



Engineering

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Petroleum Engineering



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- PS27 -Eldoret
- PS28 -Kisumu

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Our Services

Petroleum testing

Environmental testing

In this Issue



Tanzania's 25-Year Journey in Natural Gas



Bridging the Energy Gap: Expanding LPG Access for a Greener Kenya



Renewable Energy solutions, energy efficiency in manufacturing, smart grid's energy integration for industrial applications



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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 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 January, 2026** for our next issue, whose theme is **Celebrating Raila Odinga** 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.

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Message From the Editor



Eng Prof Lawrence Gumbe

Petroleum engineering is a branch of engineering concerned with the extraction, processing and transport of hydrocarbons such as crude oil or natural gas. Exploration and production are deemed to fall within the upstream sector of the oil and gas industry.

Petroleum engineers maximize the economic recovery of hydrocarbons from subsurface reservoirs. They study courses such as petroleum geology, drilling and well engineering and geomechanics to gain the knowledge and skills needed to develop sustainable solutions to ensure the safe recovery, processing, transportation, transmission, and utilisation of petroleum products, often, in challenging environments. In addition to the technical petroleum engineering skills, they also learn skills in project management, project economics and environmental impact assessment.

In Kenya, you can pursue petroleum engineering through undergraduate and postgraduate degrees at universities like Kenyatta University and Jomo Kenyatta University of Agriculture and Technology (JKUAT). Other options include diplomas and certificates in related fields like Petroleum Geoscience or Petroleum Operations, offered by technical institutions such as Kenya Institute of Energy. Some universities may also offer specific courses through their departments.

The petroleum industry is crucial to the world because it provides the majority of global energy for transportation, industry, and electricity, and is a key source for producing materials like plastics and chemicals. It also significantly impacts the global economy through exports, job creation, and revenue, making it a vital political and economic factor.

Oil and gas account for a majority (around 60%) of the world's energy consumption.

They are essential for powering vehicles, heating and cooling buildings, and running industrial machinery. Petroleum and natural gas offer a consistent and reliable energy supply, unlike some renewable sources that are dependent on weather conditions. Petroleum is a key feedstock for the chemical industry, used to produce a vast array of products, including plastics, fertilizers, and synthetic materials. Beyond fuel, petroleum is used to create many everyday items. The industry generates foreign exchange for many countries through exports, driving economic development. It is a major employer, supporting jobs across its supply chain, from extraction to refining. It contributes to national economies through taxes and other revenue streams.

Oil and gas provide a majority (over 50%) of the world's total energy consumption. This energy powers countless industrial processes, heats homes, and generates a significant amount of electricity, offering a reliable and versatile energy source around the clock.

The transportation sector is almost entirely reliant on petroleum products, such as gasoline, diesel, and jet fuel. This dependence is fundamental to global mobility, enabling personal travel, the movement of freight and goods (including food supplies), and the operation of emergency services and public transport.

Beyond fuel, petroleum is a crucial raw material for the petrochemical industry. Refined components are the basic building blocks for a vast array of everyday products, including:

- Plastics and synthetic fabrics.
- Fertilizers and pesticides, which are vital for global food production and agriculture.
- Pharmaceuticals and cosmetics (e.g., coatings for pills, binding agents for creams).
- Building materials such as roofing tiles, pipes, insulation, and asphalt for roads.
- Various other items like detergents, paints, computer hardware, and sports equipment.

Petroleum is one of the most traded commodities, and its price fluctuations influence global markets, inflation rates, and the economic stability of both importing and exporting countries.

The distribution and control of oil and gas reserves have a profound impact on international relations and national security, shaping foreign policies and alliances between countries.

Despite the growing focus on renewable energy sources due to environmental concerns, the petroleum industry continues to be integral to sustaining current levels of global economic development and modern quality of life for the foreseeable future.

The petroleum industry is of critical importance to Kenya as it serves as a major

driver of socio-economic development, primarily by providing the essential energy required to power various sectors of the economy.

The key areas of importance include:

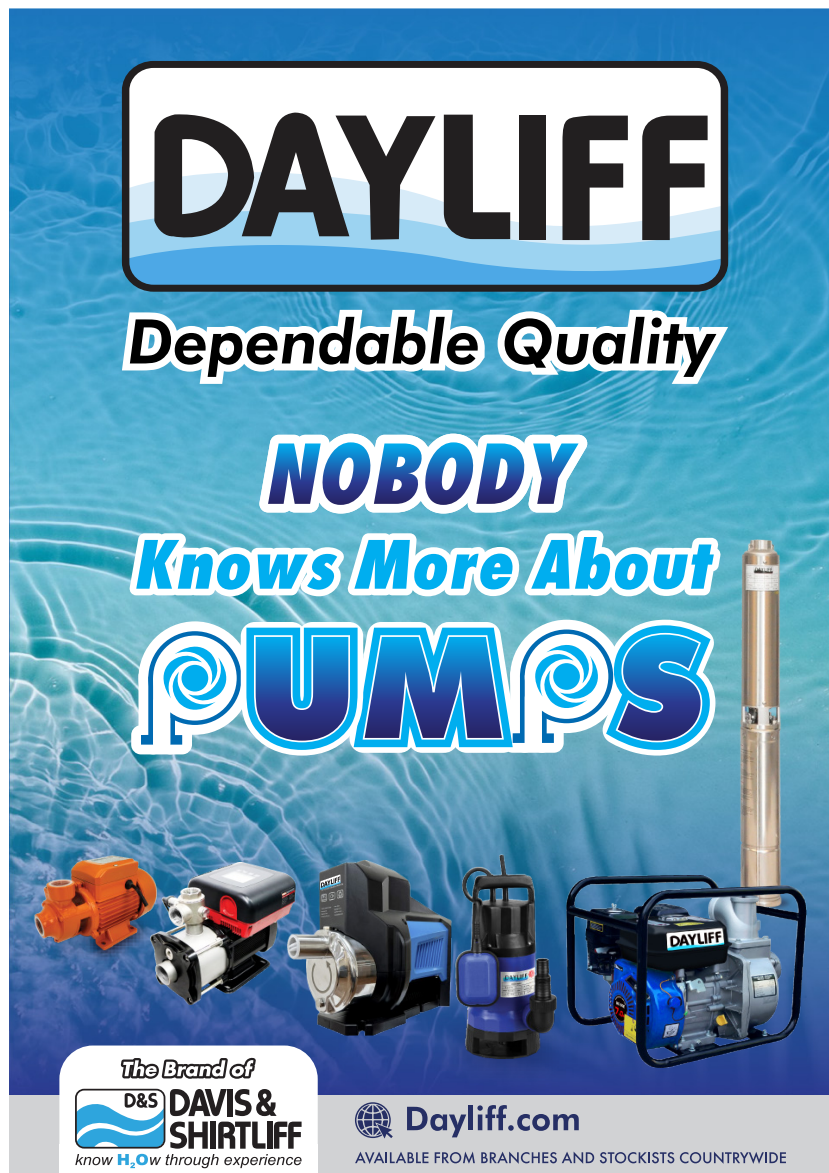
- **Energy Supply:** Petroleum is a dominant source of commercial energy in Kenya, accounting for a significant portion of the country's energy consumption. It is the "engine of progress," powering transportation, industries, commercial activities, power generation, and domestic use.
- **Economic Growth:** The sector contributes to the national Gross Domestic Product (GDP) and is a major driver in the bid to increase the GDP growth rate as part of the country's Vision 2030 development agenda.

- **Revenue Generation and Foreign Exchange:** The industry contributes to national revenue through taxes, royalties, and potential export earnings from local discoveries. The development of a local petroleum industry can also help reduce the national import bill by lessening the reliance on imported products.
- **Employment and Livelihoods:** The industry supports a wide range of jobs across the value chain, from exploration and extraction to distribution and retail operations (e.g., at fuel stations). It also supports many related small and medium enterprises (SMEs) in logistics and supply.
- **Infrastructure Development:** The needs of the petroleum sector, such as for pipelines and storage facilities, drive investment in critical infrastructure that benefits the wider economy.
- **Industrial and Commercial Support:** Industries rely heavily on petroleum products like fuel, lubricants, and coolants to maintain operations and efficiency, enabling the production and timely delivery of goods across the country.

- **Security of Supply:** A stable and efficient petroleum sector is crucial for national energy security, ensuring that businesses and individuals have reliable access to the fuel they need for their daily activities.

In essence, the petroleum industry is a foundational element of Kenya's economy, enabling commerce, trade, and overall national development. Petroleum engineering is of great importance to Kenya as it is critical for harnessing the country's discovered oil and gas reserves, driving economic growth, ensuring energy security, creating specialized jobs, and supporting the development of essential infrastructure. This issue of Engineering in Kenya is dedicated to Petroleum Engineering. We hope that you will find the issue informative, educative and entertaining.

Eng Prof Lawrence Gumbe



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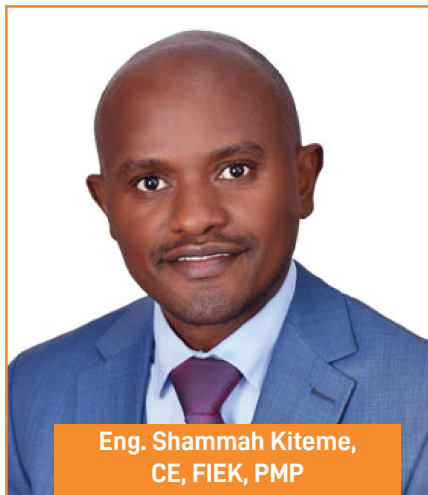
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**Eng. Shammah Kiteme,
CE, FIEK, PMP
President, Institution of
Engineers of Kenya**

Message From the President

the country holds a lot of potential. From the future prospects of crude oil drilling at commercial level to a processing of crude oil to its different by products. The petrochemical industry is big and when well established it has a potential to create many employment opportunities. Crude oil, when produced locally should be processed locally. It makes little economic sense to export crude oil just like it does not make sense to extract any other mineral and export it without value addition.

The real wealth in mineral resources largely lies in the processing bit. Processing creates value addition which in turn makes it possible to sell final products at higher prices. This also creates job opportunities in the country where mining is done. When sold in the raw form, they are processed in other countries, enriching those countries at the expense of the countries selling unprocessed raw materials.

In our pursuit for industrialization, investment in petrochemical industries is strategic. The various by-products of the crude oil processing are applicable to several industrial processes such as in plastics industry.

The training for Petroleum Engineers in our universities must focus on producing detail-oriented Engineers who are capable of solving real problems in the industry. Our approach to Engineering Education must be informed by the goal of producing industry ready Engineers who will contribute to the needs of our increasing population. Demands and dynamics are evolving. It is possible to inculcate Virtual Reality and Artificial Intelligence in our training for better learner experiences. It is clear that the field can be brought to the classroom through technology.

Overreliance on other countries has proven risky for our country, and therefore investment in a more reliable supply systems and associated infrastructure is important. It is not only safe to think about the fuel reserves and

the associated storage capacity. Reliability in supply also requires building enough manpower through training. This will guarantee sustainability with local expertise. Available training opportunities outside of the universities teaching Petroleum Engineering include the Morendat Oil and Gas Training Institute. The Petroleum Institute of East Africa also plays a critical role in advocacy, bringing players together and capacity building. Continuous advocacy for the industry is necessary for continuous policy formulation and review to match global realities in the industry.

The Institution of Engineers of Kenya (IEK) has a mandate to look into the welfare of Engineers in Kenya. Continuous Professional Development (CPD) is also a key focus and the Council has rolled out a program of activities on which members can participate to maintain their CPD by earning Professional Development Units (PDUs). This process includes life skills, soft skills and core thematic area courses.

IEK is also keen in partnering with global and local partners to create opportunities for further advanced training at the Masters and PhD level. Recently, the institution has entered into various MoUs with players locally and internationally. These are aimed at providing more opportunities for the benefit of members in these collaborations. We encourage members to take up these opportunities and capitalize on them for personal development and career enhancement.

As we look to the 32nd IEK International convention, I would like to invite all members to join us in a time of thinking ahead on how our country can develop rapidly to transform our economy and our people. Engineers will take the role of leading the future of Kenya.

This 24th issue provides a rich material for reading on petroleum engineering. I encourage all our readers to engage it and be informed, entertained and educated on the subject from various expert contributors.

While in Russia this year attending a conference on Russia-Africa dialogue, I learnt that one Russian Geologist had predicted presence of oil reserves in Kenya and the larger East Africa as far back as the 1970s. This sounded interesting to me because it is not until 2010s when the country started active prospecting of the oil. In 2012, Kenya struck oil in Ngamia 1 and has since exported the first consignment of crude on a testing basis.

Further exploration continues and there is a high chance that more oil reserves will be discovered. There is a likelihood that Kenya may become an oil exporter.

Currently, the country imports all its petroleum stock. This is done through the identified oil marketers. The Energy and Petroleum Regulatory Authority (EPRA) regulates the industry including setting the pump prices.

Kenya Pipeline Corporation (KPC) handles storage for various oil marketers and maintains a pipeline that runs from Mombasa to the western part of Kenya. Kenya Petroleum Refineries Limited (KPRL) became part of the bigger KPC and her assets were taken over by KPC. The market demand is usually met through product handling by KPC and there are hardly any shortages of fuel in the country. This is a credit to KPC's operational efficiency and market control which includes other markets in the wider East African Region.

The Petroleum Engineering sector in

Message From the Honorary Secretary



Eng. Jacton Mwembe,
PE, MIEK

I welcome you to the 24th edition of Engineering in Kenya magazine. This special issue celebrates the dynamic and evolving field of Petroleum Engineering, a discipline that continues to shape Kenya's energy future. At a time when our nation is pursuing energy self-sufficiency and sustainable growth, engineers remain at the heart of innovation, integrity and impact across the petroleum value chain.

Kenya's petroleum journey has reached a great transformative phase. From the pre-historic discoveries to the rollout of key infrastructural and policy frameworks, the nation is steadily positioning itself as a strategic energy hub in East and Central Africa.

None of these milestones would have been possible without the technical ingenuity, leadership, and resilience of Kenya's engineering community.

Across the energy and petroleum value chain, regulatory institutions have played a pivotal role in steering this transformation. Through progressive frameworks that ensure safety, environmental protection, and technical excellence, the sector has achieved a balance between growth and sustainability. Engineers have contributed towards notable developments in areas such as designing efficient systems, implementing compliance standards,

and optimizing energy use to reduce operational costs and environmental impact.

The steady integration of renewable energy principles into petroleum operations signals Kenya's evolution toward a diversified and sustainable energy model.

For petroleum engineers, this transition provides valuable opportunities to innovate developing hybrid systems that harmonize traditional fuels with cleaner, low-carbon alternatives.

At the same time, national logistics, exploration, and distribution networks have benefited immensely from engineering-led modernization. Upgrades in storage, transportation, and supply systems continue to enhance efficiency and reliability across the petroleum sector. Through collaborative partnerships among public and private entities, Kenya has demonstrated how sound engineering, robust regulation, and responsible investment can jointly drive national progress.

The petroleum exploration landscape continues to expand, guided by transparent governance and improved access to geological data. Engineers, researchers, and investors are leveraging digital tools and advanced analytics to enhance decision-making, improve production forecasting, and strengthen operational precision. This digital transformation underscores how innovation is redefining petroleum engineering globally and how Kenyan professionals are aligning with these global standards.

Equally significant is the growing role of clean energy initiatives within petroleum engineering practice. Efforts to expand the use of cleaner fuels, improve energy efficiency, and adopt environmentally responsible technologies are reshaping the sector. These initiatives not only enhance energy security but also reflect Kenya's commitment to sustainable development and regional energy

leadership.

Capacity building remains a cornerstone of this transformation in most of our universities, research institutions, and professional bodies who are continuously expanding petroleum engineering programs, accreditation systems, and professional development initiatives. This sustained investment in human capital ensures that Kenya's engineers remain globally competitive, ethically grounded, and technically proficient. Through these strategic initiatives, the engineering fraternity continues to deepen its engagement in national energy development.

Its trough continued collaboration with key sector stakeholders that we promote innovation, and nurture young professionals in the petroleum sector, Hence, we would attain our visionary goals of having efficient, sustainable, and future-ready.

As the IEK council, we believe engineers must have a voice where national energy decisions are made whether in resource allocation, infrastructure investment, or climate resilience planning. The future of petroleum engineering in Kenya will depend not only on technology but on collaboration between government, industry, academia, and communities to build a sector that is efficient, ethical, and environmentally responsible.

This special edition of Engineering in Kenya captures that spirit. It showcases the achievements, innovations, and insights of engineers driving our petroleum industry forward. I invite all stakeholders engineers, policymakers, researchers, and investors to engage with these stories, share knowledge, and continue shaping a resilient and energy secure Kenya.

I now welcome you, dear reader, to immerse yourself in this special edition a celebration of innovation, collaboration, and the bright future of petroleum engineering in Kenya.



By Eng. Derek Okova
General Manager (Pipeline
Operations and Maintenance)
Kenya Pipeline Company

Petroleum Infrastructure Developments

Q1.

With the recent upgrade raising the Nairobi-Eldoret pipeline flow to 510 m³/hr, what engineering challenges did you face in the pump station design, and what are the next steps in pushing that capacity even higher?

The project commenced in June 2022. Execution period was 18 months, with a 12-month Defect Liability Period. The project's objective was the upgrade from the Line 4 phase 1 flow rate of 378m³/hr to the phase 2 design flow rate of 510m³/hr.

The scope of the project involved

1. Building a new pumping station at PS22 Ngema, (Kilo-post 70.7 Elevation 1642.8m) from Nairobi, on the Line 4 Western Kenya Pipeline Extension. The engineering, procurement and construction works involved,
 - a. Building of a control room with associated switchgear and control equipment.
 - b. A power stepdown substation
 - c. Pump shelter complete with an overhead travelling crane
 - d. Pump plinths.
 - e. Process area
 - f. Design, sizing and installation of pipework, valves and equipment
 - g. Flow metering systems
 - h. Corrosion control and monitoring system.
 - i. Sizing, design and installation of biodigesters
2. Rerating and relocation of two fairly-new Pumps from the decommissioned Line 1 for use in the Line 4 flow enhancement project.
3. Installation of an Internet of Things Pump monitoring solution, to ensure the Hydraulic Duty point is always at the Best Efficiency Point, and enhanced condition-based maintenance.

The next stage, phase 3 of the flow rate enhancement from 510m³/hr to 757m³/hr, will involve the design, procurement and installation of a similar but appropriately-sized pumping station at PS23 (Kilo-post 124.8, Elevation 1900.4m) and PS26 (Kilo-post 223.7, Elevation 2521.5m) along the 14-inch diameter pipeline.

Engineering challenges in Pump Station Design

The geographical terrain along the Western Kenya pipeline right-of-way, particularly due to the Rift Valley's geographical feature, posed a challenge to the hydraulic designs. This, coupled with the distance (70km) from the upstream pump station, the high point elevation, the new station elevation above sea level and the pumped product characteristics.

The problem was overcome by the specially designed Mechanical Pump seals and appropriate sizing of the pump station pipework and equipment.



Q2.

The partnership with KEBS to test all incoming petroleum cargo using ISO 17025 Lab is a big move. How do you ensure lab accuracy and what technologies are being used to meet both national & global standards?

KPC transited to ISO/IEC 17025:2017; an internationally accepted quality standard for testing and calibration laboratories. The standard specifies general requirements for competence to carry out tests and/or calibrations. The standard is risk-based and differs from the previous ISO/IEC 17025:2005 which the company was accredited to on 8th July 2016 that focused on continual improvement of management system and customer service.

ISO 17025 Accreditation is an attestation of the

competence of the laboratories to perform specific tests as per the scope of accreditation schedule. It is through the accreditation that the laboratories' clients can have confidence that tests are competently handled and acceptable locally and internationally.

Some of the technologies used include: UV visible spectrophotometry, Atomic Absorption spectrophotometry (AAS), Infra-Red, X-ray florescent (X-Rf) & Gas Chromatography Mass Spectra (GC-MS).

Q3.

You are reviewing tariffs for infrastructure like storage, import handling and loading. How do you balance cost recovery while ensuring petroleum supply chain remains economical to end users?

KPC tariffs are regulated by Energy and Petroleum Regulatory Authority (EPRA). However, the tariff proposal and justification are roles that KPC undertakes both to the regulator as well as to the public. In coming up with a tariff proposal, KPC is guided by certain principles/considerations where Revenue Required is derived from a Regulatory Asset Base and its Rate of Return, as well as Operations & Maintenance Expense and Expected Depreciation for the tariff period. This revenue requirement becomes the guide in proposing a tariff for all the services rendered.

From these, it is evident that KPC must have a good control on what it does to the asset base (new investments) as well as Operations and Maintenance costs. Investments are made in projects with highest rate of returns while capital/cost employed in these projects is competitive. On the other hand, Operations and maintenance cost are contained to the minimum while offering a safe operation of the system. By controlling these aspects, a tariff that is economical is achieved.

Q4.

Following the takeover of Kenya Petroleum Refineries Limited, how is KPC leveraging those added storage assets technically and what engineering work (rehab, capacity upgrades) is underway to integrate them safely and efficiently?

Following the takeover of Kenya Petroleum Refineries Limited (KPRL), which commenced under a lease arrangement in 2017, Kenya Pipeline Company (KPC) inherited a total usable storage capacity of 483,704 cubic metres (m³). Of this, 140,478 m³ located at the KPRL Changamwe facility, previously used for refined petroleum products, was immediately deployed for the receipt, storage, and transfer of imported petroleum products. These products are subsequently transferred through the 450-kilometre, 20-inch diameter Mombasa-Nairobi Pipeline (Line 5) for distribution to the hinterland.

Since then, KPC has progressively undertaken a series of engineering rehabilitation and integration projects aimed at optimizing the use of KPRL assets, enhancing operational efficiency, and ensuring the safe handling of petroleum products. These initiatives have increased the

effective storage capacity at KPRL Changamwe Terminal from 140,478 m³ to 284,111 m³.

Key Engineering Projects and Technical Interventions

Rehabilitation and Conversion of Crude Oil Tanks: Six (6) tanks at the KPRL Port Reitz Terminal, originally designed for crude oil storage, were rehabilitated and converted for the storage of refined petroleum products. This initiative added 124,478 m³ of usable capacity to KPC's overall storage infrastructure.

Integration with the New Kipevu Oil Terminal (KOT II): The rehabilitated Port Reitz tanks have been connected to the new Kipevu Oil Terminal (KOT II), enabling the direct receipt of imported refined petroleum products from

ocean-going tankers, significantly improving import handling efficiency and reducing vessel turnaround time.

Installation of a Pumping Station and Pipeline Interconnection:

A new pumping station has been established at the Port Reitz Terminal, with a dedicated pipeline connection to Line 5, facilitating the transfer of refined products from Port Reitz storage tanks directly into the Mombasa-Nairobi pipeline system for inland distribution.

Outcome and capacity growth

Through these strategic engineering interventions, KPC has successfully more than doubled its product handling and storage capacity, growing from 326,961 m³ in 2017 to 710,344 m³ currently, an increase of over 100%.

These investments not only enhance national storage and evacuation capacity but also reinforce supply security, improve operational flexibility, and ensure the safe and efficient integration of the former KPRL facilities into KPC's national petroleum logistics system.

Q5.

KPC has reduced losses significantly below the industry standard. What leak detection monitoring or automation technologies are being deployed to detect and reduce losses and what role does sustainability play in your future pipeline strategy?

Kenya Pipeline Company (KPC) has implemented a comprehensive suite of technological, operational, and sustainability-driven initiatives aimed at minimizing product losses to levels significantly below the industry standard as follows:

a. Advanced Monitoring and Measurement Technologies

KPC has enhanced product accounting accuracy and operational integrity through:

- **Strict Meter Calibration Schedules:** Regular and precise meter calibration ensures high-integrity measurement of all petroleum products, minimizing discrepancies and enhancing accountability.
- **Automatic Tank Gauging (ATG) Systems:** Real-time tank-level monitoring provides continuous oversight of product volumes, enabling prompt detection of anomalies in storage operations.
- **Supervisory Control and Data Acquisition (SCADA):** The SCADA system facilitates real-time automation and centralized monitoring of pipeline operations and product movements across the network, strengthening control and transparency in product handling.

b. Leak Detection and Rapid Response Systems

To further safeguard the integrity of the pipeline network, KPC has installed an advanced Leak Detection System (LDS) that provides real-time detection and location

of leaks along the company's 1,320-kilometre pipeline network. This system significantly reduces response time in the unlikely event of a product release, thereby minimizing environmental impact and product loss.

In addition, heightened surveillance and patrols along the pipeline Right of Way (ROW) have been intensified to deter illegal intrusions and third-party interference, complementing the automated monitoring systems.

c. Sustainability and Future Pipeline Strategy

Sustainability is a central pillar of KPC's future strategy. The company is committed to:

- Integrating energy-efficient and low-emission technologies in pipeline operations.
- Adopting digital automation to optimize product movement and minimize waste.
- Enhancing environmental stewardship through rapid leak detection, containment readiness, and compliance with global best practices in safety and sustainability.

Through these combined efforts, KPC continues to ensure the safe, efficient, and environmentally responsible transport of petroleum products, aligning its operations with Kenya's broader sustainability and energy transition goals.

Advancing Petroleum Engineering Through Regulation, Innovation, and Global Standards



By Eng. Margaret Ogai,
CE, FIEK, Registrar /
CEO, Engineers Board of
Kenya (EBK)

Introduction

Kenya's petroleum sector is a cornerstone of the national economy, contributing approximately 12% to the GDP and supporting over 80,000 direct and indirect jobs across exploration, refining, logistics, and retail. It is a vital engine for industrialization, trade facilitation, and energy security. The sector is jointly stewarded by key actors including the Engineers Board of Kenya (EBK), the Energy and Petroleum Regulatory Authority (EPRA), the Ministry of Energy and Petroleum, the National Oil Corporation of Kenya (NOCK), and the Kenya Pipeline Company (KPC); all working to ensure sustainable and safe energy development.

As the statutory body regulating the engineering services, EBK plays a pivotal role in ensuring that the engineering related sectors including the energy sector adheres to high standards of professionalism, technical integrity, and public safety. With exploration activities in Turkana, infrastructure expansion through the Kenya Petroleum Refineries and pipelines, and increased investments in fuel storage and mobility infrastructure, the sector presents immense opportunities. However, its sustainability depends on qualified, licensed, and ethically grounded engineers capable of delivering safe and efficient energy systems.

Engineering Regulation and Global Recognition

The Board is mandated to register, license, and regulate engineers and consulting firms to ensure engineering practice in Kenya aligns with both national and global standards. A landmark achievement for Kenya's engineering profession was EBK's accession to the Washington Accord on 12th June 2025, which recognizes the equivalence of accredited engineering programs among over 20 signatory countries. This has elevated Kenya's global standing by aligning its accreditation

and licensing processes with international benchmarks, enhancing mutual recognition of Kenyan engineering qualifications and facilitating global professional mobility.

This recognition underscores Board's commitment to fostering world-class competence among Kenyan engineers and maintaining accountability to local regulations, ethical standards, and public safety.

Currently, Kenyatta University remains the only university in Kenya accredited by EBK to offer a Bachelor of Science degree in Petroleum Engineering. This milestone reflects compliance with rigorous academic and professional standards under both EBK and the Washington Accord frameworks.

However, given Kenya's growing petroleum sector and evolving energy landscape, there is an urgent need for more universities to develop and seek recognition for petroleum and related energy engineering programs. Expanding access to accredited education will ensure a consistent pipeline of competent engineers to meet industry demand, enhance research, and promote innovation in sustainable energy systems.

The Board calls upon all universities offering or intending to offer

petroleum engineering programs to seek recognition by the Board, ensuring uniform quality, global comparability, and professional readiness.

Innovation, Compliance, and Safety Challenges

While Kenya's petroleum sector has witnessed technological advances — such as digital oilfield operations, automated monitoring, and data-driven exploration — compliance and safety remain key challenges. The tragic Mradi gas explosion in February 2024, which claimed lives and caused significant property

damage, underscored systemic gaps in safety standards, professional oversight, and regulatory compliance.

These incidents highlight the urgent need for licensed professional engineers in the design, installation, and supervision of petroleum infrastructure and equipment. Compliance with engineering codes of practice, adherence to design standards, and mandatory professional supervision must be non-negotiable in petroleum projects. EBK, working in collaboration with EPRA, county governments, and industry stakeholders, is strengthening inspection, registration, and public awareness frameworks to prevent future incidents.

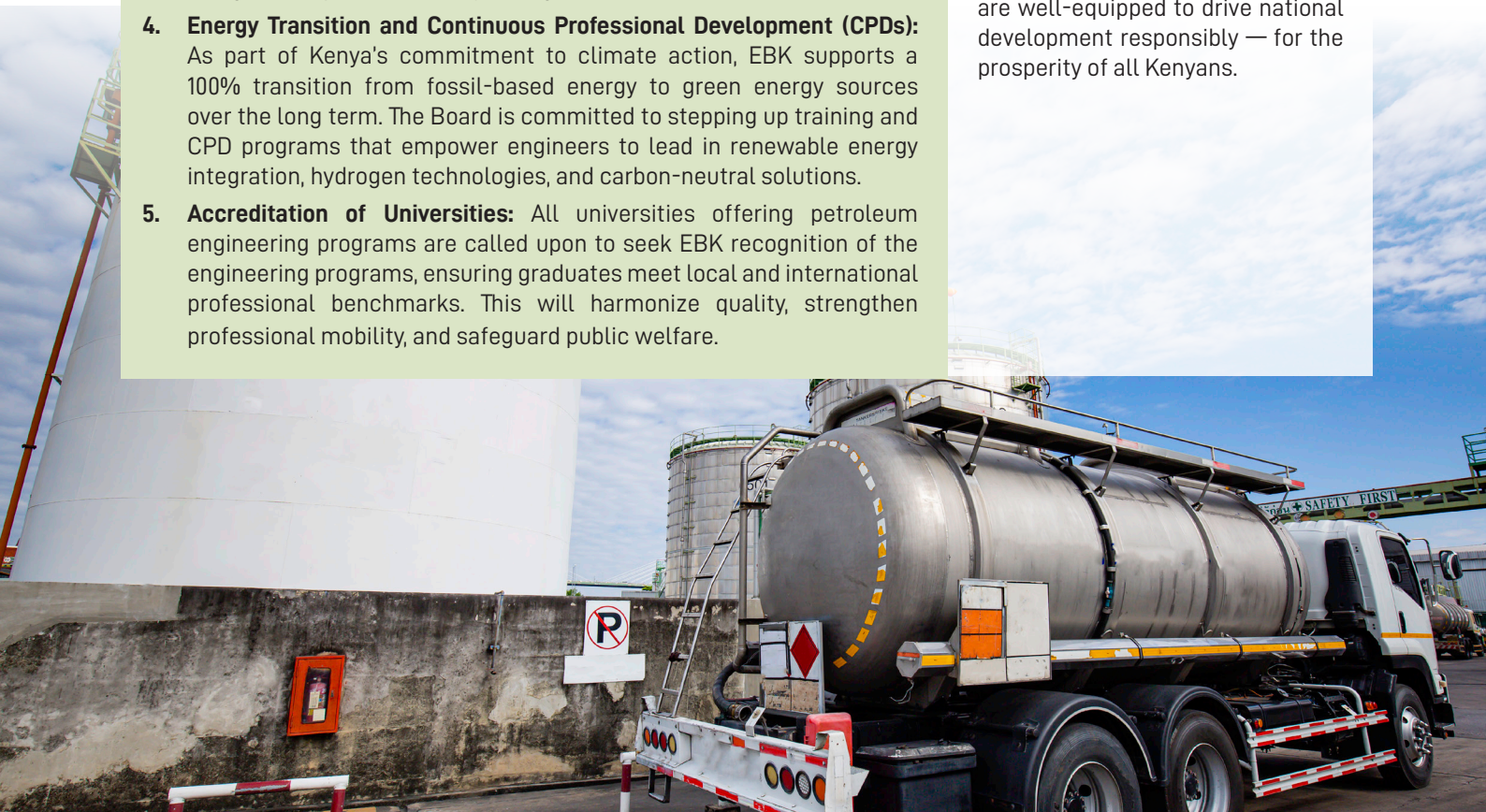
Call to Action: Building a Safe, Innovative, and Sustainable Future

- 1. Enhancing Licensure:** low percentage compliance with licencing especially downstream - petrol stations not designed and supervised by Professional Engineers. EBK calls for compliance by all engineering professions so as to improve accountability and ensure only qualified professionals undertake critical petroleum projects.
- 2. Professional Development:** EBK calls for an increase in engineer licensure through nationwide workshops, mentorships, and outreach programs to ensure a greater number of graduate engineer's transition into registered professional engineers.
- 3. Collaborative Research and International Partnerships:** The Board urges collaborative research on innovation between universities, industry, and regulatory bodies, focusing on areas such as cleaner extraction technologies, automation, and carbon reduction. EBK is also pursuing international partnerships to facilitate knowledge exchange and global exposure for Kenyan engineers.
- 4. Energy Transition and Continuous Professional Development (CPDs):** As part of Kenya's commitment to climate action, EBK supports a 100% transition from fossil-based energy to green energy sources over the long term. The Board is committed to stepping up training and CPD programs that empower engineers to lead in renewable energy integration, hydrogen technologies, and carbon-neutral solutions.
- 5. Accreditation of Universities:** All universities offering petroleum engineering programs are called upon to seek EBK recognition of the engineering programs, ensuring graduates meet local and international professional benchmarks. This will harmonize quality, strengthen professional mobility, and safeguard public welfare.

Conclusion

The Board remains steadfast in its mission to uphold engineering excellence, ensure compliance, and foster innovation in the petroleum sector. Through global partnerships under the Washington Accord, strengthened university accreditation, and expanded professional licensure, EBK is charting a course for a safer, smarter, and more sustainable energy future.

As Kenya strives toward full energy transition, EBK reaffirms its commitment to training, regulation, and collaboration to ensure petroleum and energy engineers are well-equipped to drive national development responsibly — for the prosperity of all Kenyans.



SAFETY IN ENGINEERING CONSTRUCTION REPORT PRESENTED TO INDUSTRY, STAKEHOLDERS, DECISION MAKERS



Engineers Board of Kenya, with funding support from Lloyds Register Foundation, UK, today Wednesday 12th November 2025 presented Safety in Construction Report to decision makers and stakeholders at the Royal Academy of Engineers Global Engineering Capability Review (GECR) 2025 Roundtable in Nairobi.

The project started in February and to date has achieved;

1. Baseline survey on safety in construction
2. Training needs analysis of engineering students and construction workers and built environment professionals to inculcate safety culture in construction
3. Development of curriculum on Safety for engineering students and practitioners
4. Legal and regulatory review relating to safety in construction

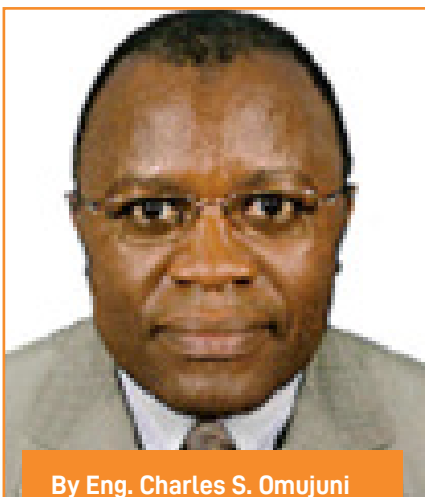
During the workshop, the stakeholders identified policy, legal and institutional gaps.

Other agencies represented included National Building Inspectorate, KETR, AAK Engineers Chapter, Engineers without Borders and engineering consultants, Registrars/Regulators from Uganda, Rwanda, Tanzania, South Sudan, National Construction Authority, ACEK, IEK, BORAQs, NITA, Department of Occupational and Health Safety (DOSHS) and Royal Academy of Engineering Representatives.





Tanzania's 25-Year Journey in Natural Gas



By Eng. Charles S. Omujuni
Board Member, Tanzania
Petroleum Development
Corporation (TPDC)

Introduction

Tanzania has achieved significant milestones in natural gas exploration, processing, and utilization. Herein is the geological potential, infrastructural development, policy and regulatory frameworks, and regional cooperation, including the recent Memorandum of Understanding (MoU) between Tanzania, Kenya, Uganda, and Zambia to enhance energy security and shared infrastructure. Strategic

recommendations for sustainability, local value addition, and technical capacity development are presented, drawing on contributions from Tanzania Electric Supply Company Limited (TANESCO), national experts, and institutions such as World Bank, European Investment Bank (EIB), Norwegian Petroleum Directorate (NPD), Tanzania Petroleum Development Corporation (TPDC), and private partners.

We have learned that gas isn't just a resource, but a driver of industrialization, energy access, and cross-border stability," says Eng. Charles Omujuni, a board member at TPDC and one of Tanzania's veteran engineers in the field.

Historical Context

Tanzania's natural gas sector has evolved from early discoveries at Songo Songo (1974) and Mnazi Bay (1982) to major offshore finds in Blocks 1, 2, 3 and 4 by Equinor and Shell, with recoverable reserves exceeding 57 Tcf. TANESCO has been a primary off-taker, integrating domestic gas into power generation for Dar es Salaam and the southern regions. Visionary leadership from Al Noor Kassam, Prof. Mwandosya, Patrick Rutabanzibwa, Sylvester

Barongo, and Baruany Luhanga helped develop the institutional and operational frameworks that underpin today's sector.

Geological Context

Natural gas reserves in Tanzania occur in sedimentary basins with three principal reservoir types:

- i. Sandstones: Dominant in Songo Songo, Mnazi Bay, and Ntorya, with high porosity (15–25%) and permeability.
- ii. Carbonates: Offshore Miocene–Paleogene limestone and dolomite reservoirs store gas in fractured structures.
- iii. Turbidite sandstones: Deepwater turbidite systems host major accumulations in Blocks 1–4.

Sylvester Barongo notes that structural and stratigraphic traps, capped by shale and mudstone, secure long-term gas containment.

Engineering and Infrastructure

Tanzania's gas infrastructure integrates the drilling, processing, transmission, distribution, and power delivery:

- a. Songo Songo Gas-to-Power Project, implemented by Ocelot Inc., AES Corporation, and Globeleq, supplies TANESCO's Ubungu and Mkuranga plants. Baruany Luhanga played a key operational role ensuring reliability
- b. The Songo Songo–Dares Salaam pipeline, constructed by Larsen and Toubro (L&T) spans 232 km, and the Madimba–Dar es Salaam pipeline constructed by Chinese contractors (CPTDC, CNPCPE), spans 542 km.
- c. Madimba (210 MMscfd) and Songo Songo (245 MMscfd) natural gas processing plants serve midstream processing, while TPDC manages distribution.
- d. The Ntorya Field expansion ensures additional domestic supply for TANESCO and industrial clients.

Policy, Regulation, and Institutional Framework

Tanzania balances national benefit with investor participation through Model Production Sharing Agreements and a multi-agency governance system:

- a. Petroleum Upstream Regulatory Agency (PURA) regulates upstream activities.
- b. Energy and Water Utilities Regulatory Authority (EWURA) oversees midstream and downstream gas, including supply to TANESCO.
- c. TPDC operates as the state commercial entity in oil and gas business.
- d. Occupational Safety and Health Authority (OSHA) ensure workplace and operational safety.
- e. National Environmental Management Council (NEMC) enforces environmental compliance.

Key contributors such as Patrick Rutabanzibwa, Baruany Luhanga, and Salvatory Ntomola structured the Natural Gas Policy and production sharing agreements to align government, investors, and local stakeholders.

Regional Integration

Tanzania actively engages regional partners to improve energy security and infrastructure:

- i. The MoU signed with Kenya, Uganda, and Zambia establishes a framework for cross-border natural gas trade, joint LNG infrastructure, power interconnection, and regulatory harmonization.
- ii. Proposed pipelines (for instance, Tanzania–Kenya) and shared storage facilities aim to optimize investment and supply reliability.

- iii. Prof. Mwandosya emphasizes the importance of harmonized environmental and safety standards across the EAC region to ensure sustainable energy integration.
- iv. Support from World Bank, EIB, and NPD facilitates capacity building and institutional coordination for regional cooperation.

Future Outlook - Sustainability, Value Addition, and Human Capital

Tanzania's natural gas sector growth requires strategic plans and actions such as:

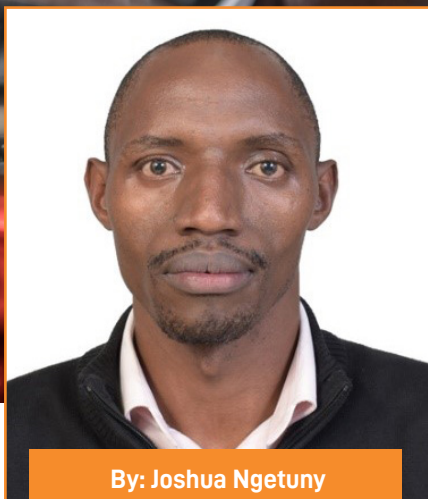
- i. Accelerate Liquefied Natural Gas (LNG) development at Lindi with Equinor and Shell.
- ii. Expand onshore production from Ntorya and other inland fields for domestic power and industrial use.
- iii. Promote downstream industries in fertilizer, methanol, and ceramics for local value addition.
- iv. Deploy digital infrastructure and predictive maintenance systems inspired by TransCanada Pipelines Inc.
- v. Strengthen safety and environmental compliance via PURA, EWURA, OSHA and NEMC.
- vi. Enhance technical capacity through partnerships with NPD and Chinese contractors.

According to Sylvester Barongo, Al Noor Kassam, and Baruany Luhanga, integrating research, operational excellence, and local skills is critical to sustainable growth.

Conclusion

Tanzania's natural gas sector reflects a balance of geological potential, engineering expertise, and robust policy frameworks. Institutions like the Ministry of Energy, TANESCO, TPDC, PURA, EWURA, OSHA, and NEMC ensure operational efficiency, safety, and sustainability. Leadership from national experts, combined with international partnerships (World Bank, EIB, NPD, Ocelot Inc, TransCanada Pipelines, AES Corporation, Globeleq, L&T, and Chinese contractors), positions Tanzania to become a regional natural gas hub. The MoU with Kenya, Uganda, and Zambia further strengthens regional energy security and shared infrastructure, promoting cross-border industrial and power generation integration.

The Role of Chemical Engineers in the Petroleum Industry



By: Joshua Ngetuny
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Chemical engineering plays a central and continuously evolving role in the petroleum industry, a sector that remains fundamental to global energy supply and economic development. By applying principles from chemistry, physics, and mathematics, chemical engineers conceptualize, design, operate, and optimize complex processes that convert crude oil and natural gas into valuable products. This article examines their diverse roles across the sector, highlighting their integral contribution to traditional operations, technological innovation, environmental protection, and the strategic management of the energy transition.

1. Core Roles of Chemical Engineers in the Petroleum Industry

Chemical engineers are indispensable across the entire petroleum value chain, from initial resource extraction to final product distribution. Their expertise ensures operational efficiency, safety, and profitability while addressing complex technical challenges.

1.1. Exploration and Drilling Operations

In the upstream sector, chemical engineers apply their knowledge to enhance the efficiency and safety of exploration and drilling activities. They are crucial in understanding reservoir fluid properties and designing processes for enhanced oil recovery (EOR), which involves injecting specialized chemical solutions to extract more hydrocarbons from reservoirs. Their work includes developing and optimizing drilling fluids, critical for wellbore stability, cutting transport cost, and pressure control during drilling. Chemical engineers also contribute to the

design of chemical additives that prevent corrosion and control undesirable reactions within wells, thus maintaining equipment integrity and maximizing recovery. They apply thermodynamics and advanced equations of state to predict fluid behaviour under extreme subsurface conditions, which is essential for effective reservoir management.

1.2. Refining and Process Design

Petroleum refining is a core domain for chemical engineers, where they design and optimize the complex processes that convert crude oil into a wide range of refined products like gasoline, diesel, and petrochemical feedstocks. This involves the detailed design of unit operations such as distillation, catalytic cracking, hydrotreating, and reforming, aiming to maximize yield and desired product specifications. They utilize advanced process engineering tools for modelling and simulation, which are essential for predicting process

behaviour and optimizing operational parameters. Chemical engineers integrate chemical reaction engineering, thermodynamics, and transport phenomena to develop energy-efficient and cost-effective refinery configurations, often leveraging enterprise-wide optimization frameworks to enhance overall profitability.

1.3. Safety and Environmental Management

Chemical engineers are at the forefront of process safety management (PSM) in the petroleum industry, developing systems and protocols to prevent accidents and mitigate risks associated with hazardous materials and processes. They conduct rigorous hazard identification using methods like Hazard and Operability Studies (HAZOP) and Failure Mode and Effects Analysis (FMEA) and perform quantitative risk assessments to evaluate the likelihood and consequences of potential incidents. Their responsibilities extend to implementing safety instrumented systems, pressure relief devices, and inherently safer designs to minimize operational risks. In environmental management, chemical engineers develop and deploy technologies for emissions control, waste treatment, and water management to comply with stringent environmental regulations. They design wastewater treatment plants to reduce pollutants like volatile organic compounds (VOCs) and dissolved gases, minimizing environmental impact.

1.4. Process Optimization and Digital Technologies

Optimization is a continuous endeavour for chemical engineers in the petroleum industry, driven by the need for increased efficiency and cost reduction. They employ process modeling and simulation to analyse and predict the performance of complex systems, facilitating process improvements and troubleshooting. Advanced control systems (ACS), including model predictive control and real-

time optimization, are designed and implemented to maintain operations near optimal setpoints, improving product quality, reducing energy consumption, and increasing throughput. These digital tools allow for precise adjustments to process variables in units like distillation towers and catalytic crackers, enhancing overall operational responsiveness.

2. Current Technological Advancements

The petroleum industry is experiencing a transformative shift, with chemical engineers at the forefront of integrating cutting-edge technologies that improve efficiency, sustainability, and safety.

2.1. Digital Process Control and Automation

Digital process control has revolutionized petroleum refining operations, advancing from basic automation to sophisticated, integrated systems. Chemical engineers utilize advanced software platforms that incorporate real-time monitoring, predictive analytics, and machine learning algorithms to optimize complex processes. These systems enable automated control loops, precise adjustments of operational parameters, and continuous monitoring of equipment health, resulting in increased uptime and reduced operational costs. With the rise of artificial intelligence (AI), chemical engineers are upskilling to leverage data-driven insights for faster decision-making, early trend detection, and proactive corrective actions to maintain smooth operations. Digital twins, which are virtual replicas of physical assets, are also being developed to support operator training, preventive maintenance and real-time process optimization, strengthening overall process and asset management.

2.2. Advanced Catalysts

The development of advanced catalysts is crucial for upgrading petroleum fractions and meeting stringent product quality standards. Chemical engineers design

and synthesize novel catalytic materials, including nano-structured and supported metal catalysts, which offer improved selectivity, conversion rates, and durability. Innovations in catalysts for hydrocracking, fluid catalytic cracking, and desulfurization processes enhance yields of valuable products and ensure compliance with environmental regulations. For instance, platinum-based catalysts are tailored for reforming and hydrotreating, while supported MoO₃ catalysts commonly used in hydro processing and desulfurization research, exhibit thermal stability and poison resistance. These advancements are critical for efficient processing of heavier, more sour crude oils.

2.3. Process Intensification

Process intensification (PI) is a strategic approach championed by chemical engineers to develop more compact, energy-efficient, and sustainable processing technologies. This involves combining or redesigning unit operations to boost efficiency, reduce environmental footprints, and improve safety. Examples include membrane engineering for selective and energy-efficient separations, and innovative reactor designs that significantly reduce equipment size and energy consumption compared to traditional methods. PI enhances capacity, selectivity, and process integration in petroleum refining, offering a pathway to significantly more sustainable production.

2.4. Carbon Capture and Storage (CCS)

To mitigate greenhouse gas emissions, chemical engineers are actively involved in the development and implementation of carbon capture and storage (CCS) technologies within the petroleum sector. This includes designing and optimizing post-combustion, oxyfuel, and chemical looping combustion capture methods for refinery units, such as fluid catalytic cracking. Chemical engineers manage the entire CCS chain, from CO₂ capture

and transport to subsurface storage, often integrating it with EOR to maximize resource utilization. Addressing challenges related to cost, operational stability, and regulatory compliance is a key area of ongoing improvement.

2.5. Hydrogen Production

Hydrogen is a critical reactant in many refining processes, particularly hydrotreating and hydrocracking. Chemical engineers optimize hydrogen generation methods to increase yield while minimizing carbon emissions. This includes conventional methods like steam methane reforming and catalytic reforming of liquefied petroleum gas, as well as emerging hydrothermal conversion techniques utilizing advanced catalysts. Innovations aim to produce "clean" hydrogen by integrating carbon capture technologies, thereby aligning with the industry's decarbonization goals and future energy demands.

3. Environmental and Sustainability Aspects

Chemical engineers play a key role in making petroleum operations more sustainable by advancing decarbonization, improving energy efficiency, and promoting circular economy practices.

3.1. Decarbonization Strategies

Chemical engineers lead the development and implementation of decarbonization technologies to reduce the petroleum industry's carbon footprint. Their work extends beyond carbon capture and storage (CCS) to include redesigning processes for alternative feedstocks like biomass and bio-based chemicals, enabling the production of cleaner fuels and materials within existing infrastructure. They also develop hydrogen production technologies, improving efficiency and supporting the decarbonization of hydro processing operations. These efforts are key to achieving ambitious climate targets and ensuring the long-term viability of the industry.

3.2. Energy Efficiency

Improving energy efficiency is a continuous focus for chemical engineers, achieved through process intensification and integrated digital process control. By implementing real-time optimization and predictive control systems, they enhance the responsiveness of refinery operations and significantly reduce energy consumption. Process intensification techniques, such as advanced heat exchanger networks and novel reactor designs, also contribute to significant energy savings and reduced emissions, strengthening sustainable processing practices.

3.3. Circular Economy Initiatives

Chemical engineers are instrumental in incorporating circular economy principles into the petroleum sector through waste minimization, resource recovery, and material recycling. They design and implement treatment processes for complex waste streams, such as produced water, drilling fluids, and chemical byproducts, transforming them into valuable inputs. This involves developing closed-loop systems that combine environmental protection with economic benefits, helping the industry transition from linear to more sustainable production models.

4. Future Perspectives

The energy transition towards a low-carbon economy presents significant challenges and opportunities for chemical engineers, necessitating an evolution of their roles and skill sets within the sector.

4.1. Evolving Role in Energy Transition

Chemical engineers are set to drive the development of sustainable energy technologies, from advanced biofuels and renewable feedstocks to the integration of renewable energy into existing industrial processes. Their expertise in understanding, designing, and operating conversion processes enables them to guide the transition from fossil fuels to alternative energy sources. This includes optimizing processes for renewable hydrogen production, battery material manufacturing, and carbon capture utilization

technologies that convert CO₂ into valuable products.

4.2. Decarbonization and Renewables Integration

The push for decarbonization will continue to drive chemical engineers to innovate in industrial electrification, energy storage, and the development of sustainable chemicals derived from non-petroleum sources. They will be critical in designing and implementing processes that combine renewable energy sources, such as solar and wind power, into refinery and petrochemical operations, reducing reliance on fossil fuels for process heat and power. This also extends to developing hybrid bio-petroleum refinery models that efficiently co-process biomass with crude oil to produce greener fuels and chemicals.

4.3. Education and Skill Development

Future chemical engineering education will increasingly emphasize sustainability, advanced analytics, data science, and cross-disciplinary collaboration to meet these evolving challenges. Graduates will need competencies in areas such as carbon management, process modeling, computational fluid dynamics, and systems-level thinking to design resilient and sustainable energy systems. Academic and industry initiatives are already focusing on broadening chemical engineering curricula to include these critical skills, preparing a workforce capable of driving innovation in a dynamic energy landscape.

5. Conclusion

Chemical engineers have historically been, and continue to be, essential to the petroleum industry's operational excellence, innovation, and economic impact. Their expertise spans the entire value chain, from exploration and drilling to refining, process design, product distribution, safety, and environmental management. As the industry confronts the urgent demands of the energy transition, climate change, and sustainability, the role of chemical

engineers is not diminishing but rather expanding and transforming. They are uniquely positioned to lead the advancement of decarbonization technologies, enhance energy efficiency, foster circular economy initiatives, and integrate renewable energy solutions, ensuring the

petroleum sector's adaptation and resilience in a rapidly changing global energy landscape. Their multidisciplinary skills and systemic approach will be critical in shaping a sustainable future for the industry and society at large.

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Energy Efficiency kicks off in Kenyan Petroleum Industry

EiK correspondent

In Kenya's petroleum sector, the quiet revolution is not in drilling rigs and new wells, but in energy efficiency and conservation. Pipelines, terminals, and refinery systems require vast amounts of power and heat; engineers are under challenge to make every watt and pump stroke count.

At the centre of this is the Kenya Pipeline Company (KPC), whose recent upgrade presents a successful model that can be emulated.

“As per the data provided by the company, the volume of energy used in fuelling activities reduced from **188.8 million kWh in the year 2017 to only 114.3 million kWh in the year 2022**, despite the volume of product throughput rising from **6.6 billion litres in 2017 to 8.2 billion litres in 2022**.”

“We have taken deliberate steps to manage the amount of energy consumed by our pumping operations,” the company states.

For a sector where loss-making activities gradually eat into the bottom-line results, KPC's latest performance figures speak volume. The company posted a pre-tax profit of KSh 10 billion during the 2023-24 financial year, a 32% improvement over the previous year, despite a modest gain in overall throughput volumes. Faith Boinett, the chairperson of KPC board, ascribed this kind of performance to enhanced operational efficiency.

Policy, infrastructure, and international agenda

In May 2024, Kenya hosted the International Energy Agency (IEA) 9th Annual Global Conference on Energy Efficiency in Nairobi, the first time the event was held in Africa. Over 500 people from more than 60 countries attended the conference, marking the importance of energy efficiency in the global transition. “We are not yet seeing the necessary progress,” said IEA Executive Director Fatih Birol, urging governments and the private sector to speed action.

This is a message that calls Kenyan petroleum engineers and other affiliated professionals to action, as they have

to see to it that midstream and downstream activities operate with reduced energy intensity and reduced greenhouse gas emissions.

Engineering levers of change

Currently, various engineering disciplines are at the forefront:

- i. Heat recovery and insulation: Refineries and terminals still lose heat through aging exchangers and bare piping. Re-engineering these saves thermal energy and reduces fuel demand.
- ii. Drive-and-pump upgrades: KPC has upgraded high flow pumping stations with improved Variable Frequency Drives (VFD). This marks a move towards accommodating large flow volumes, rather than relying on outright power.
- iii. Digital monitoring and leak control: Investing in real-time sensors, loss-detection algorithms, and data analytics enable early corrective action, preventing costly downtime.
- iv. Hybrid/renewable power for auxiliary loads: While engines still power the bulk of petroleum processing, solar arrays, batteries or hybrid systems are increasingly viable for terminals, offices and support infrastructure.
- v. Policy and regulation alignment: Energy and Petroleum Regulatory Authority and government frameworks are increasingly adopting efficiency targets and mandatory audits. Kenya hosting the IEA conference and publication of the Efficiency Policy Toolkit creates a firmer ground for this.

Way forward

Kenya hosting the IEA conference and publication of the Efficiency Policy Toolkit farther signals institutional commitment

As Kenya looks to drive forward its clean-energy transition, there is a growing role for energy efficiency in delivering benefits that can ensure affordable, reliable access.

By capitalizing on this opportunity, overall benefits will be felt not only in the pipeline, but in a wider range of areas, including industrial competitiveness, performance on climate concerns, and various matters of national security in terms of energy. This way, energy efficiency will finally get prominence.

Petroleum-Derived Plastics and Fabrics: Manufacturing Processes and Innovations.



By Daniel Kashu.
Mining and Process
Engineer Graduate

Walk into any home, office, or store today, and you will find yourself surrounded by plastics and fabrics made possible by petroleum, proof of its central role in modern society. These plastics and synthetic fabrics are cheap, strong, and incredibly useful. They've changed how we live, build, and even treat sickness. But this convenience comes with a high price: a huge environmental footprint. We face a global challenge: how do we keep the benefits of these materials while stopping the damage? This pressure is now driving major new innovations.

Plastics demonstrate how petroleum has revolutionized manufacturing. When crude oil is refined, naphtha is produced and cracked into molecules such as ethylene and propylene. These simple building blocks are polymerized into plastics that are then shaped into bottles, films,

pipes, and countless other objects. Each polymer serves a unique role, and together they form the invisible infrastructure of everyday life. Without petroleum-based plastics, modern packaging, construction, and healthcare systems would look radically different.

Textiles show another dimension of petroleum's transformative power. Synthetic fabrics such as polyester and nylon dominate wardrobes, offering qualities that cotton and wool cannot provide at scale. Clothing and other textiles are woven or knitted from fibers that are produced by spinning petroleum-derived polymers. Their strength, elasticity, and cost-effectiveness have made them indispensable in the global textile industry, fundamentally altering fashion and accessibility.

The influence of petroleum extends beyond visible products into pharmaceuticals. Many active pharmaceutical ingredients (APIs) rely on petroleum-based intermediates during synthesis. For instance, solvents such as toluene and xylene - both derived from petrochemicals - are used to dissolve, purify, or stabilize drug compounds (Author, Year). Similarly, paraffin derivatives are used in ointments, creams, and capsules. Even aspirin, one of the most common drugs globally, traces

part of its industrial production to petrochemical feedstocks. These applications demonstrate that petroleum is not only a material for packaging and clothing, but also a building block of modern medicine.

The pharmaceutical connection raises both opportunities and challenges. On one hand, petroleum ensures affordability and scalability in drug production. Without petrochemical inputs, the cost of producing antibiotics, painkillers, or cancer treatments could rise sharply, restricting access for patients worldwide. On the other hand, reliance on petroleum ties the pharmaceutical sector to the same environmental dilemmas facing plastics and fabrics. Solvents can contribute to chemical waste, and the production chain itself is energy-intensive. This paradox complicates any discussion of phasing out petroleum, because in medicine, human health and life are at stake.

There are also regulatory and ethical dimensions to petroleum's role in pharmaceuticals. Boards and health authorities are increasingly aware that some petroleum-derived excipients such as mineral oils and waxes are directly ingested or applied to human bodies. While they are generally recognized as safe, their origin sparks debate over whether long-term alternatives should be

pursued. Furthermore, the reliance of essential medicines on petroleum highlights a vulnerability: supply chain disruptions or geopolitical conflicts affecting oil markets could ripple into pharmaceutical availability, raising questions about resilience and independence in healthcare systems.

The environmental costs of petroleum-derived products, however, have become impossible to overlook. Plastics persist in landfills and oceans for centuries, while synthetic fabrics release microfibers into waterways with every wash. In pharmaceuticals, the issue manifests as solvent waste and emissions generated during large-scale production. These impacts drive innovation, from chemical recycling technologies that recover valuable monomers to fabrics engineered to shed less during use. Research into greener solvents for drug production,

along with bio-based plastics and renewable polymers, also shows promise in reducing reliance on petroleum while maintaining the advantages of synthetic materials.

The future of petroleum-derived plastics, fabrics, and pharmaceuticals hinges on striking that balance between industrial necessity and environmental responsibility. Their contribution to global development is undeniable, from keeping food fresh and people clothed to enabling life-saving drugs. Yet the challenge now lies in reshaping production and consumption to align with sustainable goals. If the same ingenuity that created these materials can be applied to reimagine them, society can retain their benefits while minimizing harm. The legacy of petroleum is all around us, but its future depends on how wisely we choose to use it.



Research into greener solvents for drug production, along with bio-based plastics and renewable polymers, also shows promise in reducing reliance on petroleum while maintaining the advantages of synthetic materials.

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Daniel's academic background in Mineral Processing and research work is fundamentally focused on Process Engineering, with a specialized interest in Extractive Metallurgy.

He is skilled in advanced concepts in process optimization, materials science, and chemical transformations, with recent projects exploring Graphite Ore metallurgical Analysis at Taita Taveta county for the efficient recovery for electrode Production.

Daniel is actively engaged in developing a robust technical understanding of complex system design and analysis, preparing for a future role that leverages this expertise to tackle challenging industrial and resource processing problems.

Key Areas of Interests

Process Engineering : Focusing on the design, operation, control, and optimization of chemical, physical, and biological processes.

Extractive Metallurgy : Exploring the science and technology of extracting metals from their ores, with an emphasis on mineral processing, hydrometallurgy, electro metallurgy and pyrometallurgy.

Unlocking Kenya's Oil Wealth: Infrastructure, Innovation, and Inclusive Growth

The petroleum industry is key to today's economy, and it is affecting the global energy supply and geopolitics. As countries strive for energy independence and sustainable options, the challenges and opportunities in this sector are clearer than ever. The industry is evolving with new technologies, fluctuating oil prices, and increasing climate change concerns.

The petroleum supply chain includes exploration, extraction, refining, transportation, and distribution. While global oil reserves remain significant, the industry is changing with strong need for diverse energy sources. Developed nations are investing more in renewable energy and at the same time, developing nations, especially in Africa, seek greater energy security through local resources.

Kenya as a nation is at a pivotal point in its energy independence journey. Oil reserves have been found in the Turkana region, prompting Kenya to explore its petrochemical potential. The Kenya Pipeline Company (KPC) plays a key role in moving crude oil from production to refineries and distribution points. However, infrastructure issues like the current pipeline network need major upgrades and expansions to handle increased production. Poor maintenance and leaks pose risks, highlighting the need for targeted investment.

As Kenya taps into its oil reserves, the link between energy policy and infrastructure is vital. The government must commit to clear policies, efficient regulation, and stakeholder involvement. This approach will boost investor confidence and support sustainable oil sector growth. Kenya's pursuit of oil production goes beyond economics; it reflects its desire to lead Africa's energy sector.

Collaboration among stakeholders, including engineering firms and policymakers, is essential. Energy sector players and manufacturers like ACTOM, who specialize in power and energy solutions, are crucial for they provide the technological

support and expertise needed to improve Kenya's energy infrastructure. Our contributions help implement modern engineering solutions that enhance efficiency and reduce environmental impacts, hence the need to invest in modern pipelines and updated distribution systems that can resolve many current inefficiencies and risks. Additionally, involving local communities through job creation and environmental stewardship will foster a sense of ownership and partnership for long-term success.

As Kenya progresses in its petroleum ambitions, it must navigate the complex energy production landscape,

and the economic growth must align with environmental care and social fairness. This balanced approach will create a sustainable petroleum industry that meets the nation's energy needs while empowering its citizens.

Kenya's petroleum industry holds immense promise but requires a balanced approach to transform the oil sector by prioritizing infrastructure, sustainability, and inclusive growth. By fostering collaboration between government and private sector key players like ACTOM, Kenya can build a resilient energy sector that drives economic development while safeguarding the environment.

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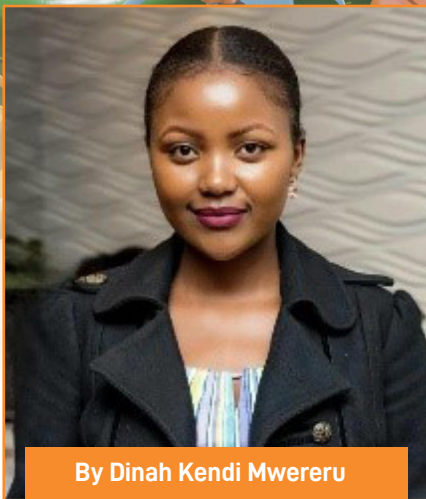
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Bridging the Energy Gap: Expanding LPG Access for a Greener Kenya



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Expanding LPG access is not merely a policy goal, it is an engineering frontier that will define how Kenya cooks, breathes, and thrives in the years ahead.

In Kenya, an energy transition is quietly gathering steam. While many households, especially in rural areas, still rely on firewood and charcoal for cooking, the government is making a bold push toward Liquefied Petroleum Gas (LPG) as a cleaner, safer, and more sustainable alternative.

Yet, despite these efforts, more than 70% of Kenyan households still depend on biomass fuels (KIPPRA 2022). Under the Clean Cooking Gas (CCG) initiative and the Kenya National Cooking Transition Strategy (2024–2028), Kenya aims to change

this, targeting a jump in LPG access from 24% to 70% by 2028, reaching 4.5 million low-income households (Kenya National Cooking Transition Strategy, 2024 – 2028 – V3). The vision goes beyond convenience; it's about health, equity, and environmental protection.

The Promise of LPG: From the Kitchen to the Nation

LPG has emerged as the quiet powerhouse of Kenya's energy transition. Once a luxury for the few, it is now powering change from kitchens to farms, hospitals to taxis.

In transport, more vehicles are converting to LPG, attracted by lower costs and cleaner emissions. Taxi drivers and small fleet owners see it as a viable alternative to petrol and diesel, proof that clean energy can also be good business.

On farms, LPG-powered irrigation

pumps are replacing diesel engines. In Voi, farmers report cutting fuel costs by half while reducing pollution and improving productivity. If scaled, this could transform agricultural energy use nationwide.

Hospitals and pharmaceutical industries, too, are turning to LPG for heating, sterilization, and ventilation, lowering costs while keeping operations resilient during power outages.

The numbers reflect this momentum. LPG consumption jumped from 360,000 tonnes in 2023 to over 414,000 tonnes in 2024, a 15% leap in one year. Per capita use has risen to 7.9 kilograms, inching toward the government's target of 15 kilograms per person by 2030 (EPRA 2025). Behind these figures are bold investments: the 30,000-tonne Mombasa common-user terminal, inland depots in Nakuru and Eldoret, and the Kenya Pipeline Company's new bulk facilities are expanding capacity and cutting transport costs.

Policy tailwinds have helped, too. The Finance Act of 2023 exempted LPG from VAT, making refills cheaper, while companies like Pro Gas, Taifa Gas, and TotalEnergies have grown the retail ecosystem.

"From kitchens to farms, LPG is powering Kenya's clean energy story."

The LPG sector in Kenya is a significant employer, engaging thousands of people across its value chain. Beyond direct jobs, the sub-sector has spurred the growth of a vibrant market for locally manufactured and imported cylinders, as well as a steady demand for accessories including regulators, hose pipes, and safety equipment. This ecosystem has also created opportunities for small and medium-sized enterprises, especially in urban centers and emerging rural hubs, where retailers and service providers are tapping into the expanding demand for clean cooking solutions.

Barriers Beneath the Flame

Despite the progress, challenges persist.

Affordability remains a key hurdle: a 6-kg starter kit still costs around KSh 3,000, putting LPG beyond reach for many rural families. Subsidized programs such as Gas Yetu are helpful but limited in scale.

Infrastructure gaps are equally critical. Outside cities, refilling stations are few and far between. Long distances to refill points force many rural users to revert to charcoal or firewood.

Then there's safety and public trust. The tragic Embakasi gas explosion in 2024 renewed concerns over illegal refilling and substandard cylinders (The Daily Nation (2024)). Although the Energy and Petroleum Regulatory Authority (EPRA) has tightened oversight, enforcement remains thin, and public awareness of safe handling is low.

Cultural perceptions add complexity. Many rural households still view LPG as an "urban fuel," while fears

of explosion persist due to limited education on safe usage. Others believe that food cooked with biomass tastes sweeter, further reinforcing the preference for traditional cooking methods.

Engineering the Way Forward

Kenya's engineers are central to solving this challenge. Innovative solutions can make LPG cleaner, safer, and more accessible.

Locally engineered mini-depots and modular storage systems can bring refilling closer to remote areas. **Smart cylinder tracking** using RFID technology could eliminate illegal refilling and enhance consumer safety.

Each cylinder that replaces a smoky jiko is a small step toward climate resilience and healthier homes."

At the **household level**, Pay-As-You-Go (PAYG) LPG systems are proving transformative. Linked to mobile money platforms, these smart meters allow users to purchase gas in small amounts, improving affordability and ensuring timely refills. Vendors can also detect leaks remotely making LPG safer than ever before.

Looking ahead, **renewable LPG (rLPG)** derived from bio-feedstocks offers a promising pathway for Kenya to align clean cooking goals with climate commitments under its Nationally Determined Contributions (NDCs).

Partnerships for Progress

Technology alone won't close the gap. Expanding LPG access requires policy alignment, infrastructure investment, and human-centered design.

Public-Private Partnerships (PPPs) will be key. The state must continue to invest in infrastructure and regulation, while the private sector innovates in distribution and service delivery. Regulators like EPRA and KEBS need stronger capacity to enforce safety standards, and financial institutions should develop credit facilities for low-income users.

Kenya can also learn from abroad. **India's Ujjwala scheme** showed how targeted subsidies can drive mass adoption, while Ghana's community refilling hubs demonstrate how rural supply chains can work efficiently.

A Cleaner Future in Sight

Kenya's LPG story is still unfolding, a story of ambition, innovation, and inclusion. It's about engineers designing safer systems, entrepreneurs building smarter distribution models, and families breathing cleaner air.

If Kenya sustains this momentum, LPG could become not just a cooking fuel but a catalyst for climate action, rural empowerment, and industrial growth.

The flame is lit; what remains is to keep it burning cleanly, safely, and for all.

The numbers reflect this momentum...

Access rate:

Approx
24%
of households

Source: EPRA

Government target:

70%
by 2028

Annual consumption:

414,000
tonnes

Per capita use:

7.9 kg
(Target: **15 kg by 2030**)

Key investments:

Mombasa terminal,
Nakuru & Eldoret
depots

Renewable Energy solutions, energy efficiency in manufacturing, smart grid's energy integration for industrial applications

Affordable and Efficient Smart Biogas System: Case Study Kisii County

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ABSTRACT

The global shift towards clean cooking solutions is essential for sustainable development and reducing greenhouse gas (GHG) emissions. This paper presents an affordable and efficient smart biogas system project implemented in Kisii County and designed to align with this shift, using a pay-as-you-go model to make clean energy accessible to economically disadvantaged populations. The system enhances financial resilience by allowing users to pay in installments, eventually leading to ownership of the system, thus supporting the global agenda for access to affordable and sustainable energy for all and climate action. The smart biogas system provides a reliable and clean energy source, crucial for poor communities. It offers long-term benefits, including reduced deforestation, decreased prevalence of respiratory diseases caused by dirty fuel cooking, and significant contributions to global sustainability goals. By

replacing traditional fuels with biogas, the system also helps mitigate the adverse health effects associated with indoor air pollution. Furthermore, the project emphasizes the importance of training and sensitizing local community members. This approach not only fosters the adoption of clean cooking technologies but also builds capacity, enhances employability, and spurs economic growth through job creation. The involvement of local stakeholders ensures that the community can sustain and expand these benefits over time. This study underscores the potential of smart biogas systems as a viable solution for addressing energy poverty, promoting environmental sustainability, and achieving socio-economic development. It serves as a model for similar initiatives worldwide, highlighting the critical role of innovative, inclusive approaches in advancing global climate and energy goals.

Keywords: Smart Biogas System, Pay- as- You-Go model, Green House Gases, Sustainable energy

“

The smart biogas system provides a reliable and clean energy source, crucial for poor communities.

Background Study

Kenya, like many developing nations, faces significant challenges in energy access, particularly for rural populations who rely heavily on traditional biomass for cooking. In rural areas such as Kisii County, firewood and charcoal remain the predominant cooking fuels, contributing to deforestation and greenhouse gas emissions. The country's Vision 2030 and commitment to Sustainable Development Goal 7 (SDG 7) emphasize the need for affordable, reliable, and sustainable energy access for all Kenyans. Additionally, indoor air pollution caused by the use of biomass fuels leads to respiratory illnesses, particularly among women and children, further underscoring the urgency for clean cooking solutions.

In this context, biogas technology offers a renewable and cleaner alternative to conventional fuels, converting organic waste into methane that can be used for cooking (Smith et al. ,2014). However, the upfront cost of biogas systems has historically been a barrier for economically disadvantaged populations. The introduction of a Pay-As-You-Go (PAYG) model, coupled with a smart biogas system, addresses this challenge by allowing users to acquire the system through manageable, incremental payments (Taneja, 2018). This project in Kisii County illustrates how such innovative financial models can promote clean energy adoption, reduce health risks, and support environmental sustainability, all while contributing to Kenya's broader energy access and climate change mitigation goals. Furthermore, Kenya has implemented various energy policies, such as the Energy Act of 2019 and the National Climate Change Action Plan (NCCAP), to promote renewable energy solutions. Mwangi and Wangeci (2020) argue that Kenya's push towards renewable energy aligns with its long-term environmental and socio-economic objectives. Therefore, integrating biogas technology into this policy framework is a logical step toward achieving the country's renewable energy targets.

Case study: Kegati Village, Kisii County

The smart biogas system was undertaken in Kegati Village in Kisii county in collaboration with Power Africa and YALI RLC. This project entailed sensitizing and training community people on the adoption of smart biogas system. This was crucial in imparting employable skills and building capacity among the community people. This project targeted community members who could leverage on the household organic wastes and animal wastes to produce clean biogas.

A sample survey study done in the select region showed that a larger percentage of the community members possess 1-3 cows which could produce enough feed stock for the deployment of the biogas system. Through the Pay As You Go Model, the community members will be able to acquire a sizable biogas system. This will eradicate indoor air pollution and promote circular economic principles in the context of waste recycling. Furthermore, the beneficiaries will access nutrient rich slurry for organic fertilizers.

Methodology

This study employed a mixed-methods approach, combining qualitative and quantitative data to assess the impact of the smart biogas system implemented in Kisii County. The project was carried out in collaboration with local stakeholders, including households, government agencies, and USAID's Power Africa.

Site Selection

Kisii County was selected due to its heavy reliance on traditional biomass fuels and its suitability for biogas technology given the availability of organic waste from agriculture and livestock.

System Design and Installation: The smart fixed dome type biogas system was designed to accommodate the energy needs of rural households. Each system was equipped with a biogas digester that converts organic waste into methane gas, and a PAYG meter for monitoring usage and payments.

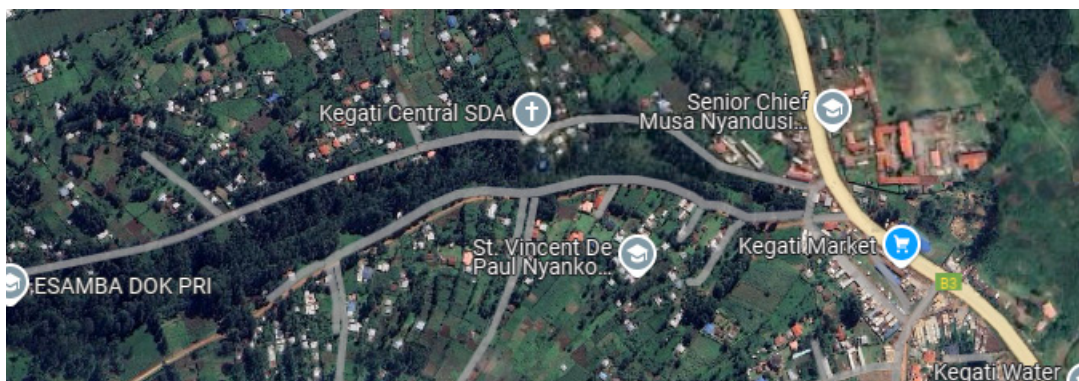


Figure 1: Kegati Village, Kisii County

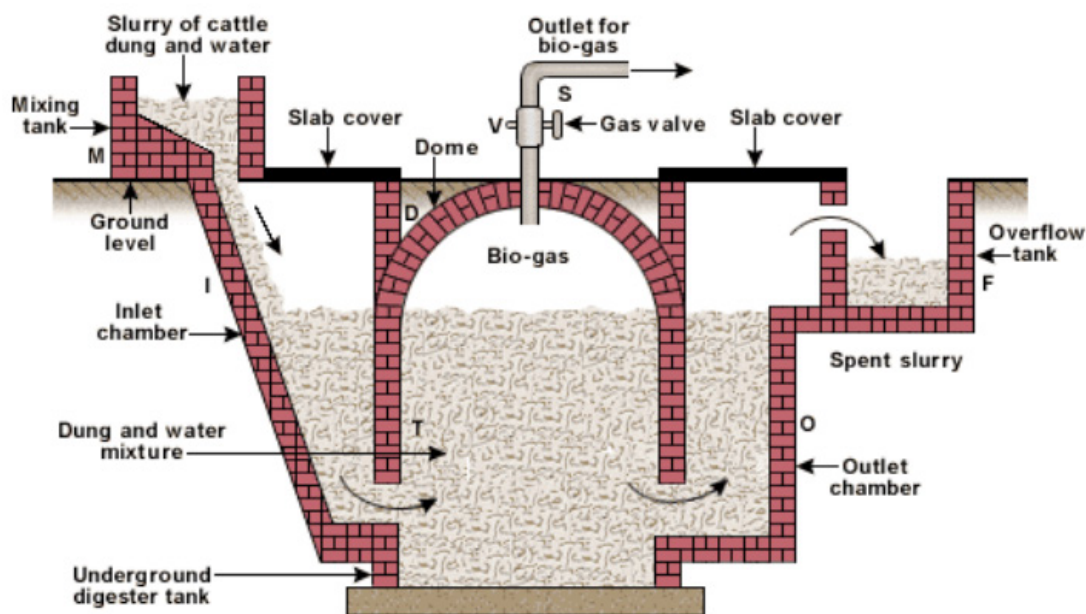


Figure 2: Fixed-dome type biogas plant

4. Capacity Building and Sensitization: Community members received training on the operation and maintenance of the biogas system, as well as the environmental and health benefits of adopting clean cooking solutions.

Results and Discussion

The implementation of the smart biogas system in Kisii County illustrates the transformative potential of renewable energy technologies when paired with innovative financial models like Pay-As-You-Go (PAYG). By addressing the affordability barrier, the project has enabled economically disadvantaged households to access clean energy, significantly reducing their reliance on traditional biomass fuels.

This shift has led to a noticeable decrease in deforestation and indoor air pollution, directly improving environmental and health outcomes. One key strength of this project lies in its holistic approach, which integrates not only the provision of technology but also community engagement and capacity building. By training local residents in the operation, maintenance, and benefits of the biogas systems, the project has empowered the community, fostering a sense of ownership and sustainability. The inclusion of local stakeholders ensures that the systems remain operational long after the initial implementation, contributing to the long-term success of the initiative.

The PAYG model has also proven effective in ensuring financial

inclusivity. Households that would typically be excluded from clean energy solutions due to high upfront costs were able to adopt the biogas system gradually. The flexibility of the payment structure helped households manage their finances while gaining access to a reliable and sustainable energy source.

However, further exploration is needed to understand the long-term sustainability of the PAYG model, particularly in regions where economic fluctuations could affect payment compliance. Additionally, scaling this project to other regions will require strong partnerships with government agencies and private sector players to ensure that the necessary infrastructure and support systems are in place.



Figure 3: Sample dome type biogas system developed at Kegati Village

Impact

The implementation of the smart biogas system in Kisii County has yielded several positive outcomes:

1. **Environmental Impact:** There was a significant reduction in deforestation, with participating households reporting a 70% decrease in firewood use. This translates to a measurable reduction in greenhouse gas emissions, contributing to both local environmental sustainability and global climate goals.
2. **Health Benefits:** Households using the biogas system reported a marked reduction in respiratory illnesses, particularly among women and children, who are most exposed to indoor air pollution. The use of clean biogas for cooking virtually eliminated harmful smoke emissions.
3. **Economic Impact:** The PAYG model allowed economically disadvantaged households to access clean energy without the burden of high upfront costs. The flexible payment system ensured that households could pay according to their financial capacity, leading to an increase in system adoption.
4. **Community Empowerment and Job Creation:** The project created employment opportunities for local technicians who installed and maintained the systems. Furthermore, the capacity-building initiatives enhanced the skills and employability of community members, contributing to local economic development.

Conclusion

The smart biogas system, coupled with the PAYG model, is a viable solution for addressing energy poverty in rural Kenya. It not only provides a clean and affordable energy source but also contributes to environmental conservation, improved public health, and socio-economic development. The results from Kisii County demonstrate the potential of this approach to be scaled up in other regions of Kenya and beyond, serving as a model for similar clean energy initiatives worldwide.

Recommendations

- **Scaling Up:** The success of the Kisii County project highlights the need for broader implementation of smart biogas systems across other rural areas in Kenya. Government support and public-private partnerships can play a crucial role in scaling up the project.
- **Policy Integration:** To enhance the impact of biogas technology, the Kenyan government should integrate smart biogas systems into national energy policies and provide subsidies or incentives for wider adoption.
- **Long-term Monitoring:** Future projects should include long-term monitoring and evaluation to measure the sustained impact of biogas systems on household energy use, health outcomes, and environmental conservation.
- **Training and Capacity Building:** Continued investment in community training programs is essential to ensure the long-term sustainability of the systems and to expand local job creation.

Acknowledgement

The authors would like to extend their sincere gratitude to **Power Africa** and the **Young African Leaders Initiative (YALI) Regional Leadership Center (RLC)** for providing the essential funding and support for this project. Without their financial assistance, the implementation of the smart biogas system in Kisii County would not have been possible. Their commitment to advancing clean energy solutions and empowering local communities has played a crucial role in the success of this initiative.

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Why investors are turning to Midstream Assets

By *EiK correspondent*

In the intricate and vast universe of the energy industry, the midstream sector often remains in the shadows of its more visible counterparts, the upstream and downstream. Yet, it is a vital sector that ensures energy resources are moved efficiently and safely from extraction sites to markets and refineries. Any failure or inadequacy in this sector would severely impede the supply chain for energy, which may ultimately have detrimental effects such as supply shortages and inflated prices for end consumers. Additionally, it is in the midstream sector where the quality and sustainability of oil and gas is evaluated, by eliminating impurities and improving product quality during initial processing.

Investing in midstream means owning infrastructure that handles natural gas flow. Its assets are usually long-lasting and require a lot of money to put up, hence they tend to generate steady cash flow over many years.

The future outlook for the Kenya Midstream Market seems to be very promising due to growing investments in the midstream infrastructure to support the growing oil and gas industry in the country. The exploration of new oil and gas resources in Kenya, in addition to the efforts by the Kenyan government to attract investors in the industry, is expected to translate to growth in midstream investments including pipeline construction, storage facilities, and transportation infrastructures in the industry. The commitment by the

Kenyan government to develop the midstream industry through the promotion of local content and favourable regulatory policies is expected to translate to growth opportunities for midstream players in the industry, locally and internationally in the coming years.

Most midstream companies earn money through fee-based contracts. These contracts charge for volume, not the price of natural gas itself. That means their income doesn't change much when natural gas prices go up or down. This makes midstream investments less risky compared to exploration and production companies that rely on volatile commodity prices.

Globally, demand for natural gas continues to rise, driven by industries such as power generation and data centres. The expansion of shale gas production and increasing exports of liquefied natural gas (LNG) have heightened the need for more robust midstream systems. These trends underscore the strategic importance of this sector in ensuring the reliable movement and processing of energy resources.

For investors, midstream offers several advantages. These companies often pay attractive dividends supported by consistent cash flow. Since their revenue depends on volume, they are less affected by swings in natural gas prices. As demand for natural gas continues to grow, so does the need for new pipelines and processing facilities. This creates

opportunities for midstream companies to expand and increase their income. Adding midstream assets to a natural gas portfolio can help balance out the higher risks seen in upstream exploration and production.

Investors can access midstream investments through publicly traded companies, master limited partnerships, or energy-focused mutual funds. These options enable participation in the growth of natural gas without being directly exposed to price swings. Ideally, for natural gas investors, midstream means investing in the essential infrastructure that moves and processes natural gas. It offers a stable income stream, growth potential from rising demand, and a way to diversify within the energy sector.

Conclusion

Investing in the midstream sector is arguably an unsung hero of the global energy value chain, a stabilizing force that ensures resilience and long-term success within the extractive industry. With a proactive and adaptive approach to risk management, companies can protect their assets, personnel and contribute to the security and stability of the global energy supply. Continuous evolution and adaptation to change are necessary to maintain the relevance and effectiveness of this sector in the decades to come.

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

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Abstract

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. To reach this goal, extensive scientific literature emphasizes the crucial role of mobilizing both private investment and household contributions. Recent Integrated Development (ID) strategies in many Sub-Saharan African (SSA) countries have proven to be the most effective way to achieve this financial mobilization. Notably, countries have found success through Business Model Innovations (BMIs) which provide electricity access integrate services such as agro-processing, food cold storage, water irrigation, internet connectivity and e-mobility. These models provide added value to consumers and boost profitability for energy providers through productive use (PU) of energy, highlighting the critical role of private investors in achieving successful electrification expansion and significantly improve living conditions in rural areas. This paper critically evaluates the current off-grid policy framework in Kenya focusing on its ability to support and stimulate market conditions favorable for the adoption of these innovative solutions. The analysis uses publicly

available policy documents as well as drafts of policies not yet approved, obtained through contacts within the country's energy regulatory framework. A detailed matrix was developed to categorize and evaluate the presence and comprehensiveness of policy instruments relevant to off-grid electrification including those facilitating PU and integrated development. The results of this analysis, discussed with stakeholders encompassing a wide range of off-grid energy expertise (including private companies, academia, and regulatory bodies), reveal a significant policy gap in supporting the productive use of off-grid energy and a general lack of strategies to drive productive use of energy and comprehensive growth through off-grid energy solutions. To address this gap the paper employs a modeling strategy focusing on a real cluster of mini grids proposed in the Kenya Off-grid Solar Access Project (KOSAP). The study explores the consequences of enhancing the productive use of the electricity generated by these mini grids, to assess the potential benefits for both developers and local populations. The conclusions drawn from this analysis provide critical insights into the necessary policy adjustments needed to foster productive use of energy through an innovative environment for off-grid energy solutions, and what consequences such adjustments would bring.

Keywords: Off-Grid, Kenya, Energy Policy, Integrated Development, Electrification, Productive Use

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

“Private sector involvement in off-grid energy projects is essential for bridging the investment gap and ensuring the long-term sustainability of electrification efforts

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) may have weaknesses, 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 specific tools needed to facilitate the operations of companies within the sector. Examples include subsidies for renewable energy projects, regulatory frameworks 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 constraints 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-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 information)	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

Present
Unclear/Tension between policies/Outdated
Absent

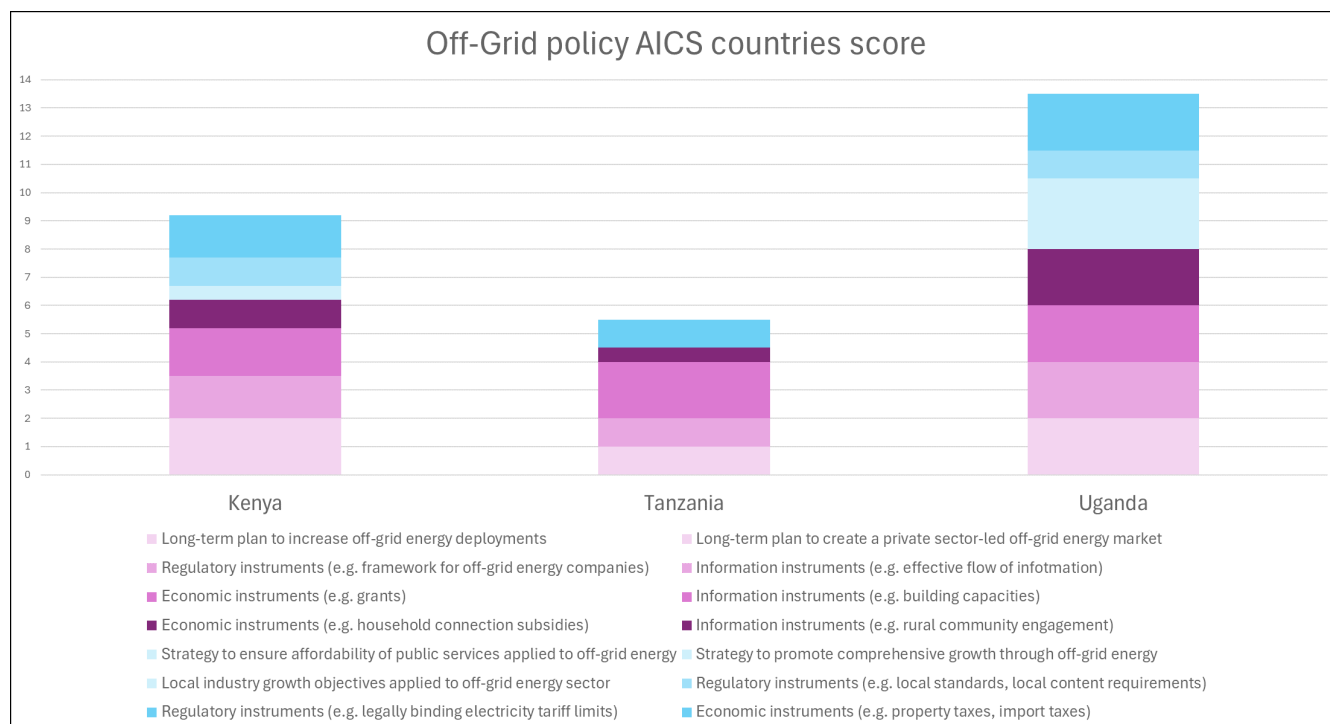


Figure 3.1: Comparison East African countries score applied to the policy matrix

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



Notably, many private stakeholders confirmed the **substantial benefit of integrating development strategies**, such as combining energy access with productive uses like agro-processing or cold storage.

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 benefits 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.

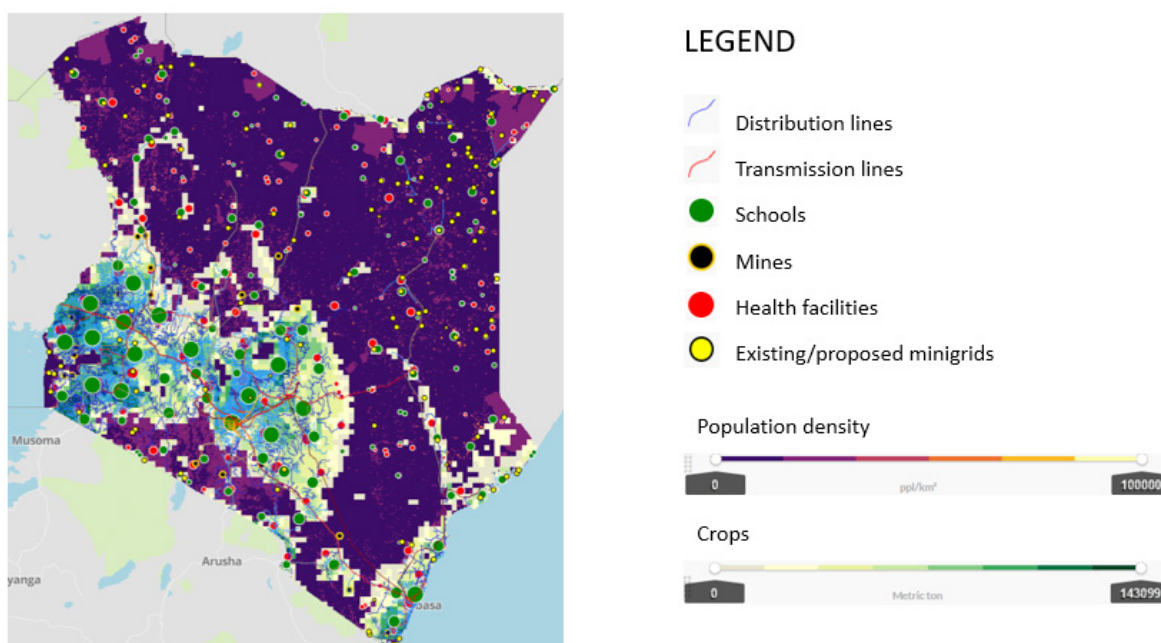


Figure 3.2: Energy Access Explorer selected layers for Kenya

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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.

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.

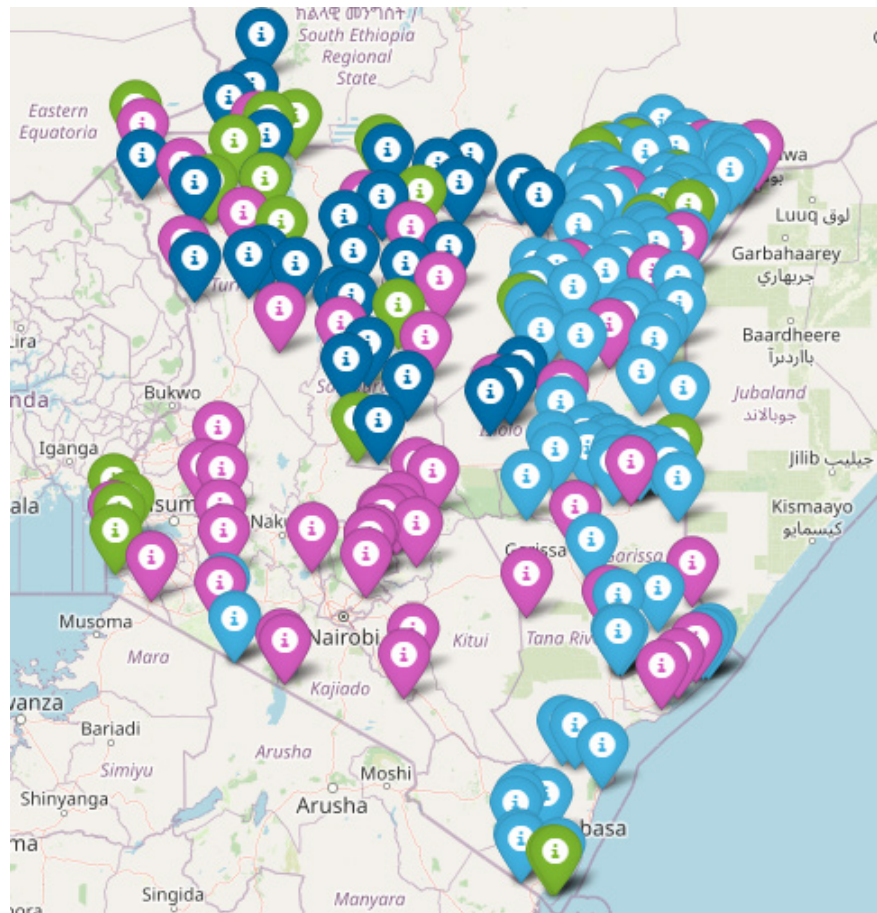


Figure 3.3: Proposed (KOSAP) and existing mini grid sites in Kenya



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.

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

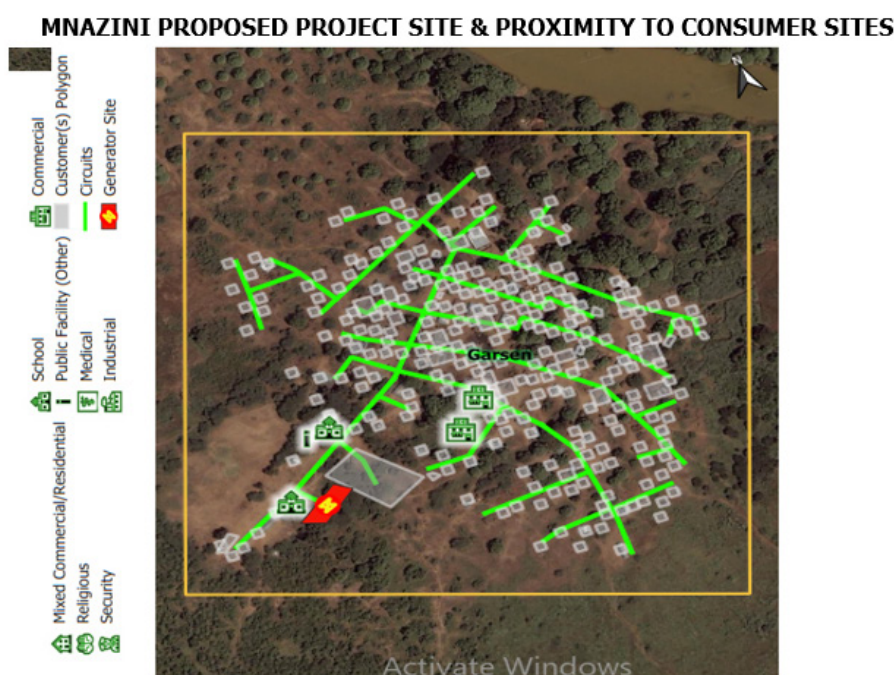


Figure 3.5: Mnazini proposed project site and proximity to consumer sites

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.

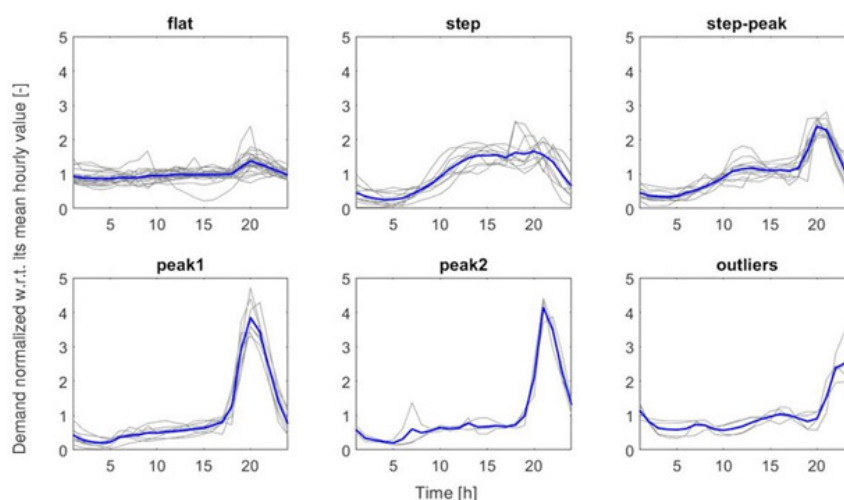


Figure 3.6 - Load demand archetypes

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

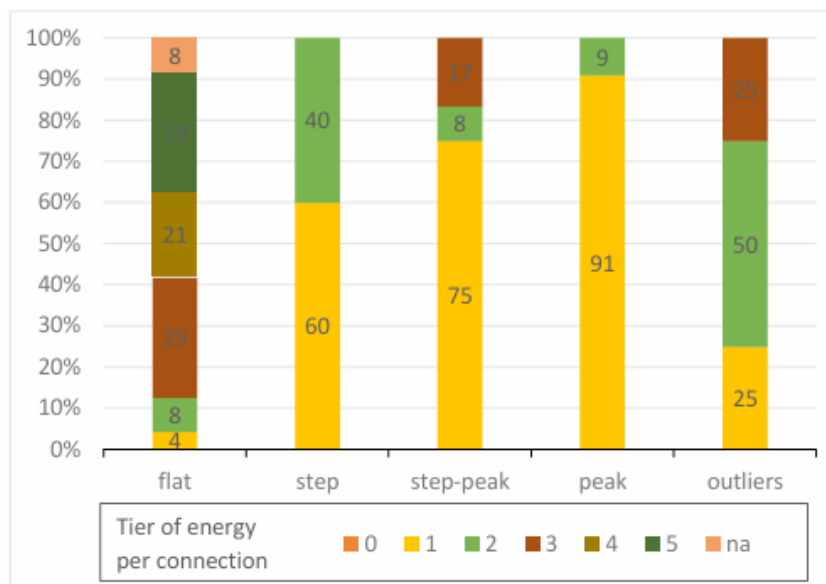


Figure 3.7 - Tier consumers share across load curve archetypes

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.

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,

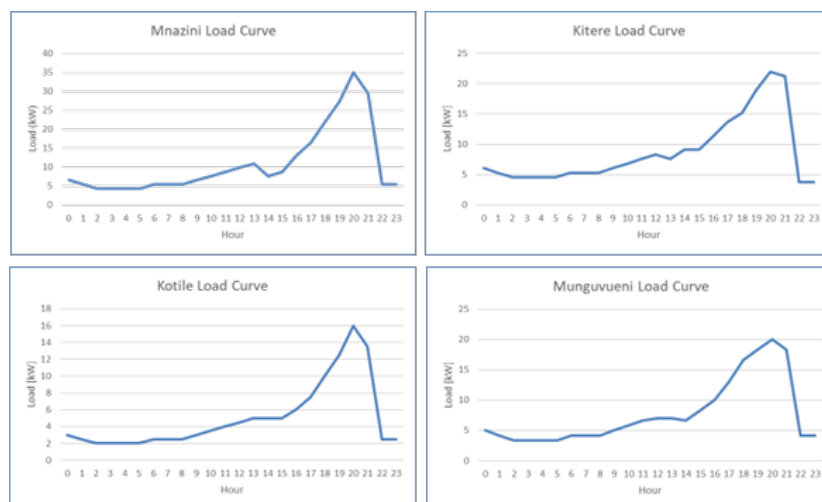


Figure 3.8: Adjusted load curves mini grid sites Tana River

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.

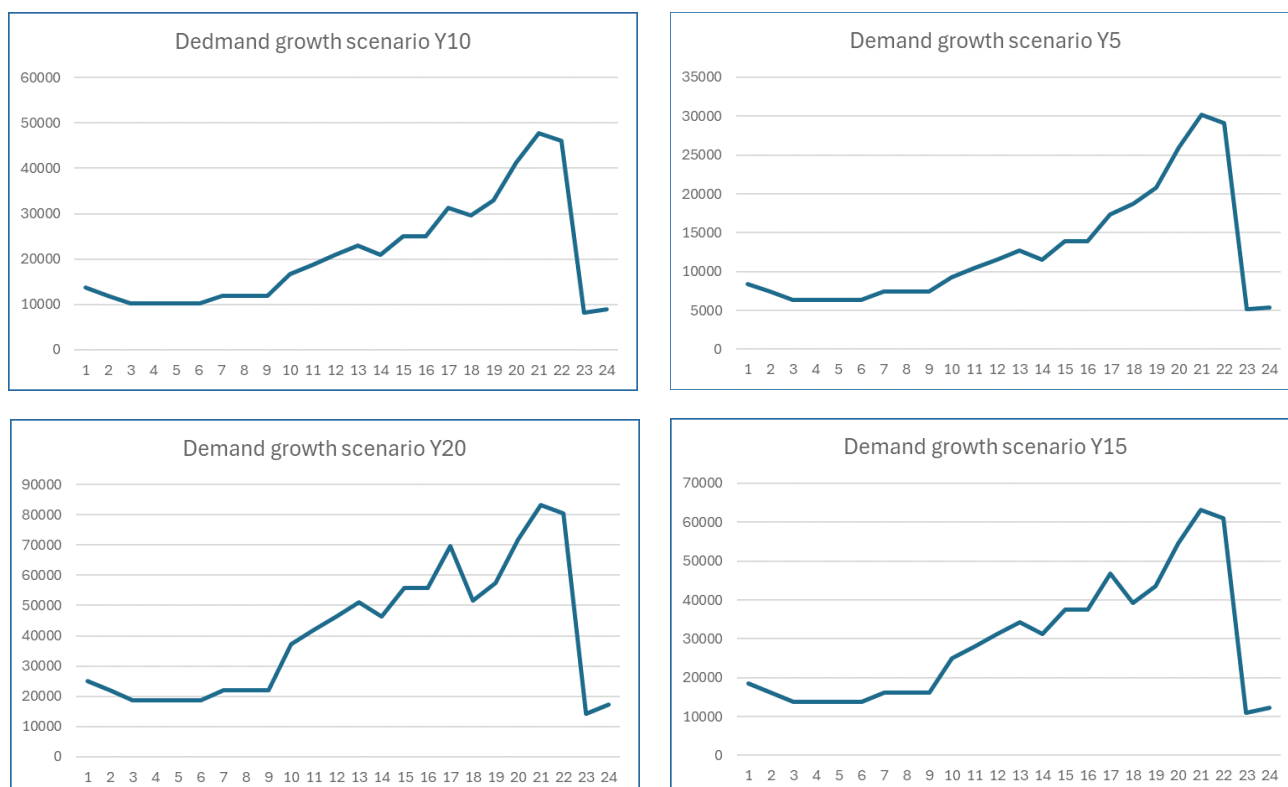


Figure 3.9: Demand growth scenario applied to Marsabit village

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.

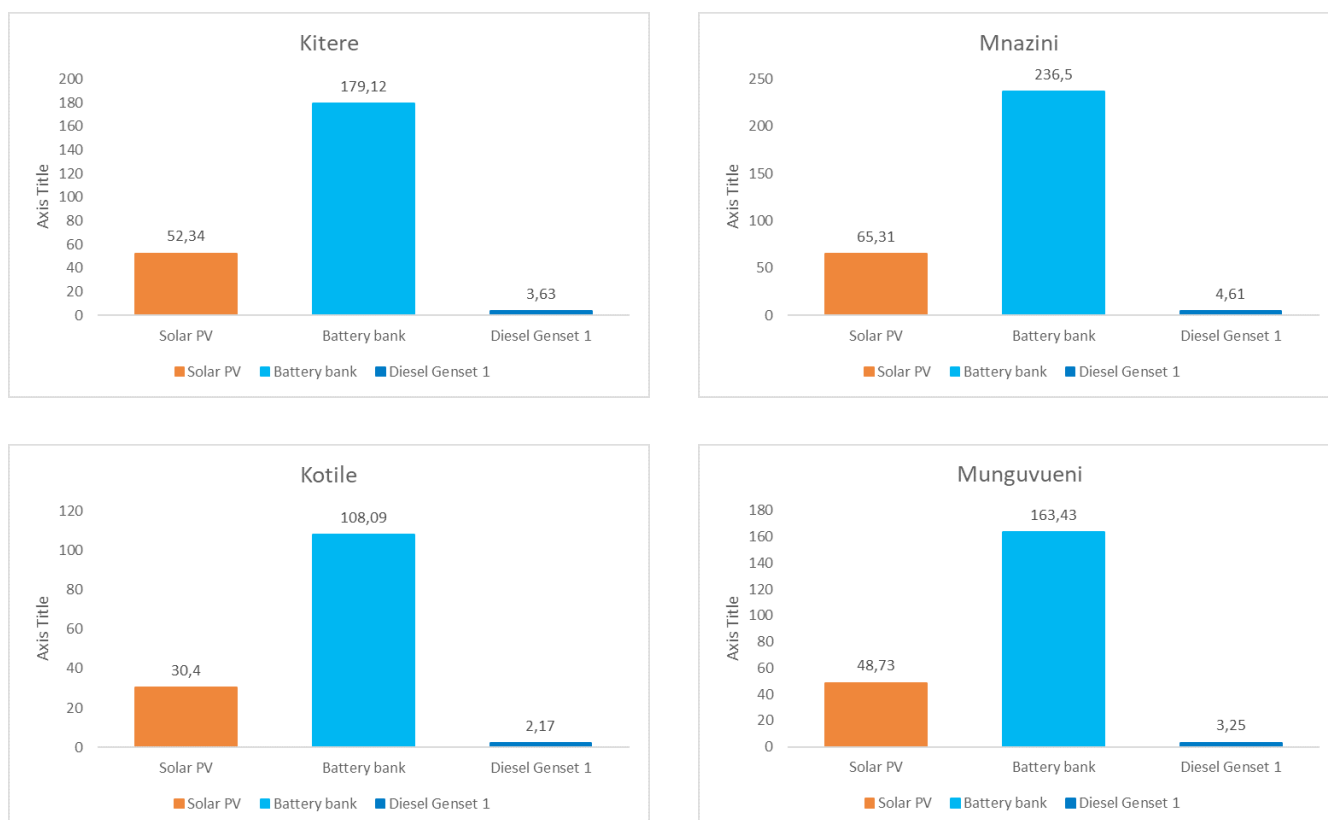


Figure 3.10: Technology capacity distribution by village (BAU scenario)

Technology capacity total share

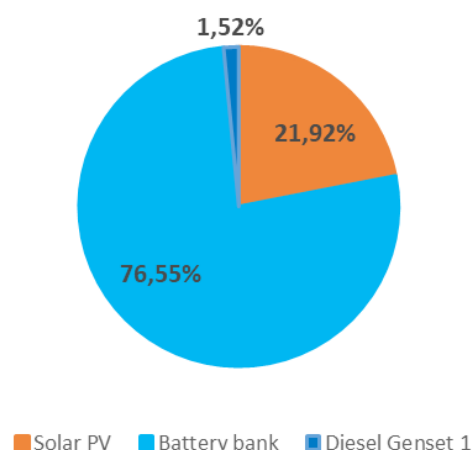


Figure 3.11: Technology capacity total share (BAU scenario)

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.

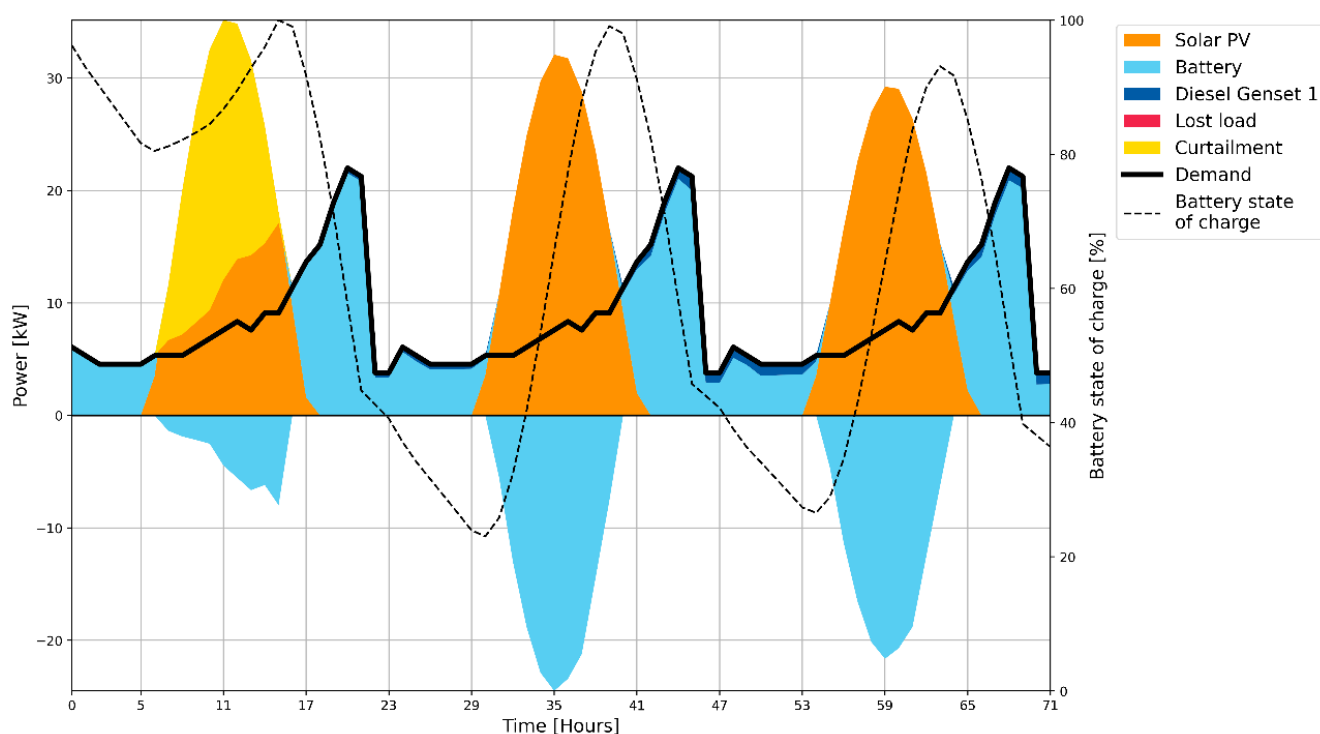


Figure 3.12: Dispatch plot (daily demand BAU scenario)

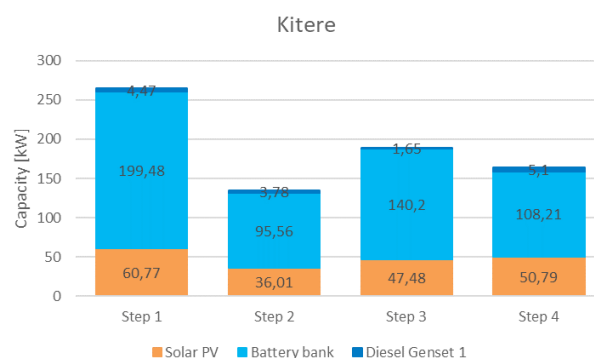
In this scenario, the system operates with minimal changes in load demand over time, which results in a relatively stable, albeit less efficient, energy use pattern. The absence of demand growth means the system doesn't benefit from economies of scale or the more efficient resource utilization that comes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

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.

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:

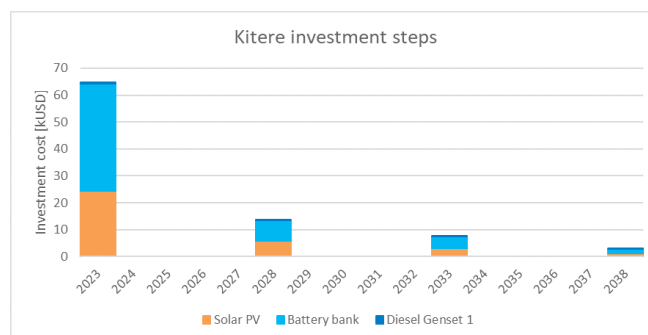


Figure 3.14 - Kitere mini grid investment steps

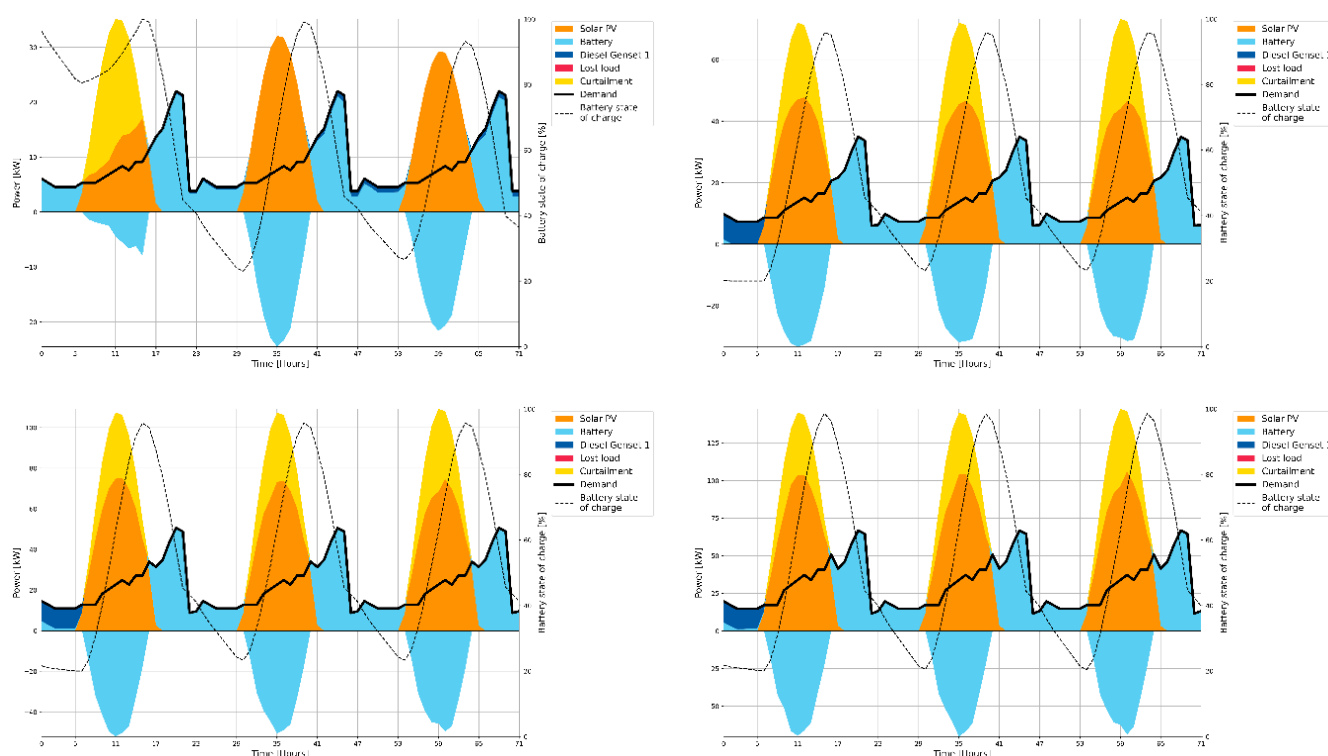


Table 3.3 – Kitere economic indicators (PU scenario)

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 Integrated 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 solutions 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 processes 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 efforts. Such a strategy would help bridge the gap between energy access and broader economic development, ensuring that rural electrification projects contribute to lasting social and economic benefits. By addressing these policy gaps and leveraging the demonstrated 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.

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Pictorials

1.

The Institution of Engineers of Kenya (IEK) held a week-long **Public-Private Partnership (PPP) training for Critical Infrastructure Projects** at Lake Naivasha Resort. The programme, which ran from October 27 to 31, 2025, brought together professionals from various sectors to share best practices in structuring and managing PPP projects.

The session was officially opened by **Eng. Kefa Seda**, Director General of the **Public Private Partnerships Directorate** at the National Treasury and Economic Planning. He emphasized the importance of collaboration between public and private sectors in advancing Kenya's infrastructure development.

The training was facilitated by **Eng. Dr. John Mativo** and **Mary Waithiegegi Chege**, who led discussions on planning, financing, and managing PPPs. The initiative demonstrated IEK's commitment to strengthening professional capacity and promoting innovation in infrastructure delivery.



2.



On 27 August 2025, IEK engineers gathered at the offices on Kindaruma Road, Nairobi, for a peaceful march under the banner **"Employment for 10,000 Engineers."** The march was a public petition to the Government, requesting urgent action to create 10,000 job opportunities for Kenyan trained engineers and to halt the marginalization of local professionals.

The engineers highlighted several key issues: unfair hiring practices by foreign firms operating in Kenya; Kenyan engineers being sidelined in major infrastructure projects; and local professionals being under paid or under utilized despite their qualifications. IEK proposed sector specific job creation numbers in affordable housing, among others.

IEK called on the Government and relevant agencies to enforce laws that protect local engineers' rights, ensure fair pay, and audit foreign firms to verify they meet Kenyan labour and professional standards. The institution described the march as a show of unity, professionalism and the engineering sector's readiness to contribute to Kenya's development

3.

The Institution of Engineers of Kenya (IEK) brought together its members, industry leaders, and government stakeholders for a memorable evening on 5 September 2025 at the Emara Ole Sereni Hotel, Nairobi. The occasion combined celebration, networking, and professional advancement as the institution hosted the annual President's Dinner alongside the official launch of the new Site Inspection Handbook.

The Handbook, a flagship publication by IEK, aims to guide engineers in carrying out consistent, safe, and high-quality site inspections across Kenya. During the launch, IEK leadership highlighted how the handbook will serve as a practical reference, helping engineers uphold professionalism while contributing to safer and more efficient infrastructure projects nationwide.

Guests enjoyed a blend of formal remarks, networking, and cultural performances that celebrated the engineering profession. The evening was a demonstration of IEK's commitment to innovation, excellence, and service to humanity, reinforcing the role of engineers as key contributors to Kenya's growth and development.



4.

Members of IEK conducted an industrial visit to ACTOM Kenya's manufacturing facility in Nairobi, offering them a behind-the-scenes insight into cutting-edge powerplant equipment manufacturing and assembly. The visit took place on **Friday, 26 September 2025**, according to the ACTOM Kenya newsletter.

During the tour, engineers viewed the full production process from raw materials and parts to finished low-voltage and protection panels within ACTOM Kenya's Power Technics Complex on Mombasa Road. The host highlighted how the local facility is part of a broader East-African manufacturing strategy, with capabilities in both manufacturing and repair of electrical equipment.

The visit underscored the importance of strengthening Kenya's local manufacture of key infrastructure components. For IEK members, it offered practical exposure to engineering operations, manufacturing quality standards and the role that local industry plays in Kenya's energy and industrialization agenda. IEK continues to facilitate such engagements to connect its membership with industry innovations and opportunities.



5.

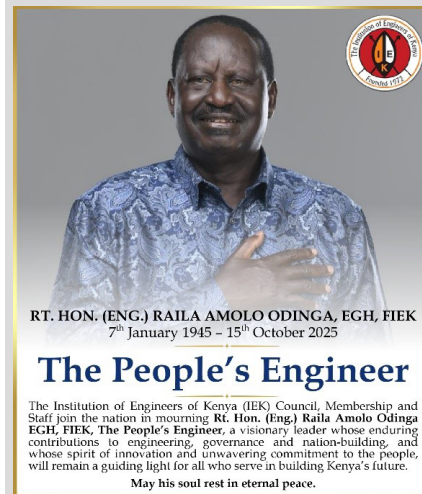
The Institution of Engineers of Kenya (IEK), made a visit to the family of the late Rt. Hon. (Eng.) Raila Amolo Odinga, C.G.H., FIEK, on Friday 24th November, to convey heartfelt condolences on behalf of the engineering fraternity. The visit reflected the Institution's deep respect for the late Hon. Odinga's immense contribution to the engineering profession, national development, and leadership in Kenya.

The IEK delegation was led by IEK President Eng. Shammah Kiteme, and included 2nd Vice President Eng. Christine Ogut, Hon. Secretary Eng. Jacton M., Council Member Eng. Lilian Kilatya, CEO Eng. Maureen Auka, Eng. Stephen Auma, and Anvar Joseph Alot, the Policy, Research and Partnerships Manager.

During the visit, the IEK leadership reflected on the late Hon. Odinga's legacy as both a political leader and a professional engineer who championed industrial growth and infrastructural development.

His contributions to the energy and construction sectors continue to inspire generations of engineers and professionals in the built environment.

The IEK team was joined by representatives from professional bodies, including the Institution of Surveyors of Kenya (ISK) and the Architectural Association of Kenya (AAK), led by ISK President Mr. Eric Nyandimo. Together, they honored The Late Hon. Odinga's enduring impact on Kenya's professional community and reaffirmed their commitment to uphold the values of service, integrity, and nation-building that he embodied.



6.

The Institution of Engineers of Kenya (IEK) Editorial Board, chaired by Eng. Prof. Lawrence Gumbe, held a strategic retreat on Friday 24th -Saturday 25th October, 2025 to review ongoing editorial initiatives and strengthen the Institution's publication strategy.

The session brought together Eng. Shammah Kiteme (President), Eng. Christine Ogut (2nd Vice President), Eng. Margaret Ogai (Registrar/CEO - Engineers Board of Kenya), Eng. Paul Ochola (Secretary), Eng. Sammy Tangu (Treasurer), Eng. Nathaniel Matalanga (Member), and Eng. Prof. Leonard Masu (Member).

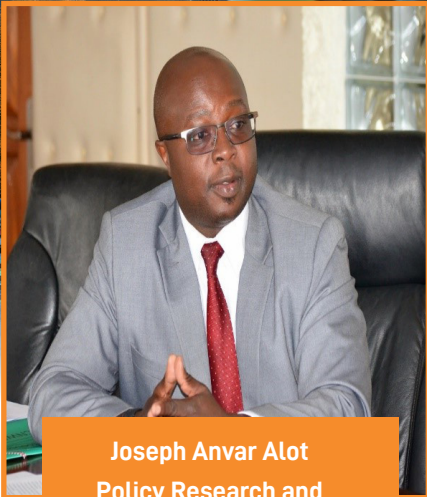
The retreat focused on strengthening IEK's flagship publications (ie) Engineering in Kenya (EiK) Magazine ,

African Journal of Engineering Research -and Innovation (AJERI) and the IEK Weekly Newsletter to better serve the engineering community and enhance professional communication.

The retreat concluded with a shared commitment to reimagine IEK's Editorial direction by building a future-ready framework that blends technical innovation with storytelling excellence. By embracing emerging technologies and fostering collaboration with strategic partners, the IEK Editorial Board reaffirmed its vision to make Engineering in Kenya Magazine, AJERI Journal and the IEK Weekly Newsletter platforms for thought leadership, innovation, and professional growth within the engineering fraternity.



Electric Mobility in Kenya: Reducing Petroleum Dependency Through Renewable Energy Solutions



Joseph Anvar Alot
Policy Research and
Partnerships Manager, IEK

Now, a quiet transformation is underway. In Nairobi's morning traffic, the deep rumble of engines is increasingly joined by the soft hum of electric buses, motorbikes and delivery vans. It's a subtle signal of something much larger, a shift away from imported fossil fuels toward an infrastructure powered by Kenya's own renewable energy and technological ingenuity.

At petrol stations across Kenya, the rhythm of the fuel pump has long been the soundtrack of movement. Diesel trucks, petrol matatus and boda bodas have powered Kenya's economy for decades, but at a high cost. The country imports nearly all its petroleum, spending billions of shillings each year on fuel that supports transport and commerce but drains foreign exchange reserves and exposes the economy to global oil-price volatility.

Electric mobility is not merely about cleaner air or modern vehicles. It signals an economic realignment, transport becomes plugged into a low-carbon energy system, and petroleum's dominance in mobility begins to decrease.

The Energy Equation: Turning Power into Motion

Kenya is in a uniquely favorable position; its electricity system is already dominated by renewables. Estimates suggest that 85% to 90% of Kenya's electricity generation comes from renewable sources (geothermal, hydro, wind, solar) as of 2023. Some reports even put Kenya's renewable share at 92% in recent years.

Because of this, every unit of electricity used to power an EV is potentially low-carbon and sourced domestically. For engineers, this means designing systems that tie transport directly into the grid, battery management systems (BMS), power electronics, and smart chargers all must be designed to handle grid variability, losses, voltage fluctuations and real operating conditions.

Engineering the Future: Skills that Drive E-Mobility

Electric mobility demands a blend of classical engineering and modern energy systems thinking:

- **Battery Chemistry & Thermal Management** – engineers must design battery packs (e.g. lithium-ion, Nickel Manganese Cobalt (NMC) and Lithium Iron Phosphate (LFP)) with reliable insulation, cooling/heating and cell balancing to maximize life cycles.
- **Power Electronics** – inverters, DC-DC converters and charger

circuits must be efficient (e.g. > 95%) and robust to grid disturbances.

- **Embedded Control Systems** – firmware for motor controllers, diagnostics, regenerative braking, safety interlocks.
- **Energy & Grid Integration** – ability to integrate charging stations, renewable generation and even vehicle-to-grid (V2G) architectures.
- **Data Analytics & Telematics** – live monitoring of battery health, predictive maintenance, fleet optimization.
- **Mechanical and Systems Engineering** – designing enclosures, mounts, vehicle integration under vibration, shock, temperature extremes.

Engineers in places like Roam and Basi Go are applying exactly these skills, assembling powertrains, calibrating battery packs, writing diagnostics software and stress-testing components under Kenyan climate, road and load conditions.

Battery-as-a-Service: Powering Mobility Through Innovation

A critical innovation driving e-mobility growth in Kenya is Battery-as-a-Service (BaaS). A model where EV owners, especially two and three-wheel operators, lease or swap batteries instead of owning them outright.

Companies such as Arc Ride are pioneering this model across East Africa. Here's how it works.

1. **Battery Swapping** - Riders exchange a depleted battery for a fully charged one at designated swap stations in under five minutes.
2. **Subscription Model** - Riders pay a small daily or per-swap fee, covering battery use, maintenance and charging.
3. **Operational Advantage** - Eliminates charging downtime, lowers upfront EV costs by up to 40% and ensures consistent performance.

From an engineering standpoint, BaaS requires significant technical innovation:

- **Battery Standardization** - Developing modular, interoperable battery designs.
- **Advanced Battery Management Systems (BMS)** - For tracking health, safety and charge cycles across thousands of units.
- **IoT Integration** - Real-time monitoring of battery state-of-charge and location data.
- **Thermal Design** - Ensuring battery safety under rapid charge/discharge cycles typical of swap operations.

The model has also prompted **new opportunities for mechanical, electrical and software engineers** from designing smart charging racks and swap kiosks to optimizing thermal management and predictive diagnostics.

Economically, BaaS allows Kenya's boda boda riders to shift from fuel dependency to an **energy service subscription**, effectively replacing petrol stations with energy-exchange hubs powered by renewables.

Bridging Industry and Academia

No industrial revolution can thrive without the synergy of research institutions and industry. While no Kenyan university currently offers dedicated degree programs specifically in EV, battery and renewable energy

modules, universities and technical institutes are already embedding EV, battery and renewable energy modules into their engineering degradation, and investigating grid integration and V2G.

Partnerships are emerging. Through its locally-registered company, Africa Smart Mobility Kenya Limited (ASMSKL), Spiro is set to establish a specialized training center at Technical University of Kenya (TU-K) aimed at developing top-talent in the electric vehicle (EV) industry. Local companies in many cases collaborate with universities on internships and joint research in control systems, battery diagnostics and vehicle dynamics. As the sector matures, formal industry-academia research hubs focused on next-generation battery chemistries, recycling and systems optimization will be crucial for Kenya to become more than an EV adopter, but also an innovator and exporter of green mobility technology.

Policy Landscape for Electric Mobility in Kenya

Kenya's electric mobility sector is supported by a growing framework of policies and regulations designed to accelerate the shift from petroleum-powered transport to renewable, electricity-driven systems. Central to this transformation is the Draft **National Electric Mobility Policy (2024)**, developed by the Ministry of Roads and Transport. The policy provides a comprehensive roadmap for transitioning from internal combustion engine vehicles to electric vehicles (EVs) across all modes of transport. It focuses on developing infrastructure such as public charging stations, supporting local vehicle assembly and battery manufacturing, building technical skills among engineers and technicians and ensuring environmental sustainability in line with Kenya's commitments under Vision 2030 and the National Climate Change Action Plan.

Complementing this policy are a series of fiscal and regulatory incentives that make EV adoption more viable. Through the Finance Acts and tax reforms, the government

has introduced zero-rating of VAT on electric vehicles, batteries, and key components, alongside reduced excise duties for fully electric vehicles. The Energy and Petroleum Regulatory Authority (EPRA) has also introduced a special electricity tariff for EV charging, offering lower off-peak rates to encourage efficient use of the grid. Additionally, the Kenya Bureau of Standards (KEBS) has issued import regulations to ensure EV quality, battery safety, and compatibility with local conditions, while the E-Mobility Task Force (2023), established under Gazette Notice No. 10132 continues to craft long-term legislative and policy reforms for the sector.

Collectively, these policies reflect Kenya's strategic intent to reduce petroleum dependency, promote renewable energy use, and strengthen local capacity in engineering, manufacturing, and innovation. However, effective implementation remains critical. Sustained coordination among engineers, policymakers, manufacturers, and investors is needed to ensure that these frameworks translate into tangible progress expanding charging infrastructure, maintaining environmental safety standards, and making EVs accessible beyond urban centers. If properly executed, Kenya's policy architecture could position the country as a continental leader in clean transportation, powered by home-grown renewable energy and local technical expertise.

Electric mobility represents the convergence of engineering precision, renewable energy innovation, and national vision. With every locally assembled e-bus and battery designed for African conditions, Kenya inches closer to true energy independence. The engineers behind the batteries, the startups building charging networks, and the policymakers enabling reform are not just changing how we move — they're reshaping Kenya's economic and environmental architecture. The journey ahead may be long, but the destination is clear: a cleaner, smarter, and self-reliant Kenya.

Socioeconomic And Infrastructural Drivers of Renewable Energy Adoption in Rural Kenya: A Comparative Study of Elgeyo Marakwet and Kisumu Counties

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Abstract

Despite Kenya's advances in renewable energy (RE) policy and off-grid electrification strategies, rural adoption remains uneven and often limited by socioeconomic and infrastructural barriers. This study presents a comparative analysis of RE adoption in two contrasting counties—Kisumu and Elgeyo Marakwet—to examine how income, infrastructure, institutional capacity, and community dynamics influence energy transitions. Using a mixed-methods approach, the research draws on data from 44 household surveys, 8 key informant interviews, 2 focus group discussions, and field observations conducted in both counties. Findings reveal that solar energy is the most widely recognized RE source, with 95% of respondents in Elgeyo Marakwet and 70% in Kisumu reporting its use, primarily for lighting and mobile charging. However, adoption of clean cooking technologies remains low due to high upfront costs and limited technical support. Fuel stacking is common across income levels, challenging the linear assumptions of the Energy Ladder model. While Kisumu benefits from stronger infrastructure (electricity access ~52%) and county-NGO partnerships, Elgeyo Marakwet faces significant access gaps (grid coverage ~30%) but demonstrates strong community willingness to adopt RE systems when supported. The study applies the Diffusion of Innovations Theory, Energy Ladder model, and Sustainable Livelihoods Framework to interpret findings. It concludes that localized, inclusive, and gender-sensitive interventions—particularly those addressing financing and institutional coordination—are essential for accelerating equitable energy transitions in Kenya's rural areas.

Keywords: Renewable energy, rural electrification solar, biogas, policy

1 INTRODUCTION

1.1 Background of the study

Access to affordable, reliable, and clean energy is central to achieving Sustainable Development Goal 7 (SDG 7), which seeks to ensure energy access for all by 2030. Globally, over 733 million people still lack electricity, with more than 80% living in sub-Saharan Africa (IEA, 2022). In Kenya, electricity access has improved significantly rising from 28% in 2013 to over 75% in 2022, largely due to grid expansion and decentralized renewable energy programs (World Bank, 2022). However, this national progress masks sharp regional disparities: rural counties such as Elgeyo Marakwet report electricity access below 30%, while peri-urban areas in Kisumu reach above 50% through a combination of grid and off-grid solutions (Kenya National Bureau of Statistics [KNBS], 2019).

Decentralized Renewable Energy Technologies (RETs), including solar photovoltaic (PV) systems, biogas digesters, and micro-hydro installations, offer a practical and scalable solution for rural electrification. Solar energy in particular has gained traction, with Kenya being one of Africa's leaders in solar home systems (IEA, 2022). Despite these advances, widespread adoption in rural regions remains elusive due to cost barriers, limited awareness, lack of technical support, and inadequate policy implementation at the local level (Ondraczek, 2014; Brew-Hammond, 2010).

1.2 Socioeconomic and Institutional Dimensions

Household-level energy transitions are shaped by a complex interplay of economic, cultural, and infrastructural variables. The Energy Ladder hypothesis (Leach, 1992) posits that as household income increases, energy use shifts from traditional biomass to modern fuels. Yet, empirical studies across Kenya reveal persistent fuel stacking, where households use multiple energy sources to hedge against price volatility, seasonal availability, and cultural cooking preferences (Masera, Saatkamp, & Kammen, 2000; Van der Kroon, Brouwer, & Van Beukering, 2013).

Recent research highlights that education level, gender of household head, asset ownership, and access to credit significantly influence renewable energy adoption (Kirai & Mugure, 2018). Women-headed households, particularly in rural settings, express strong interest in clean cooking solutions, but face institutional barriers such as lack of collateral for loans and exclusion from decision-making processes (Oparaocha & Dutta, 2011). In Kisumu, community-led projects—such as solar-powered fish markets and biogas units in schools demonstrate the potential of public-private partnerships to overcome adoption barriers. By contrast, in counties like Elgeyo Marakwet, limited road access, sparse population distribution, and weak market linkages undermine the scalability of similar interventions.

At the institutional level, Kenya has introduced progressive energy policies, including Feed-in Tariffs, Value

Added Tax (VAT) exemptions on solar equipment, and the Kenya National Electrification Strategy (KNES). However, implementation at the county level remains inconsistent. The 2010 Constitution devolved energy responsibilities to the counties, but most lack the technical capacity, planning tools, or budgetary autonomy to translate policy into local action (Gathui & Kirai, 2012; Ministry of Energy, 2018).

1.3 Research Gaps and Comparative Approach

Despite Kenya's leadership in renewable energy policy, three critical research gaps persist:

1. Comparative regional analysis of renewable energy uptake is limited, making it difficult to generalize or adapt successful models across counties.
2. Community-level perspectives on technology acceptance, perceived value, and participation in energy projects are underrepresented in policy design.
3. The roles of gender, informal institutions, and livelihood strategies in shaping adoption trajectories are rarely integrated into energy transition models.

This study responds to these gaps by comparing two counties with contrasting profiles. **Kisumu County**, a semi-urban region with a mix of grid and off-grid solutions, has benefited from international donor projects and county-led energy initiatives. **Elgeyo Marakwet**, a more rural and mountainous county, relies heavily on firewood and informal biomass



Globally, over **733 million** people still lack electricity, with more than **80%** living in sub-Saharan Africa (IEA, 2022).

markets, with fewer formal energy interventions.

By examining both counties through a mixed-methods approach including household surveys, key informant interviews, and focus group discussions this study provides a nuanced understanding of the socioeconomic, infrastructural, and policy-driven factors shaping renewable energy adoption.

1.4 Research Objectives and Questions

This study seeks to contribute to Kenya's clean energy transition by generating actionable insights into renewable energy use in rural settings. The research is guided by the following questions:

- i. What are the prevailing patterns of energy use in rural Kisumu and Elgeyo Marakwet Counties?
- ii. What socioeconomic and infrastructural factors influence the adoption or rejection of renewable energy technologies?
- iii. How do community perceptions, policy frameworks, and project implementation models differ between the two counties?

By answering these questions, the study aims to inform more inclusive and locally responsive energy planning that supports equitable and sustainable transitions across Kenya's rural counties.

2 THEORETICAL FRAMEWORKS

Understanding the adoption of renewable energy technologies (RETs) in rural Kenya requires a multidimensional theoretical lens that accounts for the interplay between individual choices, socioeconomic conditions, institutional dynamics, and community behaviors. This study draws on three complementary frameworks: the Diffusion of Innovations Theory (DoI), the Energy Ladder Model, and the Sustainable Livelihoods Framework (SLF). Together, these frameworks provide a robust conceptual foundation for interpreting household energy decisions and adoption

patterns across contrasting contexts.

2.1 Diffusion of Innovations Theory (DoI)

Developed by Rogers (2003), the Diffusion of Innovations Theory explains how, why, and at what rate new ideas and technologies spread through social systems. The theory identifies five core attributes that influence the adoption of innovations:

- i. Relative advantage – perceived benefits over existing practices
- ii. Compatibility – alignment with existing values and needs
- iii. Complexity – perceived ease of understanding and use
- iv. Trialability – ability to experiment on a small scale
- v. Observability – visibility of results to others

In rural Kenyan settings, where social networks, peer learning, and community reputation play significant roles, these attributes are particularly critical. For example, the visibility of solar panels on rooftops or biogas units in schools enhances the observability of the technology, making it more likely that neighbors will adopt. However, in areas with limited exposure to successful models or demonstrations, adoption may be inhibited by low **trialability** and high perceived **complexity**.

The theory also emphasizes the role of **change agents** such as NGOs, community leaders, and extension workers in facilitating knowledge transfer and increasing adoption. In Kisumu, such agents have enhanced adoption through targeted demonstrations, while their absence in Elgeyo Marakwet contributes to slow diffusion despite evident interest.

2.2 Energy Ladder Model

The Energy Ladder Model (Leach, 1992; Barnes & Floor, 1996) postulates that households move from traditional energy sources (e.g., firewood, dung) to transitional fuels (e.g., charcoal, kerosene) and eventually to modern energy sources (e.g., LPG, electricity) as income, education,

and infrastructure improve.

However, this model has faced empirical challenges in sub-Saharan Africa. Studies have shown that households rarely abandon older fuels entirely, even after adopting modern ones—a behavior referred to as fuel stacking (Masera, Saatkamp, & Kammen, 2000; Van der Kroon, Brouwer, & Van Beukering, 2013). Households combine energy sources based on affordability, reliability, cultural preferences, and seasonal availability.

In this study, the Energy Ladder serves as a heuristic to frame household transitions but is critically applied alongside fuel stacking behavior. The model is particularly relevant in exploring how income and infrastructure enable or constrain movement toward cleaner energy forms, especially in resource-poor settings like Elgeyo Marakwet.

2.3 Sustainable Livelihoods Framework (SLF)

The Sustainable Livelihoods Framework (SLF), developed by DFID (1999), provides a broader lens for analyzing household decision-making by focusing on the five forms of capital that support sustainable livelihoods:

- i. Human capital – education, skills, and health
- ii. Social capital – networks, group membership, and relationships of trust
- iii. Financial capital – income, savings, and credit access
- iv. Physical capital – infrastructure, tools, and technologies
- v. Natural capital – land, water, and biomass availability

The SLF is particularly valuable in understanding how energy decisions intersect with livelihood strategies. For instance, in Kisumu, high physical and social capital such as road access and women's groups support the dissemination and maintenance of RETs. In contrast, in Elgeyo Marakwet, natural capital (e.g., forest access) sustains biomass use, while low financial capital limits the uptake of modern technologies despite interest.

By considering these interrelated assets, SLF helps explain why some households adopt RETs while others do not, despite similar levels of awareness.

2.4 Integrative Value of the Frameworks

The integration of DoI, the Energy Ladder, and SLF allows for a comprehensive understanding of renewable energy adoption that is sensitive to both individual and systemic factors. Specifically, the combined frameworks enable the study to:

- i. Explain technology diffusion patterns (DoI)
- ii. Contextualize fuel use transitions and fuel stacking (Energy Ladder)
- iii. Analyze livelihood constraints and enablers (SLF)

This multidimensional approach is crucial for unpacking the nuanced dynamics of energy behavior in rural Kenya, where household choices are not only economic but also shaped by cultural, infrastructural, and institutional contexts. It also provides a sound theoretical basis for informing more inclusive and effective energy policy interventions.

3 METHODOLOGY

3.1 Research Design

This study employed a comparative case study design to examine the socioeconomic and infrastructural factors influencing renewable energy adoption in rural Kenya. This approach was chosen for its ability to provide rich, contextual insights across different settings, allowing for cross-case comparisons and the generation of transferable lessons (Yin, 2018). The two counties selected—**Kisumu** and **Elgeyo Marakwet**—presented contrasting profiles in terms of geography, infrastructure, and energy governance. Kisumu, with its semi-urban landscape and proximity to donor-supported projects, offered a setting of relatively advanced renewable energy penetration, while Elgeyo Marakwet, characterized by mountainous terrain and sparse settlements, reflected more

limited infrastructural and institutional support.

A mixed-methods approach was used to complement the breadth of quantitative data with the depth of qualitative insights (Creswell & Plano Clark, 2018). This methodological integration was instrumental in capturing both the statistical patterns of energy use and the nuanced sociocultural and institutional dynamics underpinning them. Quantitative data were obtained through structured household surveys that collected information on energy sources, income levels, education, and household demographics. These surveys enabled cross-tabulations and frequency analysis to identify adoption trends across different population segments.

3.2 Study Areas

This study was conducted in two contrasting counties in Kenya: Kisumu and Elgeyo Marakwet. These counties were purposively selected due to their divergent geographic, infrastructural, and socioeconomic profiles, which offered a robust basis for comparative analysis of renewable energy adoption in rural settings.

3.2.1 Kisumu County

Located in western Kenya, Kisumu County features a diverse landscape that includes urban centers, peri-urban settlements, and rural areas. Its proximity to **Lake Victoria** and location within a major regional trade corridor have contributed to relatively better infrastructure, such as road networks and electricity grid access. As of 2019, electricity coverage in rural parts of Kisumu was approximately 52%, supported by both grid and off-grid solutions (KNBS, 2019).

The county has been a beneficiary of **donor-funded energy programs and county-led renewable energy initiatives**, particularly in solar and biogas technologies. Solar lighting systems have been installed in public markets, schools, and health facilities, while biogas digesters are increasingly used in schools and by cooperatives. These interventions have fostered visibility and trust in renewable

energy technologies, contributing to a more enabling environment for adoption.

Kisumu's socioeconomic diversity including higher average household incomes, literacy rates, and active civil society organizations provides a relatively fertile ground for exploring institutional and community-led renewable energy adoption models.

3.2.2 Elgeyo Marakwet County

Elgeyo Marakwet, located in Kenya's Rift Valley region, presents a more rural and topographically challenging environment. The county is characterized by rugged terrain, steep escarpments, and dispersed settlements, which collectively hinder infrastructure development and energy access. Electricity coverage remains low, estimated at around 30% in most rural areas (KNBS, 2019).

Unlike Kisumu, Elgeyo Marakwet has had limited exposure to formal renewable energy programs. Most residents rely heavily on traditional biomass fuels such as firewood and charcoal, often sourced from nearby forests. The physical inaccessibility of many areas and the lack of reliable vendor networks for solar or LPG products pose significant barriers to energy transition.

Despite these constraints, the county exhibits strong social cohesion and community participation structures, including women's groups and savings cooperatives. These informal networks present opportunities for decentralized, community-based energy initiatives if supported with appropriate financial and technical assistance.

3.2.3 Justification for Comparative Selection

The contrast between Kisumu's relatively advanced infrastructure and Elgeyo Marakwet's marginalization provides a valuable framework for understanding how local context shapes the adoption of renewable energy technologies. While Kisumu offers insights into the effectiveness of coordinated institutional support and public-private partnerships, Elgeyo Marakwet highlights

the challenges and opportunities of energy access in under-resourced, geographically isolated areas.

By examining these two counties side by side, the study generates context-sensitive insights that can inform national energy planning and localized interventions, particularly in underserved rural communities.

3.3 Data Collection Methods

To capture a nuanced understanding of renewable energy adoption in rural Kenya, the study employed a mixed-methods approach, integrating both quantitative and qualitative data collection techniques. This approach was selected to ensure a comprehensive analysis of household energy behaviors, community perspectives, and institutional dynamics.

Primary data was collected through structured household surveys, which provided quantitative insights into energy usage patterns, socioeconomic characteristics, and attitudes toward renewable technologies. A total of 44 households were surveyed across the two counties Kisumu and Elgeyo Marakwet—selected through stratified random sampling to reflect variation in income levels, gender of household heads, and geographic location. The surveys incorporated both closed-ended and Likert-scale questions, enabling statistical analysis of variables such as fuel type, household income, education level, and willingness to adopt specific renewable energy technologies.

Complementing the surveys, **key informant interviews (KIIs)** were conducted with stakeholders including county energy officials, NGO project coordinators, and leaders of community-based organizations (CBOs) and women's groups. These interviews explored issues such as policy awareness, financing constraints, implementation challenges, and strategies for enhancing community engagement. Informants were selected using purposive and snowball sampling techniques, appropriate for identifying individuals

with specialized knowledge or experience in the energy sector.

To further enrich the qualitative dataset, focus group discussions (FGDs) were held separately in both Kisumu and Elgeyo Marakwet counties. Each discussion included 8 to 10 participants, providing a platform for community members to share collective experiences, perceptions, and challenges related to renewable energy use. The FGDs allowed researchers to uncover social dynamics and contextual nuances not easily captured through surveys or interviews.

Field observations also formed a key component of the data collection strategy. Researchers directly observed the condition and functionality of renewable energy installations, including solar home systems and biogas digesters. These observations extended to the accessibility of repair services, availability of spare parts, and general maintenance practices. Such firsthand insights were crucial in evaluating the operational sustainability of renewable technologies in remote settings.

Additionally, the study relied on secondary data from various policy and planning documents, including County Integrated Development Plans (CIDPs), the Kenya National Electrification Strategy (KNES), and national census and energy survey reports by the Kenya National Bureau of Statistics (KNBS). These

documents provided contextual background and helped triangulate findings from primary sources.

Collectively, this multi-pronged data collection strategy enabled a robust exploration of the socioeconomic and infrastructural drivers influencing renewable energy adoption. By combining statistical patterns with community voices and institutional perspectives, the study produced a well-rounded understanding of energy transitions in the rural Kenyan context.

4 RESULTS AND ANALYSIS

This section presents empirical findings from both quantitative and qualitative data collected across Kisumu and Elgeyo Marakwet Counties. The results are organized around key themes derived from the research questions: energy use patterns, socioeconomic drivers, adoption barriers, and community engagement.

4.1 Household Energy Use Patterns

This study identified notable regional differences and shared trends in household energy use across Kisumu and Elgeyo Marakwet counties, revealing a hybrid reliance on both traditional and modern energy sources as presented in Fig. 1. The findings reflect the complexities of rural energy transitions in Kenya, including access disparities, affordability, cultural preferences, and infrastructural limitations.

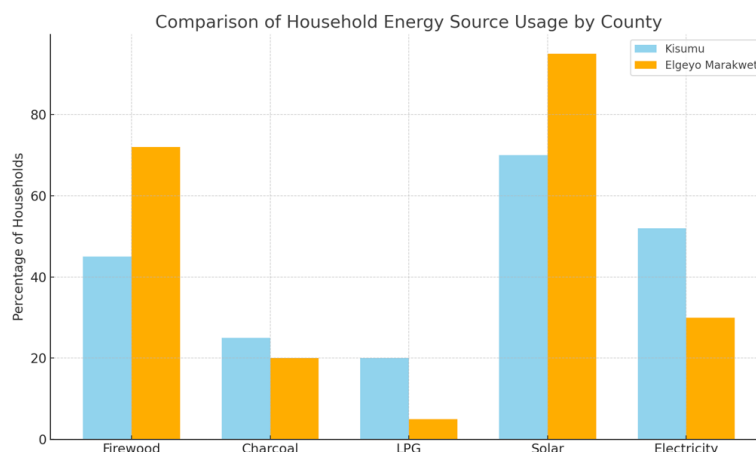


Fig. 1: Comparison of household energy use

Solar energy emerged as the most widely adopted renewable energy technology (RET) in both counties. In Elgeyo Marakwet, **95%** of surveyed households reported using solar power, mostly for lighting and charging phones. This high uptake is linked to the availability of affordable solar kits and the county's limited grid infrastructure. In Kisumu, **70%** of households also used solar energy, though its use was more often supplemental to grid or other energy sources.

The role of **electricity** both grid-connected and mini-grid varied sharply between the two regions. In Kisumu, approximately **52%** of households reported having access to electricity, reflecting stronger infrastructure, proximity to urban centers, and greater public-private investment. In contrast, only **30%** of households in Elgeyo Marakwet had electricity access, largely due to the county's mountainous terrain and dispersed settlements, which pose logistical and financial challenges to grid expansion. For many in Elgeyo Marakwet, solar systems act as the primary substitute for grid electricity.

Firewood remains a dominant cooking fuel, particularly in Elgeyo Marakwet, where **72%** of households depend on it. In Kisumu, usage is somewhat lower at **45%**, as households diversify fuel options. The continued prevalence of firewood is driven by its cultural familiarity and low upfront cost, despite associated health and environmental risks.

Liquefied Petroleum Gas (LPG) usage further highlights income and infrastructure disparities. In Kisumu, 20% of households reported using LPG for cooking, compared to **only 5%** in Elgeyo Marakwet. This difference is attributed to better fuel distribution networks, more accessible markets, and relatively higher household incomes in Kisumu. Similarly, **charcoal** was used by 25% of Kisumu households, while its use was negligible or absent in Elgeyo Marakwet, likely due to lower availability and cost.

These patterns confirm the widespread use of fuel stacking, where households employ multiple energy sources simultaneously

e.g., solar for lighting, electricity for appliances, and biomass for cooking. Even households with access to modern energy sources often continue using firewood or charcoal, suggesting that transitions are not linear but adaptive and layered. This aligns with the critique of the Energy Ladder Model, which assumes upward progression with rising income, and instead supports a more nuanced understanding of household energy decision-making (Masera, Saatkamp, & Kammen, 2000; Van der Kroon, Brouwer, & Van Beukering, 2013).

Access to electricity, whether through the grid or decentralized systems, significantly influenced energy use patterns. Households with electricity were more likely to diversify energy sources, use efficient appliances, and express willingness to adopt cleaner technologies. Conversely, in areas with limited access, households remained dependent on traditional biomass, even when aware of the benefits of alternatives.

4.2 Socioeconomic Drivers of Renewable Energy Adoption

The adoption of renewable energy technologies (RETs) in both Kisumu and Elgeyo Marakwet was shaped by a range of socioeconomic factors, with the most influential being household income, education level, gender dynamics, and access to credit. The data underscore how these interlinked variables determine the capacity and willingness of households to invest in cleaner energy options.

Income level emerged as a primary determinant of RET adoption. In Kisumu, approximately 65% of respondents with monthly incomes above KES 20,000 reported owning or using solar home systems or liquefied petroleum gas (LPG). In contrast, only 55% of similarly situated households in Elgeyo Marakwet adopted such technologies, indicating that income alone is not sufficient—supporting infrastructure and market access are also critical. These findings are consistent with prior studies emphasizing the role of economic capital in energy transitions (Martinot, Cabraal, & Mathur, 2001; Bhattacharyya, 2013).

Educational attainment also played a significant role. In Kisumu, 60% of households where the respondent had attained secondary education or higher showed a better understanding of long-term cost savings and environmental benefits associated with renewable energy. In Elgeyo Marakwet, this figure dropped slightly to 50%, reflecting the broader educational access gap between the counties. This trend reinforces evidence that human capital positively influences technology acceptance (Oparaocha & Dutta, 2011).

Gender dynamics proved to be a subtle yet powerful influence. Women, especially those heading households or actively engaged in cooperatives, expressed a high interest in clean cooking technologies such as LPG and biogas. However, their adoption rates were often constrained by lack of financial autonomy or access to credit. In Kisumu, 45% of respondents highlighted gender-related challenges in energy decision-making; in Elgeyo Marakwet, 40% reported similar issues. These findings echo concerns raised in gender-energy research about structural inequalities and institutional exclusion (Kirai & Mugure, 2018).

Finally, **access to credit and financial services** significantly influenced energy transitions. In Kisumu, 50% of respondents indicated that microfinance schemes or pay-as-you-go models facilitated the purchase of solar kits or LPG cylinders. By contrast, only 30% of respondents in Elgeyo Marakwet reported having similar financial options, underscoring the importance of localized financial infrastructure in enabling adoption.

These socioeconomic variables do not operate in isolation; rather, they intersect in ways that either enable or hinder energy transitions. The bar graph in Fig. 2 provides the relative weight of these drivers across the two counties, reinforcing the conclusion that inclusive financing, education, and gender-sensitive planning are essential for equitable energy adoption in rural Kenya.

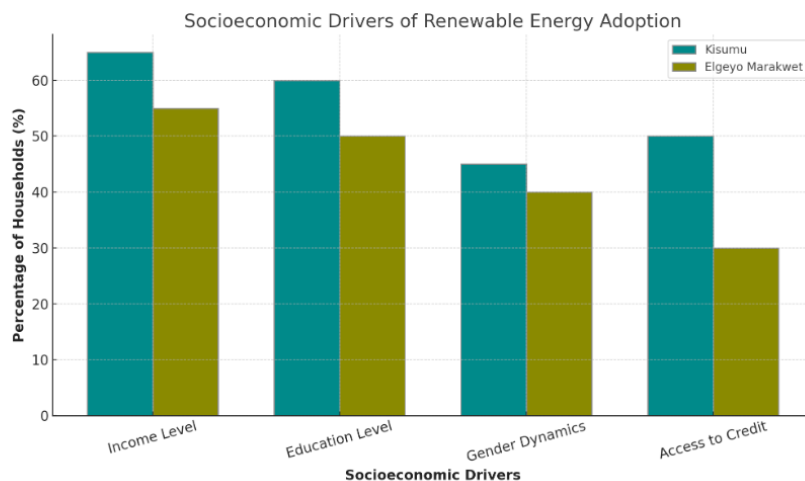


Fig. 2: Social economic drivers of renewable energy adoption

4.3 Barriers to Adoption of Renewable Energy

Despite high levels of awareness and interest in renewable energy technologies (RETs), households in both Kisumu and Elgeyo Marakwet counties face significant barriers that hinder adoption and sustained use. The key obstacles identified by respondents include high upfront costs, limited technical knowledge, inadequate infrastructure, and low awareness of supportive policies.

The most frequently cited barrier in **Elgeyo Marakwet** was **infrastructure gaps**, with 50% of respondents reporting challenges such as poor road access, sparse vendor networks, and limited availability of repair services. In comparison, 30% of Kisumu respondents reported similar concerns, benefiting from better market integration and road connectivity. These findings underscore the importance of physical capital in sustaining off-grid energy systems (Martinot, Cabraal, & Mathur, 2001).

High upfront costs were identified by 46% of Elgeyo Marakwet households as a major deterrent to adoption, compared to 40% in Kisumu. While both counties reported cost as a limiting factor, the challenge was more acute in Elgeyo Marakwet due to lower average incomes and fewer financing mechanisms. The absence of microfinance schemes or pay-as-you-go models limited household ability to invest in RETs, confirming previous findings that cost remains a dominant barrier in rural electrification efforts (Bhattacharyya, 2013).

Lack of technical knowledge was another prominent challenge, particularly in Elgeyo Marakwet, where 42% of respondents indicated that they did not have the necessary skills to maintain systems such as solar panels or biogas units. In Kisumu, **35%** of households reported similar concerns, though the presence of NGOs and training programs has mitigated the knowledge gap to some extent. One illustrative case involved a biogas system in Elgeyo Marakwet rendered inoperable due to poor user training highlighting the importance of ongoing technical support.

Finally, **low awareness of renewable energy policies and incentives** was reported by 38% of Elgeyo Marakwet respondents and 25% in Kisumu. This suggests a disconnect between national-level programs and community-level dissemination, particularly in more remote areas. Despite government initiatives such as VAT exemptions on solar equipment

and the Kenya National Electrification Strategy (Ministry of Energy, 2018), their benefits remain largely unknown at the household level.

The graph in Fig. 3 visualizes these disparities, reinforcing the conclusion that while interest in renewable energy is high, the enabling environment comprising financing, education, infrastructure, and policy outreach must be strengthened for widespread and sustained adoption.

4.4 Community Engagement and Participation

Community engagement plays a pivotal role in the successful adoption and sustainability of renewable energy technologies (RETs), particularly in rural contexts where formal infrastructure and public services are limited. The results from Kisumu and Elgeyo Marakwet counties reveal contrasting patterns in both participatory energy governance and grassroots mobilization.

In Kisumu, active collaboration between community-based organizations (CBOs), non-governmental organizations (NGOs), and county energy officers has fostered greater community involvement in energy projects, with 60% of respondents indicating direct or indirect participation. This engagement has facilitated smoother implementation of solar installations and biogas systems in public institutions such as schools and fish markets. Moreover, 70% of Kisumu respondents reported receiving energy-related information and support through NGOs, underscoring

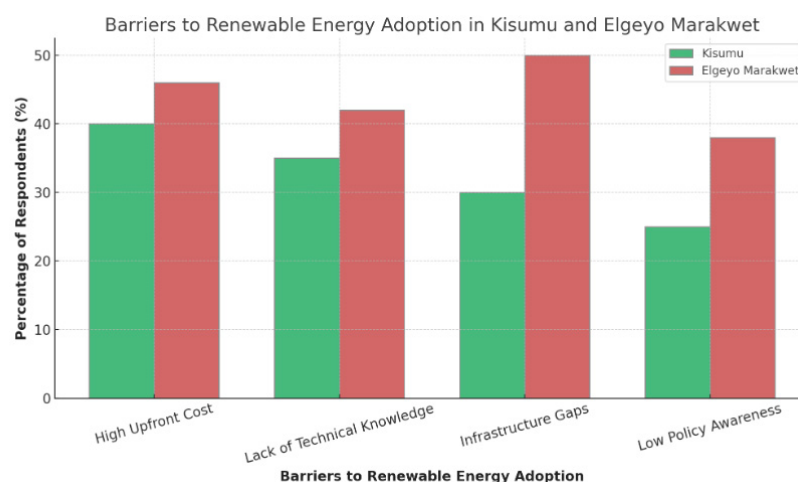


Fig. 3: Barriers to renewable energy adoption

the role of civil society in bridging knowledge gaps and boosting community confidence in new technologies.

Participation in CBOs was also high in Kisumu, with 65% of households belonging to or interacting with energy-related groups. These organizations have played a crucial role in pooling resources, conducting community demonstrations, and lobbying for county-level support. This participatory infrastructure has supported a "diffusion effect," where technology visibility and word-of-mouth enhance social acceptance, consistent with Diffusion of Innovations Theory (Rogers, 2003; Wüstenhagen, Wolsink, & Bürer, 2007).

In contrast, Elgeyo Marakwet exhibited a different pattern. Only 30% of respondents had prior involvement in energy projects or NGO-led training. However, an impressive 85% expressed a **willingness to co-invest** in community-based renewable energy projects provided financial and technical support mechanisms were in place. This reflects strong latent demand and a high level of **community readiness**, even in areas where formal participation channels are limited. **Participation in CBOs** stood at 50%, slightly lower than in Kisumu, and only 35% reported receiving energy information through NGOs, indicating a relative absence of civil society engagement in the region.

Fig. 4 illustrates these engagement dynamics, clearly demonstrating Kisumu's stronger institutional presence and Elgeyo Marakwet's high potential for community-driven

adoption if appropriate enabling structures are introduced.

5 DISCUSSION

This study aimed to examine the socioeconomic, infrastructural, and institutional drivers influencing renewable energy adoption in rural Kenya through a comparative analysis of Kisumu and Elgeyo Marakwet counties. The findings reveal both convergence and divergence in adoption patterns, underscoring the importance of localized strategies in energy planning.

5.1 Revisiting the Diffusion of Innovations Theory

The Diffusion of Innovations Theory (DoI) (Rogers, 2003) provides a useful lens for interpreting technology uptake in both counties. In Kisumu, observable installations, trialability through NGO-led projects, and perceived relative advantage of technologies especially solar and biogas have enhanced adoption. Community demonstration projects, such as solar-powered fish markets and institutional biogas systems, created a ripple effect that encouraged neighboring households to adopt similar technologies.

Conversely, in Elgeyo Marakwet, despite higher solar adoption rates (95%), the absence of structured information pathways and working community demonstration models has limited the spread of other technologies like LPG and biogas. This highlights that adoption does not occur solely through exposure to a technology, but also through the presence of enabling social systems (Ondraczek, 2014).

5.2 Challenging the Energy Ladder Model

The prevalence of fuel stacking reported by over 85% of Kisumu and 90% of Elgeyo Marakwet households further challenges the Energy Ladder Model (Leach, 1992), which assumes a linear shift from traditional to modern fuels as income increases. Instead, households use a mix of traditional and modern sources based on cultural preferences, fuel availability, and affordability. This mirrors critiques of the model by Masera, Saatkamp, and Kammen (2000), who argued that energy transitions in low-income contexts are adaptive rather than sequential.

In Elgeyo Marakwet, continued use of firewood even among households with solar lighting was driven by its abundance and cultural importance in traditional cooking. Meanwhile, in Kisumu, access to markets and relatively higher incomes encouraged diversified energy use, but firewood and charcoal remained in use due to affordability and accessibility.

5.3 Role of Institutional and Community Infrastructure

The study also affirms the importance of institutional and social capital in enabling adoption, as emphasized in the Sustainable Livelihoods Framework (SLF) (DFID, 1999). Kisumu benefited from stronger institutional support (75%), including county-level coordination, NGO presence, and financing models such as pay-as-you-go solar kits. These structures provided households with knowledge, affordability mechanisms, and trust in technology providers.

By contrast, Elgeyo Marakwet demonstrated high community readiness (85% willing to co-invest) but lacked technical training, vendor access, and policy awareness. This gap suggests a strong potential for growth if institutional infrastructure is scaled up. As Wüstenhagen, Wolsink, and Bürer (2007) argue, social acceptance and local participation are as critical as technical innovation in ensuring the success of renewable energy transitions.

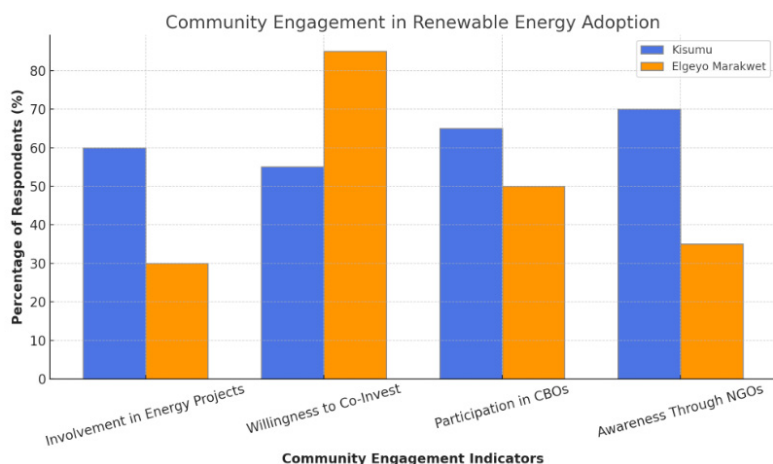


Fig. 4: Community engagement and participation

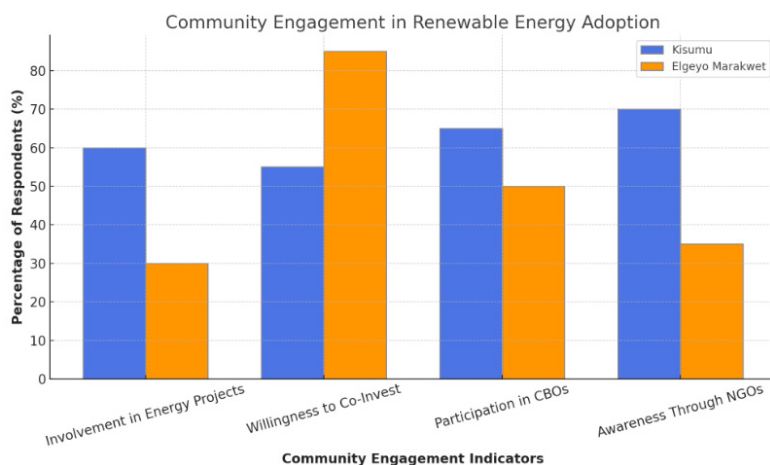


Fig. 5: Summary of key themes renewable energy adoption

5.4 Synthesis of Key Themes

Fig. 5 synthesizes findings across four central themes: solar adoption, fuel stacking, institutional support, and community participation. Kisumu performs strongly in institutional and community engagement, while Elgeyo Marakwet leads in solar adoption but lags in systemic support.

5.5 Local Context Matters

The comparative analysis strongly reinforces the view that local context is critical to understanding and enabling energy transitions. While Kisumu's progress is underpinned by donor presence, county-NGO partnerships, and peri-urban infrastructure, Elgeyo Marakwet's challenges are largely structural—sparse settlement patterns, poor road networks, and limited formal engagement.

Importantly, the lack of adoption in Elgeyo Marakwet is not due to lack of demand. Rather, it is constrained by the absence of institutional scaffolding and outreach mechanisms. When offered financial and technical support, local communities expressed a strong willingness to participate, suggesting that local contexts must inform how interventions are designed, delivered, and sustained (Wüstenhagen et al., 2007; Kirai & Mugure, 2018).

5.6 Contribution to Policy and Theory

This study contributes to both policy development and theoretical

refinement in three key ways:

- i. **Policy Contribution:** It provides evidence for the importance of community-led, gender-responsive, and context-specific programs. Policies that assume uniform technological diffusion often overlook structural inequities in access, particularly in underserved counties. Expanding access to microfinance, technical training, and county-level coordination mechanisms are essential to equitable transitions.
- ii. **Theoretical Contribution:** The research validates the combined use of the Diffusion of Innovations Theory, the Energy Ladder Model, and the Sustainable Livelihoods Framework. It shows that no single framework fully captures the dynamics of rural energy transitions. Together, these models offer a multidimensional understanding of energy adoption: from behavioral influences (DoI), to income and cultural patterns (Energy Ladder), to livelihood-based constraints (SLF).
- iii. **Empirical Insight:** By combining quantitative data (e.g., adoption rates) and qualitative narratives (e.g., community perceptions), the study deepens the empirical understanding of why renewable energy uptake varies even under similar policy environments.

Conclusion

In sum, this study reveals that while renewable energy technologies are increasingly available in rural Kenya, adoption is highly contingent upon local socioeconomic realities, institutional strength, and community engagement structures. One-size-fits-all energy strategies are likely to deepen existing inequalities rather than resolve them. As Kenya continues to push for universal energy access, future programming must integrate the lived experiences of rural communities, ensure inclusive financing, and strengthen county-level delivery mechanisms. This integrative, localized approach is essential for a just and sustainable energy transition.

Recommendations

To promote equitable, scalable, and sustainable adoption of renewable energy in rural Kenya, the following recommendations are proposed: Expand Access to Affordable Financing, Strengthen Technical Infrastructure and After-Sales Support, Enhance Community Participation and Ownership, Localize and Harmonize Energy Policy Implementation and last but not least, target Gender-Inclusive Programs

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Grid Tied Community Based Hybrid Model for Rural Electrification in Kenya

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Abstract

Access to electricity stimulates social, economic, and environmental development, the three pillars of sustainable development. Despite various initiatives by the Government of Kenya to increase electricity access in rural communities there are still some challenges like high tariffs and low productive use of energy. Off-grid areas are remote with limited access to electricity grids making them difficult and costly for the national and county governments or organizations to provide electricity to the remote areas. It is common to have such areas with high potential of renewable energy sources have high-voltage transmission grids running through them without being directly connected to the grid due to the high costs associated with building the necessary substations to step down the voltage from the transmission network to the distribution voltages required for local electrification. To address these challenges the paper proposes community-based hybrid model for rural electrification that encompasses a grid-tied, community-based system approach that goes beyond just blending different renewable technologies to improve the economics of energy provision. The proposed project includes the investment required to scale up generation in the mini-grid areas and build critical step-down substations that will expand access to electricity in underserved communities and that the cost would be recovered from the revenue collection.

Keywords: *Energy poverty, electricity access, RE, mini-grid, productive use of energy, grid tied and community-based hybrid model*

1 Introduction

Globally, countries have strived for universal electricity access particularly those in the developing world including those in Sub-Saharan Africa. At present, an estimated 600 million people, or 43% of the total population in sub-Saharan Africa, lack access to electricity. As of 2024, sub-Saharan Africa still accounts for about 70% of the global population lacking access to electricity. Despite accelerated efforts, achieving universal access by 2030, as outlined in the UN's Sustainable Development Goals (SDG 7), appears unlikely without major interventions.

Sustainable Development Goal 7 (SDG7) is a United Nations initiative that aims to achieve universal access to affordable, reliable, sustainable, and modern energy for all by 2030 [1].

Access to affordable and efficient energy is crucial for economic growth and development in Kenya. Kenya Vision 2030 identifies energy as an enabler to achieving the economic, social, and political pillars in the vision. Electricity is a basic need and an important component of household's consumption basket and the ability to afford it will affect the quality of life and welfare of individuals. Despite these strides in

electricity access by Kenya, access to electricity in rural communities there are some challenges like inadequate infrastructure, and resources and low productive use of energy. Since these areas are remote with limited access to electricity grids, it makes it difficult and costly for the national and county governments or organizations to provide electricity to these areas.

One major challenge faced in Africa is the energy poverty which prevails when people have access to electricity but are unable to afford full use of it. Statistics for the continent suggest that electricity

usage is suppressed with per capita consumption well below the global average of 3,000 kWh per person per year. At these usage levels, only basic needs such as lighting can be serviced [1]. This does not support the productive use of electricity that would markedly improve the quality of life or comfort levels, nor could it support advanced economic activity. This deduction is confirmed by the average Gross Domestic Product (GDP) per capita for most African countries; again, well below the global average. To address these challenges the paper proposes Community Based Hybrid Model for rural electrification that encompasses a grid-tied, community-based system approach that goes beyond just blending different renewable technologies to improve the economics of energy provision.

To achieve SDG7, a mixture of grid extension and off-grid systems, such as mini grids and solar home systems (SHSs), are deployed in developing countries, like those in sub-Saharan Africa (SSA) where there are significant energy access issues. Evidence from Southeast Asia reveals that beyond achieving energy access through grid expansion and off-grid systems, the main grid continues to expand and, in time, converges with the off-grid systems. The convergence of the main grid and off grid systems can result in two general outcomes. First, if the off-grid systems have not been deployed to grid standard, they are likely to be abandoned when the grid arrives. The abandonment favours the grid-supplied electricity, which is more reliable, cheaper or can support productive uses of energy. Secondly, if the main grid converges with a grid compatible mini grid, the mini grid may be integrated with the main grid [2]. Across many parts of Africa, it is common for communities to have high-voltage transmission grids running through them without being directly connected to the grid due to the high costs associated with building the necessary substations to step down the voltage from the transmission network to the

distribution voltages required for local electrification. The project includes the investment required to build critical step-down substations that will expand access to electricity in underserved communities and that the cost would be recovered from the revenue collection. Additionally, the proposal will help to scale up the penetration of renewable energy (RE) in Kenya, ensure the financial inclusion of the communities through the Just Energy Transition and stimulate economic development in the rural communities by scaling up productive use of energy.

2 Sector State of Play

Distributed and decentralized energy systems play a critical role as the least cost option of providing access to over 380 million people in sub-Saharan Africa [3]. The deployment of solar photovoltaic mini grids, for example, is expected to grow on the back of declining costs of key components, introduction of new digital solutions, innovative business models and tariffs, growing economies of scale, diversification, and flexibility.[4]

Kenya, as part of its national electrification strategy and renewable energy goals, proposed a mix of 70 percent on-grid and 30 percent off-grid solutions, including mini-grids and solar home systems, to achieve universal access by 2030. Particularly, the country targeted 35,000 connections to be achieved through 121 new mini grids that would serve housing clusters too distant from the network or too small to be connected to the national grid [5]. The country has over 100 PV-based mini-grids in operation or under construction by the Rural Electrification and Renewable Energy Corporation, other development partners and the private sector. A further 300 mini grids are planned.

A recent geospatial analysis [6] estimates that there are over 7,000 potential mini-grid sites in Kenya, with a total of over 2.1 million potential connections, of which 1.9 million are in settlements that are not electrified.

3 Project Development Objective

The main objective of the pilot project proposed in this concept note is to pioneer an innovative hybrid model for providing universal access to electricity in Africa through a Just Energy Transition inspired community empowerment rural electrification model. The model will target grid connected rural communities that have been beneficiaries of Rural electrification programs characterized by the following:

- a. The existence of an underutilized transmission grid linking the rural community to the main grid;
- b. Low energy consumption from the communities due to high unemployment, limited productive use and the absence of economic opportunities in the communities.
- c. Availability of labour and affordable land in the communities; and
- d. Availability of renewable energy resources potential in the identified areas

The potential benefits of this hybrid model will include:

- a. Improving the economics of extending the transmission grid to off grid communities and future rural electrification programs
- b. Improving the viability of mini grids in rural communities
- c. Enabling communities to participate in the main economy through grid tied mini grids leading to employment creation.
- d. Stimulating power generation driven economic activities in rural communities around the mini grids.

The goal of the project is to increase energy access of the citizens in Kenya especially the rural communities to enhance their productive activities and provide the rural communities with access to reliable low emission

energy for financial and economic activities including agriculture. It also increases the income earning capacity of local community's grid, energy sufficiency of Kenya through contribution of energy from community hybrid mini grids; and develops the enabling environment to facilitate community participation in energy generation;

The beneficiaries of the project will be the community members from direct electricity supply to households, public facilities and local investments benefiting from the revenue earned as a community dividend. Indirect benefits through catalyzed social economic activities and improved quality of life and well-being through access to electricity to support delivery of social services such as health and education in rural parts of Kenya. The project will also increase revenue for REREC on margins from power purchased from the community hybrid mini grids.

4 Mini grid ownership Models

The mini-grid ownership models vary according to who invests, holds and operates the mini-grid assets, including generation and distribution. There are four main ownership models: public utility, private sector, community and hybrid models. The choice of ownership model may depend on two variables: access to finance and the management approach public utility model, the national or regional utility owns and operates the mini-grid, and so it is responsible for installing, managing, and maintaining it. In addition, the utility likely provides the initial financing, often with support from development funds [7].

Private model leaves the ownership, development, and operation of the mini grid in the hands of a private company. The funding can come from multiple sources, including private equity, commercial loans, and public and/or development finance grants, results-based financing, or concessional loans.

Community model. The community might receive the mini-grid assets

from a government programme, a non-profit, or a development institution, and contribute some co-funding. This model is more frequent in isolated rural areas that do not attract private sector or utility interest. The main advantages of this model are the community's involvement in the development of the project and the low costs achieved, which would contribute to high acceptance among users.

Hybrid model combines the features of the aforementioned business models, with different parties building, owning, and operating the distribution and generation assets of the mini grid.

Among the different ownership models, hybrid model with community owned solutions, where the financial and technical responsibility for ongoing operations resides with the beneficiary communities, are gaining significance, with many studies highlighting how upfront community involvement during system's design and installation empowers local actors as they become active stakeholders in the project. This facilitates the system's long-term functionality, as it creates stronger sense of local ownership, and increases user satisfaction [8].

5 Proposed Project Components

Component 1: Off-Grid Policy, Implementation Strategy, Regulatory Frameworks, Licensing and Service Territory Allocation

This workstream will have two sub-components to review and, where necessary, develop or update the Off-Grid Policy and Implementation Strategy, Legal and Regulatory Framework and Licensing and Service Territory Allocation. The targeted beneficiary of this component will be the Department of Energy, Ministry of Energy (MoE), Rural Electrification and Renewable Energy Corporation (REREC)

This component will review Kenya's energy policy and rural electrification strategies to accommodate the proposed model or identify cost-

effective solutions. It aims to build and strengthen capacity for effective implementation and sustainability by assessing government institutional arrangements, reviewing rural electrification targets and investment incentives, engaging stakeholders, and examining investment barriers such as capital requirements, tariffs, and subsidies.

This sub-component involves reviewing the legal and regulatory framework for licensing power generation, distribution, and trading, along with economic regulations and utility obligations. It will also assess regulatory provisions for mini-grid licenses, including generation, distribution, and sales to end-users, and examine incentives and subsidies for mini-grids.

Component 2: Project preparation, resource mobilization and capacity building

The main goal of this component is identifying potential sites, prepare and structure the projects and work with the Ministry of energy to develop platforms that will enable similar projects to participate in the regional markets and set the foundation for upscaling to pilot project. This activity aims to assess grid capacity and identify optimal sites for integrating electricity from mini grids into the main grid. It includes evaluating existing transmission grid capacity and assessing transfer capabilities of transmission lines to potential villages. Modelling will be done to determine the grid's capacity for variable renewable energies (VRE) integration and recommend the necessary grid reinforcements to support higher VRE penetration.

This activity will assess rural electrification status in Kenya and community investment readiness to prioritize mini-grid sites. It includes analyzing proximity of villages to transmission lines, prioritizing mini-grid investment sites, identifying rural anchor investments and livelihood opportunities, and facilitating voluntary land acquisition for community equity investment.

The project will conduct pre-feasibility studies and detailed

resource assessments at potential villages, followed by detailed feasibility studies for two villages, covering business models, subsidies, interconnection terms, environmental and socio-impact assessments, and gender analysis with a monitoring, evaluation and learning (MEL) plan. Project structuring will include review of revenue models, risk allocation, development of draft IPP contract, interconnection agreements, and power purchase agreements. Market sounding events will gauge interest and gather inputs for the feasibility study and project structuring. Potential investment partners, including an equity private sector partner, will be identified. A diaspora green or sustainability bond will be structured for issuance upon commissioning of the pilot project, and a National Electricity Exchange will be developed to allow VRE mini-grid operators to sell electricity to KPLC which is the electricity off-taker in Kenya.

Component 3: Pilot hybrid mini-grid implementation and operation

The goal of this component is to procure, construct and monitor the implementation of the project. This will include working with Government to implement the policy recommendations from component 1 and procuring the project operator and equity partner based on the procurement package developed in component 2 and monitoring the project as well as preparing the groundwork for component 4.

Obtain final approval for policy recommendations from component 1; PPA, Concession Agreement, and Procurement Package from component 2. Coordinate with partners to provide guarantees for risk mitigation and launch the procurement process for the project operator.

The component will involve constructing the mini grid in compliance with grid code guidelines established in Component

1. Community training will focus on the construction, operation, and maintenance of the mini grid.

Component 4: Project preparation and replicating community hybrid mini grids to other sites

Once the grid is operational, the government of Kenya on a roll-out plan will expand the project to other viable sites identified in component 2. The activities will include issuing green bonds targeted at the community and the Kenyan Diaspora to re-finance the project using domestic capital, recycle the seed capital used to finance the debt component of the capital stack, develop local capital markets to finance local infrastructure projects of similar size, enable the community to co-invest in the project.

6 Conclusions

Access to affordable and efficient energy is crucial for economic growth and development in Kenya. Kenya Vision 2030 identifies energy as an enabler to achieving the economic, social, and political pillars in the vision. Electricity is a basic need and an important component of household's consumption basket, and the ability to afford it will affect the quality of life and welfare of individuals.

Kenya has been implementing rural electrification programmes to increase access to electricity through a mix of grid extension and off-grid solutions to achieve sustainable development goals. While the rural electrification programs have significantly increased electricity access in many parts of Kenya, contributing to socio-economic development, improved healthcare services, enhanced education opportunities, and increased productivity in agriculture and other

sectors. Challenges remain include funding constraints, geographical barriers, technical challenges in remote areas, and ensuring affordability and sustainability of electricity services.

The Community Based Hybrid Model for Rural Electrification will improve the economics of energy provision in the over 6,000 villages have been connected to the national grid as part of the Last Mile Connectivity Project (LMCP) and other initiatives. It will help to scale up the penetration of RE in Kenya, ensure the financial inclusion of the communities through the Just Energy Transition and stimulate economic development in these communities by scaling up productive use of electricity in the communities. By demonstrating an alternative model to rural electrification, the project will accelerate access for 12M citizens that still lack electricity access.



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Samwel Opana

Samwel Opana is a registered professional electrical engineer with a Master of Science Degree in Nuclear Engineering and Bachelor's Degree in Electrical Engineering. He has over 10 years of experience in power system planning, long term, medium term and operational timescales. He is also experienced in electrical system design and specifications of equipment. He has advanced expertise in network modelling, steady-state &

dynamic analysis, stability studies, harmonic analysis, reactive power planning, and electromagnetic simulations on various simulation software. Samwel worked with Kenya Power and Lighting a power utility company in Kenya as a power system-planning engineer. He is currently an Energy Planning and Modelling at AUDA-NEPAD and supported the development of the Africa Continental Power System Masterplan



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, 539th, 540th and 541st council accepted the following members under various membership categories as shown below;

Membership Class	Number Accepted- 539th Council	Number Accepted- 540th Council	Number Accepted- 541st Council	Total
Fellow	2	3	2	7
Corporate	18	81	4	103
Graduate	64	53	51	168
Graduate engineering technologist	8	6	10	24
Graduate engineering technician	4	8	4	16
Student	18	16	7	41
Total	114	167	78	359

During the period, we had 7 members who transferred from the class Corporate to Fellow member 103 from Graduate to Corporate member. In addition, we had 168 graduates, 24 graduate engineering technologists, 16 graduate engineering technicians and 41 students were accepted as members.

Gender Data

Class	Male	Female	Percentage (Male)	Percentage (Female)
Fellow	7		100%	0%
Corporate	81	22	79%	21%
Graduate	140	28	83%	17%
Graduate Engineering Technologist	18	6	78%	22%
Graduate Engineering Technician	14	2	88%	12%
Student	28	13	68%	32%
TOTAL	288	71	80%	20%

Summary

Gender	No.	Percentage
Male	288	80%
Female	71	20%
	359	100%

541st APPROVAL

FELLOW

S/N	Name	Member No
1	Timothy George Oketch	F.1571
2	Victor Odiwuor Odula	F.4016

CORPORATE

S/N	Name	Member No
1	David Araka Ndege	M.14852
2	Eric Muendo Ng'alu	M.0169
3	Gilbert Kipngeno Cheruiyot	M.9746
4	Lucas Ouma	M.9082

540th APPROVAL

FELLOW

S/N	Name	Member No
1	Duncan Ndeda Endeki	F.4667
2	Thomas Omollo Ofwa	F.2022
3	Peter Njuguna Kimemia	F.1855

CORPORATE

S/N	Name	Member No
1	Adah Jepkoech Limo	M.11071
2	Alfred Mairi Ndaro	M.13552
3	Allan Brian Kimutai	M.11609
4	Allan Ing'ura Etyang	M.10400
5	Annastacia Mumbua Nzuki	M.10942
6	Anne Jepkokei Cheboi	M.4076
7	Antonio Kinoti Maitethia	M.7545
8	Bernard Odhiambo Oloo	M.6809
9	Brian Cheche Cherop	M.13642
10	Brian Philemon Nyaigero	M.10113
11	Cedric Sean Okinda	M.9768
12	Charity Kwamboka Moya	M.10237
13	Charles Ochieng Opata	M.5924
14	Cyprian Nyakianga Soibe	M.13551
15	Dancan Odawo Ochieng	M.11619
16	Daniel Kipkorir Chumo	M.13115
17	Daniel Okuthe	M.11712
18	David Otieno Accra	M.13939
19	Denis K Kiprotich	M.8272
20	Dennis Mwinga Wanjira	M.13654
21	Douglas Ayienda Nyabuto	M.14013
22	Douglas Nyaribo Nyakoni	M.13868
23	Eric Murithi Kithinji	M.4895
24	Evans Kiprotich Bett	M.6291
25	Francis Omondi Hongo	M.10996
26	Fredrick Njiraini Kibicho	M.10784
27	George Mwaura Waweru	M.5349
28	George Njoroge Gatambia	M.10712
29	Gilbert Omollo Ouma	M.8797

30	Gitonga Jane Waithira	M.14867
31	Hilal Ahmed Sheikh Takoy	M.11058
32	Ibrahim Sheikh Yussuf	M.7834
33	Iddy Ogonyo	M.13080
34	Ifrah Kulow Maalim	M.11260
35	Isaac Nzioka Mutava	M.10716
36	Isaiah Gichohi Mwangi	M.8596
37	Jack Ondari Nyabuti	M.8501
38	James Gachibi Gachui	M.9318
39	James Kiarie Macharia	M.11475
40	Jane Nyawira Waichungo	M.10501
41	Jimson Kelvin Mwawaza	M.10020
42	John Mwangi Wanjohi	M.4264
43	Joseph Muyundo Wanyonyi	M.6876
44	Judith Kerubo Onyancha	M.12067
45	Kaveke Kiima	M.11660
46	Kelvin Mutevu Mwanzia	M.7691
47	Kelvin Omae Nyambane	M.14285
48	Lawrence Ngunjiri Mathenge	M.8097
49	Lucas Ongondo Mogaka	M.6095
50	Lydia Pauline Wanjira Kariuki	M.10257
51	Lynnjoy Akinyi Ogallo	M.13810
52	Manasses Yada Omala	M.7819
53	Maroline Akinyi Orony	M.10605
54	Michael Ian Karani	M.13475
55	Mohamed Ali Maow	M.11583
56	Monica Wairimu Maina	M.11581
57	Moses Itotia Mwangi	M.8025
58	Naima Muthoni Abdalla	M.11434
59	Nelly Cherop Kosgei	M.8603
60	Nicholas Mugereki Kanyi	M.11646
61	Nicole Ashley Mwandale	M.11320
62	Okusi Bonface Bonface	M.11491
63	Paminus Murangiri Kabiro	M.3416
64	Paul Ogola Ochwango	M.7540
65	Paxton Mukeli Kasonzoi	M.14247
66	Peter Maina Muthigani	M.7521
67	Ronald Onkware Nyasimi	M.14101
68	Ruto Kiplangat Ismael	M.10226
69	Sidney Morris Oduor	M.11528
70	Simon Letapo Lodung'u	M.13909
71	Siyad Ahmed Mohamed	M.8604
72	Solomon Wanyama Mulera	M.13086
73	Sylveser Mutuku Mutie	M.6516
74	Sylvester Guyo Mwacharo	M.11764
75	Tracy Atieno Oduor	M.12467
76	Valentine Ashiono Ayisi	M.14764

77	Victor Kimutai Koech	M.12035
78	Victoria Njeri Mwangi	M.8571
79	Wessley Essau Rabongo Akech	M.6252
80	Yusuf Ali Abdi	M.11167
81	Zacharia Lukorito Chepkania	M.4484

539TH APPROVAL

FELLOW

S/N	Name	Member No
1	Name	Member No
2	Johanes Moseti Obwocha	F.4713

CORPORATE

S/N	Name	Member No
1	Alex Musyimi Muindi	M.5190
2	D Kelvin Muchiri Njimia	M.11183
3	Daniel Omondi Onyango	M.2547
4	David Gathua Mumbi	M.10972
5	Donald Kipkech Ndiema	M.14762
6	Edwin Simiyu Wangila	M.9133
7	Emily Musangi Ndolo	M.8784
8	Emmanuel Austine Ebinga Osore	M.12540
9	Eunice Mutio Ndolo	M.10944
10	Haron Muchuni Ndegwa	M.9586
11	Jane Wachuka Maina	M.10843
12	John Kyalo Mulela	M.8324
13	Josphat Nyamwamu Omari	M.7072
14	Kennedy Asati Moturi	M.5821
15	Meshack Otieno Odhiambo	M.10108
16	Nelson Wanjala Barasa	M.9087
17	Osundwa Nixon Kachi	M.14749
18	Rosepart Aura	M.7848

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Miano Wamuyu , 23
Kenyatta University
Petroleum Engineering
Year of Study: 5th year

Balancing Energy Security and Climate Action : Africa's Dilemma: Fossil Fuels, Fairness and the Future.

Most of today's industrialized nations built their wealth by burning fossil fuels for over a century, yet they now lead calls for global decarbonization. This raises a fundamental question of fairness: Should African countries, responsible for just 4% of historic emissions, be expected to abandon their untapped resources?

The case for exploitation is compelling. Over 600 million Africans lack electricity, while nearly 900 million rely on biomass for cooking (IEA,2022). In Kenya, the ongoing closure of the Kipevu thermal plant has already triggered frequent blackouts in coastal region, even though Tanzanian Natural Gas , just a few kilometers south, could serve as a transitional fuel (Kenga, 2024). To many , it seems unjust for Africa to forego the very path that enabled others to prosper.

Yet the other side of the argument is equally urgent. Africa is bearing the brunt of climate change; facing droughts, floods and agricultural stress (WMO, 2023). Locking into fossil fuel dependence risks worsening these impacts and stranding assets as the world shifts toward cleaner energy.

The way forward lies in balance: transitional fuels, yes, but coupled with real equity; financial and technological support from wealthier nations. Only then can Africa expand energy access while avoiding the same mistakes that created today's climate crisis.

The Future of Petroleum in a Renewable Energy Era

The global energy landscape is undergoing a transformative shift toward renewables, yet petroleum remains a critical component of the energy mix. Contrary to assumptions of obsolescence, the industry is adapting through innovation and integration with sustainable practices.

Petroleum's future lies in evolving beyond a mere energy source to a strategic partner for renewables. While solar and wind power expand, their intermittency requires reliable backup—a role natural gas, with its lower carbon emissions, is poised to fill. This “bridge fuel” ensures grid stability during transitions, leveraging existing infrastructure like pipelines and storage facilities.

Moreover, petroleum engineering is embracing advancements such as digital twins, AI-driven analytics, and carbon capture, utilization, and storage (CCUS) to reduce environmental impacts. These technologies enhance operational efficiency, mitigate emissions, and extend the viability of existing reserves. Beyond energy, petroleum-derived products remain indispensable for sectors like aviation, heavy industry, and petrochemicals, where alternatives are limited.

For emerging engineers, this era offers opportunities to drive change through interdisciplinary skills in digitalization, sustainability, and low-carbon solutions. The industry's future hinges on balancing economic viability with environmental responsibility, ensuring petroleum remains relevant in a diversified energy portfolio.



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Current year :1 st year



Shaneal Nixon

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Current Year of Study: 4th

Mining Engineering stands at the intersection of energy security, climate action, and innovation. As the demand for critical minerals grows to power renewable energy, electric vehicles, and modern infrastructure, the industry is being redefined by sustainability and technology. Today's mining engineers are innovators and environmental stewards, dedicated to ensuring that resource extraction supports progress without harming future generations. Advances in automation, AI, big data, and renewable energy integration are making mining safer, smarter, and more sustainable than ever before.

When I joined Mining Engineering at JKUAT, I didn't fully know what to expect—it was a leap of faith. But through hands-on learning, research, and leadership experiences, I found a field that combines science, sustainability, and purpose. The journey hasn't been easy, but every challenge has built resilience and passion. Looking ahead, I see Mining Engineering as a path of endless opportunity—to innovate, to protect our planet, and to lead responsibly. To anyone who dreams of solving real-world problems while shaping a sustainable future, this field offers the perfect blend of challenge, meaning, and impact.

Mining has long fueled industrial growth, but as the world shifts toward renewable energy and sustainability, the sector is being redefined. Minerals such as lithium, cobalt, copper, and rare earths now form the backbone of green technologies—powering solar panels, wind turbines, and electric vehicles. Yet, mining itself must evolve by embracing cleaner, smarter, and more efficient methods.

Kenya stands at a unique advantage in this transition. With abundant mineral resources and strong renewable energy potential—geothermal, wind, and solar—the country can pioneer sustainable mining powered by clean energy. Such notable projects have been implemented in Kwale and Turkana where most of these mining practices runs on solar and wind, whereas in Naivasha, processing plants uses geothermal energy to cut emissions.

This transformation extends to education and careers. Studying Mining and Mineral Processing Engineering now means mastering both traditional extraction and modern sustainability practices. Graduates can work locally and globally, drive innovation, and influence policy. Ultimately, mining in this new era is about balance—meeting global demand while protecting the planet. For young engineers, it's more than a profession; it's an opportunity to power Kenya's growth and lead the clean energy revolution.



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Inventions in Petroleum Engineering: Just How Much More Can We Invent?

Have you ever wondered how oil and gas are recovered from reservoirs, transported, and refined into the everyday products we rely on: fuel, plastics, even lubricants? From upstream to midstream to downstream, countless inventions keep this journey alive.

The petroleum industry traces back to 600 B.C., when ancient China pioneered "shi you" oil extraction. Since then, innovation has been the lifeblood of the industry, evolving from wooden rigs to today's digital oilfields.

One of the earliest breakthroughs was the rotary drilling rig, which enabled deeper wells. Soon after, the blowout preventer (BOP), a lifesaving device that stops uncontrolled gushes of oil and gas, was introduced. Modern drilling advanced rapidly with measurement while drilling (MWD) and logging while drilling (LWD), delivering real-time geological data. Coupled with horizontal and directional drilling, these technologies opened access to reservoirs that were once considered unreachable.

Today, petroleum engineering is going digital. Artificial intelligence, seismic imaging, reservoir simulations, and predictive monitoring optimize drilling, reduce downtime, and prevent accidents. Wells equipped with sensors act like "Fitbits," constantly reporting their health. Smart wells and digital oilfields are transforming operations into precision-driven systems, allowing engineers to make faster, more informed decisions.

Environmental consciousness is also driving invention. Carbon capture, utilization, and storage (CCUS) and direct air capture technologies help reduce emissions and shrink the industry's carbon footprint. Enhanced oil recovery (EOR) techniques, including CO₂ injection and thermal recovery, extend the life of mature fields. Offshore, floating platforms and Floating Production, Storage, and Offloading units (FPSOs) operate like entire cities at sea. Behind the scenes, artificial lift systems, pipelines, heated tankers, multilateral wells, coiled tubing, and underbalanced drilling quietly ensure that energy keeps flowing.

Looking ahead, autonomous drilling, hydrogen integration, biofuels, and digital twin simulations hint at a smarter, safer, and more sustainable future. Petroleum engineering has always been defined by innovation, from the earliest "shi you" wells to modern drilling and digital breakthroughs. Yet the real question remains: Just how much more can we invent?

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