision of inputs to facilitate NEMA make informed decisions.

iii. Engagement with Academic and Research Institutions

NEMA also collaborates with universities, research institutions, and environmental consultancies to provide technical support during the EIA process. These institutions often have specialized knowledge and resources that can contribute to the technical rigor of EIAs. For instance:

iv. Collaboration with Civil Society Organizations and development partners

NEMA also works with international organizations, donor agencies, and NGOs that focus on environmental protection and sustainable development. These entities can offer both financial and technical support, especially for large-scale infrastructure projects. Their roles may include:

v. Joint Review of EIAs and Technical Reports

As part of its collaborative role, NEMA coordinates the review of EIA reports with lead agencies and technical experts. These reviews ensure that all potential environmental impacts are properly assessed and that the necessary mitigation measures are implemented. For example:

vi. Collaboration with other Regional and International Environmental agencies

NEMA maintains a close working relationship with regional environmental agencies, and international agencies including Danish, Netherlands and Swedish environmental agencies in and other international partners. The areas of collaboration includes collaboration through joint implementation of Multi-lateral Environmental Agreements (MEAs) and protocols, joint transboundary enforcements, capacity building and technical review inputs for specialized projects. NEMA collaborated with the Netherlands Commission for Environmental Assessment (NCEA) equivalent of NEMA to undertake independent review and advise the Authority on complex and sensitive sectors such nuclear power programme.

vii. Collaboration in formulation of policy and legal instruments

NEMA participates and takes part in technical working groups for the development and formulation of various regulations, guidelines and manuals in the various sectors so as to help the sector players understand the environmental assessment processes and integration of the same in sectoral developmental projects.

7. Give highlights on how NEMA takes stock of Kenya's natural resources. How is this information used within ESIAs to guide land use and infrastructure planning?

NEMA takes stock of the country natural resources through development of the Kenya State of Environment Report every two years. The process entails involvement of all key lead agencies in the environment and natural resources as well as academia and relevant research institutions. The information contained in the Kenya State of Environment Report play and instrumental role in EIAs to guide land-use and infrastructure planning largely because the information provide hotspots for biodiversity which is applied in EIA on land use and infrastructure planning by ensuring such critical habitats are safeguarded to avoid negatively affecting biodiversity. More so the information contained in the Kenya State of environment report that profile natural resources outlook identify critical areas that provide valuable ecological services to people such as water catchments and such information is applied in the EIAs to guide land use and infrastructure development by ensuring proposed land use and infrastructures do not interfere with the natural resources that support communities with critical ecological services such as water among others.

8. With climate resilience becoming a priority, which technologies are being integrated into EIA process to anticipate long-term environmental impacts?

Kenya is party to the Sendai Framework for Disaster Risk Reduction 2015-2030 (Sendai Framework) that provides concrete actions to protect development gains from the risk of disaster. NEMA is committed and implements Kenya's international obligations including The Paris Agreement on Climate Change, The Addis Ababa Action Agenda on Financing Development, the New Urban Agenda, and the Sustainable Development Goals.

Climate change negative impacts affects buildings, roads, bridges, parks, ports, streets and the systems that supports life development. Extreme weather events are known to have disrupted livelihoods, led to loss of life, damaged property and infrastructure in many parts of the county. Pursuant to the international obligations and the Climate Change Act of 2016 it is a requirement that proposed projects align to these legal requirements. The EIA processes including EIA report preparation and EIA licensing puts into consideration conditions for making projects resilient to impacts of climate change. Project designs and implementation are required to integrate technologies that will make them more resilient with aim of preventing loss of life and damage.

Environmental Impact Assessment currently requires that climate change future scenarios are mapped including temperature change, rainfall trends and humidity and how they would affect our build environment. Infrastructure projects should be designed with the issues of climate change in mind. In scenarios of enhanced rainfall technologies that includes enhanced ground water seepage, increased tree cover, green spaces in urban areas, water harvesting technologies and sustainable storm water management are recommended. Issues such as increased risk of flooding, rise in sea levels and rapid changes in temperature should be considered in the design process.


Road Construction

ENGINEERS BOARD OF KENYA
Enhancing Professionalism

Global Mobility of Engineers:
Advancing Opportunities for Kenyan Professionals

In Engineers play a critical role in driving sustainable development, and their ability to work seamlessly across borders enhances innovation, knowledge transfer, and economic competitiveness. In an increasingly interconnected world, the global mobility of engineers is no longer a luxury but a necessity. Historically, Kenyan engineers have left an indelible mark abroad, with their footprints seen in Southern and Eastern Africa during formative stages of nation-building. Today, Kenyan engineers and consulting firms continue to excel within the expanded East African region, making significant contributions in South Sudan, Rwanda, and Somalia. Their work underscores Kenya's growing reputation as a hub for engineering expertise and regional integration.

The Engineers Board of Kenya (EBK) is committed to supporting this mobility through initiatives designed to foster regional and global integration. By aligning policies and embracing innovative frameworks, EBK seeks to create a conducive environment for Kenyan engineers to thrive both regionally and internationally.

Promoting Regional Integration: The East Africa Mutual Recognition Agreement

The East Africa Mutual Recognition Agreement (EAC-MRA), signed in 2012 by Kenya, Uganda, and Tanzania and later joined by Rwanda in 2016, is a pivotal step in enhancing the mobility of engineers within the East African Community (EAC). The inclusion of South Sudan into the agreement in October 2024 has further expanded the job market for engineers in the region. Kenyan engineers are strongly encouraged to register under the MRA to access opportunities across member states and contribute to regional development.

To facilitate seamless professional recognition and cross-border practice, EBK and other signatories of the EAC-MRA are collaborating with GIZ under the DIGEAT initiative. This partnership aims to develop a digital platform that will streamline registration and verification processes, fostering transparency and ease of mobility for engineers within the region.

Towards Continental Integration: The FAEO African Accord

The African Continental Free Trade Area (AfCFTA) provides a transformative opportunity to liberalize professional engineering services across Africa. In 2024, EBK organized training sessions to equip Kenyan engineers with the knowledge and skills needed to navigate trade-in-services protocols, identify barriers, and understand AfCFTA agreements. The State Department of Trade (SDOT) has scheduled additional training sessions to enhance capacity and address trade barriers identified during audits.

At a broader level, the Federation of African Engineering Organizations (FAEO) has established a Registrar Committee to drive the creation of an African Accord. This initiative seeks to harmonize engineering standards across the continent, enabling professional mobility and supporting AfCFTA's objectives. For Kenyan engineers, this marks a gateway to a larger market, allowing them to contribute to Africa's infrastructure and industrial development.

Lessons from the EU: A Vision for Regional Harmonization

In October 2024, Registrars of EAC engineering regulators participated in a study tour to Europe organized by GIZ, focusing on the free movement of professionals. The EU's approach to mutual recognition agreements (MRAs) provided invaluable insights into facilitating cross-border engineering practice by eliminating redundant qualifications and aligning regional standards.

A notable lesson was that registration under Engineers Europe is open to engineers from across the globe, showcasing the EU's inclusive approach to professional mobility. This model not only fosters diversity but also addresses talent shortages in the region. Additionally, the "Blue Card" initiative emerged as an exemplary framework for attracting skilled professionals to areas in need, while the EU's Internal Market Information (IMI) system highlighted the importance of digital platforms in streamlining registration, verifying credentials, and enhancing transparency. For Kenya, adopting similar systems could significantly boost the mobility of its engineers and position the country as a key player in the global engineering market.

Progress Towards the Washington Accord

EBK's ongoing pursuit of provisional status under the Washington Accord underscores its dedication to international best practices in engineering education. Following an open call, three Kenyan universities were selected to present their programs at the International Engineering Alliance (IEA) meeting in June 2025. Through rigorous mock assessments and alignment with global standards, EBK is preparing to secure recognition under the Washington Accord. This milestone will elevate Kenya's engineering education, enhancing the global mobility of its engineers and boosting their competitiveness in international markets.

Conclusion

The Engineers Board of Kenya remains steadfast in its mission to produce globally competitive engineers. Through initiatives like the EAC-MRA, collaboration under the FAEO African Accord, and lessons drawn from the EU, EBK is paving the way for Kenyan engineers to seize regional and international opportunities. Coupled with progress towards Washington Accord accreditation, these efforts position Kenya as a leader in engineering excellence, ready to meet the challenges of the 21st century.

Kenya National Highway Authority
Quality Highways, Better Connections

KITALE – JUBA CORRIDOR BOOSTS SOCIO-ECONOMIC DEVELOPMENT

By Mary Njenga

Early November 2024, the Principal Secretary for the Department of Roads, Eng. Joseph Mbugua, joined a Mission that was inspecting the East Africa Regional Transport, Trade and Development Facilitation Project (EARTTDFP) and the Socio-Economic infrastructure projects along this Road which traverses through Turkana and West-Pokot counties.

The Road Project, which forms the Kitale—Juba Corridor, links Kenya to South Sudan through Nadapal and is set for completion by 31 December, 2024. It is financed by the Government of Kenya and the World Bank and is under the jurisdiction of the Kenya National Highways Authority (KeNHA).

The Road Project that only awaits commissioning as it is already substantially complete and is a remarkable key infrastructure asset that has greatly enhanced connectivity between the western parts of Kenya and Turkana County through to South Sudan.

The seamless connectivity resulting from this Project has improved security along the Corridor, which has in turn positively impacted on the growth of regional trade. Additionally, the smooth Road has reduced travel times. Today, transportation of goods and people between Kitale and Lodwar takes less than half a day, a journey that previously used to take three days whereas. Further, street lighting and the resultant security has transformed the major towns along the Corridor to a 24-hour economy.

The PS led extensive inspection Mission of this Kitale-Juba Road Corridor marked a major milestone in the country's infrastructural development. The Mission focused on assessing the newly completed section of the road linking Kenya to South Sudan through Kainuk-Lokichar-Lodwar-Kakuma-Nadapal (A1) Road, and the accompanying socio-economic infrastructures along the Corridor.

They include Corporate Social Investment facilities distributed in the two counties whose majority of the civil works progress is over 95 per cent complete. The state-of-the-art socio-economic infrastructure are spread in tandem with the road project division into Lot One (1), which covers West Pokot County, Turkana South, Turkana East, and Turkana Central sub-counties, while Lot Two (2) covers Loima, Turkana North, and Turkana West sub-counties.

Lot 1 consists of 14 CSI Projects and Lot 2 has 12 CSI Projects. The facilities are strategically situated in consultation with the relevant stakeholders. They include secondary and primary schools, healthcare centres, truck parking and rest stops, water supply projects, a police post, ICT hubs, a teachers' training institute, and a livestock market.

These pieces of infrastructure are integral in transforming the lives of people in these marginalized regions, and the ripple effect will be replicated across multiple sectors. Indeed, it will bridge the socio-economic gaps between these remote areas and the rest of the country thus realizing Kenya's broader development goals.

Occasioned by inadequate road networks and social amenities in the remote areas of Turkana and West Pokot counties, there has been limited access to resources besides the difficulty in accessing public services, social protection, and employment. This, combined with the people deep-rooted culture, has fostered some extent of retrogressive socio-cultural practices that directly violate human rights, including child marriages.

At completion, all the three primary and six secondary schools will be fully equipped according to the required learning standards, and all have adequate boarding facilities. This is a relief as the schools will also act as rescue centres for the school-going children from these pastoralist communities whose parents keep moving from one place to another in search of water and pasture for their livestock.

There will be sensitization to create awareness and empowerment so that the learners will continue with their schooling despite their families moving around in search of pasture. Similarly, the girls who may feel threatened at home will be allowed to remain in school even over the holidays with necessary safety and precautionary measures. This, it is hoped, will potentially increase school enrollment and retention, and reduce dropout rates.

In collaboration with the Catholic Diocese of Lodwar, sustained effort to reduce gender-based violence (GBV) has been achieved by ensuring timely and swift response and care for survivors. The Diocese has been keen in offering moral and emotional support. The schools include Sangak, Nakimak, and Nadwat primary schools, and Lobokata, Ngamia 1, Morukapel, and Songot girl's secondary schools, as well as Loturerei, Napeililim secondary schools. In addition, there is the Aroo Teachers Training College.

The Ministry of Information, Communication and Digital Economy through the ICT Authority (ICTA), has installed fibre optic cable along the Corridor to ease communication and aid in technological development. Adding to the constructed ICT hub, the information highway has upgraded some of the major towns along the Corridor with internet points that will support digital education initiatives.

Installation of technology allows local communities to connect to the global economy. Further, technology will enable the residents to access critical e-government services such as Kenya Revenue Authority (KRA) services, digital registration, online job applications, among others.

Another major challenge faced by communities in Turkana and West Pokot counties is access to healthcare. The lack of good roads and limited health facilities that are dispersed across the region means that patients in need of emergency medical services struggle to reach health facilities in time. The newly constructed road and completion of construction of six health centres will provide faster access to healthcare services. This will lead to improved health among the residents and quicker response times during emergencies.

The facilities will also ensure a reduction in maternal and infant mortality rates, as mothers and children can now reach medical care more promptly during critical times. The health facilities include Napetao, Kainuk, Napeililim, Nadwat, Nadapal, and Lokichar sub-county health centres.

There was also the sinking of four boreholes and piping the water to identified water points which will solve the challenge of water scarcity that forces locals to walk long distances with their livestock in search of water. The water supply stations will also be equipped with enough livestock water troughs. To facilitate a more organized business for the locals, a modern and equipped livestock market has equally been set up at Nadapal.

The construction of three amenities for truck parking and rest stops will provide safe parking and rest areas for long-distance truck drivers along the Kitale-Juba Corridor. The facilities will have stalls, shower, and toilet blocks. In addition, the Locher-Emoit police post will enhance security in the area.

Over time, socio-economic transformation will be inevitable as the newly constructed roads and facilities will create a conducive environment for investment, leading to the establishment of new businesses, industries, and factories, thus providing jobs and boosting local and national economies. The availability of facilities and resources will encourage the pastoralists to establish permanent settlements and investments leading to economic expansion, urbanization, and metropolitan areas within the major towns.

During the inspection Mission, Eng. Mbugua assured that all the projects would be finalized by the set completion dates. The PS was accompanied by a team of KeNHA engineers, representatives from the World Bank, and other stakeholders, including the National Transport and Safety Authority (NTSA), the ICT Authority (ICTA), the Kenya Revenue Authority (KRA), State Department for Roads, and the Catholic Diocese of Lodwar.

Transforming Agriculture through Innovative Irrigation Policies: Driving Manufacturing and Economic Growth

Author

Eng. Charles Muasya, MBS
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Irrigated agriculture is a key enabler in the Kenya's economy, driving food security pillar, employment, and national development. The growth in Kenya's GDP to 5.6% in 2023 was mainly driven by rebound in agricultural activities including irrigation (Economic survey, 2024). Recognizing its potential, the National Irrigation Authority (NIA) has implemented innovative irrigation policies to revolutionize agriculture and align it with national manufacturing and economic goals as encapsulated in BETA Agenda. Currently, 733,000 acres have been developed for irrigation against an irrigation potential of 1.9 million acres, translating to an average of close to 40% of the Country's potential. This article explores these innovations, their link to agro-industrial growth, and their impact on employment, exports, and climate resilience.

1. Innovations in Irrigation Policies

NIA has pioneered several policy frameworks to transform irrigation and optimize water resources:

1. **Smart Irrigation Technologies**: Advanced systems like drip and sprinkler irrigation enhance water efficiency and crop yields. Digital tools, including moisture sensors and scheduling apps, help farmers make data-driven decisions. Among this include use of WaPOR and ioF from World Bank publications in estimating scheme performance and water productivity.

2. **Public-Private Partnerships (PPPs)**: Collaborations with private investors will accelerate the development of large-scale irrigation projects, promoting technological adoption and infrastructure expansion. Key example is on conclusion of Selu Ltd for maize production on 20,000 acres in Galana Kulalu anticipating production of over 3,000,000 bags of maize in the next 3 years.

3. **Inclusivity Policies**: Equitable water allocation ensures smallholder farmers benefit from irrigation schemes, with targeted support for marginalized groups, especially women and youth in particular through the National Expanded Irrigation Programme and existing public schemes. This will create employment opportunities of 5people per acre directly.

4. **Community-Driven Governance**: Local Irrigation water user associations (IWUAs) manage irrigation resources sustainably, fostering community ownership.

5. **Innovative Financing**: Subsidies, credit facilities, and risk-sharing mechanisms enable farmers to adopt modern irrigation systems while mitigating financial risks. Co-financing is the best model well exhibited by the famous Mt. Kenya Small holder Programme.

2. Irrigation and Manufacturing Synergy

Irrigation supports the agro-industrial sector by stabilizing raw material supply and boosting value addition. Reliable water availability ensures steady production of crops critical to agro-processing, such as sugarcane, cotton, rice, maize and oilseeds. This reduces raw material shortages, enabling factories to operate efficiently and expand output. Additionally, irrigation supports diversification into high-value crops like fruits and nuts, crucial for export-oriented agro-industries. Among key agricultural products that depicted the highest performance in 2023 was maize at 39% followed by rice at 19.1% that grows mainly under irrigation.

By focusing irrigation strategies on crops suited to regional agro-climatic conditions, NIA fosters synergy between agricultural production and local manufacturing, creating opportunities for job creation and economic growth.

3. Efficient Irrigation Systems and Value Addition

Efficient irrigation underpins the growth of Kenya's manufacturing sector by ensuring reliable crop yields for processing industries. Key benefits include:

1. **Stable Raw Material Supply**: Predictable irrigation reduces crop failure risks, ensuring factories have consistent access to agricultural inputs.

2. **Value Addition**: Farmers can grow high-value crops suited for processing, enhancing competitiveness in domestic and international markets.

3. **Technological Innovation**: The surplus from efficient irrigation fuels advancements in post-harvest handling, packaging, and storage, improving product quality and marketability.

4. Rural Employment and Inclusivity

Innovative irrigation practices play a transformative role in rural areas, creating employment opportunities and fostering inclusivity:

1. **Capacity Building**: NIA trains farmers, particularly youth and women, in modern irrigation techniques and agribusiness skills, empowering them to participate in agricultural value chains. In FY 2023-2024, NIA trained and built capacity of 17,535 farmers in public schemes through training in water use management as well as good irrigation

2. **Infrastructure Jobs**: Construction and maintenance of irrigation systems provide direct employment opportunities for local communities.

3. **Support for Agripreneurs**: Access to irrigation enables smallholders to scale operations, generating jobs across the farming, transportation, and processing sectors.

4. **Gender Equity**: Dedicated programs ensure equitable resource access for women, who play a critical role in food production and household income generation. Last year, NIA facilitated linkages to farmers in Mwea, Bunyala, West Kano, Ahero, South West Kano and Lower Kuja irrigation schemes.

5. Boosting Agricultural Exports

Efficient irrigation enhances Kenya's agricultural exports by supporting the production of high-demand crops like flowers, tea, and horticultural products. NIA's export-focused initiatives include:

1. **Compliance with Export Standards**: Farmers receive training on meeting international certifications such as Global GAP and Fair Trade, ensuring competitiveness in global markets.

2. **Market Linkages**: Collaborations with export agencies connect farmers to buyers, offering fair prices and access to international markets.

3. **Post-Harvest Infrastructure**: Investments in storage and cold chain logistics minimize post-harvest losses, ensuring high-quality exports.

6. Climate Resilience in Irrigation Systems

With climate change intensifying floods, droughts, and erratic rainfall, NIA is prioritizing resilience in irrigation systems through:

1. **Water Harvesting and Storage**: Building dams, reservoirs, and water pans secures year-round water availability during dry spells to date 55MCM have been harvested. Our current strategy targets cumulative water volume of 330 MCM in the next 5 years.

2. **Flood Management**: Integrated watershed management reduces flood impacts, safeguarding infrastructure and communities.

3. **Climate-Smart Practices**: Soil conservation and agroforestry techniques prevent environmental degradation, enhancing agricultural system resilience.

4. **Research and Development**: NIA partners with research institutions through collaborations to develop drought-resistant crop varieties and advanced irrigation technologies tailored to Kenya's climate. NIA has continued to collaborate with key institutions in realizing 86,616 trees growing, 500 acres of seed production and variety testing.

7. Conclusion

NIA's innovative irrigation policies are pivotal in transforming Kenya's agriculture into a modern, resilient, and economically vital sector. By integrating advanced technologies, fostering inclusivity, and ensuring climate adaptability, NIA contributes significantly to food security, rural employment, and manufacturing growth. Furthermore, enhanced irrigation systems unlock opportunities for value addition, export growth, and agro-industrial innovation, positioning Kenya as a global leader in sustainable agriculture.

As Kenya navigates the challenges of climate change and increasing population pressures, the synergy between irrigation and manufacturing will remain critical for achieving long-term economic prosperity and global competitiveness.

Innovative Water and Sanitation Infrastructure: Policy, Manufacturing Synergies and Economic Transformation

Author

Eng. Joseph Kamau, CE, FIEK,
CEO - Athi Water Works Development Agency

1. Policies greatly influence your daily operations. Giving examples, which ones have supported innovation in water and sanitation, and what challenges do you face?

i. **The Water Act (2016)** The Water Act 2016 is a key piece of legislation that reorganized the governance structure of Kenya's water sector, promoting efficiency, accountability, and public-private partnerships (PPPs). It focuses on increasing access to water, improving infrastructure, and enhancing the sustainability of water services.

ii. **Kenya Vision 2030** Kenya Vision 2030 is the country's long-term development blueprint, which aims to transform Kenya into an industrializing, middle-income economy by 2030. The vision emphasizes the importance of infrastructure development, including water and sanitation, to achieve inclusive economic growth.

iii. **The Constitution of Kenya (2010) – Article 43** Article 43 of the Constitution guarantees every Kenyan the right to accessible, adequate, and clean water. This constitutional provision mandates that the government, through agencies like AWWDA, ensures equitable access to water and sanitation services for all citizens.

iv. **Bottom-UP Transformation Agenda**

Challenges Faced

While these policies have provided a solid framework for innovation, there are still several challenges that AWWDA faces in their implementation:

1. Financing Constraints

Despite the push for innovation and infrastructure development, financing remains one of the most significant challenges. Although PPPs are encouraged, they are often complex and require significant negotiation and risk-sharing, which can delay the implementation of projects.

2. Regulatory Bottlenecks

Although the policies and regulations are clear, the regulatory approval processes for new technologies and infrastructure projects can be slow and cumbersome. This affects the pace at which innovative solutions can be rolled out, especially in rapidly growing urban areas that need immediate infrastructure solutions.

3. Capacity and Skills Gap

While there is a strong policy focus on innovation, the capacity to implement and manage cutting-edge technologies is still developing. Many local manufacturers and contractors may lack the necessary skills or equipment to meet the demands of new, high-tech water systems.

4. Climate Change and Environmental Challenges

Climate change poses a growing challenge to water resource management. While policies encourage the development of climate-resilient water infrastructure, AWWDA faces challenges in forecasting long-term water availability, particularly in drought-prone regions. This uncertainty can make it difficult to plan and implement innovative water systems that can withstand the impacts of extreme weather events.

5. Public Awareness and Behavior Change

Despite policy support for water conservation and sanitation, changing public attitudes and behavior around water use remains challenging. Overcoming cultural and habitual water wastage, especially in urban areas, requires strong public education campaigns and the widespread adoption of water-efficient technologies.

2. How does Athi Water Works collaborate with local manufacturers to enhance infrastructure development?

a. Local Sourcing of Materials and Equipment

A key part of AWWDA's strategy is to prioritize local sourcing of materials and equipment whenever possible. This reduces costs, supports local industries, and ensures that infrastructure projects are more resilient in the long term.

- **Pipes, Pumps, and Valves**: AWWDA works closely with local manufacturers to supply critical components like pipes, pumps, and valves for water treatment plants, distribution networks, and wastewater systems.

- **Water Treatment Chemicals and Equipment**:

b. Job Creation and Skills Development

Working with local manufacturers on infrastructure projects creates direct and indirect employment opportunities for Kenyan workers. This includes jobs in manufacturing plants, installation, and maintenance of water systems, as well as in related sectors such as logistics, engineering, and project management.

- **Local Employment in Manufacturing**: As AWWDA expands water infrastructure projects across Kenya, there is a growing demand for locally produced materials, which in turn drives the need for skilled labor. By sourcing materials and equipment locally, we help create jobs and contribute to the growth of the manufacturing sector, which is a key pillar of Kenya's economic development.

- **Vocational and Technical Training**: In collaboration with Kenyan manufacturers, AWWDA has supported the creation of vocational training programs to develop skills in specialized areas like plumbing, pump maintenance, and pipe fitting. This ensures that the local workforce is equipped to participate in the growing water and sanitation sector and enhances the overall capacity of Kenya's manufacturing ecosystem.

c. Promoting Sustainable Manufacturing Practices

AWWDA actively works with local companies to promote the use of environmentally friendly materials, such as PVC pipes and energy-efficient pumps. We also explore the use of renewable energy sources like solar power to run water treatment facilities, which reduces the environmental impact of infrastructure projects.

In collaboration with local manufacturers, AWWDA is exploring ways to recycle water and wastewater, creating a circular economy for water. This includes the reuse of treated wastewater for non-potable purposes such as industrial processes, as well as the recovery of biogas from wastewater treatment for energy production. Local manufacturers involved in the production of water treatment technologies can benefit from the growing demand for such sustainable solutions.

d. Cost Reduction and Affordability

By promoting collaboration with local manufacturers, AWWDA helps ensure that essential infrastructure components are affordable, which is critical for expanding access to water and sanitation in low-income communities. This, in turn, improves the affordability and sustainability of water services for underserved populations. (Affordable water)

3. What impact does innovative water infrastructure have on local economies, particularly in underserved communities?

- **Job creation** - The construction, operation, and maintenance of innovative water systems create direct employment opportunities in underserved communities. E.g BIOCentres and boreholes run by CBOs

- **Reduction in Waterborne Diseases** - Innovative water and sanitation infrastructure—such as modern water treatment plants, wastewater recycling, and decentralized sanitation solutions—helps reduce waterborne diseases like cholera, dysentery, and typhoid.

- **Improved School Attendance and Education**-With access to clean water and sanitation, children, especially girls, are more likely to attend school regularly.

- **Resource Efficiency and Cost Savings** - Implementing technologies like water metering, leak detection, and energy-efficient water treatment plants can significantly reduce the cost of water services. For underserved communities, where affordability is often a major barrier, these innovations can help reduce water tariffs over time, making water more affordable for households and businesses alike. Sustainable water management practices also ensure that water resources are preserved for future generations, creating long-term economic stability.

- **Improved Environmental Management** - Innovative water and sanitation infrastructure that incorporates wastewater treatment, pollution control, and recycling can contribute to environmental sustainability, which in turn boosts the local economy. Clean water and a healthy environment attract tourists, improve local ecosystems, and promote the growth of eco-tourism or other environmentally-friendly industries.

- **Regional Economic Integration** - Improved water infrastructure can also support regional integration by providing reliable water access across different municipalities, districts, or regions. This can facilitate the growth of regional markets, encourage trade between communities, and create economic networks that benefit from a shared water infrastructure.

4. How does Athi Water Works address the sustainability of its infrastructure in terms of water conservation and environmental protection?

a. Efficient Water Resource Management

One of the cornerstones of our sustainability efforts is optimizing the management of water resources. Given the growing demand for water and the impact of climate change on rainfall patterns, we have focused on improving the efficiency of water use across the region. This includes:

- **Smart Metering and Data Analytics** - By leveraging digital technologies like smart meters and data analytics, we are able to monitor water consumption patterns, detect leaks, and identify inefficiencies in the system. This enables us to manage water more effectively, reduce losses, and promote conservation among users.
- As part of our sustainability strategy, we are exploring and implementing water recycling and reuse systems. For instance, treated wastewater can be reused for non-potable purposes such as irrigation, industrial processes, or landscaping, thereby reducing the demand for fresh water from natural sources. This approach helps to close the loop in water management and reduce environmental pressures on our water resources.
- **Watershed Management** - We are actively engaged in protecting the watersheds that feed into our water supply systems. This includes afforestation projects, soil erosion control, and community-based conservation initiatives to maintain the health of rivers, lakes, and underground aquifers. By ensuring the sustainability of water sources, we can safeguard long-term water availability.
- **Pollution Control and Wastewater Management** - As part of our environmental protection mandate, we work to minimize pollution of water bodies through improved wastewater treatment processes. We are investing in modern, efficient wastewater treatment plants that not only meet regulatory standards but also prioritize resource recovery, such as capturing biogas for energy and recycling treated water for reuse.

b. Green Building Standards and Sustainable Materials

As we continue to develop and expand our infrastructure, AWWDA is committed to adhering to green building standards and using sustainable materials. This includes the use of energy-efficient pumps and water treatment technologies, as well as incorporating renewable energy sources (such as solar power) into the design of water facilities. Using locally sourced, environmentally friendly materials for infrastructure projects also helps to reduce the carbon footprint of construction activities.

c. Public Education and Community Engagement

Ensuring the sustainability of our water and sanitation infrastructure goes beyond technical solutions; it also requires fostering a culture of environmental stewardship. AWWDA places high importance on community engagement and public education campaigns aimed at promoting water conservation and environmental protection. We work closely with local communities to raise awareness about the importance of water stewardship, waste management, and protecting local ecosystems, ensuring that sustainability efforts are supported by the public.

d. Public-Private Partnerships (PPPs) for Sustainable Development

We recognize that achieving sustainability in water and sanitation requires collaboration across sectors. Through public-private partnerships (PPPs), AWWDA is able to tap into the expertise and innovation of the private sector, while also ensuring that social and environmental objectives are met. These partnerships help us to scale up sustainable technologies, adopt best practices, and access financing for long-term infrastructure projects that prioritize sustainability.

e. Monitoring and Continuous Improvement

AWWDA employs a robust monitoring and evaluation framework to ensure that our sustainability goals are being met. Regular audits, assessments, and feedback mechanisms help us to track the performance of water and sanitation systems, identify areas for improvement, and make data-driven decisions. We also engage in periodic environmental impact assessments to ensure that all new projects comply with sustainability standards and do not negatively impact the environment.

f. Tree planting: To conserve the Athi water catchment areas.

PRESIDENT'S DINNER PICTORIAL

Hon. Alice Wahome E.G.H, the Cabinet Secretary for the Ministry of Lands, Public Works, Housing, and Urban Development speaking at the President's Dinner on 11th December 2024

IEK Hosts President's Dinner Unveiling "The IEK Channel" to Showcase Engineering Excellence Hon. Alice Wahome, E.G.H., graces the event at The Boma Hotel, Nairobi, as IEK launches a YouTube platform featuring documentaries, podcasts, and panel discussions to transform the narrative of engineering in Kenya.

Endorsed by IEK President Eng. Shammah Kiteme (left), KRCS Secretary General Dr. Ahmed Idris (right), and witnessed by IEK Honorary Secretary Eng. Jacton Mwembe (Far Left), the partnership prioritizes training, capacity building, and technology integration. Kenyan engineers will contribute by designing resilient infrastructure and assessing disaster risks, ensuring no community is left behind in the journey toward safer, more resilient living spaces.

Eng. Prof. Alex Muumbo FIEK and Eng. Stanley Musau FIEK were honored during the IEK President's Dinner. Also pictured are IEK President Eng. Shammah Kiteme FIEK PMP and Eng. Martin Nzomo, who stood alongside the recognized fellows in a moment of celebration.

Eng. Harrisson Keter – 1st Vice President of the IEK giving remarks at the President's Dinner

Eng. Jacton Mwembe, Honorary Secretary of the IEK, served as the Master of Ceremony (MC) at the IEK President's Dinner, guiding the evening's celebrations and recognitions.

Circular Economy in Wastewater Management

Author

Eng. Philip Gichuki
CEO - Tana Water Works Development Agency

1. How does the circular economy concept fit into the wastewater management strategy of your organization?

The concept of the circular economy aligns seamlessly with the wastewater management strategy of Tana Water Works Development Agency (TWWDA), as the Agency focuses on turning wastewater into a valuable resource rather than viewing it as a waste product. TWWDA's strategy is centred around sustainable development, resource recovery, and improving the quality of life for citizens by enhancing access to safe water and sanitation services.

A core aspect of this strategy is the recovery and reuse of resources from wastewater, which is integral to the circular economy model. Through implementation of projects such as biogas production units and bulk wastewater treatment projects which include the sludge as a recyclable by-product, TWWDA is able to contribute towards reduction of environmental pollution while creating renewable energy and promoting sustainable agricultural practices. Dried sludge is used for briquette production, turning by-products of wastewater treatment into an alternative clean energy source, further advancing the circular economy. Further, it is also used as manure that enables organic food production and enables quality yield as opposed to the use of fertilizer.

TWWDA's approach emphasizes the importance of community involvement and stakeholder collaboration in achieving circular economy goals. By engaging with the National Government, development partners, County Governments, the private sector, and local communities, the Agency fosters a shared understanding of the value of wastewater as a resource. Public awareness campaigns, capacity-building initiatives, and educational partnerships all contribute to changing perceptions about wastewater and promoting its potential for resource recovery.

Through these efforts, TWWDA is not only improving access to safe sanitation and water services but also driving sustainable practices that contribute to environmental protection and economic growth. By integrating the principles of the circular economy into its wastewater management strategy, TWWDA is helping to create a more sustainable future for Kenya.

2. What are the main initiatives or projects currently underway to recycle and repurpose wastewater?

TWWDA is implementing large-scale sewerage systems in urban and areas with rapid population growth, to enable effective management of wastewater. These systems are designed to handle significant high volumes of wastewater, enabling the recovery of water for reuse in agriculture, industries, and groundwater recharge.

Kerugoya Kutus Sewerage Project in Kirinyaga County, the first wastewater treatment facility in the county, is now complete and operational, which is designed to serve urban centres, multi-dwelling facilities, government offices and the local community. The project, implemented by the Agency, is designed to provide an efficient wastewater disposal system that enhances environmental conservation and public health. Furthermore, this project will spur economic growth of both towns and contribute to Kenya's broader development goals. Additionally, the Agency has implemented Othaya Sewerage Project-Last Mile Connectivity Phase one which ensures, more than 17,000 households will be connected to the sewerage system. The project has promoted the development of high-rise buildings, promoting vertical growth and maximizing on land use within the town. Institutions like Othaya girls benefited through the connections thereby ending their challenges with managing pit latrines.

In addition to large-scale sewerage systems, TWWDA is implementing decentralized wastewater treatment facilities (DTFs). DTFs are particularly valuable in peri-urban and rural areas, where centralized infrastructure may not be feasible. These facilities treat wastewater locally, allowing for the recovery of resources such i.e. clean water for irrigation, and organic material for composting or energy production within communities.

The Agency is implementing Kiawara Decentralized Treatment Facility which is expected to revolutionize sanitation services for approximately 5,000 residents, including students from major learning institutions in Gatarakwa and Mugunda locations. The Kiawara community and its environs will also significantly benefit from this development.

3. How is your organization transforming wastewater into valuable resources, such as energy or fertilizer?

TWWDA is committed to infrastructure development of public wastewater facilities through innovative and sustainable components. The Agency recognizes the potential of wastewater by-products to contribute to environmental conservation, economic growth, and improved livelihoods.

One of TWWDA's key components during design of bulk waste water facilities involves the inclusion of a sludge drying bed which aims to utilize sludge, a by-product of wastewater treatment, as a fertilizer. This nutrient-rich material is processed and repurposed to enhance soil fertility, supporting sustainable agricultural practices in the region. By doing so, TWWDA not only addresses waste disposal challenges but also promotes food security and economic resilience.

In addition to using it as fertilizer, sludge can be processed into briquettes—an eco-friendly alternative to firewood and charcoal. These briquettes provide a clean energy source for cooking and heating, reducing reliance on traditional fuels and contributing to forest conservation. This initiative aligns with Kenya's goals for environmental sustainability and clean energy adoption.

Furthermore, TWWDA is implementing biogas production units that convert organic waste, including sludge, into renewable energy. The biogas generated is used for cooking, heating, and electricity generation, offering a clean and sustainable energy solution for three learning institutions. These efforts reduce carbon emissions, enhance energy efficiency, and create new opportunities for renewable energy use.

Through these initiatives, TWWDA is transforming wastewater management into a resource recovery opportunity. Through these projects, the Agency is demonstrating how wastewater can drive economic and environmental benefits while addressing sanitation challenges in Kenya.

4. What role does technology play in advancing a circular economy approach in wastewater management at your organization?

Technology plays a vital role in advancing a circular economy approach to wastewater management at TWWDA. By leveraging innovative technologies, the Agency is transforming wastewater management into a sustainable and resource-efficient process, contributing to environmental protection, economic growth, and improved community livelihoods.

One of the key technological advancements at TWWDA is the introduction of conventional bulk wastewater treatment facilities. Unlike the biological pod systems, these modern facilities are designed to handle large volumes of wastewater efficiently, enabling the recovery of valuable resources such as treated water and organic sludge. These facilities are scalable, making them ideal for urban areas experiencing rapid growth.

Other technological innovations include the use of High-density polyethylene (HDPE) pipes which are petroleum-based thermoplastic polymer that are strong, durable, lightweight, and chemically resistant. These pipes are durable, leak proof and adapt well to the ground formation as opposed to the traditional concrete pipes which had several joints, prone to leakage and easily affected by shifting of ground formation. HDPE pipes are much easier to lay and they require low maintenance.

In addition to centralized facilities, TWWDA is implementing decentralized wastewater treatment systems in areas where bulk infrastructure is not feasible. These localized systems allow for on-site treatment and reuse of wastewater, particularly for agricultural irrigation, and landscaping applications. This reduces the environmental impact of wastewater disposal while ensuring water sustainability in underserved areas.

The Biogas production units is another great initiative in waste treatment, while generating renewable energy in the form of biogas, which can be used for cooking, heating, or electricity generation. This reduces reliance on fossil fuels and contributes to lowering greenhouse gas emissions, making biogas a sustainable energy alternative for institutions and communities.

5. What challenges has your organization encountered in implementing circular economy practices in wastewater management, and how are you addressing them?

One of the primary challenges is the high cost of developing water and wastewater infrastructure. These projects are capital-intensive, requiring substantial financial resources for construction, operation, and maintenance. The Agency thanks the National Government for continuously prioritizing water and wastewater infrastructure development in Kenya. In addition to resources availed by the National Government, TWWDA has sought partnerships with development organizations, private sector players, and other government agencies to mobilize funding. Furthermore, the Agency is adopting cost-effective and scalable technologies, such as decentralized wastewater treatment systems, to reduce initial investment costs while maintaining efficiency.

Another significant challenge is the limited availability of land for wastewater treatment projects. These initiatives are land-intensive, and finding suitable spaces, especially in urban or densely populated areas, is difficult due to land scarcity. TWWDA is tackling this issue by exploring innovative facility designs, which will minimize land requirements. Furthermore, the Agency collaborates with various stakeholders including County Governments and local authorities to identify and secure public land for project development.

Negative perceptions of wastewater facilities among communities also pose a challenge. Many people associate these facilities with unpleasant odours, pollution, and reduced property values, leading to resistance during project implementation. To address this, TWWDA has launched robust community engagement and awareness campaigns. The Agency educates residents about the benefits of wastewater facilities, including resource recovery, environmental protection, and economic growth. Modern treatment technologies that minimize odours and other nuisances are also employed to improve public acceptance.

Despite these challenges, TWWDA is taking proactive steps to ensure the successful implementation of circular economy practices in wastewater management. By addressing these challenges, the Agency is transforming wastewater into a valuable resource and contributing to sustainable development in Kenya.

6. How do partnerships and collaborations contribute to achieving circular economy goals in wastewater management?

Partnerships and collaborations are critical to achieving circular economy goals in wastewater management, as they bring together diverse resources, expertise, and stakeholders to ensure the success and sustainability of initiatives. At TWWDA, such collaborations have been instrumental in advancing resource recovery and sustainable wastewater management practices.

The Government of Kenya plays a central role by providing policy direction, funding, and oversight for wastewater projects. Through its leadership, transformative programs such as the Kenya Towns Sustainable Water Supply and Sanitation Program have been launched, which focus on delivering water and wastewater solutions in the country. These projects are implemented through joint funding by the Government of Kenya and the African Development Bank (AfDB), combining national commitment with international financial and technical support. This partnership has enabled the development of large-scale infrastructure that facilitates resource recovery.

Collaboration with County Governments has also been pivotal in project implementation. Counties work closely with TWWDA to identify suitable project sites, project planning, secure land, and engage local stakeholders. Their support ensures that projects align with regional development priorities and meet the needs of local communities.

Specialized Government Agencies, such as Water Resources Authority (WRA) and National Environment Management Authority (NEMA), contribute technical expertise and ensure that wastewater management practices adhere to environmental standards. Their involvement helps TWWDA achieve both resource recovery goals and environmental sustainability.

Local administration and community involvement are equally important. Community participation is key to the acceptance and long-term success of wastewater projects, especially in overcoming negative perceptions of wastewater facilities. Local leaders and community members are engaged through awareness campaigns and consultations, ensuring they understand the benefits of circular economy practices such as biogas production and sludge reuse. This fosters a sense of ownership and encourages the active participation of communities in maintaining the facilities and adopting sustainable practices.

Furthermore, partnerships with development partners, private sector stakeholders, and research institutions bring in additional expertise, innovation, and funding. Through these partnerships, TWWDA is able to implement cost-effective and scalable solutions while overcoming existing challenges. These collaborations ensure that the principles of the circular economy—such as resource recovery, environmental conservation, and economic growth—are integrated into wastewater management, contributing to a more sustainable future for Kenya.

7. How are you educating or engaging the public and businesses in the concept of wastewater as a resource?

TWWDA is committed to educating and engaging the public and businesses on the concept of wastewater as a valuable resource. By promoting awareness and fostering collaboration, the Agency ensures that communities and stakeholders understand the benefits of resource recovery and play an active role in sustainable wastewater management.

One of TWWDA's key strategies involves community awareness campaigns, where members of the public are educated on the environmental, social, and economic benefits of wastewater resource recovery. These campaigns highlight real-life examples, such as fish rearing, biogas production, the use of sludge as fertilizer, and briquette manufacturing, to demonstrate how wastewater can be transformed into valuable resources. Public consultations and stakeholder forums are also regularly organized, creating platforms for community members and businesses to share their views, ask questions, and learn more about ongoing projects.

TWWDA organizes demonstration site visits, where various stakeholder groups have the opportunity to tour an operational wastewater treatment plant. These visits act as practical examples of how waste water treatment facilities operate including resource recovery components, helping communities and businesses to visualize the potential of wastewater management while fostering support for these initiatives.

The Agency uses media and digital platforms to broaden its reach and share success stories about wastewater resource recovery. Social media campaigns, radio programs, and informational videos are utilized to improve public perception of wastewater facilities and encourage the adoption of circular economy practices.

Finally, TWWDA engages in advocacy to influence policy development that supports the circular economy in wastewater management. By collaborating with policymakers and industry leaders, the Agency works to create an enabling environment for businesses and communities to adopt sustainable practices.

Through these initiatives, TWWDA is successfully shifting perspectives on wastewater, building public trust, and encouraging business participation in resource recovery. By educating and engaging stakeholders, the Agency is paving the way for a sustainable future in wastewater management, demonstrating how wastewater can be a valuable resource for Kenya's development.

8. What are your long-term goals and vision for the future of wastewater management in line with the circular economy?

TWWDA envisions a future where wastewater management is fully integrated into the circular economy, transforming wastewater from a waste product into a valuable resource. In the long term, TWWDA seeks to build a resilient and sustainable wastewater management system that recovers valuable resources from wastewater. By harnessing the potential of technologies such as biogas production, sludge recycling for fertilizer, and briquette manufacturing, the Agency aims to not only reduce waste and pollution but also generate renewable energy, promote agriculture, and create new economic opportunities for communities. The integration of these circular economy practices will contribute to environmental sustainability, helping to conserve natural resources and reduce the Agency's carbon footprint.

A key aspect of the Agency's vision is the widespread adoption of decentralized and bulk wastewater treatment facilities across the counties. These facilities will provide scalable solutions for wastewater management, especially for urban areas with rapid growth and population increase, as well as peri-urban areas. By focusing on both large-scale infrastructure projects and localized solutions, TWWDA aims to ensure that all communities, including underserved and rural areas, have access to efficient and sustainable wastewater management systems.

TWWDA also envisions strengthening its collaborations with stakeholders at all levels—national government, county governments, the private sector, and local communities—to promote the circular economy in wastewater management. By fostering partnerships and building capacity, the Agency aims to empower water utilities to manage and maintain wastewater systems effectively, ensuring that communities benefit from improved sanitation and resource recovery.

In addition, TWWDA is committed to advancing public education and awareness about the value of wastewater as a resource. Through continued engagement with communities, businesses, and educational institutions, the Agency will work to change perceptions about wastewater, emphasizing its potential for resource recovery and its role in achieving sustainable development.

By integrating the mentioned interventions, the Agency will ensure that wastewater management plays a central role in enhancing the quality of life for citizens and achieving sustainability goals for Kenya's future. As Kofi Annan who was the seventh UN Secretary General once said, "We shall not defeat any of the infectious diseases that plague the developing world until we have also won the battle for safe drinking water, sanitation and basic healthcare."

Muratiri Treatment Works: Kerugoya - Kutus Water Supply System

Kibaranu Water Treatment Works

Muratiri Treatment Works -Kerugoya -Kutus water Supply system

Chuka Water Treatment Works

Harnessing Circular Economy and Inclusive Development for Resilient and Sustainable Future Cities.

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1.0. Introduction

Cities are already thinking about alternative and more desirable futures. Fundamentally, visions serve as a basis for all strategic planning in cities worldwide—covering scales all the way from the local, neighborhood level to city, state, and federal scales. Cities are being reimagined, reinvented, and shaped by dominant concepts and imaginaries that serve as a common vision to guide the visioning process and content of the visions. Can we utilize visioning processes as a driver of transformational change? Can we create an City systems science that brings multiple forms of knowledge together? We argue that positive futures are critical to co-creating opportunities and generating realistic pathways for transformation toward sustainability. Coproduction enables incorporation of diverse sectoral, cultural, and disciplinary viewpoints into plausible and desirable future visions. Research and practice are beginning to create positive visions, develop future scenarios, generate pathways, create plans, and initiate implementation projects for improving City sustainability, resilience, and human livelihoods in cities (McPhearson et al, 2016, 2017). This is encouraging but must be expanded. Positive futures are an opportunity to dig deeply into the key tensions and challenges to bring communities together to create shared visions or even to create pluralistic visions within which to reveal underlying conflicts, trade-offs, and tensions. Social, ecological, and technological systems (SETS) framework provide key opportunities for building an City systems science that can inform City practice and, together, envision a positive, resilient City future and chart pathways to get there (Markolf S. A., et al, 2018).

Cities are the engines of economic growth, but they are also the source of many environmental and social challenges. The increasing Cityization trend and the associated rise in energy consumption, green-house-gas emissions, waste generation and social inequality has raised the urgency to develop sustainable City strategies. Rapidly changing social, technological, environmental, and climate conditions pose unique challenges to the way City planners, decision-makers, designers, and citizens think, plan ahead, and take actions to build cities that are resilient to future change. Resilience and disaster scholars alike expect governments, institutions, and civic organizations to anticipate future risks and the occurrence of shocks and stresses in a proactive manner to mitigate and adapt. Yet, although anticipation is considered an important component of both City planning and resilience, the concept in both fields would benefit from moving beyond a bias toward quantitative predictive modeling, and toward the capacity building practices that allow different actors in the city to engage with planning long-term resilient futures (Liyin Shen et al, (2023).

The world's cities find themselves at a crossroads of uncertainty as to which scenario of City futures awaits them. Will they embark on an optimistic path of more just, green and equitable cities? Will business as usual lead them down a pessimistic path of a widening gap between the City rich who can adapt to twenty-first century challenges and the City poor who will suffer? Or will they nosedive into a high damage scenario of catastrophic destruction at the hands of cascading public health emergencies, climate crises and armed conflicts? While many factors influence these pathways, resilience is key to determining City futures. Since the World Cities Report 2020 was published in the early days of the COVID-19 pandemic, the world has become a more uncertain place punctuated by localized events with global consequence. No human settlement was left untouched by COVID-19, even with widespread, if unevenly distributed, access to safe and effective vaccines. Although many, but certainly not all, cities find themselves in 2022 figuring out how to live with COVID-19, they are now facing other shocks. The suffering caused by the COVID-19 pandemic has set back economic and social development and undermined some sustainability efforts in the short term. Beyond that, it has exacerbated inequalities and poverty. The global rise in inequality since 2020 profoundly underlines the unsustainability of many current lifestyles, consumption patterns and livelihoods and thus the urgency of transitions and transformations to build resilience for more equitable and sustainable City and societal futures. The pandemic emerged suddenly and transformed the world dramatically through 2020 and 2021.

The effects of COVID-19 have dramatically exposed City fault lines and highlight that building resilience will require a stronger, more effective multilateral system capable of complementing and reinforcing national and local efforts to put the world firmly on the trajectory of sustainable development. The term "City futures" is used here in recognition of the various potential future scenarios, but equally importantly, the diverse culturally and locally specific forms that human settlements may take in the future. Building resilience for sustainable City development requires integrated linkage of the various pillars of the global sustainable development agenda. These are the 2030 Agenda for Sustainable Development the New City Agenda, Sendai Framework for Disaster Risk Reduction, Addis Ababa Action Agenda and the Paris Agreement on Climate Change. Second, building City resilience is a multi-sectoral, multi-dimensional, multi-stake-holder process that requires a clear change of trajectory from previous paths. This approach entails more than just building back better, if doing so would occur on the same lines that perpetuate inequalities and injustice. In essence, it is about building back differently. From this mindset, it follows that poverty and inequality are incompatible with sustainability and resilience since they undermine the basis of City stability and potentially the fabric of society.

The next section examines the concept of resilience in detail, but it is important here to clarify two related terms, vulnerability and adaptation. Both are used in relation to many different hazards, risks, shocks or threats, including climate change, environmental degradation, COVID-19 and other infectious diseases, economic change, political uncertainty and instability, and armed conflict. Vulnerability refers to an inadequate ability to withstand or resist one or more of these shocks and stresses because of health status, deficient resources, or particular characteristics of an individual, group, location, infrastructure, etc. Adaptation is how individuals or groups respond by changing behaviour, such as making new investments, adjusting building standards, relocating facilities or creating early warning and rapid response systems in order to increase their ability to resist, cope with and otherwise learn to live with the hazard or risk in question.

1.1. Aims and Objectives of the Study

The aims and objectives in this paper are not merely to discuss building resilient and sustainable City futures in leveraging project management expertise, circular economy principles, and inclusive City development strategies as previous writers have been accustomed to do, rather the aims and objectives are to highlight building resilient and sustainable City futures and the implications for future innovation in leveraging project management expertise, circular economy principles, inclusive City development strategies; promote sustainable poverty reduction by strengthening governance and constructing social infrastructure; identify the problems and proffer solution confronting building resilient and sustainable City futures; contribute to the stream of scientific papers, which has scarcely dealt with methods for City future.

1.2. Statement of the Problems

The problem lies in the weakness in the development programs, implementation and execution of building resilient and sustainable City futures in leveraging project management expertise, circular economy principles, and inclusive City development strategies. The building resilient and sustainable City futures programs which successive administrations developed were often weak, segmented and isolated from various sectors of the economy. The following are some possible current bottle-necks or inhibitors, bedeviling institutional arrangements regarding building resilient and sustainable City futures in leveraging project management expertise, circular economy principles, and inclusive City development strategies. They are: - Corruption; lack of funding; lack of clarity and technical guidance; difficulty in quantifying benefits; insufficient data; lack of cross-departmental collaboration; limited understanding of City futures; land-use conflicts; bad and truncated government policies; weak and unsuitable institutions; poor governance and management; political instability; inadequate skilled man-power, etc.

1.3. Significance / Justification of the Study

The study looks at evaluating the immense contribution of building resilient and sustainable City futures in leveraging project management expertise, circular economy principles, and inclusive City development strategies towards stimulating productivity and other socio-economic activities. The imperative for a new building resilient and sustainable City futures for sustainable development agenda arises from the fact that past building resilient and sustainable City futures sustainable development planning efforts have failed. This paper concludes that building resilient and sustainable City futures is not a frill and recommends a new building resilient and sustainable City futures sustainable paradigm to address these concerns and states that without urgently harnessing building resilient and sustainable City futures for future innovation, all other social-economic activities might come to a halt.

1.4. Scope and Limitation of the Study

The scope of the study is limited to building resilient and sustainable City futures in leveraging project management expertise, circular economy principles, and inclusive City development strategies with implications for future innovation. Over the past decades, the issues confronting future building resilient and sustainable City futures in leveraging project management expertise, circular economy principles, and inclusive City development strategies innovation in design processes for building resilient and sustainable City futures had caused increasing concern.

1.5. Research Methodology and Organization of the Study

The conjectural method of research was used covering field work and specific method of articulation. The study adopted exploratory method of research cum innovation that examined and discussed relevant issues of interest in building resilient and sustainable City futures with implications for future innovation as an economically viable option for socio-economic sustainable development objectives. Because of the nature of the study (macro), the writer relied on published documents in the area of green infrastructure using commissioned studies, non-commissioned studies and published works from various sources. Some of these secondary sources are narrow in view, perspective and scope, but they serve as useful materials for researchers and designers wanting to embark on a macro-study on future design processes and thinking. Others include library books, previous works by the author, detailed investigations done on green infrastructure procurement and design processes by the author, internet and articles from learned journals. During the study, there was no case where anybody or scholar delved into discussing developing building resilient and sustainable City futures with implications for future innovation, as socio-economic viable option for poverty reduction, Cityization and industrialization.

1.6. Hypothesis

The hypothesis aims at determining the impact of building resilient and sustainable City futures sustainability as a strategic catalyst for poverty reduction, Cityization and industrialization.

H0: there is no positive relationship between the number of established building resilient and sustainable City futures for poverty reduction, Cityization and industrialization and gross domestic product (GDP).

H1: there is positive relationship between the number of established building resilient and sustainable City futures for poverty reduction, Cityization and industrialization and gross domestic product (GDP).

1.7. Definitions

Although resilience is key for cities to move toward the optimistic scenario of City futures laid out in this paper, the term itself deserves consideration. Resilience, like sustainability, has a complex history and is often used imprecisely and with diverse meanings in different communities of practice and contexts, even within the City arena (Ahern J., 2011). This imprecision is unhelpful both analytically and in terms of implementation. Indeed, despite their distinct meanings, sustainability and resilience are often conflicted or used interchangeably, including in some documents of the global sustainable development agenda (Alvial-Palavicino C., 2016).

1.8. Defining Sustainability

The term sustainability was first coined in 1972 by the Club of Rome to seek a balance between satisfying the needs of people and respecting the biophysical limits of the planet's ecosystems. Thus, sustainability sought to temper the push for economic development with a long term, ecological perspective. It was understood that sustainability was critical to guide development in the Global South. Fifteen years later, the World Commission on Environment and Development published Our Common Future, where they defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987, p. 43).

1.9. Defining resilience

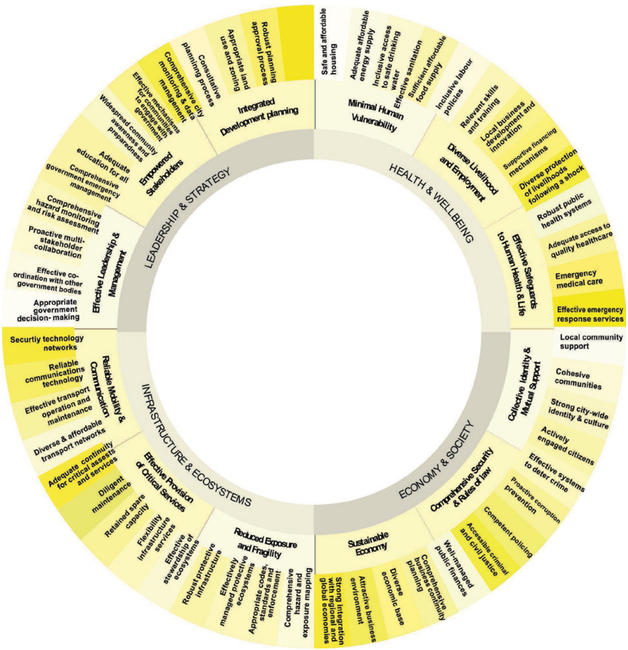
Early formulations of resilience - as reflected in the Global Report on Human Settlements 2011 - were framed in terms of the ability to withstand and recover from an external shock and were popularized by the phrase "bouncing back". Following criticism that bouncing back meant restoring the previous status quo, regardless of how unequal and unjust it was, the requirement of progressive changes to reduce poverty, inequity and injustice was added more recently (Biggs R, et al, 2012). An added difficulty is that, like sustainability, resilience is often considered to represent stability or equilibrium. However, that implies rigidity and a lack of flexibility to change and adapt as the environment and other circumstances change. Even dynamic equilibrium implies more flexible stability within certain boundaries, which may be appropriate for natural ecosystems or even farming systems, though even there the evidence shows that the severity of shocks and recovery time are not clearly related (Brundiers K, Eakin H. C., 2018). In social sciences and in City contexts, which are entirely human artifacts, dynamic equilibrium fails adequately to capture the major rethinking and restructuring now required. It is important, therefore, to define and use these terms clearly and consistently. Accordingly, here City resilience is framed as coping with and recovering from a shock by "bouncing back differently" to emphasize the need for substantive change in view of the urgency of meeting the various targets of the SDGs by 2030 and attaining net zero emissions by 2050 at the latest. Many relatively simple and low-cost adjustments, such as equipping streetlights with LED bulbs, have already been widely made, so there are often fewer low-hanging fruit left to pick in the transition to City sustainability and resilience (Chester M. V., Allenby B., 2018).

1.10. Measuring resilience

Various initiatives have sought to provide comprehensive approaches to resilience planning through integrated and territorial programming and scorecard methodologies. These include the City Resilience Program, a partnership between the World Bank and Global Facility for Disaster Reduction and Recovery, launched in 2017 to "catalyse a shift toward longer term, more comprehensive multidisciplinary packages of technical and financial services, building the pipeline for viable projects at the city level that, in turn, build resilience"(World Bank, 2020). There is also the proprietary Plan Integration of Resilience Scorecard, which has recently been applied comparatively to two contrasting modest-sized cities in the US (Berke et al, 2021). Arguably the most sophisticated, relevant and widely deployed measurement schema to date is the City Resilience Index (CRI) developed by Arup for the Rockefeller Foundation's 100 Resilient Cities programme (which disbanded in 2019) as a tool for measuring implementation of the City Resilience Framework. The CRI was intended for all member cities to adopt and implement as a tool for measuring progress towards overall resilience over time. Represented by a circle, the CRI comprises four dimensions: health and well-being; economy and society; infrastructure and ecosystems; and leadership and strategy. Each of these, in turn, has 12 goals subdivided into a total of 52 indicators designed to capture the many complementary elements of resilience (Figure 1 below). They are observable, critical factors that contribute towards the resilience of City systems. The four dimensions correspond well to the components of resilience examined in Ahern J., 2011. The extent to which the CRI had been implemented by the time of the programme's end in mid-2019 varies (The member cities are now organized into a legacy organization, the Global Resilient

Cities Network, which seeks to co-ordinate and make progress on the City resilience agenda). A key part of the process has been aligning local strategies with locally relevant elements of the global sustainable development agenda, especially the SDGs, although only a proportion have so far done this explicitly (Croese et al, 2020, p. 7). Given the index's comprehensiveness, all the themes in this Report are represented by a dimension or goal in local combinations.

Figure 1: The Rockefeller-Arup City Resilience Index. 52 Indicators add further definition to the 12 Goals (Source: www.cityresilienceindex.org)



1.11. Economic Resilience

City economic resilience refers to the ability of a city's economy to withstand and recover from turbulence and shocks (Romero-Lankao P., et al, 2016). It is essential not just to focus on economic activity as such, but to incorporate poverty reduction and more equitable distribution of economic opportunities and rewards as key characteristics. Only by so doing can the socio-spatial disadvantages and constraints facing the poorest and weakest residents be tackled. In other words, economic justice is an essential component of economic resilience. Similarly, the multidimensional nature of poverty and inequality (Shipley R. (2002), means that these also constitute social and environmental challenges that are dealt with in the respective sections below.

1.12. Social Resilience

The multidimensional nature of poverty and inequality necessitates comprehensive cross-sectoral approaches. These represent urgent short to medium-term interventions as essential prerequisites for increasing ambition towards City transformations to sustainability and resilience.

2.0. Inclusive and strengthening of city economy

An optimistic version of the post-pandemic (Markolf S. A., et al, 2018) and climate resilient era, which this Report seeks to assist local governments in achieving, requires a different structure and balance of City economic activities, driven increasingly by renewable energy, circular economic activity and green employment. Quinlan A. E., et al, 2015, notes that the need for economic diversification and structural transformation has never been more urgent because of the multiple crises confronting cities. Economic diversification and structural transformation safeguard City economies against future shocks and provide a more stable and progressive path toward inclusive growth. The pandemic underscored the risks of depending solely on a single driver such as tourism or mining, since any economic downturn could have catastrophic and lasting impacts on the City economy. As we move into the future, cities should pursue policy measures that enable economic diversification, such as smart City regulations, strategic investment incentives, green infrastructure development, skills training, innovation districts, and enterprise support and finance, particularly for small and medium-size enterprises —which are the engine of most economies. Collectively, these measures create competitive and vibrant cities that can turn around the economic fortunes of City areas and more easily adapt to unanticipated changing dynamics. Economic diversification requires City leaders who are forward-looking and strategic in formulating policies that strengthen City economic resilience and prioritize building of productive City futures that work for all. The COVID-19 pandemic is a wake-up call for both cities and subnational governments on the importance of developing economies that can withstand and recover from multiple crises while at the same time moving towards equitable and inclusive growth. In cities that are experiencing City shrinkage, economic diversification should be accompanied by proactive broader economic policies and programmes, with targeted economic restructuring that is aimed at strengthening the competitiveness of new and emerging sectors (most notably knowledge-based industries) in line with the current and future economic realities. As the world moves towards the 2030 deadline to achieve the SDGs, policymakers at all levels cannot afford to remain indifferent to the fragility and vulnerability of City economies to unanticipated shocks and crises, which can potentially reverse development gains accrued over the years. Earlier concerns that economic greening would cause large-scale job losses and impose a heavy economic price have now been allayed by the growing evidence that such losses are more than compensated for by the increasingly diverse productive and commercial opportunities required to enable the green transition (Cradock-Henry N. A., Blackett P., Hall M., Johnstone P., Teixeira E., Wreford A., 2020). Although some declining or "sunset" industries continue to resist change, the majority are switching production increasingly into green, recyclable and renewable commodities and energy systems through a mixture of fiscal measures and straightforward profitable opportunities as the scale and rate of the green shift accelerate.

3.0. The circular economy principles

The COVID-19 pandemic is a tipping point that proves the need to adopt the circular economy as an alternative model of resilient and sustainable City futures, with the potential for unlocking significant social, economic and environmental benefits (Wolfram M., 2016). In some contexts, cities were already experimenting with the concept of circular City economies to promote economic resilience in their City systems. For instance, London, Paris and Amsterdam were already champions in adopting circular economies to reposition their cities to emerging trends. Such initiatives have the potential to generate new green jobs offering decent work. The effort of individual cities is boosted by the broader European Green Deal, which aims to make Europe the first climate-neutral continent, while ensuring that no one is left behind in the transition. It is important, however, to note that the transition to a circular economy must be carefully planned, considering different factors such as social, economic and political dynamics in each country. There is no one-size fits-all approach to this transition; each city has a unique City ecosystem and therefore any repositioning of the local economy should factor in local contextual factors.

4.0. Leveraging Project Management Expertise

At the City level, local governments generally face increasingly severe financial constraints (Adger W., 2006). Building resilience and productive City futures is not an automatic process; it requires innovative, resilient and sustainable financing instruments beyond the traditional fiscal tools at the disposal of cities and national governments. The pandemic has reinforced the need for cities to diversify their revenue portfolios outside traditional property taxes and other related municipal rates and charges. Green municipal bonds represent a growing tool for leveraging the scale of capital required for major new green and circular investment schemes to promote sustainability and resilience. Examples range from specific green-blue infrastructure to financing of neighbourhood efficiency and resilience programmes like retrofitting and district heating or combined heat and power. Gothenburg, Sweden's second city and industrial hub, was the first to launch a municipal green bond in 2013 and now has a robust framework for such instruments (Brundiers K., Eakin H. C., 2018). In April 2021, Ghaziabad became the first Indian city to issue a successful municipal green bond to fund a water treatment plant to turn wastewater into drinking quality and to extend the piped water network. Kanpur, Agra and Varanasi, also in India, intend to follow Ghaziabad's example and issue such bonds as well (Elmqvist T., et al, 2019). In these contexts, enhancing infrastructural reach and reliability represent important programmes to meeting basic needs securely and achieving the relevant SDGs as contributions to overall City sustainability and resilience. The municipal green bond concept has proven increasingly popular in diverse contexts where local governments have the financial autonomy, legal power and creditworthiness to issue bonds, and the ability to avoid unaffordable debt overhangs. Local governments attracted to such opportunities should examine their legal ability to do so and, if necessary, seek legislative changes to provide them with the necessary powers or at least basis for offering legal surety as a key prerequisite for bond raising. In order to increase funding available to cities more generally and systematically, clear arguments for a green cities development bank have been articulated but, to date, have not been acted upon (Anderson et al, 2019). Cities and subnational governments should create enabling environments for effective and sustainable public-private partnerships (PPPs) to finance ambitious City infrastructure projects, particularly in contexts where public resources are limited. PPPs are becoming a popular mechanism to fund large scale infrastructure investments as these are critical for building resilient City futures.

5.0. Inclusive City Development Strategies

The COVID-19 pandemic has underlined the interdependence between individual and public health, with the highly unequal epidemiological patterns of morbidity and mortality reflecting underlying City socio-spatial inequalities (Raudsepp-Hearne C., et al, 2019). In essence, the built environment has a clear impact on health outcomes. Poorer people, who are more likely to have weaker nutritional and health status, tend to live disproportionately in housing and neighbourhoods that have poor or inadequate infrastructure, public open space, and other amenities and services. Such vulnerabilities also have age, gender and other intersectional dimensions. Hence, context-specific interventions are required to safeguard vulnerable and marginalized City groups (Iwaniec D. M., et al, 2019). The importance of extended family structures, wider social cohesion, and the extent of social and cultural capital can also be crucial factors in mitigating such effects (Hamstead Z. A. et al, 2016). National and City governments have responded in diverse ways; those acting most effectively at first have often been those with recent experience of epidemics like SARS and various strains of bird influenza. Previous experience meant that they had early warning and rapid response capacity as well as important aspects of resilience. In terms of post-COVID-19 recovery, inclusive and integrated policies are required that both tackle the immediate needs and symptoms, and the deeper underlying bases of poverty, inequality and inadequate infrastructure and services in a way that balances socioeconomic rights to achieve social justice (Chester M. V., Allenby B., 2018).

The most successful strategies to create social resilience are likely to combine three elements: - neighbourhood-scale interventions to improve physical infrastructure and basic services; necessary upgrades to sub-standard dwellings; and responsive social protection schemes tailored to household requirements. The current COVID-19 pandemic provides an opportunity for global leaders to rethink transformative City policies and programmes that can radically tackle poverty and inequalities in all its forms and dimensions. The 2021 UN-Habitat report Cities and Pandemics: Towards a More Just, Green and Healthy Future advocates for a "new social contract" in the form of universal basic income, universal health over age and universal housing and basic services. This new social contract challenges cities and subnational governments to re-imagine what public and social goods they should deliver and under what conditions. At the same time, the pandemic has exposed the gaps in social protection, given the disproportionate impact of COVID-19 containment measures on some of the most vulnerable groups in cities. City-sensitive social protection schemes are potentially, a powerful tool to redistribute wealth, address income inequalities and tackle multiple vulnerabilities that affect the most marginalized groups. Some social protection schemes, like universal basic income schemes and affordable health insurance, are normally national government responsibilities, although some devolved federal or similar systems provide health insurance at the regional level. Cities and subnational governments should design tailored social protection interventions for informal workers. Extending social protection to informal sector workers is critical for inclusive development and resilient City futures. Governments at all levels should design policies and programmes to support the formalization of informal businesses and enterprises with access to social protection; extending statutory coverage to previously uncovered workers; adapting benefits, contributions, and administrative procedures to reflect the needs of informal workers; and subsidizing contributions for those with very low incomes. Doing so will ensure livelihood and income security, especially when faced with economic disruptions and other external shocks and stresses.

In designing social protection interventions for informal sector workers, cities and subnational governments should consider gender-related risks since women and other vulnerable social groups bear the brunt of economic hardships and vulnerabilities associated with informal work. Moreover, resilient, and equitable City futures could be realized if governments ensure access to subsidized basic services for the most vulnerable City households and ensure access to adequate and affordable housing for all. Cities and subnational governments should formulate tailored strategies that respond to different form of vulnerabilities. Social protection interventions should be nuanced and wide-ranging to ensure the different risks and vulnerabilities associated with gender, age, ethnicity, migratory status, and other characteristics are effectively identified and tackled in City welfare programming.

6.0. Building resilience and City futures

A key requirement for effective, integrated citywide planning and resilience building in slums and informal settlements —which is discussed more broadly below—is that it should promote socio-spatial and economic equity. This means explicitly including areas and social groups facing particular vulnerabilities and high risks, most of whom are relatively and often absolutely marginalized and impoverished, living in informal housing and surviving through informal economic activities (Araos M., et al, 2016). Informality exists universally but in many developing countries it characterizes substantial segments of the built-up area and population (Biggs R., et al, 2012). These planning processes must be seen as legitimate among slum and informal settlement dwellers, many of whom are only too aware of the chronic daily risks and hazards of their lived experience but also lack the resources to resolve them independently. A vital step to promote such policy legitimacy and remove a major source of vulnerability among the most marginalized groups is for local governments to cease the still widespread use of demolition or eviction (Bulkeley H., 2010; Burch S., et al, 2017). Rather than literally being planned out of City areas, such areas should be planned into towns and cities through the inclusive and equity-promoting policies advocated here. A wealth of experience has been built up through community-based initiatives worldwide, using diverse approaches but generally through shared labour and self-help processes, childcare and education enterprises, rotating credit and collective savings schemes and the like. During high-risk periods, wardens or lookouts can watch for approaching floods, impending landslips, storms, firestorms and other hazards to provide early warning to residents.

7.0. The role of new technologies

Technologies continue to evolve very rapidly, creating new potentials to accelerate City change and transformations but also new challenges about their appropriateness to diverse contexts and their wider impact on equity, justice and wellbeing (Barredo J. I. E. G., 2010; Basse R. M., et al, 2014; Beckers A., et al, 2013). This is the essence of the social dimension in socio-technical approaches and the understanding of cities as socio-technical-environmental systems (Basse R. M., et al, 2014; Beckers A., et al, 2013). The rapidity of technological evolution can make it difficult to judge appropriateness in the short term, as cost, availability and accessibility can change over time. Two good examples are solar panels and mobile phones. Initially they were expensive as well as required supporting infrastructure, installation and maintenance capacity that rendered them accessible mainly to the elite and middle classes in large cities. However, dissemination and technological refinement have been rapid, even in low-income countries, with the result that both are now widely available and accessible at affordable cost, so that both now make important contributions to resilience at individual, household, neighbourhood and hence City scales. (Solar panels were discussed earlier). Mobile phones connect traders to customers, provide access to instant market information from different locations, facilitate maintenance of social contacts among family and friendship networks, enable money transfers cheaply at a distance, enhance personal safety, assist female entrepreneurs to overcome gender barriers and can be a source of early warning of impending extreme events and disasters. Related developments in digital technologies also facilitate citizen science and community mapping as part of participatory and co-productive neighbourhood upgrading and planning negotiations, which is consistent with the idea of civil technology (Basse R. M., et al, 2014; Beckers A., et al, 2013). Networked data sensors and closed-circuit television cameras measuring air quality, traffic and pedestrian flows and many other elements of City metabolism, as well as antisocial behaviour and crime, are increasingly integral to environmental monitoring and mobility management to cut airborne pollution, congestion and ultimately promote City sustainability and resilience.

8.0. Integrated City planning

Integrated City planning is an essential component and prerequisite for resilient City futures. Sometimes called "joined-up planning," it requires bringing together the various sections or departments of a local government to discuss and negotiate their respective priorities, proposals, plans and associated budgetary needs into an overall framework that also includes a spatial or territorial dimension so that the entire City area can be addressed coherently and the whole becomes more than the sum of the respective sectoral and locality- specific parts.83 Apart from the missed opportunity of such added value, failure to integrate at the city or city regional scale risks contradictions and gaps between various locality and sectoral plans, and may even increase vulnerability. A city region embraces the functional City area, which is larger than the City built-up area. This is more useful in terms of resource flows and sustainability, as well as transport and mobility planning, but adds complexity as such regions include peri-City and some rural areas (Basse R. M., et al, 2014; Beckers A., et al, 2013). In simple terms, this helps to avoid a situation where individual departments prioritize development or rehabilitation work in different localities or in the same locality at different times. Such situations lead to inefficiency, greater disruption and cost, and suboptimal outcomes. Instead, effective coordination means that the various elements of infrastructure, buildings or services are designed, delivered or upgraded together. This approach maximizes complementarities and efficiency. The number of cities undertaking such exercises is increasing, partly through the catalytic role of international membership organizations, though Cape Town has been working on disaster risk reduction and climate change mitigation and adaptation at the city scale for over a decade, gaining invaluable experience that bears out the arguments being made here (McPhillips L. E., et al, 2018; Miller C., Muñoz-Erickson T., 2018). Holistic City resilience requires that proactive responses to climate change, pandemics and disaster risk are mainstreamed into the annual and multiyear work-plans and design standards of all departments, and not undertaken as an extra bolt-on to other work or concentrated in one specific department. In turn, this requires effective forward-looking design and planning frameworks that factor in local forecasts of future climatic, environmental and public health conditions so that infrastructure, buildings and services are built or retrofitted to appropriate standards to withstand best estimates of conditions that will prevail over the coming decades. The New City Agenda provides appropriate parameters and guidelines for this (Michel-Kerjan E. O., 2010). Urgent direct attention is required to change the form and function of existing City areas to promote comprehensive sustainability and resilience (Matsler A. M., 2017), just as new City construction needs to accord with the latest design principles, construction techniques and sustainable materials in any given context to avoid locking in unsustainability for decades to come. This is essential to integrate the economic, environmental, social and institutional dimensions of resilience within the City fabric. One key element of this is the imperative to rethink City land-use and transport systems and requirements in order to reorganize large, mainly single-use and mobility-based City areas into more nucleated, 15- or 20-minute cities or communities (Birkmann J, etal, 2010; Brundiers K., Eakin H. C., 2018). They embody the step changes needed to match the scale of our looming challenges, but have yet to be retrofitted or tested in practice outside a few recent model smart city neighbourhoods that are not likely to be widely replicable. Ironically, perhaps, there will be greater potential to upgrade and modernize infrastructure and facilities without large-scale redesign and reconstruction of the built environment in older, central areas of cities and towns in some low- and lower-middle-income countries where multifunctional land uses have survived from the colonial era. In some high-income countries, inner-city neighbourhoods often retain mixed land uses and have integrated infrastructure like district heating and integrated transport systems, enabling them to function both as 15- or 20-minute districts and as integral parts of the larger city.

9.0. Building required capacity for sustainable City futures

Examples of how integrated planning capacity and frameworks can be developed as part of initiatives led by international city networks are provided by Buenos Aires and Cape Town, which took advantage of their membership in the Rockefeller Foundation's 100 Resilient Cities network to formulate their city resilience strategies (Amini F., et al, 2015). Rather than being top-down efforts that were externally driven by the global network, these were both essentially internal municipal undertakings, using their considerable internal skills and capacities to bring together the various previous fragmented and sectoral policies and strategies, updating and adapting them for coherence at the same time to fit into the integrated framework, and amenable to monitoring in terms of the City Resilience Index (Drucker J., 2014).

The human impacts on the planet and on the future of human development are now inescapable (McPhearson T., et al, 2016). The importance of the current context of unprecedented uncertainty and global societal challenges—climate/environmental change, pandemics and epidemics, economic restructuring, human security and the like—cannot be ignored. Yet, exploiting the uncertainty to delay action will only exacerbate the rate, scale, difficulty and cost of subsequent action required to tackle climate change and transform City areas for sustainability and resilience. Instead, as world leaders reaffirmed at the United Nations Framework Convention on Climate Change summit in Glasgow in November 2021, the time to act, and act decisively, is now. This urgency applies equally to local governments, and is key to achieving the optimistic City future first outlined. City futures can go in any number of directions and the duty of City actors is to steer our cities toward the most optimistic future, as outlined in the Sustainable Development Goals and the New City Agenda. Cities can continue on an unsustainable path of widening income inequality, worsening air quality, continuous City sprawl, and growing slums and informal settlements that do not provide safe, adequate housing.

10.0. Future Resilience

If we understand our present conditions as the result of past decisions, the act of naming and imagining future possibilities needs to be recognized as a form of privilege. Future-making is an exercise in agenda setting; that is, the production of alternative futures sets the parameters of what is possible, even desirable, for a society. This is the purview of few. There is a need to reflect on the equity implications associated with the exercise of imagining positive futures as a way of influencing policy. Science fiction writer William Gibson said that the future was unevenly distributed, and, in the context of creating positive City futures, the unevenness implies that not everyone has access to the tools and venues to imagine these alternatives. Indeed, we note that the ability to imagine alternative futures is offered to those who already enjoy a degree of influence in municipal decision-making and are therefore likely to reproduce the status quo (Turnhout et al. 2020; Jagannathan et al. 2020). It is imperative that marginalized communities are included in the process of imagining positive futures and have access, time, and resources to shape this conversation. The ability to think in the long-term is a form of privilege; those most vulnerable live in a reactive mode, needing to figure out how to survive the day to day, much less being able to plan for their future.

Scenario planning is a tool to inform management actions in situations of deep uncertainty. It is therefore not surprising that in recent decades, scenario approaches have been used to explore complex issues such as climate change adaptation, Cityization, or biodiversity conservation. The scenario process produces a set of alternative futures of a place, or a situation that allow comparisons between the outcomes of adopting different policy decisions. In doing so, scenarios not only offer a way of representing complexity but also a means for comparison. The ability to explicitly compare the positive and negative outcomes of competing policy options makes scenarios a valuable instrument to support and guide decision-making. There are different ways of assessing and exploring the desirability of alternative scenario visions. Traditionally, scenario work has relied on modeling outputs as a means of comparison. Models can show quantitative differences in key variables of the system, such as water use or land use, which are easy to grasp and relate directly to policy goals (Harvey D., 1973, 2004). At the same time, models have limitations. The most obvious is that modeling is restricted to the aspects of the future visions that have a quantifiable, biophysical expression. Therefore, intangible qualities that might be highly desirable, such as creating a sense of place or valuing the history of a neighborhood, cannot be captured by models. This means that one of the main strengths of the scenario technique, which is the production of rich, textured, nuanced depictions of the future based on the integration of different ways of knowing, is left out of the evaluative part of the exercise because of the lack of a physical approximation.

11.0. Conclusion

Cities are already thinking about alternative and more desirable futures. Fundamentally, visions serve as a basis for all strategic planning in cities worldwide—covering scales all the way from the local, neighborhood level to city, state and federal scales. Cities are being reimagined, reinvented and shaped by dominant concepts and imaginaries that serve as a common vision to guide the visioning process and content of the visions. Developing transformative pathways for sustainable and resilient cities hinges on the ability of city officials, policy-makers, businesses, scientists, civic leaders, and residents to think, know, and decide on future strategies in an era of unpredictability and conflicting expectations of the future. True resilience can only result from genuinely transformative ideas, policies, and practices concerning how societies go about reducing risk. Although planning for the future is at the core of City planning, current risk-based knowledge systems that rely on predictive approaches are not enough to address the complexities and uncertainties that climate change brings for cities. Anticipation is a critical component of building resilience, but needs to be better embedded in City planning practices and knowledge systems. We have argued for an anticipatory resilience approach to future-based knowledge systems that intentionally explores alternative desirable future states and have offered suggestions for a portfolio of tools suitable to building long-term foresight capacity in City planning, including scenario planning, games, storytelling, and multi-criteria mapping, to name a few, for building resilience and City futures.

12.0. References

Acuto M., et al (2018) Building a global City science. Nat Sustain 1(1):2.

Adger W (2006) Vulnerability. Global Environ Change 16(3):268–281.

Ahern J (2011) From fail-safe to safe-to-fail: sustainability and resilience in the new City world. Landscape City Plann 100(4):341–343.

Alvial-Palavicino C. (2016) The future as practice. A framework to understand anticipation in science and technology. Tecnoscienza: Ital J Sci Technol Stud 6(2):135–172.

Amini F., et al (2015) Understanding data videos: looking at narrative visualization through the cinematography lens. Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, Seoul, South Korea, pp. 1459–1468

Araos M., et al (2016) Climate change adaptation planning in large cities: a systematic global assessment. Environ Sci Policy 66:375–382.

Arnell N.W., Gosling S. N. (2016) The impacts of climate change on river flood risk at the global scale. Clim Change 134(3): 387–401. https://doi.org/10.1007/s10584-014-1084-5.

Barredo J. I. E. G. (2010) Land use scenario modeling for flood risk mitigation. Sustainability 2(5):1327–1344.

Basse R. M., et al (2014) Land use changes modelling using advanced methods: cellular automata and artificial neural networks. The spatial and explicit representation of land cover dynamics at the cross-border region scale. ApplGeogr 53:160–171.

Beckers A., et al (2013) Contribution of land use changes to future flood damage along the river Meuse in theWalloon region. Nat Hazards Earth Syst Sci 13:2301–2318.

Birkmann J, etal (2010) Extreme events and disasters: a window of opportunity for change? Analysis of organizational, institutional and political changes, formal and informal responses after mega-disasters.

Biggs R., et al (2012) Toward principles for enhancing the resilience of ecosystem services. Annu Rev Environ Resour 37:421–448.

Brundiers K., Eakin H. C. (2018) Leveraging post-disaster windows of opportunities for change towards sustainability: a framework. Sustainability 10:1390.

Bulkeley H. (2010) Cities and the governing of climate change. Annu RevEnviron Resour 35(1):229–253.

Burch S., et al (2017) Tipping toward transformation: progress, patterns and potential for climate change adaptation in the Global South. J Extreme Events 04(01):1750003.

Chester M. V., Allenby B. (2018) Toward adaptive infrastructure: flexibility and agility in a nonstationarity age.

Corner J (1999) The agency of mapping: Speculation, critique and invention. London, pp 231–252.

Coumou D., Robinson A. (2013) Historic and future increase in the global land area affected by monthly heat extremes. Environ Rese Lett 8(3):034018.

Cradock-Henry N. A., Blackett P., Hall M., Johnstone P., Teixeira E., Wreford A. (2020) Climate adaptation pathways for agriculture: insights from a participatory process. Environ Sci Policy 107:66–79.

Drucker J. (2014) Graphesis: visual forms of knowledge production (metaLABprojects). Harvard University Press, Cambridge, MA.

Eakin H., et al (2018) Critical lines of action for vulnerability and resilience research and practice: Lessons from the 2017 hurricane season.

Egerer M., et al City change as an untapped opportunity for climate adaptation. Nat npj City Sustainability.

Elmqvist T., et al (2019) Sustainability and resilience for City transformations. Nat Sustain 2:267–273. https://doi.org/10.1038/s41893-019-0250-1.

Elmqvist T (2018) The City planet: knowledge towards sustainable cities. Cambridge University Press, Cambridge, UK

Frantzeskaki N., Rok A. (2018) Co-producing City sustainability transitions knowledge with community, policy and science. Environ Innov Soc Trans 29:47–51.

Galafassi D, Daw TM, ThyressonMet al (2018) Stories in social-ecological knowledge cocreation. Ecol Soc 23(1):23.

IwaniecDM, Cook EM, BarbosaOet al (2019) The framing of City sustainability transformations. Sustainability 11(3):573.

Folke C., et al (2010) Resilience thinking: Integrating resilience, adaptability and transformability. Ecol Soc 15(4):20.

Gago-Silva A., et al (2017) Spatial dynamic modelling of future scenarios of land use change in Vaud and Valais. Western Switzerland. ISPRS Int J Geo-Inf 6(4):115.

Hamstead Z. A. et al (2016) Classification of the heterogeneous structure of City landscapes (STURLA) as an indicator of landscape function applied to surface temperature in New York City. Ecol Indic 70:574–585.

Harvey D. (1973) Social justice and the city. John Hopkins University Press, Baltimore Harvey D. (2004) Space as a keyword. Presented at the Marx and Philosophy Conference, London: Institute of Education.

Hobbie S. E., Grimm N. B. (2020) Nature-based approaches to managing climate change impacts in cities. Phil Trans R Soc B 375:20190124.

Holling C. S. (2001) Understanding the complexity of economic, ecological, and social systems. Ecosystems 4(5):390–405

Iwaniec D. M., et al (2019) The framing of City sustainability transformations. Sustainability 11:573. https://doi.org/10.3390/su11030573.

Iwaniec D. M., et al (2020) The co-production of sustainable future scenarios. Landscape and City Plan 197:103744.https://doi.org/10.1016/j.landurbplan.2020.

Iwaniec D. M., et al (2020) Integrating existing climate adaptation planning into future visions: a strategic scenario for the central Arizona-Phoenix region. Landscape City Plan 200:103820.

Jagannathan K, Arnott JC et al (2020) Great expectations? Reconciling the aspiration, outcome, and possibility of co-production. CurrOpin Environ Sustain 42:22–29.

Kabisch N., Haase D. (2014) Green justice or just green? Provision of City green spaces in Berlin, Germany. Landscape City Plann 122:129–139.

Liyin Shen et al (2023) Strategies for sustainable City development – Exploring innovative approaches for a liveable future, Switzerland.

Locke D. H., Grove J. M. (2016) Doing the hard work where it's easiest? Examining the relationships between City greening programs and social and ecological characteristics. Appl Spatial Anal Policy 9:77–96.

Markolf S. A., et al (2018) Interdependent infrastructure as linked social, ecological, and technological systems (SETSs) to address lock in and enhance resilience.

Matsler A. M. (2017) Knowing nature in the city: comparative analysis of knowledge systems challenges along the eco-techno spectrum of green infrastructurein Portland & Baltimore. Dissertation, Portland State University.

McPhillips L. E., et al (2018) Defining extreme events: a cross-disciplinary review. Earth's Future 6(3):441–455.

McPhearson T., et al (2016) Advancing City ecology toward a science of cities. . Biosci 66(3):198–212.

Michel-Kerjan E. O. (2010) Catastrophe economics: the national flood insurance program. J Econ Perspect 24(4):165–186.

McPhearson T., et al (2016) Advancing City ecology toward a science of cities. BioSci 66(3):198–212.

McPhearson T., et al (2017) Positives visions for guiding transformations toward desirable City futures. CurrOpin Environ Sustainability 22:33–40.

Meerow S., et al (2016) Defining City resilience: a review. Landscape City Plann 147:38–49.

Miller C., Muñoz-Erickson T. (2018) The rightful place of science: designing knowledge.Consortium for Science, Policy & Outcomes, Phoenix

Moser S, et al (2019). The turbulent world of resilience: Interpretations and themes for trans-disciplinary dialogue. Clim Change 153:21–40.

Pelling M. (2010) Adaptation to climate change: from resilience to transformation. Rout ledge, London and New York.

Quinlan A. E., et al (2015) Measuring and assessing resilience: broadening understanding through multiple disciplinary perspectives. J Appl Ecol 53(3):677–687.

Raudsepp-Hearne C., et al (2019) Seeds of good anthropocenes: Developing sustainability scenarios for Northern Europe. Sustain Sci 15(2):605–617.

Swart R. J., et al (2004) The problem of the future: sustainability science and scenario analysis. Glob Environ Chan 14(2):137–146.

Tanner T., et al (2009) City governance for adaptation: assessing climate change resilience in ten Asian Cities. Institute of Development Studies Working Papers, pp 1–47.

Turnhout E, Metze T, Wyborn C et al (2020) The politics of co-production: participation, power, and transformation. CurrOpin Environ Sustain 42:15–21.

Rocha J. C., et al (2018) Cascading regime shifts within and across scales. Science 362(6421):1379–1383. https://doi.org/10.1126/science.aat7850.

Romero-Lankao P., et al (2016) City sustainability and resilience: from theory to practice. Sustainability 8:1224.

Shipley R. (2002) Visioning in planning: Is the practice based on sound theory? Environ Plan A 34:7–22. https://doi.org/10.1068/a3461.

Walker B., et al (2004) Resilience, adaptability and transformability in social–ecological systems. Ecol Soc 9(2):5.

Wardekker J. A., et al (2010) Operationalizing a resilience approach to adapting an City delta to uncertain climate changes.

Wolfram M. (2016) Conceptualizing City transformative capacity: A framework for research and policy. Cities 51:121–130. https://doi.org/10.1016/j.cities.2015.11.011.

The Role of Environmental Engineering in Kenya's Forestry and Climate Change Strategies

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PS. Ng'eno spoke to Engineering in Kenya magazine correspondent on how the State Department for Environment and Climate Change is building a climate-resilient future as well as the Role of environmental engineering in Kenya's forestry and climate change strategies. He emphasized on how his state department strives to promotes the sustainable development agenda of the Kenyan nation.

"Like all other economies around the world, the Kenyan economy also suffers from climate change impacts. The Ministry of Environment, Climate Change and Forestry, realizing the threat that climate change brings to the country's economy, has not only come up with strategies for greenhouse gas (GHG) emission mitigation but provided resilience measures for sectors of the economy as well as communities through the National Climate Change Action Plan (NCCAP) 2023 – 2027," says the PS.

He further added that the climate challenges of the Kenyan economy have been presented in NCCAP III includes environmental engineering; therefore, it plays an important role in the implementation of NCCAP climate priorities such as forestry management and climate change adaptation.

Climate Challenges and NCCAP Multi-Sectoral Approach

As a result of droughts, floods, temperature changes, and other climate hazards, Kenya faces severe risks and therefore strong mitigation and adjustment strategies have to be put in place. In the period between 2023 and 2027, the NCCAP prioritizes eight sectors, with a particular focus on forestry, wildlife and tourism as well as disaster management. Environmental engineering responds to these issues by incorporating scientific and technical aspects and developing strategies that are consistent with the goals of the NCCAP.

There is an aim to reduce GHG emission for those who stand at 32% above business-as-usual projection by the year 2030. The situation looks good since forestry is estimated to account for 37.3 mtco2e as reduced GHG emissions. Aggressive re-forestation and establishment of carbon sinks are some of the critical strategies that environmental engineering lends technical support in.

Environmental Engineering as a Tools for Afforestation

Environmental conservation vis-a – vis climate change has evolved into a concerted effort at international and regional levels. Forests are major contributors to climate change mitigation. They are not only essential for carbon storage, protecting biodiversity and regulating moisture but also play a pivotal role in the overall health of the ecosystem. There is a need for robust afforestation strategies given the recent direction issued by Kenya's government to plant 15 billion trees by 2032 in a bid to increase tree cover to 30% of the country's size. There's more. Environmental engineering aims to achieve this purpose through:

1. **Afforestation and Reforestation with Precision:**

- A comprehensive verification process such as GIS and remote sensing aims to pinpoint the most efficient locations for afforestation.
- Through the use of more sophisticated environmental models, the distribution of tree species may also be modelled with respect to a subset of climates.

2. **Drip Irrigation Systems and Other Innovative Solutions:**

- While water scarcity continues to be an ongoing struggle, engineering and designing systems that are able to effectively harvest water, and irrigate through water-scarce propagation systems such as drip irrigation and aquifer recharge systems would complement the forest.
- Recycling of wastewater for use in forestry irrigation helps to conserve water while also enhancing efficiency in irrigation.

3. **Monitoring and Evaluation:**

It is possible to deploy the Internet of Things facilities for measuring and monitoring the forests' health and growth, with a view to achieve the targets of afforestation and reporting on the trees' cover and inventory.

Climate Change Adaptation and Resilient Infrastructure for Disaster Risk Management

Kenya is a region with high potential risks of flooding, landslide, and drought; hence, the construction of climate adapted structures is of great importance which is one of the specialties of environmental engineering. As climate change causes increasingly severe disasters, the NCCAP highlights a range of policies and objectives towards climate change adaptation as well as improved risk management that can be applied to communities and infrastructure at the borders of the impacts of climate change.

1. **Flood control and Management:**

- It is possible to create and design green infrastructure such as wetlands to absorb floodwaters, this facility should also assist toward prevention of urban flooding.
- Introducing Structural solutions to floods termed as flood walls, levees, and other non-structural measures like early warning systems can help develop resilience in communities.

2. **Landslides prevention:**

- Slope of the mountains and steep hills and depressed regions of a geological structure can be stabilized to prevent landslides, these can also be reforested and soil bioengineering can be employed to stabilize the region.
- Predictive modelling through the advanced monitoring systems and GIS can allow prediction of the risk of landslides and allow preparation for such instances.

3. **Drought Management:**

- In order to alleviate the effects of water shortage, environmental engineering aids in the construction of sea water desalination plants, systems for recharging groundwater reservoirs, and rainwater harvesting systems.
- Reservoirs adaptable to climate change and the networks of water supply ensure that the water is evenly spread out at levels.

Sustainable Energy and Transport Integration

Environmental engineering is very key in enhancing efficiency and transitioning toward clean energy in Kenya's Energy and Transport Sectors; both are crucial in the efforts Kenya is putting into mitigating climate change.

1. **Deployment of Renewable Energy:**

- Engineers design and optimize systems for solar, wind, and geothermal energies to reduce consumption dependence on fossil fuel sources.
- Hybrid energy systems engineered to meet particular rural needs address energy equity while cutting emissions.

2. **Green Transport Solutions**

- Design of infrastructure for Electric Vehicles, charging networks. This addresses NCCAP goals: decarbonized transport.
- Smart traffic/Bus Rapid Transit frameworks as part of engineering services will provide congestion-free and emission-less traffic in urban agglomerations.

Sustainable Urban Systems and Circular Economy

Urban regions are, without doubt, the major sources of emissions and environmental degradation thus pushing the need for urban sustainability. Environmental engineering encompasses the notion of a circular economy within the scope of urban waste management for the ease of living in a city.

1. **Waste-to-Energy Systems:**

- The energy transition of urban waste is the solution to the two problems of garbage in the cities and it at the same time is a mechanism for the creation of clean energy in cities.
- Biogas plants and anaerobic digesters have become decentralized waste management options that can be utilized.

2. **Sustainable Building Design:**

- Energy efficient strategies such as passive cooling system patterns that are designed by engineers to help in decreasing the energy requirement in urban areas.
- Sustainable materials that have been used to fix the currently existing structures hence give the building an energy performance as well.

3. **Integrated Urban Water Management:**

- These systems are the ones that are designed to boost water recycling and rainwater harvesting, which lead to efficient water use in the metropolis in a sustainable way.
- The decentralized wastewater treatment plants are of low quality and besides water quality improvement, they also recover resources they produce.

Advancing Research and Capacity Building

NCCAP underscores that investigative research and capacity building are the keys to climate resilience. Therefore, the environmental engineers are now working within the academic sector, governmental bodies, private organizations as well as to get to innovation and knowledge transfer levels.

1. **Research and Development (R&D):**

- The development of locations, adapted crops, drought-resistant species, and CCS, at low costs will allow the resilience process faster.
- Pilot projects on agroforestry and renewable energy shows a map for expanding.

2. **Capacity Building:**

- Locally trained individuals in the climate-smart practices enable them to become part of the climate action and this will be the most effective way to build the community.
- Collaboration between universities provides environmental engineers with more technical skills and hence expands their future career prospects.

3. **Public Awareness and Engagement:**

- Engineers play an important role in guiding awareness campaigns on sustainable approaches that cause community engagement in the afforestation and waste management projects.

Policy Integration and Climate Finance

Policy frameworks and financial mechanisms play an important role in the implementation of the objectives defined under NCCAP. This includes environmental engineering which by providing the necessary engineering knowledge enables the alignment of projects to policy objectives for financing purposes.

1. **Policy Alignment:**

- Engineering solutions should be implemented to satisfy the legal regulations, which include the requirements of the Climate Change Act and other NCCAP enabling policies, among others.
- Additionally, the implementation of environmental considerations into national and county development plans at the level of grassroots is holistic climate action.

2. **Climate Finance Mobilization**:

- Engineers construct bankable climate projects that pull in funds from the Green Climate Fund and other international sources.
- Drafting accounts for businesses to trade carbon credits from forestry and renewable energy projects mainly add to the finances of climate-based projects.

Conclusion

Kenya remains the cornerstone of environmental engineering's quest for a climate-resilient future and at the same time, it confronts the threats that reside at the innermost parts of NCCAP 2023–2027. Engineers who specialize in the environment bring change to forest management, disaster risk, energy, and urban systems through new technologies and best practices. To this end, the investment in capability for environmental engineering and the promotion of interdisciplinary approaches will be vital since Kenya is intensifying its climate action to successfully follow the path of low-carbon, climate-resilient development.

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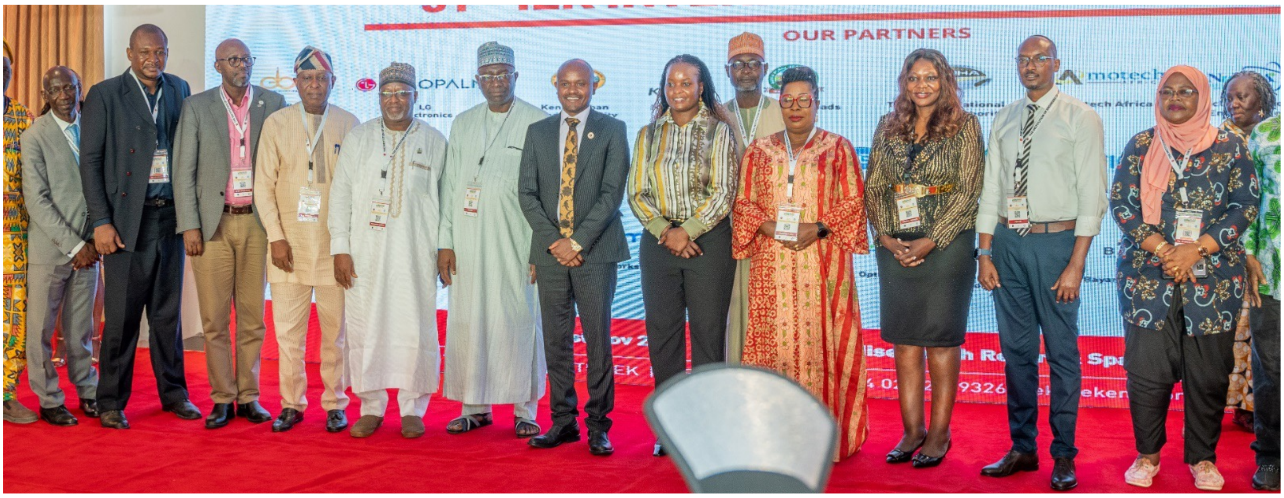

IEK President Eng. Shammah Kiteme, FIEK, CE, PMP, joined on stage by leaders of international delegations from Angola, Botswana, Burkina Faso, Nigeria, Sierra Leone, Tanzania, Zambia, Zimbabwe, Rwanda, DRC, Uganda, Malawi, and Ghana during the 31st IEK Convention.

Cs. Hon. Harriet Chiggai, Women Rights Advisor to the President, IEK President Eng. Shammah Kiteme, CE, FIEK, joined by Future Leaders Chair Eng. Annette Ingaiza, PE, MIEK, Women Engineers Committee Chair Eng. Jennifer Gache, PE, FIEK, and EBK Registrar CEO Eng. Margaret Ogai, CE, FIEK, after official opening of the 7th Women Engineers Summit and 3rd Future Leaders Summit at the of 31ST IEK Convention.

Cs. Hon. Harriette Chiggai, Women Rights Advisor to the President, graced the 7th Women Engineers Summit and 3rd Future Leaders Summit as Chief Guest, alongside the IEK Council led by President Eng. Shammah Kiteme, CE, FIEK, Future Leaders Chair Eng. Annette Ingaiza, PE, MIEK, and Women Engineers Committee Chair Eng. Jennifer Gache, PE, FIEK, during the 31stIEKConvention.

Innovative Biosystems Engineering for Climate Resilience: Insights and Innovations from JKUAT's Department of Agricultural and Biosystems Engineering

Author

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Universities play an all-important role in creating climate and environmental resilience by combining research, education, and community engagement. They are hubs for innovation, where future engineers are trained to develop sustainable solutions and technologies to mitigate and adapt to climate change. One such institution is the Jomo Kenyatta University of Agriculture and Technology, JKUAT, which has spearheaded cutting-edge research in fields like renewable energy, waste management, water conservation, and sustainable agriculture.

We spoke with **Eng. Dr. Erick Kiplangat Ronoh,** Chairman and Lecturer at the Department of Agricultural and Biosystems Engineering, School of Biosystems and Environmental Engineering at JKUAT, who shared valuable insight on the department's contribution to climate and environmental resilience. Eng. Dr. Ronoh is a registered Professional Engineer (EBK) and Corporate Member (IEK) who specializes in agricultural processing, structures, renewable energy and materials.

Approach to Climate Resilience Through Research and Academic Programmes

There are two programmes in the Department of Agricultural and Biosystems Engineering; BSc Agricultural and Biosystem Engineering, and BSc Energy and Environmental Technology. The Department has taken major steps towards building climate resilience through its academic programmes by making sure the curricula remain aligned to the changing needs of the society. It constantly reviews and develops new curricula so the training remains relevant to today's world. It has incorporated relevant undergraduate and post-graduate programmes including machinery and precision agriculture, processing and structures, natural resource, engineering, bioinstrumentation and infotronics, just to mention a few.

Moreso, it prides itself in offering accessible, quality and transformative training, research, innovation and entrepreneurship. This, Eng. Dr. Ronoh says, is the core mission of JKUAT.

"Our aim is to produce agile, adaptive and dynamic leaders in the agricultural and biosystems engineering field who can truly and effectively address the climate change concerns arising in the agriculture, energy and environment realms," he says.

Collaborative Efforts

Climate change and its allied effects can be felt across the entire engineering spectrum, thus creating the need for collaborative efforts to address climate resilience. As such, the Department of Agricultural and Biosystems Engineering is working hand in hand with its sister department, Soil, Water and Environmental Engineering Department, which offers similar courses in water engineering, environmental engineering and management, sanitation and aquaculture. The Department has core electives which are specifically geared towards enhancing training in building climate resilience.

"We do this to increase the adaptive capacity of our students, because climate change cannot be ignored," he emphasizes.

The Department has taken major steps towards increasing collaborative research. It has initiated staff-guided research with relevant stakeholders and partners to supplement training in climate change related topics. Workshops, seminars, short courses, expos and exhibitions are yet other approaches that the Department uses to promote immersive learning, exchange of experiences and best practices. This approach is specially crafted to meet food, nutrition and energy security needs of the country, in the face of climate change.

Eng. Dr. Ronoh acknowledges the input of students in combating climate change, for this reason, prefers an approach that involves both staff and students in the action plans geared towards building climate resilience.

Achievements and Innovations Geared Towards Climate Resilience

Innovation is the core of the Department of Agricultural and Biosystems Engineering. To that end, it boasts key innovations that positively impact building a more climate resilient future.

"Our key innovation is the 'appropriate' Post-harvest value addition technologies. I say Appropriate because they are tailored towards the exact needs and challenges of the farmer. Drying and cooling facilities are a problem area for most farmers. The shift towards renewable energy sources has seen the incorporation of solar dryers, which may not be very effective in the absence of the sun. We therefore envision a situation where even the backup is based on renewable energy, that is where the solar-biomass dryer comes in," reveals Eng. Dr. Ronoh.

The solar-biomass dryer enables farmers to use solar energy during the day and biomass energy at night for continuous drying of their produce. Other options based on the same hybrid concept are solar-wind turbine dryers and solar-PV drying facilities.

In the same vein, the Department has developed, optimized and disseminated affordable cooling systems to farmers in different counties. The low-cost evaporating cooling systems include those that utilize charcoal and pumice among other innovative padding materials. Collaborative efforts to develop improved solar-powered cooling facilities are currently ongoing, in collaboration with other partners, with the aim to achieve highly efficient cooling facilities.

Electricity is a challenge is rural areas where most of the farming takes place, that would explain the reliance on renewable energy sources which are also affordable.

The technologies developed by the Department of Agricultural and Biosystems Engineering are multipurpose. The drying systems for instance, have the capacity to dry cereals, semi-perishable root crops and tubers (like cassavas, potatoes, sweet potatoes, arrow roots, yams), fish and fruits and vegetables, giving them an all-rounded approach to value chains. The facilities also double up as smart storage facilities and through research, are able to establish what temperature regimes are suitable for a particular produce according to the season.

"A key component of the success of all these facilities is training on their proper usage, operation and maintenance. Through MOUs, we have had our students go back to these facilities and gather feedback on how the end-users are coping to further enhance improvements," Eng. Dr. Ronoh explains.

Climate Smart Greenhouses

Climate change and sporadic weather patterns has deeply challenged overreliance on open field cultivation. The Department is currently looking into climate-smart greenhouses that can effectively relay real-time data on humidity, nutrient levels, temperature for easier monitoring and control.

Adaptive insect-rearing structures are yet another domain the Department has ventured into to improve food/feed security and reduce carbon footprint through alternative food sources.

Shujaa Tractor

The Shujaa Tractor is a mini-tractor developed in collaboration with the Indian government though reverse engineering (under JKUAT-SRISTI technology transfer project). JKUAT lays emphasis on commercializing its innovations and as such, is looking for key stakeholders and partners to realize the same.

"The mini-tractor prototypes were deployed to different sites in Kenya to ascertain how they perform in different agricultural ecological zones. The feedback is guiding further upgrade of the mini-tractor from 10.5 HP to 16.5 HP to meet the needs of farmers across the country by providing sufficient power for the tough conditions in Kenya and the region at large.

The IROC Tractor

The IROC Tractor, an innovative creation from JKUAT developed in conjunction with the US (Christensen Machine Inc., USA), operates at 20 HP and is powered by biodiesel, significantly reducing CO_2 emissions. This eco-friendly design enhances climate resilience by promoting sustainable agricultural practices. It has been introduced to framers who have given the appropriate feedback needed to improve and make it more efficient.

Yet another key innovation is the M-Shamba Digital platform, developed by a former student at the Department as part of their undergraduate project.

"M-Shamba is a marketing platform that supports digital learning and plays a pivotal role in the farmer-to-consumer supply chain."

Emerging Production Technologies

The Department is currently working in liaison with the Departments of Mechanical Engineering and Mechatronic Engineering to explore use for bio-based materials (underutilized, unwanted or invasive materials) in the field of additive manufacturing (3D printing). Such materials not only play a key role in making low-cost building blocks for the construction sector, but can also be utilized in 3D printing. Additive manufacturing makes use of materials otherwise considered as waste like rice husks, coffee husks, maize cobs, bean pods, groundnut pods, macadamia shells, coconut shells, sugarcane peels, banana leaves, sorghum stalks, cactus, water hyacinth (an invasive species), among other local materials. They are pre-processed and put to further use (for instance, developing single-use packaging solutions) as means to a better environment.

"Post-harvest waste is a challenge that we have to contend with, a case in point being in Mwea where farmers burn rice husks which is more of a nuisance when preparing the field for the next planting season. It is our responsibility as a department to find out how the material considered waste can be utilized for a circular economy," he further explains.

Collaboration with Local Farmers and Industry Stakeholders

The Department of Agricultural and Biosystems Engineering, and indeed JKUAT as a whole, has taken a lead role in fostering partnerships and collaborative efforts with local farmers and industry stakeholders. It works hand in hand with the county governments who have a better understanding of the farmer groups and help with access and dissemination of the technologies to the end-users.

"Most of our technologies require trials to ascertain whether they meet the local needs of the farmers, like the tractor, drying and cooling facilities – the county government has played a pivotal role in ensuring this," he quips.

The Department is working with the Ministry of Agriculture and other partners towards incorporation in the diverse CSA-MSP (Climate Smart Agriculture Multi Stakeholder Platform). The platform brings aboard different stakeholders who together establish networks and work together towards building a climate resilience future.

Conclusion

The Department is deliberate about incorporating aspects of climate resilience in the undergraduate and post-graduate curricula, as it will go a long way in helping them acquire green skills.

"We have laid strong emphasis on experiential learning and topical initiatives to strengthen our students' understanding of climate resilience as it relates to their career and the society. We realign research and innovation to the national goals, the regional goals and global sustainable development goals (SDGs). Seminars and talks compliment the lectures to enhance their skills," concludes Eng. Dr. Ronoh.

The IROC Tractor (20 HP), an innovative creation from JKUAT, is powered by petrol and is generally fuel-efficient with reduced emission potential, thus significantly reducing CO_2emissions. This eco-friendly design enhances climate resilience by promoting sustainable agricultural practices for smallholder farmers.

The Shujaa Tractor, an innovative solution from JKUAT, has a power rating of 10.5 HP (to be upgraded to 16 HP) and is designed to revolutionize agricultural mechanization for smallholder farmers. Engineered for near-zero environmental impact, it combines efficiency and sustainability, setting new standards in green farming technology.

Eng. Dr. Erick Kiplangat Ronoh, Chairman and Lecturer at the Department of Agricultural and Biosystems Engineering, School of Biosystems and Environmental Engineering at JKUAT, receives a copy of Engineering in Kenya Magazine Issue 13 (Chemical Engineering) from Michael Waweru, Marketing and Communications Officer at the IEK Secretariat, following an engaging interview session.

The Aeroponic Irrigation Tower System, an innovative greenhouse research project at JKUAT, combines artificial intelligence and renewable energy to optimize water use and nutrient absorption. This groundbreaking system promotes sustainable agriculture and enhances crop productivity while minimizing environmental impact.

PICTORIALS

PICTORIAL

President's Women Rights Advisor, Hon. Harriette Chiggai, CS, receives an award from IEK President Eng. Shammah Kiteme, FIEK, CE, PMP, during the 31st IEK Convention. Also pictured are Eng. Christine Ogut, 2nd Vice President (left); Eng. Annette Ingaiza Murambi, Council Member and Chairperson of the Future Leaders Committee; and Eng. Jennifer Gache, Council Member and Chairperson of the Women Engineers Committee (WEC). Hon. Chiggai graced the occasion as the Joint Session Chief Guest, which featured the 7th Women Engineers Summit and the 3rd Future Leaders Summit running concurrently.

Hon. Davis Chirchir, EGH, Cabinet Secretary, Ministry of Roads and Transport, highlighted the importance of capacity building and the Washington Accord in driving infrastructure growth and economic development during the opening session of the 31st IEK Convention.

Hon. Davis Chirchir, EGH, Cabinet Secretary, Ministry of Roads and Transport, Eng. Joseph Mungai Mbugua, MBS - Principal Secretary, State Department for Roads, and IEK President Eng. Shammah Kiteme, FIEK, CE, PMP, in a tree planting session of the 31st IEK Convention, symbolizing a shared commitment to sustainability and environmental stewardship in engineering.

Hon. Abdullswamad Sheriff Nassir, Governor of Mombasa County, receiving a gift from IEK President Eng. Shammah Kiteme, FIEK, CE, PMP during the 31st IEK Convention.

Eng. Joseph Mungai Mbugua, MBS, Principal Secretary, State Department for Roads, receiving an award from IEK President Eng. Shammah Kiteme, FIEK, CE, PMP, during the 31st IEK Convention.

The Impact of Infrastructure Development on Communities: A Case Study of the Rehabilitation of the Ahero – Kisii – Isebania (A1) Road

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1. Introduction:

This paper is concerned with the link between transport infrastructure development and its effect on local communities within the immediate zone of influence. The study explores the impact of road projects on the social and economic conditions of the surrounding community and households within and along the project based on empirical evidence. Specifically, we investigate whether there is an impact of the rehabilitation of the Ahero – Kisii – Isebania (A1) corridor and feeder roads on the socio-economic aspects of the local communities. We will explore the specific socioeconomic indicators and their baseline metrics, gather information on their performance over the project implementation period evaluate the before and after differences.

This study is important in assessing the benefits of transport infrastructure investment for two reasons 1) wider economic and social elements and 2) household units based on average incomes and mobility indices based on exante and post-ante assessments. The study identifies various social, economic and transport indicators to be measured over the project period including household income, household mobility index and traffic volumes along the rehabilitated roads. Gertler et al (2012) emphasize that there is a causal relationship between infrastructure investment and indicator outcomes of interest. The focus is on the impact that is, changes directly attributable to infrastructure investment.

Theory of Change framework underpinned in the study highlights the required inputs to instigate socio-economic changes within and around the community (OECD, 2015).The inputs should be financial instruments as well required to mobilize the required infrastructure, policies and regulation to support the investment, materials and equipment. It also illustrates the activities to be undertaken to actualize the physical development: planning and design, construction, maintenance and stakeholder engagement. Through the ToC we are able to check for realized expectation such as improved infrastructure, accessibility and economic activities. We are also able to outline outcomes /impacts of the either immediate or long term under the key indicators under evaluation. (World Bank 2004)

Travel time savings, travel cost savings, improved healthcare, increased mobility are possible immediate outcomes of rehabilitation of the Corridor and feeder road while longer term and wider effects such as economic development, sustainable development and improved economic resilience are impact that are expected in the longterm horizon (EU, 2016)

2. Study Methodology

This section illustrates the surveys undertaken to gather data on the specific indicators, to obtain baseline and end line conditions with respect to the rehabilitation project. The study utilizes mainly observational data gathered through the surveys including but not limited to:

- Traffic surveys and Transportation Surveys
- Household Surveys

The purpose of the surveys is to obtain both primary and secondary data for statistical and thematic analysis. Household surveys includes both qualitative and quantitative data. According to Creswell & Creswell (2018), household surveys have been used to gather social information such as household incomes, expenditure, access to facilities and amenities such as healthcare, electricity and safe water, asset ownership, transportation aspects such as number of trips made by each member, travel times to common destinations and travel cost. The household surveys highlight social dynamics and patterns that are exhibited by households useful in prediction of area-level socioeconomic aspect. The household survey is used to collect information on:

1. Household demographics
2. Incomes and Expenditure (poverty index)
3. Access to facilities
4. Asset ownership
5. Mobility index (trip characteristics)

Household surveys are conducted at the towns along the A1 corridor and feeder roads periodically.

Traffic and transport surveys are also undertaken to verify the increase/decrease or improvement in traffic and transport aspects along the A1 corridor and feeder road sections. Transportation indices and associated indicators are likely to be almost instantaneously affected by infrastructure improvements. Moreso, quantifiable aspects of transport infrastructure are measured by how reliable and efficient transport infrastructure is. Elements such as congestion & travel time, change in travel patterns road safety are explored under transportation while environmental aspects such as land use changes, urban development and emissions are highlighted upon as established in the "Economic Impact of Transportation Infrastructure Investments." (Economic Development Quarterly, 2015) and "Travel Behavior Changes Resulting from Transportation Infrastructure Improvements" (Transportation Research Part A, 2018) Transport surveys is used to gather data on:

1. Traffic Volume
2. Vehicle Origin and Destination
3. Travel Time
4. Crash Data
5. Travel Cost/Km

For observational studies, researchers prefer a descriptive research approach as it provides a detailed account of events. Moreover, the researcher does not need to manipulate data but measures them in their natural environment. This study however adopts a mixed method research approach utilizing descriptive research for observational surveys while also using a quasi-experimental design to infer causal relationships for impact evaluation (Bazeley, 2018). Creswell & Clark (2017) also offer detail insights in using mixed methods research designs from data collection planning to analysis. Since the study also employs various aspects of qualitative information a mixed method is more appropriate to allow for triangulation of data enhancing validity of findings. Under the research approach above, we seek to answer the following causal inference questions:

a. What is the impact of rehabilitation of the A1 Corridor and Feeder roads on local household incomes?
b. What is the impact of rehabilitation of the A1 Corridor and Feeder roads on local household mobility?
c. What is the impact of rehabilitation of the Al Corridor and Feeder roads on freight and Passenger travel time?
d. What is the impact of rehabilitation of the Al Corridor and Feeder roads on Passenger travel cost?
e. Has the rehabilitation of A1 corridor and feeder roads impacted traffic volumes?
f. Has the rehabilitation of the A1 corridor and feeder roads impacted traffic patterns?
g. Has the rehabilitation of the A1 corridor and feeder roads impacted road accidents along the associated road?
h. To what extent has the rehabilitation project increased accessibility to facilities such as healthcare?

The population for this study includes the communities within the immediate zone of influence (ZoI). This refers to the areas surrounding the transportation network, including transportation hubs, economic activities such as trade and employment opportunities and surrounding regions whose accessibility and development is affected. It is expected that the A1 corridor and feeder roads have a 5 km radius zone of influence. This covers the immediate environment including households, businesses and other establishments. The major towns along the Ahero – Kisii -Isebania A1 Corridor and feeder roads are considered the zones of the study where the socio-economic data is collected. The data collection zones also include control points within the region from which control information on socio-economic indicators is collected. The control zones are used to undertake causal inference for impact assessment. They are selected in such a way that they are far off enough not to be affected by the interventions within the study area.

Study area includes the following zones along the A1 corridor and feeder roads Katito, Sondu, Ekerenyo, Gamba, Oyugis, Kosele, Suneka, Rangwe, Rongo, Awendo, Migori, Isebania and Tabaka. The control zones for this study include Ogongo and Kehancha. Sampling and data collection is based on the same zones assuming that each zone is independent of each other.

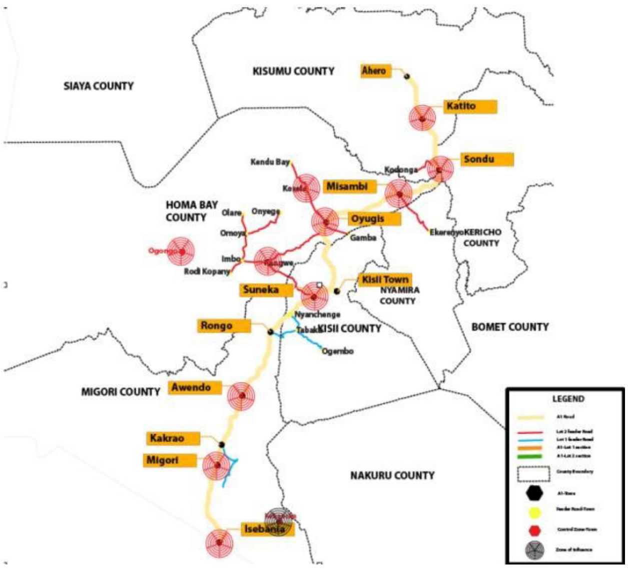

Fig. 1: Ahero - Kisii- Isebania (A1) Project Corridor

The baseline data collection for the study undertook surveys of randomly selected households. This is to ensure that the same households and respondents are interviewed, and their development/progress tracked after project implementation. Midterm surveys revealed almost 100% attrition as most of the respondents had moved to other areas.

In causal inference studies, it is standard practice to monitor progress and information of same households to be able to obtain information on the effects of interventions. Midterm and end line survey surveys involve the use of simple random sampling with the enumerators and interviewers randomly picking a household for interview. It is important to note that simple random sampling is employed across the entire survey exercise from baseline to end line surveys.

They study utilizes face to face interviews to collect observational socio-economic data for household. This is done during household surveys and focus group discussions (FGD) where respondents give information based on their knowledge and circumstances. Various forms and household questionnaire are formulated to suit the required social and economic data collection. Questions for key informant interviews and focus group discussions are also formulated covering both existing conditions and effects (both negative and positive) of the rehabilitation project. Traffic data collection is done using various equipment including Automatic traffic counters, video equipment, tablets and manual forms. Travel time data is collected using GPS devices mounted on a floating car while mounted on a goods vehicle for freight travel time.

The data collection was undertaken for baseline, midterm and end term periods to correspond to the period before implementation, during implementation and after implementation of the project. The study achieved a satisfactory sampling rate for the various surveys with. For household surveys, the samples obtained were 1500, 1200 and1175 households for the baseline, midterm and end line periods. Focus group discussions were conducted for all the intervention zones excluding the control zones. Vehicle origin and destination also employs sampling methods and procedures to obtain representative data for estimation of travel patterns in relation to the total volume of traffic along the project corridor. Levy & Lemeshow (2013)

Initial data preparation involved data cleaning and compilation. Since different tools are used to collect socioeconomic data, the data is compiled and grouped for each zone. The analysis approach adopted for this study includes descriptive analysis for preliminary data including demographic data of household members. Descriptive statistics are particularly important for social research as the technique summarizes survey results providing insight into societal trends and patterns. Descriptive analysis is also majorly used in traffic analysis to give highlights and data summary for data collected over long period. Traffic volumes are particularly analyzed and presented using descriptive charts and figures to illustrate events of interest and patterns emulated within the traffic data giving foundation of further and more advanced analysis. (Miller, 2017)

The study uses statistical techniques for Causal inference. This is done for the impact evaluation to answer key study questions established to estimate the projects impacts to the communities residing along the project corridor and feeder roads. Potential causal inference techniques are assessed to select the appropriate approach for the study including RCTs, Quasi Experiments and Difference in Difference (Diff-in-Diff). Considering the ethical and implementation challenges in using the other methods for socio-economic impact studies, the difference in difference model is preferred to estimate impacts of the project. T-test for 2 sample means is also used to describe the difference before and after for various outcomes.

The Diff-in-Diff model allows for view of the effects of an intervention by considering how group mean changes before and after the intervention (treatment group) and compare these changes with the mean over time of a similar group which did not undergo the intervention (control group). The major underlying assumption is that both the treatment and control zones/groups exhibit parallel development. For this reason, the counterfactual would be directly obtained and compared to the reality of intervention implementation. Underlying principle under Difference in Difference:

$$(Treatment(After) - Treatment(Before)) - (Control(After) - Control(Before)) =$$

$$Difference - in - Difference\ Estimate \quad (1)$$

Simply put, the Difference in Difference estimator is the difference between the mean differences of the treatment and control groups. This causal inference is meant to establish the impacts counterfactual i.e. the changes to the treatment group had the rehabilitation project not been implemented. Since we cannot measure both the factual and counterfactual at the same time, the Diff-in-Diff estimator provides an avenue for estimating the "without" scenario. The study utilizes regression analysis of the Diff-in-Diff to obtain the effects of the intervention (rehabilitation) and their interaction with time on the indicator outcomes.

The Statistical Model is specified as:

$$Outcome(y) = \beta_0 + \beta_1 Treatment + \beta_2 Post + \beta_3 Treatment * Post + \epsilon \quad (2)$$

Where:

y is the outcome variable for the indicator

Treatment is the dummy variable representing the treatment/ intervention (=1) or control (=0) zone

Post is the dummy variable indicating (=0) and post (=1) treatment/intervention

Treatment*Post is the variable indicating whether the outcome was observed in the treatment/intervention zone AND it was observed after the intervention (=1) or otherwise (=0).

Using this model, the intervention effects would be estimated by the interaction of the intervention and effects of time. This is represented by the Treatment*Post coefficient. If the coefficient is zero, it implies the intervention had no impacts on the indicator outcome. A positive or negative coefficient implies the intervention has impacts on the outcomes. Each model coefficients denotes group mean or the difference between two group means as indicated below:

β_0~ the outcome for indicators in the control zones without intervention

β_1~ the difference between treatment and control zones before intervention

β_2~ the trend due time in the control zones independent of the intervention

β_3~ (Difference-in-Difference Estimator) the average change in the intervention zones in period after intervention compared to what it would have been without intervention.

The hypothesis developed under the regression model were to test the significance of the model coefficients using the Analysis of variance (ANOVA) and probability (p) values. The null hypothesis developed for inferential analysis of the significance of the model and coefficients for impact evaluation on each indicator are stated below:

+ H_0: $\beta_0 \neq 0$ is the average indicator's outcome in the control zone before and after treatment significant.

+ H_0: $\beta_1 \neq 0$ is the difference between the indicator's outcome in the control zone and intervention zone before rehabilitation of the road significant.

+ H_0: $\beta_2 \neq 0$ is the difference between the indicator's average outcome in control zone before and after intervention significant.

+ H_0: $\beta_3 \neq 0$ does the intervention have an impact?

The hypothesis was tested at alpha (α) level of 5% to ascertain the significance of the model coefficients as well as satisfy underlying assumptions of parallel development and difference in zonal means. The zonal aggregate data on household indicators were tabulated for baseline and end line periods. The data was then analyzed using a linear regression model to obtain the estimates of the regression coefficients. All analyses were done at 5% alpha level giving a 0.05 chance of incorrectly rejecting the null hypothesis of significant regression coefficients.

The surveys are undertaken taking due care of respondent confidentiality and prior consent. Since the respondents are randomly selected on site by the enumerators, the interviewers sought consent from the household heads and available respondents during the household surveys. If the household head or respondent declines being interviewed then the enumerators would move on to the next household. Similarly focus group discussion members were also selected based on consent and confidentiality.

The study had potential risks during the surveys and analysis approach. The household surveys approach is initially intended for similar households selected during the baseline. However, due to attrition the households selected for each zone were randomly selected within the same zones. The information was then aggregated for each zone to mitigate for the bias.

3. Results

Based on the above hypothesis, the study seeks to determine the changes in the various traffic and socio-economic indicators attributable to the rehabilitation of the Ahero – Kisii – Isebania (A1) corridor and construction of the feeder roads. Of particular interest is the transportation and socio-economic aspects that illustrate better-off/worse ff of communities within the immediate zone of influence of the rehabilitated corridor and feeder sections.

Transportation Indicators Analysis:

a. Average Annual Daily Traffic

Traffic volumes recorded along specific sections of the A1 corridor before and after the rehabilitation was done. A simplistic "before and after" analysis approach is adopted to illustrate the physical impact the condition of the A1 corridor has on vehicle throughput. A paired two-sample mean T-test analysis was done for the pre-project and post project traffic volumes and results are shown below.

Table 1. Two Sample Paired T-Test for AADT

T-Test: Paired Two Sample Means	Pre-project	Post-Project
Mean	7094.375	9468
Variance	11948415.98	16860222.57
Observations	8	8
Pearson Correlation	0.937719375	
Hypothesized Mean Difference	0	
df	7	
t Stat	-4.536892949	
P(T<=t) one-tail	0.001338799	
t Critical one-tail	1.894578605	
P(T<=t) two-tail	0.002677598	
t Critical two-tail	2.364624252	

Expectedly, the study observes increased traffic along most of the study corridor sections. A T-test for difference in means at 0.05 alpha level reinforces this information as seen above. The P-value for the T-test is 0.0026776 (less than α=0.05) infers that the pre-rehabilitation and post-rehabilitation volumes are not equal. Post-rehabilitation sectional AADT was significantly higher than expected pointing to observable impact of the A1 Corridor rehabilitation on traffic throughput.

b. Travel Times

The corridor travel times are also analyzed for pre and post rehabilitation differences under the following hypothesis.

+ H_0: *pre and post project observed travel times are equal*

+ H_1: *pre and post project observed travel times are **not** equal*

A paired two sample mean T-test analysis results for the difference in travel time before and after the rehabilitation of the corridor and feeder roads is presented below.

Table 2: two Sample Paired T-Test for Travel Time

T-Test: paired Two Sample Means	Baseline Travel Time	End line Travel Time
Mean	0.020962963	0.011805556
Variance	0.000137463	3.61001E-05
Observations	15	15
Pearson Correlation	0.791772505	
Hypothesized Mean Difference	0	
Degree of Freedom	14	
t Stat	4.503846146	
P(T<=t) one-tail	**0.000247766**	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	0.000495531	
t Critical two-tail		

At α=0.05, the Paired two Sample T-test shows that there is significant difference between pre and post project travel times. Single-tailed T-test also shows that the post project travel times are significantly lower. This can only be attributed to the improved transportation infrastructure that facilitates improved operations and reduced travel times. c. Cost of Public Transport

Cost of public transport is a major transport performance along the corridor and feeder roads. Public transport costs per kilometer is seen to reduce by 7.6 KSh/kilometer on average. A similar T-Test analysis undertaken for the cost of transport along the sections of the feeder roads and the results are presented below. Table 3: Two- Sample Paired T-Test for Travel Cost/Kilometer

T-Test: paired Two Sample Means	Cost/Km Baseline	Cost/Km End term
Mean	15.55833333	10.575
Variance	23.08992424	11.20386364
Observations	12	12
Pearson Correlation	-0.105256794	
Hypothesized Mean Difference	0	
df	11	
t Stat	2.812269004	
P(T<=t) one-tail	0.00844989	
t Critical one-tail	1.795884819	
P(T<=t) two-tail	0.016899779	
t Critical two-tail	2.20098516	

The p-value of the 2 tailed T-test shows (which is less than α =0.05) infers that the null hypothesis of equal average cost before and after the rehabilitation is not accurate. The analysis shows that public transportation costs have significantly reduced from baseline and majorly attributable to the road rehabilitation. Qualitative information collected through information revealed improved transportation along the corridor coupled with accessibility to convenient and costly modes of transport. Majority of participants from Ekerenyo noted reduced transport costs for previously far costly distances and destinations.

Socio Economic Indicators Analysis:

a. Household Mobility Analysis

The study conducts a regression analysis for the difference in difference estimate to establish the impact of the project on household person trips per day. Analysis of Variance (ANOVA) reveals that the data is not sufficient to support the model significance in analyzing the impact of the project on household mobility.

Table 4: Analysis of Variance Table for Mobility Index DiD Regression

ANOVA

	df	SS	MS	F	Significance F
Regression	3	1.667573	0.555858	0.776474	0.518608
Residual	24	17.18098	0.715874		
Total	27	18.84856			

Table 5: DID Regression Output for Household Mobility

Regression	Coeff	Std Error	t-Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept (b0)	2.85	0.60	4.77	0.00007	1.62	4.09	1.62	4.09
Group (b1)	-0.25	0.65	-0.39	0.7001	-1.59	1.08	-1.59	1.08
Post Intervention (b2)	-0.59	0.85	-0.70	0.4923	-2.34	1.16	-2.34	1.16
Diff-in-Diff (b3)	**1.02**	0.91	1.11	0.2768	-0.87	2.90	-0.87	2.90

The regression coefficient results for household trip rate difference in difference estimation has the following results. The p-values of each of the regression coefficients except the constant B0 were greater than the threshold probability (alpha =0.05), implying that variation in person-trip rates were majorly due to other factors. However, from the coefficient of difference in difference (B3), the mobility index increased by 1.02 trips for members of households along the corridor and feeder road after intervention.

b. Household Income Rate Analysis

The regression analysis of the household average income was done after applying adjustment factors to the average household incomes obtained from each zone. This adjustment was necessary to curb the influence of inflation as the incomes obtained from each zone were unreasonably high. A 7.3 % p.a. inflation rate was adopted to give the incomes the true value that would be attributed to the intervention.

The generic Diff-in-Diff regression model was adopted, and the regression coefficient significance established by

Analysis of variance and associated p-values as shown in table 2-17 and table 2-18 below

Table 6: Analysis of Variance Table for Average income DiD Regression

ANOVA

	df	SS	MS	F	Significance F
Regression	3	1645764220	548588073.4	53.57641	2.81E-10
Residual	22	225265891	10239359		
Total	25	1871030111			

The analysis variance table above shows that the model attained acceptable predictive power as the significance F (pvalue) is much below the threshold of α=0.05. The null hypothesis of non-significant model was therefore not accepted with support as supported with the data. The variation in the household incomes could be rightfully attributed to the intervention.

Table 7:Regression Output for Income DiD Regression

Upper Lower Upper P-value 95% 95.0% 95.0%

Regression	Coeff	Std Error	t Stat	Lower 95%	Upper 95%	P-value
Intercept (b0)	11214	2263	5	6521	15906	0.00006
Group (b1)	-7960	2444	-3	-13028	-2891	0.00361
Post Intervention (b2)	931	3919	0	-7197	9059	0.81441
Diff-in-Diff (b3)	16000	4140	4	7413	24586	0.00084

Regression coefficient table above shows that all the coefficients were significant (≠0). However, the estimate of coefficient β_2 was not statistically significant as its p-value was greater than the threshold of 0.05. This implies that the difference in household incomes in the control zones before and after were to be statistically not different thus not significant. Moreover, this also indicates that the control zones are reliable. The estimate of β_1 (-7,960) shows that the control zones had higher average incomes by Ksh 7690 before the rehabilitation project. Thus, the average income of households in control zones was 11214 +7960 = Ksh 18,904 before the rehabilitation of the corridor and feeder roads.

4. Discussion

The results presented above illustrate the outcomes of the rehabilitation of the Ahero – Kisii – Isebania (A1) corridor and feeder sections. Generally, it is evident that there has been tremendous improvements of key transport and socioeconomic aspects and indicators. The study revealed increased traffic along all sections of the corridor and feeder roads. Aside from the year-on-year normal traffic growth, the traffic increase is attributed to the improved roads and consequently traffic operations. Similarly, the analysis reveals that the rehabilitation improved transit travel times drastically compared with pre-rehabilitation travel times. Cost of transport improvement also registered significant drop as a result of the improved road infrastructure. This is also attributable to increased supply of safe and reliable modes of transport due to improved infrastructure.

Socio-economic indicators household mobility and average household incomes statistically recorded improvement. The project statistically had impact on households along the corridor and feeder roads as the Diff-inDiff estimate was KSh16,000. This implies that households along the corridor earn KSh16,000 more after rehabilitation compared to if the rehabilitation was not implemented. The average income for households along the corridor and feeder roads would be 11,214+16,000= 27,214 post corridor rehabilitation based on the causal inference analysis. Despite the regression analysis of variance for household mobility index not being statistically significant, the regression coefficient for the Difference in difference estimate (B3) indicates that the mobility index for households within the corridor and feeder road's zone of influence increased by 1.02 trips post-rehabilitation.

With regards to urbanization with relation to infrastructure, the rehabilitation has resulted into increased access by households to electricity and piped water by household. Trade and agriculture have also registered improvement attributable to increased access to markets by sellers and expansion of existing markets. More products have also been able to be transported to the markets at much lower transport costs. Focus group discussions and key informant interviews responses reveal that majority of the households are have access to a variety of transport modes, technologies such as internet and computer services and banking facilities that point towards the initial stages of urbanization resulting from the rehabilitation project. Furthermore, rate of employment has increased as a result due to the increased and variety of economic activities arising from better transportation. Fewer households are below the poverty line as more households are able to earn more due to increased economic opportunities.

Infrastructure development is the backbone of rapid urbanization and industrial development. Key economies such as agriculture, education, employment all rely on reliable and efficient transportation facilitated by available and affordable modes driving rapid expansion of towns into cities. Inter-regional trade resulting from improved reliable infrastructure contributes to increased economic opportunities opening up the supply chain to expansive inter-regional markets.

5. Conclusion

Infrastructure development has been and is still closely tied to growth and expansion of rural and semi-urban areas. The case study of the impacts of rehabilitation of the Ahero – Kisii - Isebania (A1) corridor and feeder roads notes increased accessibility by local communities, reduced travel time and travel cost/kilometer. The improvement of the corridor also is directly linked to increased traffic as vehicle flows shift and traffic diversion from alternative less improved routes.

Regionally, there are increased economic opportunities for local residents. More employment opportunities have been opened up due to better transportation, new transportation corridors. In economic terms utilization of local resources through purchase of local material, utilization of local labour encourages the local economy by injecting and circulating money through subsequent purchases by the laborers and contractors. Post rehabilitation conditions have seen significant improvements in terms of healthcare from newly built Trauma center, agriculture and trade due to increased accessibility and establishment of new markets. Shorter transport times and low cost has also encouraged traders to make more trips and supply more commodities due to improved road network.

Infrastructure investment and development thus plays a significant role in the natural development of urbanization and improvement in local and regional economies.

6. References

Baker, R. J., & R. L.: Sampling Methods in Research: A Review." International Journal of Research Methodology . ", 11(2), 123-134 (2008).

Bazeley, P.: Integrating Analyses in Mixed Methods Research. In The SAGE Handbook of Qualitative Research (5th ed., pp. 529-546). Thousand Oaks, CA: SAGE Publications (2018).

Creswell, J. W., & Plano Clark, V. L.: Designing and Conducting Mixed Methods Research (3rd ed.). Thousand Oaks, CA: SAGE Publications (2017).

Fetters, M. D., Curry, L. A., & Creswell, J. W.: Achieving Integration in Mixed Methods Designs—Principles and Practices. Health Services Research, 48(6), 2134-2156 (2013).

OECD.: Infrastructure Investment and Economic Growth,

Plano Clark, V. L., & Creswell, J. W.: The Mixed Methods Reader. Thousand Oaks, CA: SAGE Publications (2008).

Thompson, S. K.: "Sampling." Wiley Encyclopedia of Operations Research and Management Science (2012).

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The IEK Council, led by President Eng. Shammah Kiteme, CE, FIEK, held a strategic meeting with KEBS Managing Director, Esther Ngari to explore partnerships aimed at advancing Kenya's engineering profession and strengthening national safety standards. The discussions focused on collaborative initiatives, including workshops and training sessions to support engineers in adopting Eurocodes, industrial visits to KEBS labs for practical insights, and joint research efforts to enhance design standards, such as vehicle parts standardization for safer roads. KEBS MD Esther Ngari endorsed the proposals, emphasizing the importance of training webinars on Eurocodes and research collaborations to bolster safety and innovation in Kenya's engineering sector.

During a courtesy visit aimed at strengthening collaboration to advance Kenya's engineering profession and improve national safety standards, IEK President Eng. Shammah Kiteme presented the latest issue of 'African Journal of Engineering Research and Innovation (AJERI) to KEBS Managing Director , Esther Ngari. The gesture symbolized a shared commitment to promoting excellence and innovation in engineering for the benefit of the nation

Murang'a University of Technology (MUT) successfully hosted its inaugural Innovation and Industry Linkage Week, a vibrant event that brought together students, faculty, industry leaders, and innovators to showcase groundbreaking ideas and projects. The occasion, graced by Chief Guest Dr. Tonny K. Omwansa, CEO of the Kenya National Innovation Agency (KeNIA), alongside MUT Vice Chancellor Prof. Dickson Nyariki and DVC ARSA Prof. Prisca Tuitoek, highlighted the university's commitment to fostering creativity and bridging the gap between academia and industry. Eng. Grace Kagondu, FIEK, delivered a thought-provoking keynote on the 3IF framework (Integrate, Innovate, and Implement) as a holistic approach to tackling urbanization and informal settlements.

Adding to the event's significance, Prof. (Eng.) Christopher Maina Muriithi, Council Member of the Institution of Engineers of Kenya (IEK), presented the latest issue of Engineering in Kenya magazine, themed Mining Engineering, to MUT students at the IEK booth. The exhibitions by the School of Engineering and Technology (SET), featured innovative projects like the Save Stride Navigator, Smart Door Alarm System, and Solar-Powered Sand Screening Machine, underscoring the transformative role of engineering in driving sustainable development and shaping the future of industry.

The IEK Council, led by President Eng. Shammah Kiteme, proudly represented Kenya at the Annual International Engineering Conference in Abuja, Nigeria. Engaging with over 6,000 global stakeholders under the theme 'Sustainable Engineering Solutions to Food Security and Climate Change', the delegation reinforced Kenya's commitment to collaborative solutions addressing critical global challenges. The IEK Councill also paid a courtesy call to Kenya's High Commissioner to Nigeria, Ambassador Isaac Parashina, showing the IEK's dedication to fostering international partnerships.

Climate change against national Greenhouse gas emission reduction commitment for developing countries- Adaptation by power utilities: A case study for Kenya

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1. Introduction

Kenya's ministry of energy and petroleum makes and articulates energy policies to create an enabling environment for efficient operation and growth of the sector.

The energy and petroleum regulatory authority (EPRA) regulates and licenses players in the entire energy sector. Its other functions include tariff setting and oversight, coordination of the development of the integrated energy plan monitoring and enforcement of sector regulations e.g. the energy management regulations.

Kenya's energy act 2019 sets up other agencies, namely:

- Nuclear power and energy agency (NUPEA) to handle nuclear energy programme.
- Rural electrification and renewable energy (REREC) to manage the rural electrification projects.
- Kenya electricity transmission company (KETRACO) to manage the electricity transmission assets.

Other key energy sector players are Kenya electricity generating company (KenGen) that generates the bulk of energy consumed in Kenya and the Kenya power and lighting company (KPLC) that does the power distribution and retail functions in the country.

In 2020, the Ministry of Energy released the Kenya National Energy Efficiency and Conservation Strategy[4]. It establishes energy efficiency targets in the buildings, industry, agriculture, transport, and power sectors to meet the goal of reducing the national energy intensity by 2.8% per year. The strategy also aims to ensure that energy efficiency measures contribute to the achievement of the nationally determined targets (NDC) by keeping Green House Gas (GHG) emissions as per the targets in table 1 below.

2. Methods

In Kenya, climate change action is guided by the climate change act 2016 which provides the framework for mainstreaming climate change across all sectors of the economy. The law has been applied to the development, management, implementation and regulation of mechanism to enhance climate change resilience and low carbon development for sustainable development in the country.

The act obligates the cabinet secretary responsible for climate change affairs to formulate a five-year national climate change action plan (NCCAP) that addresses all sectors of the economy. The plan covers thematic areas of agriculture, forestry, industry, energy, transport and waste. The first NCCAP ran from 2013-2017 and the second from 2018-2022.

Table 1 below shows Kenya's emission reduction potential and the nationally determined contribution (NDC) targets by sectors (in $MtCO_2e$ per year) projected to 2030:

Table 1: Kenya's emission reduction potential and the NDC targets by sector (in $MtCO_2e$ per year [3])

	GHG Emission reduction potential (MtCO2e)				NDC Target
Sector	2015	2020	2025	2030	2030
Forestry	2.71	16.24	29.76	40.2	20.1
Electricity generation	0.28	2.24	8.61	18.63	9.32
Energy demand	2.74	5.16	7.92	12.17	6.09
transport	1.54	3.52	5.13	6.92	3.46
Agriculture	0.63	2.57	4.41	5.53	2.77
Industrial processes	0.26	0.69	1.03	1.56	0.78
waste	0.05	0.33	0.5	0.78	0.39

Table 2 below is a summary of the various energy mitigation actions for the electricity generation and demand sectors above:

Table 2: Estimated technical potential emission reduction by 2030 [6-7]

		MtCO2e
Electricity Generation	Clean coal	1
	landfill gas generation	0.4
	Solar-grid connected	0.65
	Hydro	1.1
	wind	1.7
	Geothermal	14
Energy demand	Solar thermal water heating	0.2
	Energy efficient light bulbs	1.1
	LPG stove substitution	1.4
	Renewable lamps	1.8
	Cogeneration in agriculture	1.75
	Improved cook stoves	5.7
Total		30.8

The 2018-2022 NCCAP encompasses development of new 2,405MW of grid-connected renewable power generation and retirement of three thermal plant. The highest mitigation opportunity is in geothermal expansion, envisaged to add 2,775MW to the grid by 2030.

Others targeted measures are: 157MW of Biomass and 30MW of distributed solar/mini grids –largely done by REREC in the counties of Wajir, Mandera, Marsabit, Turkana and Garissa.

3. 3 Results

Table 3 below shows the various interventions and the achieved results.

Table 3: 2018-2022 NCCAP Energy mitigation actions

Actions	Expected results by June 2023	Results achieved by June 2022
Increased generation of renewable energy.	Develop 2,405MW of new renewables that include geothermal, biomass, hydro, distributed solar and mini-grids, solar and wind. Retire 300MW of thermal plants – 120MW Kipevu, 108MW Iberafrica and 74MW Tsavo.	2,883MW of generation on renewables. 913MW geothermal plants in Olkaria and Menengai 300MW lake Turkana wind among others in Ngong, Meru and Kipeto 442MW solar in Strathmore, Makindu among others 10% of TVET institutions using solar and five solar mini-grids done- 4 in Marsabit and 1 in Kisumu. Tsavo power has been retired
Increased generation capacity for captive renewable energy	Increase captive renewable energy generation capacity by 250MW by 2022 – 50MW of solar, wind and hydro and 200MW of cogeneration. Direct use of geothermal resources to power industrial applications- Naivasha industrial park.	Meru county has 200 solar-powered boreholes under their captive energy goals. 153MW Kwale sugar biomass plant done 93MW KTDA generation done GDC has established geothermal heated milk pasteurizers.
Improved energy efficiency and energy conservation	Reduce transmission and distribution utility losses from 18% to 14%. Distribute 3.3m CFL bulbs to shave 50MW from the peak demand. Energy efficiency in buildings and industry – EPRA regulations.	4.25m CFL bulbs distributed to 1.4m households by KPLC-funded by MoE. Energy management compliance certificates awarded to many factories under the energy management regulations 2012. The Ministry of Energy has worked with the Kenya Association of Manufacturers (KAM) to establish a Centre for Energy Efficiency and Conservation that promotes energy efficiency.
Climate proof energy infrastructure	Concrete poles to replace wooden poles. Optimize existing hydro plants.	20.47% (22,500 poles) now concrete. Kengen has done a feasibility study on how to optimize hydro power plants by increasing dam storage eg Masinga wall has been raised by 1.5m- because of erratic rain patterns. In other instances, the number of turbines is increased to allow excess spill to generate power- Kindaruma added the third turbine.
Enabling actions (technology)	Research on new technologies to reduce GHG emissions. Climate change resilient technologies such as coolers and scrubbers promoted.	Renewable energies research laboratory established. Energy efficiency research and testing facility established at KIRDI.
Enabling actions (capacity development)	Training and public awareness on climate change adaptation and mitigation mechanism. Train 100 students per year at the KPI on renewable energy technologies. Train 60 participants at the UNU Geothermal's training program.	TVET Instructors trained on solar PV and solar water heating installations. Marsabit county trained staff on solar installations. KPLC trained 163 students on solar installation.

Currently 78% (2,266MW) of generation capacity in Kenya is renewable as seen in table 4 below:

Table 4: Kenya's installed generation capacity [8]

	Installed(MW)	Effective/Contract-ed(MW)
Hydro	838.51	810
Geothermal	904.98	817
Thermal (MSD)	621.89	589
Thermal (GT)	60.00	56
Wind	436.05	426
Biomass	2.00	2
Solar	212.51	212
Imports	200.00	0
Total Capacity MW	3,276	2,911

The country has a peak demand of 2,149MW with 80.1% of the population having access to electric power.

The graphical illustrations below show the above trends:

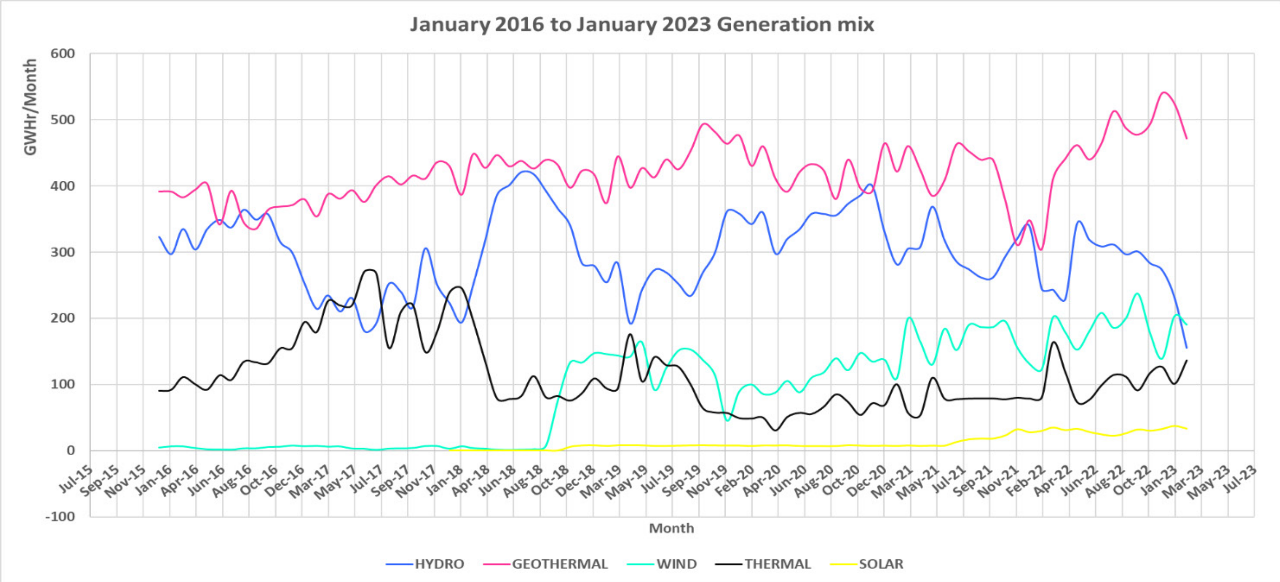

Figure 1: Changes in various sources of energy from January 2016 to January 2023 [8]

4. 4 Discussion

Kenya uses 231/838MW (28% of the total installed capacity, largely to meet peak load demand as compared to the convectional base load) of hydro capacity – due to persistent drought for three years in a row.

Wind power has cut by more than half the gap between it and hydro- now doing 17.8% of the total load against hydro's 14.47%.

Solar energy has a big room for growth- now at 3.11% of the total national load.

Geothermal still takes the lion's share at 44.07% of the total load.

Kenya is on the road to retire all 300MW thermal power plants. Tsavo power 75MW plant already retired, 120MW Kipevu and 108MW Iberafrica pending- Currently contributing 12.72% of the total grid energy.

The draft net metering regulations 2022 are under discussion. These will go a long way in the contribution of the energy sector towards reduction of the targeted GHG emissions.

The electric mobility and time of use tariffs were introduced in April 2023. These will spur more utilization of the generated clean energy. As at the end of 2022, Kenya had well over 400 registered electric vehicles in the country.

5. 5 Conclusion

Kenya is a leader in the generation and utilization of clean energy in Africa [10]. Kenya is number one in the generation of geothermal energy in the continent. The place of the energy sector is well cut out in the 2023-2027 NCCAP and beyond as Kenya seeks to leverage on the above gains and more. The future is bright.

References

[1] Republic of Kenya. (2016).*Climate change act number 11 of 2016*, National Council for law reporting, Kenya.

[2] Republic of Kenya. (2019). *The energy act number 1 of 2019*, National Council for law reporting, Kenya[3] Republic of Kenya. (2016). *Kenya National adaptation plan: 2015-2030*, Ministry of environment and forestry, Kenya.[4] Republic of Kenya. (2020). *Kenya national energy efficiency and conservation strategy*, Ministry of Energy and Petroleum, Kenya.[5] Republic of Kenya. (2021). *National climate change action plan: Second implementation status report for the fy 2019/2020*, Ministry of environment and forestry, Kenya.

[6] Republic of Kenya. (2018). *National climate change action plan (Kenya): 2018-2022. Vol.3: Mitigation technical analysis report*, Ministry of environment and forestry, Kenya.

[7] International climate initiative. (2019).*Climate change and sustainable development in the Kenyan electricity sector.*

[8] Kenya Power & Lighting Co. Plc. (2023). *National Control Center Data, 2016-2023.*

[9] Energy and Petroleum Regularoty Authority. (2023). *Retail electricity tariff review for the 2022/23-2025/36 4th tariff control period (TCP)*.

[10] Mo Ibrahim Foundation. (2022). *The road to COP27: Making Africa's case in the global climate debate*.

Sustainable Solutions to Water Scarcity in Machakos Town: Harnessing Urban Stormwater Runoff for Irrigation

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1. Introduction

Globally, climate change has reduced the available water resources and created a growing scarcity (Allan et al., 2013). In Machakos Town, Kenya, despite substantial precipitation, a critical shortage of water still affects agricultural practices, especially in educational institutions. In highly urbanized environments like Machakos town center, managing stormwater runoff becomes particularly challenging. The urban expansion and limited infiltration have resulted in a high rainfall runoff ratio, which heightens the risk of flooding and water pollution during extreme weather events (Varma, 2022).

Previous research has highlighted the potential of stormwater management as an enabler for climate resilience and sustainable development. Studies conducted in various areas, from St. Paul, Minnesota (Saint Paul.gov, 2019) to Syokimau Town in Kenya (Masila, 2020), have demonstrated the broad aspects and importance of stormwater management to water quality, ecosystem sustainability, and urban resilience. However, most of these studies have focused on large-scale urban developments or natural landscapes, leaving a gap in understanding how such systems can be implemented in space-constrained, peri-urban areas like Machakos Town.

The research aims to address this gap by proposing an underground water harnessing facility at Kenyatta Stadium. This approach differs from published work by focusing on a modular, scalable solution that can be implemented in a space-limited urban location, maximizing water capture and reuse efficiency on a compact footprint. By targeting educational institutions for irrigation, this creates a direct link between sustainable water management and practical learning environments. To design this facility effectively, two critical questions need to be answered, which shall form the objectives.

1. What is the peak discharge from the surrounding catchment area (Kiima Kimwe and Iveti Hills) that will serve as a design parameter for the underground water storage facility?
2. Is the quality of the runoff water suitable for irrigation when compared to the agricultural water quality standards outlined in the FAO Irrigation and Drainage Paper 29 Rev. 1?

The methodology applied is a combination of hydrological modeling and water quality assessment. Peak surface runoff rates are calculated using the Rational Method, considering the runoff coefficient, the intensity of rainfall, and the storm drainage area. Water quality assessment is based on laboratory analysis of samples collected at strategic points in the catchment area. By analyzing stormwater as a resource, the study reframes it as an asset for sustainable urban development rather than a problem to be mitigated. The study provides a model for the development of sustainable stormwater management in Machakos Town, which can optimize its agricultural activities especially in institutions of learning and ensure water security in the context of climate change.

2. Methodology

The study employed a mixed-methods approach to address the research objectives, combining quantitative hydrological modeling with qualitative water quality analysis. The research was conducted in Machakos town, the capital of Machakos County. The study area, bounded by latitude -1°31’0.01” S and longitude 37°16’0.01” E, was characterized by a U-shaped ridge of hills comprising the Iveti Hills, Mitaboni plateau, and Mua Hills.

To calculate the peak discharge from the surrounding catchment area, the researchers utilized the Rational Method, an industry-standard approach for estimating peak surface runoff rates in watersheds. This method considered adopts the Rational Equation.The research team first delineated the catchment area boundaries, encompassing Iveti Hills, Kiima Kimwe Hills, and Machakos Town. A contour map was generated using a combination of Google Earth, ArcGIS, and Civil3D software. This map served as the basis for calculating the catchment area for each drain and cumulatively for the total catchment area. The runoff coefficient (C) was determined through an analysis of the rainfall-runoff relationship. Runoff data were collected from randomly selected drains in the study area during the rainy season in October. Manning’s formula was applied to calculate the flow rate.

Rainfall intensity data were obtained from a rain gauge placed at an open space at Machakos University. Data were collected over a period of three months to account for seasonal variations. Historical rainfall data from 1990 to 2014, provided by the Machakos Water and Sewerage Company, were also incorporated into the analysis to establish long-term trends.

To assess the suitability of runoff water for irrigation, water quality tests were conducted focusing on pH and Total Dissolved Solids (TDS). Water samples were collected from two strategic locations: drains at Machakos Medical and Technical Training College (MMTTC) and Government of Kenya Prison, Machakos. These sites were chosen as they collected water from Kiima Kimwe Hills and Iveti Hills, respectively, providing a comprehensive representation of the catchment area.

TDS was determined through gravimetric analysis in the laboratory. pH was tested using an electronic pH meter. To contextualize the water quality results, the researchers referred to the agricultural water quality standards outlined in FAO Irrigation and Drainage Paper 29 Rev. 1 (Ayers & Westcot, 1985). This comparison allowed for the determination of the suitability of the runoff water for irrigation purposes.

In addition to these primary data collection methods, a comprehensive literature review was conducted to understand crop water requirements for maize, French beans, vegetables, and mangoes, which were of interest to local school administrations. The findings from a study by Onyancha et al. (2017) were adopted for these crop requirements. Average irrigation requirement (mm) for Machakos is 1421 mm. (Ministry of Water and Irrigation, 2005). The value can be conveniently adopted, considering that the water requirements of individual crops remain below the specified value.

Data integrity was ensured using triplicate measurements, structured data sheets, calibrated equipment, and correct handling of samples. However, limited to the wet season of 2023 and concentrating on water quality analysis in terms of pH and TDS, the methodology applies to the general context of urban stormwater management and is replicable in similar contexts. Despite the limitations, the combination of hydrological modeling with water quality analysis provides a complete assessment of stormwater harvesting and reuse potential in Machakos Town, while also providing a framework for future, more extensive studies.

3. Results

The study yielded various statistical findings relating to catchment areas, flow rates, runoff coefficients, and water quality parameters of stormwater in Machakos Town. These statistical findings help to understand the dynamics and possibilities of urban stormwater management for sustainable development.

Catchment Area Analysis

Table 1. Outlet and Associated Catchment Area in sq. meters.

Outlet	Area
KBL	570,700.3915
MMTC	294,653.8273
Prison	1,725,645.5162
	2,590,999.7350

The research team demarcated the total catchment area that supplies runoff water to three tested outlets, namely KBL, MMTC, and Prison, which add up to 2,590,999.7350 square meters. The prison outlet received runoff from the largest catchment area of 1,725,645.5162 sq. meters, which was over three times larger than the KBL catchment and almost six times larger than the MMTC catchment as shown in Table 1. This disparity in size was attributed to the prison outlet receiving runoff from both Iveti Hills and parts of Machakos Town, while the other outlets had smaller, more localized catchments.

Flow Rate Analysis

Flow rates were calculated using Manning's equation, which accounts for channel geometry, water depth, channel slope, and Manning's roughness coefficient. All drains exhibited similar trapezoidal cross-sectional geometry.

The flow patterns in Fig. 1 reinforce common observable urban stormwater behaviors, including sharp rising limbs to peak flows when rainfall overwhelms drainage capacities, followed by exponential recessions over hours.The prison outlet demonstrated a distinct flow pattern over the course of measurements. Initially, a high flow rate of 3.49 cubic meters per second was recorded at 11:00, corresponding to a large pulse of stormwater entering the drainage channel networks from impervious surfaces. The flow rate then followed an approximately exponential decay pattern, reducing to 1.51 m3/s by 19:00.

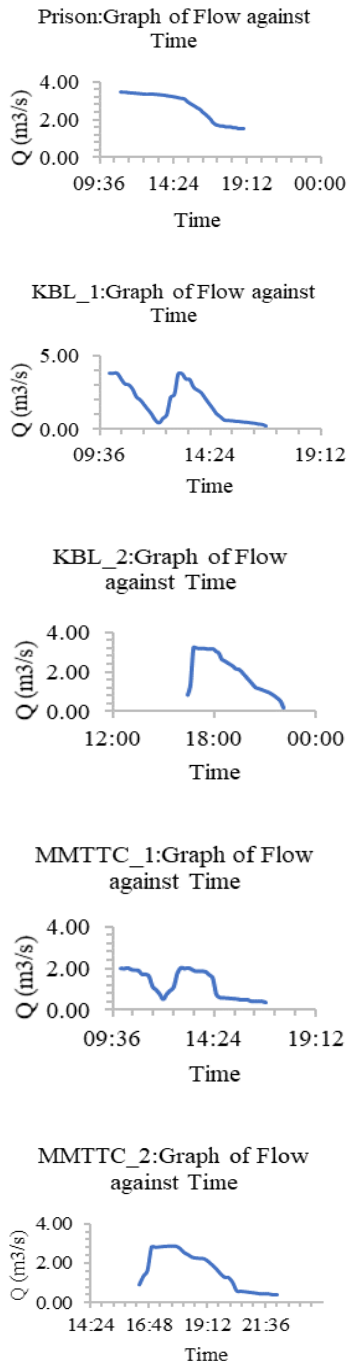

Fig. 1. *Graphs of flow against time for various outlets.*

The KBL_1 outlet, representing the Kiima Kimwe catchment, displayed a similar exponential decay pattern but with a lower peak and more gradual decline. The maximum flow of 3.78 m3/s occurred at 10:00, followed by a decrease and a subsequent spike to 3.75 m3/s, before declining to 0.18 m3/s by 16:50.The KBL_2 outlet measurements resembled the exponential falling limb pattern but with a higher peak of 3.96 m3/s.

The MMTC_1 outlet exhibited a unique double-peak pattern, with flow rates peaking at 2.03 m3/s at 10:20 and again at 12:50, suggesting two distinct precipitation events. The MMTC_2 outlet data closely mirrored the global stormwater drainage profile shapes observed at other locations, with an initial sharp peak of 2.88 m3/s followed by an exponential decay over 11 hours.

Runoff Coefficient Analysis

The runoff coefficients were estimated for each of the catchments based on their relative area and determined to represent the fraction of rainfall converted to surface runoff. Iveti Hills (draining to the Prison outlet) had a coefficient of 0.60, and Kiima Kimwe had higher runoff coefficients of between 0.53 and 0.92 depending on the subbasins. It is worth noting the MMTC outlet, which drains the runoff from the town center, showed a coefficient of 0.89. The weighted coefficients for each of the catchments are Iveti 0.60 for Iveti, Kiima Kimwe 0.74 for Kiima Kimwe, and an overall weighted coefficient of 0.65 for the whole study area.

Water Quality Analysis

Water quality testing provided insights into the characteristics of stormwater runoff from the Kiima Kimwe and Iveti catchments. Key parameters analyzed included total suspended solids (TSS), total dissolved solids (TDS), and pH.

Total Suspended Solids (TSS)

Higher TSS levels were measured in the Kiima Kimwe samples relative to the Iveti catchment. K1 displayed 5.0403 g/250 ml, while K2 contained 5.6124 g/250 ml of undissolved particulate matter. Concentrations of Iveti TSS were minimum at 0.4639 g/250 ml (I1) and 3.3533 g/250 ml (I2). The highest TSS concentration measured in the K2 of 5.6124 g/250 ml, which is equivalent to 22.5 mg/l, exceeds the 10 mg/l threshold for drip irrigation.

Total Dissolved Solids (TDS)

Dissolved salts and minerals contributed a much lower portion of total solids than the suspended particulates. TDS (in Kiima Kimwe) was higher up to 0.0813 g/250 ml (K2) and lower at 0.0710 g/250 ml (K1). Iveti's TDS was a bit higher at 0.0907 g/250 ml (I1) and 0.1002 g/250 ml (I2).

pH Levels

The pH of stormwater samples showed that it is slightly alkaline. The collected waters from Kiima Kimwe had pH values of 7.98, which were at the edge of the recommended range for agriculture of 6 to 8. The collected waters from Iveti had pH values of 7.14, which is within the recommended range of 6 to 7 for agriculture.

4. Discussion

The study results have provided new knowledge that can complement existing knowledge in the context of stormwater harvesting in a similar setting. What clearly emerges from the study is a promise of stormwater harvesting as a solution to the problem of water scarcity, especially for irrigation in schools.

The catchment area and flow rate relations also validate previous findings. The rapid runoff response (short rising limb) and the exponential recession characteristics in the flow rate analysis are consistent with what other studies have found about urban hydrology in general. Tom et al. (2022), for example, in their analysis of the urban hydrology of the Nairobi metropolitan area, noted that rapid runoff response and exponential recession in urban hydrology are an inevitable consequence of the high proportion of the landscape covered by impervious surfaces. However, the findings from the study provided local specific data for the case of Machakos Town that can inform actions to address the problem.

The high runoff coefficients calculated for the study area, ranging from 0.53 to 0.92, agree with typical values for urban areas reported by Angrill, (2017) . Machakos receives an average of 60.84 millimeters of rainfall per month over the expansive 2.59 million square meter watershed area, and taking into account a typical runoff coefficient of 0.64, calculations show roughly 99 million cubic meters of stormwater runoff could be collected monthly.

The results the proposed site for the underground water harvesting facility at Kenyatta Stadium, with an area equivalent to a football pitch, offers considerable storage potential that merits further exploration. A standard football pitch is around 7,140 square meters. At a depth of 3 meters (allowing for structural and safety requirements), this could have a storage volume of approximately 21,420 cubic meters, potentially storing 21.6 percent of the typical 99 million cubic meters of stormwater runoff per month. More importantly, it greatly exceeds the annual irrigation demand of 4,282 cubic meters for the target area, meaning such a facility could potentially act as a significant buffer against dry spells and provide water for community irrigation purposes.

Nevertheless, this is a rough estimation based on broad geographical availability of space. Stepping from the promising initial findings to a detailed, well-informed design for it, research is needed into the exact design capacity of the storage facility. This should address several aspects: Detailed geotechnical surveys would be required to assess the feasibility of building underground at any given site. More precise hydrological modeling would help determine inflow rates and storage requirements based on local rainfall patterns and climate change projections. Engineering studies would be required to optimize the design for efficient water capture and storage and for the distribution of water once it's stored. Environmental impact assessments would be of utmost importance to ensure that building the facility wouldn't damage local ecosystems or groundwater systems.

The water quality results are encouraging but also show where the scheme could face problems. The Total Suspended Solids (TSS) values, especially for the Kiima Kimwe results, exceeded the 10 mg/L limit for drip irrigation stipulated by Ayers & Westcot (1985) – which was expected for urban catchments with erosion potential but which implies that any scheme needs systems for sediment removal. On the other hand, the generally low TDS figures and the slightly alkaline pH are encouraging, and the overall water quality has varying parameters similar to that found by Angrill, (2017), who concluded that with improvement urban runoff is suitable for irrigation.

The proposed underground water harnessing facility at Kenyatta Stadium is a novel approach to stormwater management, consistent with the high runoff coefficients and large stormwater volumes generated in this study. Utilizing underground space would make better use of limited space in Machakos Town. The capacity of this facility would be optimized based on analysis of the flow rates, so that it could accommodate at least the peak discharges, while still providing storage for prolonged dry periods. Harnessing water underground has the advantage of avoiding potential water quality degradation due to surface contaminants and evaporation losses. In Beijing, a large underground facility was developed for the 2008 Olympics to collect rainwater for landscape irrigation and other non-potable uses (Zhang et al., 2018). The Beijing case is an excellent example of existing large-scale urban stormwater harvesting.

The research advances the body of knowledge on urban stormwater management in several key ways. Firstly, it provides a comprehensive assessment of stormwater harvesting potential in a peri-urban African context, an area that has received limited attention in previous studies. The integration of catchment analysis, flow rate modeling, and water quality assessment offers a holistic approach that can be replicated in similar urban environments facing water scarcity issues.

Secondly, Cropwat modeling determined water needs for prominent regional cultivation, including maize, French beans, assorted vegetables, and mango trees. Generating cumulative irrigation depth values spanning entire growth seasons found totals ranging from 450 mm for vegetables up to 1421 mm for mangoes. Stacked against the estimated annual irrigation demand of just 4,282 cubic meters for the target area of 3,033 square meters at an irrigation depth of 1,412 millimeters, the potential stormwater volumes represent an enormously abundant yet overlooked resource that could help fulfill irrigation needs if property is harnessed.

Thirdly, the research provides localized data on runoff coefficients and water quality parameters specific to Machakos Town, filling a crucial gap in the understanding of urban hydrology in this region. The results confirm the stormwater's general adequacy for irrigation demands if simple sediment removal and routine chemical monitoring practices are instituted. They inform evidence-based policy-making for water resource management in similar East African urban centers.

5. Conclusion

The specific hydrological and urban characteristics of Machakos Town may limit the direct transferability of these results to other contexts. Additionally, while the study demonstrates the potential for stormwater harvesting, realizing this potential will require overcoming significant technical, economic, and institutional challenges. The proposed underground water harnessing facility at Kenyatta Stadium represents a promising solution to these challenges, offering a space-efficient and potentially cost-effective means of capturing and storing stormwater for irrigation purposes. These studies will help to advance the research, and it is suggested that the following steps should be undertaken in the future:

Long-term stormwater quality and quantity monitoring, which will take the seasonal and inter-annual variability into consideration, and will help to build the dataset needed for the system design;

A detailed cost-benefit analysis for the implementation of a large-scale stormwater harvesting system, including the infrastructure costs, maintenance requirements, and savings in water supply;

Detailed performance, maintenance, and integration with existing urban infrastructure design for the proposed underground facility;

A careful analysis regarding the social and institutional factors that hinder and enhance stormwater harvesting initiatives in Machakos Town and other urban settings;

Pilot studies of different designs of stormwater treatment technologies should be carried out, including the proposed underground facility and other systems such as ECOCYCLE;

Exploring the effects of climate change on regional urban runoff and water quality in the long term.

This study provides a robust basis for rethinking stormwater management in urban areas of water-scarce East Africa through the creation of an integrated and decentralized water cycle approach that taps, reuses, and fully capitalizes on the harvesting of urban runoff, particularly for irrigation in educational institutions. Through showing the significant potential of urban runoff, the study shifts the conventional perception of stormwater as a nuisance to water as a resource. The underground water harvesting facility at Kenyatta Stadium provides a concrete solution through the use of an innovative approach that can simultaneously address the twin challenges of water scarcity and lack of space in a rapidly urbanizing world.

Acknowledgment

The authors give thanks to God for His wisdom and guidance through this project. They send their sincerest appreciation to Machakos Water and Sewerage Company for providing Bernard with crucial data. They are grateful to Machakos University for allowing Catherine access to the laboratory for water quality testing and to Machakos Government Prison for their permission to collect water samples around their premises. This author-led initiative, unfunded, seeks to address water scarcity in Machakos Town

References

Allan, C., Xia, J., & Pahl-Wostl., C. Climate change and water security: challenges for adaptive water management. Current Opinion in Environmental Sustainability, pp. 625-632. (2013). https://doi.org/10.1016/j.cosust.2013.09.004

Angrill, Sara, Anna Petit-Boix, Tito Morales-Pinzón, Alejandro Josa, Joan Rieradevall, and Xavier Gabarrell. "Urban rainwater runoff quantity and quality–A potential endogenous resource in cities?." Journal of Environmental Management 189 14-21. (2017). https://doi.org/10.1016/j.jenvman.2016.12.027

Ayers, R. S., & Westcot, D. W. Water quality for agriculture, Vol. 29. Rome: Food and Agriculture Organization of the United Nations. (1985).

Masila, K. Modelling Hydrological Response to Urbanization: Case Study Syokimau-Katani Area, Machakos County, Kenya. University of Nairobi. (2020).

Ministry of Water and Irrigation. Practice Manual for Water Supply Services in Kenya. (2005)

Onyancha, D. M., C. K. K. Gachene, and G. Kironchi. "FAO-cropwat model-based estimation of the crop water requirement of major crops in Mwala, Machakos county." Research Journal's Journal of Ecology 4, no. 2 (2017). http://www.researchjournali.com/view.php?id=3751

Saint Paul.gov. Clean water infrastructure at Allianz Field, City of Saint Paul. Water Resources Management. (2019). https://www.stpaul.gov/sites/default/files/Media%20Root/Planning%20&%20Economic%20Development/Allianz-Field-Wastewater-Fact-Sheet.pdf

Tom, Randa O., Krhoda O. George, Atela O. Joanes, and Akala Haron. "Review of flood modelling and models in developing cities and informal settlements: A case of Nairobi city." Journal of Hydrology: Regional Studies 43 (2022). https://doi.org/10.1016/j.ejrh.2022.101188

Varma, V. G. Water-efficient technologies for sustainable development. Current Directions in Water Scarcity Research, Vol. 6., 101-128. (2022). https://doi.org/10.1016/B978-0-323-91838-1.00009-9

Zhang, Shuhan, Yongkun Li, Meihong Ma, Ting Song, and Ruining Song. "Storm water management and flood control in sponge city construction of Beijing." Water 10, no. 8 (2018). https://doi.org/10.3390/w10081040


River Section

Ground Water Quality Assessment Using GIS and Remote Sensing: A Case Study of Burnt Forest, Uasin Gishu County, Kenya

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Introduction

The phrase "Water is life" is often used lightly to emphasize the importance of water in sustaining life on earth. However, the depth of this statement cannot be fully captured nor understood without a clear picture of the world's water demand and available supply. Access to clean and safe water is one of the major contemporary issues the world is currently grappling with as the accessible clean water sources continue decreasing by the day, yet the demand is increasing. While closing the water deficit is a major concern in the fight against water scarcity, maintaining the water quality of the available waters is equally important, and the gap widens. Various water sources are susceptible to different kinds of contamination and pollution. Groundwater sources are the largest contributor of fresh water; about 97% of water available and suitable for human use is vulnerable to contamination by industrial discharges, urban activities, agriculture, groundwater pumping, and disposal of waste, which affects its quality (Mishra, 2023). Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source, and therefore, it becomes very important to monitor the quality of groundwater regularly and to devise ways and means to protect it (Verma et al., 2020). Growing urban centres such as Burnt Forest located in the agricultural area in the North Rift part of Kenya are the most vulnerable as no effective sewerage systems are in place. Most families use pit latrines and septic tanks, yet they depend on wells as the main sources of water for domestic use. Therefore, groundwater vulnerability assessment is crucial in determining how vulnerable a certain region is to a specific threat, whether natural or man-made.

This study sought to evaluate groundwater quality in the Burnt Forest area and thematically represent it using the Geographic Information System (GIS) and remote sensing techniques.

Study Area

The study was conducted in the Burnt Forest area in Kesses constituency, Uasin Gishu County, along the Eldoret-Nakuru Highway. Geographically, the area falls within a latitude of 0.2154° N and a longitude of 35.4316°E (Figure 1) with an area of approximately 2.8 km^2. Burnt Forest is among the fastest-growing peri-urban areas along the Eldoret-Nakuru highway, which has an approximate population of 5,242 permanent residents. However, the actual population influencing water and sanitation services is most likely much higher because of the various social amenities within the area, such as schools, Burnt Forest Level IV hospital, the market, and the police station. The area is divided into six administrative estates or villages: Kahuho, Town Centre, Wainaina, Job Estate, Pipeline, and Turudi. The area falls under the Timboroa sub-catchment, part of the larger Mau water catchment complex, which lies on the Tinderet volcanic; hence, the rocks are mostly porphyritic phonolites and nepheline phonolites of the tertiary age (Walsh, 1969). Burnt Forest has an altitude of approximately 2762 meters above sea level with a mean annual temperature of 18°C and average annual rainfall of 1205 mm, the rainy season extending between April and September. Evapotranspiration range between 50-150 mm/month. Figure 1 shows the location and details of the study area.

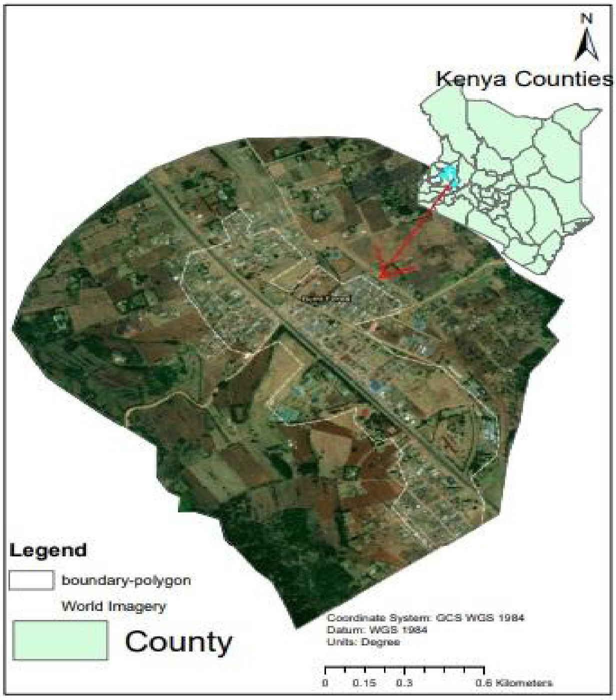


Figure 1: Study area location and details

Materials and Methods

Figure 2 presents a methodology flowchart used in the study. The methodology basically entailed the collection of data, both spatial and non-spatial. The first step was to delineate the study area's boundary using Google Earth Pro and export to ArcGIS. The land use categories were classified based on Sentinel characterization to show how they relate to the water quality. Similarly, the DEM was used to show the topography and slope of the study area and extract the contours which cumulatively influence groundwater movement. In developing the water quality index (WQI), the sample size of water sources was determined using Cochran's formula (Nanjundeswaraswamy & Divakar, 2021), after which the water samples were collected at random from different water sources within the study area, noting their locations and those of nearest contaminant sources, more so sanitation facilities using mobile GPS application. The physical, chemical, and microbial characteristics of the water samples were then tested and analyzed in accordance with standard laboratory procedures, and WQI was calculated using the weighted average index method. Thematic maps of the various tested water quality parameters were developed using the inverse distance weighting (IDW) interpolation technique in ArcGIS. In order to demonstrate conformity with the guidelines, the thematic layer of each parameter was then classed into five classes, with one being the least acceptable and five the most suitable, taking into account the WHO standards for drinking water. The weighted overlay function in ArcMap 10.2 software was then used to construct a drinking water quality index for the research area based on the classified characteristics and their corresponding weights as shown in Table 1.

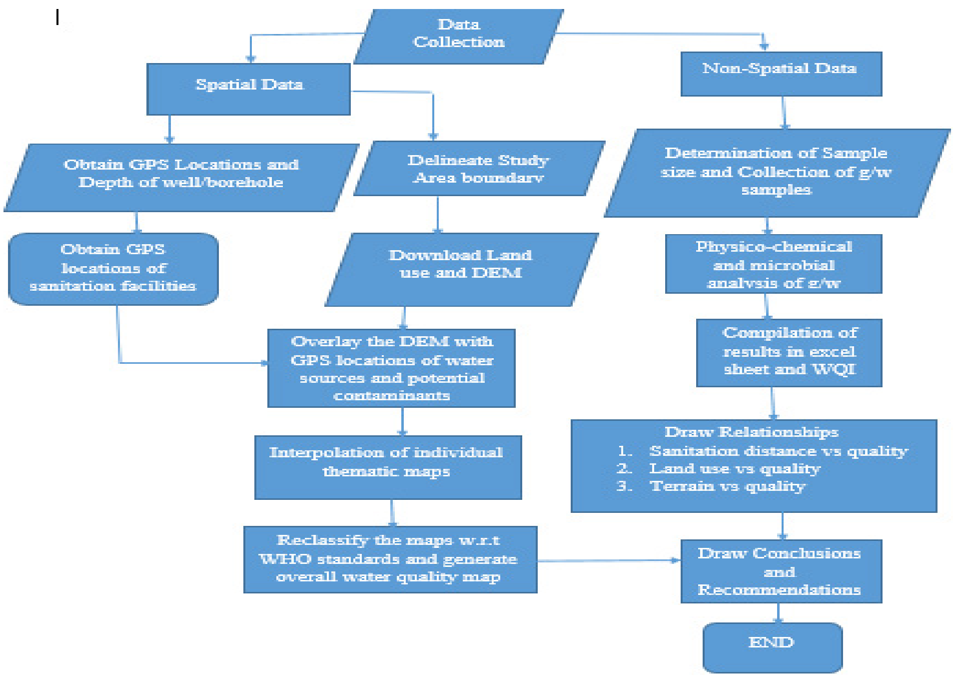


Figure 2: Schematic representation of the data collection process

Table 1: Water quality parameters standards and assigned weights

Sn	Parameter	Standard (WHO/ NEMA)	Assigned Weight, Wu
1	Feacal coliforms (E-coli)	Nil/100 ml	5
2	Total coliforms	<98% of the sample	5
3	Turbidity	5 NTU	4
4	Electrical conductivity	<2500Us/cm	3
5	TDS	1200 (mg/L)	3
6	pH	6.5 – 8.5	4
7	Total Hardness	10-500 mg/L.	3
8	Nitrates	10 (mg/L)	5
9	Chlorides	250	4

Results and Discussion

Land Use Map and Digital Elevation Model

The data used in the study include a digital elevation model (DEM) downloaded from Divagis.org and analyzed using ArcGIS. Additionally, the satellite land use imagery-Sentinel-2 data of 10 meters resolution of the study area downloaded from the European Space Agency was used to compare land use and water quality. Figures 3 and 4 are land use and DEM of the study area, respectively.

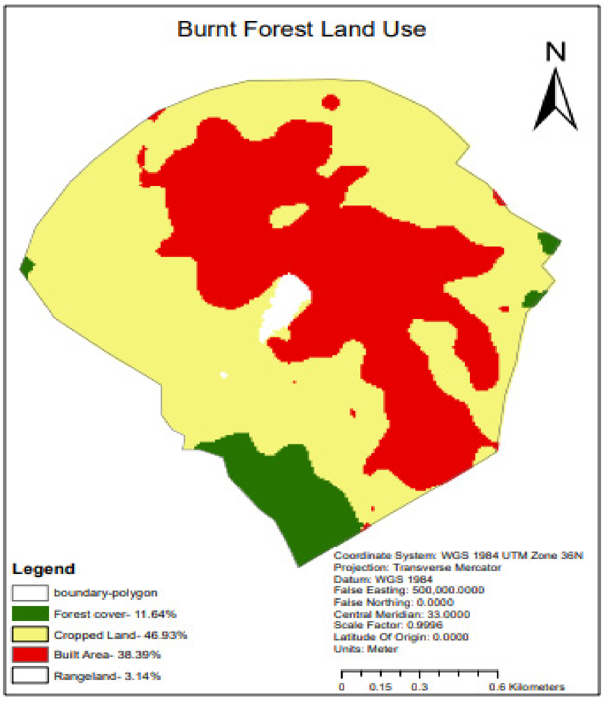


Figure 3: Land use map of the study area

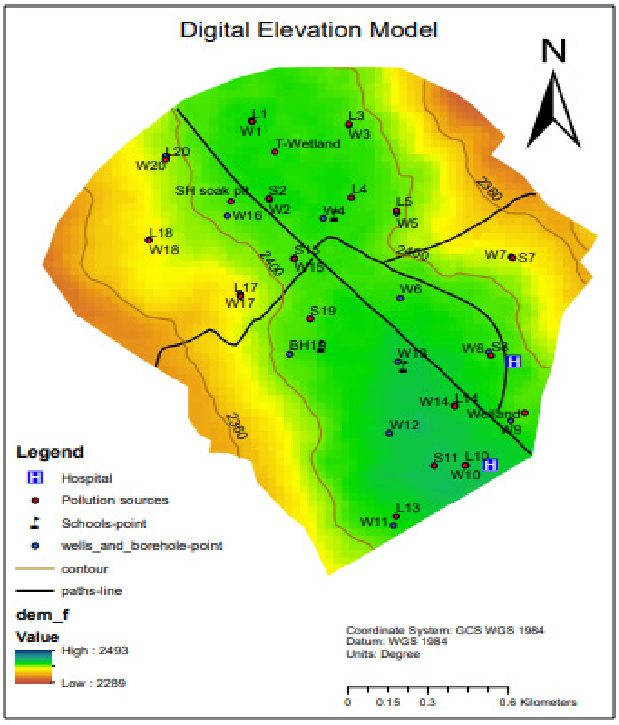


Figure 4: DEM of the study area

Physical, Chemical and Microbial Characteristics of Groundwater

Table 2 shows the results of groundwater samples' physical, chemical and microbial analysis for the 20 water sources spatially sample in the study area. The depths of sampled wells ranged from 8 to 12 meters, with a borehole at approximately 30 meters. The sources were sampled during a fairly rainy season when the water levels in the wells were about 3 to 5m whereas the borehole pump water was sampled.

Table 2: Water quality parameters values

Well ID	Distance *(m)	FC** (MPN/ 100ml)	TC*** (MPN/ 100ml)	Nitrates (mg/l)	Chlorides (mg/l)	Turbidity (NTU)	Total hardness (mg/L)	pH	TDS (mg/L)	EC (µs/ cm)	WQI
W 1	20		60	14.6		18	75	5.53	175	349	128.76
W 2	25		36	12.2		4	80	6.34	252	506	60.36
W 3	10	15	200	35.4	57.5	66	100	6.48	83	168	212.75
W 4	>30		48	19.3		22	50	6.58	93	187	116.17
W 5	7	105	200	47.2	11.49	10	75	6.62	144	288	133.26
W 6	18		23	25.8		8	105	5.89	342	683	112.91
W 7	8	8	96	45	12.56	6	65	5.3	228	457	118.36
W 8	25		33	25.8		4	25	5.25	118	237	114.18
W 9	10	3	75	27.9	2	6	85	6.78	203	406	61.24
W 10	8	10	151	32.4	10.11	8	115	5.7	76	152	126.76
W 11	15	5	52	22	5.45	10	90	6.52	162	323	67.39
W 12	18		75	12.6		2	15	5.4	60	124	78.11
W 13	10	7	200	51.8	12.56	54	80	5.77	41	82	221.73
W 14	25		90	14.3		18	75	5.29	199	398	135.76
W 15	20		80	8.1		14	150	5.67	250	406	103.34
W 16	10	24	200	56	39.5	24	30	5.77	328	657	165.17
W 17	30		14	26		4	165	6.27	364	728	91.90
W 18	12	5	120	37.5	20.78	8	95	5.78	125	250	101.18
BH 19	>30	0	12	12.7	7	10	110	7.08	212	426	43.12
W 20	25		29	9		46	120	6	58	117	186.32
r-correlation		-0.690	-0.764	-0.207	-0.097	-0.080	0.060	-0.048	-0.057	-0.240	

Distance* - Proximity of water sources to the nearest pollution sources (pit latrines, septic tanks, or dump sites).

FC** - Feacal Coliforms

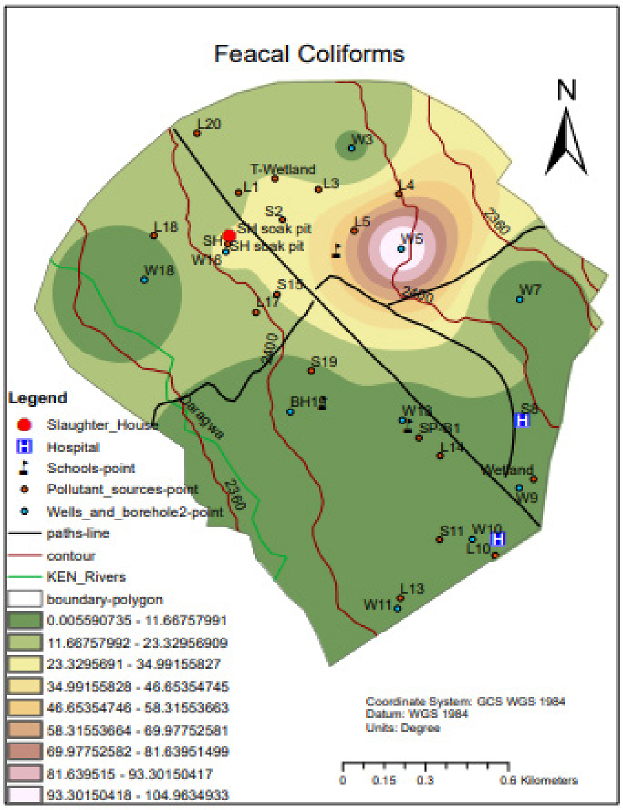
TC*** - Total Coliforms

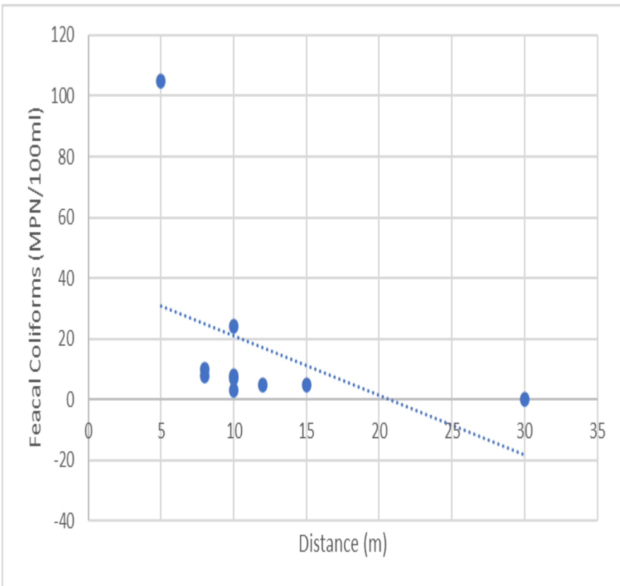
Thematic Maps for Individual Water Quality Parameters

(i) Feacal Coliforms

The sampled water sources in the area displayed varied feacal coliform counts. Figure 5 shows the spatial distribution of feacal coliforms in the study area while figure 6 shows the relationship between FC and distance to pollution sources.

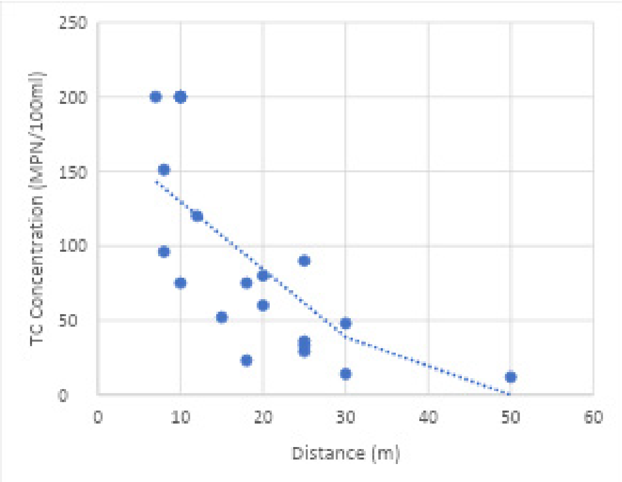
The map (Figure 5) shows that the upper area had the highest values, indicating the most pollution, whereas the lower side had a lower risk. The relationship between feacal coliform counts and distances to pollutant sources portrays a moderate inverse correlation of r = -0.3773. This can be attributed to the high population densities in these areas as well as proximity to onsite sanitation facilities, whereas the low values on the lower side can be attributed to less population pressure on these sides. According to Masood et al. (2024), water sources located in highly populated urban areas are susceptible to faecal contamination due to their proximity to water sources. Furthermore, the sanitary survey conducted by Kitonga et al. (2018) in Ainabkoi, where the study area is partly located, attributes faecal contamination of groundwater sources to poor sanitation, such as improper siting of wells with respect to pit latrines or septic tanks. Also, the relationship between feacal coliform counts and distances to pollutant sources portrays a moderate inverse correlation of r = -0.3773 as shown in Figure 6. This implies that sources closer to sanitation facilities are highly likely to have high coliforms counts whereas those far away are less likely to be contaminated by coliform bacteria. These results are reiterated by Kiprotich, (2006) study that feacal contamination in water sources is inversely proportional to sanitation facilities distances.



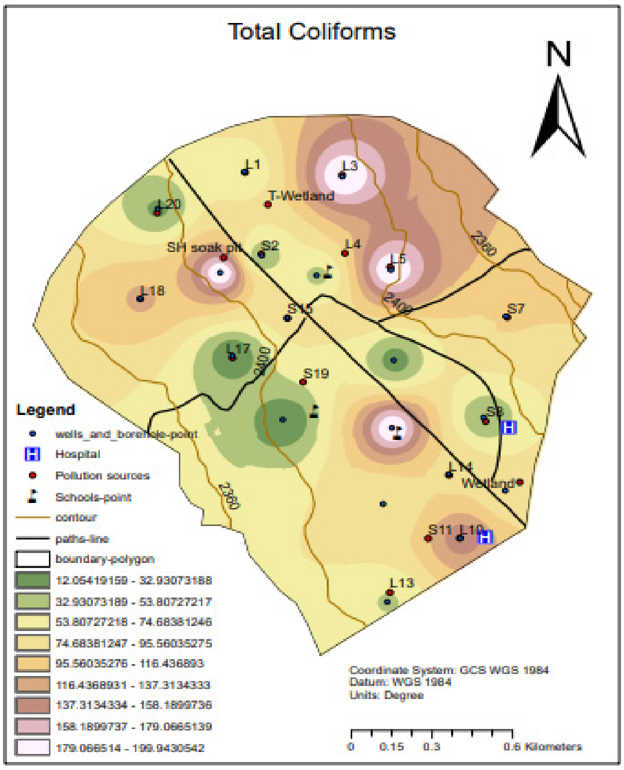


(ii) Total Coliforms

The sampled water sources in the area recorded varying total coliform values as shown in figure 7 which indicates their spatial distribution.



The map (Figure 7) shows that most of the area has total coliform counts ranging from 55-117 MPN/100ml. The areas with high coliform counts are concentrated in densely populated neighbourhoods with different potential contaminant sources. Activities such as careless dumping of waste, municipal waste disposal, or improper disposal of hazardous materials contaminate groundwater and contribute to high total coliform counts in wells. Kitonga et al. (2019) further stresses that a poorly organized environment around the homestead, with poultry and livestock kept near the well will have an impact on the coliform contamination of ground water sources. According to Kitonga et al. (2019), the distance at which the household premises, the cowsheds, greenhouses, vegetable gardens, pit latrines, dumps and other aggressive sources of pollution can be located and still have an impact on well water quality is 145 meters. Most residents in the study area reside in plots small as 15 m by 30 m while they have a well, livestock, a garden, and a pit latrine in the small piece of land. Similarly, the relationship between total coliform counts and distances to pollutant sources portrays a strong inverse correlation of r = -0.690 as shown in Figure 8, implying that coliform contamination in water sources is inversely proportional to the distance to pollution sources such as cowsheds, greenhouses, vegetable gardens, pit latrines, and dumps.



(iii) Chlorides

The chlorides concentrations of the sampled water sources in the study area were moderately low. Figure 9 shows the spatial distribution of chlorides in the area.

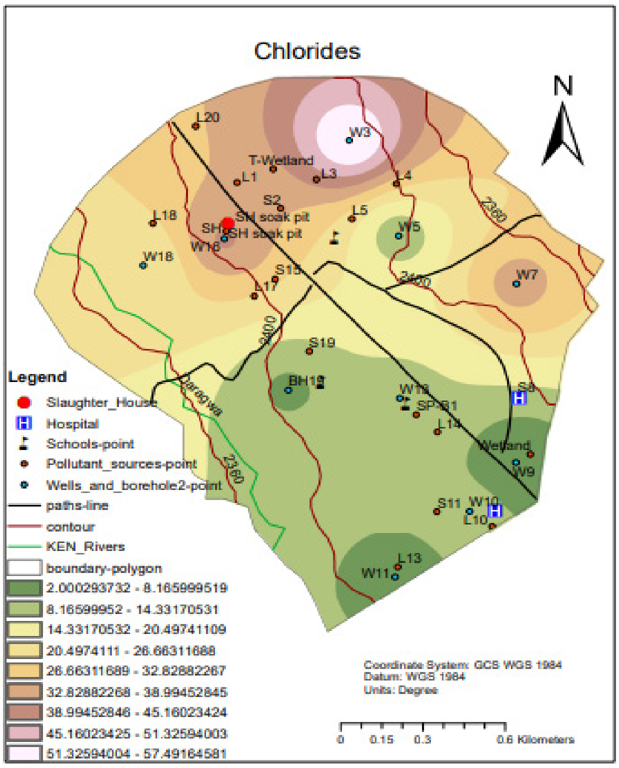
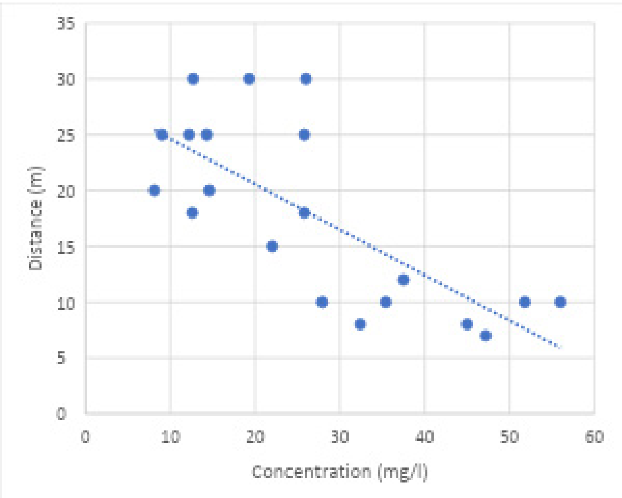


Figure 9: Chlorides concentrations spatial distribution map

From the map (Figure 9), the northern part of the study area had slightly higher chloride values than the southern part. The chloride values in the area were generally lower, with the highest recorded value being 57.1 mg/l, which is much lower than WHO's 250 mg/l. According to Gupta (2019), lower chloride values are largely attributed to the geologic formation of the area, as some geological formations naturally contain lower levels of chloride, leading to low chloride values in the well water. In this regard, the wells in the study area were not that deep (not more than 12 m deep), hence no chloride contribution from underground rock formations.

(iv) Nitrates

The area recorded moderate nitrate values, as shown in the spatial distribution map in Figure 10.



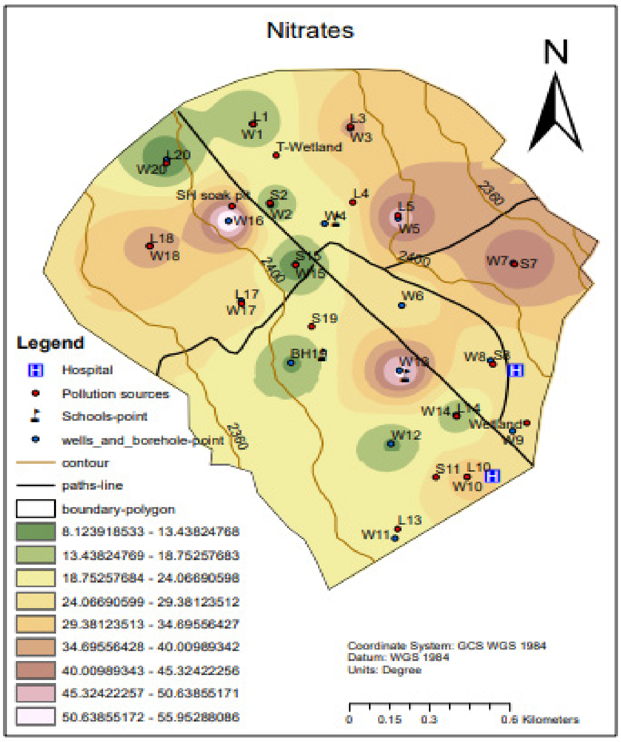


Figure 11: Relationship between nitrates concentrations and distances to sanitation facilities

From the map (Figure 10), the majority of the area had nitrates concentrations between 18 and 40 mg/l. From the maps, the lighter the shade of colour, the greater the concentration of nitrates in the water samples of that area. Well 16 specifically had the highest concentrations of Nitrates. This is attributed to its close proximity to the slaughterhouse, and hence, the facility's waste (cattle kraals) must have contributed to the high concentrations. According to Kitonga et al. (2018), animal wastes from active or abandoned feedlots may be a significant source of nitrates in groundwater. When manure is stored in open lots for eight months, 7% nitrogen, 14% phosphorus and potassium enter the environment in the form of leachate, resulting in groundwater pollution from the leachate greatly exceeding the maximum allowable concentrations for the area (Kitonga et al., 2018). The direction of groundwater flow also has an important influence on the probability of contamination. Based on groundwater hydrology, water flows downslope along the gradient of the groundwater surface or water table (Kitonga et al., 2018). This gradient generally conforms to the surface contours. Thus, water quality in wells is highly influenced by pollutants moving from up-slope in the vicinity of the well. This is the case in the study area as sources closer to the highway, which is elevated, had lower nitrate concentrations, whereas those in lower areas had high concentrations. Additionally, from the recorded data, the distances of sources to sanitation sources shows a strong inverse correlation of r= -0.7642 with nitrates concentration levels as shown in Figure 11. This implies closer the source to the sanitation facility the higher the likelihood of high nitrate concentrations.

(v) Turbidity

The generated thematic map for Turbidity in Figure 12 shows the spatial distribution of turbidity in the study area. It was observed that the northern part had the highest values for turbidity, signaling the greatest pollution.

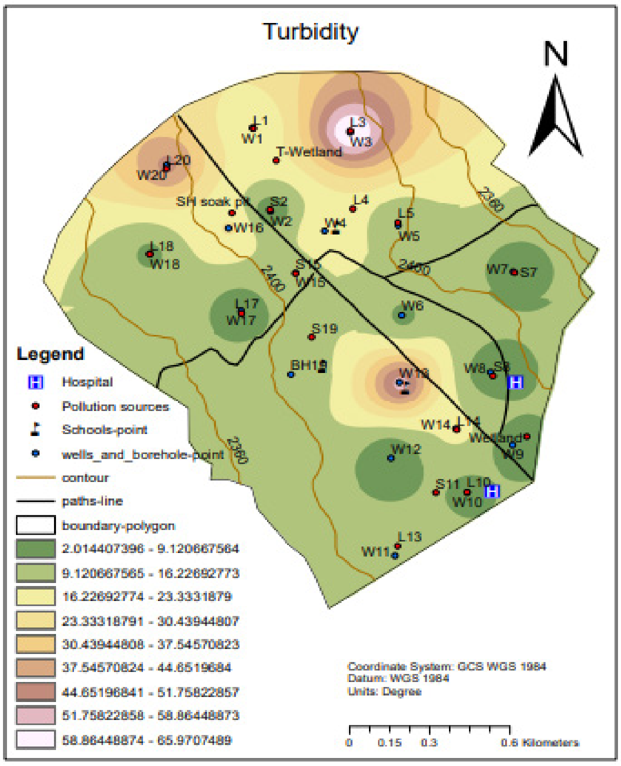


Figure 12: Turbidity spatial distribution map

From the map (Figure 12), the majority of the area had low turbidity values, with a small portion of the Northern part recording values above 15 NTU. This can be attributed to the general terrain of the area, as the land gently slopes towards that part, increasing the possibility of runoff pollution, which increases Turbidity (Kitonga et al., 2018). As in the case of nitrates, turbidity is largely influenced by the terrain of the area. As water flows downstream, it carries with it different pollutants that risk downstream sources of pollution. Hence, turbidity in wells is highly influenced by pollutants moving from up-slope in the vicinity of the well.

(vi) Total Hardness

Figure 13 shows the spatial distribution of total hardness concentrations in the study area.

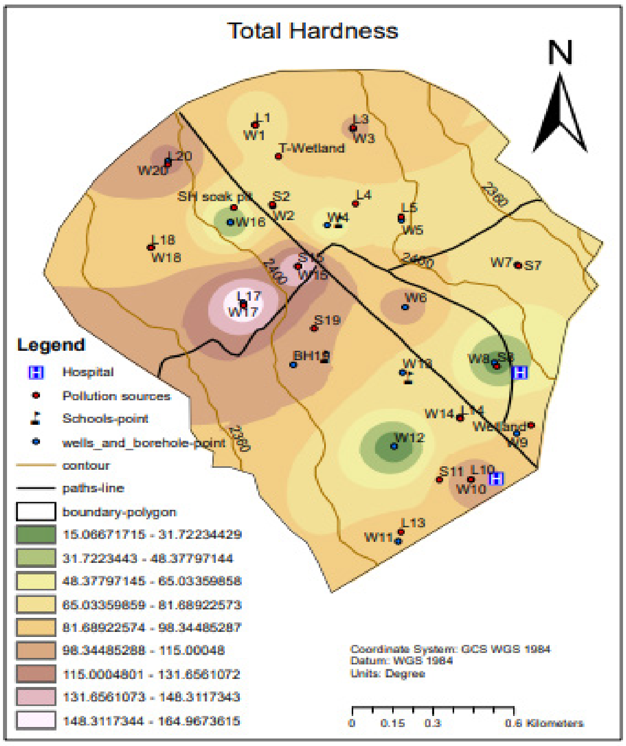


Figure 13: Total Hardness spatial distribution map

From the map (Figure 13), most parts of the area have total hardness values ranging from 48-98 mg/l. These low values can similarly be attributed to the area's geologic formation, as the aquifer's composition and surrounding geological formations can influence the hardness of well water. According to Masood et al. (2024), the hardness of the water is reflected by the geological formations from where the water is derived. Some geological formations naturally contain fewer minerals, such as calcium and magnesium, which are major contributors to water hardness. Carbonates naturally present in surface soils and sediments will increase the hardness of surface waters. Similarly, subsurface limestone formations increase the hardness of subsurface waters.

(vii) pH

The thematic map in Figure 14 shows the spatial distribution of pH in study areas. From the map, it is clear that the pH water quality in the majority of the area is acidic.

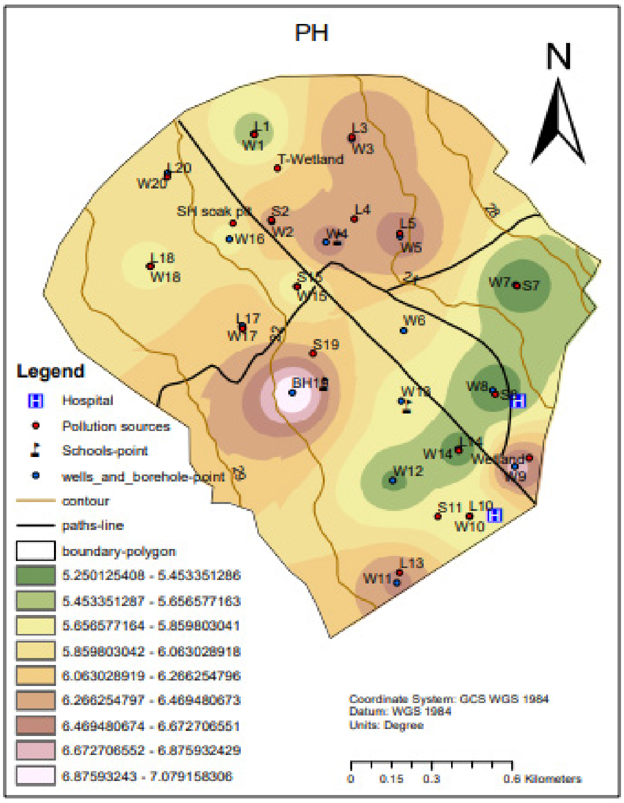


Figure 14: pH spatial distribution map

From the map (Figure 14), the majority of the area recorded acidic pH values ranging from 5.6 to 6.0. This acidity can be attributed to the location of water sources in close proximity to sanitation sources. Sewage tends to percolate to groundwater over time, increasing its acidity. Agricultural practices such as the use of fertilizers and organic manure, pesticides, and herbicides in agricultural areas can contribute to soil acidification and leach acidic compounds into groundwater, resulting in acidic pH values in wells (Kiprotich & Ndambuki, 2012). Borehole 19 had the most optimum pH value, indicating the absence of any possible contamination that could alter the pH of the water.

(viii) Total Dissolved Solids

Figure 15 is a thematic map of TDS spatial distribution in the area.

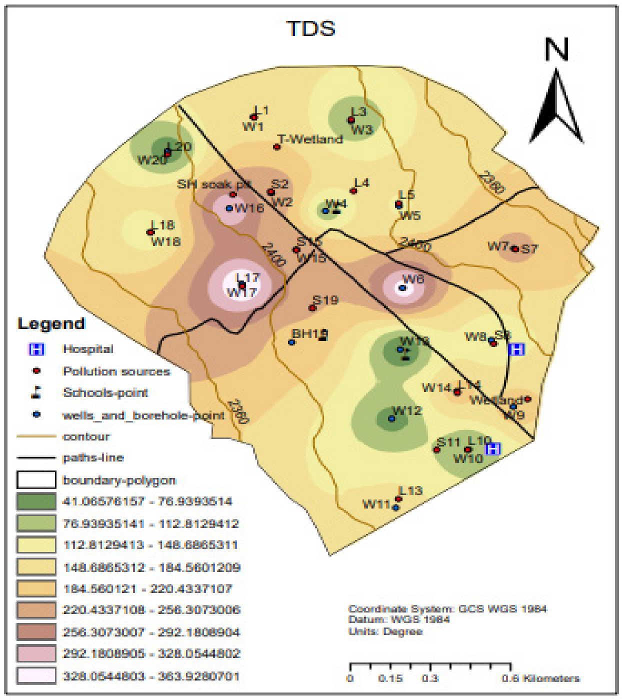


Figure 15: TDS spatial distribution map

From the map (Figure 15), the majority of the area had TDS values ranging from 112 mg/l to 220 mg/l, which are very low. There are also a number of isolated sources with considerably low TDS levels below 75 mg/l. As stated earlier, the low TDS concentrations in groundwater sources can be attributed to natural filtration, as water passing through certain geological formations or soil layers can naturally filter out minerals and other dissolved substances, leading to lower TDS levels Pandey et al. (2020). The water sources in the area are mostly fed by groundwater systems that undergo natural filtration. Furthermore, surface protection of wells minimizes the chances of runoff in to the sources, which tends to decrease TDS levels.

(ix) Electrical Conductivity

Figure 16 shows the spatial distribution of electrical conductivity in the study area.

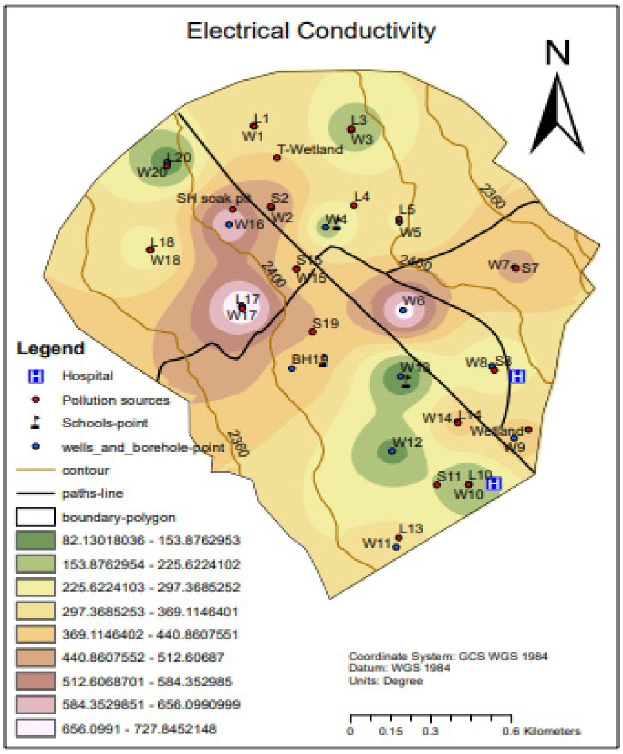


Figure 16: Electrical Conductivity Spatial Distribution Map

From the map (Figure 16), the majority of the area has moderate electrical conductivity with values ranging between 225 μS/cm and 440 μS/cm. Well 16, which is located in close proximity to the slaughterhouse, recorded slightly higher values. This can be attributed to slaughterhouse waste, such as blood and intestinal waste rich in ionic concentration, which percolates in the ground and finds its way into nearby water sources. Well 17, which recorded the highest electrical conductivity value, is located close to a pit latrine, about 12 m. Wells located closer to sources of pollution or human activity are likely to have elevated dissolved ions and pollutants levels, resulting in higher electrical conductivity (Kiprotich & Ndambuki, 2012). Furthermore, according to Mugun (2015), the concentration of total suspended solids in groundwater sources is directly proportional to that of electrical conductivity. Therefore, the moderate electrical conductivity values in the area can be attributed to factors similar to TDS.

Water Quality Index

The Water Quality Index (WQI) is a numeric expression used to transform large quantities of water characterization data into a single number. It is a measure of how the water quality variables compare to the water quality guidelines for a specific site. It is used to assess the appropriateness of the quality of the water for a variety of uses (Kawo & Karuppannan, 2018), such as habitat for aquatic life, irrigation, recreation, and drinking water. The water quality index converts complex or complicated water quality data into information that is understandable and usable by the public.

Figure 17 indicates an overall water quality thematic map of the study area.

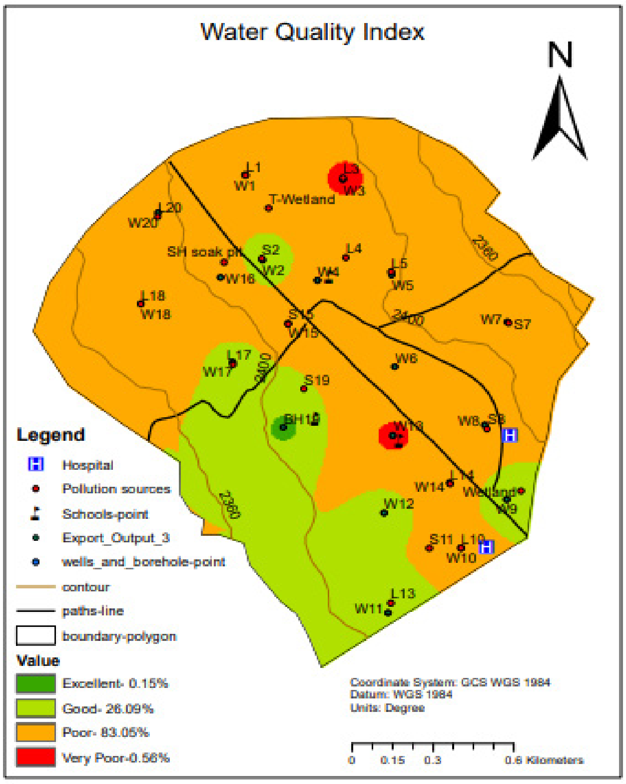


Figure 16: Water Quality Index Spatial Map

From the map (Figure 17), 83.05% of the area has poor water quality, 26.09% has good, 0.56% has very poor, and 0.15% has excellent water quality. The northeastern part of the study area has a higher population density compared to the western part, hence the poor and good water quality. The one source (BH 19) with excellent water quality is a well-protected school borehole isolated from various contamination sources. Hence, the excellent water quality can be attributed to the natural filtration of water as it percolates deep underground. According to Matsumbe (2020), boreholes tend to have better water quality than shallow wells because of the low possibility of surface contamination by runoff and stormwater. Furthermore, boreholes draw water from aquifers located deep underground; hence, as water percolates into the aquifers, it undergoes natural filtration, eliminating pollutants and improving water quality in the process. Wells 3, 14, 16, and 20 exhibited the highest index values (lowest water quality), implying areas with more pronounced water quality challenges within the study area. The other four water sources with very poor quality can be attributed to their very close proximity to pollution sources.

Unplanned urbanization and the conversion of agricultural land to residential areas are two of the major causes of water quality deterioration. Burnt Forest's population has increased exponentially over the last decade. Commercializing peri-urban centres attracts more people seeking job opportunities or livelihood sources, leading to overexploiting resources such as groundwater.

Overlay of Overall Water Quality

Figure 18 shows the study area's overall water quality compliance map from the overlay of all nine tested water quality parameters. From the map, the majority of the study area (57.24%) had between 70-81% compliance with WHO standards on the tested parameters. However, there are sections (19.24% of the study area) with lower compliance, below 65%, indicating poor water quality. This overall water quality of the study area reiterates the water quality index as the northeastern part of the study area seems to have lower compliance, which is attributed to high population density compared to the southwestern part, which displays higher compliance with less population density.

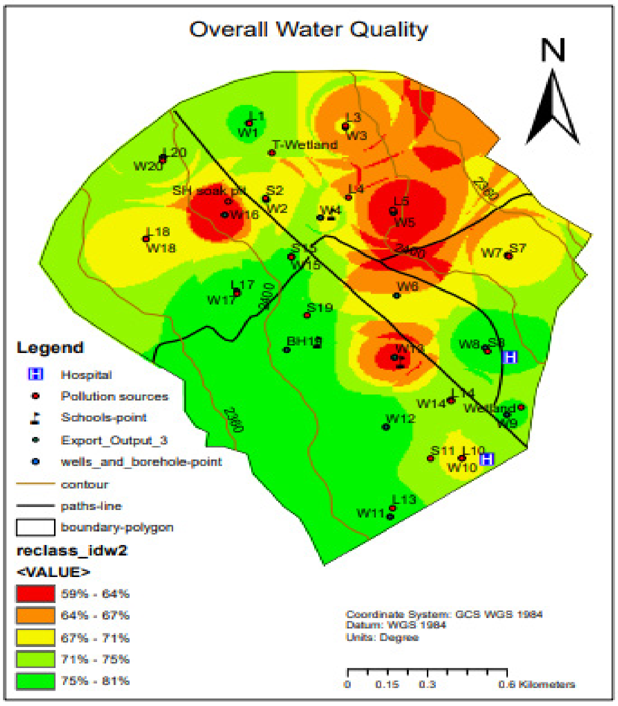


Figure 18: Overlay of Overall Water Quality Map

It can be seen that groundwater compliance with WHO standards is in deed lower in built-up areas when the land use/land cover map of the study area is compared with the overall water quality map. These results underscore the necessity of targeted actions to improve water quality in different sectors, especially in areas where the percentage of compliance is low, indicating more serious water quality concerns, with the goal of raising the general quality of groundwater for better environmental and public health in the area.

Conclusion and Recommendations

In this study, the groundwater quality of the Burnt Forest area was evaluated and mapped using the Geographic Information System (GIS) to understand the present status of groundwater quality. Based on the study's findings, the most densely populated areas had the poorest water quality, the relationship between distance and contamination of the water is inversely proportional with r values ranging from -0.048 to -0.764, and the terrain of the study area affects various water quality parameters. Also, most of the physicochemical and bacteriological parameters assessed in the study did not conform to the WHO and NEMA guideline values for portable water. The study area complied with WHO guideline standards in three tested parameters only: total hardness, total dissolved solids, and electrical conductivity. Faecal coliforms, nitrates, turbidity, and chlorides showed partial compliance, while total coliforms and pH showed total non-compliance. Furthermore, the estimated WQI values showed that 50% of the area has poor water quality, 47.6% is good, 2.04% is very poor, and 0.36% has excellent water quality. Nitrates, chlorides, and turbidity, which are related to the high WQI values, made significant contributions. The overall water quality compliance map generated by overlaying all the parameters reiterates WQI values' spatial distribution. Therefore, the study advances the following recommendations: rehabilitation of the Burnt Forest water treatment and supply system to ensure residents have reliable access to clean and safe water throughout the year. Also, the study recommends the adoption of a more appropriate and sustainable waste and wastewater treatment and disposal system for the slaughterhouse to eliminate the nuisance and contamination of nearby groundwater sources by the generated waste. Lastly, the residents should employ better well and sanitation facilities management practices (in accordance with WHO guidelines) to prevent the contamination of water sources and employ low-cost sustainable household point of use water purification techniques such as boiling, bio-sand filters and thermal treatment with solar radiation, among others to improve quality of drinking water.

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References

Gupta, R., Jindal, T., Khan, A. S., Srivastava, P., & Kanaujia, A. (2019). Assessment of ground water quality and its suitability for drinking in industrial area Jajmau, Kanpur, India.

Kawo, N. S., & Karuppannan, S. (2018). Groundwater quality assessment using water quality index and GIS technique in Modjo River Basin, central Ethiopia. *Journal of African Earth Sciences*, *147*, 300-311.

Kiprotich, K. C. & Ndambuki, J. M. (2012). Well water contamination by pit latrines: A case study of Langas. International Journal of Water Resources and Environmental Engineering Vol. 4(2), pp. 35-43.

Kitonga, L. M., Moturi, W. N., Mwonga, S. M., & Taabu, I. (2018). Assessment of physico-chemical characteristics of groundwater among different farm sizes in Ainabkoi sub-county, Uasin Gishu County, Kenya.

Masood, M. U., Rashid, M., Haider, S., Naz, I., Pande, C. B., Heddam, S., ... & Sammen, S. S. (2024). Exploring Groundwater Quality Assessment: A Geostatistical and Integrated Water Quality Indices Perspective. *Water*, *16*(1), 138.

Matsimbe, J. (2020). Comparative Study of Water Quality From Boreholes and Hand-Dug Wells: Case of Namatapa in Bangwe Township. *Engineering and Technology Quarterly Reviews*, *3*(3).

Mishra, R. K. (2023). Fresh water availability and its global challenge. *British Journal of Multidisciplinary and Advanced Studies*, *4*(3), 1-78.

Mugun, K. K. (2015). Assessment of Drinking Water Quality In Shallow Wells In Koitoror Location Of Uasin Gishu County, Kenya. Kenyatta University

Nanjundeswaraswamy, T. S., & Divakar, S. (2021). Determination of sample size and sampling methods in applied research. *Proceedings on engineering sciences*, *3*(1), 25-32.

Pandey, H. K., Tiwari, V., Kumar, S., Yadav, A., & Srivastava, S. K. (2020). Groundwater quality assessment of Allahabad smart city using GIS and water quality index. *Sustainable Water Resources Management*, *6*, 1-14.

Verma, P., Singh, P. K., Sinha, R. R., & Tiwari, A. K. (2020). Assessment of groundwater quality status by using water quality index (WQI) and geographic information system (GIS) approaches: a case study of the Bokaro district, India. *Applied Water Science*, *10*, 1-16.

Walsh, J. (1969). Geology of the Eldama Ravine-Kabarnet area. *Rep. Geol. Surv. Kenya*, *83*, 1-48.

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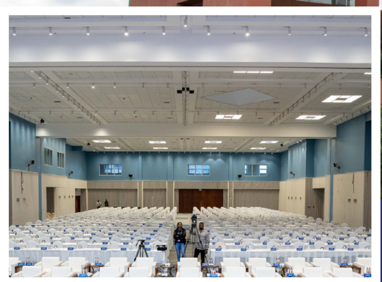

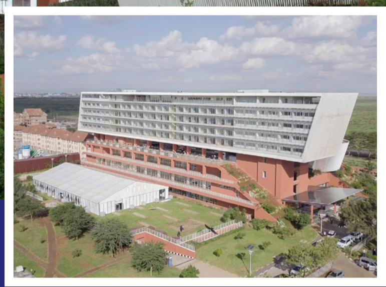

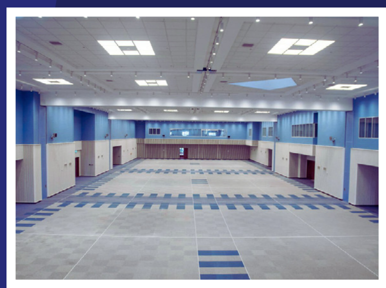

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Integrated Development and Productive Use of Energy for Off-Grid Electrification in Kenya

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1. Introduction

In Sub-Saharan Africa (SSA) faces significant challenges in achieving universal access to electricity, as outlined in Sustainable Development Goal 7 (SDG7), which aims to provide reliable, affordable, and sustainable modern energy to all by 2030. Despite ongoing efforts, a large portion of SSA's population, particularly in rural areas, remains without access to electricity. Over 567 million people in the region are still unserved, which has been exacerbated by rapid population growth that has outpaced electrification initiatives (1). While some countries, such as Kenya and Ethiopia, have made notable progress in recent years, rural areas remain significantly underserved due to the high costs and logistical difficulties of grid extensions. Off-grid solutions, such as mini-grids and stand-alone systems, have emerged as viable alternatives to traditional grid expansion in reaching remote and rural communities (2). However, the success of these off-grid energy projects hinges largely on mobilizing substantial financial investments. The financing gap is stark: SSA requires an estimated $25 billion annually to meet its electrification goals, but current investments fall far short of this target (2). Much of the funding for these projects has traditionally come from public sources and development finance institutions, but this approach alone is insufficient to meet the growing demand. There is a growing recognition of the need for private sector involvement, as well as household contributions, to fill this financing gap (3).

One of the key obstacles to attracting private investment in off-grid energy projects is the high cost of capital, which is driven by factors such as high interest rates, inflation, and the perceived risks associated with operating in emerging markets (4). These challenges are further compounded by debt sustainability concerns in many countries, which limit their ability to finance infrastructure projects. In SSA, the cost of financing for energy projects is significantly higher than in more developed markets, making it difficult to secure investment for small, high-risk projects like off-grid systems. Early-stage financing, essential for activities such as feasibility studies and pilot projects, is particularly hard to come by, further delaying the development of bankable projects that could attract larger investments (5).

In response to these challenges, new financing mechanisms are being explored. Concessional finance, which includes grants, low-interest loans, and risk guarantees, is playing an increasingly important role in reducing the perceived risk of off-grid energy investments and making these projects more appealing to private investors (5). Other innovative financing models, such as results-based financing, fintech solutions, and public-private partnerships, have also gained traction as tools to attract private capital. These models allow for more flexible, efficient, and accountable financing, ensuring that investments are closely tied to tangible outcomes, such as the number of new electricity connections or improvements in community access to energy services (6).

Private sector involvement in off-grid energy projects is essential for bridging the investment gap and ensuring the long-term sustainability of electrification efforts (7)(8). Business Model Innovations (BMIs) have emerged as a critical strategy in this context, particularly those that go beyond the provision of basic electricity services to include additional value-added services, such as agro-processing, cold storage, internet connectivity, and electric mobility. These models not only improve the economic viability of off-grid energy projects but also attract private investment by providing a diversified revenue stream. In doing so, BMIs align with the broader goals of rural development by boosting local economies and improving the quality of life in off-grid communities (9).

However, the challenge remains in scaling these business models across SSA. The demand for productive use of energy is often low in off-grid areas, particularly in regions where the local economy is underdeveloped, and there are few businesses or industries to drive electricity consumption. One promising approach to overcoming this challenge is the "Big Pull" strategy, which aims to simultaneously build energy infrastructure and create demand for electricity by promoting productive economic activities (10). This approach mirrors the "Big Push" development theory but focuses on attracting resources and investments from the bottom up, rather than relying solely on top-down interventions. By fostering demand for electricity through business activities like agricultural processing, small-scale manufacturing, and services, off-grid energy providers can ensure more stable and predictable revenue streams, which in turn makes the projects more attractive to investors.

Several case studies have demonstrated the effectiveness of this integrated development approach. For instance, appliance financing programs in countries like Nigeria and Kenya have shown that providing businesses and households with affordable, income-generating appliances, such as grain mills or woodworking equipment, can significantly increase electricity demand (11). This demand boost improves the financial viability of mini-grid projects by enabling providers to sell more electricity, thereby spreading the fixed costs of infrastructure over a larger customer base. In Tanzania, initiatives like the Rural Electrification Densification Programme (REDP) have further highlighted the importance of promoting productive uses of electricity (12). By providing technical training, business support, and financing for small-scale productive appliances, the REDP program has contributed to the growth of local businesses and improved socio-economic outcomes in newly electrified villages.

In the broader context of rural development, access to reliable and affordable electricity has far-reaching implications for sectors such as education and healthcare. Schools equipped with electricity are better able to provide quality education through access to modern teaching tools, internet connectivity, and science equipment. In households, electricity enables children to study after dark, contributing to improved educational outcomes. Similarly, healthcare facilities in off-grid areas benefit from the ability to power essential medical equipment, such as refrigeration units for vaccines and diagnostic tools, improving the overall quality of healthcare services available to rural populations (13).

Ultimately, the key to successful off-grid electrification in SSA lies in the integration of energy access with broader socio-economic development goals. By promoting productive uses of energy and fostering local business growth, off-grid energy providers can create a virtuous cycle of development that improves livelihoods, enhances food security, and boosts educational and healthcare outcomes. This requires not only innovative business models but also supportive policy frameworks that encourage private investment, reduce financing risks, and ensure that off-grid energy solutions are accessible to all. To achieve these goals, governments and development agencies must work closely with the private sector to create an enabling environment that fosters both the supply and demand for off-grid energy services.

2. Settings and methods

The extensive literature review undertaken in this background analysis reveals several key findings to be addressed. This research focuses on building a scheme to identify the completeness of the policy framework that enables these innovative business models while addressing the socio-economic development of the regions involved. The selected country for this research, where the research activities have been undertaken, is Kenya, known for having a relatively comprehensive off-grid policy framework. Kenya has set ambitious goals for achieving full electrification as part of its national development objectives. Programs like The Last Mile Connectivity Project and the Kenya National Electrification Strategy (KNES) aimed to extend electricity access across the whole country. However, despite the success of the country's electricity access rollout in recent years these targets remain unmet prompting a revised timeline for achieving universal access by 2026. The analysis aims to identify potential policy gaps within Kenya's off-grid policy framework. Drawing from the results of this analysis, any identified gaps will be addressed through modeling to demonstrate the benefits of filling these gaps. This approach not only highlights the necessity of robust policy frameworks but also showcases the tangible socio-economic benefits that can be achieved through effective policy implementation and innovative business models in the off-grid energy sector.

2.1. The policy matrix

The matrix includes a wide range of indicators to cover all aspects of off-grid policy development, including those aimed at facilitating business model innovations (BMI), following the structure set by (Trotter et. al.) in "Policy mixes for business model innovation: The case of off-grid energy for sustainable development in sub-Saharan Africa"(9): the structure assesses both the overarching policy strategies and the specific policy instruments implemented to achieve these strategies. The policy matrix is divided into two main components: society-wide policies and sector-specific policies, each with their own strategies and instruments.

Policy Strategy and Instrument Mix

1. **Policy Strategy**: The policy strategy component encompasses the combination of policy objectives and the principal plans for achieving them. These strategies often address multiple objectives at varying levels of abstraction, such as long-term targets for climate policy, renewable energy adoption, and the deployment of specific technologies. Effective policy strategies can reinforce each other by signaling a growing market and providing clear direction while allowing flexibility for innovation and opportunity.

2. **Instrument Mix**: The instrument mix consists of the concrete tools used to achieve the overarching objectives outlined in the policy strategies. These instruments can be categorized into:

    - **Technology-push instruments**: These include R&D grants and subsidies designed to reduce the cost of innovation and encourage the development of new technologies.

    - **Demand-pull instruments**: Tools such as feed-in tariffs and tax incentives that enhance market expectations and create demand for emerging technologies.

    - **Systemic instruments**: These ensure that the necessary infrastructure is in place to support both technology-push and demand-pull instruments, facilitating a cohesive and supportive environment for innovation.

Balancing these instruments is crucial to effectively supporting structural changes within the energy sector. For instance, while individual instruments like the EU Emissions Trading System (EU ETS) mayhaveweaknesses, their combination with long-term targets has been instrumental in driving structural changes in the electricity industry (14).

Types of Policies in the Matrix

1. **Sector-Specific Policies**:

   - **Policy Strategies**: These are designed to create a long-term foundation for companies to establish themselves within the off-grid energy market. They provide a roadmap for achieving specific sectoral objectives and help in signaling the direction of market development.

   - **Policy Instrument Mix**: This includes the supportive conditions and spe cific tools needed to facilitate the operations of companies within the sector. Examples include subsidies for renewable energy projects, regulatory frame works that enable mini-grid development, and financial incentives for private investments.

2. **Society-Wide Policies:**

   - **Policy Strategies**: These integrate broader societal objectives into the sector specific strategies. They ensure that the development of the off-grid energy sector aligns with national and international goals, such as climate change mitigation, sustainable development, and social equity.

   - **Policy Instrument Mix**: This involves the implementation of societal con straints and requirements, such as environmental regulations, social impact assessments, and policies aimed at ensuring equitable access to energy.

The policy matrix is also designed to assess the framework by including internationally recognized indicators from the RISE-ESMAP (Regulatory Indicators for Sustainable Energy- Energy Sector Management Assistance Program) framework (15). These indicators ensure that the matrix aligns with global policy standards. Additionally, input from interviews with local experts from academia, the private sector, and public policy makers has been incorporated to create a more robust and thorough evaluation tool. This inclusion ensures that the matrix not only evaluates the presence of policies but also their effectiveness in promoting an integrated approach to rural electrification and economic development.

2.2. Energy modeling strategy

As identified in the literature review, attracting private and household investment through Business Model Innovation (BMI) and productive use of energy is crucial for the successful implementation of off-grid electrification strategies. A key policy gap that needs to be addressed is the integration of off-grid energy solutions with broader socio economic development goals. This chapter aims to demonstrate the practical benefits of bridging this gap through energy modeling. The strategy chosen involves characterizing a real mini-grid cluster and applying a growth demand scenario for the productive use (PU) of energy. The analysis will focus on assessing the benefits of demand growth.

1. Selecting the Mini-Grid Cluster

The first step is to select and characterize a real mini-grid cluster. This involves gathering data on existing mini grids, including their locations, capacities, technologies used (such as photovoltaic (PV) systems, battery storage, and diesel generators), and the types of customers served (residential, commercial, and institutional). The characterization will include analyzing load curves, peak demands, and daily energy consumption patterns.

2. Growth Demand Scenario for Productive Use of Energy

A growth demand scenario will be applied to the characterized mini-grid cluster. This scenario will consider an increase in energy demand driven by the productive use of energy, such as agricultural processing, cold storage, internet services, and other commercial activities. The scenario will project the potential growth in demand over a specific period, reflecting the economic development and increased energy needs of the community.

3. Analyzing the Benefits of Demand Growth

The initial analysis will focus on the benefits of demand growth. Increased energy demand from productive uses can enhance the economic viability of mini-grids by generating higher revenue and improving load factors. This, in turn, can attract more investment and support the sustainable operation of the mini-grids. Microgrids-py software (16) will be used to simulate and optimize this scenario, focusing on minimizing the Net Present Cost (NPC).

4. Optimization Objectives

The primary optimization objectives for both scenarios will be the Levelized Cost of Energy (LCOE) and the Net Present Cost (NPC) of the plants.

3. Results

3.1. Policy evaluation results

POLICY MATRIX			Kenya	Tanzania	Uganda
Sector-Specific	Policy strategy	Long-term plan to increase off-grid energy deployments	1	0,5	1
		Long-term plan to create a private sector-led off-grid energy market	1	0,5	1
	Systemic instruments	Regulatory instruments (e.g. framework for off-grid energy companies)	1	1	1
		Information instruments (e.g. effective flow of infotmation)	0,5	0	1
	Technology-push instruments	Economic instruments (e.g. grants)	1	1	1
		Information instruments (e.g. building capacities)	0,7	1	1
	Demand-pull instruments	Economic instruments (e.g. household connection subsidies)	1	0,5	1
		Information instruments (e.g. rural community engagement)	0	0	1
Society-wide	Policy strategy	Strategy to ensure affordability of public services applied to off-grid energy	0	0	1
		Strategy to promote comprehensive growth through off-grid energy	0,5	0	0,5
		Local industry growth objectives applied to off-grid energy sector	0	0	1
	Systemic instruments	Regulatory instruments (e.g. local standards, local content requirements)	1	0	1
	Demand-pull instruments	Regulatory instruments (e.g. legally binding electricity tariff limits)	1	0	1
		Economic instruments (e.g. property taxes, import taxes)	0,5	1	1
SCORE			9,2	5,5	13,5

Legend

- Green: Present
- Yellow: Unclear/Tension between policies/Outdated
- Red: Absent

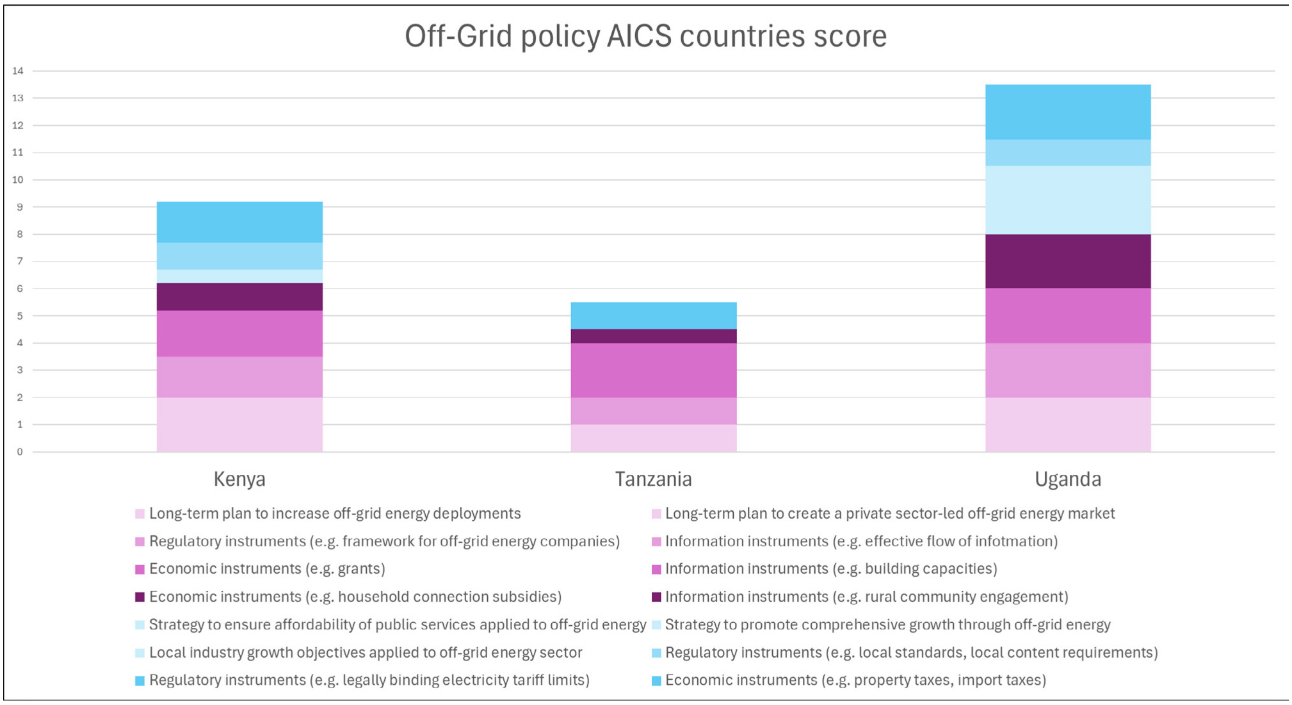


Figure 3.1: Comparison East African countries score applied to the policy matrix

This comparison helps us identifying two major policy gaps in the Kenyan framework:

1. Lack of information instruments

Kenya lacks a program to engage with communities who are about to receive mini grid electricity or who have just recently received mini grid electricity, to increase awareness, uptake, and demand for electricity services. There is no legal requirement for community engagement, to actively include the private sector developing new sector regulations or to hold infrequent but regular off-grid sector events. Between companies and consumers, between companies and policy makers, and between different companies themselves, these interactions are pivotal to ensure clarity in the market. Uganda for instance targets all three of these interactions: the government legally requires community engagement, actively includes the private sector developing new sector regulations and holds infrequent but regular off-grid sector events (9). Moreover, there is no national or large-scale program to engage with communities who are about to receive mini grid electricity or who have just recently received mini grid electricity, to increase awareness, uptake, and demand for electricity services. Not by chance, as discussed by (Taneja, 2018) (17), a major issue related to the economic feasibility of mini grids is the declining average consumption levels as a result of the very low consumption levels of people who have gained electricity access in recent years.

2. Missing society-wide strategy to promote Integrated development and PU

Kenya, despite its substantial progress in rural electrification, lacks comprehensive strategies that link off-grid energy solutions with broader integrated development goals. Integrated development is one of the best ways to achieve global electrification while respecting the so-called "Energy Trilemma" of respecting simultaneously environmental, economic and social sustainability, as shown in the Figure 2.3. In this framework, according to the World Energy Council's report "World energy trilemma index 2024", Kenya's score places the country in the bottom 25% globally (18). While several initiatives under Kenya Vision 2030 aim to promote rural development, these efforts are not sufficiently connected to off-grid energy programs, resulting in missed opportunities for holistic socio-economic growth.

Kenya Vision 2030 (19) is a long-term development blueprint aimed at transforming Kenya into a newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030. The vision includes various rural development strategies designed to enhance financial inclusion, support agricultural productivity, foster business startups, and develop marine fisheries. However, these strategies do not explicitly integrate off-grid energy solutions, which could significantly amplify their impact. One of the key initiatives, the Rural Kenya Financial Inclusion Facility, aims to enhance access to financial services for rural populations. This initiative focuses on expanding banking services, providing microloans, and offering financial literacy programs to rural residents. While these efforts are crucial for economic empowerment, integrating off-grid energy solutions could further support financial inclusion by enabling rural households and businesses to utilize affordable and reliable energy for productive activities. Similarly, the Agricultural and Rural Financial Inclusion Kenya strategy targets the financial inclusion of agricultural and rural communities by providing tailored financial products such as loans, insurance, and savings accounts. These financial services are designed to support agricultural productivity and resilience. However, without a direct link to off-grid energy solutions, these communities may struggle with energy-related challenges that hinder their full economic potential. Integrating off-grid energy into this strategy could enhance agricultural efficiency through the use of energy-powered irrigation systems, cold storage, and processing equipment. Kenya Vision 2030 also includes initiatives to incubate rural business startups, providing them with the necessary resources, mentorship, and funding to thrive. These incubators play a vital role in nurturing entrepreneurship and innovation in rural areas. However, the success of these startups often depends on access to reliable and affordable energy. By incorporating off-grid energy solutions into the incubation process, these startups could significantly reduce operational costs, improve productivity, and scale their businesses more effectively. The Kenya Marine Fisheries and Socio-Economic Development (KEMFSED) project aims to enhance the socio-economic benefits of marine fisheries in Kenya by improving fisheries management, infrastructure, and market access. This initiative focuses on sustainable fisheries practices and boosting the livelihoods of coastal communities. Integrating off grid energy solutions could support these objectives by providing energy for fish processing, refrigeration, and transportation, thereby reducing post-harvest losses and increasing market competitiveness. Lastly, talking about industrial and commercial development, Kenya has prioritized Special Economic Zones (a similar model to the one China uses and had used in the past) as a key enabler to the manufacturing sector which aims at delivering industrialization and social transformation for investment attraction: easier trading mechanisms and tax exemptions make these area particularly attractive for enhancing commercial uses of energy, but logically the identified areas are densely populated and close to the main grid. A model like this, applied to off-grid areas, would be beneficial to increase the potential of commercial activities. Lack of these incentives or ways to add financial pressure to innovate (for example regulatory constraints on the amount of households to electrify, even if not profitable) is linked to the lack of productive uses of energy in these off-grid sites. According to (Trotter et al. 2022), where this society-wide objective of affordability of public services has not featured in relevant policy strategies, mini-grid companies in their sample are charging roughly double the per-kWh price compared to what mini-grid companies charge where such constraints exist.

Key findings through stakeholder engagement

Interviews with sector experts provided valuable insights that reinforced the findings from the literature review and policy analysis, and helped reshaping the policy matrix to be as pragmatic and as inclusive as possible. Several respondents pointed out that, while Kenya has made notable progress in rural electrification, there are significant gaps in its policy framework, particularly in promoting integrated development and productive use of energy. One recurring issue identified through these interviews was the lack of adequate communication and stakeholder involvement in planning and decision-making processes for large-scale projects like the Kenya Off-Grid Solar Access Project (KOSAP). Despite the project's significance, many interviewees highlighted that local populations and developers were not sufficiently engaged during the planning stages. This lack of involvement has contributed to various challenges in project implementation and reduced the overall effectiveness of the electrification efforts, leading to continuous delays in the tendering process. Notably, many private stakeholders confirmed the substantial benefits of integrating development strategies, such as combining energy access with productive uses like agro-processing or cold storage. They emphasized that applying these integrated development strategies has not only enhanced the profitability and bankability of projects, but also made them more attractive to international financing institutions due to their strong social involvement approach. This alignment with socio-economic development goals improves investor confidence, as projects that actively engage local communities and promote productive uses of energy are seen as both financially viable and socially impactful. While gaps were identified, stakeholders also pointed out positive initiatives led by Kenya in terms of off-grid electrification. For instance, the fact that counties—Kenya's federal regions—are empowered to present their own electrification plans was viewed as a positive development. The National Electrification Strategy (KNES), developed in 2018, serves as a guiding document, but counties can tailor their approaches to align with their specific climatic, geological, and socio-economic conditions (21). While this approach introduces complexity in planning, as county-level plans must be harmonized with the national electrification strategy, it also ensures that local needs and challenges are addressed more effectively. Many interviewees highlighted that this decentralized planning can result in more targeted and context-specific electrification strategies, especially in rural areas with unique energy requirements.

3.2. Energy modeling results

Site selection

The Energy Access Explorer, an online platform that provides data-driven insights into energy access, played a crucial role in this process. This tool aggregates and analyzes data from various sources on demographics, infrastructure, and natural resources highlighting areas with limited energy access and identifying opportunities for energy infrastructure investment. This GIS tool allows through its datasets to apply different layers of demand, supply and demographic indicators. Figure 3.1 shows the selected layers used in the site selection process. An interactive map, shown in Figure 3.2, was constructed using the data present in the Energy Access Explorer databases gathered with additional missing data on proposed mini grid (in particular the KOSAP proposed mini grid sites managed by KPLC), detailing the locations of mini grids, including information on the technology used and the customer base. This map provided a comprehensive overview of the energy landscape, facilitating a strategic approach to site selection. The most suitable area for detailed analysis was then identified using the Energy Access Explorer tool. Selection criteria, which can be found in Annex 1, included the proximity of mini grid sites to each other, crucial for potential interconnection, the presence of crop agriculture, schools, and hospitals, and distance from the main grid. Schools and hospitals require reliable power for operation, while agricultural activities benefit from electricity for irrigation, processing, and preservation of produce, thereby supporting the local economy. Focusing on areas with these characteristics aims to maximize the socio-economic bene fits of the mini grid systems, ensuring sustainability from an operational standpoint and contributing significantly to community development. This approach helps in creating a robust demand base through public infrastructure and the productive use of energy, essential for the financial viability of the mini grids, and supports broader goals of improving living standards and economic opportunities in rural areas.

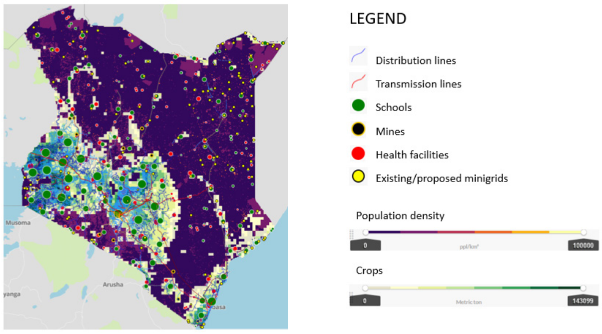


Figure 3.2: Energy Access Explorer selected layers for Kenya

The result of this analysis pointed Tana Delta KOSAP mini grid cluster as the one more suitable for our analysis shown in Figure 6 below.

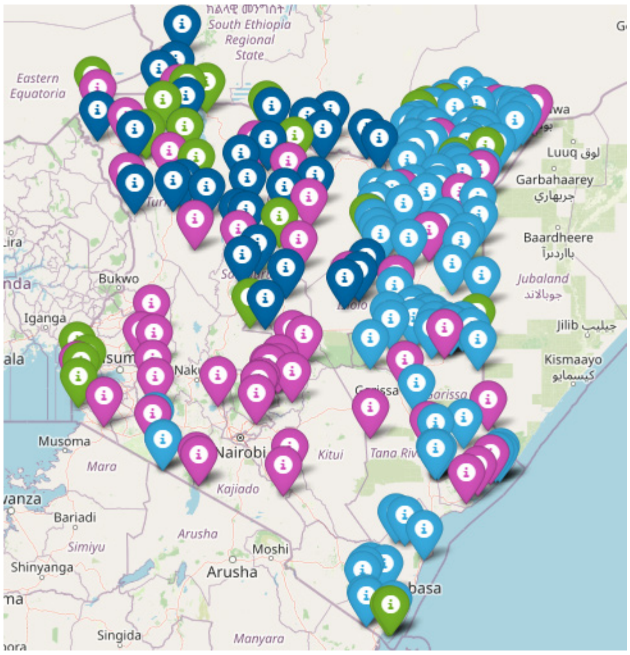


Figure 3.3: Proposed (KOSAP) and existing mini grid sites in Kenya

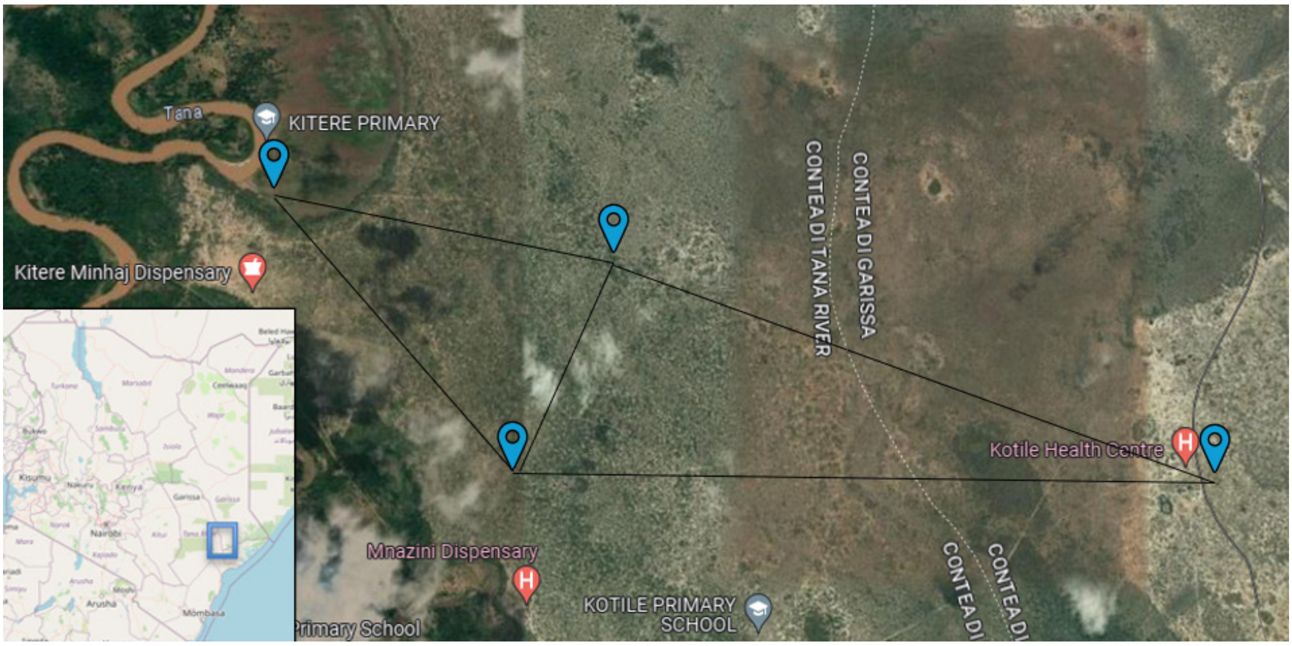


Figure 3.4: Site selection result: Tana Delta KOSAP mini grid cluster and relative distances

The fact that the selected site is part of the KOSAP project is advantageous, as the Environmental and Social Impact Assessment (ESIA) reports for KOSAP provide detailed information on the planned capacity of each technology to be installed, as well as the geographical and socio-economic characteristics of each site (Figure 3.5). This information is crucial for developers to identify the types of potential customers and their specific needs, which are essential for the Public-Private Partnership (PPP) framework.

Table 3.1: Tana River cluster main characteristics

Site	Latitude	Longitude	Commissioning Date	Mini-grid technology
Mnazini	-1,980944	40,145972	mag-25	PV-Hybrid
Kitere	-1,956722	40,151878	mag-25	PV-Hybrid
Kotile	-1,977612	40,21064	mag-25	PV-Hybrid
Munguvueni	-2,018028	40,151722	mag-25	PV-Hybrid

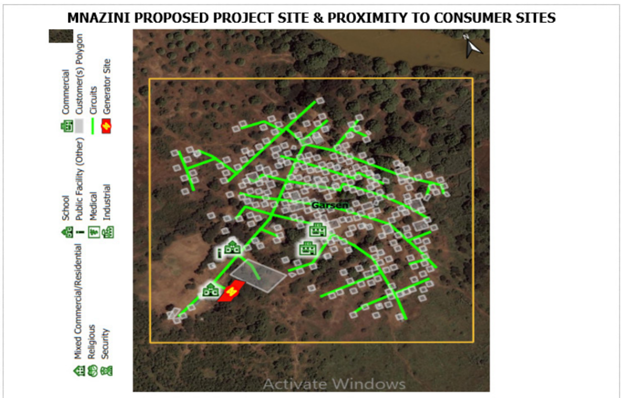


Figure 3.5: Mnazini proposed project site and proximity to consumer sites

3.3. Site characterization: Load curve

The ESIA reports offer only daily and peak demand data, which are insufficient for constructing the detailed hourly load curves necessary for modeling analysis. To address this, assumptions were made using the load curve archetypes defined in (Lorenzoni et al. 2020) "Classification and modeling of load profiles of isolated mini-grids in developing countries: A data-driven approach" research, shown in the Figure 3.6 below.

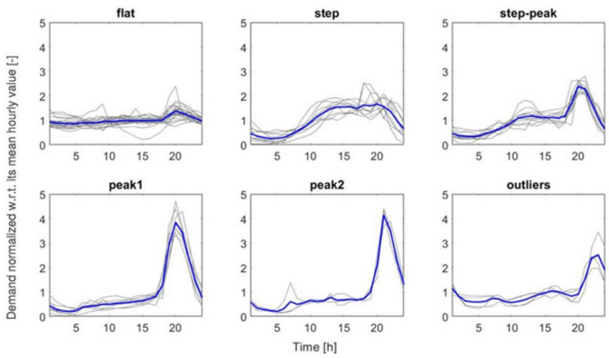


Figure 3.6 - Load demand archetypes

The share of costumers Tier per load curve archetype is shown in the Figure 3.7 below:

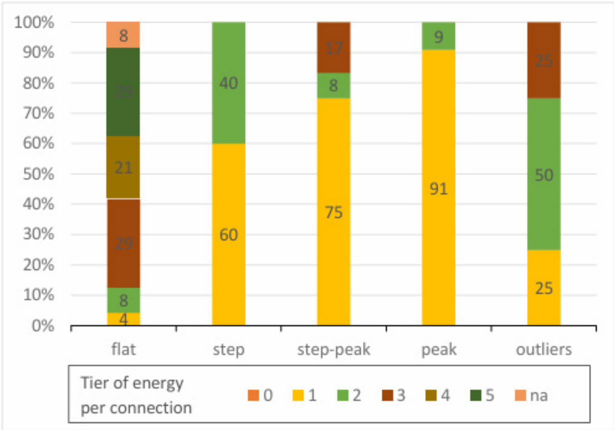


Figure 3.7 - Tier consumers share across load curve archetypes

Looking at the ESIA reports the breakdown of residential and non-residential users, which indicates a predominant majority of residential users (mostly Tier 1) versus a minority of small businesses (typically Tier 2), together with a high expected peak demand in contrast to a relatively low daily demand, suggest that the Peak archetype should be selected as our assumed archetype for the mini grid sites under our scope.

This load curve archetype, assumed to be reasonably representative of other mini-grid sites in the region, was scaled to match the selected sites, adjusting for the specific breakdown of customer types (residential, non-residential) and for the peak power forecasted in each site, as shown in the Figure 9 below.

The curves have slightly different shapes due to the different percentage of non-residential costumers: according to (Lorenzoni et al. 2020) load demand archetypes, we can assign 90% of non-residential costumers contribution in the first 15 hours of the day.

The integration of these archetypes and existing data sources into a coherent load profile model helps to bridge the gap between available data and the detailed demand profiles needed for advanced energy system modeling. This approach ensures that the analysis is grounded in realistic assumptions about energy use, which is crucial for accurate system sizing and operational planning in off-grid and mini-grid contexts.

The solar renewable time series have been obtained by the well-known renewable.ninja service for the proposed case studies. Given the proximity of the sites, only one common time series will be utilized.

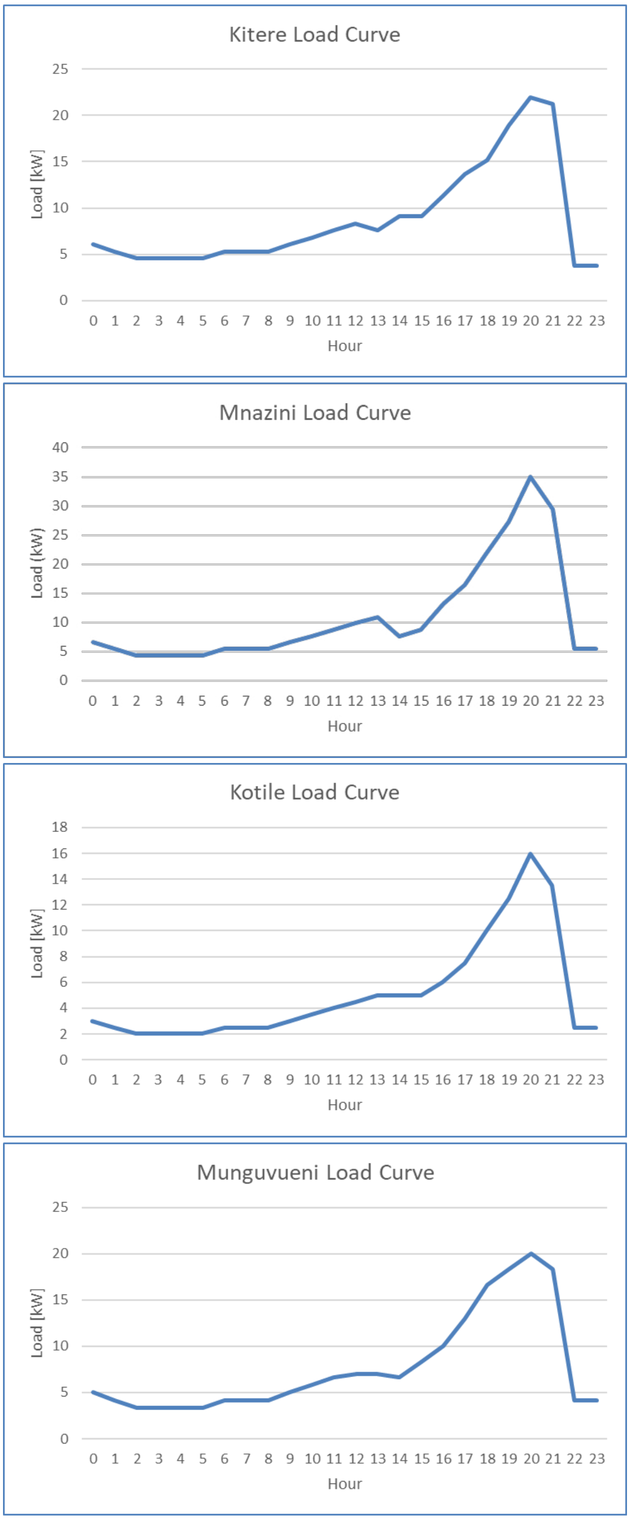


Figure 3.8: Adjusted load curves mini grid sites Tana River

3.4. Site characterization: technology performance and economic parameters

The technical parameters have been selected using the available data on the ESIA reports (20) together with the baseline scenario data listed in the Microgrids.py documentation (16), which refer to an average East African baseline case scenario.

The diesel generator operates with an efficiency of 0.25 liters per hour per kilowatt (L/h/kW). For the photovoltaic (PV) system, the inverter efficiency is set at 98%, with a tilt angle of 15° and an expected operational lifetime of 25 years. The battery energy storage system (BESS) utilizes lithium-ion technology, with a roundtrip energy conversion efficiency of 90%. The Depth of Discharge (DOD) is 80%, allowing for charge and discharge cycles within 4 hours, and the minimum cycles lifetime is specified at 3000 cycles.

Regarding the renewable energy mix, the Environmental and Social Impact Assessment (ESIA) reports indicate a goal of having a minimum of 60% of the total energy generated come from renewable sources.

In terms of economic parameters, the capital expenditure (CAPEX) for the PV system is $2000 per kilowatt , with an annual fixed operational expenditure (OPEX) of $16.6 per kilowatt. The CAPEX for the diesel generator is set at $100 per kilowatt, with an annual fixed OPEX of $24 per kilowatt and a fuel cost of $0.0493 per kilowatt-hour (kWh). Additionally, the variable OPEX for the diesel generator is estimated at $0.025 per kWh.For the battery storage system, the CAPEX is set at $250 per kilowatt. The cost of the electricity transmission line required to interconnect the mini-grid sites is estimated at $11,000 per kilometer (17).

3.5. PU growth scenario selection

A successful implementation of the discussed Integrated Development (ID) policies is expected to lead to an increase in the productive use of energy. To analyse its impact on the business models of our selected mini-grid cluster, we need to assume a certain growth in energy demand over time. The basis for our assumed demand growth is based on results drawn from real case scenarios of PU enhancements in rural settlements (11)(12).

Based on this information, the strategy could be as follows: plan for a 30% increase in energy demand every four years, with existing commercial users experiencing an annual demand growth of 48%. Additionally, the emergence of new commercial activities, which address specific village needs, could independently boost electricity consumption by 10%. These new commercial ventures might be limited to two or three, with one emerging every three years. This approach effectively synthesizes the insights from previously cited projects that have successfully implemented these policies in various off-grid locations. Moreover, this increase in electricity consumption will gradually shift the shape of the curve from a peak to a step-peak shape, which is characteristic of villages with an increased number of commercial activities (which typically operate during daytime hours, mainly between 9am and 5pm).

After implementing these changes, the projected demand shift is illustrated in Figure 3.9. A minor peak in demand, followed by a slight drop, is observed during the late afternoon hours. This pattern is consistent across various mini grid load curves and may be explained by the timing when commercial activities are winding down, but residential consumption remains low as people have not yet returned home.

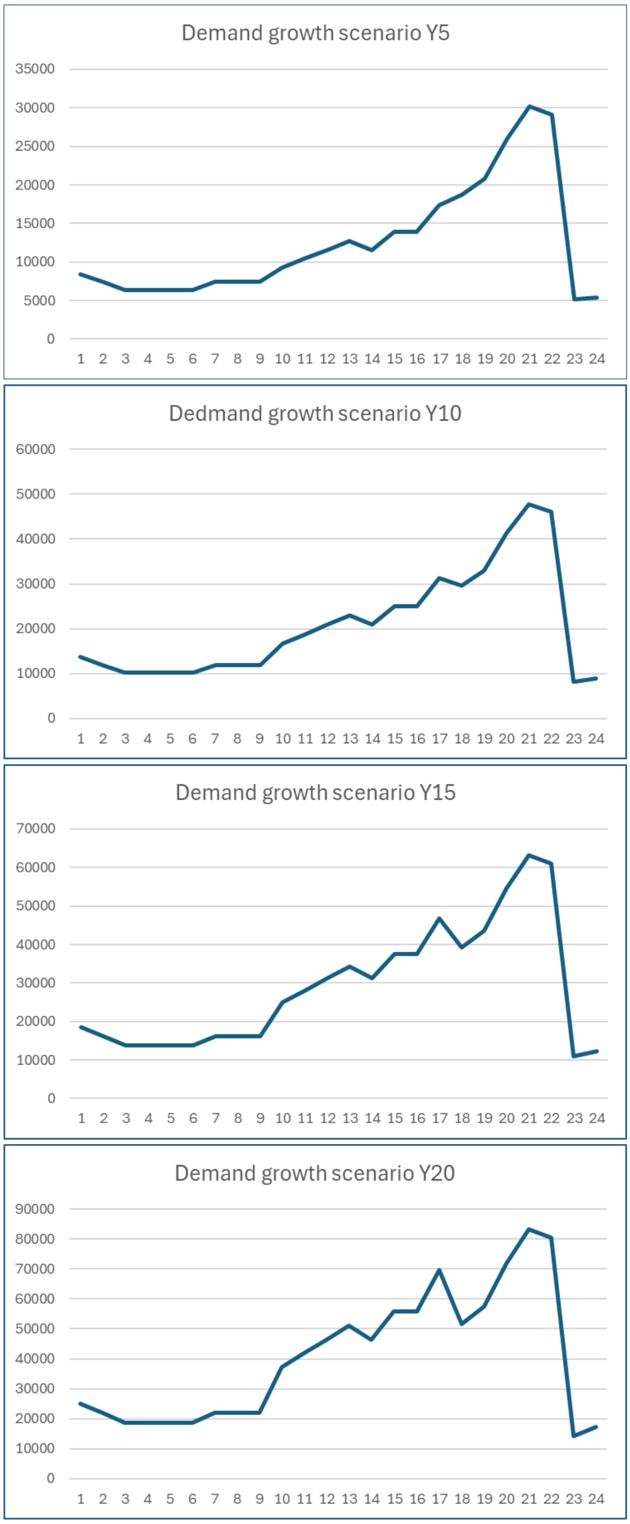


Figure 3.9: Demand growth scenario applied to Marsabit village

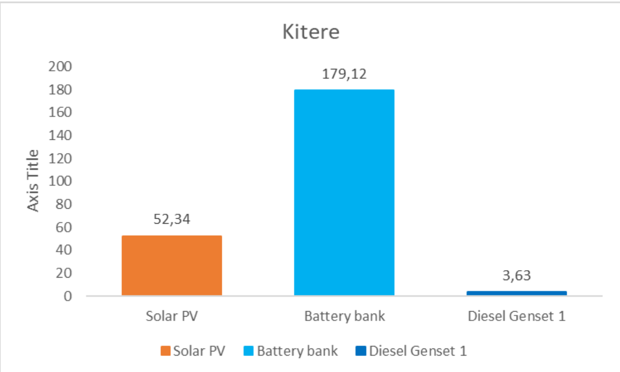
3.6. MicrogridsPy optimization for isolated scenario: PU vs BAU

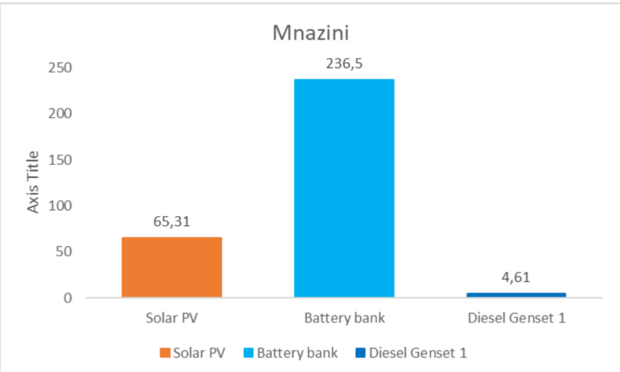
The potential benefits of the demand growth, driven by the successful implementation of Integrated Development (ID) policies, were analyzed using MicrogridsPy software. This tool allows for the simulation and optimization of isolated mini-grid scenarios under varying demand conditions. Two distinct scenarios were explored: a baseline scenario representing the Business-As-Usual (BAU) approach, and a growth scenario reflecting an increase in productive use (PU) of energy.

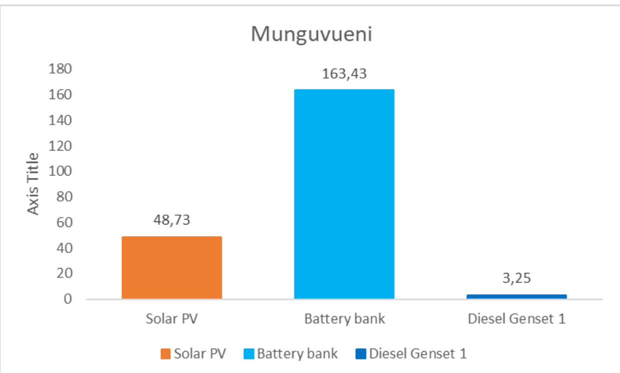
Baseline Scenario (BAU):

In the BAU scenario, no demand growth was assumed. The simulation modeled an isolated mini-grid system in which all investments in energy infrastructure—such as generation capacity, storage, and backup systems—were made upfront in the first year. This scenario serves as a reference point for understanding how a static energy demand without significant growth in productive use impacts the financial and operational performance of the system.

The optimization outcomes for the four selected villages are presented in the figures below. Figures 3.10 and 3.11 illustrate the capacity sizes of each installed technology in the four villages. As shown, the optimal solution primarily relies on photovoltaic (PV) systems and battery energy storage systems (BESS), with a minor contribution from diesel-powered generators across all four cases.







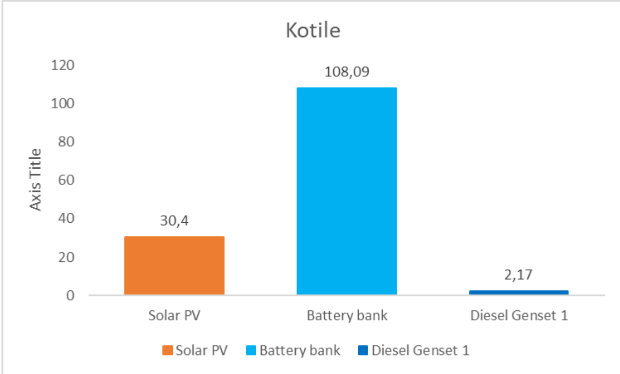


Figure 3.10: Technology capacity distribution by village (BAU scenario)

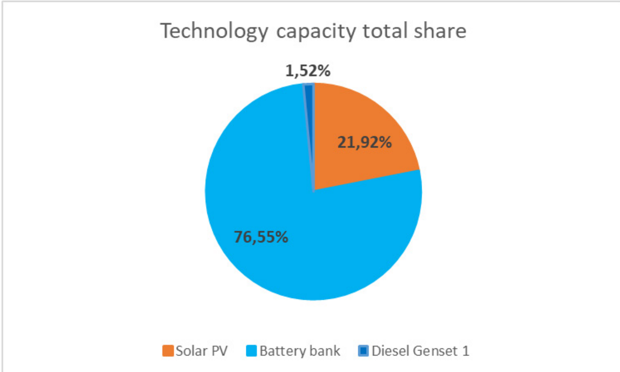


Figure 3.11: Technology capacity total share (BAU scenario)

Figure 3.12 displays the dispatch plot for the first three operational days. In this plot, curtailment occurs only on the first day, as excess PV production exceeds the system's ability to absorb it. However, in the following days, the batteries fully absorb the PV generation, ensuring smooth operation without unmet demand or further curtailment.

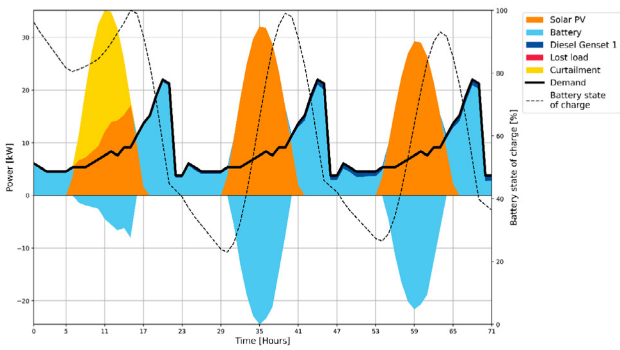


Figure 3.12: Dispatch plot (daily demand BAU scenario)

In this scenario, the system operates with minimal changes in load demand over time, which results in a relatively stable, albeit less efficient, energy use pattern. The absence of demand growth means the system doesn't benefit from economies of scale or the more efficient resource utilization that comes with increasing load factors.

Finally, the table below presents the main economic parameters for the villages, further highlighting the differences in costs and performance under the BAU scenario. As seen, the lack of demand growth limits the system's potential to reduce costs and improve efficiency:

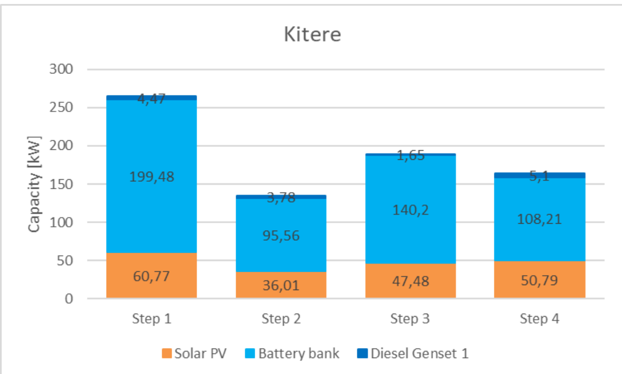
Table 3.2 - Mini grids economic indicators (BAU scenario)

Site	Net present cost [kUSD]	Yearly demand [kWh]	LCOE [USD/ kWh]	Total revenue [kUSD]	Return of investment [y]
Kitere	94,136	76700	0,2845	436,425	4,3
Kotile	60,104	44347	0,2783	246,838	4,9
Mnazini	129,979	94900	0,2813	533,907	4,9
Munguvueni	94,136	67950	0,2845	386,640	4,9

Demand Growth Scenario (PU)

In the PU growth scenario, the anticipated increase in demand, was applied. This scenario involved four investment steps, one every five years, to match the projected increase in energy demand. Each investment phase accounted for the expansion of generation and storage capacity to accommodate the rise in productive use of energy. Given the similar characteristics of the 4 sites, let's take one as an example: The optimization outcomes for the Kitere village are presented in the figures below.

The Figure 3.13 below shows the different investment steps for each technology stacked in column



By adopting a phased investment approach, the model was able to progressively scale up the system's infrastructure in response to growing energy needs, thus spreading out capital expenditures over time and improving financial sustainability.

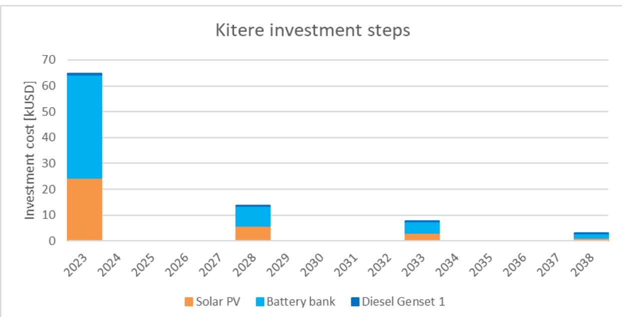


Figure 3.14 - Kitere mini grid investment steps

Despite a substantial increase in the capacity installed at each step, the investment steps are smaller each time: this happens because this is the actualized value and to each investment a 10% interest rate is applied.

Here below the Figure representing the dispatch plot and its changes every 5 years:

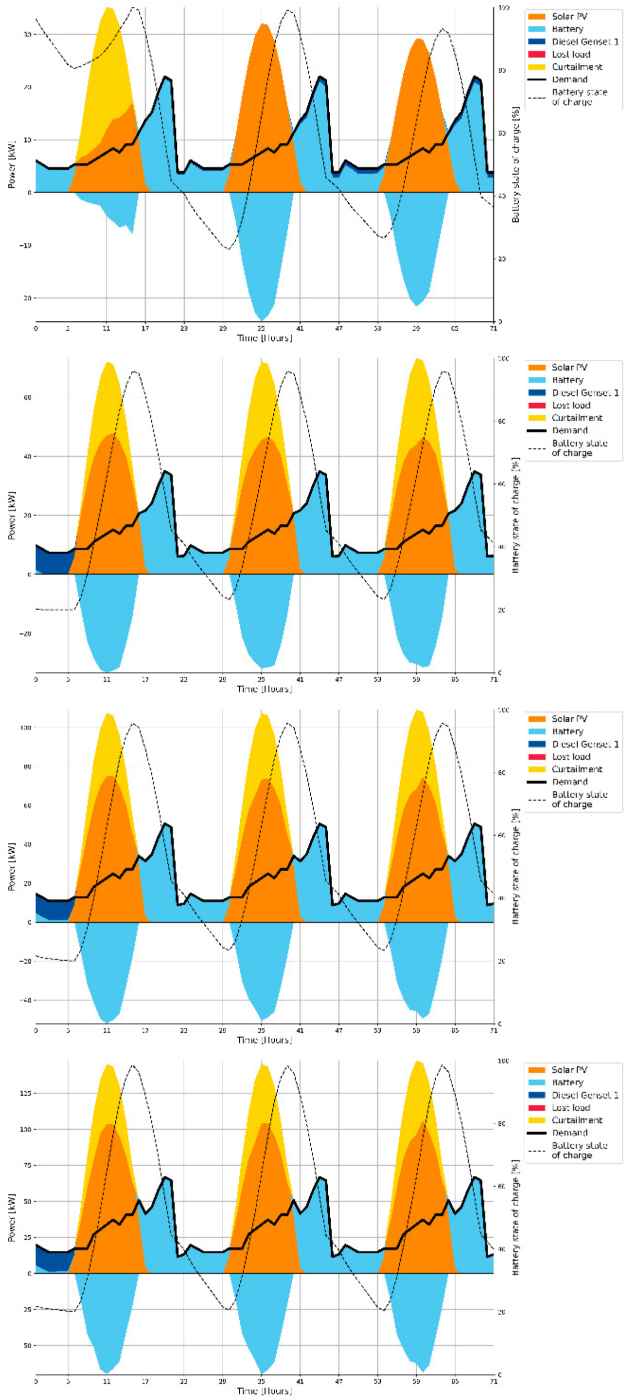


Table 3.3 – Kitere economic indicators (PU scenario)

Step	Net step present cost [kUSD]	Total step demand [MWh]	LCOE [USD/kWh]	Step revenue [kUSD]	Return of investment [y]
2023-2028	107,983	466,094	0,2144	99,930	3,2
2028-2033	13,622	762,847		163,554	
2033-2038	7,623	1116,010		239,272	
2038-2043	2,757	1554,333		333,249	

For the studied Kitere site, in the PU growth scenario, with a 40% increase in NPC, the benefits included a 25% reduction in LCOE, a 91% increase in revenue, and a return on investment that was achieved 25% faster.

4. Discussion

Comparing the output of the optimization simulation between the BAU and the PU scenarios, it is highlighted how the increase in demand output driven by productive use leads to a significant decrease in both the Levelized Cost of Energy (LCOE) and the Net Present Cost (NPC) of the mini-grids, relative to the amount of electricity produced and cost of the project. This cost reduction is primarily due to higher utilization rates of the installed energy systems. In the Business-As-Usual (BAU) scenario, where demand remains static, the system's capacity is underutilized, resulting in higher LCOE and NPC. Conversely, in the demand growth scenario, the increased load factors, facilitated by productive use of energy, lead to more efficient system operation and cost reductions. Additionally, this improved system efficiency and higher utilization of resources contribute to a shorter return on investment (ROI) period. The combination of these factors highlights the significant financial benefits that can be achieved by fostering productive use and encouraging demand growth in off-grid energy projects.

5. Conclusions

The extensive analysis conducted throughout this thesis reveals several key shortcomings in Kenya's off-grid electrification policies, particularly when it comes to promoting Inte grated Development (ID) and the productive use of energy (PU). While Kenya has made significant strides in rural electrification, its policy framework lacks a society-wide strategy that ties off-grid energy to broader economic and social development goals. This gap is especially critical when considering the potential of Business Model Innovations (BMIs) and productive use to drive private investments and foster long-term sustainability in rural electrification efforts. Kenya's rural development programs, such as those outlined in Kenya Vision 2030, focus on economic growth and sector-specific goals but do not integrate off-grid energy solu tions into these broader development plans. As a result, opportunities to maximize the benefits of electrification—through productive use in sectors like agriculture, education, and healthcare—are missed. Additionally, there are few mechanisms for involving local communities and stakeholders in decision-making processes, leaving the local population disengaged from projects that directly impact their lives. This lack of participatory pro cesses and information-sharing instruments further hinders the effectiveness of Kenya's off-grid energy programs. The optimization analysis provided in this thesis demonstrates that addressing these policy gaps has tangible benefits. The results clearly show that fostering productive use of energy, alongside ID strategies, significantly improves the financial viability of mini-grid projects. The introduction of demand growth through productive use not only lowers the Levelized Cost of Energy (LCOE), but also reduces the return on investment (ROI) period for developers. This makes mini grids more economically viable for developers, while simultaneously offering more affordable electricity to local communities. In conclusion, Kenya must prioritize the development of a more integrated, society-wide strategy that promotes the productive use of energy within its off-grid electrification ef forts. Such a strategy would help bridge the gap between energy access and broader economic development, ensuring that rural electrification projects contribute to lasting 56 4. Conclusions social and economic benefits. By addressing these policy gaps and leveraging the demon strated benefits of BMIs and productive use, Kenya can accelerate its path to universal electrification and foster sustainable growth in its off-grid regions.

Acknowledgement

I would like to express my deepest gratitude to everyone who has supported me throughout the process of completing this thesis. First and foremost, I extend my sincere thanks to my supervisor, Professor Riccardo Mereu, for his unwavering guidance, availability, and invaluable advice, which have significantly enriched this work. I am also deeply grateful to my co-supervisors, Professor Niccolò Stevanato and PhD candidate Alessandro Onori, for their expertise, support, and insightful contributions, which have been instrumental in the completion of this research. I am especially thankful to Professor Alex Muumbo, my external co-supervisor, for welcoming me to Kenya and helping me to shape and direct my work in a meaningful way. Additionally, I am deeply thankful to my colleagues from the Kenya energy agencies and regulatory bodies, whose generosity and cooperation in providing the necessary data for this research were vital to its success.

References

W. Bank and I. E. Agency. Tracking sdg 7: The energy progress report 2024, chapter 1: Access to electricity, 2024.

I. E. Agency. Africa energy outlook 2022: World energy outlook special report, 2022.

E. S. M. A. P. (ESMAP). Mini grids in kenya: A case study of a market at a turning point, 2017.

I. E. Agency. World energy investment 2024, 2024.

I. E. Agency and A. D. B. Group. Financing clean energy in africa: World energy out look special report, 2023.

E. S. M. A. P. (ESMAP). Funding the sun: New paradigms for financing off-grid solar companies, 2020.

S. Booth, X. Li, I. Baring-Gould, D. Kollanyi, A. Bharadwaj, and P. Weston. Pro ductive use of energy in african micro-grids: Technical and business considerations, 2018.

W. Bank. Scaling up renewable energy development: Developing mini-grids in sub-saharan africa, 2023.

P. A. Trotter and A. Brophy. Policy mixes for business model innovation: The case of off-grid energy for sustainable development in sub-saharan africa.

U. of Cape Town Energy Research Centre, U. of Oxford Smith School of Enterprise, and the Environment. Electricity for integrated rural development: The role of businesses, the public sector, and communities in uganda and zambia, 2019.

CrossBoundary. Appliance financing 1.0, 2.0, and 3.0,

A. D. B. Group. Mini-grid productive use and demand management

E. Impact. Solar power improves patient outcomes and helps save lives in rural kenyan health clinics

U. of Cape Town Energy Research Centre, U. of Oxford Smith School of Enterprise, and the Environment. Electricity for integrated rural development: The role of businesses, the public sector, and communities in uganda and zambia, 2019.

ESMAP. Kenya: Regulatory indicators for sustainable energy, n.d

SESAM-Polimi. Microgridspy-sesam, n.d

J. Taneja. If you build it, will they consume? key challenges for universal, reliable, and low-cost electricity delivery in kenya. Center for Global Development Working Paper, 491, 2018

W. E. Council. World energy trilemma index 2024, 2023

G. of Kenya. Fourth medium term plan (mtp iv) 2023-2027, 2024.

R. Electrification and R. E. Corporation. Environmental and social impact project (esia) reports, n.d..

Energy Sector Management Assistance Program (ESMAP). (2017). Mini Grids in Kenya: A Case Study of a Market at a Turning Point. Washington, DC: World Bank

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The Role of Nuclear Power in Achieving Environmental Sustainability and Climate Resilience in Kenya

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1. NUCLEAR ENERGY CONTRIBUTION TO KENYA GREENHOUSE GAS EMISSION REDUCTION GOALS

Nuclear power is a low-carbon source of energy accounting for approximately one third of low carbon electricity generated globally. Since 1970, nuclear energy has reduced acceleration of global climate warming by preventing the release of over 60 $GtCO_2$. Currently, it is estimated that nuclear power is preventing annual release of 1.2-2.4 $GtCO_2$ emissions globally. Nuclear energy produces almost no greenhouse gas emissions or air pollutants during their operation and emissions over their entire life cycle are very low. Hence, nuclear power – as a steady, reliable supply of power and a dispatchable low carbon source of electricity – can play a key role in the transition to a clean energy future while meeting the development goals.

In the context of climate change, nuclear energy will help the country to reduce greenhouse gas emissions in the electricity sector as well as potentially providing low carbon heat for other applications such as hydrogen production, desalination of water and district heating. By displacing fossil fuel fired power plants for these applications, nuclear power can help to reduce emissions of carbon dioxide and other greenhouse gasses, and thereby help to mitigate climate change. It provides a vital complement to renewables such as wind and solar power, which are intermittent sources of energy. 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 while achieving its development goals. 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.

2. BENEFITS OF INTEGRATING NUCLEAR IN ENERGY MIX IN COMPARISON TO RENEWABLE AND NON-RENEWABLE SOURCES

Nuclear energy pairs perfectly with renewables and non-renewables sources to create a reliable, stable, diversified and clean energy system. It provides carbon-free, around-the-clock power to fill the gaps when the sun isn't shining or the wind isn't blowing. Nuclear plays a complementary role to other energy sources in an energy mix. The nuclear-renewable energy system addresses the need for grid flexibility. The combination of renewables with nuclear energy can provide a large fraction of a system's electricity, while minimizing inefficiencies associated with curtailed generation or energy storage losses. The integration leverages the benefits of each technology and its mode of operation to provide reliable, sustainable, and affordable low-emission electricity. Moreover, nuclear energy can enhance the efficiency of renewable energy sources.

Nuclear power continues to evolve with new technologies under development that will expand the envelope of nuclear power applications and increase its integration with other low-carbon energy sources, such as variable renewables. With the advent of small modular reactors (SMRs) there are new opportunities for increased use of clean nuclear energy for electric applications to support renewable sources. SMRs offer unique opportunities for hybrid system applications due to their small size, modular implementation, operational flexibility, and investment flexibility.

3. STEPS TO ADHERE TO ENVIRONMENTAL SUSTAINABILITY IN KENYA'S NUCLEAR POWER PROGRAMME

Environmental conservation is of prime importance in the use of nuclear technology for electricity generation. Impacts on people and environment require careful assessment of the environmental stresses associated with the proposed Nuclear Power Plants (NPPs). Environmental Assessment is therefore crucial in the initial stages of a nuclear power programme. This addresses radiological and conventional impacts during nuclear power plant construction and operation.

Kenya has completed the Strategic Environmental and Social Assessment (SESA) for the Nuclear Power Programme, which is undergoing review by the National Environment Management Authority (NEMA). This assessment documents the significant environmental issues associated with the programme and proposes actions to address these issues. The SESA is instrumental in ensuring that environmental protection is integrated throughout the adoption of the nuclear power programme. The recommendations of the assessment will be used to ensure that a robust institutional and regulatory framework is in place to regulate the construction and operation of a nuclear power plant in Kenya.

Kenya will conduct a site and project-specific Environmental and Social Impact Assessment (ESIA) at the NPP site. This assessment will consider radioactive release during normal operation and accident conditions, impacts on sensitive marine and terrestrial environments, and social and economic impacts. To mitigate these impacts, the owner/operator of the NPP is expected to meet all licensing and approval conditions established by NEMA and relevant oversight agencies through the implementation of the Environmental Management and Monitoring Programme (EMMP) before the NPP is commissioned.

Kenya has collaborated with the International Atomic Energy Agency to build capacity on environmental impact assessment for nuclear power plants including Radiological Environmental Impact Assessment (REIA).

4. HOW NUCLEAR CAN ENHANCE ENERGY SECURITY IN THE FACE OF CLIMATE CHANGE

Nuclear energy can be a source of climate-resilient energy. Concurrent climate change induced threats escalating at pace and in intensity have growing implications for the supply, demand and infrastructure of the world's energy system. Climate change will impact every aspect of the energy sector: the output of each energy generating technology, the volume of energy demanded and the combined physical and nonphysical infrastructure that ensures safe and reliable operations during extreme weather events.

Frequent extreme weather conditions and rapidly growing shares of renewable energy generation introduce an unprecedented level of volatility and uncertainty in power markets. Nuclear energy can facilitate the integration of high shares of renewables and support long term energy security. The climate resilience of the global nuclear fleet makes it an excellent complement to other low carbon energy sources as climate risks increase (IAEA).

Reductions in nuclear output due to cooling water availability and other climate events are small — in 2022 these energy losses accounted for 0.3% of global nuclear generation. Historical data show that extreme events such as heat waves, storms and droughts have a minimal impact on the operations of nuclear plants, making nuclear energy a key partner with renewables in decarbonized energy systems.

Nuclear power plants can operate continuously, providing a stable source of electricity that is not affected by weather conditions. Nuclear power plants are also capable of performing load following functions, adapting output for daily shifts in renewable generation. Temperature and availability of cooling water are key climate variables most relevant to sustaining high levels of nuclear production. Nuclear technology is proven to be resilient to other climate variables such as heavy precipitation, high winds, extreme cold and storms that more readily impact other energy generating. The figure below illustrates the annual nuclear energy production and weather-related losses between 2000 and 2022.

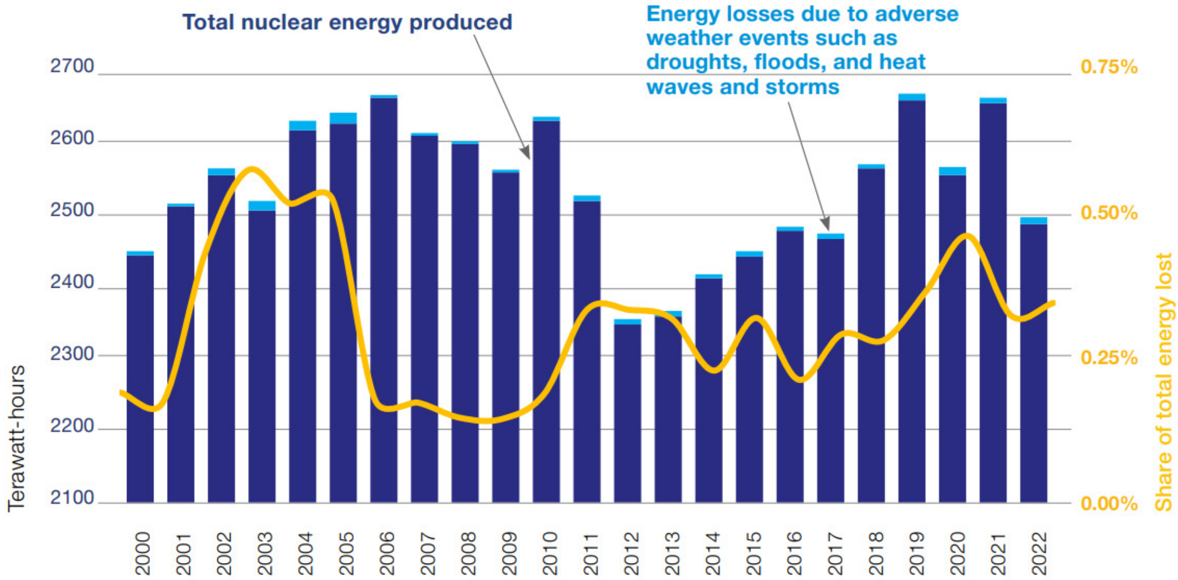


Figure 2: Annual nuclear energy production and weather-related losses between 2000 and 2022

5. WHAT ROLE DOES NUPEA ENVISION FOR NUCLEAR POWER IN KENYA'S TRANSITION TO A LOW-CARBON ECONOMY, AND HOW DOES THIS ALIGN WITH KENYA'S COMMITMENTS TO INTERNATIONAL CLIMATE AGREEMENTS?

Nuclear energy produces almost no greenhouse gas emissions or air pollutants during their operation and emissions over their entire life cycle are very low. Hence, nuclear power – as a steady, reliable supply of power and a dispatchable low carbon source of electricity – can play a key role in the transition to a clean energy future while meeting the development goals.

Nuclear energy will help to reduce greenhouse gas emissions in the electricity sector as well as potentially providing low carbon heat for other applications such as hydrogen production, desalination of water and district heating. By displacing fossil fuel fired power plants for these applications, nuclear power will help to reduce emissions of carbon dioxide and other greenhouse gasses, and thereby help to mitigate climate change. Nuclear energy provides a vital complement to renewables such as wind and solar power, which are intermittent sources of energy. 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 while achieving its development goals. 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.

6. STAKEHOLDER ENGAGEMENT IN KENYA'S NUCLEAR POWER PROGRAMME

Stakeholder involvement and public consultation is an essential part of a new and operating nuclear energy programme. Involving stakeholders enhances public confidence, awareness and understanding in the application of nuclear science and technology and the purpose to build trust through an inclusive approach to enable all stakeholders to make known their views and to ensure that these views are addressed/considered. The Agency recognizes that stakeholder engagement for a nuclear power programme is a continuous exercise which is undertaken throughout the lifespan of a nuclear power plant and therefore, it shall endeavor to sustain strategic partnerships and collaborative partnerships with all key stakeholders.

With respect to broadening public knowledge and understanding of Kenya's nuclear power program, the Agency has been conducting stakeholder engagement initiatives at national and local host community levels through collaborative, consultative, and educational approaches. The channels of these engagements include various media and platforms such as county forums, engagement with policy makers, potential host communities, professional bodies, industries, and academia among others. These engagements have been executed by implementing NuPEA's Stakeholder Involvement and Public Communication Strategy.

At national level, the Agency has undertaken extensive engagement with relevant stakeholders to raise awareness of the nuclear power programme in Kenya such as:

- The National Energy Conference in 2014;
- Third Regional Conference on Energy and Nuclear Power in Africa in 2015;
- Kenya Nuclear Energy Week & Regional Conference; International Conference on Nuclear Energy in 2017;
- African Business Platform in 2019;
- Nuclear Students Ambassadors Program and Mentorship in 2021;
- Essay Contests in 2020 and 2023;
- Public participation forums on the Strategic Environmental Assessment (SESA) of Kenya's nuclear power programme; and the Nuclear Regulatory Act 2019.

Between 2020 and 2023, the Agency conducted public participation forums for the Strategic Environment Assessment process in 22 counties. This provided a platform for gathering and analyzing comments and incorporating them into the report. The first round of consultations was conducted within the following Counties: - Kwale County, Mombasa County, Kilifi County, Kisumu County, Siaya County, Busia County, Homabay County, Migori County, Turkana County, Uasin Gishu, Nandi County, Kericho County, Bomet County, Nakuru County, Murang'a County, Meru County, Embu County, Lamu County, Nyeri County, Tana River County, Kitui County, Garissa County. The second round of consultations were conducted to validate the views that had been reported in the draft report. These were conducted within 18 Counties initially visited. This exercise was concluded in a National Validation Workshop on 24th March 2023 to cover the nation as a whole.

NuPEA established a project coordinating office in Mombasa County, to undertake structured stakeholder engagements and site related activities specific to the Coast region, with a focus on the host community. It is envisaged that this close proximity by the Agency to the proposed host community will help to boost the Agency's efforts to further progress in stakeholder sensitization about the government's plan to implement its nuclear power programme and related projects in Kilifi County.

In the host communities of Uyombo and the larger Matsangoni, the Agency has undertaken sensitization engagements on nuclear energy for stakeholders drawn from various community organized groups and institutions in the coast region including:

1. The local National Government Administration – Kilifi County Commissioner's Office
2. Uyombo-Matsangoni community committee
3. County governments of Kilifi and Kwale
4. Religious groups
5. Youth groups
6. Women groups
7. People Living With Disabilities (PWDs)
8. Beach Management Units (BMUs)
9. Retired Government Officers
10. Academic institutions
11. Journalists
12. Village elders
13. Nyumba Kumi (community police)
14. Kilifi County Government Nuclear Energy Committee
15. Civil Society Organizations
16. Professional groups
17. Farmers

At the host county, the Agency in collaboration with the International Atomic Energy Agency (IAEA) held a workshop on stakeholder involvement and nuclear power communication at Silver Palm Spa and Resort. The objective of the workshop was to incorporate nuclear industry expert perspectives to enhance public understanding of nuclear energy matters, and to develop capacity related to stakeholder involvement, for the key stakeholders involved in Kenya's nuclear power programme.

Overall, NuPEA's approach underscores a commitment to transparency, inclusivity, and ongoing dialogue with stakeholders to ensure informed decision-making and public trust in Kenya's nuclear power programme.

Unlocking the Potential of Carbon Credits: Engineering Solutions for Climate Resilience in Kenya

By EiK Correspondent

The world in the recent past has faced unprecedented climate change, prompting professionals in all sectors to apply innovative solutions to mitigate its impacts. One such emerging solution that has gained global traction is the carbon credits. By incorporating these credits into engineering solutions, Keny has a unique opportunity to not only enhance its climate resilience but also foster sustainable development. Kenya, just like many other countries, has been the victim of climate change which has presented in the form of flooding and other adverse weather changes. The integration of carbon credits into engineering systems could offer multifaceted benefits, from reducing emissions to driving local economic growth.

What Are Carbon Credits, and Why Do They Matter?

Carbon credits, or carbon offsets, are market-based instruments designed to reduce global carbon emissions by allowing entities to "offset" their emissions by investing in projects that capture or prevent the release of greenhouse gases. Essentially, a carbon credit represents the right to emit one metric ton of CO_2 or its equivalent in other greenhouse gases, such as methane, nitrous oxide, and fluorinated gases. The value of carbon credits stems from their ability to finance projects that either sequester carbon, such as reforestation efforts, or reduce emissions through the adoption of cleaner technologies.

The most notable mechanism for generating carbon credits is the Clean Development Mechanism (CDM), established under the Kyoto Protocol. This mechanism encourages investment in emission-reduction projects in developing countries like Kenya, where the cost of emission reductions tends to be lower. By selling these credits on the global market, Kenya can simultaneously generate revenue while fostering sustainable development through technology transfer, capacity building, and improved infrastructure.

How Can Carbon Credits Support Engineering Solutions in Kenya?

Kenya's vulnerability to climate change is becoming increasingly evident through extreme weather events such as droughts, floods, and unpredictable rainfall patterns. These climatic shifts have profound implications for agriculture, water supply, and infrastructure, sectors that are particularly critical for the nation's economy. Engineering solutions have a pivotal role to play in addressing these challenges, and carbon credits can be instrumental in enabling these solutions.

One area where carbon credits can directly contribute is through the development of climate-resilient infrastructure. The construction of buildings, roads, and bridges that are designed to withstand extreme weather conditions often requires significant investment. By leveraging carbon credits, Kenya can finance the development of these resilient systems, ensuring that infrastructure projects are both sustainable and adaptable to future climatic scenarios. For instance, engineering innovations that incorporate green building techniques, energy-efficient designs, and alternative construction materials could be incentivized through carbon credit generation.

How Renewable Energy Projects Can Harness Carbon Credits

One of the most significant opportunities for our country lies in the renewable energy sector. As the country strives to reduce its dependency on fossil fuels, the integration of clean energy solutions such as wind, solar, and geothermal power presents a promising avenue for generating carbon credits. Kenya is already a leader in the geothermal sector, with vast untapped potential in its Rift Valley region. By scaling up the development of geothermal and other renewable energy resources, this country could not only meet her growing energy demands but also generate carbon credits by reducing reliance on fossil-fuel-based energy production.

In particular, solar energy projects have the potential to benefit from carbon credits in rural and off-grid communities. The integration of photovoltaic solar systems into rural electrification projects could drastically reduce emissions by displacing the use of traditional biomass fuels such as firewood and charcoal. Furthermore, these systems offer significant improvements in energy access, enhancing quality of life while simultaneously reducing deforestation rates, which contributes to carbon sequestration.

Carbon Credits and Sustainable Agriculture

Agriculture is the backbone of Kenya's economy, yet it is highly susceptible to climate variability. Traditional farming practices, including slash-and-burn techniques, have led to deforestation and soil degradation, exacerbating carbon emissions. However, sustainable agricultural practices, which promote soil health, biodiversity, and reduced emissions, are gaining traction. Through carbon credit schemes, farmers are incentivized to adopt these methods.

Engineering solutions that support sustainable farming practices—such as precision agriculture, efficient irrigation systems, and agroforestry—can be integrated with carbon credit mechanisms to enhance climate resilience. For example, soil carbon sequestration projects, which involve engineering solutions like biochar production or cover cropping, can generate carbon credits by capturing CO2 from the atmosphere and storing it in the soil. These projects not only sequester carbon but also enhance the long-term productivity and resilience of agricultural lands.

What Role Can Carbon Credits Play in Forest Conservation?

Kenya's forests, particularly the Mau Forest Complex and the Aberdare Range, are crucial to our nation's ecological balance, providing vital water resources, carbon sequestration, and biodiversity. However, these forests are under constant threat from illegal logging, deforestation, and land degradation. Carbon credits are a means through which forest conservation efforts can be funded, hence creating a sustainable economic incentive for the protection of these critical and highly endangered ecosystems.

Engineering innovations in forest management, such as the development of forest monitoring systems, improved land-use planning, and community-based conservation strategies, are other avenues that can be explored using carbon credit revenue. By promoting reforestation, afforestation, and agroforestry, Kenya can generate carbon credits while restoring vital ecosystems that provide a wide range of ecosystem services. The sale of these credits could fund further restoration efforts, contributing to long-term environmental sustainability.

Conclusion

In conclusion, carbon credits hold immense potential for unlocking engineering solutions that foster climate resilience in Kenya. As global climate goals tighten, Kenya's ability to leverage its natural resources and engineering expertise through carbon credit markets will be key to achieving both environmental and socio-economic prosperity.

Building Kenya's Sustainable Future: Aligning With the 15 billion Tree Initiative and Climate-Resilient Infrastructure by 2032

By EiK Correspondent

Kenya stands at a crucial juncture in its journey toward a sustainable future. Climate change has brought with it radical challenges, including but not limited to erratic rainfall, prolonged droughts, and frequent flooding. All this point to one sure conclusion: the solutions to these problems must be multifaceted. One of the most ambitious and promising initiatives aimed at mitigating these challenges is the 15 billion Tree Initiative, launched by the Kenyan government in 2022. The initiative seeks to plant 15 billion trees by 2032, a bold step towards combating deforestation, restoring ecosystems, and enhancing climate resilience. However, the success of this initiative hinges not just on the planting of trees but on how these efforts are integrated with the development of climate-resilient infrastructure.

What Role Do Trees Play in Building Climate Resilience?

The 15 billion Tree Initiative goes way beyond just planting trees; it is about revolutionizing Kenya's relationship with nature and its infrastructure. Trees have long been recognized for their role in carbon sequestration, but their benefits extend far beyond this. In regions where climate change has intensified, such as the semi-arid areas in northern Kenya or flood-prone regions along major rivers, trees can potentially mitigate environmental extremes.

When trees are planted along riverbanks, they stabilize soil and prevent erosion, which is particularly crucial for protecting infrastructure such as roads, bridges, and water reservoirs. In urban areas like Nairobi, tree cover combats the urban heat island effect by cooling the cities, reducing dependance on air conditioning, and contributing to better air quality. Additionally, trees help manage rainfall by increasing water retention in the soil, thus reducing surface runoff which has been a major propeller of floods. Through these natural processes, trees become a key component of a larger strategy to enhance Kenya's climate resilience.

One prominent example of this synergy is found in Kenya's restoration efforts in the Tana River Basin, where tree planting along riverbanks has significantly reduced soil erosion and flooding, ultimately protecting surrounding infrastructure. This reflects the broader potential of combining tree planting with climate-resilient infrastructure to mitigate the impacts of both floods and droughts, two of Kenya's most pressing climate challenges.

Contribution of Engineers to the Integration of Trees and Infrastructure

Integrating the 15 billion Tree Initiative with infrastructure development requires the engineering sector to embrace green infrastructure, a concept that merges the natural benefits of trees with built structures. This approach emphasizes the use of nature-based solutions to enhance infrastructure resilience while promoting environmental sustainability.

In urban areas, the incorporation of tree planting into infrastructure projects can result in more sustainable cities. Green roofs, tree-lined streets, and permeable pavements can all reduce the urban heat island effect, enhance water management, and provide much-needed green spaces. These elements not only contribute to improved quality of life for urban dwellers but also serve as critical components in managing the effects of climate change.

In Nairobi, projects like the Karura Forest and Ngong Forest have demonstrated how green spaces can simultaneously provide environmental benefits, enhance urban biodiversity, and serve as critical water catchments all while lending to the social aspects of having these spaces. These forests help maintain groundwater levels, improve air quality, and reduce flood risks. Expanding such projects throughout the country by integrating tree planting with infrastructure development could significantly increase Kenya's climate resilience by mitigating the impacts of climate change while reducing infrastructure costs in the long term.

Can the 15 billion Tree Initiative Address Infrastructure Vulnerabilities?

Kenya's infrastructure, including roads, bridges, and dams, is vulnerable to the increasing effects of climate change. Rising temperatures, erratic rainfall, and flooding present significant risks to the integrity of these structures. The 15 billion Tree Initiative presents a unique opportunity to address these vulnerabilities through a holistic approach to land management and infrastructure development.

For instance, the reforestation of watersheds and riverbanks can help prevent soil erosion and landslides, which frequently undermine the structural integrity of infrastructure such as roads and bridges. One example of this is the Mau Forest, where large-scale reforestation projects have helped stabilize the watershed, ensuring that rivers maintain their flow without excessive sedimentation. This, in turn, has reduced the need for costly infrastructure repairs and improved water management for both urban and rural areas.

Moreover, the use of trees to mitigate climate risks also extends to agricultural infrastructure. In regions prone to drought, the use of drought-resistant tree species for agroforestry can help improve soil moisture retention and enhance the resilience of crops. Engineering solutions that integrate such systems with irrigation technologies—such as drip irrigation or rainwater harvesting systems—can reduce the risk of crop failure and water scarcity. These efforts align with the broader goals of the 15 billion Tree Initiative, providing long-term solutions to climate resilience while also boosting agricultural productivity.

How Can Policy and Stakeholder Collaboration Accelerate the Vision of a Resilient Kenya?

Achieving the vision of planting 15 billion trees by 2032 requires not only technical and engineering solutions but also strong policy frameworks and stakeholder collaboration. The role of the government, local authorities, and private sector entities is critical in creating an enabling environment for the successful integration of tree planting with infrastructure development.

Policies that promote sustainable land use, encourage the use of green technologies in infrastructure projects, and incentivize private sector investment in reforestation can accelerate the achievement of the 15 billion Tree Initiative. In addition, engaging communities in tree planting efforts and raising awareness about the benefits of sustainable land management will foster broader participation and ensure the long-term success of the initiative.

Engineering projects that focus on green infrastructure should be supported through policy incentives, ensuring that climate resilience becomes a key priority in national development. For example, urban planning regulations could be amended to require new buildings to incorporate green roofs or tree-lined streets, while rural development projects could integrate agroforestry practices into agricultural planning.

Conclusion

The integration of the 15 billion Tree Initiative with climate-resilient infrastructure offers Kenya an opportunity to tackle the interconnected challenges of climate change, deforestation, and infrastructure vulnerability. By 2032, Kenya has the potential to lead the way in demonstrating how the harmonious integration of nature and engineering can build a truly climate-resilient nation.

Seedling Planting

Kenya's Road to Net Zero Carbon Emissions

By EiK Correspondent

Climate change is a major threat to Kenya as it touches many parts of life, including agriculture, water sources, health, and infrastructure. As a developing country, Kenya is facing numerous stringent economic pressures which prevent it from investing in climate change mitigation and adaptation measures. The cost of the transition to renewable energy, which includes the strengthening of infrastructure resilience and the promotion of sustainable agricultural practices, are areas where the money usually goes which are considered more important.

"Financial limitations are the primary barrier to effective climate change management in Kenya," says Faith Karanja who is an environmental economist at the University of Nairobi.

"Even though the government acknowledges the need to address climate change, lack of resources and competing development priorities hinder the appropriate allocation of such funds to this purpose," she adds.

Further to this, Kenya's infrastructure especially in rural areas is usually not capable of countering the impacts of climate change for instance severe weather events.

The Kenya National Adaptation Plan (NAP) says that infrastructure resilience is one of the main priorities for the country's development. "The resilience of the Infrastructure to Climate Change is one of the main critical things for sustainable development. This involves big investments in technology, capacity building, and infrastructure improvements," the NAP says.

Despite dealing with the said challenges, there are initiating steps that Kenya can opt for to counter climate change and make it more resilient to its effects. Kenya has made some remarkable achievements in this regard such as the exploitation of renewable energy sources, especially geothermal, wind, and solar power. Expanding these efforts can considerably reduce the nation's dependence on fossil fuels and thus, overcome the problem of greenhouse gas emissions.

A report by the Kenya Electricity Generation Company (KenGen) states that renewable energy sources covered around 75% of the total power generation in Kenya in 2020. "The main incentive for economic growth and energy security would be the reduction of emissions, which should be the first goal and can be achieved only with renewables," KenGen adds.

"Kenya is a country endowed with vast renewable energy potential, and exploiting this potential is crucial for our sustainable development," says KenGen.

Eco-friendly agricultural techniques can aid in challenges faced by climate change on food availability and livelihoods. This involves the dissemination of climate-smart agriculture, a combination of the latest sustainable land management techniques, better crop varieties, and high-efficient water use.

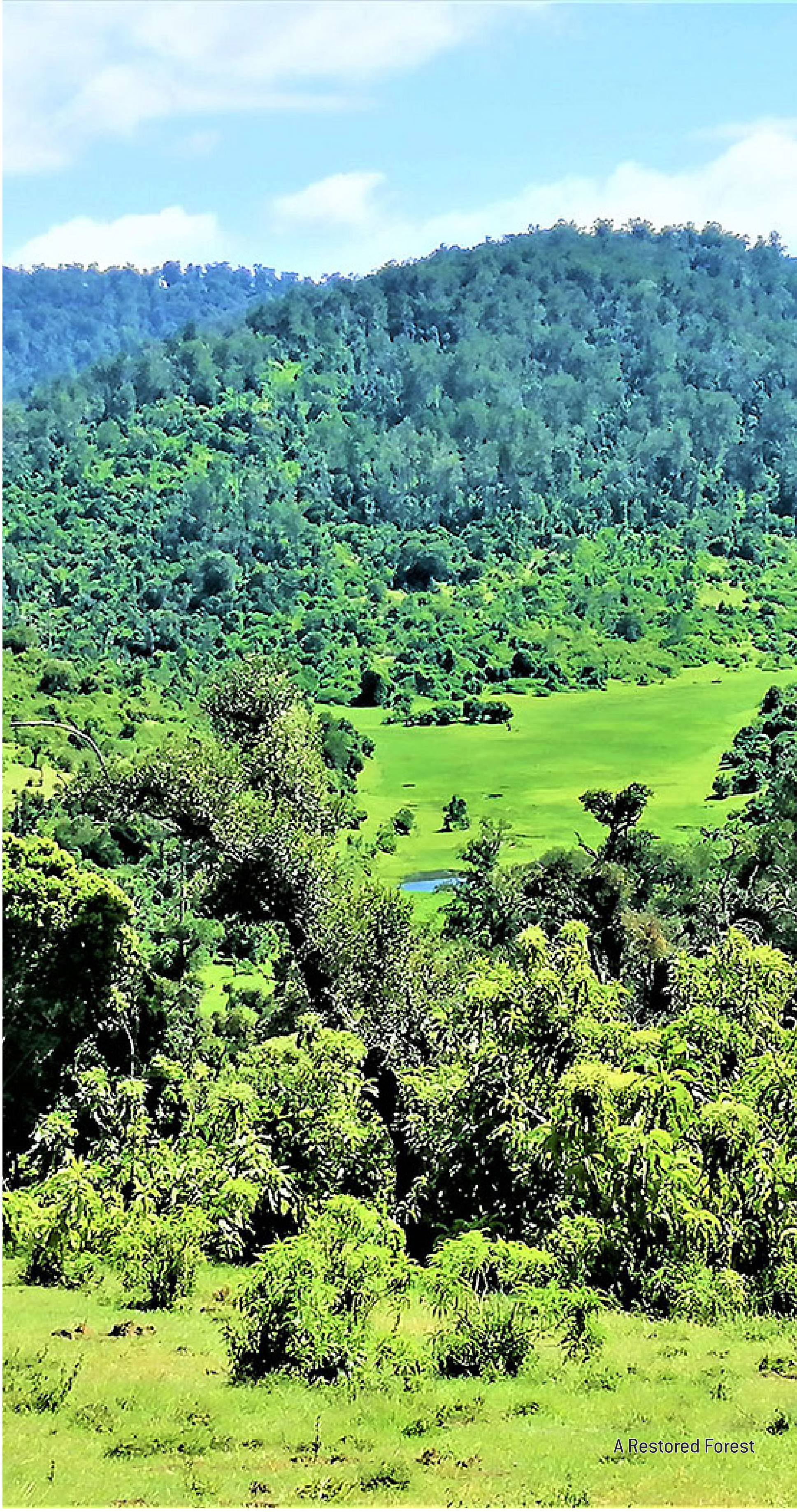
The Food and Agriculture Organisation (FAO) reaffirms the significance of the aforementioned practices, their role in the promotion of productivity, and CO_2 emissions reduction. It also highlighted that they are the eco-friendly measures to be taken.

According to the United Nations Environment Programme (UNEP), climate-smart agriculture is indeed vital for the development of resilient agriculture in our country. "By receiving knowledge from sustainable farming, farmers can increase yields of crops, maintain resources, and become more resilient to climate variations," UNEP stated.

Strengthening institutional frameworks and good governance is crucial for proper management of climate change. The creation of the State Department for Environment and Climate Change under the Ministry of Environment, Climate Change and Forestry is a vital step in this direction.

Furthermore, improving on public engagement and awareness is indispensable for generating community support for climate actions. This can be done through various institutional partnerships and leveraging media and technology to disseminate information

Although climate change mitigation in Kenya has proven to be a complex transition, the country will be able to control its effects and have a substantial flexibility that will grant us a safe future.


A Restored Forest

HOW KENYA IS HARNESSING SOLAR POWER TO LIGHT UP OFF-GRID AREAS: FUTURE RURAL ELECTRIFICATION AND RENEWABLE ENERGY

Author

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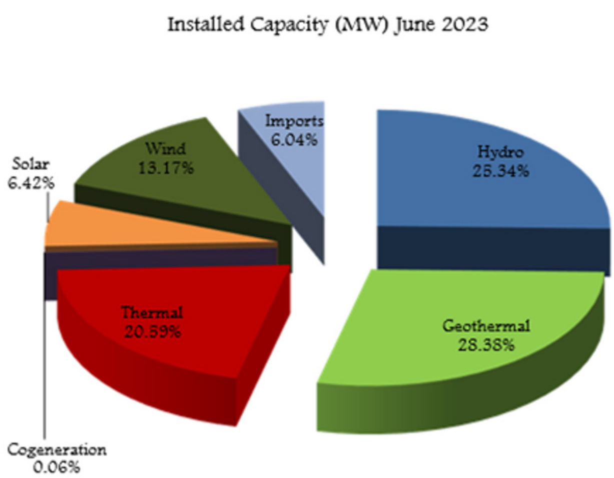
Background

The unbundling of the Kenya Energy sector resulted in separation of electrical generation, transmission and distribution into three different state agencies unlike before when the Kenya Power Company was the sole entity in charge of the entire electrical power supply chain. The formation of Ketraco (Kenya Electricity Transmission Company), KenGen (Kenya Electricity Generating Company) and KPLC (Kenya Power & Lighting Company) was the beginning of the horizontal integration of the power sector. Each of these entities has a distinct mandate. KenGen is the power producer (generating company), Ketraco is responsible for national and regional transmission, especially on the high voltage lines and development of new transmission infrastructure while KPLC is responsible for distribution and retail supply to end users. KPLC still retains some generation and transmission functions (on the lower voltage lines) and more so by nature of resources initially developed by Kenya Power Co that cannot be transferred to Ketraco and KenGen. The need for regulation and policy also necessitated formation of the Energy Regulatory Commission (ERC) to regulate the energy sector. ERC was upgraded to Energy & Petroleum Regulatory Authority (EPRA) which now regulates electricity, petroleum, natural gas and renewable energy. The Rural Electrification Authority was formed to fast track last mile connectivity and expansion of the National grid to the rural areas at subsidised costs. REA has now upgraded to Rural Electrification and Renewable Energy Corporation (REREC) to include green energy projects. The ministry of Energy and Petroleum carries out the formulation and articulation of the overall power sector policies and creating a favourable environment for the power sector operators.

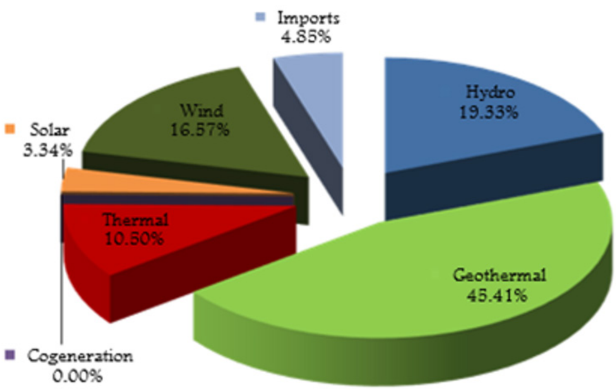
Other than generation by the state owned KenGen there are Independent Power Producers (IPPs) such as Geothermal Development Corporation (GDC), Iberafrica Power EA, Tsavo Power Company, Mumias Sugar Company, Orpower4Inc, Rabai Power Company, Lake Turkana Wind Farm and Imenti Tea Factory Company among others. All these IPPs sell their power to KPLC. The Kenya Nuclear Power and Energy Agency (NuPEA) was formed to strategise and build nuclear power capacity in the country.

Sources of Energy in Kenya

Kenya is a leader in renewable energy production (90%) which includes geothermal, hydro, wind and solar. Other sources include biomass, HFO and petroleum imports. Green hydogen and ethanol are beginning to pick among the new sources of energy. The energy sector is optimistic about developing a wide range of sources depending on capacity to generate. Tidal energy may also be considered given the proximity to the Indian Ocean, Lake Victoria and other lakes within the country. Nuclear energy production is yet to pick, the first power plant may take the next decade to actualise. The current electrical generated capacity is 3GW with an expected 5GW by 2030.



Generation Mix (MWh) June 23



source: https://www.trade.gov/country-commercial-guides/kenya-energy-electrical-power-systems

The government is providing 2000MW while the IPPs are producing the remaining 1000MW. Considering the population explosion in Kenya and Africa (by 2030 one in every four youthful people will be from Africa) and the need to power the digital transformation age, enormous power is required in the next few years. IOT, AI and other emerging technologies will drive systems that consume huge amounts of power. For instance the national/regional data and plant control centres, EV charging systems, smart building and transportation systems will lead to tripling or quadrapling of demand. New storage facilities are being developed such as solar stacked batteries, super fast charging systems and compressed air but the National grid needs to build sufficient capacity to meet this demand.

The main source of electricity in Kenya has remained hydro electric generation. In the last two decades geothermal power has overtaken and still has potential for 10GW generation up from the current 1GW. Wind energy has potential of 3GW. The potential for solar energy on the other hand is enormous given the sunny climate throughout the year. There are plans to tap solar power to reach remote communities that are still far from the National grid. KenGen and KPLC will also migrate the off grid diesel plants to solar hybrid stations hence building capacity for off grid green energy storage.

Solar Power

The estimated potential for solar energy is 15GW. The current installed capacity is less than 200MW. The largest installation is Garissa solar plant at 55MW, which is powering 625,000 homes. So far the government has approved more than 35 projects under the Feed-in-tariff. Almost 10 projects have kicked off and more are expected to begin construction soon.

The 2024 Energy regulations (Electricity Market, Bulk Supply and Open Access) will end the current Ketraco and KPLC monopoly in transmission and distribution and provide open access for the same by private distributors. These feed-in-tariff operators will increase competition, efficiency and reliability and improve the quality of service in the electricity market. They will also attract more investment in generation, transmission, distribution, and retail supply. The electrical grid has been evolving from a centralized monopolistic and government controlled network to a distributed and liberalized network, which can also be managed and controlled at various regional centres. This will increase electrical power reliability by moving away from one point of failure in a centralised network. Automating the grid and introducing energy management systems will also provide a self healing network that can quickly locate faults and reconfigure itself.

Based on the distributed model solar plants will compete favourably as the power supply can be localised to various regions. Unlike hydro and geothermal, solar power is DC and cannot be carried over long distances. For those areas that are so far away extending the National grid network may take such a long time. Solar power comes in handy as the licensed operators can generate low capacities and distribute in the neighbourhoods. Below are the tariff rates for feed-in-tariffs (FITs).

The FiT values for small renewable projects (up to 10 MW of installed capacity) connected to the grid

	Installed capacity (MW)	Standard FiT (US $/ kWh)	Percentage Escalable portion of the Tariff	Min. capacity (MW)	Max. capacity (MW)
Wind	0.5 -10	0.11	12%	0.5	10
Hydro*	0.5	0.105	8%	0.5	10
	10	0.0825			
Biomass	0.5-10	0.10	15%	0.5	10
Biogas	0.2-10	0.10	15%	0.2	10
Solar (Grid)	0.5-10	0.12	8%	0.5	10
Solar (Off-grid)	0.5-10	0.20	8%	0.5	1

*For values between 0.5-10MW, interpolation shall be applied to determine tariff for hydro.

Upto 10 MW

The FiT values for renewable projects above 10 MW of installed capacity

	Installed capacity (MW)	Standard FiT (US $/ kWh)	Percentage Escalable portion of the Tariff	Min. capacity (MW)	Max. capacity (MW)	Max. Cumulative capacity (MW)
Wind	10.1-50	0.11	12%	10.1	50	500
Geothermal	35-70	0.088	20% for first 12 years and 15% after	35	70	500
Hydro	10.1-20	0.0825	8%	10.1	20	200
Biomass	10.1-40	0.10	15%	10.1	40	200
Solar (Grid)	10.1-40	0.12	12%	10.1	40	100

Above 10 MW

source: Ministry of Energy -Feed-in-Tariffs Policy nn Wind, Biomass, Small-Hydro, Geothermal, Biogas and Solar Resource Generated Electricity - 2012

The other advantage of solar power is the stand alone model. Any person who needs electricity can just purchase solar panels, inverter, batteries, controller etc and install without any requirement for the last mile grid availability. This enables faster connectivity.

Applications

Solar energy has a huge potential to transform rural areas. Applications include lighting homes, businesses and institutions. Solar power will lower carbon emissions by reducing over reliance on kerosene and wood biomass. Children will be able to study at night hence improving education standards. Solar water pumps will provide clean water for drinking and water for irrigation therefore improving people's health by reducing water borne diseases and boosting agricultural produce. Powering radios, TVs, refrigerators and other devices can improve quality of life by giving rural folk access to information and entertainment through mass media, facilitating online and remote work by use of computers and providing charging facilities for mobile phones and electric cars.

Providing solar lighting in markets and town centres will improve security hence extend hours for business. Street lights will improve visibility when driving at night especially for public transport.

Solar can be used to power rural industries, health facilities, schools, markets, homes and all the facilities. Raising the quality of life in rural areas will reduce rural-urban migration as people can access uniform facilities everywhere.

Besides, solar energy will also create jobs through supply, installation and maintenance of the solar systems. A case is M-kopa which employs over 1000 people in Kenya and Uganda.

Hence there is need to tap into this capacity for economic growth of the country.

Conclusion

The Institution of Engineers of Kenya recognizes the significant progress that has been made in the Energy sector, as well as the challenges that remain. By working together, the government, market players, and other stakeholders can address these challenges and unlock the full potential of solar mini grids for the benefit of all Kenyans. The IEK remains committed to supporting these efforts and contributing to the realization of Kenya's digital future.

Harnessing Agricultural Waste: The Role of Engineers in Biomass Energy Revolution

Author | ***Vivian Njagi***

As the global push for renewable energy intensifies, Kenya has emerged as a leader in leveraging agricultural waste for clean energy production. Biomass energy, which harnesses organic materials like agricultural residues, is playing a transformative role in addressing energy insecurity and environmental challenges. At the heart of this revolution are engineers, mechanical, chemical, and electrical whose expertise is driving innovation in briquette and pellet production. Companies like Lean Energy Solutions Ltd exemplify this effort, turning waste into value and paving the way for a sustainable energy future.

Biomass Energy: Turning Waste into Power

Biomass energy utilizes organic materials, including coffee husks, maize stalks, and sugarcane bagasse, to create clean and efficient fuels. Unlike traditional wood or charcoal, biomass products like briquettes and pellets are eco-friendlier and more efficient. According to Lean Energy Solutions Ltd, their Lean Briqs are an innovative alternative to coal and wood in industrial boilers and kilns, boasting a high calorific value of 3800–4200 Kcal/Kg, low ash content (6–8%), and carbon neutrality.

These advantages make biomass energy a cornerstone of Kenya's renewable energy portfolio, addressing industrial and domestic energy needs while combating deforestation and greenhouse gas emissions.

The Role of Engineers in Biomass Energy

Mechanical Engineers: Innovating Production Equipment

Mechanical engineers are at the forefront of creating the machinery that transforms agricultural waste into briquettes and pellets. Their contributions include:

Designing Specialized Machinery: Engineers develop compactors and extrusion machines to compress agricultural residues and coffee husks into uniform briquettes. These machines ensure consistency in size, density, and durability.

Efficiency Optimization: Continuous improvement of machinery reduces energy consumption and enhances throughput, making the production process cost-effective and sustainable.

Maintenance and Reliability: Ensuring the reliability of machinery through proactive maintenance is crucial to uninterrupted production.

Chemical Engineers: Enhancing Combustion and Sustainability

Chemical engineers focus on improving the combustion properties of biomass products and minimizing environmental impact. Key roles include:

Material Analysis: Engineers determine the calorific value, moisture content, and other properties of agricultural residues to ensure suitability for production.

Combustion Efficiency: By optimizing the mix ratios and incorporating additives, chemical engineers enhance combustion efficiency and reduce emissions.

Emission Control: Processes designed by chemical engineers help control pollutants like sulfur oxides and particulate matter, ensuring cleaner energy solutions.

Electrical Engineers: Driving Automation and Energy Efficiency

Electrical engineers play a vital role in automating biomass production lines and integrating renewable energy sources into operations. Their contributions include:

Automation: Designing programmable logic controllers (PLCs) and control systems streamlines production, improving precision and reducing labor costs.

Energy Optimization: Engineers enhance energy efficiency by incorporating energy recovery systems and ensuring machinery consumes minimal power.

Integration with Renewables: Facilities can be powered by solar or wind energy, reducing the carbon footprint of biomass production.

Briquette and Pellet Production: A Case Study

Lean Energy Solutions Ltd has demonstrated how agricultural waste can be transformed into sustainable energy products. The company's process begins with the collection and preparation of materials like maize cobs, coffee husks, and sugarcane bagasse. These materials are dried, ground, and mixed in precise ratios before being compacted into cylindrical briquettes. Finally, the briquettes are dried to enhance durability and shelf life, then packaged for distribution.

This production process highlights the seamless collaboration between mechanical, chemical, and electrical engineers, ensuring high-quality products that meet market demands.

Benefits of Biomass Energy

Biomass energy offers numerous advantages for Kenya's energy landscape:

1. Environmental Conservation: Biomass products reduce deforestation and are carbon-neutral, as the carbon released during combustion is offset by plant growth.
2. Energy Security: By utilizing local agricultural waste, Kenya reduces its dependence on imported fossil fuels.
3. Economic Opportunities: The sector generates jobs in raw material collection, production, and distribution.
4. Cost-Effectiveness: Briquettes and pellets are affordable and efficient, offering a practical alternative to traditional fuels.

Lean Energy Solutions Ltd emphasizes the eco-friendliness of their Lean Briqs, noting their low sulfur content, which allows maximum heat recovery while minimizing environmental impact.

Overcoming Challenges in Biomass Energy

Despite its potential, biomass energy faces hurdles such as logistical challenges in raw material collection, limited access to advanced technology, and low market awareness. Lean Energy Solutions Ltd underscores the need for continued investment in research, development, and public awareness to unlock the full potential of biomass energy.

The Path Forward

The future of biomass energy in Kenya lies in innovation, collaboration, and commitment to sustainability. Engineers will continue to play a pivotal role in refining technologies and processes, ensuring biomass energy remains a viable and impactful solution.

As Lean Energy Solutions Ltd demonstrates, the integration of engineering expertise and agricultural waste can yield transformative results. Biomass energy is not just an alternative; it's a necessity for a sustainable future and so Kemya is not only addressing its energy needs but also setting an example for the world on the power of renewable resources.

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The College also organizes seminars and discussion forums on topical issues in the Insurance industry. Such seminars are normally announced in the press from time to time. Other services offered include; Catering Services, Conferencing Services, Team building and wedding spaces

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STUDENTS' VOICES

Name: Diana Moraa

Age:23

University: JKUAT

Major/Program: Agricultural and Biosystems Engineering

Year of Study:5th

Over the years, I have witnessed farmers facing challenges due to climate change. This inspired me to pursue environmental engineering and make a tangible impact on the world. I am particularly drawn to waste management and sustainable energy because both areas contribute to reducing carbon emissions and resource conservation.

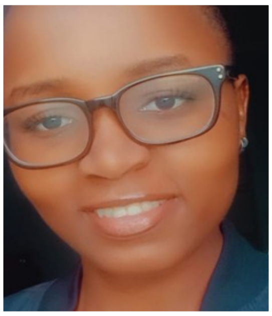
One challenge I faced in my early years was complex mathematical units (calculus, ODE, BPE). Every engineer can attest to this. I overcame this by forming study groups and utilizing online resources.

JKUAT has played a pivotal role in shaping my career by providing both technical skills in terms of intern workshops attachment and practical applications. In partnership with government waste management institutions, we are given real life experiences.

I had the opportunity to be attached to Mananasi Fiber Limited. Where I applied theoretical knowledge on carbon sequestration and water recycling techniques. I got a deeper understanding of sustainable practices and project management.

JKUAT offers programs like Sustain AM, triggering innovation and encouraging collaboration through interdisciplinary projects. These experiences enhanced my problem-solving skills.

Environmental engineers can significantly impact sustainable infrastructure development. My education, with a focus on sustainable design, has equipped me with the knowledge and skills to contribute effectively in this area.



Name: Catherine Njeri Karanja

Age: 22 years

University: Machakos University

Major/Program: Bachelor of science in Civil Engineering

Year of Study: 5th year

Environmental engineering is particularly fulfilling for Civil Engineering students and a noble cause to work toward building a sustainable world by innovatively developing technologies that can address a range of environmental issues. This and the ability of this field to contribute towards solving global issues such as, climate change and water scarcity fuels my passion.

I am captivated by the aspects of sustainable energy since they can significantly address challenges of climate change. The greatest challenge has been balancing theoretical studies and practical, though projects and an attachment at Losai Management have equipped me with practical experience. According to my curriculum I am well prepared in areas including waste management and pollution control and I have developed essential problem-solving skills. Internships were very helpful, especially the involvement in the project focused on the water treatment design, which showed that environmental problems are not a simple matter of finding a solution.

Am certain that environmental engineers could bring great contributions to renewable energy and integration as well as urban growth. This readiness is due to my education, where flexibility, technical skill, and systems thinking as applied to environmental issues have been stressed.

STUDENTS' VOICES

Name: Murage Moffat Muraya

Age: 26 years

University: University of Eldoret

Program: Bachelor of Engineering - Civil and Structural Engineering

Year of Study: 4th

Driven by the urgent need to address environmental degradation from human activities like urbanization and agriculture, I was inspired to pursue a career in environmental engineering. This field offers innovative solutions to mitigate climate change, reduce pollution, and promote sustainable resource management, aligning with the United Nations Sustainable Development Goals.

I am particularly passionate about solving waste management and climate change challenges, as poor waste disposal significantly impacts ecosystems, human health, and water quality. My university education has provided a solid foundation in public health engineering and wastewater treatment, complemented by practical lab sessions and case studies that sharpen my analytical and problem-solving skills.

My hands-on experience includes an Environmental Impact Assessment (EIA) project in Kiambu during an industrial attachment in May 2024. This project deepened my understanding of integrating sustainable practices into structural design, emphasizing the importance of balancing development with environmental protection.

The University of Eldoret has further nurtured my growth through access to state-of-the-art laboratories, interdisciplinary projects, and collaborative research initiatives. These opportunities have enhanced my teamwork and innovation skills, preparing me to tackle pressing global issues.

As I enter the workforce, I am equipped to drive impactful solutions in waste management, renewable energy, and pollution control, contributing to a cleaner, more sustainable future.

Name: Edrian Onyango

Age: 23 Years

University: University of Eldoret

Major/Program: Civil and Structural Engineering

Year of Study: 5th

University engineering students are at the forefront of addressing global environmental challenges, leveraging their education to develop impactful and sustainable solutions. Inspired by the devastating effects of pollution, particularly in Kenya, I have grown passionate about applying engineering principles to environmental protection.

Water pollution management stands out as a critical challenge in Kenya. My focus is on innovative wastewater treatment technologies to ensure safe and sustainable water resources. Despite limited integration of environmental engineering into my civil and structural engineering curriculum, I have proactively sought additional knowledge through external research and practical experiences.

The University of Eldoret has equipped students with a strong foundation in environmental conservation through courses on hydrology, solid waste management, and environmental engineering. Field trips, site visits, and laboratory sessions complement theoretical knowledge, enhancing hands-on skills. Trough internships I have been able to deepened my understanding of environmental regulations, data analysis, and sustainable project implementation.

My participation in trade fairs, research projects, and community initiatives such as clean-up drives and renewable energy studies has honed my research and critical thinking skills. These opportunities have demonstrated the potential of young engineers to address issues like waste management, pollution control, and sustainable infrastructure.

Collaboration and innovation between engineering firms and institutions can strengthen industry-education linkages, empowering engineering students to drive significant progress toward a sustainable future for humanity and the planet.

STUDENTS' VOICES

Faith Nguna Mutinda

Age :22

Murang'a University of Technology

BSC in Electrical and Electronics Engineering

Year of Study: 5th Year

I would like to thank my college for all the support in developing my skills in renewable energy systems. In my studies, I perfected solar PV system design and optimization, including energy and storage integration. This background forms the basis for achieving significant advancement in green technologies in the fight against climate change.

Real-life challenges have sculpted a greater part of my journey. Since there is no electricity at my village, I created awareness in my village on solar energy and helped my parents install solar panels. The hands-on experience not only catered to community needs but also heightened my learning in the mechanisms of renewable energy implementation.

Coursework in electrical installation and protection provided me with the tools for designing efficient systems that reduce waste. Classes on energy policies, smart grids, and climate-informed design broadened my perspective on the role of engineers in adapting to climate change and conducting environmental impact assessments.

These skills were further enriched through my practical exposure. During my work experience at Kenya Power, I had hands-on experience with high-voltage and low-voltage lines, expanding my knowledge in power systems. While at the Machakos Public Works Engineering Department, I designed electrical installations with the help of AutoCAD, refining my technical expertise.

I highly recommend that students be involved in green energy research to equip future engineers with solutions for a sustainable world.

Name: Esther Naliaka

Age: 18 years old

University: University of Eldoret

Major/Program: Civil and Structural Engineering

Year of Study: 1st Year

Transforming Agriculture for Economic Growth

With 80% of Kenya's landmass classified as arid and semi-arid, environmental engineering has emerged as a critical driver in addressing food insecurity through innovative irrigation policies. These strategies leverage modern technologies such as center-pivot systems, pressurized drip irrigation, and gravity-powered micro-irrigation to enhance water efficiency and maximize crop yields. By optimizing resource utilization, these solutions not only improve food production but also bolster farmers' profitability amidst rapid urbanization and population growth.

Organizations like the National Irrigation Authority and the Ministry of Agriculture, Livestock, and Fisheries have played pivotal roles by providing subsidies for water-saving technologies. This support has facilitated the adoption of sustainable practices such as rainwater harvesting, water recycling, and reuse, ensuring a steady water supply across all seasons. These measures have contributed to diversifying agricultural outputs and stabilizing rural economies.

Beyond agriculture, these advancements have spurred industrial growth in the manufacturing sector, creating jobs and narrowing income disparities. The involvement of private and foreign investors in water-scarce regions has further fostered balanced regional development.

Environmental engineers, equipped with innovative solutions, are essential in driving these transformations. Their contributions strengthen Kenya's food security, ensure sustainable agricultural practices, and catalyze economic growth.

STUDENTS' VOICES

Name: David Kariuki

Age: 20

University: Kenyatta University

Major/Program: Agricultural & Biosystems Engineering

Year of Study: 2nd

The urgency of global environmental challenges inspired my pursuit of agricultural and biosystems engineering, focusing on environmental solutions. Growing up in Kenya, I witnessed the effects of climate change, including erratic rainfall and land degradation. These experiences highlighted the importance of engineers in developing sustainable solutions. I believe environmental engineering plays a critical role in addressing challenges like water management, sustainable energy, and pollution control.

I'm particularly passionate about water management, especially in regions with inconsistent access to clean water. One of my goals is to design systems like precision irrigation and wastewater recycling to optimize water usage and enhance food security.

Despite my enthusiasm, my journey has had challenges, particularly connecting theoretical knowledge with real-world applications. I've sought insights from professionals in the field to understand how environmental engineering solutions are implemented in practice.

Kenyatta University's curriculum has introduced me to foundational engineering principles, but I have not yet explored agricultural systems or system design. Through my involvement with the Kenyatta University Engineering Student Association (ESA KU), I've networked with professionals and learned more about how environmental engineers contribute to global challenges. As I continue to prepare for a career in this field, I believe that environmental engineers can make a substantial impact on developing sustainable infrastructure and combating climate change. I'm confident my education is setting a strong foundation for a future in this field.

Name: Abdikafi Abdi Mohamed

University: Kenyatta University

Major/Program: Civil Engineering

Year of Study: Year 4

BUILDING RESILIENCE: THE FUTURE OF GREEN ARCHITECTURE IN THE FACE OF CLIMATE CHANGE

The climate crisis has prompted industries to reassess their sustainability practices. As a structural engineering student and environmental advocate, I am particularly interested in eco-friendly architecture due to its significant impact on global communities. Rising sea levels, unpredictable weather, deforestation, and resource depletion underscore the need for a shift in construction methods. This article explores how green architecture can transform building design in the face of climate change.

Green architecture, or sustainable design, aims to minimize buildings' environmental impact. It utilizes renewable energy, efficient materials, and energy-saving technologies to create structures that adapt to climate change. As extreme weather events increase, enhancing building resilience is essential.

Our infrastructure faces significant challenges due to climate change, as traditional buildings struggle to withstand extreme weather events like hurricanes, floods, and droughts. This situation has created a pressing demand for more durable construction. Environmentally friendly structures, which incorporate sustainable and energy-efficient materials and technologies, are better equipped to endure climate-related disasters.

Green architecture aims to reduce energy consumption and waste, lowering carbon footprints. It utilizes renewable energy sources like solar panels and wind turbines to decrease reliance on fossil fuels. Features such as green roofs and urban gardens help mitigate urban heat islands, improve air quality, and enhance biodiversity, fostering healthier urban ecosystems.

STUDENTS' VOICES

Name: Kipngeno Emmanuel

Age: 22 Years

University: Muranga University of Technology.

Program: Mechanical Engineering.

Year of Study: 3rd Year

Being a third-year Mechanical engineering student, I have realized that my field of study plays a major role in environmental conservation. Flood engineering has in the past helped reduce the impact of rainwater on the environment. Innovations have curbed this through reducing water pollution and destruction of infrastructure hence ensuring environmental sustainability. By encouraging more innovations in this field, it has made the country to establish itself in terms of environmental preservation.

The collaboration between civil and mechanical engineering through integrated project designs has ensured that water management is paramount hence leading to development of sustainable water management and distribution systems.

In the event of overcoming the challenges encountered when navigating through flood engineering; tackling of mathematical models and different kinds of flow models has refined my analytic skills by leveraging more on simulation and fluid dynamic softwares.

However, by engaging in study groups various project related to drainage systems in urban areas have been designed making it easy to implement theoretical solution in to real word scenarios. By adapting a sustainable infrastructure in drainage systems in urban areas has proven helpful occasionally.

My plea is to the Engineers Board of Kenya (EBK) and the Institution of Engineers of Kenya, (IEK) to provide more professional development opportunities and accreditation to Mechanical Engineers which will foster economic and technological advancements.

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 529th and 530th council accepted the following members under various membership categories as shown below;

MEMBERSHIP CLASS	NUMBER ACCEPTED-529TH COUNCIL	NUMBER ACCEPTED-530TH COUNCIL	TOTAL
FELLOW	1	1	2
CORPORATE	5	0	5
GRADUATE	71	51	122
GRADUATE ENGINEERING TECHNOLOGIST	4	3	7
GRADUATE ENGINEERING TECHNICIAN	8	7	15
STUDENT	5	10	15
TOTAL	**94**	**72**	**166**

During the period, we had 2 members who transferred from the class of Corporate to Fellow member and 5 from Graduate to Corporate member. In addition, we had 122 graduates, 7 graduate engineering technologists, 15 graduate engineering technicians and 15 students were accepted as members.

Gender Data

Class	Male	Female	Percentage (Male)	Percentage (Female)
Fellow	2	0	100%	0%
Corporate	4	1	80%	20%
Graduate	96	26	79%	21%
Graduate Engineering Technologist	7	-	100%	0%
Graduate Engineering Technician	13	2	87%	13%
Student	7	8	47%	53%
TOTAL	**129**	**37**	**78%**	**22%**

Summary

Gender	No.	Percentage
Male	129	78%
Female	37	22%
	166	**100%**

529TH APPROVAL

FELLOW

	NAME	MEMBER NO.
	Joseph Odongo Oketch	F. 3462

CORPORATE

	NAME	MEMBER NO.
1	Billman Ongaga Ondieki	M.12158
2	Cynthia Olga Kafwa	M.8712
3	Johnstone Mutisya Mwanthi	M.3758
4	Kimutai Yegon	M.13126
5	Eliud Lemayian	M.4570

530TH APPROVAL

FELLOW

	NAME	MEMBER NO.
	Alex Munyasya Muumbo	F. 3593

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;

REPUBLIC OF KENYA

ENGINEERS BOARD OF KENYA
Enhancing Professionalism

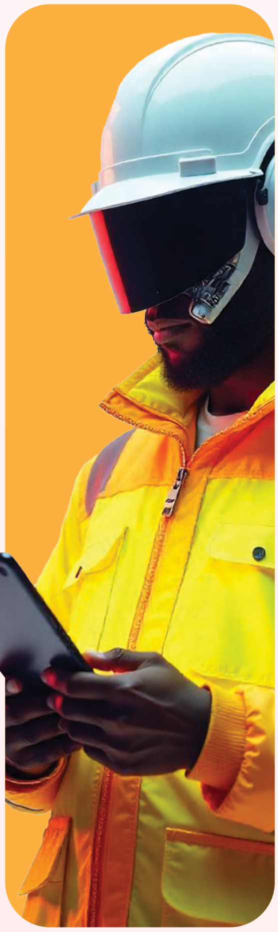
ENGINEERING PARTNERSHIPS CONVENTION | 2025

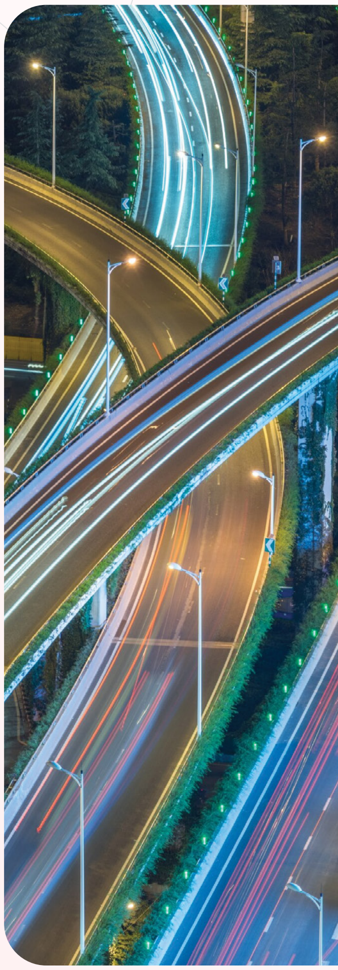
THE 6TH ENGINEERING PARTNERSHIPS CONVENTION

Theme: Engineering a Digital World

7th - 9th May 2025

Nairobi, Kenya





Objectives of the Convention

- Develop strategies for engineering green technology that promotes sustainable economic growth and address disparities
- Establish a digital platform that promotes engineering interconnectivity and access to technology solutions across the region
- Highlight the latest technological advancements across the regions, facilitating an exchange of ideas and showcasing homegrown innovations at the expo.

Contacts Us For More Information

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REPUBLIC OF KENYA | Ministry of Roads and Transport

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Kenya VISION 2030