Ministry of Energy

MAKUENI COUNTY ENERGY PLAN

2023 - 2032

FOREWORD

I am privileged to introduce the Makueni County Energy Plan 2023-2032. This plan is a historic milestone for the county since energy is a key driver for innovation, sustainability, and shared prosperity.

The innovations and strategies outlined in this plan have been well aligned with global and national development aspirations to attain universal access to energy for all by the year 2030. The programs, the corresponding outcomes, outputs, and targets aim to achieve socio-economic transformation. The plan therefore identifies solutions for both domestic and productive use of energy. It will be implemented using an integrated planning and budgeting approach through a five-year County Integrated Development Plan (CIDP) and a stepwise planning process of the Annual Development Plans (ADPs).

The development of this plan was multisectoral, emphasizing our belief in and desire for strategic partnerships in our development journey. Through these strategic partnerships, innovative solutions, and a commitment to environmental stewardship, we aim to create a model for sustainable energy development within the county.

I commend the collaborative efforts of experts, stakeholders, and community members who have contributed to developing this comprehensive energy plan. Their insights, expertise, and passion have made the journey to universal access to modern energy possible. Let us embrace this plan, not merely as a document but as a shared vision for the future of Makueni. In the spirit of inclusivity, sustainability, and progress, I invite all stakeholders to be part of the vision and actively engage in its actualization. Together, we can harness the power of energy to light our t path toward a prosperous, equitable, and sustainable Makueni.

I thank you for your commitment to the betterment of our beloved county and reiterate the responsibility of my government to support and address the needs of the people of Makueni. This plan is a testament to our dedication to providing reliable and affordable energy to every household, powering businesses, and propelling our county toward economic prosperity.

Mutula Kilonzo Jr. CBS.
Governor

PREFACE

It is with great pleasure and a sense of responsibility that I present to you the Makueni County Energy Plan (CEP)–a blueprint for a sustainable, resilient, and energy-efficient future for our community. As the County Executive Committee Member for the Department of Infrastructure, Transport, Public works, Housing and Energy, I recognize the pivotal role that energy plays in shaping the economic, social, and environmental landscape of our county.

Makueni County is thus pleased to have attained this critical milestone of developing a comprehensive County Energy Plan. The Plan represents a collaborative effort to promote energy security and foster economic growth while addressing the challenges posed by climate change. Our development partners in developing this plan were: Strathmore University; World Resources Institute (WRI), who spearheaded the process from scratch; and the Ministry of Energy and Petroleum, who provided the guiding framework. Makueni County Department of Infrastructure, Transport, Public works, Housing and Energy played a lead role in this process.

To ensure that the CEP was aligned to the needs and priorities of the community, primary data collection was carried out in all the six sub-counties covering households, enterprises, county facilities and institutions. Key informant interviews, Focused Group Discussions (FGDs) with sectoral stakeholders, experts, and the community formed part of this extensive exercise. The plan contains a detailed roadmap outlining our goals, strategies, and action plans. It not only addresses immediate concerns but also envisions a future where our county leads in adopting innovative and sustainable energy practices. Through the integration of renewable energy sources, energy-efficient technologies, and community engagement initiatives, we aim to create a model for others to emulate.

I extend my gratitude to the residents, business community, local organizations, partners and government agencies that have contributed their insights, ideas, and offered their support in different ways throughout this process. Your commitment to a greener and more prosperous future has been inspiring. As we embark on the implementation of the County Energy Plan, I invite each of you to actively participate in this transformative journey. By working together, we can achieve our shared vision by not only meeting our energy needs but also preserving our environment for future generations.

Sincerely,

Eng. Sebastian Kyoni
CECM- Infrastructure, Transport, Public Works, Housing and Energy

ACKNOWLEDGEMENTS

The Department of Infrastructure, Transport, Public Works and Energy is mandated with ensuring access to affordable, reliable, sustainable and clean energy in line with the Energy Act 2019 and SDG 7. It is for this reason that I express my personal and institutional gratitude to all actors who participated in the development of the county energy plan. Our adoption of a participatory and data-centric approach ensured insightful consultations with all stakeholders which ultimately led to the development of a consensus-driven plan. Witnessing the readiness of this plan for implementation fills me with immense pride.

First and foremost, I extend my deepest appreciation to H.E. Governor Mutula Kilonzo Junior, CBS, and the Deputy Governor, H.E. Lucy Mulili, for their unwavering support and exemplary leadership throughout the entire process. Their steadfast dedication to sustainable development and the well-being of Makueni residents played a pivotal role in bringing this plan to fruition.

Special recognition is due to the County Executive Committee Members, County Energy Planning Committee, under the guidance of the County Executive Committee Member for Infrastructure, Transport, Public Works, Housing, and Energy, Eng. Sebastian Kyoni. His steadfast guidance and leadership were instrumental in shaping the overall direction of the plan and ensuring its aligned with government shared objectives.

The drafting team deserves significant commendation for their relentless efforts. Led by team from Strathmore University, World Resources Institute (WRI), and the County Energy Plan Technical Committee, this dedicated members produced an outstanding plan. I wish to specially mention and acknowledge the contributions of the core team members: Patrick Mwanzia, Sarah Odera, Lucy Nguti, Hilarious Kifalu, Stephen Kiama, Anne Njoroge, Benson Ireri, Victor Otieno, Dimitris Mentis, Douglas Ronoh, Beryl Ajwang, Stanlus Matheka, Jacklyne Kiting'o, Benson Mutuku, Eng. Gregory Kioko, Eng. Richard Kamami, Eng. Charles Kiilu, Harrison Mwololo, and Christopher Yulu. Their commitment, passion, expertise, and collaborative spirit were invaluable assets to this plan, setting a high standard for future endeavors in Makueni County.

I recognize the vital contributions made by the County Assembly Members; led by Speaker Hon. Douglas Mbilu and particularly the Committee of Infrastructure, Transport, Public Works, Housing, and Energy for their dedication to ensuring strategic alignment of the plan with the needs of Makueni residents. The community Members and especially the Ward Energy Champions who took their time and provided valuable insights, comments, and suggestions toward this plan. You played crucial role in shaping the plan to reflect the aspirations and realities of our County.

It would be impossible to thank everyone personally in this plan. Once more, I express my gratitude to everyone who contributed to this significant accomplishment. Let us sustain the same collaborative efforts during the implementation phase of the Makueni County Energy Plan, as well as other future initiatives aimed at achieving a transformative and sustainable development for our beloved county.

Sincerely,

Eng. Naomi Nthambi Mwanza
Chief Officer – Energy and Housing

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LIST OF ACRONYMS

AD	Aerobic Digestion
ADP	Annual Development Plan
BAU	Business As Usual
CBOs	Community Based Organizations
CEP	County Energy Plan
CIDP	County Integrated Development Plan
CEPC	County Energy Planning Committee
COD	Chemical Oxygen Demand
EAE	Energy Access Explorer
EPRA	Energy and Petroleum Regulatory Authority
FGDs	Focus Group Discussions
GCP	Gross County Product
GDC	Geothermal Development Company
GDP	Gross Domestic Product
GESI	Gender Equity and Social Inclusion
GHI	Global Horizontal Indication
GIS	Geographic Information Systems
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HCF	Health Care Facility
HHs	Households
ICS	Improved Cook Stove
IEA	International Energy Agency
INEP	Integrated National Energy Planning Framework
KenGen	Kenya Electricity Generating Company
KES	Kenya Shillings
KG	Kilogram
KFS	Kenya Forestry Service
LCPDP	Least Cost Power Development Plan
KNBS	Kenya National Bureau of Statistics
KOSAP	Kenya Off Grid Solar Access Project
KPLC	Kenya Power and Lighting Company
KW	Kilowatt
kWh	Kilowatt-hours
LEAP	Low Emissions Analysis Platform
LED	Light Emitting Diode
LPG	Liquified Petroleum Gas
MEPS	Modern Energy Performance Standards
M&E	Monitoring and Evaluation
MG	Mini-grid
MSMEs	Micro Small Medium Enterprises
MW	Megawatt
NGO	Non-Governmental Organization
NSAs	Non-State Actors
OnSSET	Open-Source Spatial Electrification Tool

PLWD	Persons Living With Disabilities
PUE	Productive Use of Energy
SA	Stand Alone Solar PV
SE4ALL	Sustainable Energy for All
SDGs	Sustainable Development Goals
SERC	Strathmore Energy Research Center
SFWC	Specific Freshwater Consumption
SHS	Solar Home Systems
SMEs	Small and Medium Sized Enterprises
TWG	Technical Working Group
UK PACT	UK Partnering for Accelerated Climate Transitions
UNEP	United Nations Environment Programme
UNDP	United Nations Development Program
USD	United States Dollars
WRI	World Resources Institute
WtE	Waste-to-Energy
WHO	World Health Organization
WWTP	Wastewater Treatment Plants

EXECUTIVE SUMMARY

Introduction

The Energy Act 2019 mandates all counties in Kenya to develop energy plans for their jurisdictions. These plans and others from national service providers such as Kenya Power are to be integrated into one national energy plan. Guidelines for the development of these plans are provided by the Draft Integrated National Energy Planning Framework 2023. The development of Makueni County's Energy Plan is in line with these regulations.

The development of this CEP presents an opportunity to guide the county in effectively planning and allocating resources to drive socio-economic and environmental development. Recognizing energy as an enabler of development, the CEP allows for consideration of the local context in the identification of solutions for both domestic and productive use of energy. The mainstreaming of energy planning at the county level is key to the country's progress towards achieving universal access to energy for all by the year 2030. The overarching goal of this CEP is to ensure the provision of clean, sustainable, reliable, and affordable energy for socio-economic development to improve livelihoods in Makueni County. This goal is supported by the following objectives:

- To provide a medium-term planning framework for advancing clean, sustainable, reliable and affordable energy within the county;
- To ensure proactive compliance with the provisions outlined in the Constitution of Kenya (2010) and the Energy Act (2019) regarding energy planning and administration; and
- To address the challenges hindering universal energy access and capitalize on opportunities for productive use of energy at the county level.

The development of the plan relied heavily on data, encompassing information about current and potential energy consumers, energy access levels, prevalent challenges, and energy needs in Makueni County. Both quantitative and qualitative data were employed, with surveys collecting quantitative data from various entities, including households (n=634), businesses (n=394), healthcare facilities (n=55), and educational institutions (n=365). Additional quantitative data on energy efficiency was obtained from public facilities. Qualitative data was gathered through focus group discussions with diverse groups such as: women groups, youth groups, men's groups and people living with disabilities. Furthermore, data was also collected from various agricultural cooperatives, including dairy farmers, beekeepers, and horticulture farmers. In addition, interviews were conducted with various entrepreneurs, along with key informant sessions involving county government officials. The analysis specifically focused on energy consumption for lighting and cooking. Energy modelling tools were utilized to identify cost-effective solutions for universal electricity access and clean cooking, while a bioenergy balance was developed to assess the sustainability of biomass consumption in Makueni County.

Energy Access and Energy Efficiency in Makueni County

In 2022, the electricity access in Makueni County was 75.1%, comprising 29.2% and 5.7 from mini grids in 2022. The remaining percentage had electricity access from solar home systems and solar lanterns. Higher grid connectivity rates were observed in educational institutions at 85.8%, and micro & small medium enterprises at 80.3%. These facilities may have benefited from national government initiatives that sought to electrify public facilities and markets.

Utilization of clean fuels in the county is low, as only 7.6% of households and 1.4% of educational facilities use LPG to cook. 72.5% of the households and 95% of the educational institutions use firewood to cook. Use of electricity for cooking was only observed in households at a paltry 0.3%. Healthcare facilities emerged to be the lead category using clean fuels with 32.1% using LPG for cooking. It should be noted that majority of healthcare facilities that were visited did not cook on site since they attend to outpatients only.

Beyond infrastructure access, key energy challenges involved affordability, quality, and unreliable supply. Grid electricity was cost prohibitive for many domestic and business users, forcing some to resort to solar or charcoal. Solar home systems and clean cookstoves were sometimes of low quality, therefore failing before their expected lifetimes and forcing people to revert to unclean energy sources. Unreliable grid power with long restoration times reduced operating capacity for productive users. This, coupled with increased operational costs for back-up generators, reduced their competitiveness or made them operate below their desired capacity.

Energy efficiency varied across the county. While light-emitting diodes (LED) bulbs were widely adopted in households and public institutions, some learning institutions and a tier-four county hospital primarily used compact fluorescent bulbs. Cooking technologies exhibited low efficiency due to the prevalent use of firewood. Efficiency in water distribution was assessed, revealing that half of the county buildings had water harvesting systems, but there was a lack of greywater treatment plants. The adoption of low-flow water appliances was generally low, with county offices being the exception, showing a higher adoption rate for such technologies.

Implementation of the County Energy Plan

Implementation of the county energy plan will cost approximately KES 73 billion, broken down as shown in Table 1 below. It is expected that the Government of Makueni County will not only use its own internal resources but mobilize financial resources from development partners, private sector, and the National Government to make the CEP vision a reality.

Table 1: CEP Implementation Costs

Item	Cost (KES)
Electricity Access and Productive Use of Energy	72.3 Billion
Bio-energy supply and clean cooking	1.9 Billion
Energy Efficiency	153.5 Million
Cross-cutting recommendations (energy policy, establishment of energy centers and energy access fund)	517 Million
Total	**KES 74.9 Billion**

The following are the key CEP recommendations:

- Strengthen the energy department by hiring additional skilled staff to spearhead the implementation of the CEP.
- Establish a clean energy fund to accelerate the adoption of clean energy solutions. The fund ought to work with the existing financial institutions to ensure fast tracking, since they have systems in place.
- Establish energy centers to act as demonstration nerve centers to the community in disseminating the emerging energy solutions.
- Promote improved and clean cooking energy solutions.
- Since Makueni has a good grid network, there is need for optimization of the existing grid infrastructure through densification and intensification.
- Kenya Power to strengthen grid infrastructure to improve the power reliability and ability to handle the growing demand.
- Prioritize opportunities for productive use of energy in the agricultural sector, which is the socio-economic backbone of the county. These opportunities encompass: powering irrigation systems, facilitating mango drying, facilitating cold rooms, sustaining dairy plants, and facilitating mango processing.
- Retrofit all public buildings and street lights with LEDs and automatic light control to reduce energy wastage.
- Integrate the county hospitals with solar PV systems to reduce the power bill. Tier 4 and 5 hospitals in Makindu and Wote sub-counties were proposed to be used as pilots.
- Replace all the county motorbikes with electricity powered bikes.

1.0 INTRODUCTION

This chapter gives an overview of Makueni County Energy Plan, its scope, purpose, overarching goal, its objectives and the activities undertaken to prepare the plan. It also gives the background of energy planning and historical energy access. The chapter also describes the Makueni County administration, demographics, climatic conditions, and stakeholders in the energy sector. It concludes by describing how the CEP is integrated with the existing county plans, legal, policy and regulatory frameworks.

1.1 BACKGROUND

Before ratification of the Energy Act 2019, energy planning in Kenya focused on the electricity sector. This planning was undertaken in a centralized manner, and the results were documented in the Least Cost Power Development Plan.

However, after the promulgation of the constitution in 2010 and the ratification of the Energy Act 2019, county governments were required to develop their own energy plans. Sections 5(3) of the Act requires each county government to develop and submit a County Energy Plan (CEP) to the Cabinet Secretary in the Ministry of Energy and Petroleum in respect of its energy requirements. These CEPs, together with plans from national energy service providers such as Kenya Power, are to be consolidated by the Cabinet Secretary into Integrated National Energy Plan (INEP).

Development of energy plans at county levels serves as an opportunity to consider the local context in the identification of solutions for both domestic and productive use of energy. County energy planning is therefore a conduit for providing appropriate energy solutions that will fast track socio-economic development in Kenya.

1.2 OBJECTIVES

The overarching goal of this CEP is to ensure the provision of clean, sustainable, reliable, and affordable energy for socio-economic development and enhanced livelihood in Makueni County. This goal is supported by the following CEP objectives:

i. To provide a medium-term planning framework for advancing clean, sustainable, reliable and affordable energy within the county;

ii. To ensure proactive compliance with the provisions outlined in the Constitution of Kenya (2010) and the Energy Act (2019) regarding energy planning and administration; and

iii. To address the challenges hindering universal energy access and capitalize on opportunities for productive use of energy at the county level.

1.3 DEVELOPMENT OF THE COUNTY ENERGY PLAN

The development of the CEP involved: the constitution of committees, capacity building, stakeholder engagement, data collection, development of models, development of a GIS toolkit, consideration of Gender Equity and Social Inclusion (GESI), drafting, validation and dissemination of the plan.

These are described in detail below.

1.3.1 Committee Constitution and Capacity Building

This CEP was developed by the Government of Makueni County, with technical assistance from Strathmore University (SU) and World Resources Institute (WRI). A Technical Working Group (TWG) comprising of technical officers from the County Government Departments, and officers from Strathmore University and WRI was constituted. The TWG was chaired by the Chief Officer responsible for energy in the Government of Makueni County. A steering committee—the County Energy Planning Committee (CEPC)—was constituted to provide overall oversight and policy guidance to the TWG during the entire process. This committee was chaired by the County Executive Member in charge of the Department of Infrastructure, Transport, Public works, Housing and Energy.

To enhance the capacity of the TWG, County Directors, Chief Officers, Instructors in the County Technical Training Institutes (CTTIs), energy champions and other officers across the departments were trained on various energy aspects as shown in Table 1-1

Table 1-1: Capacity Building Programs

Title of Capacity Building Program	Target Audience	Objective
Energy Policy and Planning	Chief Officers and Directors	To enable trainees to: • Understand basic concepts in the energy sector e.g. renewable energy, energy efficiency • Understand the energy ecosystem in the country • Enable collaborative working across the various ministries within the county
Fundamentals of Energy Planning	Technical working group	Equip trainees with an understanding of tools that were used in the process of developing Makueni County's future energy plans
Energy Champions	Community members within the wards	Equip trainees with: • An understanding of climate change in relation to renewable energy with a focus on solar home systems and improved cookstoves • Communication skills necessary to advocate for energy transition within their communities
Carbon Credits Training	Chief Officers and Directors	Equip trainees with an understanding of how carbon credits can be utilised in Makueni County to enhance energy transition.

Energy Champions Capacity Building

Issuance of certificate after the completion of Ward Energy Champions Training

1.3.2 Stakeholder Mapping and Engagement

Stakeholder mapping and engagement was conducted to obtain relevant data and information that would be used to develop the CEP. The framework described in Figure 1-1 was used to identify relevant stakeholders. An additional goal was to foster collaborative relationships between departments in the Government of Makueni County and external stakeholders. This would strengthen support for future county energy planning initiatives. The stakeholders engaged included: Kenya Power and Lighting Company, Energy and Petroleum Regulation Authority (EPRA), Rural Electrification and Renewable Energy Corporation (REREC), Kenya National Bureau of Statistics (KNBS), and Kenya Forest Service (KFS). Other stakeholders included: Kenya Electricity Transmission Company Limited (KETRACO), Nuclear Power and Energy Agency (NuPEA), Independent Power Producers (IPPs) and private sector, including NGOs (e.g. MADET), as well as the community through surveys (households, SMEs, institutions etc.) and focus group discussions (men, women, youth, PLWDs, co-operatives, SMEs etc.). Other entities supporting counties in the development of energy plans, such as the Sustainable Energy Technical Assistance (SETA) Project, were also engaged to share their ideas and insights. This process was continuous throughout the CEP development.

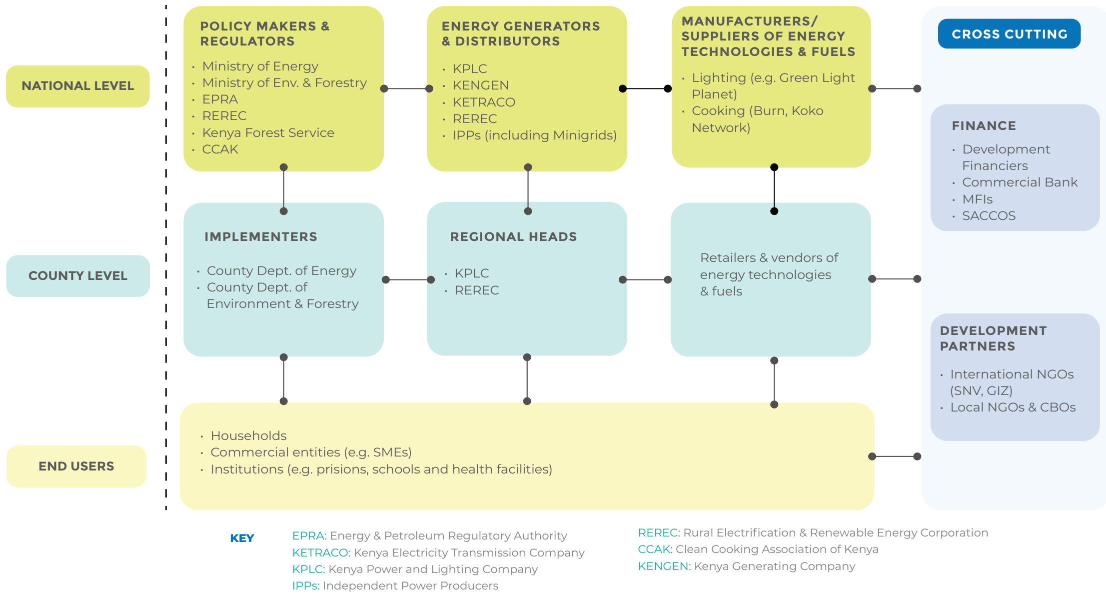

Figure 1-1 : Stakeholder Mapping Framework

1.3.3 Data collection

Data collection for the CEP began with literature review of the various county documents, including but not limited to: Integrated County Development Plans, County Annual Plans, County Statistical Abstract, previous studies, or research that had been conducted, and other documents detailing various programs. The findings from this process were complimented through primary data collection, which entailed conducting direct surveys with households, institutions, and health care facilities. This was based on representative samples from the three categories. The total number of surveys conducted were 1448: households (634); institutions (365), businesses (394) and healthcare facilities (55). Additionally, focus group discussions were conducted with representative groups from different sectors (e.g. Juakali, dairy farmers, women groups, boda boda association etc.) to understand their views and aspirations when it comes to energy access. A total of 18 focus group discussions were conducted, strategically distributed across all the sub-counties to ensure representative and inclusive sampling throughout the county. As part of the productive use assessment, key informant interviews were conducted with Chief Officers of the various departments at the county. This was followed up by field visits to various companies/organisations within the county. Tools used for data collection can be accessed on the county website[1]

1.3.4 Least Cost Electrification and Clean Cooking Modelling

Informed by the outputs from the data collection, possible scenarios for future supply and demand of electricity in Makueni County were modelled using the Open-Source Spatial Electrification Tool (OnSSET). OnSSET is a bottom-up GIS- based cost optimization toolkit used to identify least cost technological options for electrification of un-served areas. Clean cooking modelling was undertaken using Low Emissions Analysis Platform (LEAP) tool that considered firewood, charcoal, biogas and LPG as fuel options for cooking.

1.3.5 Energy Access Explorer for Prioritising Energy Interventions

The CEP also involved the development of a customized version of the Energy Access Explorer (EAE). EAE is an open-source dynamic geospatial information system that enables stakeholders to visualize and analyse high-priority areas where access to energy should be expanded for equitable development. EAE also integrated outputs of least-cost electrification modelling based on the Open-Source Spatial Electrification Tool (OnSSET).

1 https://makueni.go.ke/category/departments/energy/

1.3.6 Gender Equity and Social Inclusion (GESI) consideration

GESI was considered throughout the development of the plan. Disaggregated data was obtained in view of understanding unique challenges facing marginalised communities and available opportunities. Further, there was capacity building meant to empower the government to integrate GESI considerations into policy making, and reporting aimed to present GESI-disaggregated findings.

1.3.7 CEP Document Drafting

The CEP document was drafted in line with the INEP Framework chapters. The inputs included: analysed data collected through literature reviews, primary data collection, energy resources assessment, electricity and clean cooking modelling inputs.

1.3.8 Validation and Dissemination of the CEP

Validation of results contained in the CEP was undertaken through presentations made to: County Energy Planning Committee, County government officials, community members who had taken part in data collection, and development partners involved in County Energy Planning. They gave feedback that enabled the team to produce the first CEP draft. This document was then subsequently reviewed by a team of selected energy experts engaged in energy planning and the Ministry of Energy staff, leading to the production of the final draft.

1.3.9 Integration of Energy into the County Planning Framework

The county planning framework has prioritized energy as a key enabler to socio-economic development. Makueni Vision 2025, under the Energy, Infrastructure and ICT pillar, acknowledges that reliable energy supply is an important driver of industrial growth, which creates employment. Reliable energy supply also plays an important role in lighting homes, streets and businesses –which can enable a 24-hour economy in the county. Makueni Vision 2025 identified several challenges, among them; disparities in electricity connectivity, frequent power outages, low electricity coverage in areas with low population density, lack of green energy generation and distribution policy, and overreliance on unclean energy like firewood and charcoal. To address these challenges, four strategic interventions were proposed: improving energy distribution and coverage; developing a comprehensive energy sector development and distribution policy; promoting green energy generation; and collaborating with Kenya Pipeline to establish an oil pumping station in the county to reduce fuel costs in the county. CIDP III prioritizes access to reliable and clean energy through collaborations with key development partners. The objective is to enhance energy resource development, upgrade rural and urban electrification, promote uptake of green energy, and ensure continuous maintenance of energy assets in the county. To that end, two programs —Green energy promotion and Rural electrification—were proposed and slated for implementation over the next five years. Notably, Green energy development and promotion was selected among the 10 flagship projects to be implemented over this period. Among the key activities proposed under the flagship project are: the energization of the Athi River agricultural economic zone, collaboration with the National government to ensure the completion of Thwake dam Hydro power generation (17.6 MW), sensitization campaigns to enhance the adoption of green energy, development of an energy centre in the county, and solar development in Makindu, Mtito Andei, Ndua Farm, Kivyalu in Kikumbulyu North, and Kavumbu in Kalawa Ward. The implementation of CIDP III will be carried out through five Annual Development Plans.

Development, adoption and implementation of the CEP—which will incorporate the strategies from the Makueni Vision 2025 and CIDP III—holds the potential to drive positive transformations in the energy sector, setting a course towards a more sustainable and prosperous county.

1.4 COUNTY OVERVIEW

1.4.1 Location and size

Makueni County is in the south-eastern part of Kenya and borders the following counties: Machakos to the North, Kitui to the East, Taita Taveta to the South, and Kajiado to the West. The county lies between Latitude 1º 35´ and 3° 00´ South and Longitude 37º10´ and 38º30´ East with an approximate land area of 8,176.7 KM2. The county is headquartered at Wote town, 130 KMs from Nairobi, where both the County Government head offices and the national government county offices are situated. It is divided into six county government administrative sub-counties, which are also the parliamentary constituencies, namely: Makueni, Mbooni, Kibwezi East, Kibwezi West, Kaiti, and Kilome. These sub-counties are further subdivided into 30 electoral wards. Makueni County is a member of the South Eastern Kenya Economic Block (SEKEB), alongside Kitui and Machakos Counties (Government of Makueni County, 2023)

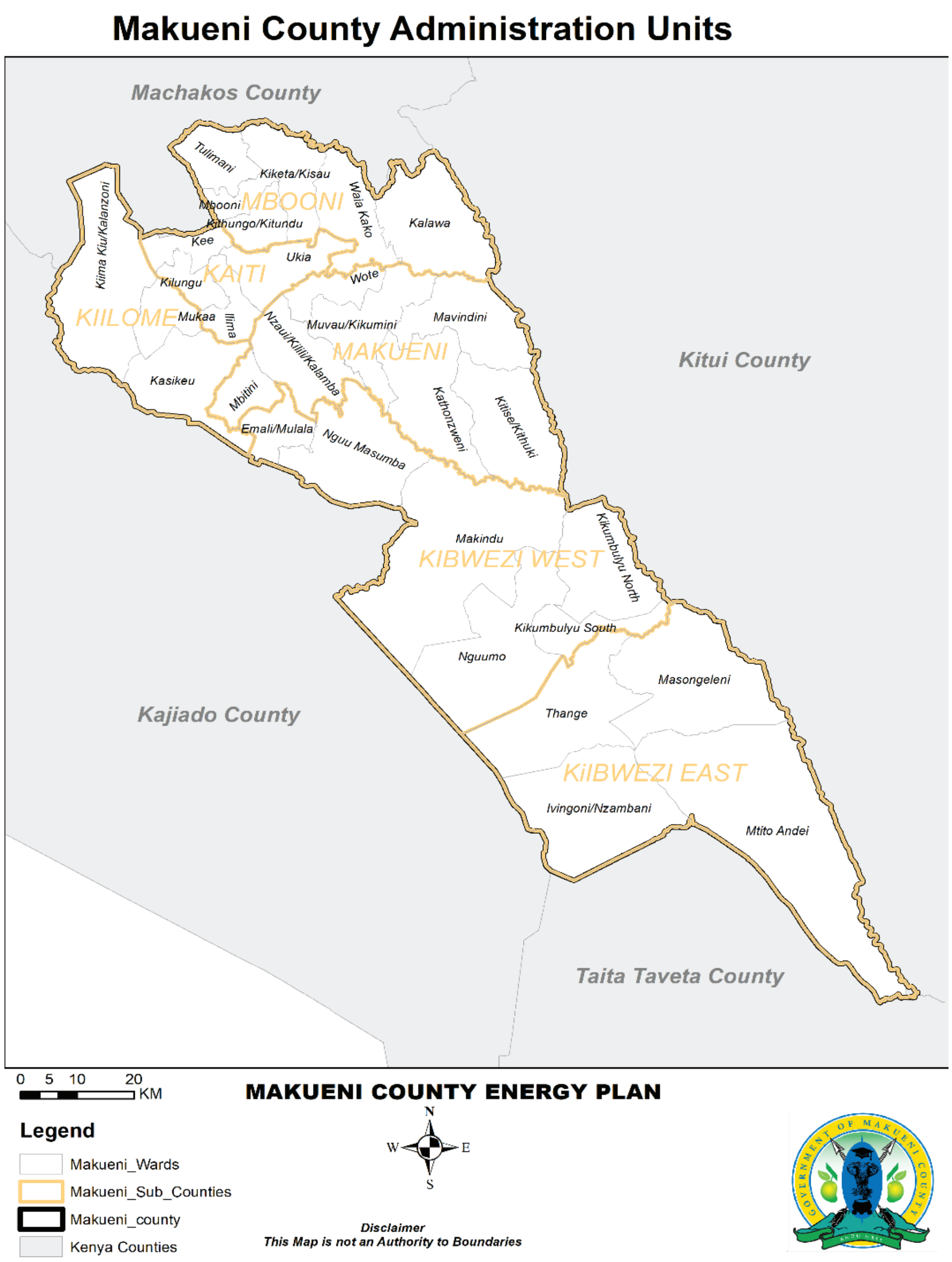

Figure 1-2: Makueni County

1.4.2 Demographic features

According to the 2019 census, the county's population stood at 987,653, comprised of 489,691 males, 497,942 females and 20 individuals identifying as inter-sex (KPHC 2019). With the population growth rate of 1.1%, the population is projected to increase to 1,042,300, 1,053,891 and 1,098,921 by 2023, 2025 and 2028 respectively. The county has an average population density of 121 persons/KM2 with Kilungu Sub-County recording the highest population of 395 persons/KM2 and Kibwezi Sub-County recording the lowest, at 63 persons/KM2. The Akamba community predominantly inhabits the county at 97%, while other communities constitute the remaining 3%.

1.4.3 Socio-economic Activities

The county had a Gross County Product (GCP) of KES 111 billion in 2020. The economic structure is mainly composed of three sectors; agricultural, industrial and service. Their contribution to Makueni's GCP is seen in Figure 1-3. At 53%, the service sector contributes the highest to the GCP, following by Agriculture at 30%.

The service sector is made up of the following: transport and storage (12%), wholesale and retail trade (9%), information and communication (2%), accommodation and food services (3%), financial and insurance activities (1%), education (8%), human health services (4%), professional services (2%), public administration services (11%) and other service activities (4%).

In agriculture, farmers engage in the cultivation of various crops such as maize, beans, millet, sorghum, fruits (mangoes, oranges, bananas), and vegetables. Livestock rearing—including cattle, goats, and poultry—is also widely practiced. Notably, the county produced 230,685 MT of grains and legumes, 8,372,653 MT of fruits, 99,364 MT of vegetables and 22 million litres of milk in 2022. Agro-processing initiatives that add value to agricultural produce are on the increase in the county, creating employment opportunities and contributing to the local economy.

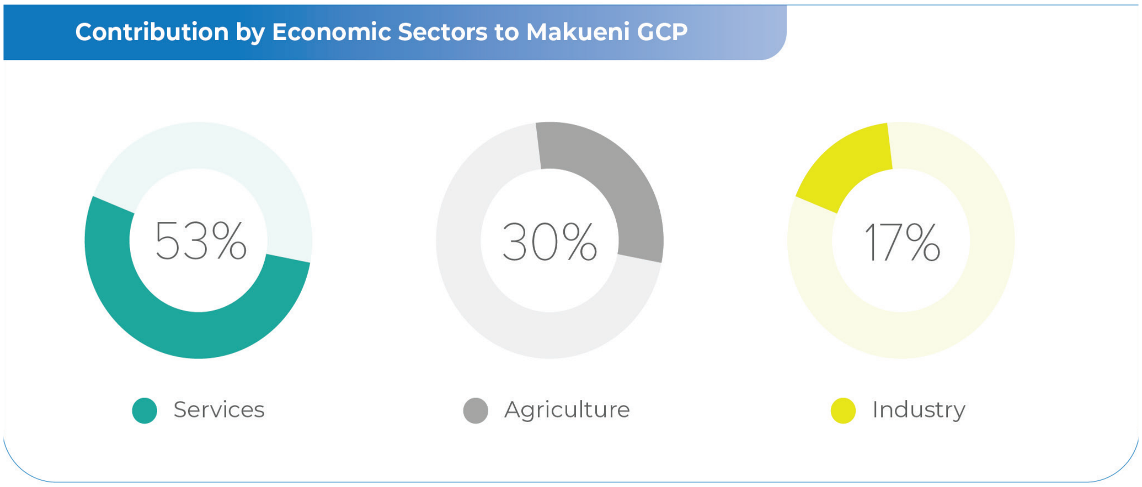

Figure 1-3 Contribution by Economic Sectors to Makueni County GCP

The industrial sector contributes a total of 17% to the county economy. It is comprised of: manufacturing (5%), construction (5%), mining and quarrying (1%), real estate activities (5%), and water supply (1%).

Figure 1-4 shows Makueni GCP from 2013 to 2020 in billions. The county's economy has doubled during the covered duration, and its growth prospects are promising due to the vibrant working population and structural transformations in the county.

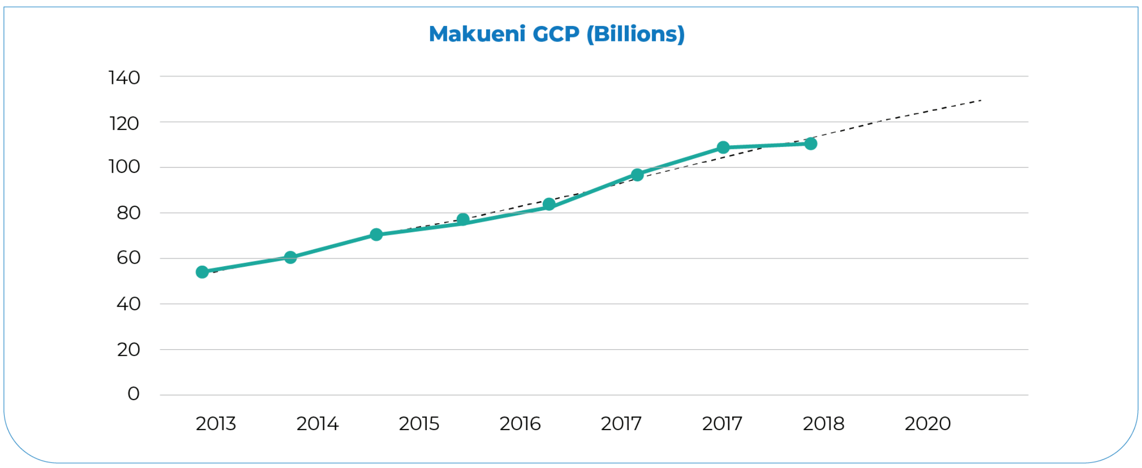

Figure 1-4: Makueni Gross County Product in Current Prices (KES. Billions)

Source: GCP Report, KNBS (2021)

1.4.4 Ecological Profile

Makueni County is characterized by its diverse agro-ecological zones, which include the Upper Middle, Lower High, and Lower Middle zones. Each zone has its own unique agricultural practices and farming activities. The Upper Middle (UM) zone encompasses the uplands of Mbooni and Kaiti. In this zone, farmers engage in coffee, avocado, macadamia, maize, and beans farming. Additionally, dairy farming is also prevalent in this area. The Lower High (LH) zone is primarily located in Makueni and Kilome sub-counties. In this zone, farmers cultivate mangoes, citrus fruits, grains, and root tubers. These crops thrive in the specific climatic conditions of the LH zone. Livestock production in also prevalent in this zone. The Lower Middle (LM) zone covers Kibwezi West and Kibwezi East. In this zone, farmers predominantly grow cowpeas, pigeon peas, dolichols, green grams, and sorghum. The LM zone is also characterized by extensive rangelands suitable for livestock production. These agro-ecological zones showcase the diversity of agricultural practices and farming activities within the county. Each zone has its own unique crops and farming methods that contribute to the county's agricultural sector and overall socio-economic development.

1.5 NATIONAL POLICY AND REGULATORY FRAMEWORK FOR THE ENERGY SECTOR

Makueni County is governed by policies and regulations established by both the National and County Governments. The following is a brief description of the national policies and regulations that have a bearing on the energy sector in Makueni.

Table 1-2: National Laws relating to Makueni's Energy Regulatory Framework

NATIONAL ENERGY LEGAL FRAMEWORK		
LEGISLATION	**YEAR**	**OBJECT**
Constitution of Kenya	2010	This is the supreme law of the Republic of Kenya that binds all persons and all State organs at both levels of government. It created the devolved system of government, consisting of the national government and 47 county governments. It distributes functions and powers between the two levels of Government as detailed in Chapter Eleven and the Fourth Schedule. In relation to the County Governments, Part 2 of the Fourth Schedule provides that they shall be responsible for county planning and development, including electricity and gas reticulation and energy regulation.
County Governments Act	2012	The Act provides for the implementation of the Constitutional framework on powers, functions and responsibilities of County governments. The Act requires Counties to formulate plans and establishes the framework for county planning, including the principles, objectives and types of plans. The Act emphasizes the need for alignment of national and county plans.
Environmental Management and Coordination Act	1999 *Rev. 2022	The law establishes the legal and institutional framework for the management of the environment and all related matters. The Act promotes the use of renewable energy. The National Environment and Management Agency (NEMA) in collaboration with relevant agencies is mandated to work with related agencies in the preservation of non-renewable energy sources, promotion of research in renewable energy and creating incentives for promotion of renewable energy sources. The Act requires County Governors to constitute a County Environment Committee. The Ministry of Energy shall be among those represented in the County Environment Committee.

Climate Change Act	2016 *Re-vised 2023	The Act establishes a regulatory framework for enhanced response to climate change and measures to achieve low carbon and climate resilient development. The Act requires inclusion of energy conservation measures and promotion of renewable energy sources in formulation of the Country's National Climate Change Action Plan. The Act provides that the Cabinet Secretary responsible for energy shall be a member of the National Climate Change Council, which is the main institution responsible for implementation of the Act. The Chairperson of the Council of Governors is also a member of the Council.
Energy Act The Energy (Reliability and Quality of Energy Supply and Service) Regulations The Energy (Petroleum Pricing) (Revocation) Regulations	2019	The Act seeks to consolidate the laws relating to energy and to allocate related functions to the National and County governments. The Act further establishes the institutional frameworks for the energy sector including the powers and functions of energy sector entities. In alignment with the Environment Management and Coordination Act and the Climate Change Act, the law promotes renewable energy. The Act mandates each County Government to develop and submit a county energy plan to the Cabinet Secretary in respect of its energy requirements. This requirement necessitated the development of this CEP. The Fifth Schedule of the Act provides for the distribution of functions between the national government and county governments. The functions of County Governments under the Act include: county energy planning, regulation, operations and development, as well as establishment of a fund for the purpose of promotion of efficient use of energy and its conservation within the county.
NATIONAL ENERGY POLICY FRAMEWORK		
Kenya National Climate Change Action Plan (NCCAP)	2023-2027	NCCAP recognizes the critical role of energy in achieving Kenya's proposed Nationally Determined Contribution (NDC) target of a 32% reduction in greenhouse gas emissions by 2030. NCCAP 2027 promotes the generation and use of renewable energy and the mainstreaming of energy efficiency in all sectors. The plan supports the transition from reliance on biomass and fossil fuel to the adoption of clean cooking solutions and the use of alternative sources of energy, such as wind, solar and geothermal energy.
Draft Kenya National Energy Policy, 2018 (KNEP 2018)	2018	The Policy outlines Kenya's goal to achieve the national and county development needs, using affordable, competitive, sustainable and reliable supply of energy, while protecting and conserving the environment for inter-generational benefit. The Policy acknowledges the challenges related to the limited access to and affordability of modern and clean energy solutions and emphasizes the need to undertake measures to make clean and modern energy services affordable and accessible. The CEP was developed with these objectives in mind, addressing both electrification and clean cooking. Noting the inadequate public awareness on the adverse health effects of the use of wood-fuel and kerosene, especially on women and children, the Plan underscores the importance of adoption of clean cooking solutions.

Energy Gender Policy	2019	The broad objective of this policy is to guide the mainstreaming of gender in institutions, policies and programs in the MoE and its agencies, County Governments, and amongst other stakeholders. The specific objectives of the policy include: increasing awareness on gender in the Energy sector, promoting clean cooking solutions and environmental sustainability, ensuring compliance with the Constitution, among others. It also provides policy recommendations, commitments and implementation strategies to ensure smooth and sustainable mainstreaming of gender in the generation, transmission and distribution of energy resources across the country.
Kenya National Electrification Strategy (KNES)2018	2018	It is the roadmap to achieving universal access to electricity by 2022 (later amended to 2026). Its principal objective is to ensure universal access to electricity for all households and businesses in Kenya in the shortest time possible, while maintaining an acceptable quality of service. With the help of a geospatial planning tool, KNES identified the least cost technology options (grid extension, grid intensification, mini-grids, and standalone systems) and the associated investments required for universal electricity access.
Bioenergy Strategy	2020	Sets forth guidelines and approaches, and further identifies strategic interventions that can promote the development and sustainable utilisation of bioenergy resources in Kenya over the 2020-2027 period.
Kenya National Energy Efficiency and Conservation Strategy (KNEECS)	2020	Section 3.1 of the Strategy recognises the role of County Governments in promoting energy efficiency and conservation. With approval by EPRA, these functions include, but are not limited to: a) amend the energy conservation building codes to suit the local climatic conditions b) Direct compliance with the provisions of the energy efficiency and conservation building codes, c) Direct an energy audit conducted by an accredited energy auditor d) Take all measures necessary to create awareness and disseminate information for the efficient use of energy and its conservation, e) Train personnel and specialists in techniques for the efficient use of energy and its conservation, f) Take steps to encourage preferential treatment for the use of energy-efficient equipment or appliances. In addition, County governments are mandated to mobilize adequate resources to finance their relevant energy efficiency and conservation programmes/projects.
Least Cost Power Development Plan (LCPDP) 2021-2041	2021	The LCPDP is a Kenya Energy Sector Report Plan that provides guidelines on generation expansion opportunities, transmission and distribution, infrastructure development, and related resource requirements. The CEP adopted projects earmarked for Makueni County within the LCPDP.
Kenya Vision 2030	2008	The CEP is aligned to Vision 2030, a long-term development blueprint. Vision 2030 positions energy as an enabler through productive uses to stimulate economic growth and employment creation.

1.6 COUNTY POLICY AND REGULATORY FRAMEWORK

Makueni County's policy and regulatory framework is depicted in Table 1-3

Table 1-3: County Policy and Regulatory Framework

MAKUENI ENERGY LEGAL FRAMEWORK		
Legislation	**Year**	**Outcomes**
Makueni Climate Change Act	2022	The object of the Act is to provide for a framework for the county to respond efficiently to the effects of climate change, through mitigation and adaptation strategies, etc. In recognition of the importance of renewable energy in the climate change governance framework, the Act provides for inclusion of the Chief Officer responsible for energy or a representative in the composition of the Climate Change Board.
Makueni County Water Act	2020	The Makueni County Water Act provides a framework for water management, utilisation, and distribution in the county. The Act provides for management of water resources in a manner that it is beneficial to all residents of Makueni. It also provides a legal framework on how water from different sources shall be managed and how efficiency will be enhanced while ensuring the right tools and technologies are employed in water management, supply and utilisation. Energy is a key resource in the effective and efficient distribution of water
MAKUENI ENERGY POLICY FRAMEWORK		
Policy	**Year**	**Outcomes**
Makueni County Vision	2025	This is a development blueprint for the County that is aimed at socio-economic transformation of the County by the year 2025. The vision aims to achieve: accelerated and inclusive economic growth and development, improved access to quality water and health services, enhanced access to quality education, increased job creation, increased household incomes, and sustainable food security. The strategies to be pursued include: green energy generation (solar and wind) through public-private partnerships, promotion of the use of green energy (solar, wind and biogas) at the household level, and lighting of markets and streets.
Makueni County CIDP (2023-2027)	2023	The Makueni County Integrated Development Plan 2023-27 is the third generation of the five-year county plans since devolution, as mandated by Section 102 (h), 104 (1) and 108 of the County Government Act 2012. The overall vision of the plan is to have a prosperous value-based county with a high quality of life. The CIDP, whose theme is 'A resilient economy for sustainable development' was developed through a participatory approach with the involvement of Sector Working Groups and diverse stakeholders. The CIDP recognizes renewable energy development and promotion as a key priority sector. Regarding access to reliable and clean energy, the sector plans to collaborate with key development partners. This collaboration seeks to enhance energy resource development, improve both rural and urban electrification, promote uptake of green energy sources, and continuously maintain energy assets across the county.

Makueni Environment and Climate Change Policy		The policy provides a framework for the mainstreaming of sustainable environmental management, including low carbon and climate change resilience, in the county's sectoral development plans. The policy seeks to transition the county from over reliance on charcoal and firewood to use of renewable energy.
Makueni County Spatial Plan (CSP)	2019-2029	The County Spatial Plan outlines a Spatial Development Framework (SDF) for the county, which is a strategic vision that guides the overall spatial distribution of current and desirable land uses. The SDF aims to promote sustainable functional and integrated human settlements, maximize resource efficiency, and enhance regional identity and unique character of a place. The development strategies envisioned in the CSP include: Economic development strategy, Agricultural development strategy, Settlement development strategy, Environment and natural resource strategy, Transportation development strategy, and Social Infrastructure and services development strategy. Energy is a key driver of these development strategies.
Makueni Draft County Electrification, Gas Reticulation and Energy Regulation Policy	2023	The Makueni County Electrification, Gas Reticulation and Energy Regulation Policy framework provides the necessary legal instrument and mechanism for coordination and development of the county's energy infrastructural development. The policy addresses the following issues: county energy planning, energy regulation, and county energy operations and development. It also ensures that there is strict adherence to energy regulations and standards in the county.

1.7 COUNTY ENERGY PROFILE

Table 1-4 below shows a summary of the baseline-electricity access in households, schools, health care facilities and other institutions in Makueni County.

Table 1-4: Percentage electricity access

Year	2019	2020	2021
Total connectivity of the HHs (grid and mini grid)	20.5%	26%	31.3%
HH connected to solar home systems	44%	-	-
Total connectivity of the SMEs	68%	88%	96%
Total connectivity of the institutions	81%	93%	96%

Table 1-5 below shows a brief summary of the baseline-cooking energy mix in households in 2019. Complete historical data for the period was unavailable.

Table 1-5: Households Sources of Cooking Energy (KNBS, 2019)[2]

Year	2019
Firewood %	76.1%
Charcoal %	10.15%
Briquettes %	-
Pellets %	-
Kerosene %	4.63%
Bioethanol %	
LPG %	8.6%
Electricity%	0.2%
Biogas%	0.24%
Others e.g. Solar %	0.09%

Table 1-6 below shows the energy resources available in Makueni County.

Table 1-6: Resource Assessment in Makueni County

Sector	Potential energy capacity	Unit of Measure	Source
Biomass			
Wood fuel+	6,200 per year	Ton/yr	Calculation undertaken in chapter 2
	368, 766, per year	TJ/yr	Calculation undertaken in chapter 2
Agricultural residues++	1,198, per year	TJ/yr	Calculation undertaken in chapter 2
Animal Waste*	117	Million m3/yr	Calculation undertaken in chapter 2
Waste			
Solid	1,766	MWh/yr	Calculation undertaken in chapter 2
Geothermal			
Potential for different sites	N/A	N/A	
Hydro			
Potential for different sites	0.16 MW	MW	Korkovelos, A. (2016)
Solar			
Solar radiation by area	Average GHI of 2,008 kWh/m2 per year	kWh/m2	Global solar atlas
Wind			
Potential by area	Average windspeed at 100m height: 3.8 m/s	m/s	Global wind atlas
Fossil resources- including coal	N/A	N/A	
Nuclear	N/A	N/A	
Other energy resources	N/A	N/A	

2 KNBS (2019) Kenya Population and Housing Census Volume IV: Distribution of Population by Socio-Economic Characteristics - Kenya National Bureau of Statistics.

2.0 ENERGY RESOURCE ASSESSMENT

This chapter will quantify primary resources available for energy generation and consumption in Makueni County. It focuses on biomass, wind, solar and hydropower. Energy sources such as coal and geothermal that are not available in Makueni County are omitted from the discussion.

2.1 BIOMASS ENERGY RESOURCES

In Kenya, bioenergy is typically consumed in the form of woody biomass, primarily as firewood and charcoal. Other forms of biomass include crop residues or animal dung, which provide energy needs for cooking, heating, drying or electricity production. Biomass energy resources are derived from forests—closed forests, woodlands, bush lands, grasslands, farmlands, and plantations—as well as from agricultural and industrial residues.

2.1.1 Estimation of woody biomass coverage

The woody biomass resources of Makueni County include: public forests, bushland and/ shrub land, and on-farm trees under agroforestry systems. The County's Spatial Plan indicates that forests account for 17% of the total land cover in Makueni (136,590 ha), bushlands cover 48% of the county (385,666 ha), grasslands 5% (40,174 ha), croplands 6% (48,208 ha), barren lands 16% (128,555 ha) and 8% (64,278 ha) is under intensive settlement[3]. The total forest cover, spanning both protected and non-protected areas, including gazetted and non-gazetted lands, is recorded at 136,590 ha.

The forestland reported in the County Spatial Plan is assumed to include forests managed by the national government (including those in protected areas like national parks), county government, or by private entities such as group ranches.

The County Spatial Plan further indicates that there are five (5) gazetted forests under the national government, managed by the Kenya Forest Service (Makuli, Nthangu, Mbooni, Kibwezi, Kilungu forests); 28 community forests, covering approximately 15,200 Ha, and managed by the County Government, as well as 3 non-gazetted forests covering 4,000 ha[3]. The County Statistical Abstract of 2022[4] records the number and respective sizes of the gazetted (15,004 Ha) and non-gazetted forests (7,601 ha), disaggregated by sub-counties, as summarized in Table 2-1. The two categories are assumed to be available for bioenergy purposes. Forests that do not fall into either the gazetted or non-gazetted category amount to a total of 113,984 ha. These are assumed to constitute forests within and outside protected areas. It should be noted that only the woody biomass located outside protected areas is available for bioenergy production. The subsequent sections estimate the coverage of all the woody biomass that is outside protected areas within Makueni and therefore available for bioenergy production.

Table 2-1: Number and Size of Gazetted & Non-Gazetted Forests, 2020/2021.

Source: Kenya Forest Service

Size (Ha) of the gazetted and non-gazetted Forests, 2020-2021								
Year	Sub-county	Mbooni	Kilome	Kaiti	Makueni	Kibwezi West	Kibwezi East	Total
2020/2021	Gazetted forests (Ha)	4,354	615	2,878	967	341	5,850	15,005
2020/2021	Non-Gazetted forests (Ha)	49	1	8	504	6,914	125	7,601

To visualize the forestland available for bioenergy production, a map was created using datasets obtained from the County GIS & Physical Planning Office. Protected areas were excluded from the analysis as extraction of biomass from these areas is prohibited. Following this, the associated woodlands, shrub lands and available boundary layers of gazetted, county and community forests were superimposed using GIS analysis. The resulting map is shown in Figure 2-2. The associated statistics are summarized in bar graphs in Figure 2-1. Table 2-2 below shows the total land under forests, woodlands, and shrub lands. It should be noted that the woody biomass resources covered in this report are situated outside protected areas. Consequently, it is assumed that extractive use is permitted, based on sustainable yield concepts.

3 (County Government of Makueni, 2019).

4 (County Government of Makueni, 2022)

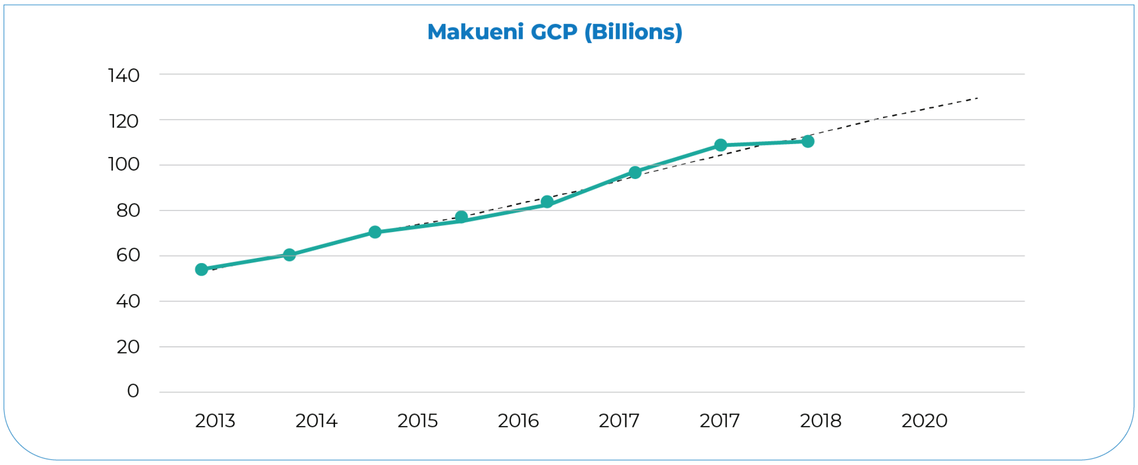

Figure 2-1: Distribution of Woody Biomass in Makueni

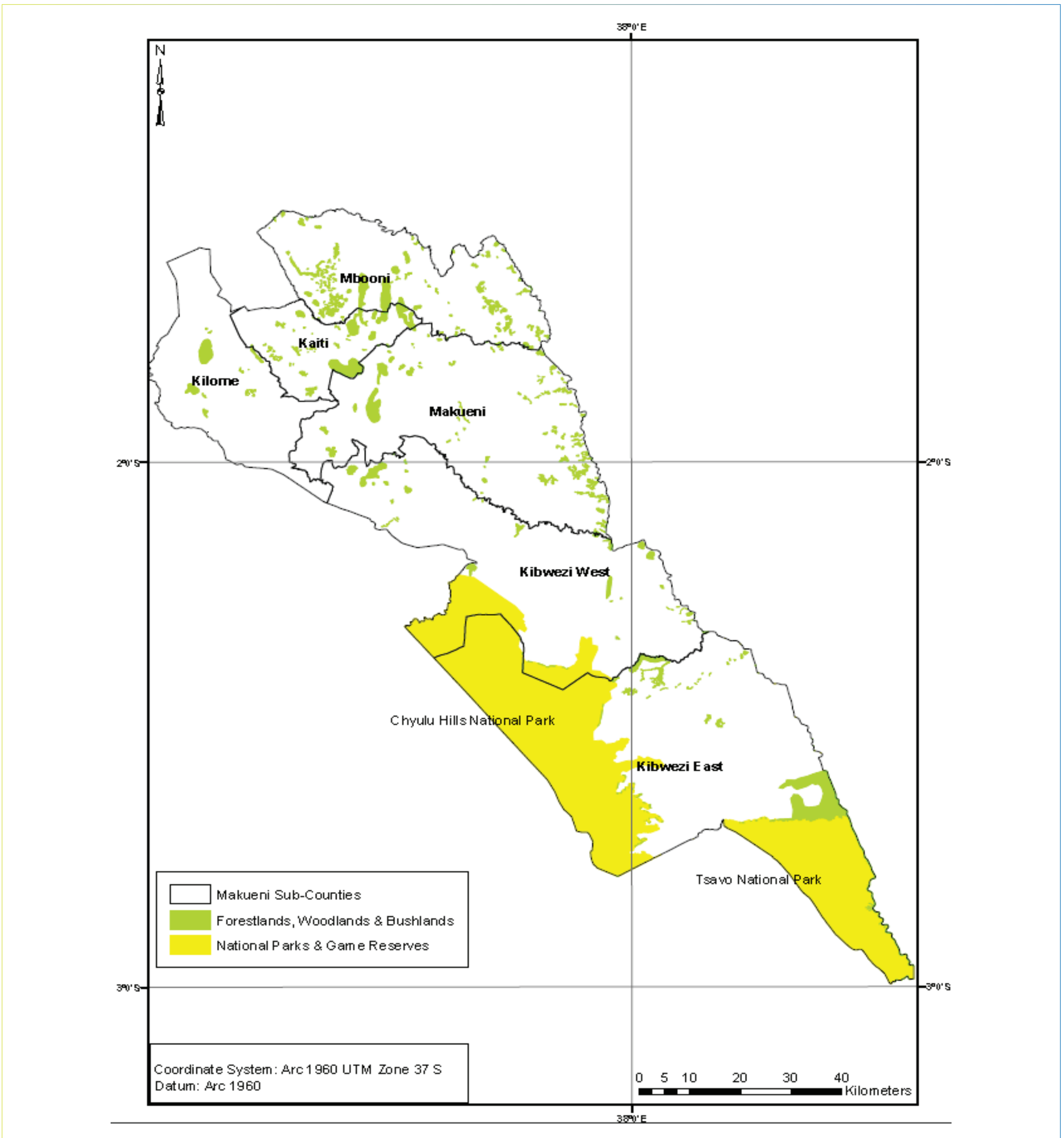

Figure 2-2: Distribution of Woody Biomass in Makueni

Table 2-2: Coverage of woody biomass (Ha) assumed to be available for bioenergy purposes.

Note: protected areas/forestlands are not include

Cover	Size (Ha)
Forestland	5,824
Woodland	9,743
Shrub land	12,710
Total	**28,277**

Tree cover in Makueni County has been decimated substantially due to expansion of settlement areas and agricultural activity. According to Global Forest Watch, the County lost 2,092 ha between 2001 and 2021, representing 1.5 % of the total forest cover in the County. The loss occurred uniformly across forest tenures, impacting both protected and non-protected areas, as well as forests managed by national and county governments and private entities. Table 2-3 below describes the size of forest land lost in each of the sub-counties. The highest loss was experienced in Kibwezi West, Makueni and Mbooni sub-counties while the lowest was in Kibwezi East sub-county.

Table 2-3: Forest Loss in Makueni

Sub-county	Land lost (Ha)	Land lost (%)
Kibwezi West	473	23%
Makueni	468	22%
Mbooni	446	21%
Kaiti	321	15%
Kilome	246	12%
Kibwezi East	138	7%
Total	**2,092**	**100%**

Makueni County possesses a viable bioenergy resource in the form of trees cultivated by local farmers. Focus group discussions conducted across the six sub-counties revealed that farmers in Makueni County practise tree growing. County statistical records provide the tree seedlings that are grown within the county[5]. Eucalyptus spp. is prevalent in Mbooni, Kilome, and Kaiti sub-counties, while Acacia spp. is primarily found in Kibwezi West and East sub-counties. Finally, Combretum spp. prevails as the dominant tree species in Makueni sub-county. These seedlings are sold to interested parties for planting.

Table 2-4: Seedlings Production, Makueni County, 2021.

Source: Department of Agriculture, Irrigation, Livestock, Fisheries & Cooperative Development, County Government of Makueni

Sub-county	Mbooni	Kilome	Kaiti	Makueni	Kibwezi West	Kibwezi East	Total
Dominant tree species	Eucalyptus spp.	Eucalyptus spp.	Eucalyptus spp.	Combretum spp.	Acacia spp.	Acacia spp.	
No. of Seedlings Produced	92,168	32,478	46,300	40,166	19,538		230,650

5 County Government of Makueni (2022). Makueni County Statistical Abstract 2022, Wote. Kenya

Data on spatial distribution of the seedlings was not available. However, it is assumed that on-farm tree growing is ongoing in all the six sub-counties, which can be used to supply biomass for energy production. Estimation of on-farm tree cover (Ha) for each sub-county was computed using the expression below[6] while input data summarized in Table 2-5. Application of this approach assumes the instantaneous coverage, not accounting for the coverage that will be attained after seedling survival. The resulting statistics were then used to compute the expected area under trees () for the year 2023 as summarized in Figure 2-3 below.

Equation. 2-0

$$EAT=\mu*p*PNH$$

Where:

> ***EAT*** *is the expected area under trees,*
>
> ***μ*** *is the mean area (ha) under trees per given household*
>
> ***p*** *is the average proportion/percentage of smallholder farms under trees for respective sub-counties*
>
> ***PNH*** *is the projected number of households. An annual growth rate of 2.62% was utilised to project the number of households based on the Least Cost Power Development Plan. Projection of on-farm tree cover also assumes that growth in household number implies construction of more homesteads and therefore carving into tree cover assumed as 0.025 ha for each new household.*

Table 2-5: Summary of sub-county statistics on household's access to land (ha), natural and planted forests or woodlots on-farm (ha)

		Mbooni	Kilome	Kaiti	Makueni	Kibwezi West	Kibwezi East	Source
Household's access to land (ha)	ha	1.58	1.58	1.58	1.58	1.58	1.58	CIDP 2013-2017
(Mean on-farm forests/ woodlots (ha) per household)	ha	0.4	0.4	0.7	0.2	0.4	0.4	Primary data collection
(Average fraction of smallholder farms under trees)	%	27	27	45	10	25	25	Primary data collection

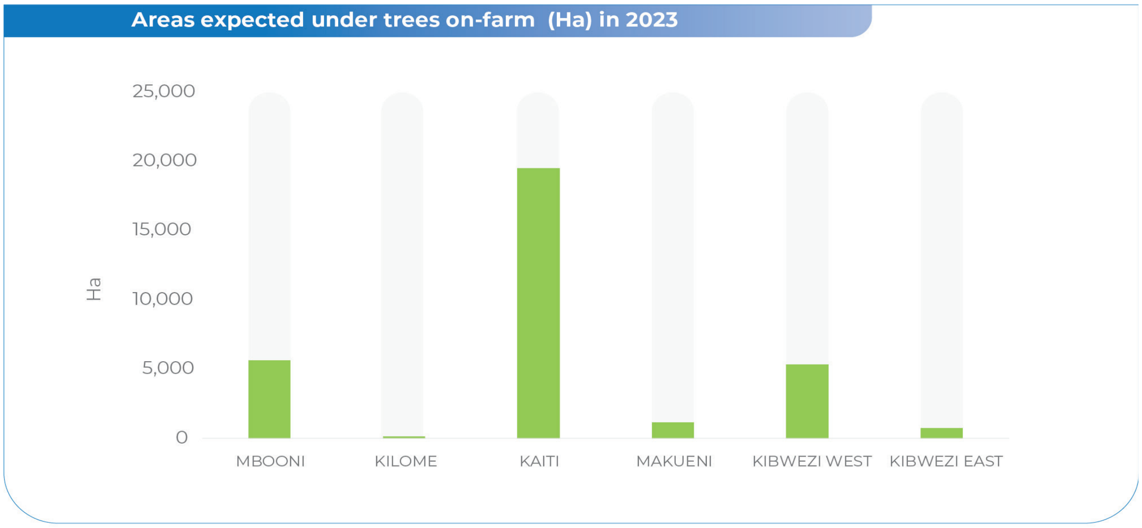

Figure 2-3: Areas expected under trees on-farm (Ha) in Makueni County, by sub-county

6 Githiomi, J.K., Kung'u, J. B., and Mugendi, D.N. (2012). Analysis of woodfuel supply and demand balance in Kiambu, Thika and Maragwa districts in central Kenya. Journal of Horticulture and Forestry, Vol (4(6), pp 103-110. DOI: 10.5897/JHF12.003

2.1.2 Estimation of baseline sustainable supply from woody biomass cover of Makueni County

Sustainable supply of wood fuel from farmlands as well as outside farmlands was calculated using the following equation[7]:

Equation 2-1

*SS =AAP*H*

Where:

> ***AAP*** *(average annual productivity) is dependent on wood cover type. In farmlands, the annual net productivity (AAP) of woody biomass is assumed to be 1.44 m^3/ha/year. Outside farmlands, AAP was assumed to be 0.79 m^3/ha/year, representing the average productivity of closed forests/tree cover, woodlands or vegetation in flooded areas, and bushlands*[8]

> ***H*** *is the land area (Ha) for each land cover type, and*

> *is the Sustainable Supply (SS).*

The sustainable production rate for biomass for energy use would be a fraction of this since not all wood can be harvested to maintain stocks (taking into account factors like loss to disease etc.) and considering other uses (e.g., timber). It was assumed that half (50%) of the wood harvested would go into energy use, which would then be referred to as the sustainable annual productivity of wood for energy use. Further study is required to develop an exact percentage. It should be noted that there is no statistical data on the percentage of woody biomass harvested for firewood versus charcoal. This might be attributed to the fact that charcoal trading within Makueni County is illegal. Further study on the percentage harvested for bioenergy is recommended.

The net sub-county supplies of woody biomass were converted from m^3 to kg. Wood density is species and age specific[9]. For example, mango tree, one of the densest wood species found in Kenya, has a density of 675 kg/$m^3_{\text{solid-bone-dry}}$ [10] while Pinus patula, a common pine planted in Kenya and one of the lighter woods found in in the country, has an average density of 450 kg/$m^3_{\text{solid-bone-dry}}$ [11] . For the case of woody biomass resource assessment of Makueni County, an average value of 562.5 kg/$m^3_{\text{solid-bone-dry}}$ was adopted[12]. When converted, the net annual productivity of wood from farms and forests is found to be 19,409 tonnes for the year 2023. The values disaggregated by sub-county are summarized in Figure 2-4.

7 Ibid

8 Ministry of Energy (MoE) (2002). Study on Kenya's energy demand, supply and policy strategy for households, small scale industries and service establishments. Kamfor Consultants, Nairobi, Kenya

9 Githiomi, J. K., & Kariuki, J. G. (2010). Wood basic density of Eucalyptus grandis from plantations in Central Rift Valley, Kenya: Variation with age, height level and between sapwood and heartwood. Journal of Tropical Forest Science, 281–286.

10 The Wood Database. (2017). Mango | The Wood Database—Lumber Identification (Hardwoods). http://www.wood-database.com/mango/

11 Adlard, P., Godwin Baily, C., & Austin, S. (1979). Wood density variation in plantation-grown pinus patula from the Viphya Plateau, Malawi (No. 5; C.F.I Occasional Papers, p. 27). Commonwealth Forestry Institute.

12 Buchholz T, Kiama S, Kifalu H, Ronoh G, DaSilva IP, Ngunzi V 2021. Bioenergy analysis for 65 factories of the Kenya Tea Development Agency Holdings Company Ltd (KTDA). Strathmore Energy Research Centre (SERC), Strathmore University, Nairobi, Kenya, 57p.

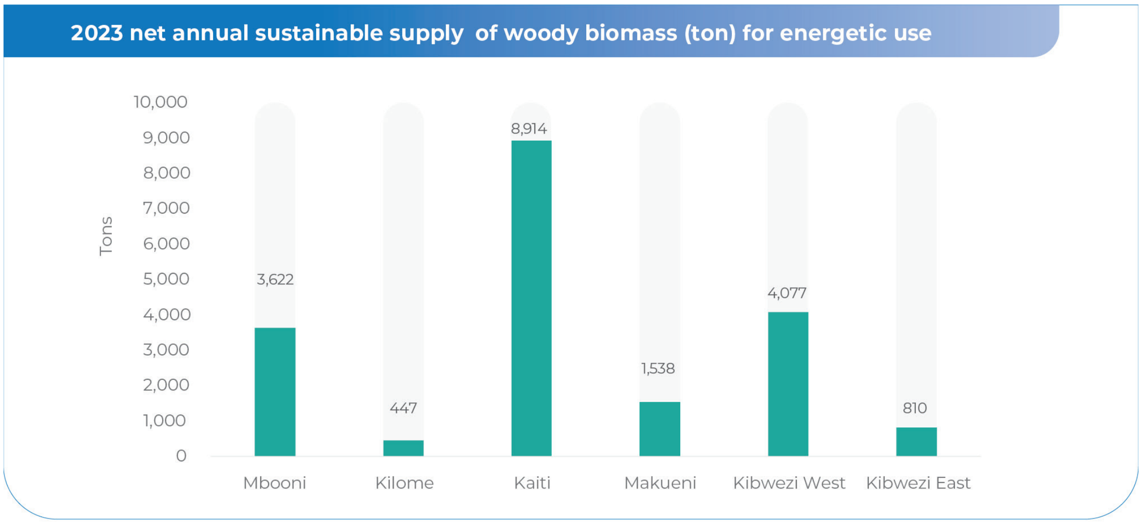

Figure 2-4: Future projections of sustainable supply of bioenergy from woody biomass

The future projections of sustainable supply from woody biomass-cover accounts for the business-as-usual scenario, which is based on two key assumptions:

- Loss of cover outside farmland, due to deforestation and forest degradation. This was accounted for by first estimating the annual tree cover loss in Makueni County, calculated using data obtained from Global Forest Watch (2022)[13].
- Annual growth rate of households, resulting in more farms with farm-forestry. It is presumed that every new household would like to mimic the pattern of other households by dedicating a part of their farmland to trees. Household growth rate for Makueni County was assumed as 2.67%[14].

The two assumptions above were considered in calculating projected annual sustainable yield.

Figure 2-5 below provides the total projected annual sustainable supply (tonnes/year) from farmlands and outside of farmlands.

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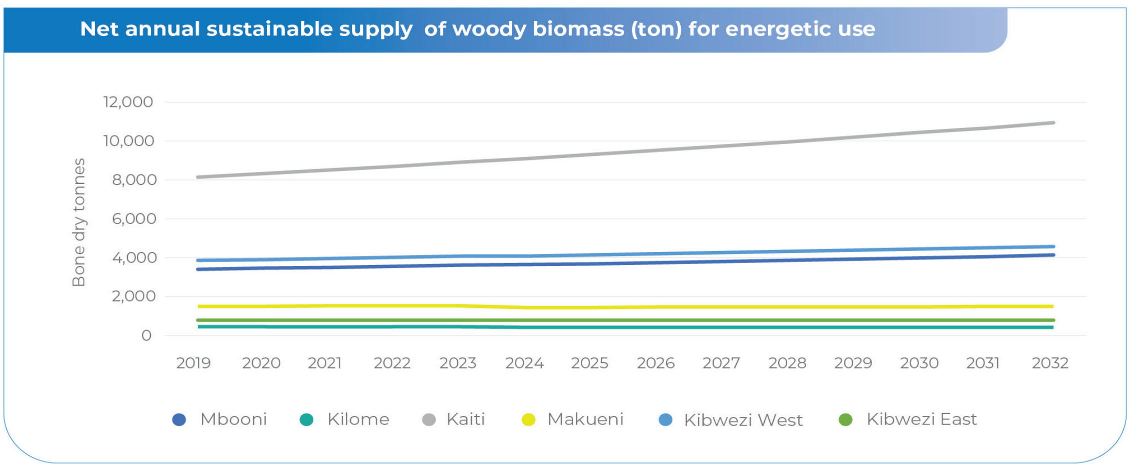


Figure 2-5: Net annual sustainable supply of wood (for energetic use) from forests and on-farm woodlots & trees, disaggregated by sub-county

13 Global Forest Watch: Forest Monitoring, Land Use. Available online: https://www.globalforestwatch.org. (Accessed on 8 May 2023).

14 Ministry of Energy. Least Cost Power Development Plan (2022-2041).

2.1.3 Alternative bioenergy resources in Makueni County

Kenya's Bioenergy Strategy[15] reports that the country's agricultural activities generate enormous residues that can be used as feedstock for production of energy and other by-products such as bio-fertilizers. This section assesses the bioenergy resource potential associated with agricultural and agro-processing activities in Makueni County. Key sub-sectors considered include the following:

- Livestock husbandry that generates dung, an important feedstock for anaerobic digestion. It is used to produce biogas for residential uses such as cooking, heating water and space heating.
- Crop farming associated with crop residues. Residues from primary crops such as maize, sorghum, millet, beans, cow-peas, green grams, and pigeon peas can be turned to briquettes (or pellets) fuel.
- Mango processing plant in Kalamba generates wastewater and solid waste that can be utilized for biogas production for heat generation.
- Slaughter-houses/abattoirs are also associated with generation of solid and liquid wastes that can be used to produce biogas for powering mini-grid.

2.1.4 Potential for biogas production from livestock population

The county has substantial population of livestock, especially beef cattle, dairy cattle, sheep and goats and poultry, as reported in Makueni County Statistical Abstract[16] . From this report, only beef and dairy cattle and small ruminants (sheep and goats) were considered for anaerobic digestion for biogas production. Dairy cattle population was split into zero-grazed versus 'other' dairy cattle. Separately for each animal category, linear projection of future numbers was implemented in a spreadsheet. Results of this projection can be seen in Annex A.3

Potential biogas production from these livestock categories was estimated for baseline year 2023 and projected up to 2032 based on simple linear projection of livestock population. The calculations were based on the following assumptions:

a) Unlike nomadic communities, animals spend all their nights in a shed within the homestead.

b) The dung that can be collected annually is proportional to the number of days/nights the animals spend in the cowsheds or pens.

c) All animal waste (100%) is available for biogas production. During focus group discussions, farmers were informed that the slurry from bio-digester can be used as fertilizer. As such, they indicated that they could avail all the waste for biogas production.

d) Biogas yield used the IPCC[17] parameters (13 % and 18 % methane for a kg of volatile solids for cattle and small ruminants, respectively).

Potential biogas production was estimated separately for cattle (beef, zero-grazed and other dairy cattle) and small ruminants (sheep and goats), using the following expression.

Equation 2-2

$$\textit{Annual biogas production}_{animal} = animal. * TDM_{animal} * DHB_{animal} * AFCDa_{nimal} * RW_{animal} * VS_{animal} * BY_{animal}$$

Where:

Animal is the total number of cattle or sheep and goats

TDM_{animal} is the total daily manure production per unit animal

DHB_{animal} is the mean # of days spent by animals in home boma

15 Ministry of Energy (MoE) (2020). Bioenergy strategy 2020-2027.

16 County Government of Makueni (2022). Makueni County Statistical Abstract 2022

17 IPCC, 2019: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V.

$AFCD_{animal}$ is the available fraction of animal dung not collected for some other uses

RW_{animal} is the percentage waste from animals that can be recovered for biogas production

VS_{animal} is the Volatile solids (VS) as % fresh manure for each animal

BY_{animal} is the Biogas yield of each animal

Estimation of equivalent energy from biogas was provided at sub-county level. Summary of annual production estimates for the year 2023 are reported in Figure 2-6 while projected estimates up to 2032 are reported in Figure 2-7 below. Details of the calculation are reported in a spreadsheet, which can be provided upon request.

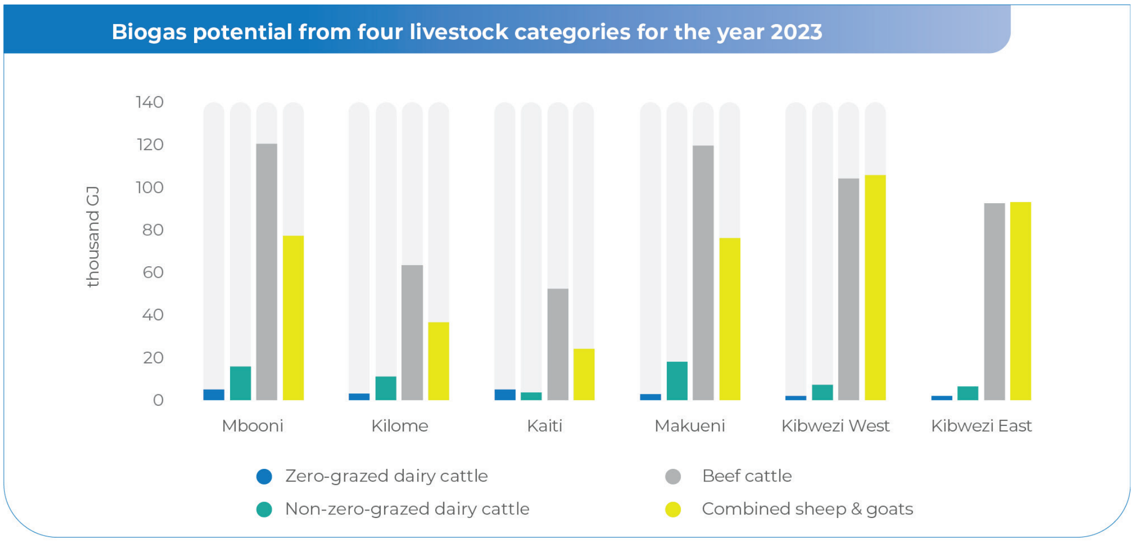


Figure 2-6: Summary of estimated quantity of annual biogas production potential and equivalent energy from each of the four main livestock categories

Figure 2-6 illustrates that biogas production from beef cattle and small ruminants (sheep & goats) takes precedence. The proportion associated with the other feedstocks varies between sub-counties. Proportion of feedstock from zero-grazed cattle is relatively higher in Mbooni sub-county while feedstock from non-zero grazed cattle is relatively high in Makueni and Mbooni sub-counties, compared to other sub-counties.

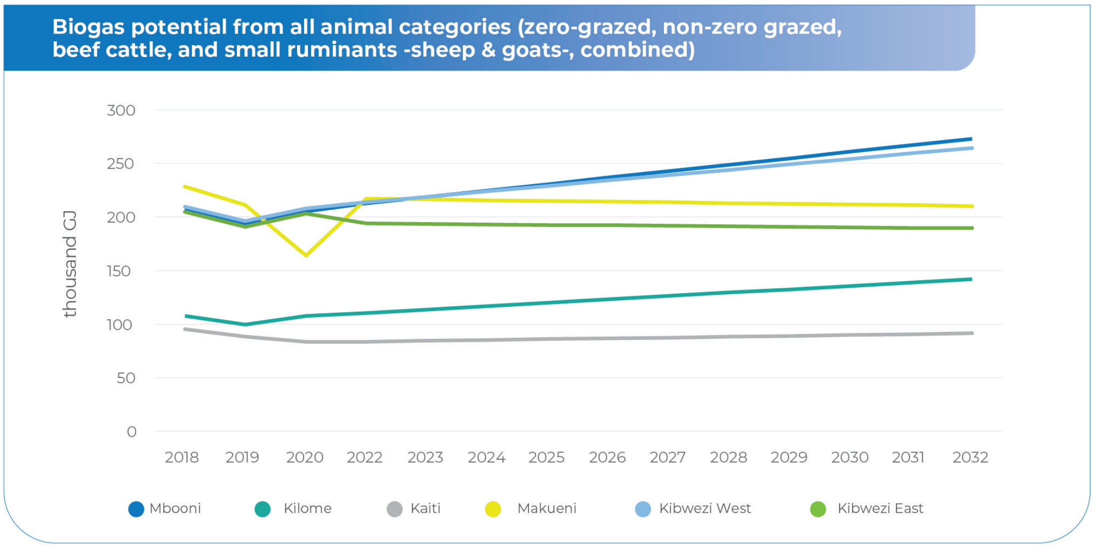


Figure 2-7: Summary of estimated future trends of the quantity of annual biogas production potential (in thousand GJ) from cattle, sheep, and goats

2.1.5 Potential for bioenergy production from crop residues

Makueni County Statistical Abstract 2022 records production capacity of the main food crops grown, including maize, beans, cowpeas, pigeon peas, green grams, and sorghum. The main horticultural and industrial crops include avocado, macadamia, coffee, mangoes, and sisal[18][19].

Residues from crops such as maize, coffee, macadamia, sorghum, beans, pigeon peas, cow peas and green grams are potential bioenergy feedstock. They can, for instance, be used to produce briquettes or pellets for local consumption (e.g., for residential cooking, water and space heating) and have been assessed in sub-sections below. Processing of industrial crops such as sisal and fruits such as mangoes generates wastes including substrates and wastewaters, which are important bioenergy resources. Bioenergy resource assessment has only been considered for the major food crops as well as those industrial crops and mango fruits crops processed in Makueni County. Assumptions for calculating Makueni County's agricultural crop residue availability is derived from Welfle et al. (2020)[20], NIRAS-LTS (2021)[21], Maj et al. (2019)[22], Mai-Moulin et al. (2016)[23] and Wekesa (2013)[24].

To understand the potential bioenergy resource available during the horizon covered by the CEP, projection of the county production of these crops was undertake at sub-county level. Simple linear projection was undertaken by adopting trends from historical data between 2017 and 2021 obtained from county records. Details of this projection can be provided upon request.

Mangoes are generally grown in all the six sub-counties of Makueni County. The Makueni Fruit Processing Plant (MFPP) in Kalamba has been processing mangoes to puree since 2017. Coffee is mainly grown in hilly areas of Mbooni sub-county and processed by about seven factories run by Kikima Coffee Farmers Cooperatives in Mbooni sub-county. In Kibwezi East sub-county, there is a large sisal plantation and sisal processing is done at DWA Sisal Factory. The County Government of Makueni[25] reports eight operational processing centres for sisal, developed in collaboration with the national government. Macadamia and avocado are not processed in Makueni County and are mainly bought by merchants from other counties.

Major crops whose residues have potential for briquettes or pellet manufacturing are summarized in Table 2-6. For estimation of residues for the manufacturing of briquettes or pellets, equation 2-3 is used, and was adapted from the approach used by Welfle et al. (2020) and NIRAS-LTS (2021):

Equation 2-3

$$ARB=Cp*RPR*RF*OF$$

Where:

ARB = available residual biomass in tonnes per year

Cp = crop production in tonnes per year

18 NIRAS LTS International (2021). Policy Briefing Paper Bioenergy in the Sisal Processing Sector in Kenya

19 County Government of Makueni 2022. Makueni County Statistical Abstract

20 Welfle, A., Chingaira, S., Kassenov, A. (2020). Decarbonising Kenya's domestic & industry Sectors through bioenergy: An assessment of biomass resource potential & GHG performances. Biomass and Bioenergy, Volume 142, 105757, ISSN 0961-9534, https://doi.org/10.1016/j.biombioe.2020.105757.

21 NIRAS-LTS, E4tech, AIGUASOL and Aston University (2021b). Bioenergy for Sustainable Local Energy Services and Energy Access in Africa, Demand Sector Report 7: Sisal Processing, Kenya. For Carbon Trust and UK Government. London.

22 Maj, G., Szyszlak-Bargłowicz, J., Zaj, G., Słowik, T., Krzaczek, P. and Piekarski, W. (2019). Energy and Emission Characteristics of Biowaste from the Corn Grain Drying Process. Energies 2019, 12, 4383; doi:10.3390/en12224383

23 Mai-Moulin, T., Dardamanis, A., and Junginger, M. (2016). Biomass Use and Potential for Export from Kenya to the European Union 2015-2030. Assessment of sustainable lignocellulosic biomass potential for Kenya for export to the European Union 2015 to 2020. BioTrade2020plus

24 Wekesa, A. (2013). Using GIS to assess the potential of crop residues for energy generation in Kenya. A thesis submitted in partial fulfilment of the requirements for the Degree of Master of Forestry Science in the University of Canterbury

25 County Government of Makueni (2018). County Annual Progress Report, 2018

RPR = residue-to-product ratio in tonnes of residues per tonnes of product

RF = recoverable fraction per tonnes of product

OF = biomass fraction available after considering other uses per ton of product

The technical bioenergy potential from the crop residues relevant for briquettes or pellets (Table 2-6) manufacturing was then calculated considering the available residual biomass and its energy content, using equation 2-4 below. The results are presented in Figure 2-8

Equation 2-4

$$BEP = ARB*(1-MC)*HHV$$

Where:

BEP = bioenergy potential in GJ

ARB = available residual biomass in tonnes per year

MC = moisture content

HHV = higher heating value in GJ per ton

Table 2-6: Key crops producing residues with high potential for manufacture of briquettes/pellets

Key residues producing crops		++Residue to product ratio	++Residue recovery factor	+++Competition for residues (other than fuel)**	*Moisture content as received (wt %)	HHV or LHV (MJ/kg)
Maize	Stalk	1.60	80 %	67 %		15 *LHV
	Husk	0.20	100 %	+67 %		18.02 *LHV
	Cobs	0.29	100 %	0 %		9.69 *LHV
Cow peas	Stalk	1.10	*50 %	0 %		15.0 LHV
Coffee	Husks	0.24	100 %	0 %		12.69 * LHV
Macadamia	Nutshells	0.7	60 %	0 %	10	21*HHV
Sorghum	Stalk	4.20	80 %	67 %		12.38 *LHV
Beans	Stalk	1.10	*50 %	0 %		16.0 * LHV
Pigeon peas	Stalk	1.10	*50 %	0 %		15.0 LHV
Green grams	Stalk	1.10	*50 %	0 %		15.0 LHV

** The variable on moisture content as received was only needed for quantification of bioenergy for macadamia residues as its higher heating value (HHV) was available. We assumed a 10 % moisture content on a wet basis by weight.*

***Where competition for residue is 0%, all residue is available for bioenergy purposes*

+ With information from primary data collection, it was assumed that 65 % of maize husks and cobs are already put into use in Makueni County

++Welfle et al. (2020), NIRAS-LTS (2021), Maj et al. (2019), Mai-Moulin et al. (2016)

+++ Primary data collection

The available crop-based feedstock to produce briquettes or pellets can be harnessed by small and medium enterprises, as they can economically develop local supply chain to aggregate the feedstock from small-scale farmers. As shown in Figure 2-8, predominance of available feedstock varies across the six sub-counties. This information guides the identification of the key feedstocks that can be prioritized in each sub-county.

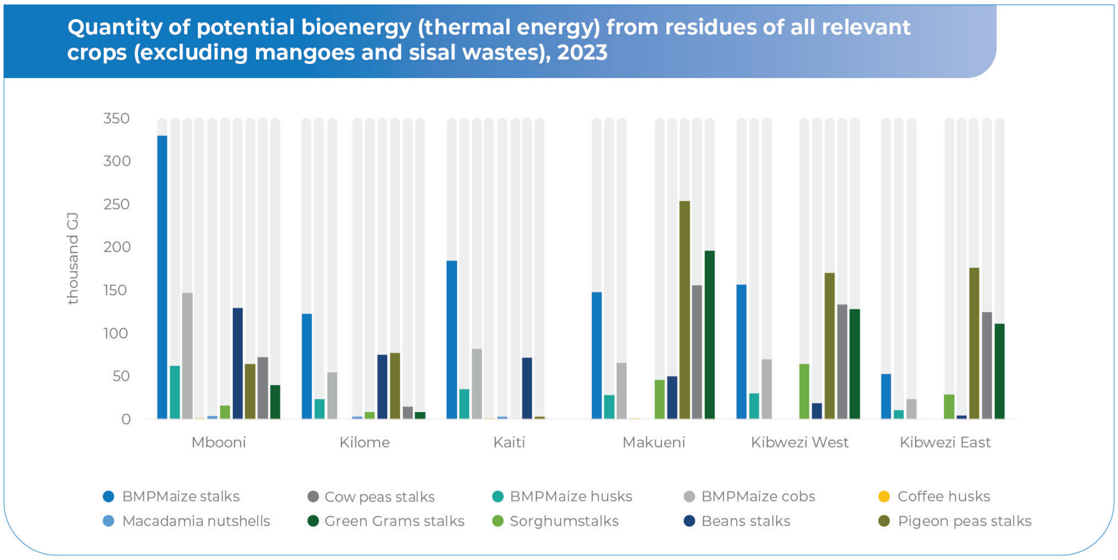


Figure 2-8: Total calories (thousand GJ) for crop-specific residues for the year 2023, disaggregated by sub-counties

Similar procedures were employed to estimate future trends of potential energy that could be generated from crop residues through manufacturing of briquettes/pellets. The estimates in Figure 2-9 were based on future projections of crop production (MT) up to 2032.

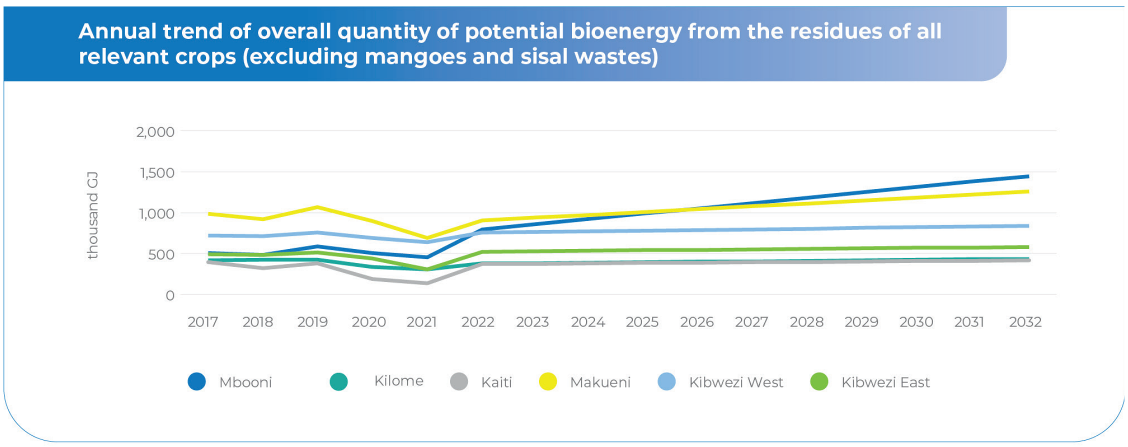


Figure 2-9: Estimated future trends of overall potential bioenergy (thousand GJ) from a combination of all relevant crop residues (excluding mangoes and sisal wastes) through manufacturing of briquettes/pellets, disaggregated by sub-county.

2.1.5.1 Biogas potential from industrial processing of sisal and mangos

Industrial processing of sisal and mangoes generates wastes (substrates and wastewaters) that has potential for biogas production. Respective summaries of the production of substrates and wastewaters together with the characteristics of parameters that can be used in deriving the potential of biogas are reported in Annex A.3 A conservative approach was adopted and as such, the lowest values for these parameters were used.

The technical bioenergy potential for biogas production from generated solid wastes was then calculated considering the available residual biomass and its energy content, using the expression in Annex A.2

The potential biogas that can be produced for each of the two agro-industrial crops (mangoes and sisal) is the sum proportions from the respective sources (i.e. solids and wastewater). Estimates for year 2023 are 62,066 Nm3/yr or 2,000 GJ (from mango wastes) and 5,065,956 Nm3/yr or 127,000 GJ (from sisal wastes). The future projection (up to 2032) are shown in Figure 2-10. Kibwezi East sub-county has large sisal plantations but the coverage of the plantations is not expected to change in the foreseeable future. Therefore, projections of biogas or bioenergy production from sisal wastes is expected to remain constant.

Potential biogas production from mango and sisal processing (in Makueni and Kibwezi East sub-counties, respectively) can be harnessed through public-private partnership (PPP). The biogas can be utilized for cooking and supplied to local SMEs.

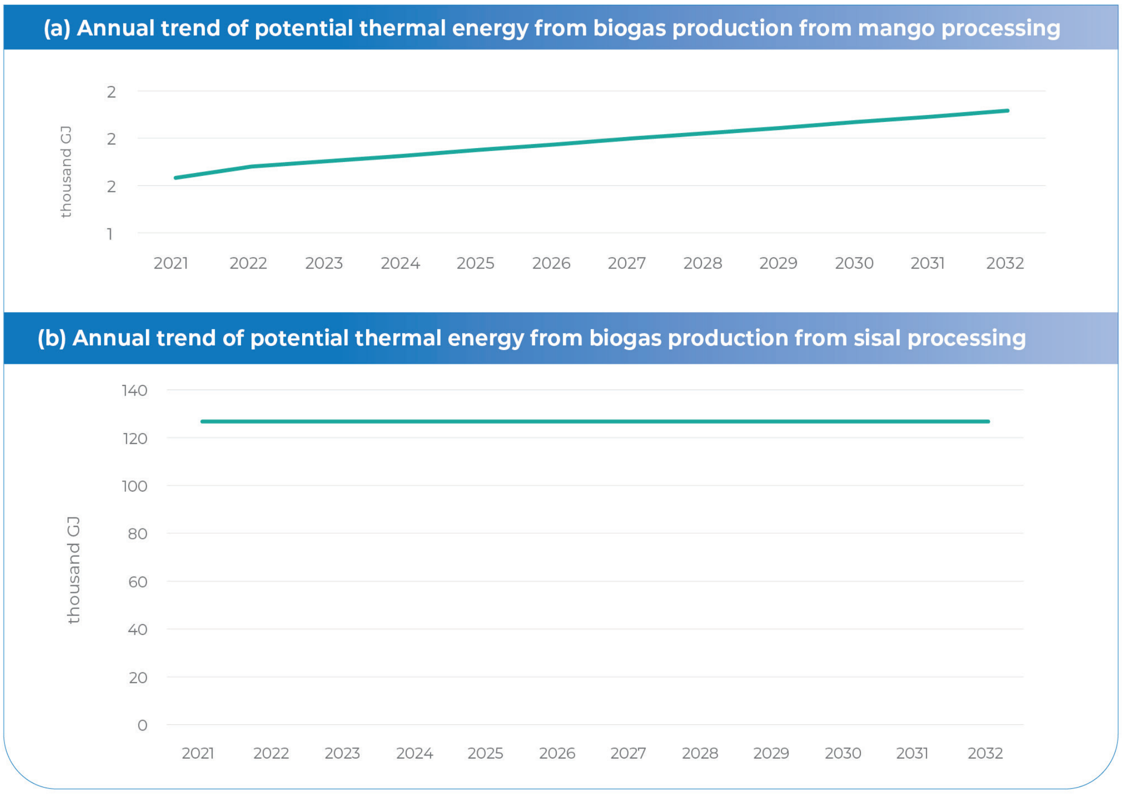


Figure 2-10: Future projection (up to 2032) of the potential thermal energy production (in thousand GJ) from agro-processing of mangoes and sisal in Makueni County

2.1.6 Biogas production from slaughterhouses

The meat industry produces large amounts of waste because a substantial amount of animal weight is considered unfit for human and animal consumption as shown in

Table 2-7. Additionally, meat processing plants and slaughterhouses are known for being the big consumers of water and big generators of wastewater. (Aleksić et al., 2020). Aleksić et al, (2020) report specific freshwater consumption (SFWC) from slaughterhouses and meat processing plants to be about 360–560 (l/head).

Table 2-7: Potential waste from different animals slaughtered and the specific freshwater consumption used in slaughterhouses

Animal type	Weight of animal	Weight of meat		Weight of waste per unit animal		Specific freshwater consumption (SFWC)
	kg	kg	%	kg	%	l/head
Cattle	350	140	40	210	60	560
Sheep/goats	30	12	40	18	60	360

The tabulated parameters and the data describing the number of animals slaughtered as provided by the Government of Makueni County were used to calculate the quantity of substrate waste and wastewater generated from the slaughterhouses in each of the six sub-counties.

The estimation of bioenergy (thermal) potential (GJ/annum) was then quantified using the characteristics (mean values) of agro-industrial wastewaters for anaerobic digestion as reported in GIZ (2010)[26]

The animals slaughtered are mainly cattle and the small ruminants (sheep and goats) and the respective numbers of animals slaughtered annually between 2017 and 2021 can be found in the County Statistical Abstract of 2022[27]. The number of slaughtered animals was projected up to 2032, using simple linear projection that was undertaken using the data available. The results of the analysis shown in Figure 2-11 demonstrate a huge opportunity for slaughterhouse wastes-to-energy through anaerobic digestion (AD) at commercial scale. The wastes are suitable for AD as they are composed of high organic contents of mostly well degradable substances. Viable projects of turning slaughterhouses wastes to biogas exists, for example in Keekonyoike (Kiserian, Kajiado County), Nyongara (in Dagoretti, Kiambu County), Bungoma municipalities (Bungoma County), and in Homabay town (Homabay County).

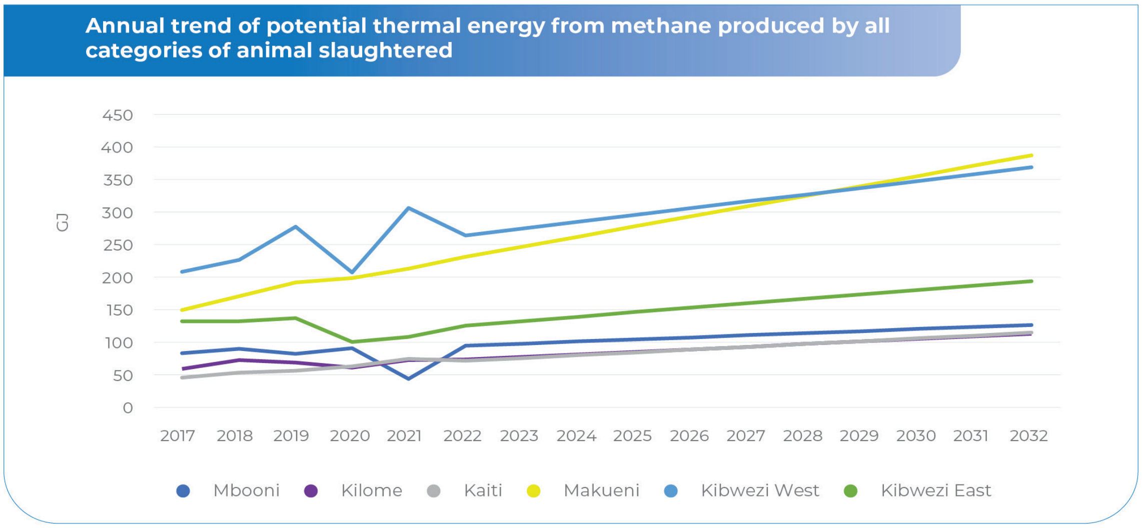


Figure 2-11: Estimated future trends of total potential thermal energy (GJ) from slaughterhouses (for all categories of animals slaughtered) in Makueni County, disaggregated by sub-county

In view of the continued increase in energy costs, in-house use of thermal energy generated from slaughterhouse wastes would serve as financial justification of the project as this would offset the purchase costs associated with thermal energy. It is therefore important for project originators to understand that the primary driver for an investment in AD will be to meet a company's own energy and waste management needs. As part of the recommended feasibility studies, the Government of Makueni County should assess complementary business (especially SMEs) that could suitably use the thermal energy that would potentially be produced from slaughterhouses WtE plants. Viable options should also be explored during the studies, for example creating the opportunity to supply biogas/methane to hotels and restaurants neighbouring the slaughterhouses. This is being implemented by Keekonyoike slaughterhouse in Kajiado County.

2.1.7 Biogas production from municipal wastes

Solid waste and sludge generated by towns and urban centers in Makueni County can be used as feedstock for generation of biogas that could potentially be used for electricity generation and fuel. According to Makueni County Urban Development Plan-2020 April, the county lacks effective solid and liquid waste management systems in almost all urban areas. The County Government has also rolled out several waste management projects in the urban areas, including the initiation of solid and liquid waste management mechanism in 124 markets. Additionally, land has been acquired for five dumpsites in Mtito Andei, Kibwezi, Makin-

26 GIZ (2010). Assessment on potential for agro-industrial biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations. German Biomass Research Centre

27 https://makueni.go.ke/download/makueni-county-statistical-abstract-2022/

du, Emali and Wote Towns—which are not well developed for efficient handling of solid waste. The County Statistical Abstract documents the annual generation of solid wastes, disaggregated by sub-county. This information, tabulated in Table 2-8, was used to estimate potential energy from solid wastes. However, there is a lack of data regarding the daily or monthly volume of sludge for the entire county. Notably, there is no urban area in Makueni County with a centralized sewer system. However, there is a decentralized treatment facility (DTF) in Sultan Hamud Township that is as a result of a collaboration between the County Government and Nolturesh Water and Sanitation Company[28]. According to the County Statistical Abstract, there are plans to construct another DTF within Mtito Andei Township, a project that will be spearheaded by KIMAWASCO (Kibwezi Makindu Water and Sanitation Company).

The Makueni County Referral Hospital has a sewer system that is connected to lagoons, although it suffers illegal connections to the main trunks. Majority of the premises and institutions in the county use septic tanks and pit latrines. A recommendation is for Makueni County to undertake data collection on daily volumes of sludge draining into the existing sewer systems upon which to base future estimates of potential bioenergy from sewer wastes. Incineration and anaerobic digestion represent two existing types of MSW waste-to-energy technologies. Both require prior separation of recyclables to achieve optimal resource recovery and the residue can potentially produce electricity, heat, or both. This assessment considered the anaerobic digestion (for production of biogas) as the most viable technology, since most of the solid waste has the highest proportion of organic materials. Estimation of biogas potential from solid substrates employed Equation 2-5 in a similar manner as explained in GIZ (2010)[29]:

Equation 2-5

$$Q_{biogasmsw} = FM_{collected} * Availability * DM_{content} * VS_{content} * Biogas_{potentialmsw} * Methane_{cont}$$

Where:

$FM_{collected}$ is the amount of residue (tonnes per year)

Availability is the seasonal availability of the residue (for biogas production, a residue should be available throughout the year or should be storable)

$DM_{content}$ is the dry matter (DM) content of the residue (% fresh matter, FM)

$VS_{content}$ is the volatile solids (VS) content (% DM)

$Biogas_{potential\text{-}msw}$ is the biogas potential for the substrate (m^3/t VS); and methane content in the biogas (%)

$Methane_{cont}$ is the percentage methane content in the biogas

The biogas potential was estimated using the data on the volume/mass of the fresh substrates summarized in Table 2-9 (obtained from the County Statistical Abstract). Figure 2-12 shows the daily volume of solid wastes (MSW), projected up to 2032, using simple linear projection ran using trends from the available historical data. The largest daily volumes are projected in Kibwezi East, Kibwezi West and Makueni sub-counties, while the smallest are found in Kilome and Kaiti sub-counties. For calculation, collectable proportion of MSW (Availability) is assumed to be 20 % based on expert judgement.

Table 2-8: Average daily quantity of solid waste collected in urban areas, 2019-2021.

Source: County Government of Makueni, 2022

Sub-county	Tonnes		
	2019	**2020**	**2021**
Mbooni	18.40	18.60	18.80
Kilome	11.20	11.30	11.40

28 County Government of Makueni and the World Bank (2019). Makueni Countywide Inclusive Sanitation: Situation analysis: Technical Assistance for Supporting Kenya to Tackle Sanitation Challenges (Sanitation TA).

29 GIZ (2010). Assessment on potential for agro-industrial biogas in Kenya: Potentials, Estimates for Tariffs, Policy and Business Recommendations. German Biomass Research Centre

Kaiti	12.50	12.60	12.70
Makueni	17.90	18.10	18.30
Kibwezi West	19.00	19.20	19.40
Kibwezi East	23.20	23.50	23.80
Total	**102.20**	**103.30**	**104.40**

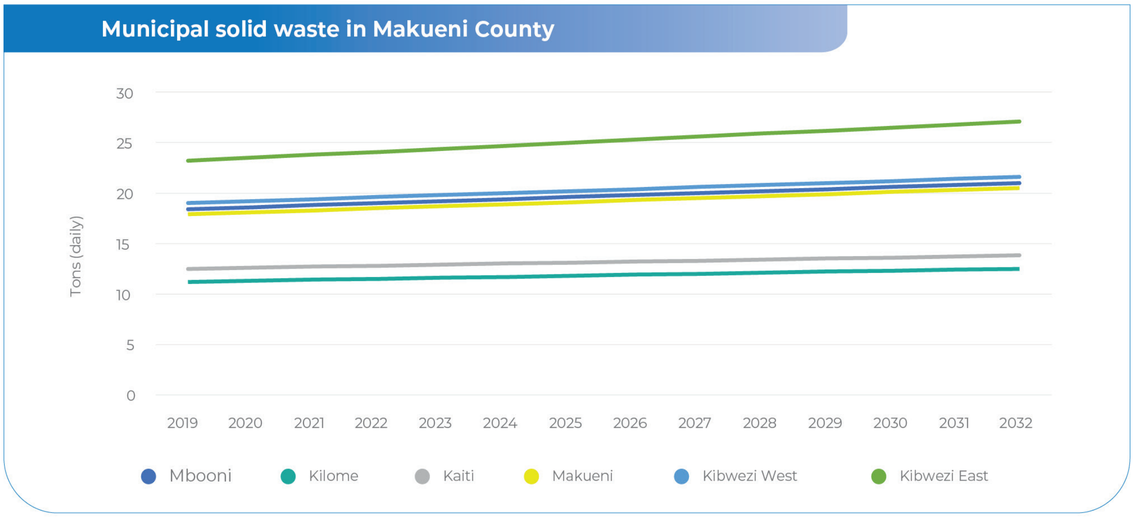


Figure 2-12: Estimated future trends of MSW in Makueni County, disaggregated by sub-county

The average characteristics and the conversion factors of methane to either electricity production or thermal energy was obtained from GIZ (2010)[30] and summarized in Table 2-9. Based on the calculations, the trend of potential electricity production from MSW of Makueni County is summarized in Figure 2-13, disaggregated by sub-counties.

Table 2-9: Data on biogas potentials/characteristics from solid substrates.
Source: GIZ (2010)

x	VS content (% DM)	Biogas potential (m3/ton VS)	Methane content (%)	Methane potential (m3/ton FM)
45	60	398	64	85

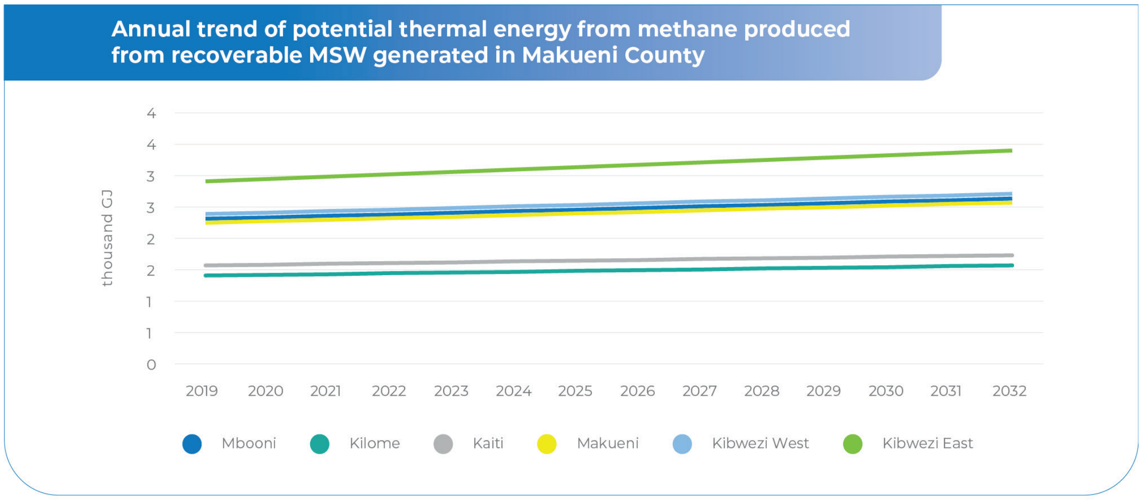


Figure 2-13: Estimated future trends of potential thermal energy (thousand GJ) from MSW generated in Makueni County, disaggregated by sub-county

30 Ibid

The respective quantities of the annual electricity are quite substantial and as such feasibility studies should be conducted to establish their commercial potential. Waste-to-energy (WtE) power plants operate efficiently in developed countries; however, simple transfer of these technologies may be inappropriate for developing country conditions. Aspects such as composition of waste, waste segregation, financing models, among others, should be considered during such feasibility studies. Closely related, installation of utility-size WtE plants ought to be located close to a sanitary landfill (SLF) for efficiency goals. The Government of Makueni County will have to secure space for a new SLF, potentially in a site that would not constrain logistics for waste collection and dumping. Mutz et al. (2017) have further alluded that the costs associated with recovering energy from solid waste is high and cannot potentially be recouped exclusively through sales of energy. They further note that even international companies experienced in investing in WtE plants are reluctant to invest in WtE in developing countries as they foresee huge legal, financial and reputational risks. Similarly, such projects would be equally expensive and a financial risk to a County Government. The Government of Makueni County should conduct an independent assessment of costs and financial implications of such WtE projects. The assessment can inform the decision to undertake a Public-Private Partnership with private entrepreneurs who would be willing to test innovative technologies and 'learning-along-the way' while developing new logistics for waste segregation and transportation.

2.1.8 Bioenergy crops

Primary data collection (particularly from focus group discussions) documented evidence that biofuels crops had in the past been promoted across the various sub-counties of Makueni. The key crops that were cited include castor, croton, jatropha. The promotion of bioenergy crops, however, failed to scale-up when farmers failed to secure a viable market for the harvested crops. Recently, an opportunity for farmers in bioenergy crops has emerged in Makueni County, following the establishment of an Agri-hub in Wote Municipality for the purpose of aggregating and pressing oil seeds. The oil extracted from the agri-hub is processed and sent to Italy, where the parent company has bio-refineries for transforming the oil to biofuels. It's notable that presently, the bulk of oil seeds is sourced from outside Makueni County. The agri-hub has embarked on a promotion campaign in various counties in Kenya, aimed at scaling up the growing of bioenergy seed-crops by contracting farmers for agri-feedstock with potential for enhancing growth of green jobs. The waste and residues generated from pressing oil seeds is also good by-product for manufacturing briquettes or pellets that can be harnessed by SMEs through business partnership with the Agri-hub. A recommendation is for the Government of Makueni County to partner with the Agri-hub to ensure success of the promotion of commercial farming of bioenergy crops as well as for incentivizing SMEs to take up such briquettes/pellets manufacturing businesses.

Currently, there is no data on the production level of the oil seeds (croton, castor, jatropha, among others) in Makueni County, neither in terms of hectares planted nor metric tonnes harvested. Primary data collection revealed that annually, 16 MT and 25 MT of croton and castor oil respectively, are produced from the Agri-hub. Primary data further revealed that about 413,910 kg of croton-related wastes and 102,200 kg of castor-related wastes are generated and disposed in a landfill in Wote Municipality. Longitudinal data collection is required to verify these figures.

The potential bioenergy from the respective wastes/residuals from croton and castor as feedstock for briquettes or pellets was calculated following similar procedure as employed for bioenergy assessment of the other crop-based residues. The quantity of wastes/residues (in tonnes) obtained from the Agri-hub was multiplied with low heating value (LHV, GJ/ton). Croton shells were assumed to have a LHV of 18.9 GJ/ton (equated with those of macadamia shells) while castor shells are 12.69 GJ/ton (equated with coffee shells). It was also assumed that all the residues are recoverable as they can be collected from the factory-gate with minimal wastes. Figure 2-14 shows the potential annual bioenergy (GJ) that could be generated by harnessing the wastes/residues from both croton and castor shells. The variation in the amount of the potential energy is proportional to the wastes streams of the two feedstocks, croton being the highest.

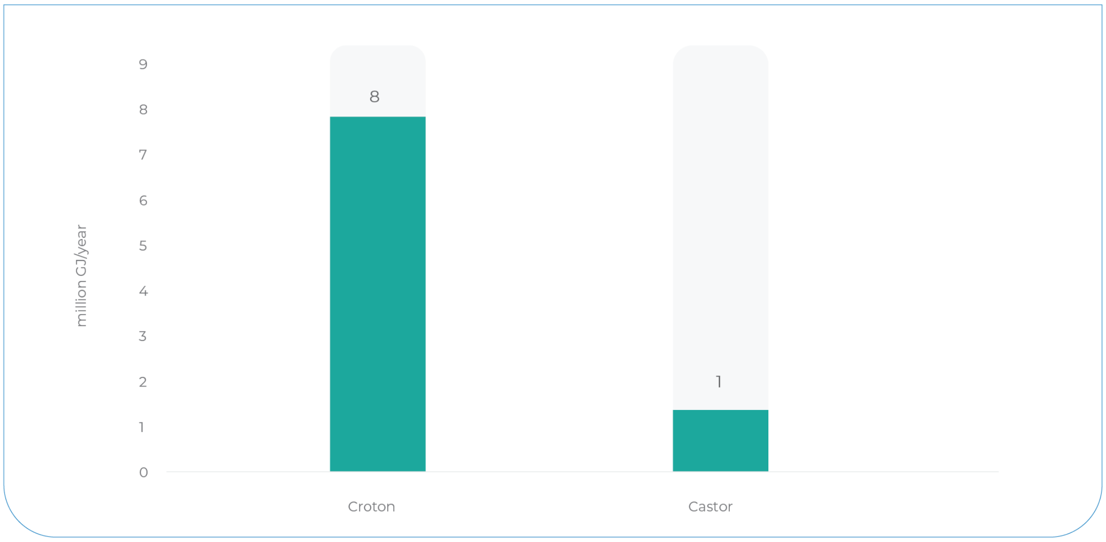


Figure 2-14: Potential bioenergy (million GJ) that can be produced by using wastes or residues generated through oil pressing of croton and castor seeds by the Agri-hub in Makueni County

2.2 SOLAR POWER

According to the Global Solar Atlas, the solar potential in Makueni is significant, particularly in the southern and north-western parts of the county. The solar potential is illustrated using the Global Horizontal Irradiation (GHI) that considers the long-term energy availability of solar resource at any location in the county. The GHI is the sum of direct and diffuse irradiation components received by a horizontal surface and is measured in kilowatt hours per square metre (kWh/m^2). Figure 2-16 shows the long-term yearly average Global Horizontal Irradiation (GHI) in Makueni County, with the average GHI being about 2,008 kWh/m^2.

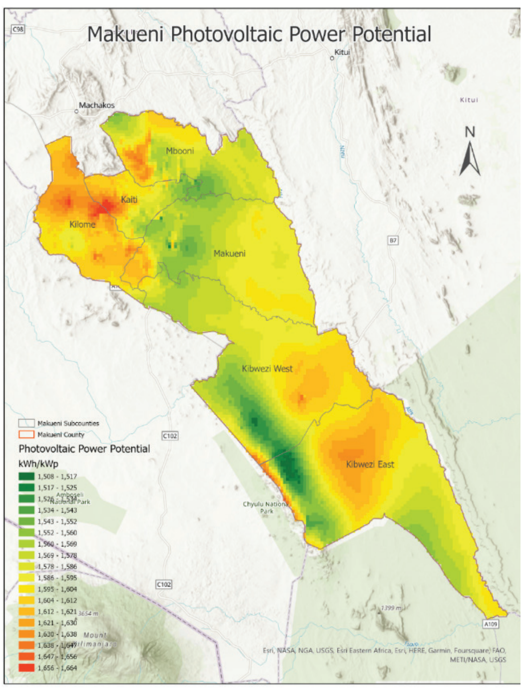


Figure 2-15: Long-term yearly average of global horizontal irradiation (GHI) in kWh/m2 in Makueni County

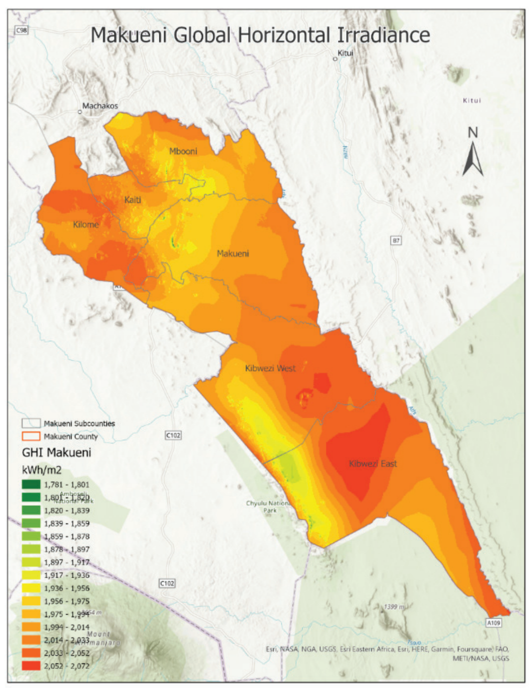


Figure 2-16: Long-term yearly average of potential photovoltaic electricity production in kWh/kW-peak in Makueni County

This implies a high potential for photovoltaic electricity production (see Figure 2-15). This potential is measured using the Photovoltaic Power Potential, which provides an aggregated and harmonized view on solar resource and the potential for development of utility-scale photovoltaic (PV) power plants. It considers spatial constraints of implementing or setting up solar power plants that vary from place to place, such as the air temperature affecting the system performance, the system configuration, shading and soiling, and topographic and land-use constraints. The PV power output (PVOUT), defined as the specific yield, is used to illustrate this potential. PVOUT, measured in kilowatt hours per installed kilowatt-peak of the system capacity (kWh/kWp), represents the amount of power that can be generated per unit of the installed PV capacity over the long-term. The average potential photovoltaic power output for Makueni is about 4.35 kWh/kW-peak per day. In other words, a small residential PV system in the county could supply, on average, more than 1,500 kWh per year.

This illustrates very high solar potential that could be utilized to meet the demand for power in off-grid areas in Makueni.

2.3 WIND POWER

The Global Wind Atlas provides data that was used to visualize the mean annual wind speed and the wind power capacity factor of Makueni County as shown below.

The capacity factor is defined as the average power generated, divided by the rated peak power (the amount of energy actually produced by a wind turbine compared to the energy produced if the machine ran at its rated power over a given period of time). It is used as a performance parameter for comparing the potential for wind power generation at different sites.

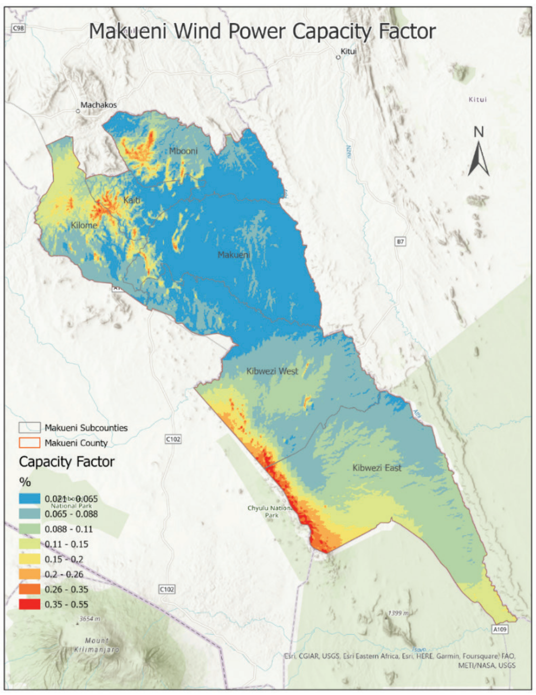


Figure 2-17: Mean annual wind speed at 100 meters heights for Makueni County

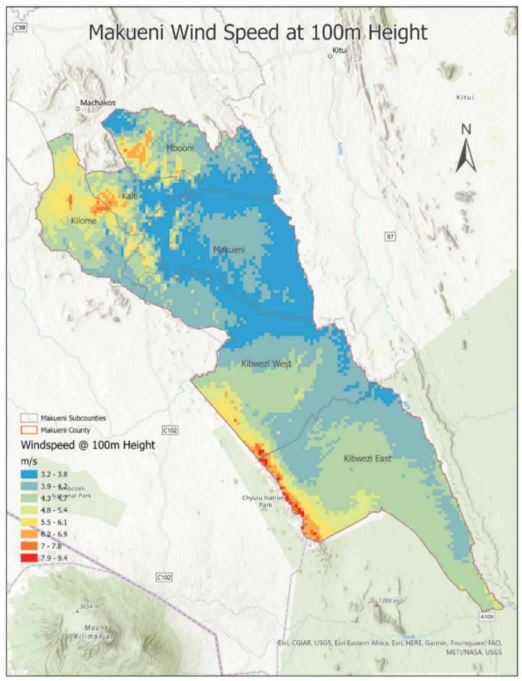


Figure 2-18: Wind power capacity factor for Makueni County

According to Figure 2-18, higher wind speeds of above 6m/s at a height of 100m are located towards the northern and south-western parts of the county within Kilome, Kaiti, Mbooni, Kibwezi West and Kibwezi East sub-counties.

This translates to an equally higher percentage of wind power capacity factor in the same areas as is evident in the chart in Figure 2-19, comparing the average wind power capacity factors across the sub-counties of Makueni.

Kilome and Kibwezi East sub-counties have capacity factors of 10% and above, an initial indication of potentially suitable sites for wind power installations.

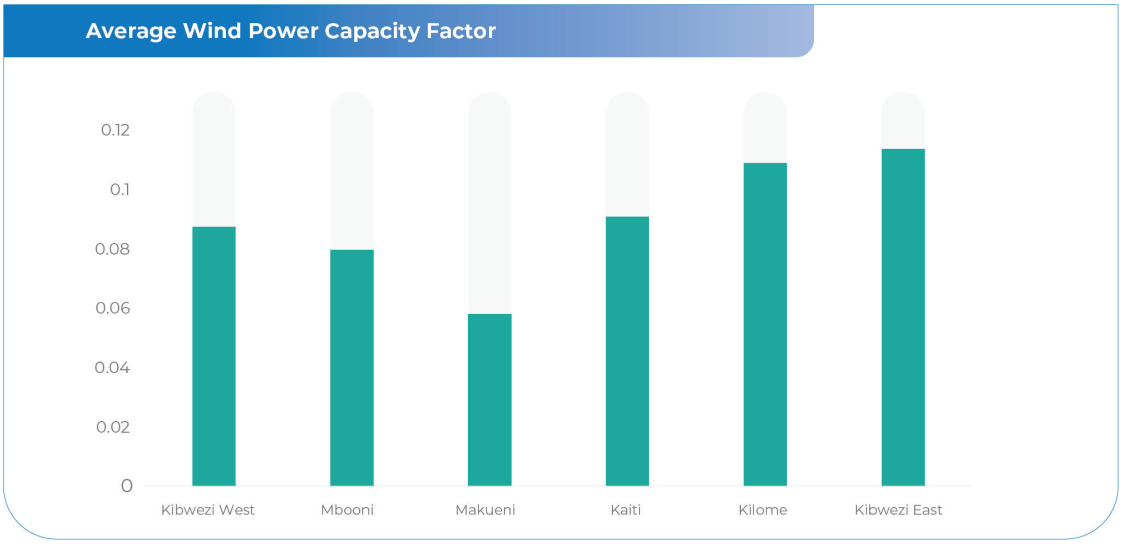


Figure 2-19: Wind Power Capacity Factor values (%) in Makueni County using data from the Global Wind Atlas2, calculated by author.

2.4 HYDROPOWER

Hydropower remains one of the main sources of power supply for Kenya's electricity sector. It accounts for about 45% of KenGen's total installed capacity[31].The total installed large hydropower capacity in Kenya is 826 MW. However, the small hydropower potential in Kenya is estimated to be 3,000 MW, of which less than 30 MW has been exploited and only 15 MW supply the grid[32].

According to resource assessment results of small and mini hydropower potential in Sub Saharan Africa carried out by KTH Division of Energy Systems Analysis[33], one site was identified in Makueni County as a potential site for setting up small and mini hydropower plants.

Most countries recognize "mini" hydropower systems as systems that generate more than 100 kW but less than 1 MW. "Small" hydropower systems, on the other hand, are systems that generate more than 1 MW but less than 10 MW.[34]

The map in Figure 2-20 shows the locations of one identified site in Makueni County from this assessment by KTH for setting up a mini hydropower plant. The map also highlights sites in neighbouring counties that Makueni County can collaboratively leverage for utilization.

Hydropower potential is located in Kibwezi West sub-county, with an estimated capacity of 0.16 MW.

31 [10]KenGen. (2022). Hydro. Available at: ***https://www.kengen.co.ke/index.php/business/power-generation/hydro.html.*** (Accessed 10/02/2022).

32 EPRA. (2022). Hydro Energy. Available at: https://renewableenergy.go.ke/technologies/hydro-energy/. (Accessed 10/02/2022)

33 Korkovelos, A. (2016). Sub Saharan Africa - Small & Mini Hydropower Potential. Available at: https://energydata.info/dataset/small-and-mini-hydropower-potential-in-sub-saharan-africa. (Accessed 10/02/2022)

34 KEREA.(2023). Small Hydro. Available at:https://kerea.org/renewables/small-hydro/.(Accessed 1/27/2022).

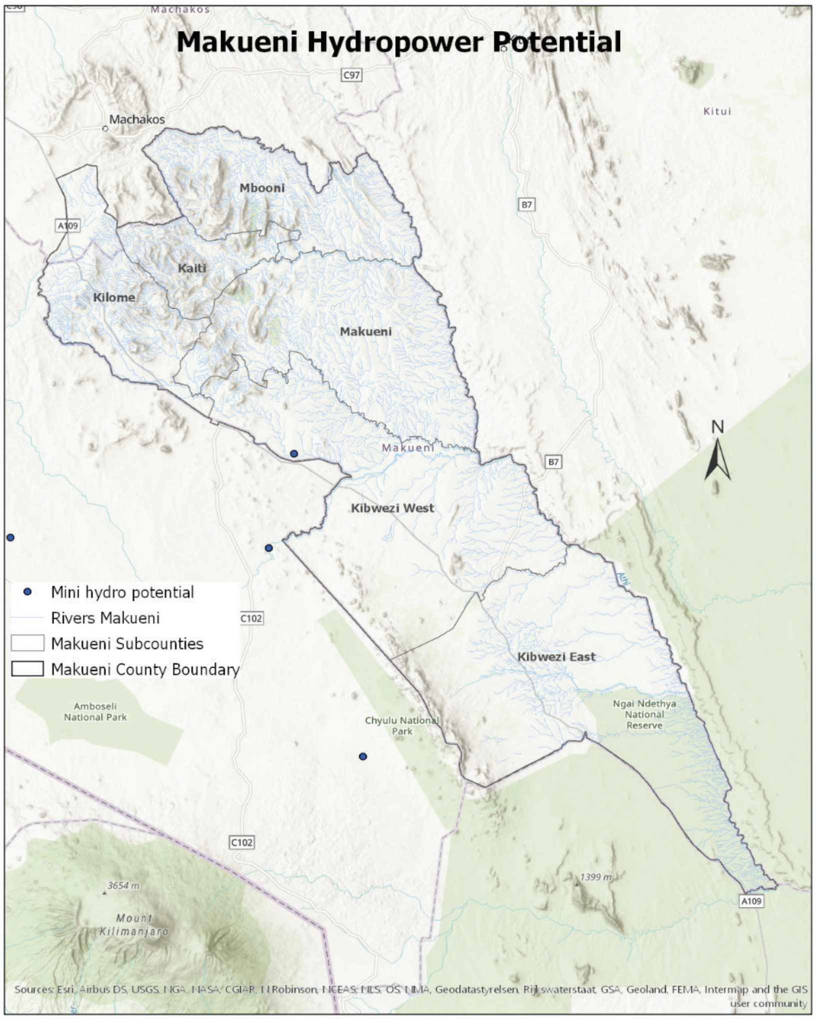


Figure 2-20: Map showing potential sites for setting up small and mini hydro power plants in Makueni.

Another site identified in Kajiado County, near the western border of Makueni along river Kiboko with a potential of 0.4 MW is highlighted. This could potentially benefit populations in Makueni near that border, illustrating the need for inter-county energy resource assessments and collaboration with regards to energy access projects.

While hydropower may not be the most viable source of energy in Makueni in terms of total combined potential in the sites identified, it may provide a useful source of energy, especially for setting up mini grids.


Solar Light
30W
IP67

3.0 ENERGY ACCESS

This chapter covers energy access for households, productive engagements and community facilities-also termed as the locales of energy access.[35]

The chapter is structured as follows: The first section discusses electricity access in households, community services (education, health, trade centres) and for productive use (with focus on SMEs) and the results of electrification modelling. The second section covers access to energy for cooking and presents the results of a modelling exercise undertaken to project future energy access for cooking. Barriers to electrification and clean cooking are also discussed in the respective sections. Finally, recommendations towards improved energy access in Makueni based on the analysis are described.

3.1 ELECTRICITY ACCESS IN MAKUENI COUNTY

3.1.1 Access to Electricity: Households

The 2022 survey results indicated that 75.1% of households in Makueni County have access to electricity, with solar systems providing access to 40.2% (this includes 16.7% contribution from solar lanterns), grid at 29.2%, and mini-grid at 5.7% as shown in Figure 3-1 below. The Makueni County Statistical Abstract (2022)[36] indicates that 31.3% have electricity access. However, the Abstract does not disaggregate to show which type of technologies provide the access.

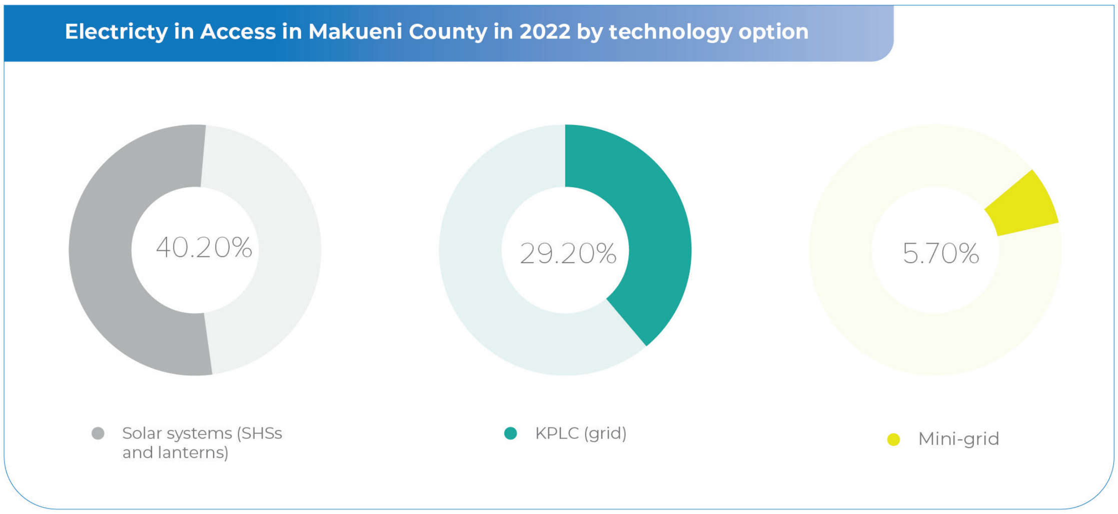


Figure 3-1: Electricity Access in Makueni County in 2022

A comparative analysis between data collected during the primary data collection and the 2019 census is shown in Table 3-1. It should be noted that the 2019 census[37] did not disaggregate between mini-grid and grid connection

35 "Bhatia, Mikul; Angelou, Niki. 2015. Beyond Connections: Energy Access Redefined. ESMAP Technical Report;008/15. © World Bank, Washington, DC. http://hdl.handle.net/10986/24368 License: CC BY 3.0 IGO." World Bank Document

36 Kenya National Bureau of Statistics,KNBS (2021): Makueni County Statistical Abstract. MAKUENI-COUNTY-STATISTICAL-ABSTRACT - Kenya National Bureau of Statistics (knbs.or.ke)

37 Kenya National Bureau of Statistics, KNBS (2019): Kenya Population and Housing Census: Volume IV.2019-Kenya-population-and-Housing-Census-Volume-4-Distribution-of-Population-by-Socio-Economic-Characteristics.pdf (knbs.or.ke)

Table 3-1: Electricity Access for Households in Makueni County

Technology option	2019	2022*
KPLC	20.4%	29.2%
Mini-grid connection		5.7%
Standalone supply (SHSs + solar lanterns)	44.0%	40.2%
Total (HH) connectivity	**64.4%**	**75.1%**

Access to grid showed a growth of about 9% from 20.4% in 2019 (KNBS, 2019) to 29.2% (primary data collection). The growth can be attributed to the Last Mile Electricity Connectivity efforts, among other factors. For instance, in 2020-2021, the Last Mile connected about 31,016 households in Makueni County at a cost of about KES 1,513.84 million (Makueni County Statistical Abstract, 2022)[38]. There is a slight decrease in solar systems, potentially due to the grid expansion.

Studies have indicated that lighting is usually the first service that households usually adopt upon receiving access.[39] Therefore, this CEP assumed that 75.1% of the households have access to electricity for lighting. Other sources of energy used for lighting are as shown in Figure 3-2 below. Further, it should be noted that the stacking is undertaken in lighting technologies. Therefore, the percentages do not add up to 100%.

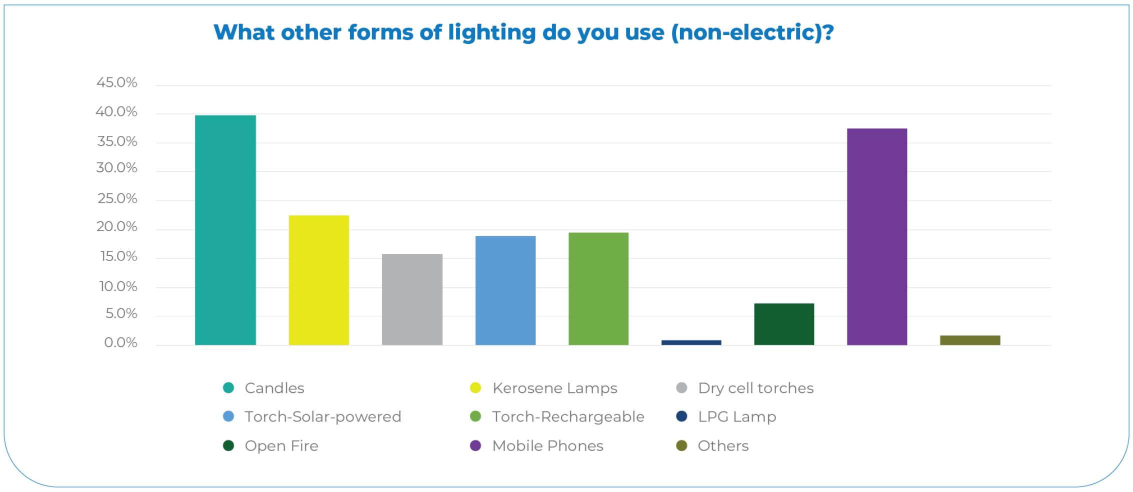


Figure 3-2: Other sources of lighting other than electricity used in Makueni County in 2022

During the focus group discussions, it emerged that there was a strong preference for grid electricity as opposed to solar home systems. This is based on the array of services that users can obtain from the grid, including the capacity to establish enterprises like barbershops or salons. Solar home systems were mostly driven by lack of access to the grid or high upfront cost of connecting to the grid. From the discussions, several challenges as of regards to the use of solar home systems were highlighted. These include: (i) weather conditions, which limited charging of batteries hence limiting the number of lighting hours at night. Some users indicated that children had to limit their studying hours at night because the system performance was poor on cloudy days; (ii) inability to identify quality products. The systems sometimes broke down way before their expected lifetime, leaving the users in darkness and (iii) daily repayment burden for the Pay-As-You-Go system and the immediate disconnection of their systems upon non-payment.

38 Kenya National Bureau of Statistics,KNBS (2021): Makueni County Statistical Abstract. MAKUENI-COUNTY-STATISTICAL-ABSTRACT - Kenya National Bureau of Statistics (knbs.or.ke)

39 Energy for Development and Poverty Reduction: The Household Benefits of Lighting with Electricity: Consumer Surplus Explained

3.1.2 Gender Analysis

A total of 632 households were surveyed, of which 73.7% were headed by males, 25.8% by females, and 0.5% by children. In terms of absolute numbers, child-headed households were only three and therefore do not provide a statistically significant trend. They were thus discarded from the analysis. It is however worth noting that two out of the three child-headed households did not have electricity access while the remaining one had grid access. A comparison of the genders reveals that female-headed households have higher electricity access rates and spend less on electricity, as shown in Table 3-2. In terms of technology, Figure 3-3 shows that male-headed households have higher grid access rates as compared to female-headed households. Higher grid connectivity by male-headed households contributes to their higher expenditure on electricity.

Table 3-2: Comparison of electricity access, average cost of electricity and willingness to pay disaggregated by type household head.

Type of Household	Percentage without access (%)	Average Monthly Expenditure on Electricity (KES)	Willingness to pay for improved connection (KES)
Male-headed	54	931	658
Female-headed	49	476	402

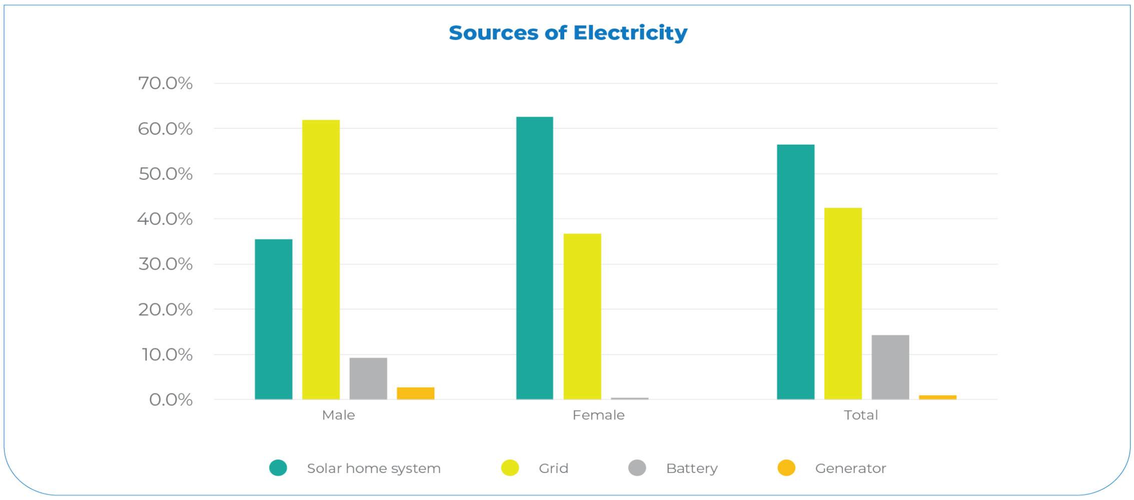


Figure 3-3: Technologies for electricity access by gender

3.1.2.1 Multi-Tier Framework (MTF) of Energy Access Analysis

The Multi-Tier Framework (MTF) initiative redefines how electricity access is measured by going beyond the traditional binary measure of “connected or not connected.” Instead, it evaluates electricity access[40] by considering the combination of seven attributes—namely: capacity, availability, reliability, affordability, quality, health, and safety — of across six tiers.[41] This way, the MTF helps identify and analyze the main reasons why households are not using electricity, or why their usage is limited (i.e., by capacity, reliability, or affordability issues). It then recommends a set of measures to eliminate such constraints.[4] This helps the governments to fine-tune their policies and approaches for electricity access. Detailed definition of the attributes and tiers are provided in Annex B.1

Capacity: The percentage of households that is connected through both grid and mini-grid is 34.9% that represent MTF tier 3 and above. This means that only 34.9% of households have access to electricity that can potentially stimulate productive uses. Households in tier 3 can afford a basic consumption package of 365 kWh per year.[42]

Availability: Only 24.3% of households surveyed can be said to belong to tier 3 (i.e., electricity is available for 8 hours and above per day). 47% are between tiers 2 and 3 (at least 4 hours), 29.6% belong to tier 1 and 0 (less than 4 hours per day). Although 29.2% of households are connected to

40 Multi-Tier Framework for Energy Access (MTF) | ESMAP

41 Electricity | Multi Tier Framework (esmap.org)

42 Electricity | Multi Tier Framework (esmap.org)

the grid, only 24.3% of households belong to tier 3, according to the MTF, implying that the grid is not providing adequate service in the county. This might explain the low consumption in households, which contributes to dwindling financial sustainability of the utility.

Reliability: Survey results revealed that 35% of households in Makueni connected to grid electricity experience at least one outages per week. Additionally, 33.7 % of the outages/interruption last between 2-5 hours a day. According to MTF's reliability attribute, households that experience at most three disruptions per week with a total duration of more than 2 hours belong to tier 3 and below.

Affordability: The affordability attribute was applied for grid-connected households only. According to the MTF, households that spend more than 5% of their household income on electricity belong to Tier 2 and below[43], indicating that electricity services are not affordable to them. From the survey results, households in Makueni spent KES 675 on electricity per month, on average. Thus, based on 5% metric and working backwards (i.e. KES 675=5%), this translates to a monthly income of approximately KES 13,510. Therefore, households with a monthly income of KES 13,510 or more are assumed to afford electricity services. In Makueni County, only 23.7% of HHs have a monthly income of KES 20,000 and above, 25% have an income of KES 10001-20,000 and more than half have an income of less than 10,000 per month. Conservatively estimated, slightly more than half of Makueni households cannot afford electricity services. Thus, priority should be given to interventions that: 1) improve income through productive uses, and 2) lower electricity costs.

Quality: The quality of the electricity supply refers to the absence of severe voltage fluctuations that can damage a household's appliances. The survey results did not identify challenges related to voltage fluctuations. However, a few instances of appliance damage due to electricity fluctuations were reported during FGDs. Further, it was also reported that in some areas, electricity from the grid had a lower voltage than was required, and as such, end users were unable to utilize the grid for certain activities, such as lighting. Top of Form

Health and Safety: This attribute assesses whether there has been a major injury reported in the past year attributable to the power source. Households with absence of fatal accidents are classified as tier 4 and 5[44]. On average, 14.8% of HHs reported that someone died or experienced permanent limb (bodily injury) damage while using electricity system in the last 12 months, thus belonging to tier 3 and below.

As shown in Figure 3-4, limited capacity and affordability of supply are the dominant challenges limiting households to Tier 2 and below in Makueni County. It should be noted that formality and quality are included in the plot due to a lack of statistical data. Consequently, there is a need for concerted efforts to improve households' income through productive use of energy programs and/or subsidize electricity tariffs for Makueni households. This approach aims to make electricity more affordable and allow access to appropriate capacity.

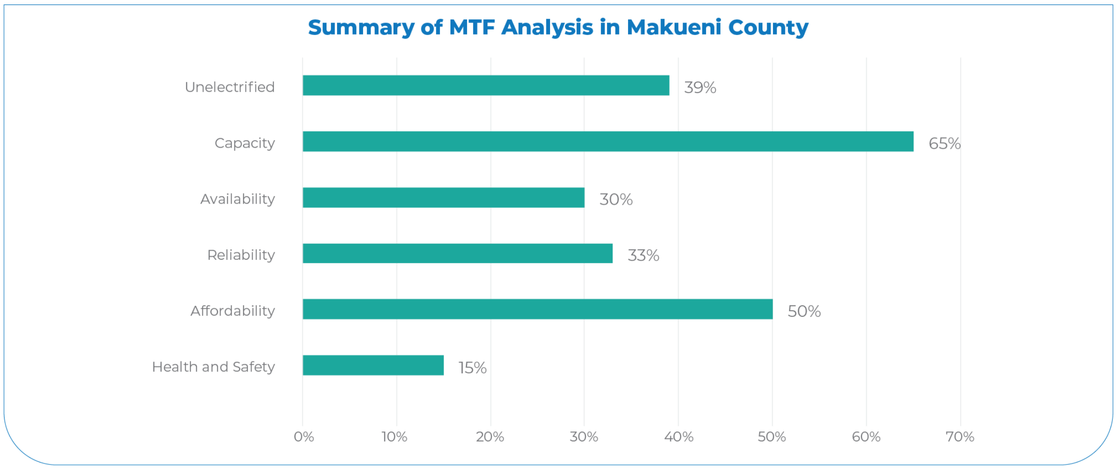


Figure 3-4: Summary of MTF Analysis for electricity in HHs

43 Electricity | Multi Tier Framework (esmap.org)

44 The MTF for Electricity Access — IMPACT-R Report - APIDE DRC

3.1.3 Access to Electricity: Educational Institutions

The average aggregate electricity connectivity for educational institutions is at 86%, as shown in Table 3-3. It is worth noting that while the connection rate was high, 20% of educational institutions were unable to utilize electricity for various reasons, including incomplete wiring within their facilities, failed transformers, and meters that are awaiting commissioning. Whilst the high numbers can be attributed to the national government's public facilities electrification program, an audit is required to identify and address such challenges and solve them.

Table 3-3: Main source of energy for lighting by educational institutions

Main source of energy used for lighting by educational institutions	County Total
National Grid-KPLC	85.8%
Mini-grids	0.3%
Other stand-alone systems (e.g. SHSs)	7.1%
Generator	1.7%
Rechargeable batteries*	0.8%
Firewood	0.3%

**these are batteries that are charged at separate locations, which may have grid facilities, and brought back to the educational facilities for use*

Source: Primary data collection

Educational facilities without grid connectivity attributed this to reasons such as: unreliability of the grid, cost of connection to the grid, and distance from the grid. Some indicated that they have little use for electricity in their premises.

The status of electricity connectivity for educational institutions in 2019-2021 calculated from Makueni County 2022 Statistical Abstract[45]are shown in Table 3-4 below. It is noteworthy that the primary data collection statistics are slightly lower than the county data. This is likely because some of the institutions that are connected as per county data did not consider themselves connected because of the challenges described above. It should also be noted that the County Statistical Abstract does not collect data on the technologies used to provide electricity access. As such, a trend analysis on the electrification according to various technologies was not possible.

Table 3-4: Electricity connectivity status for educational institutions in 2019-2021 in Makueni County

Type of educational institution	2019	2020	2021
Primary Schools	85.9%	96%	98.1%
Secondary Schools	-	100%	100.0%
Polytechnics	46.3%	78%	77.8%
Aggregate average	66.1%	91%	92%

Source: Experts Analysis from Statistical Abstract, 2022, and primary data collection, 2023

During primary data collection, institutions in urban areas reported an average monthly spend of KES 19, 800 on electricity while those in rural areas reported an average monthly spend of KES 8,440. Further analysis should be carried out to ascertain this, including energy use assessment to identify energy efficiency measures where needful. Most of the institutions did not provide information on generator fuel consumption.

3.1.4 Access to Electricity: Health Care Facilities(HCFs)

A total of 53 HCFs were surveyed. These are disaggregated by levels and location as shown in Table 3-5.

45 Kenya National Bureau of Statistics,KNBS (2021): Makueni County Statistical Abstract. MAKUENI-COUNTY-STATISTICAL-ABSTRACT - Kenya National Bureau of Statistics (knbs.or.ke)

Table 3-5: Type and location of HCFs surveyed.

Type of health care facility	Rural	Urban	Total
Level 2= dispensaries and clinics	34	2	36
Level 3= health centres, maternity and nursing homes	14	3	17

The combined average primary electricity connectivity from all sources of the HCF surveyed during primary data collection was 84% as shown in Table 3-6

Table 3-6 The primary lighting source for Health Care facilities

The primary lighting source for HCFs	Rural	Urban	Total
Drycell battery (Torch)	5.7%	0.0%	5.7%
Grid-based electricity	50.0%	80.0%	52.8%
Mini-grid based electricity	6.3%	0.0%	5.7%
Solar Home System/Lanterns	18.8%	20.0%	18.9%
Total	**80.8%**	**100.0%**	**83.1%**

In terms of urban-rural disaggregation, 80.8% of HCFs in rural areas had access to electricity while all HCFs in urban areas were connected. The HCFs spend an average of KES 5,030 on electricity bills per month.

3.1.5 Access to Electricity: Trade Centres (Markets)

In 2021, 96.5% of trade centres were connected to electricity supply, mostly from the grid, except for a few that use solar (KNBS, 2022)[46]. Kitonyoni rural market operates an off-grid 13.5kWp photo-voltaic solar plant that benefits more than 3,000 residents from Kitonyoni sub-county. Kithuki solar power mini grid project benefits about one hundred households in Kithuki sub-location location (ADP 2023/24)[47].). Figure 3-5 shows the number of trade centres with access to electricity. While the number of trade centres is constant, the number of trade centres connected to electricity grew from 776 in 2019 to 1,102 in 2021, indicating 42% growth. This can be attributed to electrification programs for public facilities by the national government.

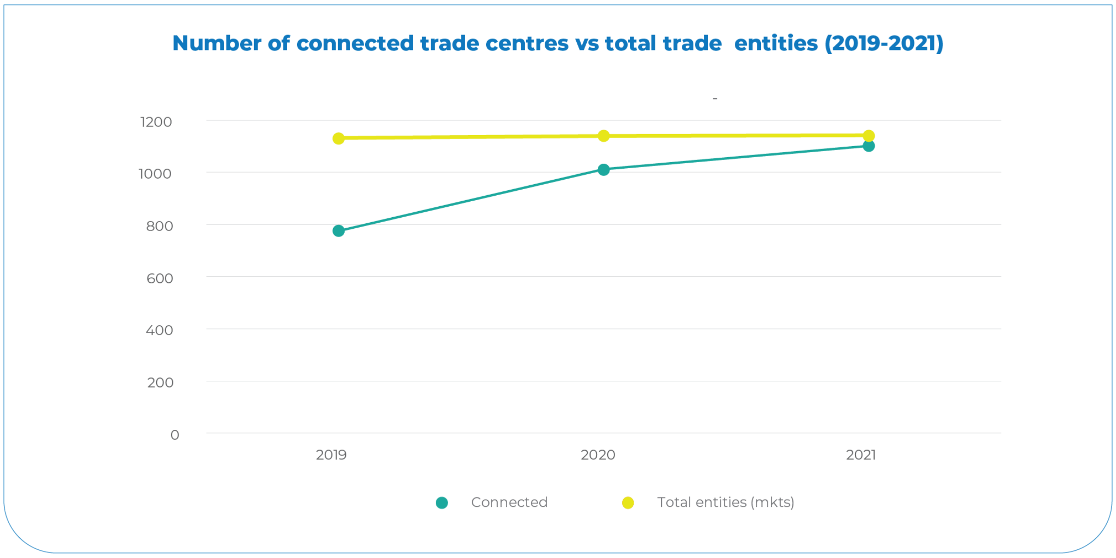


Figure 3-5: Number of connected trade centres vs total entities (2019-2021)

46 Kenya National Bureau of Statistics,KNBS (2021): Makueni County Statistical Abstract. MAKUENI-COUNTY-STATISTICAL-ABSTRACT - Kenya National Bureau of Statistics (knbs.or.ke)

47 Government of Makueni County (2022). Annual Development Plan (ADP) 2023/2024.

It was reported that the quality of streetlights within market centres remains a challenge despite the number of installations having increased. In some areas, it was reported that the streetlights broke down soon after installation. In other areas where solar streetlights were used, it was reported that the lights only functioned for a short duration after which they failed. Residents strongly associated streetlights and security, calling for electrification of all markets and installation of quality streetlights.

3.1.6 Access to Electricity: Businesses (MSMEs)

The main source of electricity for businesses in Makueni County is the national grid at an average of 80%, with solar coming distant second at 10% as shown in Figure 3-6. The national grid remains dominant in both urban and rural setups at 90.6% and 75% respectively. This indicates that most businesses are probably located in places with electricity networks like trade centres (markets).

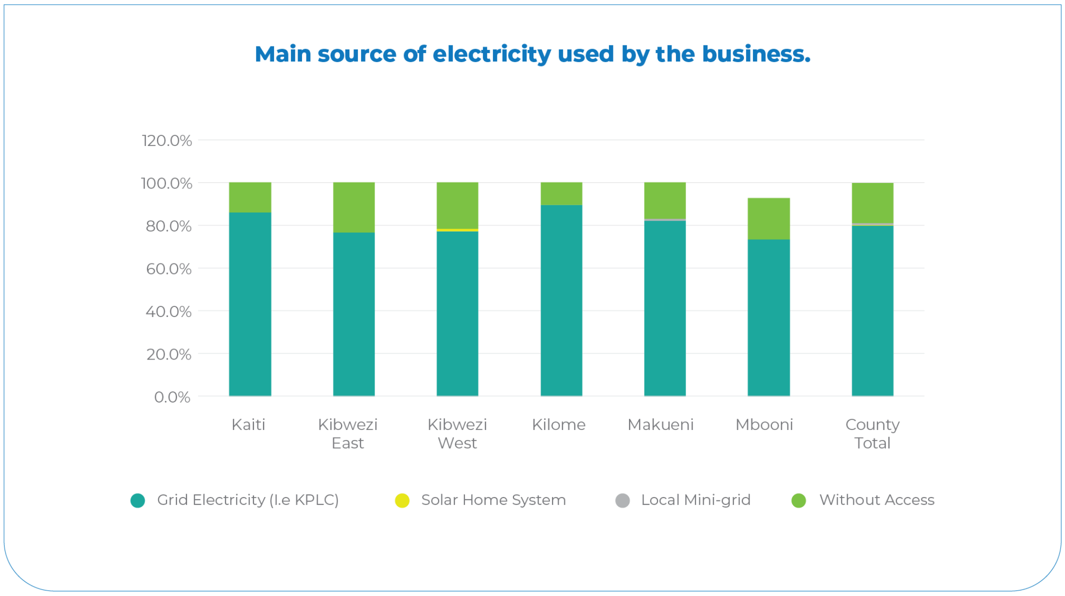


Figure 3-6: Main source of electricity used by businesses

The average monthly electricity expenditure by businesses in Makueni County is KES 4,750. Kilome and Kibwezi West sub-counties registered average monthly expenditures that double the County's average at KES 11,700 and 9,450, respectively. Businesses in urban areas spent on average three times more (KES 9,100) on electricity bills than those in rural areas.

The main challenge experienced by SMES was unreliable electricity supply. During the focus group discussions, erratic supply emerged as a key issue, with only a few respondents within Wote and Kibwezi towns indicating that reliability had recently improved. Participants indicated that reliability reduced their competitiveness as their customers opted for other areas to receive services. Those with back-up systems like generators indicated that the cost of fueling these systems was passed on to customers, which also reduced their competitiveness. Another obstacle noted was power outages that are as a result of grid infrastructure; in certain instances, it took Kenya Power authorities a considerable amount of time to react. This delay might be attributed to a limited number of service offices operating within the county.

Tree and fruit nurseries watered using solar power.

3.2 PROGRESSION TO UNIVERSAL ACCESS TO ELECTRICITY

This section presents the results of GIS modelling that sought to develop least cost electrification solutions for Makueni between 2023 and 2032 as prescribed in the INEP Framework. This section is outlined as follows: First, an analysis of baseline data is discussed, followed by the presentation of the electrification scenarios. Finally, barriers to electrification in Makueni County are discussed.

3.2.1 Baseline Electrification Data

The electricity system infrastructure in Makueni consists of the national grid that comprises the medium voltage (MV) and high voltage (HV) lines, substations, transformers, and a mini grid system. Figure 3-7 highlights the current infrastructure together with the locations of a mini grid within Makueni County.

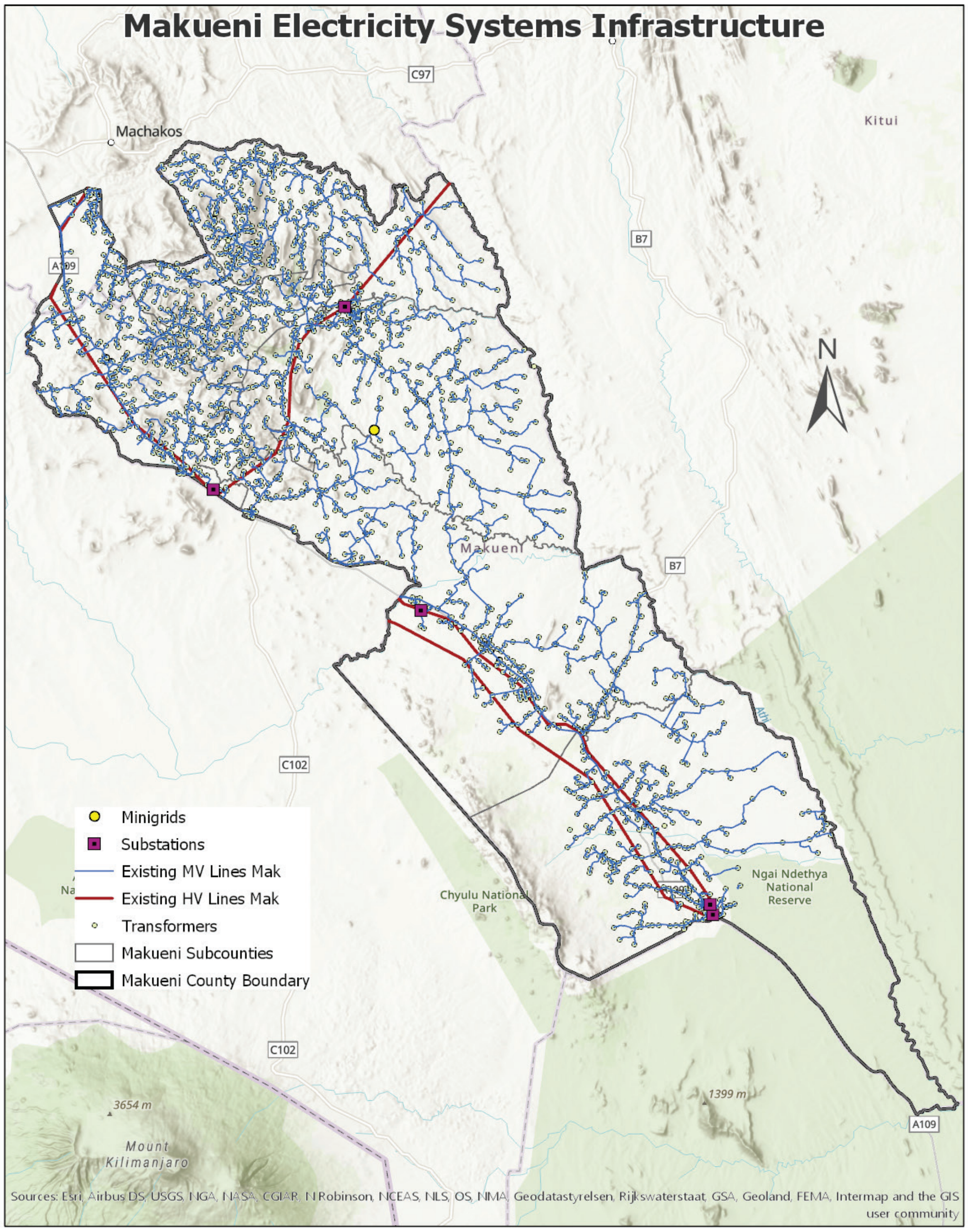


Figure 3-7: Electricity Systems Infrastructure

Table 3-7 outlines the length of existing medium and high voltage lines in Makueni, together with the number of mini grids plus other grid-related infrastructure.

Table 3-7: Summary of Existing Electricity Infrastructure in Makueni County

Infrastructure	Status	Count/Length	General Location
HV Lines (KPLC, 2017)	Existing	273.6 Km	Across the county
MV Lines (KPLC, 2023)	Existing	3,024.1 Km	Across the county
Transformers (KPLC, 2023)	Existing	2,027	Across the county
Substations (KPLC, 2023)	Existing	5	Across the county
Minigrids (CLUB-ER and Carbon Trust, 2019)	Existing	1	Makueni sub-county

Additional baseline datasets on energy demand and supply were integrated onto the Energy Access Explorer (EAE). EAE is an online, open-source, interactive, geospatial platform that enables clean energy entrepreneurs, energy planners, donors, and development-oriented institutions, among other users to identify high priority areas where energy access can be expanded. This tool uses spatial data to link energy supply with growing or unmet demand, which is essential to gaining a better picture of energy access and expanding energy services to those who need it the most.[48] A more detailed overview of the EAE can be found on the Energy Access Explorer website[49]

3.2.2 Future energy access outlook (and scenarios)

Possible scenarios for Makueni County's electricity future supply and demand for households, educational and Heath facilities were modelled using the Open-Source Spatial Electrification Tool (OnSSET). OnSSET is a bottom-up GIS-based cost optimization toolkit that runs on python-based code for identifying least cost technological options for electrification of un-served areas (Mentis, D. et al, 2020).50 It calculates scenarios for expanding access through an analysis of electrification options: grid-connected, mini grids and standalone systems (e.g. Solar home systems, associated investment, and capacity needs. An electrification algorithm identifies and selects the technology configuration with the lowest Levelized Cost of Electricity (LCOE) for a given settlement. (See Annex B.2 for LCOE Calculation and further data inputs for OnSSET).

Various scenarios were developed at both county and sub-county level to model the least cost technology option for electrification to achieve universal electrification by the year 2028 with one scenario developed to achieve universal electrification by 2026. Thereafter, additional demand from increasing population up to 2032 was modelled to maintain universal electrification until 2032 by leveraging the least cost technology choices identified. Annex B.3 explains in detail alternative scenarios made possible through the OnSSET modelling tool.

Tiers of access were derived from the multi-tier framework (MTF), which acknowledges that energy access is not binary. It is based on the principle that people will get access to different services from energy as their access levels or consumption grows. The table in annex B.1 shows the growing access to energy services depicted by the multi-tier framework as the energy access levels grow.

It should be noted that these scenarios did not explicitly consider data on productive use of energy, because geolocated information on PUE was not available at the time this plan was developed. Moreover, a county wide data collection exercise to incorporate information on PUE would have gone beyond the time horizon of this CEP. Integration of PUE on the OnSSET modelling will be done in an updated version of this CEP. For this version, it was therefore assumed that productive use would be able to connect to household supply. This approach relies on linking PUE loads to the nearest electrification solution proposed for the household settlements using GIS approaches. More details on this analysis have been described in the section 3.2.4 of this chapter.

The base year for this analysis was set at 2019. OnSSET provides results for an intermediate year and the final year. The intermediate year was set at 2028 while the final year, as previously mentioned, was 2032.

3.2.3 Scenarios Description

Three scenarios were developed to determine possible electrification pathways for Makueni County. The three scenarios (Domestic Electrification-Low Demand, Domestic Electrification High Demand, and Domestic Electrification High Demand with Forced Grid Intensification) developed for this CEP are described in detail in the Table 3-8 below. While the following sections describe the results obtained from modelling the scenarios, it should be noted that two sub scenarios were modelled for Domestic Electrification High Demand. This was done to have two target years for universal electricity access: 2026 as per the national government policy, and 2028, which was deemed a more realistic case for Makueni County.

48 Mentis, D. et al. (2019). EAE: Data and Methods. Available at: https://www.wri.org/research/energy-access-explorer-data-and-methods. (Accessed: 5 May 2022).

49 https://www.energyaccessexplorer.org/

50 Mentis, D. et al. (2020). Introduction to OnSSET. Available at: https://onsset.readthedocs.io/en/latest/introduction.html. (Accessed: 10 May 2022).

Table 3-8: Key Assumptions for the various scenarios modelled.

Assumption category	Domestic Electrification-Low Demand	Domestic Electrification-High Demand	Domestic Electrification - High Demand, Forced Grid Intensification	Domestic Electrification - High Demand, Forced Grid Intensification - (broken down at Sub- County level
Demand Side assumptions	• Normal/expected population growth at 1.1% • Tier one* of demand for rural consumers and tier four for urban consumers • 100% electrification rate by 2028. • 100% electrification maintained with additional demand due to population increase factored up to 2032	• High population growth at 2% • High electricity demand target (Tier 3* of consumption for rural areas and tier 5 for urban areas) • 100% electrification rate by 2026 with another scenario reflecting universal access by 2028 • 100% electrification maintained with additional demand due to population increase factored up to 2032.	• High population growth at 2% • High electricity demand target (Tier 3-rural areas* and Tier 5-urban areas) • 100% electrification rate in 2028 • 100% electrification maintained with additional demand due to population increase factored up to 2032.	• High population growth at 2% • High electricity demand target (Tier 3* consumption in rural areas and tier 5 in urban areas) • 100% electrification target in 2028 • 100% electrification maintained up to 2032.
Supply side assumptions	• Low generating cost for the grid (0.047$/kWh) • PV capacity cost as defined by the user. • Prioritisation of least cost electrification technologies (grid, mini-grids, and solar home systems	• High generating cost for the grid (0.059$/kWh) • PV capacity cost reduced by 25% • Prioritisation of least cost electrification technologies (grid, mini-grids, and solar home systems)	• High generating cost for the grid (0.059$/kWh) • PV capacity cost reduced by 25% • Forcing grid electrification for areas that are within a 2km distance from the grid and allowing selection of least cost technologies for areas that are beyond this distance.	• High generating cost for the grid (0.059$/kWh) • PV capacity cost reduced by 25% • Forcing grid electrification for areas that are within a 2km distance from the grid and allowing selection of least cost technologies for areas that are beyond this distance.

**Tiers of demand are used to approximate demand in rural and urban areas and not to define electrification solutions*

3.2.3.1 Domestic Electrification -Low Demand Scenario

Figure 3-8 shows the technology choice per settlement in 2032 while Table 3-9 shows the capacity required for electrification in the domestic electrification scenario.

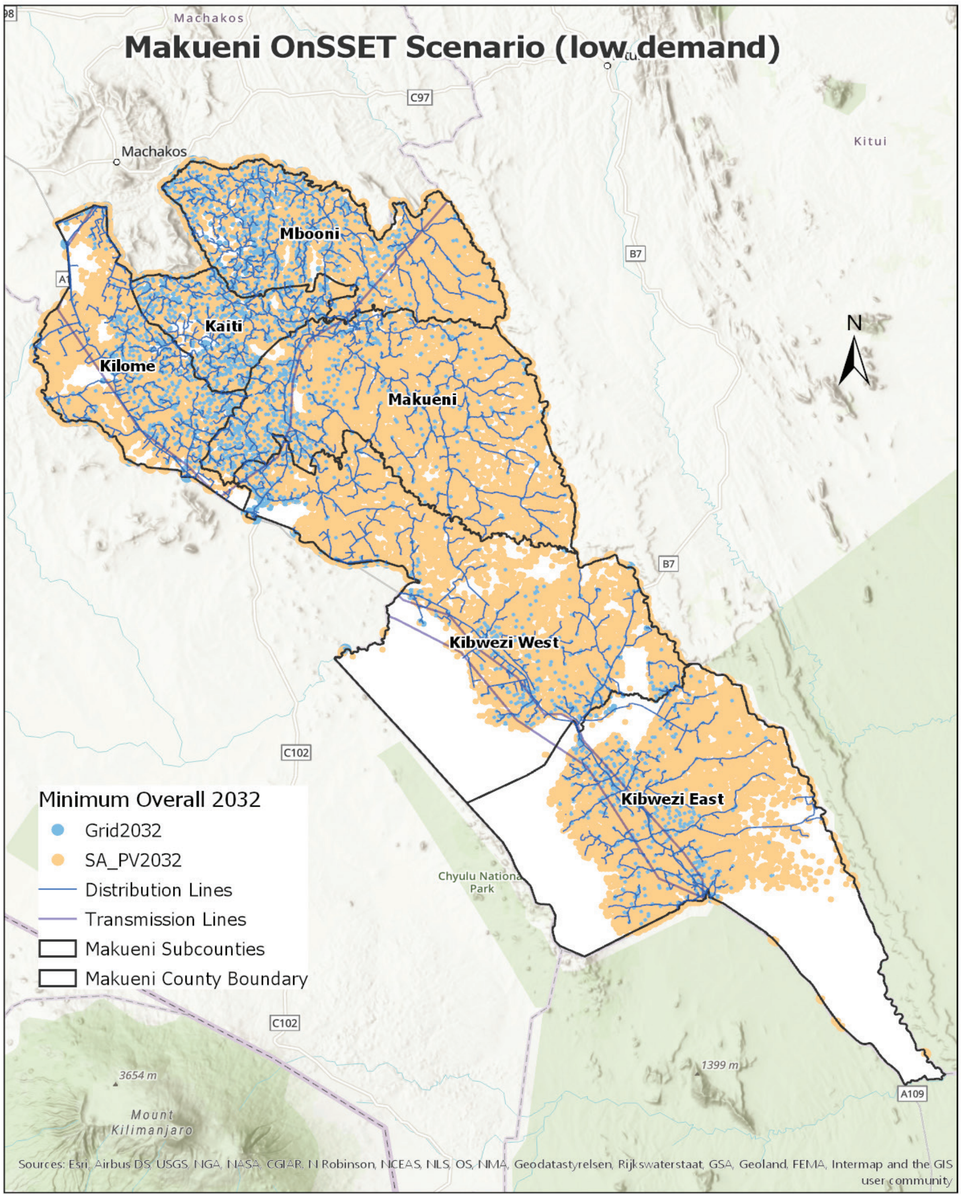


Figure 3-8: Domestic Electrification-Low Demand Scenario Results

Table 3-9: Capacity Required for Electrification in the Domestic Electrification-Low Demand Scenario

Technology	2028 (MW)	2032 (MW)	Total (MW)
Grid	16.1	3.3	19.3
Stand Alone (SA) PV	2.3	0.04	2.34
Total	**21.6 MW**		

The model selects the grid and standalone solar PV as least cost options for electrification. Grid has the highest capacity at 19.3 MW. This could be due to the wide coverage of the grid network for distribution across the county, making it cheaper to undertake grid densification to the population settlements close to it.

The investment costs required to implement this scenario are tabulated in Table 3-10 below. The total cost for deploying this scenario is USD 132.5 million. Eighty-five percent (85%) of this investment is allocated to electricity access through the grid.

Table 3-10: Investment (USD) required for Scenario for Domestic Electrification-Low Demand Scenario in 2028 & 2032.

Technology	2028 (Million USD)	2032 (Million USD)	Total
Grid	105.0	7.4	112.4
Stand Alone (SA) PV	19.91	0.21	20.12
Total	**132.5**		

3.2.3.2 Domestic Electrification -High Demand Scenario

The map in Figure 3-9 shows the technology choice per settlement in 2032 for the domestic electrification scenario while Table 3-11 shows the capacity of technologies required for electrification.

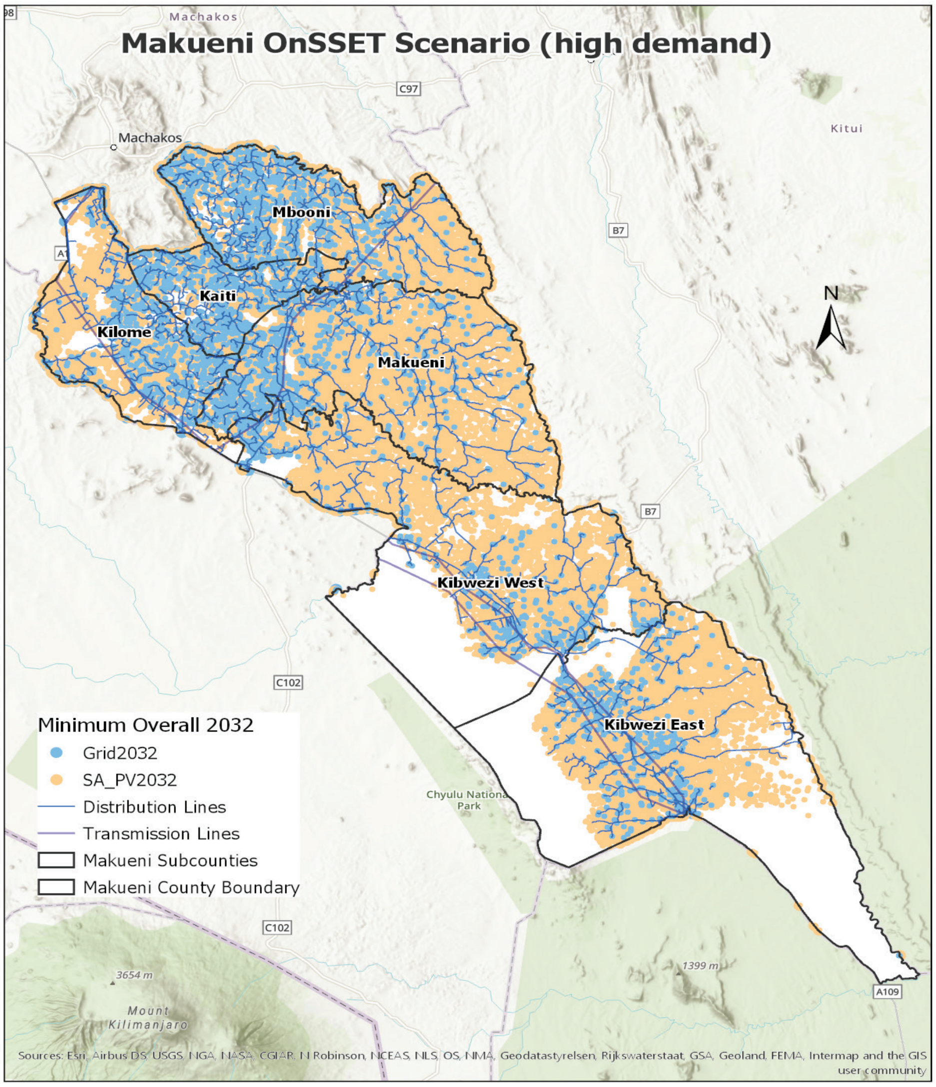


Figure 3-9: Domestic electrification high demand scenario

Table 3-11: Capacity of Electrification Technologies Required

Technology	2028 (MW)	2032 (MW)	Total (MW)
Grid	35.6	7.2	42.7
Stand Alone (SA) PV	50.8043	2.9007	53.605
Total	**96.4 MW**		

From Table 3-11 above, we note that the technologies proposed to be used for electrification are similar to Domestic Electrification, Low Demand Scenario. However, there is an additional capacity required for all the technology choices due to increased demand by the population settlements and also due to the higher tiers of consumption assigned to both urban and rural populations in this scenario. This indicates that the technology choices for the unelectrified populations still largely remains the least cost solutions but with increased capacities to meet the extra demand. As such, this scenario would require additional generation capacity added to the grid and stand-alone solar home systems would need to be of higher capacities. Innovative financing models or subsidies through projects such as KOSAP may therefore need to be applied where stand-alone PV systems are the least cost option.

Productive use of energy also needs to be promoted to make the investments more sustainable in the long run, while improving the livelihoods of the communities. The investment cost for this scenario is described in Table 3-12. As expected, they are higher than the Domestic Electrification Scenario-Low demand because of the higher population needed to be electrified.

Table 3-12: Investment (USD) required for Scenario Domestic Electrification High Demand Scenario in 2028 & 2032

Technology	2028 (Million USD)	2032 (Million USD)	Total
Grid	166.4	14.3	180.6
Stand Alone (SA) PV	170.3	9.3	179.5
Mini-grid (MG) PV	0 0		0
Mini-grid (MG) Hydro	0.024	0.004	0.028
Total	**360**		

The populations proposed to be connected to the different least cost technology options by 2032 are compared in the chart in the Figure 3-10.

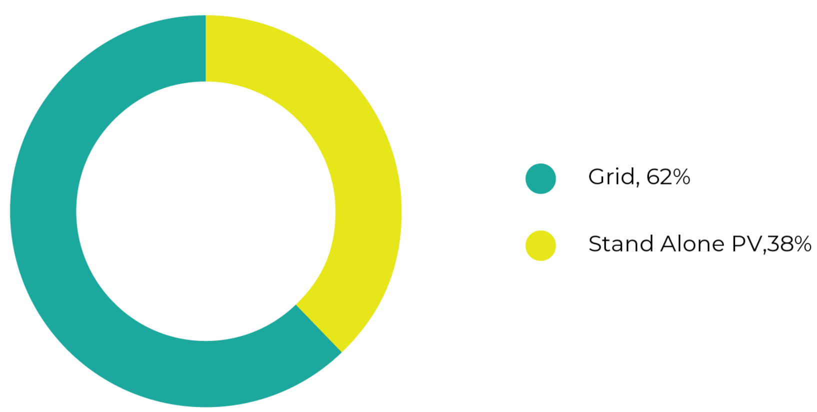


Figure 3-10: Least cost electrification technology population distribution by 2032

3.2.3.3 Domestic Electrification -High Demand Scenario (Universal Access by 2026)

This scenario is based on the same set of assumptions as in 3.5.3.2 above. The only difference is that the end year for achieving universal electricity access has been set as 2026. This choice for the end year electrification access target was influenced by the recommendations of the INEP. The map in Figure 3-11 shows the technology choice per settlement in 2026 for the domestic electrification scenario while Table 3-13 shows the capacity of technologies required for electrification.

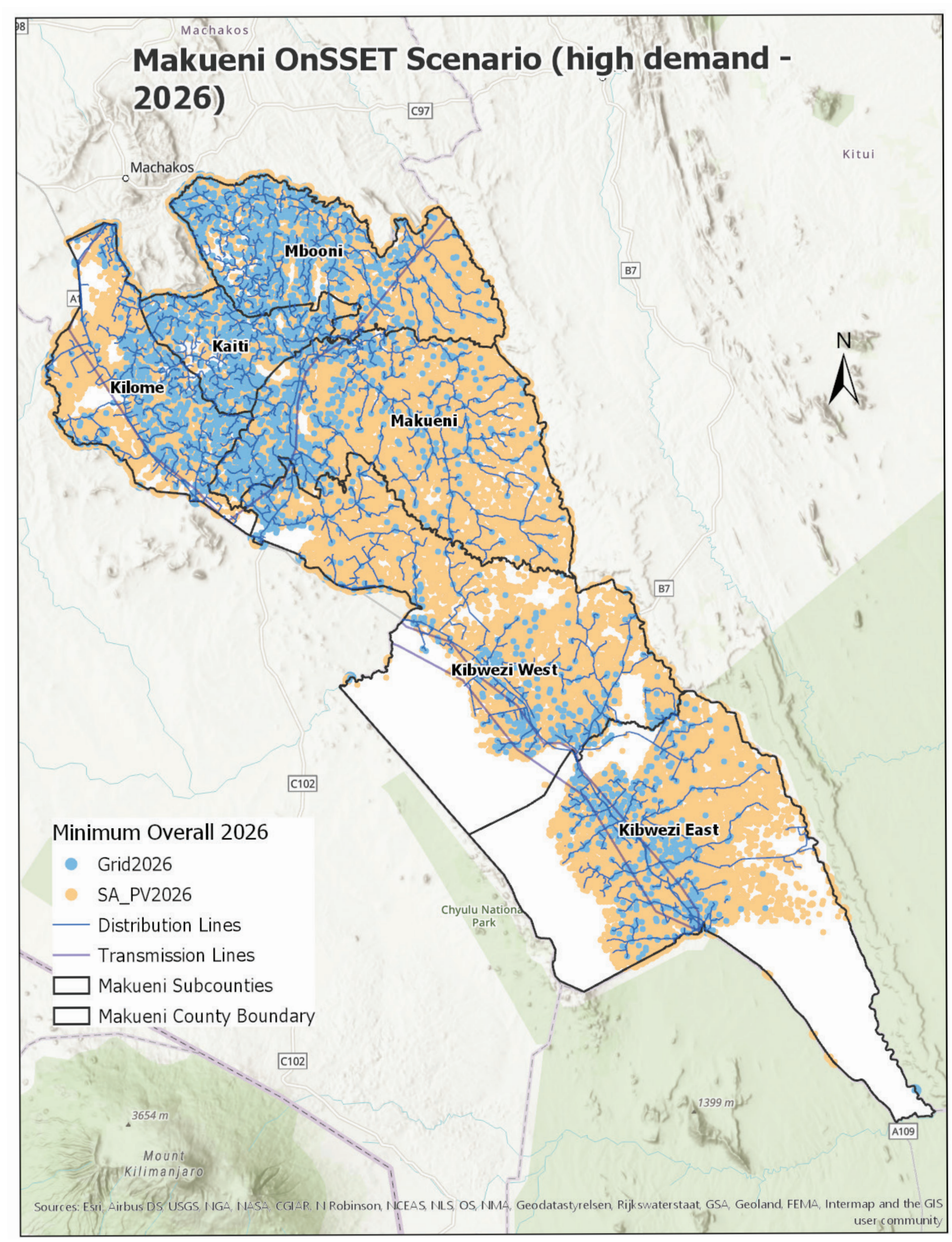


Figure 3-11: Domestic electrification high demand scenario

Table 3-13: Capacity of Electrification Technologies Required

Technology	2024 (MW)	2026 (MW)	Total (MW)
Grid	31.4	4.0	35.4
Stand Alone (SA) PV	47.204	0.9309	48.205
Total			**83.7 MW**

This scenario proposes a total of 83.7 MW increase in capacity to achieve universal electrification by 2026. This total capacity is less than its equivalent scenario by the end year of 2032. Since we expect to have less total population in 2026 compared to 2032, there will be less demand, factoring in the consistent population growth rate in both scenarios.

The investment costs for this scenario are described in Table 3-14. As expected, they are also lower than the previous scenario.

Table 3-14: Investment (USD) required for Scenario Domestic Electrification High Demand Scenario in 2024 & 2026.

Technology	2024 (Million USD)	2026 (Million USD)	Total
Grid	148.8	10.9	159.7
Stand Alone (SA) PV	158.523	4.6089	163.1322
Total	**322.9**		

The populations proposed to be connected to the different least cost technology options by 2026 are compared in the chart in the Figure 3-12.

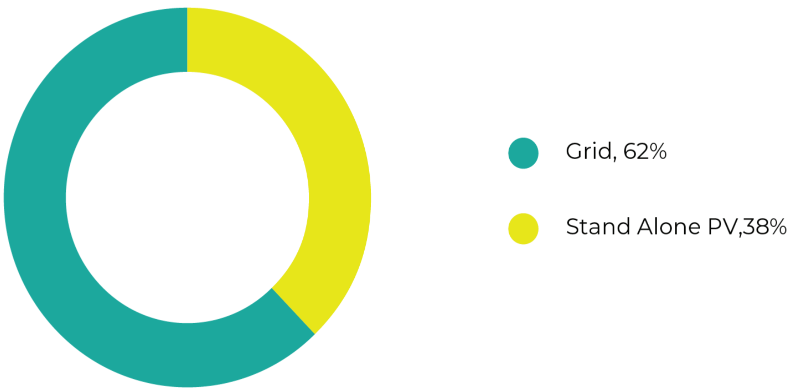


Figure 3-12: Least cost electrification technology population distribution by 2026

3.2.3.3 Domestic Electrification - High Demand Grid Intensification Scenario

This scenario forces grid electrification in areas that are 2km away from the grid. This means that the model will prioritise grid extension and densification in areas that are within a 2km radius from the grid, whether it is a least cost option or not. Figure 3-13 describes the technology choice per settlement in 2032 while Table 3-15 shows the capacity of electrification technologies used.

This scenario deploys only grid electrification as the least cost solution with a total of 38.4 MW as compared to the previous scenarios of 19.3 MW and 42.7 MW for scenarios 1 and 2, respectively, considering only grid electrification. This scenario choses grid as the only solution for electrification due to the wide coverage of the grid network and the much higher demand tiers from the rural and urban households.

The mandatory electrification of populations using grid within 2km from an existing distribution line only makes the remaining unelectrified populations much closer to the newly electrified population and could lead to their electrification by extending the grid network.

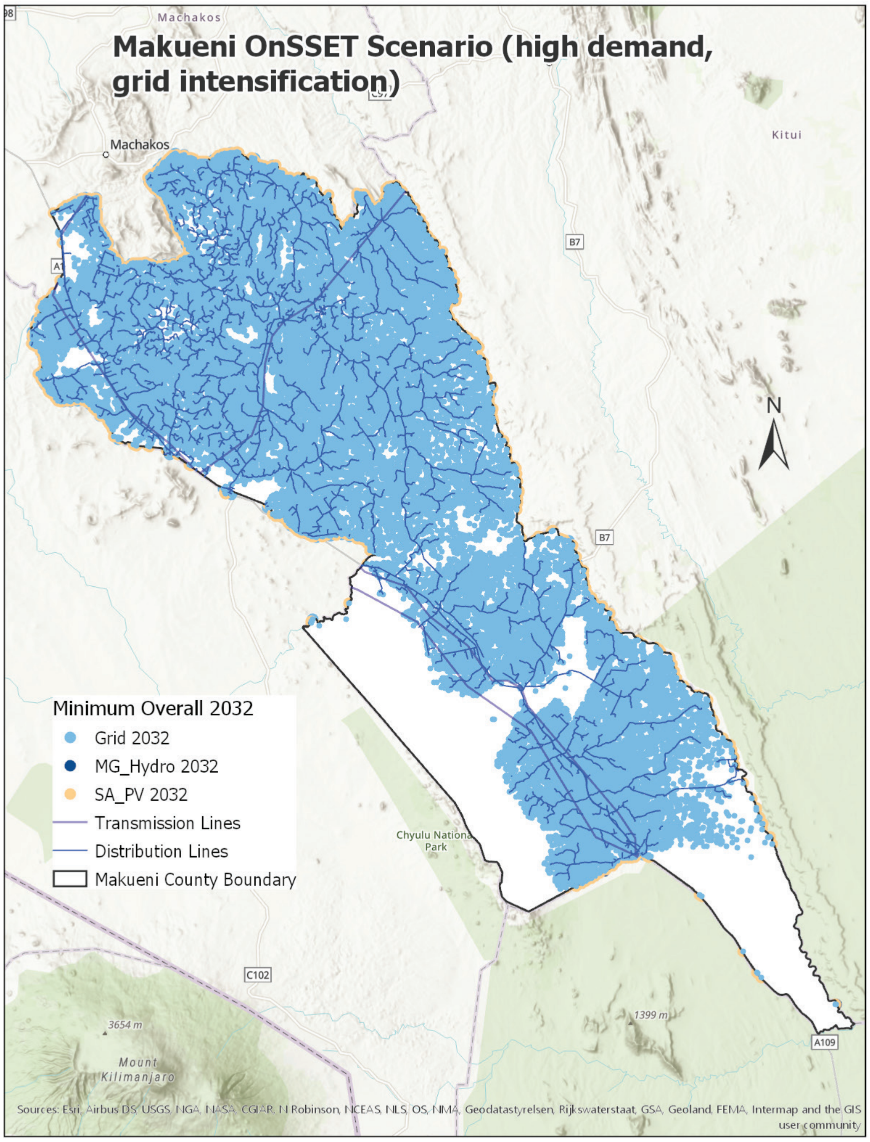


Figure 3-13: Technology choice per settlement in 2032

Table 3-15: Capacity of Electrification Technologies (MW)

Technology	2028	2032	Total
Grid	31.7	6.8	38.4
Total			**38.4**

With regards to investment needs, Table 3-16 shows the investment costs required to deliver this scenario at USD 571.8 million, which is significantly more than the previous two scenarios i.e., USD 132.5 (Domestic Electrification – Low Demand), USD 360.1 (Domestic Electrification – High Demand -2032), and USD 322.9 (Domestic Electrification – High Demand -2026). This can be attributed to forcing the model to depart from least cost solutions for electrification and utilise the grid within a 2km radius. Despite the reduced capacity, this scenario will cost more to implement than the previous scenarios by approximately USD 212 million. This can be attributed to the cost of grid expansion.

Table 3-16: Investment (USD) required in Forced Grid Scenario in 2028 & 2032.

Technology	2028 (Million USD)	2032 (Million USD)
Grid	557.1	14.8
Total	**571.8**	

While it may be more costly, the grid allows consumers to pay less for consumption, particularly as compared to mini grids where electricity can cost up to five times more. Further, grid consumers can also acquire more appliances without considering or acquiring increased system capacity as compared to solar home systems. Additionally, grid electrification is likely to be conducive for productive use of energy due to relatively lower electricity costs and sufficient electricity supply.

3.2.3.3 Progress to universal electrification

Progress towards universal electrification from 2023 to 2032 for the three scenarios was undertaken using this scenario and is tabulated in Table 3-17.

Table 3-17: Electricity connectivity progression.

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Total connectivity of the HHs in %	55.6%	64.4%	73.3%	82.2%	91.1%	100%	100%	100%	100%	100%
HHs Population connected to solar home systems (Domestic Electrification - Low Demand Scenario)	211,799 254,158		296,518	338,878	381,237	423,597	1,952	3,904	5,855	7,807
HHs Population connected to the grid (Low demand scenario)	232,112	278,534	324,957	371,379	417,802	464,224	11,337	22,675	34,012	45,349
HHs Population connected to solar home systems (Domestic Electrification - High Demand Scenario)	229,197	275,036	320,876	366,715	412,555	458,394	6,324	12,648	18,972	25,296
HHs Population connected to the grid (High demand scenario)	260,033	312,039	364,046	416,052	468,059	520,065	19,066	38,132	57,197	76,263
HHs Population connected to the grid (Domestic Electrification - High Demand, Grid Intensification Scenario)	489,473	587,367	685,262	783,156	881,051	978,945	25,290	50,580	75,869	101,159

Comparison between the population proposed to be connected to the different technologies across the three scenarios between 2023 and 2032 was done, and the results can be visualized in Figure 3-15.

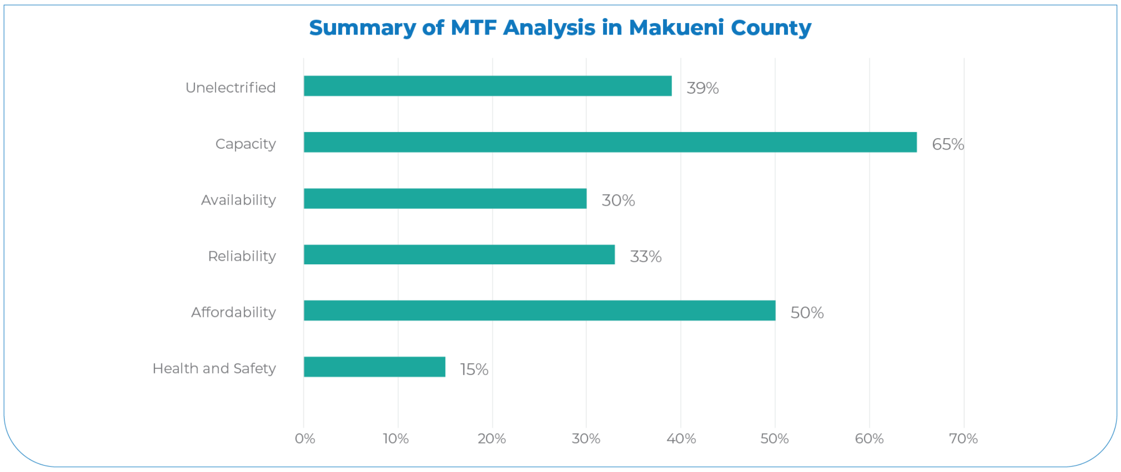


Figure 3-14: Population Connected to Solar Home Systems between 2023 and 2032

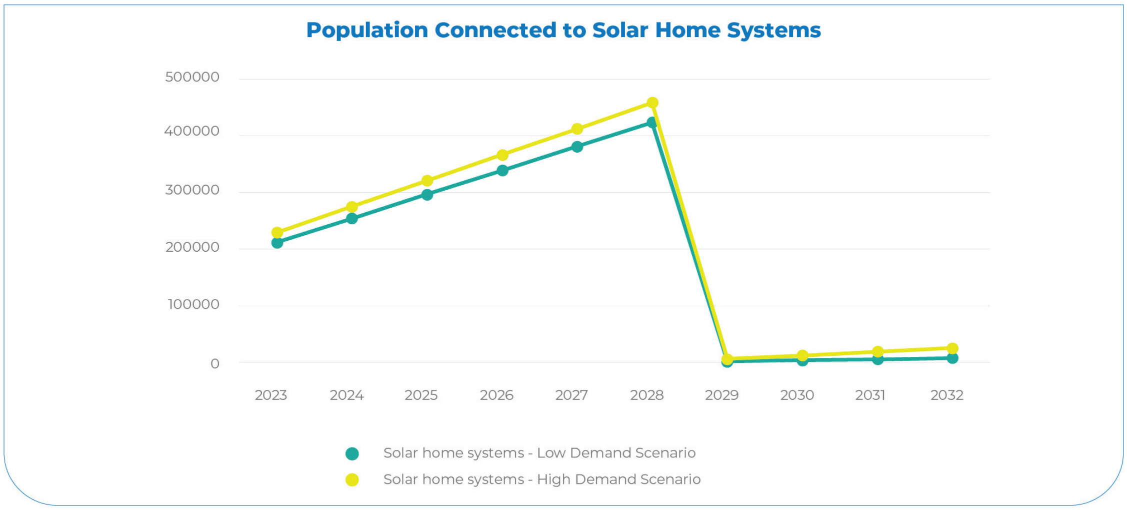


Figure 3-15: Population Connected to Grid between 2023-2032

3.2.3.4 Affordability Analysis

The three scenarios; Domestic Electrification - Low Demand, Domestic Electrification - High Demand, and Domestic Electrification - High Demand, Grid Intensification, were broken down to sub-county level with the goal of undertaking a more granular affordability analysis. Affordability analysis was undertaken to determine the ability of the households to pay based on a comparison between levelized cost of electricity in these scenarios and the average electricity expenditure per household projected into the future. The results of this analysis can be seen in Table 3-18, which shows that all the sub-counties would have a deficit between what they can afford versus what they would need to pay for the electricity (assuming current affordability situation remains constant). This is due to the higher tiers of demand for both rural (tier 3) and urban (tier 5) modelled. This, coupled with a higher population growth projected, would result to higher costs of energy. Given the current situation, and considering the electricity expenses reported, it is likely that most of the households are utilizing the lower tiers of energy. However, if they were supplied with the higher tiers of energy access as per this scenario, they would have enough energy to power productive use of energy applications. This, in turn, could lead to an improved quality of life and increased income from the increased yield and value of agricultural products as well as new income sources from PUE.

This new income could then be channelled to paying for the increased costs of electricity from this scenario.

As seen in Table 3-18 below, (domestic electrification- low demand scenario), only Kaiti sub-county will have a deficit between what they can afford versus what they would need to pay for the electricity while the rest will be able to pay for the selected technology of choice (assuming current affordability situation remains constant). This is due to the lower tiers of demand for both rural (tier 1) and urban (tier 4) modelled.

Table 3-18: Affordability Analysis: Domestic Electrification - Low Demand Scenario

Sub-county	**Average amount per household spent (KES) on electricity per month (2032)**	**Extrapolated total electricity expenditure per year in 2032 (Million KES)**	Modelled Electricity Cost **(million KES)**	**Deficit (Million KES)**
Kaiti	906.3	196.7	634.3	-437.6
Mbooni	2,692.50	1,946.2	806.2	1,139.9
Kibwezi West	2,660.9	861.6	408.2	453.4
Makueni	1,058.5	1,318	396.4	921.5
Kilome	1,037.5	435.2	369.3	65.9
Kibwezi East	1,642.7	1,171.4	175	996.4
County Totals	**9,998.40**	**5,929.1**	**2,789.5**	**3,139.6**

Further info on Table 3-18 above[51,52]

Table 3-19 on the domestic electrification- high demand scenario, shows that all the sub-counties would have a deficit between what they can afford versus what they would need to pay for the electricity (assuming current affordability situation remains constant). This is due to the higher tiers of demand for both rural (tier 3) and urban (tier 5) modelled. This, coupled with a higher population growth as projected, would result to higher costs of energy. Given the current situation, based on what was indicated by what they are currently paying for electricity, most of the households could be using the lower tiers of energy. However, if they were supplied with the higher tiers of energy access as per this scenario, they would have enough energy to power productive use of energy applications. This, in turn, would lead to an improved quality of life and increased income from the

51 Future value of money calculations: Available at: https://www.investopedia.com/articles/03/082703.asp. (Accessed on: 11/20/2022)

52 *The extrapolated total electricity expenditure is arrived at by using the expected number of households (projected at a rate of 1.67%) and the average electricity expenditure in 2019 obtained from primary data collection. The model's discount rate (10%) is used to obtain the value of money in 2026. The average amount spent on electricity per household in 2026 is calculated based on the future value[84] of the amount spent per household in 2021 as per the primary household surveys assuming a 10% annual increment.

increased yield and value of agricultural products as well as new income sources from PUE. This new income could then be channelled to paying for the increased costs of electricity from this scenario.

Table 3-19: Affordability Analysis: Domestic Electrification - High Demand Scenario

Sub-county	Average amount per household spent (KES) on electricity per month (2032)	Extrapolated total electricity expenditure per year in 2032 (Million KES)	Modelled Electricity Cost (Million KES)	Deficit (Million KES)
Kaiti	906.3	196.7	1,412.5	-1,215.7
Mbooni	2,692.50	1,946.2	2,300.3	-354.1
Kibwezi West	2,660.9	861.6	1,991.2	-1,129.6
Makueni	1,058.5	1,318	2,145.6	-827.6
Kilome	1,037.5	435.2	1,223.9	-788.7
Kibwezi East	1,642.7	1,171.4	1,610.2	-438.9
County Totals	**9,998.40**	**5,929.1**	**10,683.7**	**-4,754.6**

Table 3-20 shows the domestic electrification- high demand, grid intensification scenario. It indicates that only Kaiti and Kilome sub-counties would have a deficit between what they can afford versus what they would need to pay for the electricity, while the rest will be able to pay for the selected technology of choice assuming current affordability situation remains constant. This increase in affordability could be attributed to the fact that this scenario proposes a hundred percent connection to the grid for all unelectrified households. While the tiers of access of energy to the households would increase, rural (tier 3) and urban (tier 5), the households would benefit from reduction in consumer costs due to increased economies of scale for the grid distribution company.

Additional funding or innovative financing models to meet the deficit for the sub-counties that would be unable to pay for the proposed solutions could also be explored.

Table 3-20: Affordability Analysis: Domestic Electrification - High Demand Scenario, Grid Intensification

Sub-county	Average amount per household spent (KES) on electricity per month (2032)	Extrapolated total electricity expenditure per year in 2032 (Million KES)	Modelled Electricity Cost	Deficit (Million KES)
Kaiti	906.3	196.7	1,065.1	-868.3
Mbooni	2,692.50	1,946.2	1,403.6	542.6
Kibwezi West	2,660.9	861.6	779.6	82
Makueni	1,058.5	1,318	781	536.9
Kilome	1,037.5	435.2	665.3	-230.1
Kibwezi East	1,642.7	1,171.4	410.6	760.7
County Totals	**9,998.40**	**5,929.1**	**5,105.3**	**823.8**

3.2.4 Institutions Electrification Pathways and Statistics

Institutional electrification was considered through grid intensification plus off-grid options. Proximity analysis was undertaken to establish institutions that were further than 600m from the distribution transformers. These institutions were assumed to be unelectrified. The unelectrified institutions were further extracted and overlaid with outputs from the County Domestic Electrification-High Demand Scenario. Using GIS proximity analysis (near tool), the institutions were assigned a least cost electrification technology option based on the solution assigned to the nearest settlement cluster. The sections below present the findings for electrification of health care facilities and education facilities.

3.2.4.1 Health care facilities

A total of 44 healthcare facilities in the county were flagged as unelectrified (not connected to the grid) based on this analysis. These are symbolised in light blue in Figure 3-16 below.

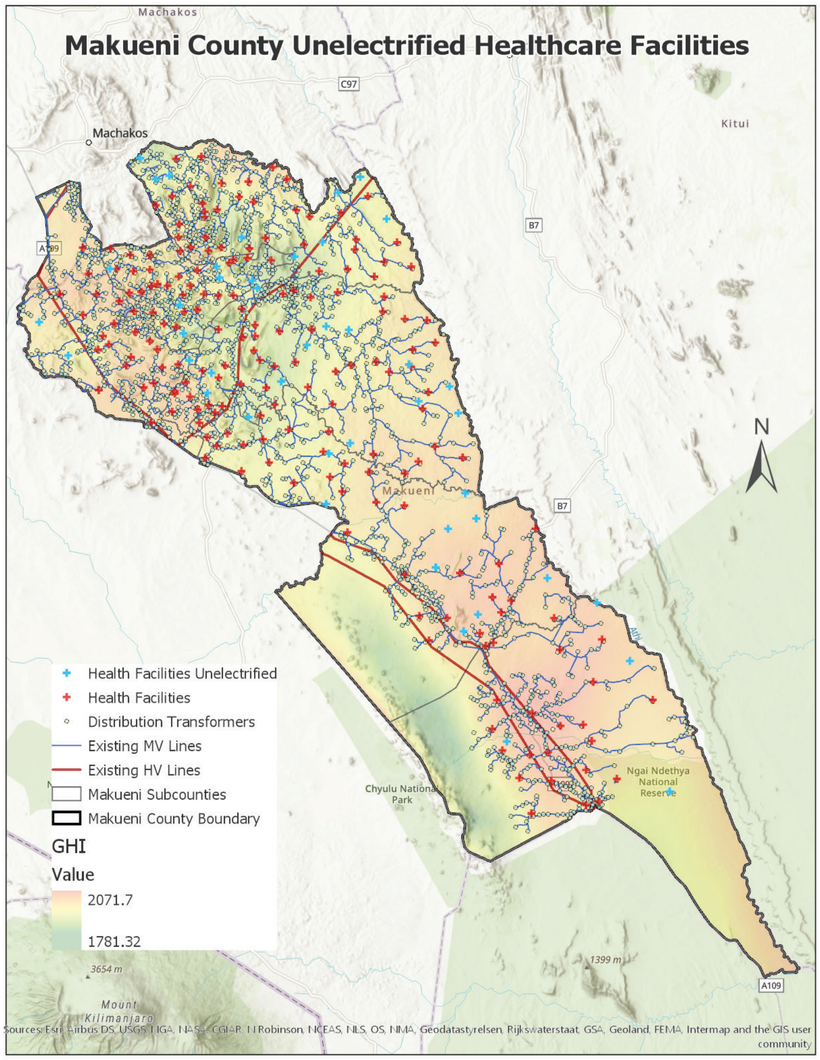


Figure 3-16: Map showing unelectrified health care facilities in Makueni County

Table 3-21 presents a summary of least cost electrification technologies for health care facilities based on the findings from the GIS proximity analysis.

Table 3-21: Electrification technologies for Unelectrified Health Care Facilities

Sub-county	Grid	SA PV	Totals
Kaiti	2	4	**6**
Kibwezi East	1	3	**4**
Kibwezi West	2	7	**9**
Kilome	0	3	**3**
Makueni	3	10	**13**
Mbooni	4	5	**9**
County Totals	**12**	**32**	**44**

The findings in Table 3-21 indicate that most healthcare facilities (73%) will be electrified by stand-alone solar PV. The remaining ones (27%) will be electrified by the grid as the least cost electrification option.

3.2.4.2 Educational facilities

A total of 170 schools in the county were flagged as unelectrified (not connected to the grid). These are symbolised in blue in Figure 3-17 below.

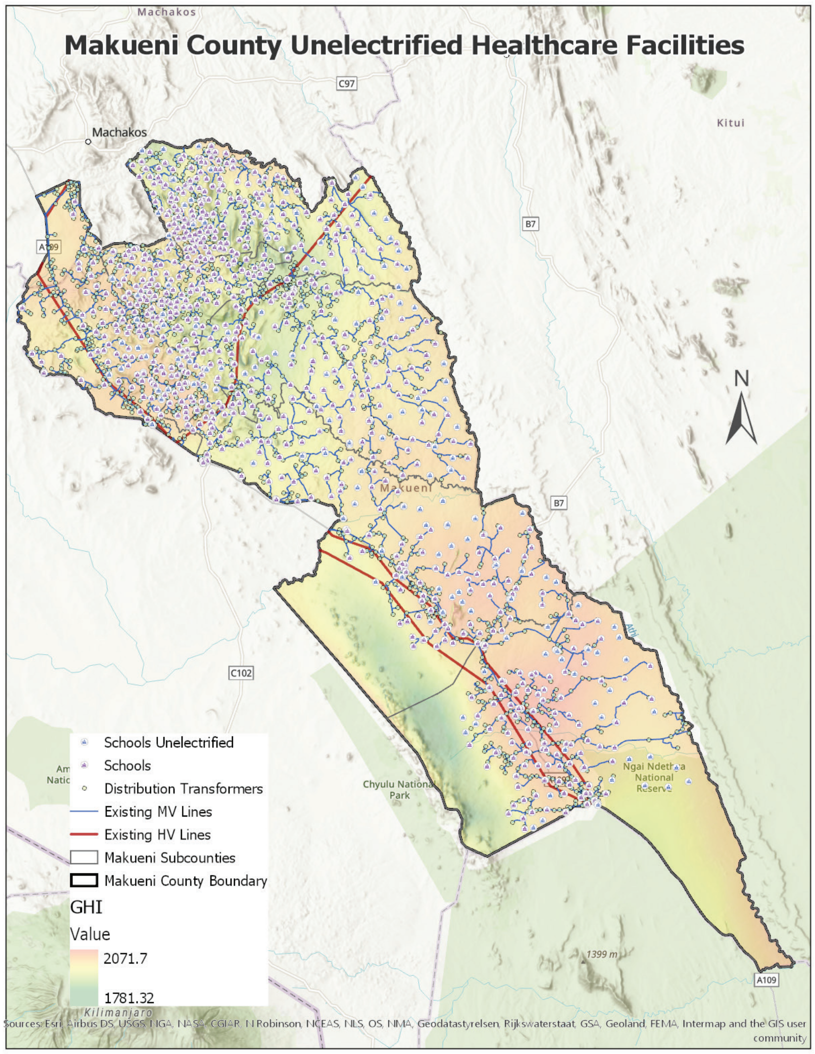


Figure 3-17: Map showing unelectrified schools in Narok County

Table 3-22 presents a summary of electrification technologies that can be used to electrify educational facilities.

Table 3-22: Electrification Technologies for Unelectrified Schools

Sub-county	Grid	SA PV	Totals
Kaiti	1	5	**6**
Kibwezi East	7	25	**32**
Kibwezi West	11	30	**41**
Kilome	2	13	**15**
Makueni	11	29	**40**
Mbooni	9	27	**36**
County Totals	**41**	**129**	**170**

Like in the case of health facilities, majority of the schools will be electrified using stand-alone solar PV (76%) followed by those electrified using the grid (24%). This indicates that stand-alone solar PV remains the most viable and least-cost option to meet the electricity demand of most schools and health facilities that are off-grid.

3.2.4.3 List of prioritized potential intervention options

Based on the results of the OnSSET high demand scenario described in section 3.2.3.3 (high demand scenario), the output map was analysed to identify clusters of population settlements that have a similar electrification technology solution. This was undertaken to identify potential areas for setting up electrification projects using the most feasible and least cost technology choice.

On Figure 3-18, clusters of population settlements that have the same recommended technology choice for electrification have been circled using different colours. Potential areas for extending the grid have been circled maroon, while those that have potential for setting up mini grids using hydropower have been circled purple.

The remaining areas are mainly those suitable for setting up standalone solar home systems and are uniformly distributed across the county in areas further from the grid network. They are coloured brown. These are areas further away from where grid could be extended or where mini grids could not be set up.

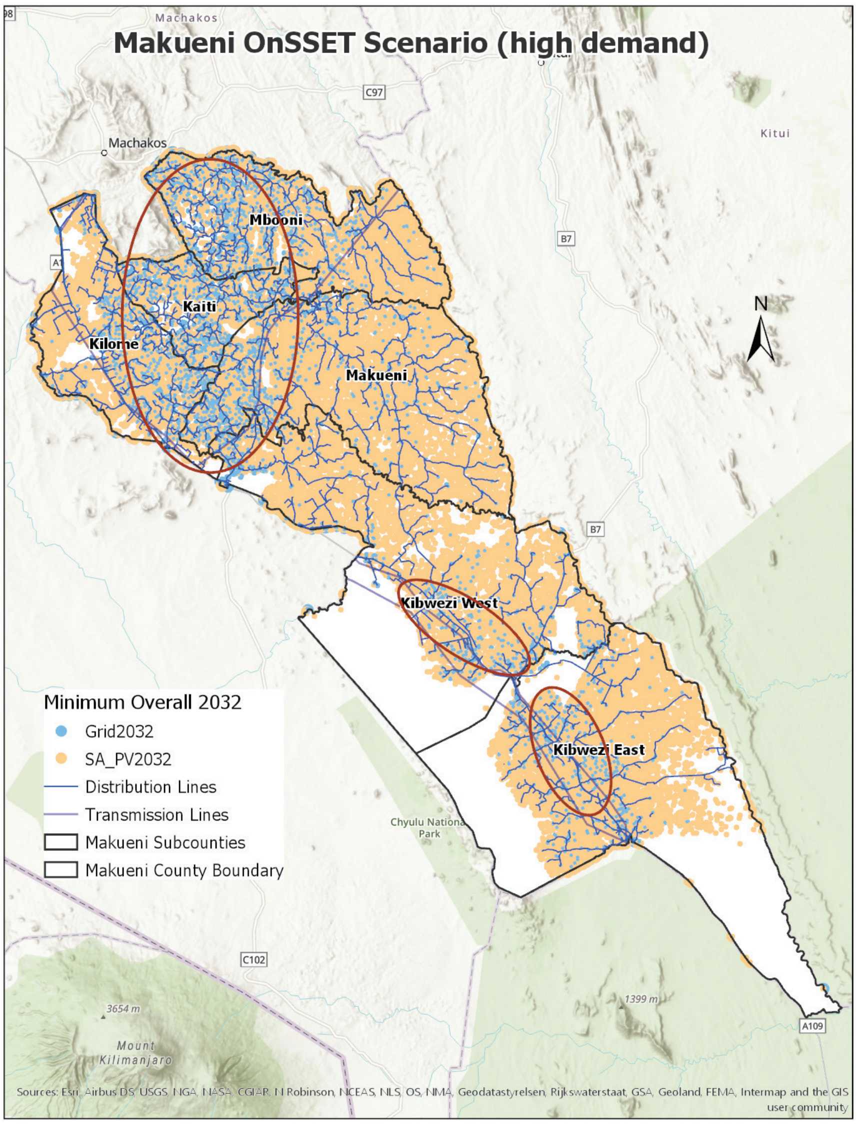


Figure 3-18: Map showing potential areas for setting up power plants

The total capacities and costs for the three electrification technologies were also broken down in section 3.2.3.3. As shown in the map in Figure 3-18, most of the sites proposed for grid densification and intensification would be in Mbooni, Kaiti and Kilome sub-counties. Other proposed sites are parts of Kibwezi West and Kibwezi East sub-counties as per the recommendations of this scenario.

Stand-alone solar home systems have mostly been proposed in Makueni and the northern parts of

Kibwezi West sub-counties.

More detailed feasibility and technical analysis would need to be done to determine the exact design, capacity and actual end users of the proposed power plants that would meet the needs of the unelectrified population identified and ensure universal access to electricity to all in Makueni by 2032.

3.2.5 Barriers to increasing electricity access and potential interventions

Barriers to electricity access are discussed in Table 3-23. Chapter 6 provides detailed interventions for electricity access.

Table 3-23: Barriers to electricity access

Barrier	Description	Potential intervention
Distance to distribution infrastructure and transformer failures	As stated in section 3.1.3, one of the main reasons given by rural institutions was distance from grid or transformer and technical failures	Install additional transformers on existing medium-voltage to connect households within and beyond 600 meters of existing distribution transformers
High connection fees	FGDs and PUE assessments revealed that high connection fees is one of the barriers preventing grid connection with both domestic and commercial consumers	Provide subsidies and credit based mechanisms to provide connection to low income households in rural areas
Low-income levels	As shown in Section 3.1.2.1, conservatively speaking, more than half of HHs have an income of less than 10,000 per month and thus cannot afford electricity services.	Put in place efforts to improve households' income through supportive productive use of energy programs.
Lack of clear roadmap and coordinated efforts	Lack of integrated energy access roadmap/plan that clearly state the targets, priority areas of interventions, investments required and concrete partnerships may be a hindrance to speedy energy access in the county.	Develop clear roadmap and policy to implement the CEP
Limited funding	Limited funding due to competition with other development sectors	Provide additional funding allocation to energy projects or come up with innovative financing models. Scaling up off grid service through subsidy scheme

3.3 ACCESS TO MODERN COOKING SOLUTIONS

This CEP adopts the International Energy Agency (IEA) definition of clean cooking access as "a household that has reliable access to and uses as their primary cooking means, fuels and equipment (cookstoves or technologies) that significantly limit or avoid the release of pollutants harmful to human health." Clean cooking technologies that meet this definition include stoves using natural gas, liquefied petroleum gas (LPG), electricity, bioethanol, and biogas. Under the Multi-Tier Framework for Clean Cooking, clean cookstoves are classified as tier 4 and above. Improved biomass cookstoves (ICS) of ISO tier 3 can act as a transitional technology from traditional biomass cookstoves and three-stone fires to the clean-cooking technologies listed above. (IEA, 2023)[53]

LPG GAS

BIOETHANOL

BIOGAS

53 IEA (2023), A Vision for Clean Cooking Access for All, IEA, Paris https://www.iea.org/reports/a-vision-for-clean-cooking-access-for-all, License: CC BY 4.0

3.3.1 Energy for Cooking Access: Households

Firewood remains the primary cooking fuel for households in Makueni County across all sub-counties at an average of 72.5% in 2022 (primary data collection) compared to 76.1% in 2019 (KNBS, 2019), registering a very small change. Figure 3-19 shows comparison between access to primary fuel used for cooking in Makueni County in 2019 and 2022. The burden of collecting firewood is primarily carried by women and children. The average time spent collecting firewood across the county is between 30 minutes to one hour. However, Kibwezi East is an outlier, having an average collection time of 1.2 hours, as shown in Table 3-24 below.

Table 3-24: Daily firewood collection duration in Makueni County

Sub-county	Daily Collection Time (Minutes)
Kaiti	48
Kibwezi East	72
Kibwezi West	42
Kilome	30
Makueni	36
Mbooni	30

Households with small parcels of land emerged as most disadvantaged users of firewood. During the focus group discussions, women from these households indicated that they must purchase firewood from their neighbours who sometimes refused to sell to them. They reported that this negatively impacted their dignity. Costs of accessing the firewood increased due to labour costs as firewood was purchased in the form of trees that had to be chopped and further transported to their households. Another challenge users of firewood faced was unavailability of dry wood during the rainy season, which made households resort to purchasing firewood at a high price. There was also low awareness and availability of firewood improved cookstoves. Respondents indicated that they used the three stone cookstoves because available improved cookstoves targeted charcoal users.

There is slight reduction in charcoal use from 10.1% in 2019 to 8.2% in 2022 (primary data collection, KNBS 2019). The reduction could be associated with the ban on commercial charcoal production in the county, making it difficult to transport large quantities of the commodity. Charcoal consumption in Makueni County is predominantly used in urban areas. During focus group discussions, those using charcoal indicated that the rising costs of LPG had compelled them to resort to charcoal. They indicated that they avoided firewood because of the damage it causes to their houses.

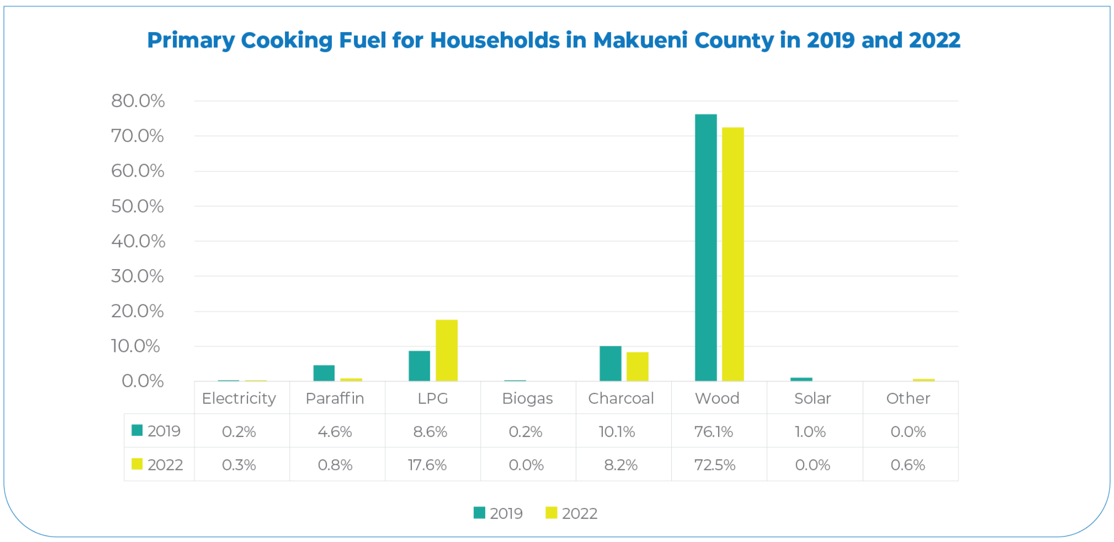


Figure 3-19: Primary cooking fuel in Makueni County

Access to clean cooking fuels (i.e. sum of electricity, LPG, biogas, solar etc.) in Makueni County increased from 10% in 2019 to 17.9% in 2022. LPG, which registered an increased adoption rate from 8.6% in 2019 to 17.6% in 2022, was the leading cooking fuel (KNBS, 2019 & primary data collection). The increased LPG adoption could be attributed to the increasing availability of the fuel across the country and the implementation of national government policies geared towards promotion of LPG adoption, for instance VAT exemption since 2016. Adoption of LPG is highest in Kibwezi West where the use of firewood is the lowest. This shows that there is a strong relationship in fuel switching.

Despite the increased LPG adoption, during focus group discussions, some respondents reported that rising costs of LPG had caused some households to abandon the fuel, and switch to firewood. This can be attributed to the re-introduction of VAT on LPG in 2021, which caused a significant price increase. In 2023/2024, the Government of Kenya scrapped the VAT on LPG. Further surveys should be undertaken to understand the impact of this price decrease. The clean cooking access in Makueni County is two percentage points below the national average, which stands at 20% as of 2023 (SDG report, 2023).

In 2022, 29.2% of Makueni households had access to grid electricity, although only 0.3% use it to cook. This low adoption may be a question of many factors, including but not limited to: 1) lack of awareness on e-cooking, 2) cost of electric cookstoves, 3) affordability and reliability of electricity supply. According to IEA (2023) low reliability can make consumers reluctant to adopt electric cooking as their primary cooking solution. Makueni County can promote the uptake of electric cooking solutions, especially in urban areas where electricity is more reliable.

As shown in Figure 3-20 below, 67% of households in Makueni still use inefficient three-stone open fire as the main technology for cooking, followed by metallic charcoal stoves (33%) and LPG (21%). Fuel stacking is not taken into consideration. During the focus group discussions, it emerged that households primarily rely on three-stone open fire because of the high costs of improved cookstoves. A challenge reported by users of clean cookstoves was the quality of the products. In some cases, users reported that the products only lasted for 6 months. The users were disappointed as they had purchased the cookstoves on credit, only to discover that they never delivered the services they had envisioned.

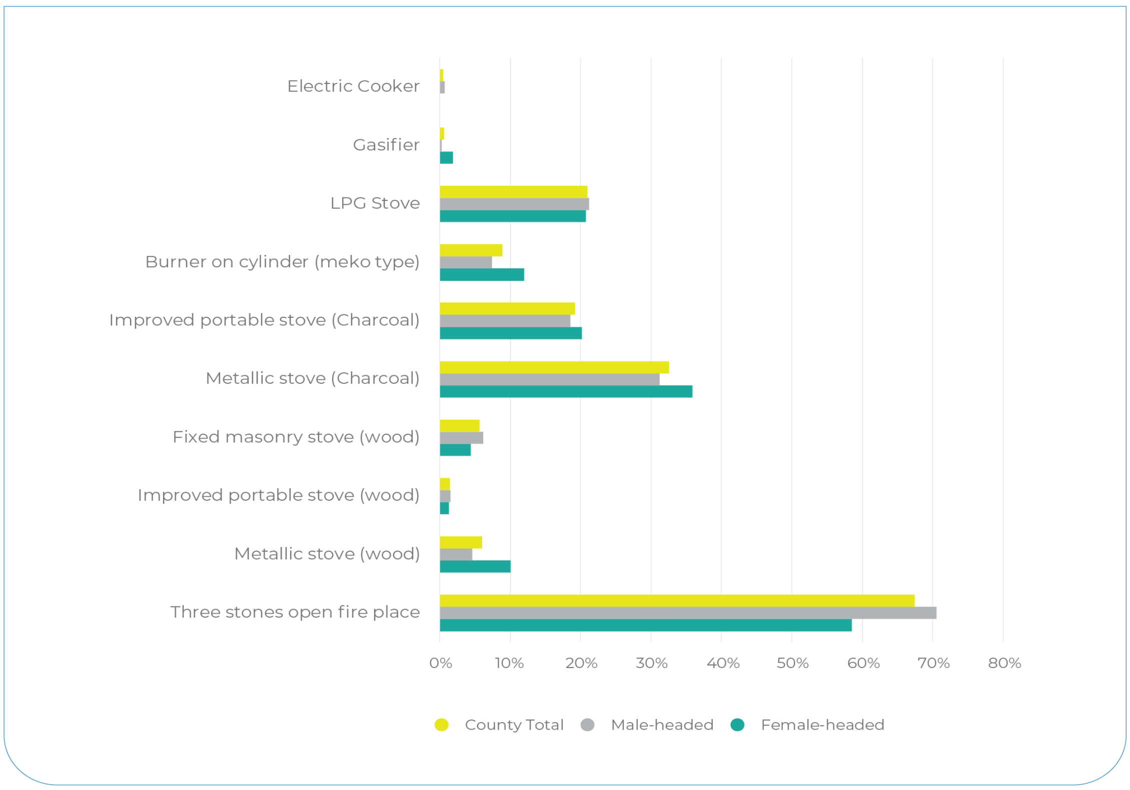


Figure 3-20: Technologies used by households for cooking.

3.3.2 Energy for Cooking Access: Educational facilities (Learning institutions)

Based on the primary data collection, 95 % of learning institutions in Makueni County cook meals using firewood as the primary fuel while only 1.4% and 1.1% use LPG and charcoal respectively, as shown in Figure 3-21. There is little variation between rural and urban and across sub-counties. When asked about the second main source of energy for cooking, 60% of the schools had no alternative fuels while 29.9% and 5.2 % selected charcoal and LPG, respectively, as their secondary fuel.

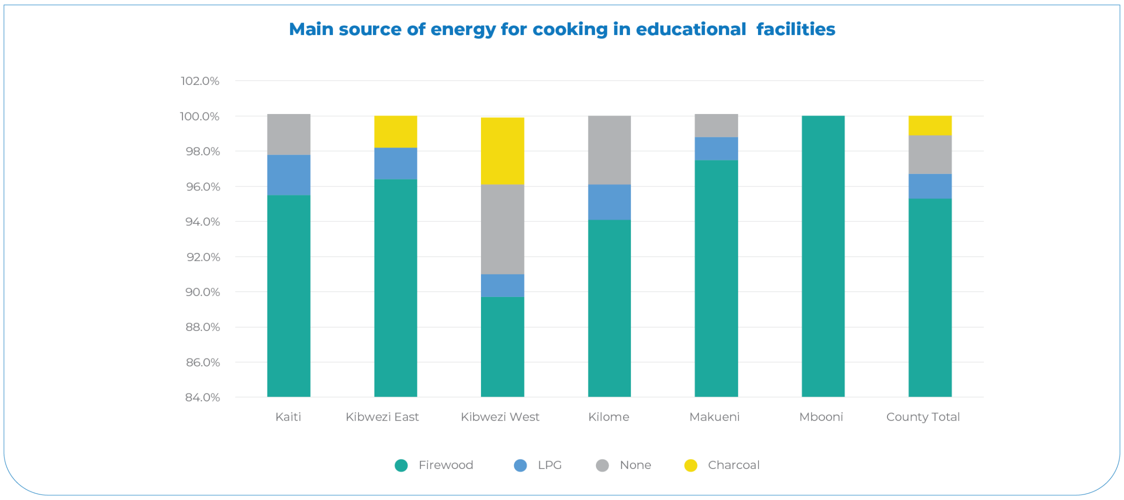


Figure 3-21: Primary source of energy for cooking in educational facilities

Given an opportunity to transition from the current primary fuel for cooking, most of the institutions preferred LPG, followed by biogas, then electricity as shown in Figure 3-22. This showed that most institutions aspire to have modern cooking fuels. There are also indications that the schools have biogas potential since it is chosen as the second most preferred fuel.

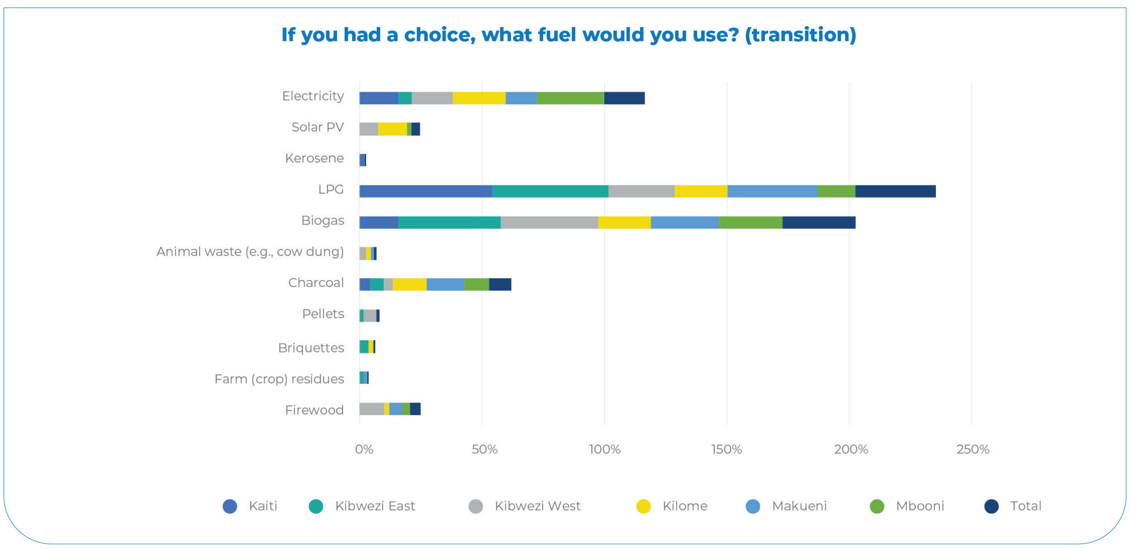
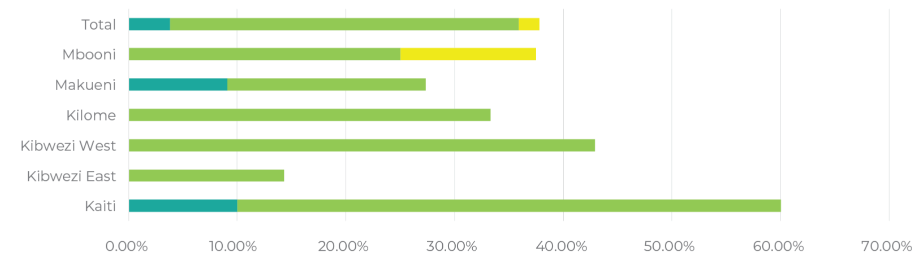


Figure 3-22: Willingness of education facilities to transition to modern cooking fuels.

3.3.3 Energy for Cooking Access: Health Care Facilities (HCFs)

Overall, 37.7% of health care facilities have a kitchen for cooking (primary data collection) of which 32.1% use LPG as the main fuel for cooking, followed by charcoal and firewood at 3.8% and 1.9% respectively. However, there is a significant variation across the sub-counties as shown in Figure 3-23.



	Kaiti	Kibwezi East	Kibwezi West	Kilome	Makueni	Mbooni	Total
Charcoal	10.00%	0%	0%	0%	9.10%	0%	3.80%
LPG	50.00%	14.30%	42.90%	33.30%	18.20%	25.00%	32.10%
Firewood	0%	0%	0%	0%	0%	12.50%	1.90%

Charcoal LPG Firewood

Figure 3-23: Primary fuel for cooking used by health care facilities

3.3.4 Energy for Cooking Access: MSMES

Thirty-three percent of the MSMEs that were surveyed cook in their premises with the primary fuel being firewood (14.3%) followed by charcoal (11.4%) then LPG (4.1%), electricity (1.7%), kerosene (1%) and biogas (0.2%) as shown in Figure 3-24. Interventions that encourage use of firewood ICS, LPG and electricity should be adopted by MSMEs to transition from firewood, charcoal and kerosene use.

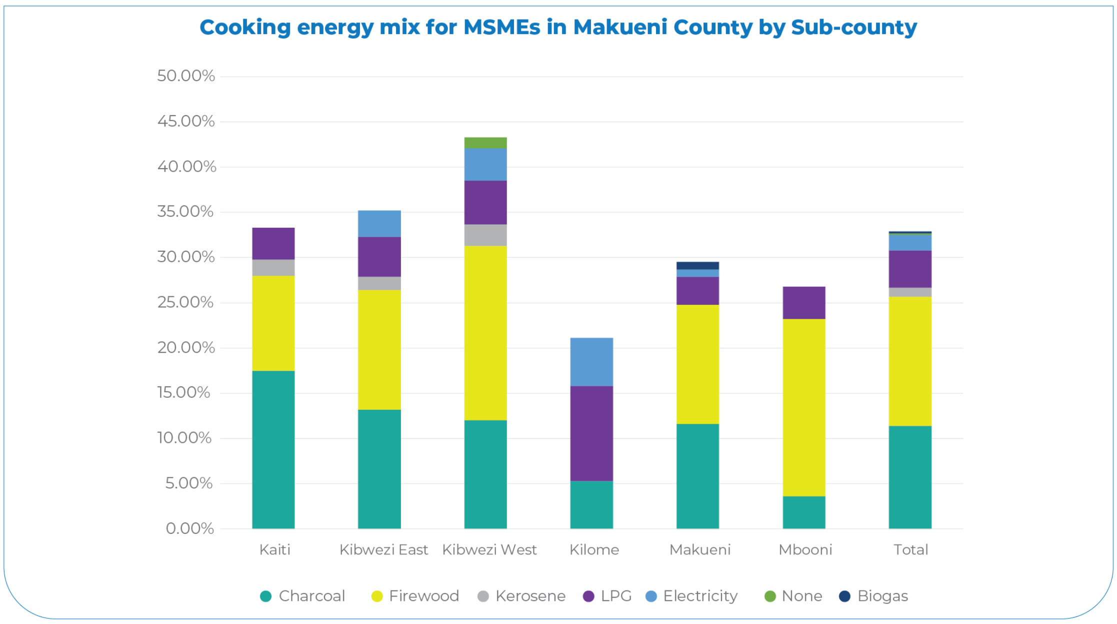
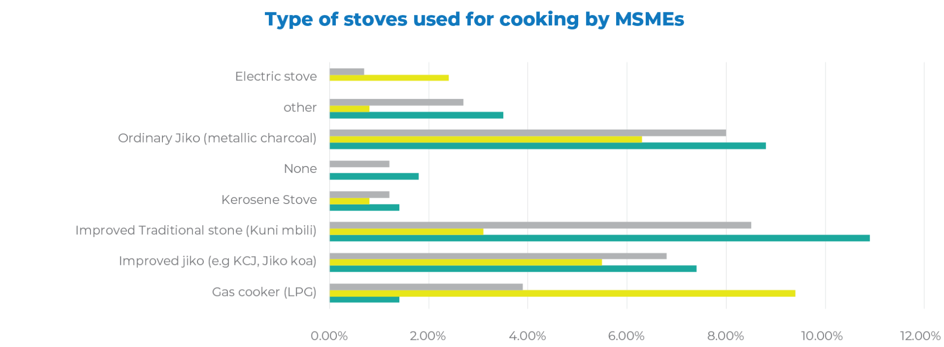


Figure 3-24: Cooking energy mix for MSMEs in Makueni County

The stoves used by MSMEs for cooking are shown in Figure 3-25.



	Gas cooker (LPG)	Improved jiko (e.g KCJ, Jiko koa)	Improved Traditional stone (Kuni mbili)	Kerosene Stove	None	Ordinary Jiko (metallic charcoal)	other	Electric stove
Total	3.90%	6.80%	8.50%	1.20%	1.20%	8.00%	2.70%	0.70%
Urban	9.40%	5.50%	3.10%	0.80%	0%	6.30%	0.80%	2.40%
Rural	1.40%	7.40%	10.90%	1.40%	1.80%	8.80%	3.50%	0%

Total Urban Rural

Figure 3-25: Types of stoves used for cooking by MSMEs

From the preceding analysis, it is seen that only healthcare facilities have a significant penetration of clean fuels for cooking with households, learning institutions and SMEs having a high consumption of firewood. A bioenergy balance shown in Figure 3-26 below compares biomass consumption to sustainable supply of biomass from all the consumer categories in all the sub-counties of Makueni. It shows that Makueni County is operating at a deficit of sustainable biomass (firewood and charcoal). As such, it is imperative that a transition to other sources of bioenergy be undertaken, and other fuels such as LPG and electricity used for cooking.

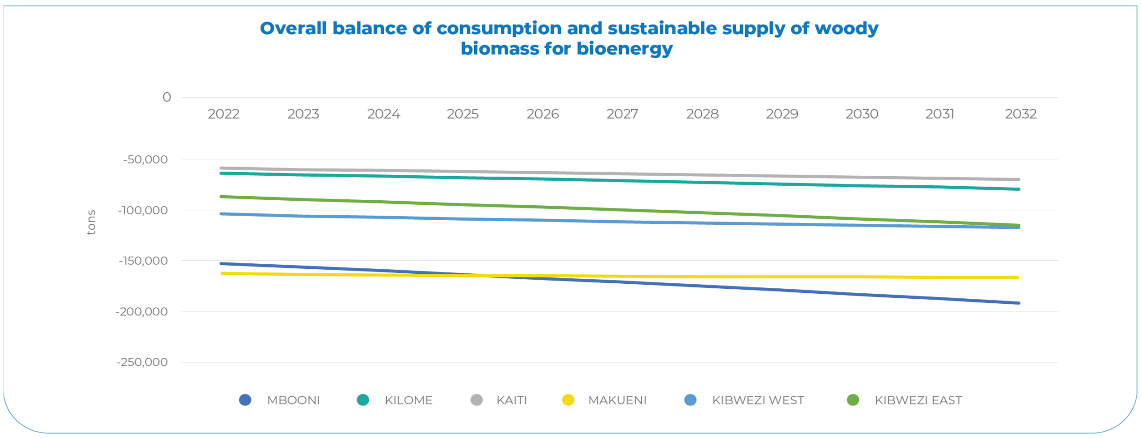


Figure 3-26: Bioenergy Balance in Makueni County

3.3.5 Outlook for clean cooking access

Three cooking sector scenarios were designed and analyzed using the Low Emission Analysis Platform (LEAP) tool. LEAP is an integrated, scenario-based modelling tool originally developed by the Stockholm Environment Institute to track energy consumption, production, and resource extraction in all sectors of an economy, including cooking. LEAP is typically used at the national scale although it also works for cities, regions, and multi-country analyses.[54] The scenarios were:

54 LEAP: Low Emissions Analysis Platform (sei.org)

1. Baseline scenario - This scenario represented the Business-As-Usual (BAU)/reference scenario, which included only the current initiatives such as the MoE Behavioral Change Communication (BCC) Campaign, construction of demonstration biogas plants, and elimination of VAT on LPG as from August 2023, in line with current government policy.
2. Policy Scenario - This scenario was designed to assess the effect of additional policy interventions besides current government practices aimed at promoting the adoption of clean cooking technologies and fuels within the county. The assessment also encompasses transitional technologies such as the Improved wood and charcoal cookstoves (Tier 2 and 3) in the development pathway. It proposed 25% Improved Cookstoves (ICS) Subsidy to bridge the affordability gap to incentivize the transition from TSOF to higher tier cookstoves, especially in rural areas.
3. SDG Scenario - This scenario was designed to achieve the SDG target of universal access to clean and modern cooking energy by 2028 as per national clean cooking targets. It was built around the vision that the economic growth will be as per the economic blueprint vision 2030, where the annual GDP growth rate is 10%, and the people have the capacity in terms of resources to transition to modern clean cooking solutions across the county. It sought to achieve a complete phase out of unsustainable solid biomass in combination with traditional stoves and kerosene stoves by 2028. Modern energy for cooking solutions such as the use of LPG, Bioethanol, Electricity and Biogas will be adopted as the primary mode of cooking in all the sectors of the county.

The LEAP modelling tool allowed for sectoral demand analysis that is linked to the type of devices in use, i.e. households, institutions, and SMEs, through a hierarchical tree to account for bottom-up end use energy accounting system. Detailed modelling data and assumptions are provided in Annex B.4.The modelling results showed that with the adoption of clean cooking solutions, the cooking energy demand reduced significantly as can be seen in Figure 3-27. This is due to the high efficiency of the modern clean cookstoves, coupled with the high calorific value of the clean cooking solution such as e-cooking, LPG, bioethanol, and biogas, as compared to firewood and charcoal. The total demand of energy in 2032 from 5.2million GJ to 4.1 million GJ, to 3.1 million GJ and to 2.0 million GJ under BAU, Policy and SDG7 Scenarios respectively, is as shown in Figure 3-27

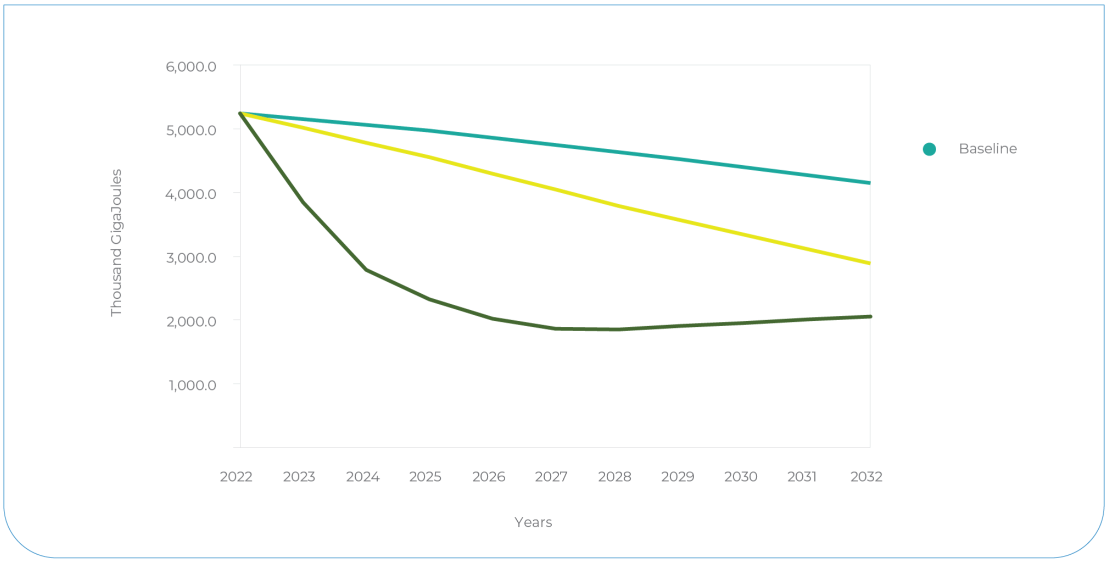


Figure 3-27: Energy Demand Comparison per Scenario (2022-2032)

The total cost of implementing the Baseline scenario is USD 286 Million (including the cost of policy interventions currently in use by the National Government). Implementing the Policy scenario will cost USD 298 Million, while the SDG 7 is USD 380 Million, as shown in Figure 3-28.

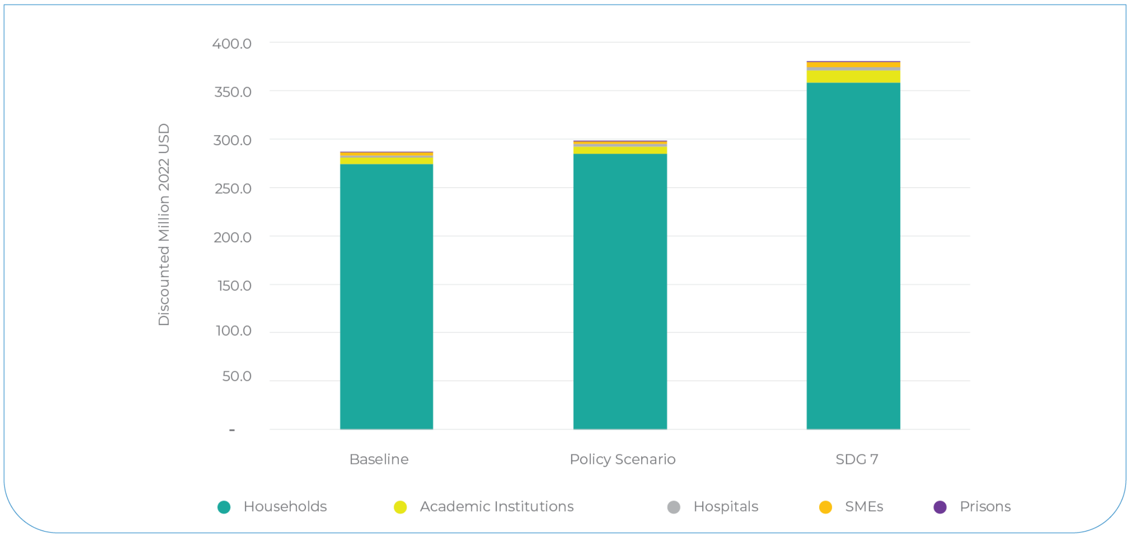


Figure 3-28: Cumulative Cost 2022-2032 Per Scenario Discounted at 10% to 2022

The consumption of electricity for cooking increases in all the scenarios. The demand increases from 0-0.05MW, 0-2.5MW and 0-6.8MW in baseline, policy, and SDG scenarios respectively.

3.3.5.1 BAU Scenario

The demand for cooking energy under baseline scenario is dominated by firewood as can be seen in Table 3-25 and Figure 3-29, even though the prevalence of the three stone open fire (TSOF) reduces from 4% to 0 by 2030, and 75% to 40% by 2032 in urban and rural HH respectively. The consumption of firewood reduces from 224,150 Tonnes to 186,000 tonnes following a slow adoption of ICS. The consumption of charcoal also reduces from 47,200Tonnes to 16,860Tonnes with adoption of ICS as opposed to use of the ordinary metallic charcoal stove that is quite prevalent at 38%. Consumption of LPG increases from 7,000Tonnes to 15,800Tonnes as more citizens adopt/stack LPG. Biomass, which in this case refers to briquettes and pellets, does not feature in the cooking energy mix.

Table 3-25: Changes in demand of main fuels under BAU scenario

Cooking fuel	Base year (2023)	End year (2032)	% change
Firewood (tonnes)	224150	186000	-17.0%
Charcoal (tonnes)	47200	16860	-64.3%
LPG (tonnes)	7000	15800	125.7%

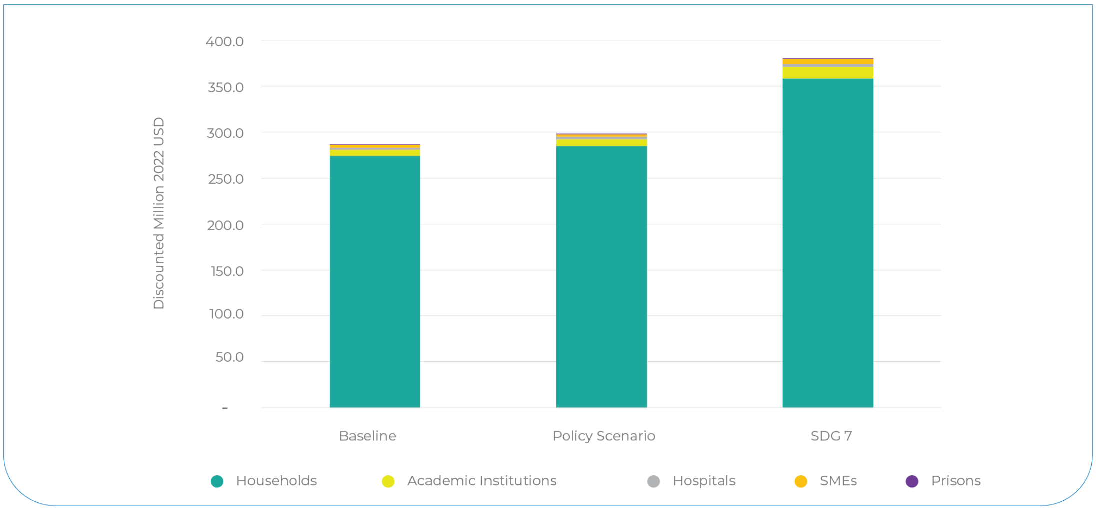


Figure 3-29: Energy Demand under Baseline Scenario (2022-2032)

Analysis of the energy demand per sector as shown in Figure 3-30 indicates that the greatest share is consumed by the households. Consequently, interventions on efficiency and/or switching from the traditional cooking solutions to clean cooking solutions for the household sector would contribute significantly to reducing the energy demand in Makueni County.

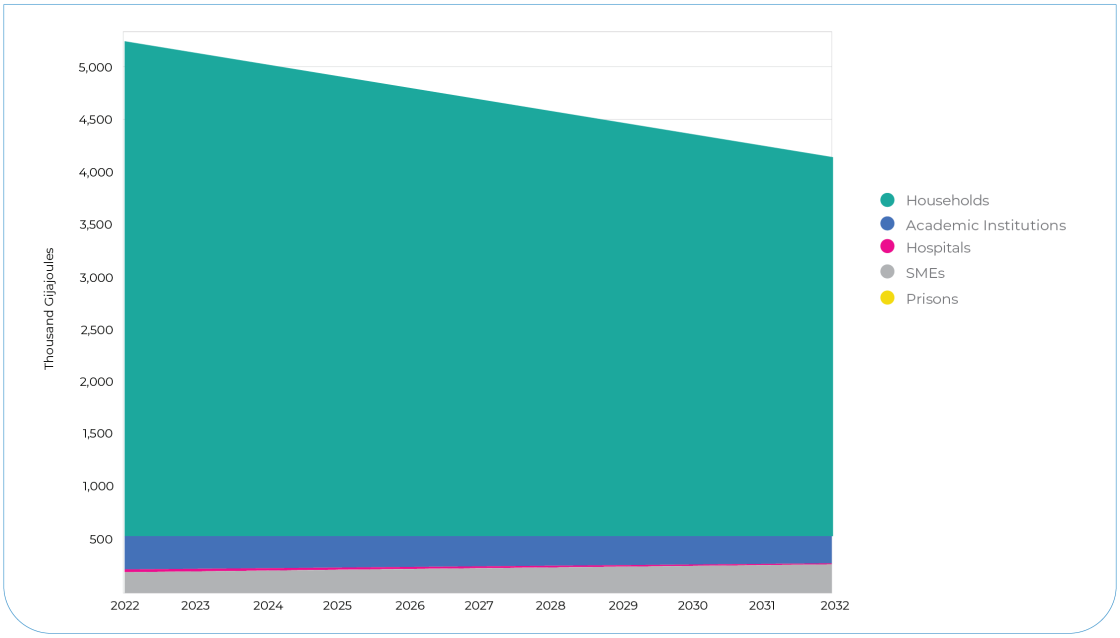


Figure 3-30: Energy Demand per sector under Baseline Scenario (2022-2032)

Table 3-26, Table 3-27, Table 3-28, and Table 3-29 provide percentages of households, learning institutions and hospitals using various technologies for cooking.

Table 3-26: Percentage of Households using different cooking Technologies in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
TSOF	61	59	57	55	53	51	48	46	44	42	40
Improved Wood Cook-stoves	12	13	14	15	16	18	19	20	21	22	24
Metallic Char-coal Stove	5	4	3	2	1	0	-	-	-	-	-
Improved Char-coal Stove	3	4	4	5	5	6	6	7	7	8	8
Advanced Biomass Stove Gasifier and other Tier 3+ stoves	-	-	-	-	-	-	-	-	-	-	-
Bioethanol stove	-	-	-	-	-	-	-	-	-	-	-
LPG Stove	18	20	22	24	27	29	31	33	36	38	40
Electric Hot plate/coil	-	-	-	-	-	-	-	-	-	-	-
Electric Pres-sure cooker	-	-	-	-	-	-	-	-	-	-	-

Table 3-27: Percentage of Learning Institutions using different Stoves in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
3-Stone	34	32	29	27	24	22	20	17	15	12	10
Institutional Rocket stove	49	51	53	55	57	59	61	64	66	68	70
Traditional Metallic Charcoal Stove	24	22	19	17	14	12	10	7	5	2	0
Improved Charcoal Stove	16	15	14	13	12	11	9	8	7	6	5
LPG	5	6	7	8	9	10	11	12	13	14	15
Biogas	3	3	3	4	4	4	4	4	5	5	5

Table 3-28: Percentage of Healthcare facilities using different Stoves in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Traditional Metallic Charcoal Stove	30	27	24	21	18	15	12	9	6	3	0
LPG Stoves	70	73	76	79	82	85	88	91	94	97	100
Gasifier Stoves	0	1	2	3	4	5	6	7	8	9	10
EPC-Institutional	0	1	2	3	4	5	6	7	8	9	10

Table 3-29: Percentage of SMEs using different Stoves in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Wood Improved Cookstoves (ICS)	34	33	31	30	28	27	26	24	23	21	20
Traditional Metallic Charcoal Stove	47	42	38	33	28	24	19	14	9	5	0
Improved Charcoal Stove	30	28	26	24	22	20	18	16	14	12	10
Gasifier Stoves	0	2	4	6	8	10	12	14	16	18	20
Kerosene	4	4	3	3	2	2	2	1	1	0	0
LPG	21	23	25	27	29	31	32	34	36	38	40
Electric	4	5	5	6	6	7	8	8	9	9	10

3.3.5.2 Policy Scenario

The energy demand under the Policy scenario largely reduces as shown in Figure 3-31. To complement the National Government initiatives and policies on clean cooking, the County Government provides incentives for households, especially those in the rural areas, to purchase firewood-based ICS. This includes a 25% subsidy on the price of the ICS. This scenario does not eliminate firewood and charcoal. It should also be noted that advanced biomass stove gasifiers and other Tier 3+ stoves are technologies used to burn briquettes and pellets. Thus, the undefined biomass in the graph under this scenario represents briquettes/pellets in the fuel tables.

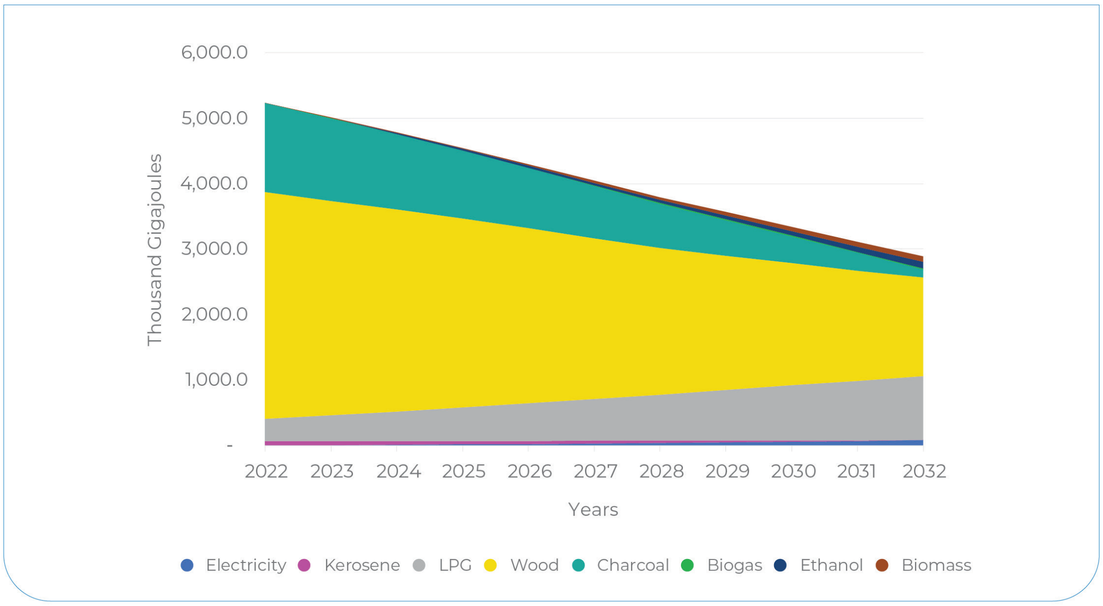


Figure 3-31: Energy Demand under the Policy Scenario (2022-2032)

As shown in Table 3-30 below, the demand for firewood and charcoal reduces while the demand for LPG increases. A total investment of KES 169.16 million over the implementation period of the CEP is required to increase penetration of ICS to 55% across the county. The proposed 25% Improved Cookstoves (ICS) Subsidy aims to bridge the affordability gap to incentivize the transition from TSOF, especially in rural areas to higher tier cookstoves. The implementation of this subsidy will require a total investment of 4.7Million per year as shown in Table 3-31 below.

Table 3-30: Changes in cooking fuel demand between 2023 and 2032 under Policy Scenario

Cooking fuel	Base year (2023)	End year (2032)	%Change
Firewood	224150	96890	-56.8%
Charcoal	47200	4355	-90.8%
LPG	7000	20700	195.7%

Table 3-31: Improved Cookstove investment analysis

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
ICS (Penetration)	15%	19%	23%	27%	31%	35%	39%	43%	47%	51%	55%	
No. of HH	23,753	29,863	35,840	41,661	47,046	52,145	56,924	61,349	65,382	68,986	72,119	
Target ICS Installation/ year	N/A	N/A	6,655	6,499	6,064	5,777	5,458	5,103	4,712	4,283	3,812	44551
Investment required (Million Ksh)	N/A	N/A	23.29	22.75	21.22	20.22	19.00	17.86	16.49	14.99	13.34	169.16
Budget for ICS Subsidy 25% (Million Ksh)	N/A	N/A	5.82	5.70	5.31	5.06	4.78	4.47	4.12	3.75	3.34	42.35

Implementing this policy would require the following interventions:

1. An average investment of KES 18.9 million annually or KES 169.16 million over the implementation period to increase penetration of ICS to 55% across the county.
2. A 25% improved cookstove subsidy representing KES 4.7 million per year.
3. Significant promotion of LPG cookstoves and enterprises, and moderate promotion of biomass,

ethanol, biogas, and electricity.

4. Training of ICS and biogas technicians.
5. Initiatives that improve households' income so that they can purchase the stoves and fuels.

Table 3-32, Table 3-33, Table 3-34, and Table 3-35 show the percentage of households, learning institutions, hospitals and SMEs using various cooking fuels and technologies.

Table 3-32: Percentage of Households using different cooking Technologies in the County

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
TSOF	61	55	49	43	37	31	24	18	12	6	-
Improved Wood Cookstoves	12	16	20	24	29	33	37	42	46	50	55
Metallic Charcoal Stove	5	4	3	2	1	-	-	-	-	-	-
Improved Charcoal Stove	3	4	5	5	6	7	6	6	6	6	5
Advanced Biomass Stove Gasifier and other Tier 3+ stoves	-	1	2	2	3	4	5	5	6	7	8
Bioethanol stove	-	1	2	2	3	4	5	5	6	7	8
LPG Stove	18	21	24	27	30	34	37	40	43	46	50
Electric Pressure cooker	-	0	1	1	1	2	2	2	3	3	4
Biogas	-	0	1	1	1	2	2	2	3	3	4

Table 3-33: Percentage of Educational Institutions using different Stoves in the County

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
3-Stone	34	28	23	17	11	6	0	0	0	0	0
Institutional Rocket stove	49	54	59	64	69	74	79	85	90	95	100
Traditional Metallic Charcoal Stove	24	22	19	17	14	12	10	7	5	2	0
Improved Char-coal Stove	16	14	13	11	10	8	6	5	3	2	0
LPG	5	7	8	10	11	13	14	16	17	19	20
Biogas	3	4	4	5	6	7	7	8	9	9	10

Table 3-34: Percentage of Healthcare Facilities using different Stoves in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Traditional Metallic Charcoal Stove	30	27	24	21	18	15	12	9	6	3	0
LPG Stoves	70	73	76	79	82	85	88	91	94	97	100
Gasifier Stoves	0	2	3	5	6	8	9	11	12	14	15
EPC-Institutional	0	2	3	5	6	8	9	11	12	14	15

Table 3-35: Percentage of SMEs using different Stoves in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Wood Improved Cookstoves (ICS)	34	32	30	28	26	25	23	21	19	17	15

Traditional Metallic Charcoal Stove	47	42	38	33	28	24	19	14	9	5	0
Improved Charcoal Stove	30	28	25	23	20	18	15	13	10	8	5
Gasifier Stoves	0	3	5	8	10	13	15	18	20	23	25
Kerosene	4	4	3	3	2	2	2	1	1	0	0
LPG	21	23	25	27	29	31	32	34	36	38	40
Electric	4	5	6	7	8	10	11	12	13	14	15

3.3.5.3 SDG 7 Scenario

The total demand for cooking energy under the SDG scenario, which completely phases out the use of solid biomass by 2028, as well as other polluting fuels, reduces significantly from 5.2Million GJ to 2.0Million GJ as can be seen in Figure 3-32. The only exception in the SDG scenario as far as the use of solid biomass is concerned is in the SMEs sector, which transitioned from using charcoal stoves for roasting meat, tubers, and corn to using gasifier stoves with fans (Tier 4) together with pellets/ briquettes.

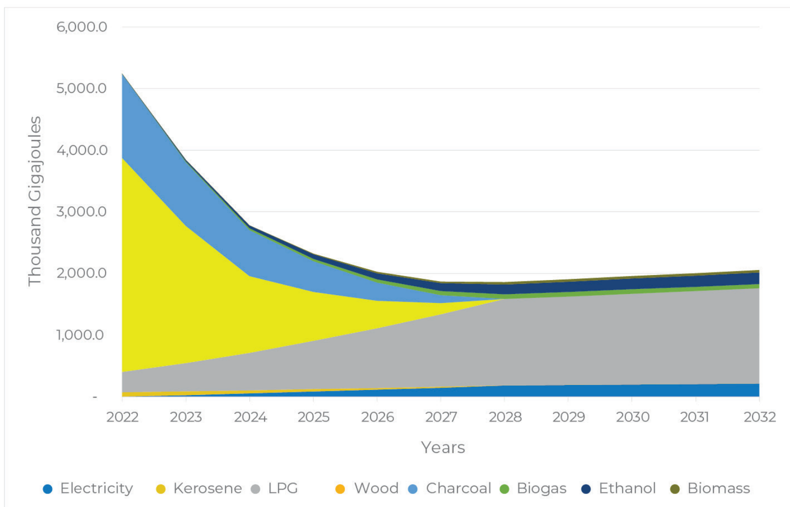


Figure 3-32: Energy Demand under the SDG 7 Scenario (2022-2032)

The businesses are expected to continue using sustainably sourced pellets/briquettes, driven by the cultural preference and taste for roasting among the people. The increasing demand for the briquettes/pellets constitutes 0-2% of the total demand across the planning horizon, hence it can be met sustainably. The demand for LPG also increases as LPG becomes the main primary cooking fuel across all the sectors. Changes in demand across various fuels is highlighted between 2023 and 2032 are shown in Table 3-36 below.

Table 3-36: Changes in cooking fuel demand between 2023 and 2032 under SDG7 Scenario

Cooking fuel	Base year (2023)	End year (2032)	%Change
Firewood	224,150	0	-100.0%
Charcoal	47,200	0	-100.0%
LPG	7,000	20,700	365.7%
Pellets/briquettes	500	2,000	300.0%
Biogas			

To enhance the penetration of both 6kg and 13kg LPG across rural and urban areas, an average investment of KES 124 million annually, including subsidies, is required as shown in Table 3-37 below. To complement the national Government initiatives on transitioning to clean cooking, an investment analysis was conducted for a 10% subsidy for 6KG LPG meko. The required budget is on average KES 5 million annually, as shown in Table 3-37.

Table 3-37: Cookstove Penetration Rate and Investment Data

Urban HH Penetration	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Meko 6Kg	16%	18%	20%	22%	24%	26%	27%	29%	31%	33%	35%
Multiple Burner (13KG)	61%	62%	63%	64%	65%	66%	66%	67%	68%	69%	70%
Rural HH Penetration	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Meko 6Kg	8%	14%	20%	27%	33%	39%	45%	51%	58%	64%	70%
Multiple burner (13 KG)	16%	18%	21%	23%	26%	28%	30%	33%	35%	38%	40%
Investments & Subsidy Required	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Investment required (USD) LPG 6Kg	-	-	342,250	346,460	348,615	350436	351,781	352,615	352,899	352,594	351,661
Investment required LPG 13Kg	-	-	450,916	462,404	487,481	498,882	510,353	521,885	533,467	545,086	556,732
Subsidy Budget (Ksh) LPG 6Kg	-	-	4,962,618	5,023,670	5,054,912	5,081,325	5,100,831	5,112,913	5,117,032	5,112,618	5,099,077
Subsidy Budget (USD) LPG 6Kg	-	-	34,224	34,646	34,861	35,043	35,178	35,261	35,290	35,259	35,166
Subsidy Budget (Ksh) LPG 13Kg	-	-	6,538,281	6,704,857	7,068,476	7,233,789	7,400,123	7,567,333	7,735,264	7,903,751	8,072,615
Subsidy Budget (USD) LPG 13Kg	-	-	10,754	11,028	11,626	11,898	12,171	12,446	12,722	13,000	13,277
Total Subsidy budget (Ksh)	-	-	1,150,0899	11,728,528	12,123,389	12,315,115	12,500,954	12,680,247	12,852,297	13,016,370	13,171,693
Total Subsidy budget (USD)	-	-	44,979	45,674	46,487	46,941	47,349	47,708	48,012	48,259	48,443

Implementing this policy would require the following interventions:

1. An average of KES 124 million annually to increase penetration across rural and urban areas.
2. A10% subsidy for 6 KG LPG, translating to KES 5 million per year.
3. Ambitious promotion of LPG, ethanol, and electricity.
4. Improving people's livelihoods so that they can afford energy services and appliances.
5. Promotion of biogas in rural areas and SMEs utilizing the market & abattoir large scale digesters developed under the Public Private Partnership (PPP) framework.
6. Training of biogas technicians (refer to Chapter 6 for detailed interventions)

Table 3-38, Table 3-39, Table 3-40, and Table 3-41 below show the percentage of households, learning institutions, hospitals, and SMEs using the different cooking fuels and technologies.

Table 3-38: Percentage of households using different cooking technologies in the County-SDG 7 Scenario

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
TSOF	61	49	37	24	12	-	-	-	-	-	-
Improved Wood Cook-stoves	12	9	7	5	3	1	-	-	-	-	-
Metallic Charcoal Stove	5	4	3	2	1	-	-	-	-	-	-
Improved Charcoal Stove	3	3	2	1	1	-	-	-	-	-	-
Advanced Biomass Stove Gasifier and other Tier 3+ stoves	-	-	-	-	-	-	-	-	-	-	-
Bioethanol stove	-	-	2	3	5	7	8	10	12	13	15
LPG Stove	18	30	42	55	67	80	92	100	100	100	100
Electric Pressure cooker	-	1	2	3	5	6	7	8	9	10	10
Biogas Stoves	-	1	2	2	3	4	5	6	6	7	8

Table 3-39: Percentage of Educational Institutions using different Stoves in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
3-Stone	34	31	27	24	20	17	14	10	7	3	0
Institutional Rock-et stove	49	44	39	34	29	24	19	15	10	5	0
Traditional Metallic Charcoal Stove	24	22	19	17	14	12	10	7	5	2	0
Improved Char-coal Stove	16	14	13	11	10	8	6	5	3	2	0
LPG	5	15	24	34	43	53	62	72	81	91	100
Biogas	3	5	6	8	10	12	13	15	17	18	20

Table 3-40: Percentage of Hospitals using different Stoves in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Traditional Metallic Charcoal Stove	30	27	24	21	18	15	12	9	6	3	0
LPG Stoves	70	73	76	79	82	85	88	91	94	97	100
Gasifier Stoves	0	0	0	0	0	0	0	0	0	0	0
EPC-Institutional	0	5	10	15	20	25	30	35	40	45	50

Table 3-41 : Percentage of SMEs using different Stoves in the county

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Wood Improved Cookstoves (ICS) (%)	34	28	23	17	11	6	0	0	0	0	0
Traditional Metallic Charcoal Stove (%)	47	39	31	24	16	8	0	0	0	0	0
Improved Charcoal Stove (%)	30	25	20	15	10	5	0	0	0	0	0
Gasifier Stoves (%)	0	5	10	15	20	25	30	30	30	30	30
Kerosene (%)	4	3	3	2	1	1	0	0	0	0	0
LPG (%)	21	34	47	61	74	87	100	100	100	100	100
Electric (%)	4	7	9	12	15	17	20	20	20	20	20
Biogas Stoves (%)	0	0.8	1.7	2.5	3.3	4.2	5	5	5	5	5

3.4 BARRIERS TO CLEAN COOKING SOLUTIONS ACCESS

The major barriers to scaling up deployment of clean cooking technologies in Makueni County are highlighted in Table 3-42 below.

Table 3-42: Barriers to clean cooking access in Makueni County

Barrier	Description of key issues
Institutional Barriers	• Clean cooking access is usually hindered by fragmented objectives between ministries (departments) e.g., between energy and environment departments. • To date, it is not clear which department in Government of Makueni County is championing clean cooking and there is no roadmap for its development. • Cooking fuel/technologies have not been accorded attention e.g., little attention is given to cooking technologies in key government documents e.g. CIDP, ADPs etc. • Official data regarding cooking fuels, technologies, producers etc. in is not available.
Policy shifts	As highlighted in section 3.3.1, rising costs of LPG due to reintroduction of VAT had pushed some households to abandon the fuel and switch to firewood.
Limited Fuel and Stove supply (ICS, LPG, Ethanol stoves etc.)	ICS producers are small-scale. LPG Supply chain is limited mainly to major urban areas like Wote, Kibwezi etc. with little presence in village trading centres.
Low income	Low incomes and lack of infrastructure in rural areas undermine the initiative to convert rural household cooking to LPG, bioethanol, e-cooking etc.
Low access to reliable electricity	Besides perception of high cost of cooking using electricity, low rates of reliable electricity access (currently at 29%) is also a major barrier to electric cooking.
Cost/Affordability	Most households in Makueni still depend on firewood because they collect it from the local environment freely (rural) or purchase at low prices (urban) compared to most modern fuels. So they are unlikely to switch to modern fuels if they are unaffordable.
Limited awareness of clean cooking fuels and technologies	Most people of Makueni are not aware of clean cooking fuels and technologies e.g. bioethanol, e-cooking etc.

3.5 CLEAN COOKING INTERVENTION OPTIONS

These interventions are based on the general clean cooking access situation in Makueni County, and it is aligned to the implementation of the Policy Scenario. More details are provided in Chapter 6.

- Achieving universal access to clean cooking will depend on strong leadership commitment and programmes domiciled at the energy department and reinforced by financial support.
- Significantly strengthening and intensifying/expanding LPG distribution network by provision of fiscal incentives for LPG stoves and cylinders that target low-income households.
- Supporting the implementation of 25% Improved biomass cookstoves (ICS) subsidy at a budget of KES 4.7 million per year, especially for households in remote and rural areas. Further, increasing the adoption of ICS from 15% to 55%, translating to 5568 ICS units per year (under Policy Scenario).
- Promotion of bio-ethanol stoves and fuel through enhanced distribution, incentivising the cookstoves, and creation of awareness at grassroots, especially targeting women and youth.
- Promotion of large-scale digesters (e.g. abattoirs, schools etc.) developed under the Public- Private Partnership (PPP) framework and domestic biodigesters in suitable areas e.g. where there is enough agricultural or farming waste.
- Promotion of electric cooking in urban areas where electricity supply is more reliable and incomes better through incentivized electric cookstoves in partnerships with EPC providers, MFIs etc. and supporting the implementation of national e-cooking strategy (under development) in the county.

- Partnering with organisations to support school cooking programs e.g. World Food Program to promote clean cooking in schools and communities as well as to explore access to carbon markets.

3.6 RECOMMENDATIONS

The following recommendations are made as a result of the analysis in this chapter.

3.6.1 Policy recommendations

- Develop strong leadership commitment and programmes that are reinforced by financial support and qualified staff domiciled at the energy department.
- At the county level, develop and promote public-private partnerships (PPP) policies/guidelines to help mobilise resources for health care facilities, water utilities, and the productive uses of energy in the agricultural sector, targeting smallholder farmers.
- At the national level, lobby for predictable and stable policy environment and tax incentives for both off grid technologies and clean cooking fuels & technologies for a minimum of 5 years.
- Significantly strengthen and intensify/expand LPG, ICS and bioethanol distribution network by provision of fiscal incentives for LPG, ICS and bioethanol stoves and cylinders that target low-income households.

3.6.2 Financial Recommendations

- Provide additional funding allocation to energy projects or innovative financing models and bankable projects to help unlock finance.
- Scale up off grid service through a subsidy scheme, incorporating results-based financing (RBF), to facilitate electricity access for both households and productive use. This initiative aims to incentivize rapid deployment of mini-grids and SHSs with tariffs more comparable to the Kenya Power tariff.
- Scale up demand for productive uses of renewable energy (PURE) technologies by creating consumer subsidies that help smallholder farmers and large-scale producers to access the technologies at affordable prices.
- Improve affordability of clean cooking technologies through subsidization and provisions of low cost appliances. This can be achieved by, for example, supporting implementation of 25% Improved biomass cookstoves (ICS) subsidy at a budget of KES 4.7 million per year, especially for households in remote and rural areas (according to Policy Scenario).

3.6.3 Technical Recommendations

- Increase electricity access from 75.1% of today's population to universal access by 2028 via grid expansion, grid intensification & densification, mini-grids and SHSs.
- Support provision of access through the grid, mini-grids and SHSs with a least capacity of 50 W in rural areas (tier 2) to at least 200 W (tier 3) in urban areas to provide sufficient energy to stimulate productive uses with women and youth at the core.
- Install additional transformers on existing medium-voltage to connect households within and beyond 600 meters of existing distribution transformers.
- Prioritise income boosting projects (PURE), especially in agricultural value chains e.g. milk chilling, crop processing, and irrigation etc. to increase disposable income and improve the livelihoods.
- Build LPG infrastructure to serve increased demand: identify optimal locations/market centers to act as filling stations or micro distribution centres and prioritize them for private sector development.
- Introduce pilot projects to test the viability of community biodigesters (e.g. abattoirs, schools etc.) developed under the Public-Private Partnership (PPP) frameworks and domestic biodigesters in suitable areas e.g. areas with sufficient agricultural or farming waste.
- Work with Kenya Power to enhance stability of electricity from the grid to ensure viability of

e-cooking in urban areas. Incentivize electric cookstoves in partnerships with EPC providers, MFIs etc. and support implementation of national e-cooking strategy (under development) in the county.

- Partner with organisations supporting school cooking programs e.g. World Food Program to promote clean cooking in schools and communities as well as to explore access carbon markets.

3.6.4 Capacity Building and Awareness Creation

- Create a stakeholder engagement plan highlighting the electrification, clean cooking, PURE gaps and opportunities in Makueni, as well as the required role of public, private sector players and donor agencies in realizing the clean cooking opportunity.
- Develop a local technical and business training programme for both clean cooking and productive use of energy value chains focusing on youth, women, men, and PLWDs.

4.0 ENERGY EFFICIENCY AND CONSERVATION

Energy Efficiency (EE) entails using less energy to perform the same task, without compromising the quality of the goods or services. This entails adoption of efficient technologies and processes, which can perform the same tasks while consuming less energy. Energy Conservation (EC), on the other hand, is associated with reducing energy consumption through the prevention of wasteful use of energy (it is mainly behavioural change), for example switching off lights when a room is not in use. The use of alternative renewable sources of energy also contributes to energy conservation efforts.

This Chapter describes the assessment of energy efficiency and conservation (EE&C) practices in Makueni County. It covers county public buildings, households, public institutions, public health centres, and commercial industries as envisioned in the INEP guidelines.

In this assessment, two approaches were used as follows;

- A walk-through audit was used to conduct a detailed EE&C assessment for county buildings and county utility services such as water supply plants, energy intensive health facilities (level 4 & 5 hospitals) and energy intensive commercial industries. The walk-through audit involved observation and taking stock of the state of efficiency of buildings and appliances.
- A separate wider EE&C assessment was undertaken for less energy intensive county public facilities such as public educational institutions and health centers (level 3 & below), small MSME/cottage industries and households. This was done through surveys that involved face to face interviews with respondents and did not include appliance verifications as in the case of walk-through audits.

4.1 ENERGY EFFICIENCY AND CONSERVATION STANDARDS, BENCHMARKS AND GUIDELINES

The guidelines that were used to conduct energy efficiency assessments were obtained from the Kenya National Energy Efficiency Strategy that helped identify priority areas for energy efficiency in Kenya. The five identified priority sectors are as follows: households, buildings, industry & agriculture, transport, and power utilities. It also includes strategies and targets for the aforementioned priority sectors which have been presented in Annex C.1. Other standards that were used include the Minimum Energy Performance Standards to assess the efficiency of various appliances (described below). The Excellence in Design for Greater Efficiency (EDGE) tool was used to calculate Modern Energy Performance Standards (MEPS) for buildings.

Finally, guidelines from the Kenya Green Buildings Society were used to provide further recommendations to enhance efficiency of buildings and are described in section 4.1.3

4.1.1 Minimum Energy Performance Standards (MEPS)

The Energy (Appliances Energy Performance and Labelling) regulations, 2016, provided for establishments of Minimum Energy Performance Standards (MEPS) for appliances such as motors, fluorescent lamps, domestic refrigerators, and air conditioners. MEPS are the test procedures employed in the determination of the energy performance and guidelines for labelling of appliance energy performance rating. The higher the star rating, the higher the energy efficiency level. The KEBS standards referenced in this assessment are:

- KS 2449-1: 2013 (Rotating Electrical Machines): This standard indicates the MEPs for induction electric rated from 0.73kW and up to but not including 185 kW55 motors. One-star ratings are provided for the least efficient motors and three-star ratings for the most efficient.
- KS 2463: 2019 (Non-Ducted Air Conditioners): This standard specifies the ratings of a single-package and split-system non-ducted air conditioners. The energy efficiency of air conditioners is measured using the Energy Efficiency Ratio (EER) that is a ratio of cooling power output to power input. The EER relate to energy performance class rating of Star 1(least efficient) to Star 5(highest efficient).
- KS 2464-2: 2020 (Refrigerating Appliances): This standards provides MEPS for household and commercial refrigerators. The standard also specified class rating indices based on appliance annual energy consumption compared to standard annual energy consumption for a refriger-

ator class. The indices relate to energy performance class rating of Star 1(least efficient) to Star 5(highest efficient).

4.1.2 Excellence in Design for Greater Efficiency (EDGE)

EDGE (EDGE, 2022) is an online green building certification application that allows assessment of the most cost-effective ways to incorporate energy and water efficiency in buildings such as offices, homes, hotels, hospitals and retail spaces. It was developed by the International Finance Corporation (IFC), a member of the World Bank Group. The EDGE application can be used to model building efficiency metrics such as energy use index (EUI) that was used to provide energy performance metrics for building energy performance. It can be used to benchmark a base case scenario with minimal energy efficiency measures to an improved case where energy efficiency measures have been applied. The inputs to the model include building metrics such as annual energy consumption (electricity and fuels) and indoor floor area. The output of the model is EUI expressed as total energy used within a building in a year (kWh), per gross floor area (m^2) or equivalent of value units, normally presented as $kWh/m^2/yr$.

4.1.3 Kenya Green Building Society Guidelines

Guidelines for green buildings[56] also provide specific parameters that should be adopted in building design to enhance energy and water efficiency and focus on effective passive building design. This design incorporates solar thermal performance, water and energy conservation measures in the building orientation, building envelope and building appliances and fixtures. The goal is to minimise the requirements for heating and cooling by utilizing properties of the building skin materials. Additionally, the design encourages local renewable energy generation, solar water heating, as well as encouraging natural lighting during the day. The design also provides for use of efficient low flow water appliances and wastewater harvesting and recycling. Further details of the design guidelines have been presented in Annex C.2.

4.2 ENERGY EFFICIENCY AND CONSERVATION ASSESSMENT

Energy Efficiency and Conservation in Makueni County is the mandate of the Department of Infrastructure, Transport, Public Works, Housing and Energy. The department oversees the uptake of energy efficient infrastructure and appliances. Meetings with the county officers and subsequent review of their records revealed that while the records describing energy access and renewable energy penetration within the county are up to date, energy efficiency monitoring and documentation lags behind. This could be caused by lack of a functional energy management team. Energy management in the county is managed by project based ad hoc committees within the energy section of the Department of Infrastructure, Transport, Public Works, Housing and Energy who are appointed to address specific activities.

A training needs assessment carried out shows that most of the County Officers (67%) were not versed with the prevailing energy policy requirements and provisions of various regulations that govern energy efficiency. They thus require additional capacity building to mainstream energy efficiency and conservation. A similar observation was noted across the majority of commercial industries assessed. However, these industries possess the prerequisite skills, making policy training, coupled with technical training on energy management, sufficient for them to undertake this task.

Specific facilities such as agricultural value addition plants, public and commercial buildings, and institutions like hospitals prioritize operation and maintenance programs with significantly less attention on energy efficiency. Opportunities for energy efficient installations are then only available in new constructions and installations where modern efficient technology is used. Older facilities, on the other hand, continue utilising less efficient technology.

A key challenge in mainstreaming energy efficiency is the lack of a nationwide EE&C building code that would provide specific guidelines that can be adopted by counties. While the KNEECS, 2020 indicates that a national building code will be available in 2025, intermediary interventions such as development of county specific benchmarks/guidelines within the county may help counties to improve their energy efficiency at the local level.

56 IFC. Sintali. (March 2020). EDGE Expert Training: Guidelines for Green Buildings. Nairobi: IFC

It is worth noting that in Makueni, like rural counties with low energy access rates, funding is directed towards enhancing energy access, leaving energy efficiency significantly underfunded. This makes mainstreaming of EE&C activities a challenge. Identification of low hanging fruits coupled with capacity building to enhance county officers' capacity can be a starting point for mainstreaming energy efficiency.

4.2.1 County Office Buildings and Level 4&5 Hospitals

From the energy efficiency assessment carried out, the dominant energy consuming appliances in County buildings were for lighting, air conditioning and refrigeration. Air conditioning appliances were only found in selected executive offices, server rooms, and speciality treatment rooms in the case of the hospitals. Cooking and hot water systems were only assessed at the hospital. Speciality treatment and diagnostic equipment were not considered in the assessment as they required specialized skills. The assessment is therefore limited to building envelope design, lighting, air-conditioning as well as cooking and hot water systems as described in the sections below.

4.2.1.1 Building Envelope Design and Orientation

The KGBS Guidelines recommend that buildings be orientated along the east to west axis, have reflective lighter skin colour on walls and roofs, install window and walls shading devices and use insulated windows in treated spaces to minimize heat gain and reduce cooling energy requirements. The guidelines also recommend a window to wall ratio (WWR) of 30%, which allows just enough lighting and avoids excessive solar thermal loads, for glass transfers more heat than walls.

Figure 4-1: Buildings orientation

The assessment of county public building envelope had mixed performance with regards to east to west orientation. This aspect is illustrated in Figure 4-1 that shows examples of east to west oriented buildings such as the County Offices and Makueni County Referral Hospital. Offices such as Departments of Trade, the Treasury and the Department of Public works were oriented towards the South to North axis. Figure 4-1 also shows the buildings that are constructed with darker roof colours.

A summary of assessment of county public building skin design has been presented in Table 4-1. It shows the proportion of assessed county buildings with efficient light-coloured walls and roofs and shaded windows and walls that enhance building cooling by building external heat ingress. Low compliance to the above standards leads to higher thermal loads. This is particularly impactful in buildings where air-conditioning is utilised as additional energy is consumed for cooling.

Table 4-1: Building envelope design

Building Envelope	Offices %	Hospitals %	Average %
Building Orientation (East to West)	36	100	63
Light Color Exterior Walls	61	70	65
Light Color Roof	21	30	25
Window Shading	14	10	13
Window to Wall Ratio	48	40	44
Walls Shading/Trees along facades	50	70	58

Makueni L5, CTScan.
Light colored walls with shading & e-coated windows

Mutiliku L4. Ward
Light color walls with dark roof

County Offices
Light color walls, window shading, trees along walls

Department Public Works
Dark wall colors & roof with front wall shading

Figure 4-2: Walls and windows

Figure 4-2 shows samples of light-coloured building skin designed to reflect heat, which is favourable for the hot climatic conditions in Makueni County. In comparison, dark-coloured building skin that absorbs heat may necessitate space cooling requirements. Building Lighting Points

LED bulbs (which are considered the most efficient lighting technology) are the most adopted lighting appliances in most county public buildings. A notable exception was the County Referral Hospital that still predominantly uses fluorescent lighting as shown in Table 4-2.

Table 4-2: Lighting Efficiency in Makueni Public Buildings

Lighting Use & Efficiency	County Office %	Sub-county & Dept. %	Makueni L5 Hosp. %	Sub-county L4 Hosp. %	County Average* (All buildings) %
Lights ON and not in Use	0	14	0	23	15
Occupancy Sensor (indoor)	no	no	no	no	n/a
Daylight Sensor (outdoor)	no	no	yes	no	n/a
LED bulb	73	61	4	45	52
Fluorescent bulb	27	36	94	36	40
CFL (Energy Saver) bulb	0	3	2	18	8
Incandescent/Halogen bulb	0	0	0	1	0
Other bulbs	0	0	0	0	0

* The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.

Table 4-2 shows the penetration rate of high efficiency LED lighting compared to other lighting technologies for offices and hospitals and County average of the assessed buildings. It is worth noting that the use of inefficient incandescent/halogen lamps was low within county buildings, which is a good practice.

It is recommended that a gradual transition from fluorescent to LED bulbs should be made whenever failure of inefficient bulbs occurs. Most newly constructed buildings were largely fitted with LED lighting. Figure 4-3 show a different lighting used in Makueni County buildings.

An assessment of the management of lighting systems revealed that operation was largely manual with mixed performance in energy conservation. Fifteen percent of the installed lighting points were observed as 'on' when rooms were not occupied. Lighting automation was minimal and only observed at the County Referral Hospital's outdoor lighting that had daylight sensors. There were no occupancy sensors installed in any of the buildings that were assessed and these are best practised for common areas such as washrooms where lighting wastage is common.


Fluorescent tube lighting


LED panel lighting

Figure 4-3: Lighting Devices

4.2.1.3 Buildings Cooling and Refrigeration Systems

Spaces in most county public buildings are passively cooled, with some exceptions in a few executive offices and speciality areas such as IT rooms, hospital diagnostic and procedure rooms with sensitive procedure equipment such as theatre, X-ray, HDU and ICU procedure rooms. The use of refrigerators was also limited to hospitals with minimal usage in office buildings.

Most of the air conditioning (AC) units in County buildings do not meet the minimum energy efficiency ratio as the standard. Table 4-3 shows the proportion of air conditioning units whose EER was equal or above the specified standard and refrigerators that meet the MEPS.

Table 4-3: Energy Efficiency Ratio

Cooling Equipment Efficiency	County Offices %	Sub-county & Dept. Offices %	Makueni L5 Hosp %	Sub-county L4 Hosp. %	County Average *(all buildings) %
AC % above min EER	100	33	35	18	39
Refrigerators % meeting MEPS		75	0	0	15

**The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.*

Building heating was observed in Makueni L5 and Mukuyuni L4 hospitals only. There were no other heating cases observed in the rest of the buildings assessed.

4.2.1.4 Buildings Water Efficiency

The assessment of water appliances revealed that the adoption of low flow appliances, which is best practice, is low as shown in Table 4-4. Also shown is the penetration rate of rain water harvesting and wastewater recycling.

Table 4-4 :Water appliance efficiency

Water faucets & Appliances	County Offices %	Sub-county & Dept. Offices %	Makueni L5 Hosp %	Sub-county L4 Hosp. %	County Average (All buildings) %*
Low flow appliances	81	27	13	18	27
Rain water harvesting	0	50	0	50	42
Grey water treatment	0	0	0	0	0

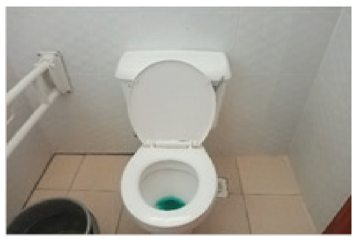
* The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.

Low flow appliances include; aerated low flow faucets, dual flush water closest, low flow showers, and urinals. The county offices had the highest adoption rate made of low flow sink faucets and water closets. A few facilities were observed to still use pit latrines. Some of the facilities had installed recoverable rain water harvesting, mainly in sub-county facilities. None of the facilities had installed grey water treatment and recycling.

A sample of low flow appliances compared to some of the standard lamina flow appliances observed in County Buildings are presented in Figure 4-4


Standard flow urinal


Standard flow faucet


Standard(single flush) WC


Low flow urinal


Low flow (aerated) faucet


Low flow (dual flush) WC

Figure 4-4: Water appliances

4.2.1.5 Water Heating

Water heating was predominantly observed in the inpatient sections of the level 4 and 5 hospitals with insignificant requirements for offices. There was a mix of technologies that included instant heated shower heads to solar water heaters as shown in Figure 4-5 while several other showers had no heating.

Figure 4-5: Hot water appliances

The use of instant heaters and solar water heating is energy efficient. An observation was however made that the solar water heating system at the referral hospital was not fully functional due to unreliable water supply. Hot water for procedures was largely availed through electric bulk heaters (geysers) that consume more energy.

There was minimal hot water use in laundry as most facilities used hand washing with cold water. A few facilities operated with washing machines with inbuilt electrical heaters. Adoption of solar water heating to replace part of electrical heating requirements will reduce energy consumption.

4.2.1.6 Cooking

The county facilities that utilized cooking are largely hospitals and a few sub-county offices. As shown in Figure 4-6, the main cooking fuel in use in most facilities is gas (LPG), which is a clean fuel and the respective cookstoves have higher energy efficiency. The use of firewood and charcoal in the buildings was observed as minimal with only one L4 hospital using gas and charcoal for cooking.

Figure 4-6: Gas cookstoves

4.2.1.7 Renewable Energy

There was evidence of a gradual adoption of renewable energy sources in county facilities. Some facilities, such as the referral hospital, have installed solar PV systems supplying specific stand-alone electrical appliances such as water supply pumps and boreholes pumps. Other facilities, such as Mbooni sub-county offices, have solar PV systems which meet all their electricity needs. At least 33% of the assessed facilities had a solar PV/solar water heater powered system installed. Most facilities have strategies to expand their solar systems where such capacity is required. The solar PV and thermal units observed during the field work are captured in Figure 4-7

Solar PV panel, Mbooni SB Offices

Solar Water Heaters, Makueni Referral Hospital

Figure 4-7: Renewable energy sources

4.2.1.8 Energy Use Index

Using the EDGE modelling tool, two scenarios of the energy use index (EUI) were generated; a base case (using inefficient appliances) and an improved case (efficient appliance installed). The base case data is internally generated by the modelling tool (from preloaded research data) and is based from typical energy usage of a building fitted with standard efficiency appliances. The base case data is grouped in country geographical regions and allows a building to be assessed based on its specific location. The improved case is modelled by the tool user based on possible improvements that can be made in appliances retrofits improvements that is acquired from improvement recommendations such as from the walk-through audits.

These scenarios were generated for county offices and hospitals and were to be used to determine the energy efficiency status of county buildings. An actual case was generated based on actual energy consumption from utility bills and indoor floor area of buildings. This was compared to the base case and improved case to show energy performance of the facilities with respect to the base to improved case rating. The difference between the actual case and improved case shows the available opportunity for improvement compared to benchmarks. The difference between the actual case and the base case shows the current state of energy efficiency and the current effort that has been put in place to ensure energy efficiency. Table 4-5 shows the EUI for actual case, base case and improved case, with possible improvement room for benchmarking.

Table 4-5: EUI facilities

EUI	Units	County Offices	Sub-county & Dept. Offices	Makueni L5 Hosp	Sub-county L4 Hosp.
Actual case	$kWh/m^2/yr$	39	28	78	70
EDGE base case	$kWh/m^2/yr$	46	46	170	170
EDGE improved case	$kWh/m^2/yr$	21	21	96	96
Improvement	$kWh/m^2/yr$	18	7	-18	-26

In all cases, the actual EUI was better than the base case. However, only in the case of the county level four and level 5 hospitals was the actual EUI lower than the improved case. Lower EUI in the county hospitals can be attributed to lack of some appliances that were used to determine the improved EUI. In county hospitals, for example, clothes are washed by hand, and instead of using machine washers and dryers, they are dried using natural sunlight. Further, many showers are not heated and kitchen equipment were minimal. On the positive side, high usage of passive lighting and ventilation also contributed to the low EUI. It should however be noted that increase in equipment for laundry, hot water and kitchen use will raise the EUI possibly above the improved case if energy efficiency is not observed.

The County Government is currently mainstreaming EUI improvements in County Hospitals as a special focus area.

4.2.2 Households, Learning Institutions, Health Centres and MSMEs

This section describes energy efficiency in households, learning institutions, health centres and MSMEs.

4.2.2.1 Energy Efficiency in Households

The households in Makueni County have a high adoption rate of highly efficient LED lighting bulbs as shown in Table 4-6.

Table 4-6: Household lighting bulb by Sub-county

Light Bulb	Kaiti %	Kibwezi East %	Kibwezi West %	Kilome %	Makueni %	Mbooni %	Average* (all sub-counties) %
LED	100.00	70.00	71.13	88.89	91.49	77.97	79.79
Fluorescent	7.14	0.00	14.43	4.44	0.00	0.00	5.82
Energy Saver	0.00	76.67	46.39	11.11	10.64	25.42	31.85
Incandescent	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Halogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	3.09	0.00	0.00	0.00	1.02

* The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.

Table 4-6 shows the adoption rate of lighting by bulb type first per sub-county and then a county average of all assessed populations in the County. The highest adoption of LED bulbs was in Kaiti and Makueni sub-counties. There was limited usage of inefficient light bulbs such as incandescent and halogen bulbs that are inefficient. There was significant usage of compact fluorescent light-CFL (energy saver) and fluorescent bulbs. Whereas the CFL and fluorescent bulbs operate at higher efficiency than incandescent and halogen bulbs, the LED bulbs are more desirable as they operate at much higher efficiency. Community energy efficiency programs should aim to fully transition to LED bulbs. Other bulb types, mostly vapour discharge flood lights, usage were minimal at 1% and these require to transition to LED as well.

Cooking efficiency has been discussed in section 3.3.1, and shows that 67% of households still use the traditional three stone cookstove and 38% of the households use metallic cookstoves that have poor energy efficiency as their primary choice cookstoves. The adoption of improved cookstoves as the primary choice was low at 26%, indicating that effort is required to transition to efficient cookstoves. Adoption of higher tier stoves like LPG is still low. During focus group discussions, it was found that households adopted some measures to conserve energy. This included using pots to insulate the three stone cookstove, thus preventing atmospheric heat loss.

4.2.2.2 Energy efficiency in Learning Institutions

Learning institutions have a low adoption rate of LED lighting bulbs (which are most efficient as previously indicated) as shown in Table 4-7.

Table 4-7: Learning Institutions lighting bulb

Light Bulb	Kaiti %	Kibwezi East %	Kibwezi West %	Kilome %	Makueni %	Mbooni %	*County Average %
	Percentage Adoption						
LED	9.10	7.30	24.40	7.80	21.50	17.20	15.90
Energy saver	68.20	50.90	55.10	45.10	62.00	53.40	55.90
Fluorescent	11.40	27.30	5.10	29.40	7.60	17.20	15.10
Incandescent/ Halogen	11.40	0	3.80	9.80	5.10	5.20	5.50
Other	0	7.30	6.40	5.90	2.50	3.40	4.40

** The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.*

The most used light bulb is the compact fluorescent lamp-CFL (energy saver), with the fluorescent light bulb coming in second. There is still substantial use of inefficient incandescent and halogen light bulb with highest use observed in institutions within Kaiti and Kilome sub-counties. Efforts should therefore be made to have these institutions transition to efficient lighting. Similarly, whereas CFL and fluorescent bulbs are more efficient than incandescent bulbs, a full transition to the high efficient LED bulb will ensure higher energy saving.

Adoption rates of high efficiency bulbs between rural and urban institutions is nearly the same at approximately 16%, as shown in Table 4-8. Focus is then required in both locations to improve adoption.

Table 4-8: Institutions lighting bulb rural/urban

Light Bulb adoption %	Rural	Urban	*County Average (All sub-counties)
LED	16.00	15.50	15.90
Energy saver	55.70	56.90	55.90
Fluorescent	14.00	20.70	15.10
Incandescent/Halogen	5.90	3.40	5.50
Other	4.90	1.70	4.40

* The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.

Cooking efficiency has been discussed in section 3.3.2, showing that 34% of institutions still use the traditional three stone stove and 2% use metallic cookstove that have poor energy efficiency as their primary choice cookstoves. The adoption of improved cookstoves as the primary cooking technology is at 49%. This indicates that there is substantial effort required to transition the institutions to more use of efficient cookstoves. Adoption of higher tier stoves, particularly gas-fired and electric cookstoves as primary cookstoves stands at meagre at 1%. Firewood is the main primary fuel at 95%.

4.2.2.3 Energy Efficiency in Health Centres (Level 1 to 3)

The main energy intensive processes in health facilities are in specialized diagnosis and treatment of equipment, lighting, refrigeration, and air conditioning (cooling or heating) in a few high care areas. Whereas higher intensive facilities (level 4&5) have been discussed in Section 4.2.1, this section deals with assessment of lower energy intense facilities of level 1 to 3 as they operate fewer and lower rated powered appliances.

The adoption rate of high energy efficient LED lighting bulbs in Health Centres is low as shown in Table 4-9, especially in Kibwezi East and Kilome sub-counties, which have insignificant adoption.

Table 4-9: Health centre light bulb

Light Bulb adoption %	Kaiti	Kibwezi East	Kibwezi West	Kilome	Makueni	Mbooni	*County average (All sub-counties)
LED	20.00	0	21.40	0	27.30	12.50	17.00
Energy saver	30.00	42.90	35.70	66.70	18.20	62.50	37.70
Fluorescent	40.00	0	28.60	0	18.20	0	18.90
Incandescent	0	0	0	0	18.20	12.50	5.70
Other	0	14.30	0	33.30	0	0	3.80

* The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.

Table 4-9 shows that lighting is primarily undertaken using CFL (energy saver) and fluorescent bulbs. There is significant use of inefficient lighting of incandescent bulbs, with the highest in Makueni and Mbooni sub-county Health Centres. These require to be replaced with efficient lighting. Similarly, the CFL and fluorescent bulbs should be upgraded to LED bulbs that offer higher efficiency and better return in energy saving.

The adoption of LED bulbs is higher in urban health facilities compared to rural facilities as shown in Table 4-10. This indicates that energy efficiency programs with focus on lighting should be prioritised in rural health facilities to mainstream adoption.

Table 4-10: Health centres light bulb adoption - rural/urban

Light Bulb adoption %	Rural	Urban	*County Average (All sub-ounties)
LED	14.60	40.00	17.00
Energy saver	35.40	60.00	37.70
Fluorescent	20.80	0	18.90
Incandescent	6.30	0	5.70
Other	4.20	0	3.80

** The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.*

Cooking efficiency has been discussed in 3.3.3 and shows that 26% of health facilities use LPG as their primary stove. Seventy percent of the assessed centres did not employ cooking in the stations because they only had outpatient services. About 3.8% of the facilities use metallic cookstoves that are inefficient.

4.2.2.4 MSMEs

MSMEs in Makueni County exhibit a diverse range of products and services. Common electricity consuming appliances prevalent in MSMEs include; lighting, refrigeration, air conditioning, and cooking. The adoption rate of LED lighting bulbs in MSMEs is low as shown in Table 4-11, especially in Kibwezi East that has insignificant adoption.

Table 4-11: MSME light bulb

Lighting Bulb adoption %	Kaiti	Kibwezi East	Kibwezi West	Kilome	Makueni	Mbooni	*County Average
LED Bulb	36.80	0	24.10	10.50	19.40	14.30	18.40
Energy saver bulb	49.10	67.60	49.40	57.90	61.20	67.90	59.00
Fluorescent	0	5.90	0	10.50	2.30	1.80	2.40
Incandescent bulb	7.00	1.50	9.60	10.50	6.20	1.80	5.80
Other bulb	0	4.40	0	5.30	1.60	1.80	1.70
None	0	4.40	3.60	5.30	5.40	3.60	3.90

** The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.*

Table 4-11 shows that most of the lighting is through CFL bulbs (energy saver) and fluorescent bulbs. There is significant use of inefficient lighting of incandescent bulbs being prevalent in Kaiti, Kibwezi West, and Kilome sub-counties. Energy efficiency programs in lighting should focus on these areas to transition to efficient lighting. Similarly, the CFL and fluorescent bulbs should be upgraded to LED bulbs that offer higher efficiency and better return in energy saving.

Within MSMEs, the distribution of LED lighting bulbs is higher in rural centres at 20% compared to urban centres at 14%. The share of solar home systems as discussed in Section 3.1.6 of energy access is 44% and may be the driver of higher rural LED penetration rate as SHS are mainly pre-fitted with LED lighting.

Table 4-12: MSMEs light bulb rural/urban

Lighting Bulb adoption %	Rural	Urban	*County Average
LED Bulb	20.40	14.20	18.40
Energy saver bulb	55.80	66.10	59.00
Fluorescent	2.10	3.10	2.40
Incandescent bulb	4.60	8.70	5.80
Other bulb	1.40	2.40	1.70
None	3.50	4.70	3.90

* The County average is weighted across the populations in sub-counties and is not a simple average of sub-county average.

Cooking efficiency has been discussed in section 3.3.4 and shows that 15% of MSMEs have adopted improved cookstoves and 5% use higher tier technologies such as LPG cookers and electric cookstoves as their primary cookstoves. There were a significant number of facilities that still use inefficient metallic cookstoves at 8% with insignificant usage of traditional three stone cookstoves as their primary choice stove. Majority of the MSMEs assessed estimated at 68% did not carry out cooking in the business.

4.2.2.5 Cross Cutting Appliances

The adoption rate of cross cutting appliances was low in households, educational institutions, and MSMEs as shown in Table 4-13, with the exception of computers in educational institutions and health centres.

Table 4-13: Cross-Cutting appliances

Appliance adoption %	Households	Educational Institutions	Health Centers	MSMEs	Average adoption across county
Air Conditioning	0	1.40	1.90	4.10	2.47
Refrigerator	9.02	7.40	71.70	23.30	27.86
Water heating	8.22	4.40	47.20	10.00	17.46
Computer	11.94	66.30	41.50	17.70	34.36
Average	9.73	19.88	40.58	13.78	20.53

The highest adoption of refrigerators in health centres was primarily driven by the need for storage of drugs, reagents and vaccines. The adoption of appliances may increase with higher electricity access rates. The highest adoption rate of water heating was in health centres, mostly used for sterilization. The adoption of solar water heating to partly substitute heating loads will reduce energy consumption. Improvements in energy access will result in higher adoption rates of appliances and procurement of higher efficiency appliances will reduce energy consumption.

4.2.3 Energy Consumption in Industries

The energy intensive industries in Makueni County are few and comprise of one fruit processing factory, one bio-diesel manufacturing plant, and several commercial agricultural farms. Other less intensive industries include: several coffee and dairy process plants, grain handling plants, a motor cycle assembly plant, and horticultural product handling plant. A brief summary of key industries and energy requirements is shown in Table 4-14. The table also outlines some of the key challenges faced in energy sourcing and energy efficiency programs.

Table 4-14: Major Commercial Industries

Item	Industry	Qty	Key Processes	Energy Consumption	Comments
1	Lodges and Hotels	89 with at least 4 Game Lodges	Cooking with electricity and LPG, laundry, water pumps, lighting for common areas as well as guest rooms and air conditioning fuelled by electricity. Several lodges have employed solar PV generators	A typical game lodge consumes approximately 570MWh/yr of electricity and 48tonnes/yr LPG	
2	Fruit Processing plant (operated by the County Government)	1	Mango puree processing and mango juice processing. These processes are operated by electric motors for process plants and product conveyors and steam from a biomass boiler for sterilization.	The Fruit processing plant consumes approximately 173 tonnes/yr of biomass, 16200m3/year of water and 115MWh/yr of electricity	Frequent grid power outages affect industry. Future strategies include solar installations, including hybrid systems
3	Agricultural Farms		Agricultural farms grow a variety of crops that include vegetables and flowers. The powered processes include borehole water pumps, transfer and distribution water pumps, water filtration plants for irrigation systems, cold rooms, fertigation, and humidity control systems.	Typical commercial farms consume 1,725MWh of grid electricity annually, 100 to 150MWh of solar generated electricity and 22 to 280MWh of diesel generated electricity. Approximately 300,000m^3 to 550,000m^3 of water is used per year for irrigation. Approximately 12 to 13 tonnes/year of firewood is used for cooking, supplemented by approximately 380kg of gas (biogas & LPG supplements)	Grid power failure and low voltage supply contributes to higher diesel power usage that is expensive. Strategies include expansion of solar power systems. The farms lack enough energy expertise to maintain and install efficiency appliances. Water installations are expensive and borehole water is still billed by the County. Require assistance in expansion of solar plant adoption and require water supply.
4	Grain Handling Plants	2	Power intensive process is the pre-cleaning plant and separation plant and product conveyors operated by electric motors.	Typical grain handling plant consumes 68MWh/yr of grid electricity and 2.3MWh of diesel generated electricity (600l of diesel) per year	Grid power fluctuations leads to higher diesel generating cost. High capital cost of solar PV. As such, funding assistance is required. There is inadequate expertise to implement energy efficiency programs
5	Coffee mills	10	Main process is the pulping crusher that peels the cherries and may be operated by electrical powered plants or in some cases diesel powered motors with grid electricity only used for lighting and auxiliary services.	Typical energy consumption is approximately 50MWh per year equivalent of electricity.	

6	Dairy Plants		The dairy plants in the county are small. Energy intensive processes are electrical pumps/motors for water and milk products used in processing plants and product transfer. Electrical boilers are used to supply hot water used for pasteurizing and sterilizing. Some plants incorporate solar in processes such as bulk cooling plants.	Typical dairy plants consume 15 to 60 MWh of electricity per year	Key concerns are on frequent grid power failure, leading to high expenses in diesel generated electricity. Operates plant at night where power is more stable.
7	Horticulture Products handling Facilities	1	Key energy intensive processes are operation of cold rooms for products before sales to markets	Typical energy consumption is approximately 200MWh per year, includes diesel generated electricity during grid failure and 9,800 litres of water	Frequent grid power failure. Limited expertise in alternative power sources such as solar. Require assistance
8	Motor Assembly Plants	1	Key energy usage in auxiliary services such as air compressors, powered tools and workshop equipment. Powered conveyers are used to transfer motorcycles between stations. Manual labour used in assembly plant	Typical energy consumption is 15MWh per year with 4.7 tonnes of firewood used for cooking	High cost of electricity. Lack of expertise in energy efficiency programs. Require assistance to install alternative energy supply such as solar
9	Bio Diesel Plant	1	Approximately 40 MT of bio diesel produced from cotton and castor. Energy intense operations are oil presses, and filtrations plants. Other energy consuming processes include product transfer between processes and general handling.	Approximately 1050MWh per year of grid electricity and 380MWh of diesel generated electricity. 2880 kg per year of LPG for thermal heating. Annual water consumption approximately 3000m3.	Frequent power fluctuations from grid electricity that include phase failure. High electricity tariff price and high cost of fuel. Future strategies are to diversify energy sources to alternative sources. County Government to assist in reducing energy costs and migrating to alternative energy sources
10	Private Institutions		The key energy intensive processes are in water pumping from boreholes and distribution systems, kitchen equipment, lighting in lecture rooms, offices, residences and outdoors, a few air conditioning systems in speciality and executive rooms. Firewood is largely used for cooking, supplemented by LPG gas.	Approximately MWh of electricity per year and 12 tonnes of firewood per year	Challenges include poor lighting control with lights left on. Strategies include automation of outdoor lighting. Other strategies include installation and expansion of solar captive systems.
11	Water treatment & Pumping plants (operated by the County Government)	2	Energy intensive processes are water pumps. Some plants are operated from surface water sources while others are from ground sources. Water is pumped to overhead reservoirs and distributed by gravity or may be pumped directly into distribution systems. Additional pumping systems operate the treatment system.	Approximately 80 to 120 MWh of electricity per year	Challenges include power fluctuations, high electricity tariffs and high cost of fuel. Strategies include solarisation of pumping systems

4.2.4 Energy Efficiency in Transport

According to KNEECS (2020), fuel consumption in the transport sector country wide is currently on the rise with road transport accounting for 80% of domestic freight and passenger traffic while 30% of all the vehicles in the country are more than 15 years old[57]. This has led to poor efficiency and high operating cost. According to the KNBS Economic review (2023), the number of vehicles across the county rose as follows: Lorries by 42.5%, minibuses by 10.3%, and trailers by 8.5%[58] all between 2021 and 2021. Equally, fuel consumption is on the rise.

Railway transportation, on the other hand, is improving with the standard gauge railway line (SGR) that operates between Mombasa and Nairobi County with stops in Emali, Kibwezi, and Mtito-Andei towns. SGR freight volumes increased by 12.6% while passenger traffic increased by 20% between 2021 and 2022[59].

Currently, the county has approximately 20,000 motorcycles. They operate under Saccos where each Sacco has between 500 to 1000 operators. The County Government operates approximately 200 motorcycles across the departments, mostly within the Transport and Agriculture Departments who operate several field extension activities.

The county has seen a rise in e-mobility use mainly in the increase of hybrid vehicles along the county roads. There is no conclusive list of pure-electric driven means of transport in the county. With the increasing promotion of e-mobility solutions within the country, it is expected that the number of such solutions will also increase within major urban centres as there is stable grid electricity that can be used to recharge the vehicles.

4.3 BARRIERS TOWARDS ENERGY EFFICIENCY AND CONSERVATION

Implementing energy efficiency and conservation measures requires both financial resources and technical capability. The following are some of the major constraints the county faces in implementing energy efficiency and conservation measures.

4.3.1 Financial Resources

The county government's main source of funds is the national exchequer. Other sources are own-source revenue and grants. The allocation from the exchequer is not enough to fund the county operations, thus some of the projects may have to utilize equipment that are of low efficiency. The existing working equipment may not be replaced immediately for more energy efficient ones as there are more pressing needs, especially in the health sector that needs the funds to operate.

Further, the funding through grants typically has clauses on the equipment that should be adopted for certain projects. This aspect impedes equipment choice decisions based on energy efficiency. All in all, the County Government is conscious about energy efficiency and will enact regulations and guidelines on the same, including suitable frameworks that allow External Energy Service Companies (ESCOs) to participate in funding energy efficiency programs.

4.3.2 Access to quality appliances

The development of new and modern energy technology has been competitive and the market is flooded with a large pool of appliances. This, in some cases, has subjected consumers to sub-standard appliances which fail before their expected lifetime, particularly in the case of the LED lighting. Such failure discourages adoption rate of efficient lighting. The County Government should therefore employ systems to enforce prevailing appliance quality within its jurisdiction.

4.3.3 Energy Management Teams, Governance & Training

At the time of writing the CEP, the county has just constituted energy teams that are fully equipped with capacity to manage energy efficiency and conservation programs. The county requires capacity building to create a pool of competent officers responsible for energy efficiency that will support the governance of energy management at County and public facility levels. Further, as envisioned

57 KNEECS. (2020)

58 KNBS Economic Review, 2023

59 Ibid

in the Energy Act, Section 195, the County is required to develop energy teams to inspect compliance to the minimum energy performance standards. This requires capacity building to develop and implement energy policies and governance structures and further resources to implement energy efficiency programs and energy measurement and monitoring systems.

4.4 RECOMMENDATIONS

The following section is a summary of the recommended actions for the county buildings, households, educational institutions and industries. It is based on the energy efficiency assessment done in Makueni County, energy policies in Kenya and best practices.

4.4.1 Policy & Governance Recommendations

- Create awareness programs in EE&C for all communities in the county to encourage adoption of energy efficient appliances and conservation activities. The county carried out capacity building for energy champions in all wards that may be used in such campaigns. Other CBOs involved in community work and local media can be empowered in EE&C and used to carry out campaigns.
- Create an energy inspection team within the county that may enforce compliance to the minimum energy performance standards as envisioned in the Energy Act 2019. Capacity building for such teams will be required to build an experienced technical team.
- All county public buildings that meet the threshold of designated facilities with energy consumption of 180,000 kWh per year to comply with the provisions of The Energy Management Regulations, 2012. These include, amongst other provisions, to carry out energy audits every 3 years and realise at least 50% of recommended energy savings. Capacity building for such facility managers should include energy management trainings. This will enable the development and implementation of local facility energy policies, organizational structures, and energy efficiency activities to be carried out in line with the provisions of the regulations.
- Whereas the National Government has strategies in place to create a nationwide green building code by 2025, the County may complement this effort by creating a County building code to enhance passive buildings construction for new buildings. Demarcation of land for development to be done in a way that encourages efficient building orientation to support green buildings constructions.
- Support and mainstream industries or local groups that produce energy efficient appliances such as improved jiko through exhibitions, campaigns, and incentives where applicable.
- Create a building energy efficiency rating benchmarking standard that all county public buildings can be assessed against. Equally, celebrate outstanding achievements and recognitions through an appropriate recognition award to challenge inefficient buildings to adopt energy efficient measures.
- Facilitate higher adoption rate of e-mobility through sensitization campaigns on economic and environmental benefits and development of network of charging stations.

4.4.2 Financial Resources Recommendations

- Mainstream EE&C during budget allocations to enable funding for specified energy efficiency projects to avoid priority downgrading amongst other county projects.
- Create budget funding for incentives to local groups and industries producing energy efficient technology such as improved jiko.
- Create budget funding for capacity building for recruitment and training of local energy inspection teams and energy champions.

4.4.3 Technical Recommendations

- Retrofit existing County Public buildings with energy efficient appliances such as LED lighting and lighting automation, air conditioning & refrigeration appliances that meet MEP standards, efficient cookstoves, and low flow water appliances. Take every opportunity presented by failure of existing appliance to replace them with higher efficiency appliance.
- Retrofit existing buildings with energy efficient building skin, especially where space treatment

is done such as light-coloured or reflective external walls, window shading, and window glass coating. Growing trees along building facades will assist in building passive cooling.

- Promote use of electric vehicles through County Pilot project on all two-wheel vehicles through replacement with electrical or retrofitting electric motor in existing internal combustion engines.
- Install renewable energy sources to partly or fully substitute convectional energy sources such as solar PV plants, solar water heating, biogas and others where applicable for at least 25%[60] of electricity requirements and 30%[61] of water heating requirements or more.
- Install wastewater recovery systems such as rain water harvesting and grey water recycling plants to reduce water pumping cost.
- Transition county public institutions into cleaner fuels that are fired by efficient cookstoves such as LPG, biogas, or electricity.
- Construct demonstration energy efficiency centres. An existing or new office building, heal facility or educational institution can be fully retrofitted with energy efficiency appliance & practice and used as a benchmark centre for other facilities.

60 EDGE default recommendation

61 EDGE default recommendation

5.0 CROSS CUTTING ISSUES

5.1 GENDER AND SOCIAL INCLUSION

Women and men experience energy issues differently. In Makueni County where 72.5% cook with firewood, women are primarily tasked with fetching firewood and cooking. From one of the focus group discussions, it was indicated that "A woman who cannot chop firewood and carry it on her back is not a woman in the traditional sense". Fetching firewood is therefore deeply rooted in gender roles within Makueni County. Women also do most cooking and as such, they are more exposed to the indoor air pollution emerging from the cookstoves. This was acknowledged by both men and women in their respective focus groups. The men indicated that this health impact affects them because they have to cater for medical costs for their spouses and children. Both men and women, in their separate groups, also indicated that they feel the financial burden of transiting to cleaner cookstoves, which largely seem unaffordable to the people in the county. The women indicated the need for credit or subsidies to enable them to purchase the cooking technologies in the market. Additionally, another barrier was that majority of the stoves in the market target charcoal users while majority of households cook using firewood.

Men indicated that they feel the burden of having to acquire other fuels when firewood is scarce. Sometimes, particularly during the rainy season, firewood is scarce and they therefore have to obtain money to purchase alternative fuels.

Poverty is also a big determinant of accessibility of firewood. The 'rich' have larger pieces of land and are therefore able to grow trees that they use for firewood whereas the 'poor' have to purchase firewood. This made them feel like beggars as sometimes those with trees do not want to sell. As a result, some people would request the county government for permission to collect firewood from the forest reserve. Some women indicated that it was possible to sleep hungry, not because of lack of food but lack of firewood as indicated in the following statement by one of the respondents: "Sometimes someone can even sleep hungry because they have no firewood, especially during the rainy season when the wood is wet, and they have no money to buy charcoal."

Women further indicated that the quality of clean cookstoves that is sold to them is wanting, with some products lasting only for 6 months. In this case, the specific cookstove in question had been purchased on credit and after they completed their payments, the product broke down and they had to revert to the three stone cookstove.

Productive use of energy was an important issue for both men and women. Both genders indicated that they would like reliable electricity access to start businesses or enhance productivity of existing businesses. The businesses mentioned were similar and included barbershops, salons, and agricultural ventures like hatcheries. They preferred grid electricity for productive use because solar home systems were limited in their capacity with some indicating that the grid was more 'powerful'.

People living with disabilities (PLWDs), especially those with mobility impairments, highlighted that apart from limited energy access, they face impediments in accessing appliances. Most cooking fuels and appliances are available in urban centers, making them spend more money on transport to acquire them. Also, the only way to acquire firewood is to purchase it because their condition does not allow them to collect firewood even when it is 'free'. They are also affected more by indoor air pollution as a result of cooking because most of their time is spent indoors. They recommended that energy service providers should consider bringing the services nearer to them and that PLWDs should have special tariffs or reduced costs on energy to enhance adoption.

On the other hand, a key challenge faced by youth in Makueni is unemployement. They indicated that they would like energy projects implemented in the county with a goal to create jobs for them.

5.2 ENVIRONMENT AND CLIMATE CHANGE

Makueni County is largely dependent on agriculture for the growth of its economy. Farmers in the County indicated that climate change has caused unpredictable rainfall and therefore they are not able to indicate how much crop they harvest as this is dependent on rain. This not only impacts crops production but also bee farming as bees migrate when there is lack of water.

To preserve the environment and mitigate climate change, the County Government has restricted collection of firewood from forest reserve as well as commercial production of charcoal. Some community members have decried this as indicated in the previous section, indicating that firewood is scarce and expensive and this policy is causing them harm rather than good. Charcoal production is still happening albeit illegally. 8.2% of households within the county use charcoal to cook, which happens to be in urban areas. During focus group discussions, it was indicated that firewood use in urban areas is restricted by landlords as it damages households.

Residents of Makueni County are aware of the detriment caused by felling trees for firewood without planting more. As such, they called for support on tree planting initiatives that would enable them to sustainably access firewood.

Further, it is also necessary to support agricultural initiatives such as irrigation to increase land productivity and reduce reliance on rain-fed agriculture. During data collection, it was observed that many farmers are in self-help groups. The County Government can therefore channel support through these groups. Those that are not in groups can be encouraged to organize themselves with the goal of receiving support.

5.3 RISK AND DISASTER MANAGEMENT

During the focus group discussions, it was reported that people face significant challenges with grid infrastructure. For example, in an area called Kikoko, a mainline burned electricity posts connected to it. In another area, a pole fell on a matatu as it was passing by. In Makutano market, grid electricity supply is too low to carry out activities like welding. Further, it was reported that when welders try to use it, all appliances connected to the grid experience very high voltages and get damaged. It was also reported in all the focus group discussions that electricity supply in Makueni is very unreliable. After a blackout in some cases, electricity surges, damaging appliances that had remained connected. Restoring damaged transformers also takes long as Kenya Power has few service centers in Makueni.

It is therefore imperative that Kenya Power undertakes activities to strengthen the grid in Makueni County. Further, the quality of installations pertaining to the grid need to be reviewed with the goal of safety and quality service provision.

5.4 COMMUNICATION

Communication between the County Government and the people of Makueni County takes place through public consultation. This process is required for the development of the CIDP. Community had used the CIDP process to present their energy needs. However, some community members indicated that they had little awareness on energy and as such had not used the presented their energy needs during previous public participation processes. There was also engagements that had been undertaken were with Kenya Power during the implementation of the Last Mile program.

During the Focus Group Discussions, some groups reported that they had received messages to participate in public participation forums held by the County Government. However, some people indicated that they had been left out, either because they had not been invited or had received invitations late (sometimes as late as midnight for engagements which were to happen the following day at 8am) This made them feel marginalized. However, some community members also indicated that public participation that was undertaken by the government was inclusive. Notably, these members indicated that the public participation process was led by the community with government officials only documenting what was discussed during meetings.

Further, the community indicated that their voices are only called for during development of plans. They received no feedback on whether their proposal had been adopted by the government. They indicated that they only way they would know whether their proposals had been adopted was to see the projects they recommended being implemented. They therefore expressed the need for feedback from the county government and further indicated that they would like to be involved in all phases of project development and not just in the planning phase.

Community members also indicated that WhatsApp groups could be used to provide two-way communication between them and the County Government. They also indicated that the County Government could communicate with them through various CBOs which would be used to disseminate information to the community.

When it comes to appliances used for communication, the community valued energy because it allowed them to own (or charge) devices used for communication like mobile phones, radios, and televisions. The television seemed to be an aspirational appliance because of its ability to entertain and give information and a feeling of connectedness with the outside world.

5.5 RESEARCH AND DEVELOPMENT

Research and development can support energy access and productive use of energy in Makueni. Productive use can be strengthened through research by identification of low hanging fruits with high potential for societal transformation. Community members particularly expressed the need for innovation surrounding harvesting and distribution of water in the County. Farmers indicated that absence of irrigation and water harvesting made them vulnerable to rainfall patterns and therefore making them less competitive. They indicated that some of their produce required frequent watering and rainfall patterns in the county led to reduced yield. They also expressed the need for identification of business models that can support uptake of appliances for productive use, such as solar water pumps, juicer extractors and cold rooms identification of mechanisms that can support partnerships between government, community and private investors to fast track productive use is necessary.

Makueni County has also expressed interest in adopting e-mobility, particularly for the County Government vehicles. Research can inform strategies that the county can adopt to create an enabling environment for the adoption of electric vehicles. It can also inform the impact of this technology on the electricity grid and selection of off-grid or grid-based technologies for charging the vehicles.

The County also seeks to create an environment that fosters adoption of e-mobility by s. Two wheelers (motorbikes) used for agricultural extension services used by the County were identified as a low hanging fruit. Research and development can inform conversion of these internal combustion engines into electric vehicles. Transport providers indicated the need for public awareness around e-mobility. They expressed an awareness of the technology but desired to understand its benefits and availability of infrastructure required (such as charging stations) for its successful deployment. The County Government will engage public service transport providers for county wide success of this initiative.

6.0 PROJECTS AND PROGRAMS

Project/Program	Status (New or Ongoing)	Gap	Objective	Specific Activities
Cross-Cutting				
Establishment of Energy centres	Ongoing	Limited awareness on energy efficiency, renewable energy and alternative bioenergy sources like briquettes and pellets	To create awareness on energy efficiency, renewable energy, and alternative bioenergy	• Re-engineering the energy centres to be centres of excellence in energy innovation and development • Identification of technologies and fuels to be demonstrated at centres including clean cookstoves, alternative bioenergy fuels, e-vehicles (2-wheelers), LED bulbs • Construction or retrofitting of existing buildings • Training of staff to demonstrate technologies
Development of energy policy	New	Makueni County does not have an energy policy to guide its operations	To develop an energy policy covering the areas of bioenergy, energy efficiency, renewable energy and energy access.	• Development of policy visions for: Energy Access; energy efficiency; renewable energy and productive use of energy • Engagement of community, industry, and National Government to obtain policy intervention points • Review of existing policies such as CIDP, CEP • Development of energy policy
Establishment of energy access fund	New	Limited capacity of community to purchase efficient and clean technologies	To establish an energy fund that will provide friendly credit and subsidies to community and institutions to purchase clean and efficient energy technologies	• Feasibility study to design the fund and its management procedures. • Mobilisation of donor funding from local and international partners that can be used to make the 'friendly' credit terms • Sourcing a fund manager

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	Community	Year 1-10	**Risk:** Demonstration centres do not lead to uptake of efficient technologies and clean and sustainable fuels in the county **Mitigation:** Raising awareness will also be conducted through energy champions, CBOs, FBOs and NGOs	GMC	KES 12 M	Govern-ment of Makueni County
	GMC Community	Year 2	**Risk:** Difficulty in managing conflicting views of stakeholders Energy policy does not lead to achievement of targets. **Mitigation:** Obtaining expert facilitators to guide engagements and obtain consensus Implementation framework will be developed in line with CEP and energy policy to support attaining of targets	GMC	KES 5 M	Govern-ment of Makueni County
	Community Institutions	Year 1-10	**Risk:** -Limited donor support to launch the fund **Mitigation:** Seek support from multiple donors during feasibility study and involve them during design to incorporate terms that attract donors	GMC	KES 500 Mn	GMC Devel-opment partners Financiers

Project/Program	Status (New or Ongoing)	Gap	Objective	Specific Activities
Energy Efficiency				
Capacity Building for enhanced energy efficiency in the County	New	Low adoption rate of energy efficient appliances at household, health-care facilities, SMEs and learning institutions level	To enhance energy efficiency	Training of energy champions on energy efficiency
	New	Non-compliance with Energy Management Regulations (EMR)2012	To enhance energy efficiency through skills development	Training of County facilities managers on energy management (to comply with EMR, 2012)
	New	Limited capacity on energy efficiency within the County Government	To empower staff with the knowledge and skills to formulate and implement an effective energy efficiency policy	Training of county officers on energy efficiency policy development
Development of E- mobility strategy	New	Low adoption rate of EV (2, 3 and 4 wheelers).	To promote higher adoption rate of e-mobility	Development of Makueni e-Mobility strategy
Conversion of county government 2 wheelers from internal combustion engines to electric vehicles	New	Increased expenditure on transport due to dependence on fossil fuels	To optimize energy consumption in the transportation sector	Replace 200 cycles with electric powered type

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	Community	Year 1	**Risk:** Limited adoption of energy efficient appliances even after training **Mitigation:** Incorporation of communication and marketing skills in training to enhance engagement with community	GMC	KES 0.5 million	UKPACT
	County Facility managers	Year 1	**Risk:** Limited buy in by facility management **Mitigation**: equipping trainees with relevant negotiation tools	GMC	KES 2 M	UKPACT
	Government of Makueni County	Year 1	**Risk:** Inability to develop policy after workshop **Mitigation:** engagement between private facilities and GMC to form outline of policy during training.	GMC	KES 2 M	GMC (appointed staff)
	Government of Makueni County and the local community	Year 2	**Risk:** Strategy does not yield the required results **Mitigation;** Involve all stakeholders in development of strategy and learn from other regions	GMC	KES 2 M	GMC
	Department of Transport & Agriculture And community members	Year 3-Year 8	**Risk:** Challenges in operation and maintenance of new technologies -Challenges in management of e-waste from e-vehicles -Range anxiety experienced by drivers **Mitigation:** training for the counties maintenance Department to support maintaining e-vehicles -Use of vehicles within distances that can be covered on one charge -Development of an e-waste strategy	GMC	KES 10 M per year Total KES 50M	County Budget and Development partners

Project/Program	**Status (New or Ongoing)**	**Gap**	**Objective**	**Specific Activities**
Development of energy efficiency and conservation building code for Makueni County	New	No existing Energy Efficiency Building Code in Kenya	To establish comprehensive guidelines and standards for development of building code	Develop a County EE&C building code
Installation of Lighting automation and control systems in county buildings and facilities	New	Electricity wastage	To enhance operational efficiency	• Retrofit all outdoor lighting with daylight (photo) sensors • Retrofit toilet lighting with occupancy (motion) sensor • Training on energy management
Installation of low flow appliances to replace standard flow appliances	New	Water wastage leading to higher energy costs	To enhance energy efficiency	• Install aerators in all standard flow sink faucets • Install low flow shower heads • Install dual flush toilets • Install low flow urinals
Water harvesting for county buildings and public facilities	Ongoing	Only half of the facilities have installed rainwater harvesting systems	To efficiently manage water resources	• Mapping of activities without rainwater harvesting • Expand rainwater harvesting in all facilities (50% of buildings had water harvesting) • Install collection tanks for facilities with rain harvesting ridges -
Water treatment program for county buildings and public facilities (should be implemented in collaboration with water department	New	No wastewater treatment	To implement wastewater treatment	Install grey water treatment facilities in all buildings
Electricity Access and Productive Use of Energy				
Grid densification, intensification, and extension	Ongoing	Low grid electricity access rates in Makueni	To achieve universal electricity access by 2028 and maintain the universal access all the way to 2032.	• Grid densification, intensification and extension in Makueni as recommended by OnSSET. GIS based results from OnSSET will be provided as an accompaniment to this report and will be used to guide locations.

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	Government of Makueni County	Year 2	**Risk:** National Government may release EE&C building code by 2025. **Mitigation:** Liaison with National Agencies required (MoE & EPRA, CoG) to determine release dates of national code	GMC	KES 2 M	GMC
	Government of Makueni County and community	Year 1-Year 5	**Risk:** Technology failure before end of life **Mitigation:** Ensure installation of appliances with good guarantee periods	GMC	KES 1.5 M Total KES 7.5 M	GMC
	Government of Makueni County and community	Year 1-Year 5	**Risk:** Technology failure before end of life **Mitigation:** Ensure installation of appliances with good guarantee periods	GMC	KES 1.4M per year Total KES 7M	County Budget
	Government of Makueni County and community	Year 3-Year 8	**Risk:** Technology failure before end of life **Mitigation**: Ensure installation of appliances with good guarantee periods	GMC	KES 1.56 M per year Total KES 7.8 M	County budget and devel-opment partners
	Government of Makueni County and community		**Risk:** Contamination of water before use **Mitigation:** Ensure gutters are and tanks are cleaned regularly	GMC	KES 14.5 M per year	County budget Devel-opment partners
	Community, Institutions.	Year 1-Year10	**Risk:** Inability to secure funding and Challenges in aligning with state agencies. **Mitigation:** seeking donor funding in collaboration with state agencies	MoEP, Kenya Power, REREC, KET-RACO,Government of Makueni County	KES 27.3 B	Govern-ment of Kenya

Project/Program	Status (New or Ongoing)	Gap	Objective	Specific Activities
Hydroelectric power (HEP) development program	New	Unharnessed potential of HEP in Makueni County to support electricity access and productive use	-To help meet national RE targets -To increase production and access to clean energy	• Develop small hydro plants (SHPs) along Athi River to energise productive uses, including Thwake dam (17.6MW), Kalawa plant (2.5MW), and Kivyalu plant (5MW)
Solar power development program		Unharnessed potential of HEP in Makueni County to support electricity access and productive use	-To help meet national RE targets -To increase production and access to clean energy -To contribute to power stability and reliability	• Investigation of commercial solar potential across Makueni County to identify sites for the development of bankable projects • Development of specific power plants in CIDP III like Dwa Solar Plant (2.5MW), Mtito Andei (30MW), Makindu solar plant (35MW), Eni Solar Plant (5MW)
Installation of standalone solar home systems	New	Low electricity access rates in Makueni County	To achieve universal electricity access by 2028	Collaborate with solar home system distribution companies to distribute 83,395 Stand-Alone Solar systems

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	Farmers, industrial parks, community	Year 1- Year10	**Risk**: Failed/delayed integration into the national energy plan (e.g. in the LCPDP) -Inadequate resource mobilization -Longer project duration for the bigger plants. **Mitigation:** Collaborate with state agencies and seek investors and donor support	MoE, GMC, IPPs, EPRA, Kenya Power, KETRACO,development partners	KES 15.1 B	MoE, GMC, Development Partners, EPC companies, etc.
	GMC, GoK	Year 1-Year3 (considering LCPDP)	**Risks:** Failed/delayed integration into the national energy plan (e.g. in the LCPDP) -Lack of capital or financing mechanisms -Longer project duration for the bigger plants. **Mitigation:** Collaborate with state agencies and seek investors	MoE, GMC, IPPs, EPRA, Kenya Power, KETRACO, development partners	TBC	GoK, GMC, Development Partners
	Households, Institutions, Businesses, PUE	Year 1-Year 10	**Risk:** Limited capacity of community to afford standalone solar home systems -system failure before end of life due to counterfeit products in the markets and incompetent installers **Mitigation:** subsidies at household level, carbon market, lobby for removal -enforcement of EPRA regulations on Solar PV products and installers. -enforcement of KEBS standards of quality on SHSs	GMC, Private Developers, funders/ investors	KES 27.1 B	Private sector entrepreneurs on Solar PVs, DFIs, Carbon markets

Project/Program	Status (New or Ongoing)	Gap	Objective	Specific Activities
Feasibility study for provision of power for two Industrial Parks in the CIDP III	New	The energy demand and electrification solution for the planned industrial parks not yet known	To estimate electricity demand for powering the industrial parks	• Feasibility study to establish energy needs, overall project costs, financing models, partners to be involved etc. • Establish whether the proposed power plants above are near the parks (i.e. the industrial parks should be located near power sources to reduce transmission & distribution costs)
Mapping and development of wind projects	New	Limited understanding of the wind resource in Makueni	To identify bankable wind resources	• Mapping and identification of attractive wind zones)
Solarization of Health Care Facilities (HCFs)	Ongoing	Some HCFs are unelectrified. Electrified HCFs incur high costs of energy and experience unreliable supply	To electrify HCF through solar PV To reduce the cost of energy while enhancing electricity reliability for HCFs	• Mapping of all unelectrified health facilities using EAE • Assessment of energy needs and installation of solar or stabilization of the grid • Pilot solarization of Makueni Referral Level 5 and Makindu Level 4

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	GMC, Community, investors	Year 1	**Risk:** Improper public participation. -Delays in getting interested investors and companies. -Land availability and access risks; political risks **Mitigation:** Ensuring the feasibility studies are high quality to address donor and community concerns	GMC, MoE, Devt partners, angel investors etc.	KES 7 M	GMC
	GMC, MoE,	Year 1	**Risk:** Lack of adequate and reliable data **Mitigation:** Metering resource to collect data	MoE, development Partners, Project Developers	KES 6 M	GoK, GMC, Development partners
	GMC, community	Year 1	**Risks:** -Contractual risks with installation firm -Challenges in demand estimation and obtaining financing **Mitigation:** -Proper due diligence will be undertaken and experts engaged to support in contracting -Collaborating with agencies like SEforALL who support electrification of health care facilities to sense check demand and seeking donor support	GMC, Private Developers, funders/ investors	KES 500 M	GMC, Investors, NGOs

Project/Program	Status (New or Ongoing)	Gap	Objective	Specific Activities
Schools' electrification program.	Ongoing	170 schools are unelectrified as of Sept 2023 based on EAE analysis	To electrify unelectrified schools	• Map out all the schools that are not electrified • Assess the least cost option to electrify them -grid/microgrid/stand alone systems • Assess the resource requirement • Allocate and engage partners to support in the implementation of the program
Electrification of agricultural cooperatives with pilots at: Kathonzweni, Kikima, Kilala Dairy processing plants	Ongoing	Unreliable power supply at agricultural cooperatives.	To reduce energy costs and increase reliability	• Energy demand assessment for agricultural cooperatives facilities and cold rooms • An economic & technical analysis of the best option -grid strengthening/ solarisation
Provision of appropriate power solutions for domestic water projects in Makueni County	New	Inadequate power for water projects Unelectrified water points/sources High energy costs incurred by water utilities	To reduce expenditure on energy for distribution of water	• Carry out energy needs assessment/ feasibility study for grid- tied solarization at the water sources (both current planned). Installation of grid tied solar systems (current stations and expansion)
Powering Irrigation schemes	New	Limited irrigation in Makueni County	To power planned irrigation schemes.	• Feasibility study to map current and potential irrigation schemes • Identification of clean energy solution to power irrigation schemes
Powering Cold storage facilities	Ongoing	Some cold-rooms are not electrified	To electrify existing and planned cold-rooms	• Mapping unelectrified coldrooms and identification of capacity for planned cold-rooms. Feasibility study to identify appropriate power solutions. Installation of appropriate solutions
Development PURE investment Prospectus (IP) for resource mobilisation	New	Lack of investment ready projects to unlock finance	To develop an investment prospectus detailing PURE investment opportunities in Makueni County	• Identify priority PURE interventions and locations for implementation • Estimate investment needs of PURE projects • Integration of PURE loads in least cost electrification modelling

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	Schools, community	Year 1 -Year 10	**Risk:** Lack of funding **Mitigation:** Seek donor and investor support	GMC, KPLC, REREC, Partners	KES 680 M	REREC, GMC, Partners, KPLC
	GMC, Coops, farmers	Year 2	**Risk:** Challenge in obtaining funding **Mitigation:** Support will be sought from development partners	GMC, development partners, KPLC, coops	KES 60M	GMC, member cooperatives, development partners, private investors
	Consumers, water utilities, GMC		**Risk:** Challenge in obtaining funding **Mitigation:** Support will be sought from development partners	GMC, Water Utilities, Devt partners	KES 20 Mn (for feasibility studies installationcost will be determined after feasibility study)	GMC, Private Sector, Devt Partners, water utilities etc
	Farmers, GMC	Year 1-10	**Risk:**Limited agricultural output after irrigation **Mitigation:** Assess farmers needs and conduct training and market linkages where necessary	GMC, development partners	KES 870 M	GMC, development partners,
	Farmers, exporters of agricultural produce	2025 Year 1-5	**Risk:**Inadequate finance resources, and farm produce **Mitigation:** Support will be sought from development partners	GMC, Development partners	KES 650 M	GMC, partners
	GMC, Makueni residents	2024	**Risk:** Limited uptake of projects by private sector after development of IP **Mitigation**: Wide engagement during the development of the IPs	WRI, Strathmore, GMC	KES 10M	UK-PACT-study phase, other partners for implementation

Project/Program	Status (New or Ongoing)	Gap	Objective	Specific Activities
Bioenergy and Clean cooking				
Promotion of commercial farming of bioenergy crops	New	High dependency of woody biomass for cooking and limited adoption of alternative sources of bioenergy	To increase availability of alternative and sustainable sources of bioenergy feedstock	• Feasibility study to determine types of crops to be grown and target bioenergy fuels • Partner with existing NGOs to promote commercial farming of bioenergy crops (e.g., castor, croton) • Construction of aggregation centres in key production areas at Sub- County level. • Collection of up-to-date information on feedstock availability and availing the information to private sector and public through County website
County programme on landscape restoration and woodfuel development	New	Makueni County is highly dependent on firewood	To ensure firewood used is sustainable and serves as stimulant for landscape restoration	• Develop Restoration Opportunities Profile (CROP) based on application of satellite images, isolating restoration sites in each sub-county, including on-farm, public forestlands and degraded rangelands • Mobilizing private tree nurseries entrepreneurs and tree farmers (including individual farmers) and developing incentive mechanisms for tree growing. • Partnering with key National Government agencies, establishing demonstration of professionally managed site-specific woodlots of short-rotation trees in each of the six (6) sub-counties. • Partnering with key National Government agencies, customizing JazamitiApp for tracking and monitoring progress in tree growing and harvesting in each sub-county. • Sensitisation of communities through community forest association

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	Local community Private sector	Year 1-Year 3	**Risk:** -Low priority of this activity by Agriculture Department where extension work is domiciled **-Mitigation:** Include agriculture department in the technical working group to enhance cooperation	GMC	KES 3M	GMC
	CGM	Year 1, 2,3,4,5	In order for the program to attain success at a scale that has impact on landscape and climate change mitigation, incentives must trigger interest to the mass (public). This will require an innovative business model that demonstrates to the public financial returns for the trees they grow. Lack of such model, the public will develop lukewarm attitude in taking up the program. Unfortunately, this kind of business models has not been piloted by public organizations nor by national or county governments in Kenya.	CGM	KES 60 Mn (assuming 2 million per sub-county, annually)	CGM

Project/Program	Status (New or Ongoing)	Gap	Objective	Specific Activities
Enhancement of private sector participation in alternative sources of bioenergy	New	low adoption of clean cookstoves in Makueni	To promote clean cookstoves and fuels that are locally manufactured	• Identification of CTTIs to support the trainings • Identification of the types of cookstoves and bioenergy fuels to be included in the curriculum • Development of Curriculum • Conducting training of trainers • Identification of existing courses that can host the cookstoves curriculum as a module
	New	Few enterprises engaging in alternative bioenergy	To enhance capacity of local community to participate in the alternative bioenergy sector as entrepreneurs	• Conducting biannual trainings on bioenergy fuels and technologies through CTTIs • Supporting community -driven bioenergy focused start-ups through Clean Energy/Technology Adoption Fund
	New		To facilitate business entry private sector players in alternative bioenergy fuels into Makueni County	• Develop partnerships with development partners to conduct feasibility studies and to support in creation of an enabling environment for alternative bioenergy • Develop incentives to allow the private sector to establish commercial alternative bioenergy production plants
Awareness creation on clean cooking	New	There is low adoption of clean cooking technologies and fuels in Makueni County	To create awareness about clean cooking opportunities in Makueni County	• Establishment of suitable messaging and awareness creation channels such as local media, CBOs and FBOs • Partnering with Community health promoters to conduct awareness

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	Local artisans and community	Year 1	**Risk:** Low adoption of clean cookstoves in the county even after training. **Mitigation:** The energy champions who will raise awareness regarding the clean cookstoves after training	GMC and CTTIs	KES 8 Mn (assuming 3 artisans in each of the 6 sub-counties are trained at a cost of 100,000/=)	GMC
	Community	Year 1 & 2	**Risk:** Delay in funds allocation Delay in launching the Clean Energy/Technology Adoption Fund **Mitigation:** Partnership with potential donors and investors will be sought	GMC	KES 25 M (2.5 million annually, catering for bi-annual trainings and loans disbursement through the Clean Energy/ Technology Adoption Fund)	GMC Development partners
	`Community	Year 1 & 2	**Risk:** Limited private sector interest in entry to Makueni bioenergy Market Inadequate procedure governing private public partnerships in Makueni County **Mitigation:** Bilateral engagements between GMC and private sector to take up identified opportunities identified through the feasibility studies To complete the procedure governing public private partnerships in Makueni County	GMC	KES 3 M	GMC Development partners
	Local community	Year 2	**Risk:** Low adoption even after awareness creation. **Mitigation:** creation of financial incentives to support adoption	GMC	KES 3 M	GMC

Project/Program	Status (New or Ongoing)	Gap	Objective	Specific Activities
Enhanced distri-bution chain for clean cooking technologies and fuels	New	Low number of clean cooking fuels and technologies MSMEs	To enhance dis-tribution of clean cookstoves and fuels in Makueni County	• Promotion of clean cooking businesses e.g., by waiving licence fees for registered/certified LPG, ICS and bioethanol agents and following up to ensure quality products are sold to HHs. • Enable self-help groups (SHGs) and other local outlets to become extension last mile distributors.
LPG Investment	New	Low adoption of LPG (6 and 13 Kg)	To increase uptake of 13kg to 40% and 6 kg LPG to 70% in urban and rural areas respectively	• Purchase of appropriate LPG cylinders by and for households • Provision of subsidies to increase affordability of furling & cylinders. • Support of LPG distribution enterprises
TOTAL	KES 74.9 Billion			

	Target Beneficiary	Time	Project Implementation Risks	Implementing Agency	Project Cost	Source of Funds
	Clean Cooking SMES, HHs, SHGs	Year 1	**Risks:** Challenges in identifying genuine businesses; limited businesses interested in clean cooking; limited human capacity across the value chain **Mitigation**: Conduct awareness raising and workshops where clean cookstove distributors can engage local businesses to enhance interest County should verify registration of businesses before issuing waivers	Cookstoves value chain actors, GMC, private actors etc.	KES 2 M	GMC
	Urban and rural households	10	Identification of appropriate households Supply of LPG Changes in LPG tax regimes	GMC	1.8 B	GMC, LPG distributors, development partners, households

7.0 IMPLEMENTATION, COORDINATION, MONITORING AND EVALUATION

The attainment of universal energy access by 2028 in Makueni County is dependent on the implementation of policies, programs and projects suggested in this document. This will require both horizontal, as well as vertical coordination with state, as well as Non-State Actors (NSAs). Horizontally, collaboration across various departments within Government of Makueni County will be crucial, while vertically, coordination will be required with national government agencies, including the Ministry of Energy, as well as other institutions such as REA and KPLC, among others. Additionally, collaboration with private sector, development partners, Micro-Finance Institutions (MFIs), civil society organisations (CSOs), community-based organisations (CBOs), among others, will be key.

For effective coordination, the Department of Infrastructure, Transport, Public Works, Housing and Energy will spearhead the process. A strong monitoring and evaluation framework will be required to track progress and give insight that can be used to correct performance to ensure impactful implementation. This framework should be collaboratively developed by the same department in conjunction with the Department for Finance, Planning, Budget & Revenue. Additionally, input from other stakeholders should be considered.

The rest of this chapter focuses on the implementation, coordination and monitoring and evaluation (M&E) framework for the Makueni 2022 CEP. There will also be training components to build capacity for the implementation and coordination of new solutions, technologies, and approaches. The procedures detailed in this chapter were derived from consultative meetings held with officials from the Government of Makueni County over the duration of the CEP development process.

7.1 IMPLEMENTATION AND COORDINATION

Implementation of this energy plan will be led by the Department of Infrastructure, Transport, Public Works, Housing and Energy. Sufficient county government budget allocation and support from various development partners for the execution of the programs and projects as recommended in the CEP will ensure the success of the plan. The County Government Act, 2012, provides that, only programmes and projects planned for in the county government planning framework can be financed from the county government fund. The government will take advantage of the next review of the CIDP 2023 – 2027 to incorporate programs and projects prioritized under this CEP in the development plan. Further, the CEP Implementation Committee (CEP-IC) will ensure that annual CEP priorities are integrated in the Annual Development Plan (ADP) to guarantee their funding and implementation.

County government will establish the CEP Implementation Committee (CEP- IC). This committee will coordinate the different efforts geared towards implementation of the plan. The committee, depicted in Figure 6-1 will constitute the CECM responsible for Energy in the County government, two Chief Officers (CO responsible for energy and CO. responsible county planning), directors from relevant departments of County Government, representatives from the MoE, KPLC, REREC, and development partners working in the energy sector within the county, as well as private sector representative. The committee will be led by the CECM responsible for energy, deputized by the two COs – one for energy, and the other one for county planning. It will meet on a quarterly basis to provide advisory support and track implementation of the CEP. The committee will report to the County Energy Planning Committee described in the INEP framework. The CEP-IC will lead in the implementation of programs and projects captured in the energy plan. To enable them undertake their assignment effectively, the committee will be allowed to co-opt external members who have the required expertise on a temporary basis to ensure smooth project delivery.

In addition to the CEP - IC, a technical work group will be instituted, chaired by the CO responsible for energy, to coordinate the day-to-day activities in the implementation of the energy plan. The Director responsible of Monitoring and Evaluation matters will deputise the CO in this committee to ensure that activities are implemented in line with the proposed monitoring and evaluation framework. Other members of the committee will include Directors from relevant national and county government departments.

Overseeing the implementation of the plan will require strengthening of technical energy expertise in the county government. The Directorate of Energy will be staffed with additional experts with prerequisite skills to enhance its capacity. It may include redeployment of officers who were appointed to support development of the energy plan from different departments. Capacity building initiatives highlighted in Chapter six will also be useful in fast tracking the implementation of the CEP.

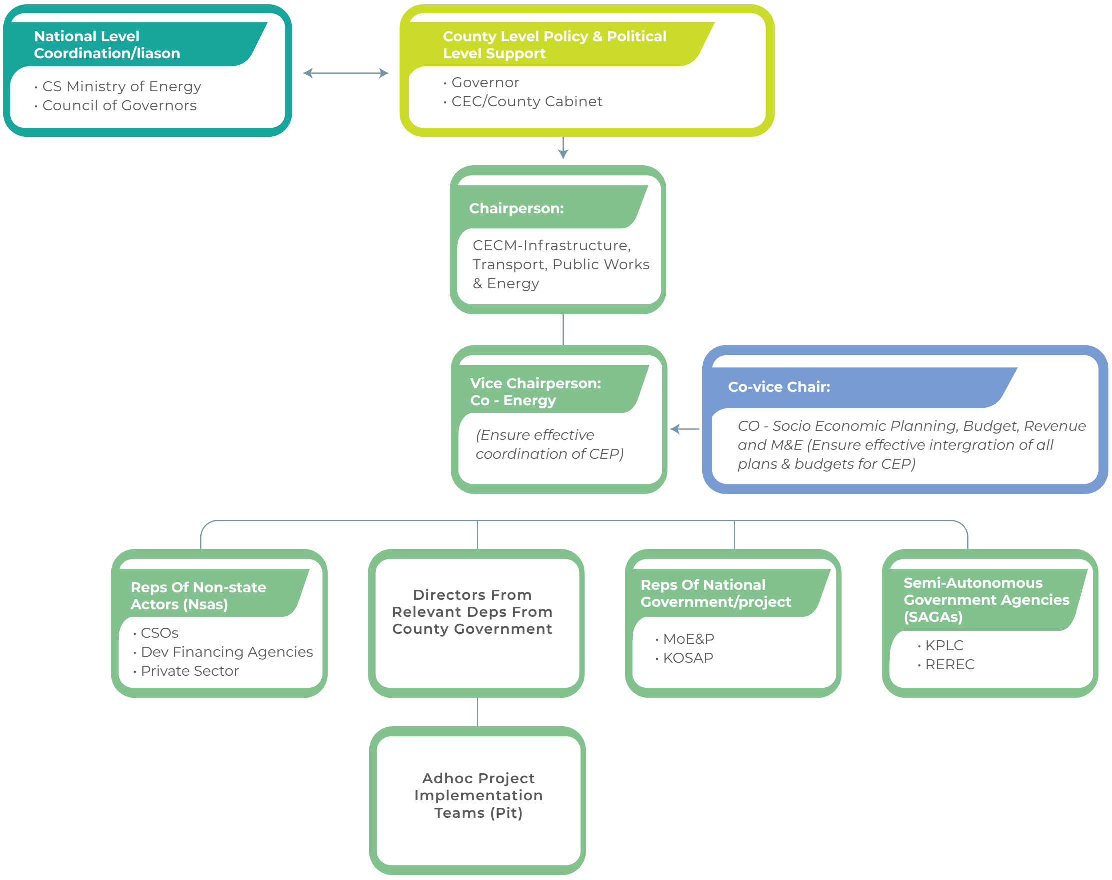


Figure 6-1: Constitution of the Proposed County Energy Plan Implementation Committee

While the Government of Makueni County is keen to promote a 'one-government-approach' in the management of its programmes and projects, consultative process during the development of the CEP revealed two major approaches currently being used to allocate budget for implementation of projects in the County. The first approach is where a particular department takes full responsibility for the design and allocation of resources for the implementation of projects that fall under its mandate. During key informant interviews, it emerged that this approach to budgeting may make the financial load too heavy for one department to carry, hindering resource efficiency and effectiveness in project implementation.

The second and most preferred approach is the integrated planning and budgeting, particularly in programs and projects that require coordination between different departments. This approach enhances collaboration working with each department, thus not only contributing financial resources but also technical expertise for success. The government will adopt this approach during implementation of all county CEP programs and projects to ensure success and mitigate against the implementation constraints.

7.2 MONITORING AND EVALUATION FRAMEWORK

Monitoring and evaluation of the CEP will be led by the M&E officer attached in the Department from Monitoring and Evaluation directorate. The officer will submit a bi-annual progress report to the M&E directorate with a copy to CEP – IC and the Technical Working Group. Monitoring will focus on programs and projects recommended within the CEP. The insights obtained during the monitoring will be used to undertake corrective measures and ensure the implementation is within the planned path. Periodic evaluation will also be carried out. This will involve both ex-ante evaluation and ex-post evaluation of projects, programs, and policies that are in the CEP. Table 7-1 provides a Monitoring and Evaluation Framework with clear targets and indicators that will be used to guide CEP implementation.

Table 7-1: Monitoring and Evaluation Framework

Project	Key Output/ Outcome	Indicators	Baseline Year
Cross-cutting issues			
Establishment of energy centres	Energy centres established.	Number of energy centres established	2023
		Number of technologies demonstrated	2023
Development of an Energy Policy	Energy policy developed	Energy policy developed	2023
	Energy policy implemented	Proportion of energy policy implemented	2023
Establishment of energy access fund	Design of energy access fund operational strategy including credit terms & identification of potential beneficiaries	Energy access fund operational strategy designed	2023
	Energy access fund established	Energy access fund	2023
		Amount of funds allocated to energy access fund (in KES)	2023
		Number of beneficiaries accessing the energy access fund	2023
Energy Efficiency			
Capacity Building for enhanced energy efficiency in the County	Increased adoption of energy efficient appliances in household's institutions and SMES	Proportion of households adopting LED lighting (%)	2022
		Proportion of Health centres adopting LED lighting (%)	2022
		Proportion of Institutions adopting LED lighting (%)	2022
		Proportion of SMEs adopting LED lighting (%)	2022
		Proportion of households, adopting improved and clean cookstoves (%)	2022
		Proportion of health centres adopting improved and clean cookstoves (%)	2022
		Proportion of educational institutions adopting improved and clean cookstoves (%)	2022
		Proportion of SMEs adopting improved and clean cookstoves (%)	2022
	compliance with Energy Management Regulations (EMR)2012	% compliance with Energy Management Regulations (EMR)2012	2023
	Enhanced Capacity on energy efficiency among count staff	Number of relevant county staff trained	2023
Development of e-mobility strategy	E-mobility Strategy developed	E-mobility strategy developed	2023
		Adoption rate of e-mobility across two wheelers- 'boda bodas'	2023

	Baseline Value	Mid Target	End Target	Source of data	Frequency	Responsibility	Reporting entity
	0	3	6	GMC, REREC	Annual	CO-Energy	GMC
	0	2	4	GMC, REREC	Annual	CO-Energy	GMC
	0	1	1	GMC	Annual	CECM-Energy	GMC
	0	40%	80%	GMC	Annual	CECM-Energy	GMC
	0	1	1	GMC	Annual	CO-Energy	GMC
	0	1	1	GMC	Annual	Head of County Treasury	GMC
	0	KES 150 Mn	KES 500 Mn	GMC	Annual	CO-Energy	GMC
	0	30%	100%	GMC	Annual	CO-Energy	GMC
	79.8%	90%	100%	KNBS	Annual	CO-Energy	GMC
	17%	60%	100%	GMC	Annual	CO-Energy	GMC
	16%	60%	100%	GMC	Annual	CO-Energy	GMC
	18.4%	70%	100%	GMC/KNBS	Annual	CO-Energy	GMC
	57%	75%	90%	KNBS	Annual	CO-Energy	GMC
	32.1%	60%	100%	GMC	Annual	CO-Energy	GMC
	2.5%	60%	70%	GMC	Annual	CO-Energy	GMC
	5.8%	25%	33%	GMC	Annual	CO-Energy	GMC
	-	30%	100%	GMC	Annual	CO-Energy	GMC
	0	All relevant staff trained	All relevant staff trained				
	0	1	1	GMC	Annual	CO-Energy	GMC
	0	20%	40%	GMC	Annual	CO-Energy	GMC

Project	Key Output/ Outcome	Indicators	Baseline Year
Conversion of county government two-wheelers from internal combustion engines to electric vehicles	Increased energy efficiency in the county transport sector	Proportion/number of county two-wheelers converted to electric vehicles (%)	2022
Development of energy efficiency and conservation building code for Makueni County	Energy efficiency and conservation building code developed	County Energy Efficiency Building Code developed	2023
		Level of compliance to County Energy Efficiency Building Code (%)	2023
Installation of automation and control light systems in county buildings and facilities	Increased operation efficiency	Proportion of county buildings fitted with lighting automation control systems (%)	2023
Installation of low flow appliances to replace standard flow appliances for water efficiency	Increased efficiency of water consumption	Proportion of county buildings and facilities fitted with low flow appliances (%)	2023
Water harvesting for county buildings and public facilities	Water harvesting structure constructed or developed according to county standards	Proportion of county buildings and public facilities installed with water harvesting structures (%)	2023
Water treatment programme for county buildings and public facilities	Grey water treatment facilities installed	Proportion of county buildings fitted with grey water treatment facilities (%)	2023
Electricity Access and Productive Use of Energy			
Grid densification, intensification, and extension	Increased access to electricity	Proportion of households connected to electricity (%)	2022
Increased generation of electricity from renewable energy program	Increased production of hydro-power	Number of hydro plants developed	2022
		Megawatts of energy generated	2023
	Increased production of solar power	Number of solar power plants developed	2022
		Megawatts of solar energy generated	2022
Distribution of solar home systems	Increased access electricity from solar home systems	Proportion of household using solar home systems (%)	2022
		Number of stand-alone solar systems distributed	2023
Feasibility study for provision of power for two Industrial Parks in the CIDP III	Feasibility study done	No. of Feasibility study done	2023
Mapping and development of attractive wind projects	Wind Energy potential areas mapped	Wind energy potential mapping report	2023
	Wind energy projects developed	No. of Wind Projects Developed or development ongoing	2023
Solarization of Health Care Facilities (HCFs)	Health Care facilities connected to Solar Energy	Proportion of health facilities connected to solar energy (%)	2023
Schools' electrification program.	Access to electricity in schools	Proportion of schools connected to electricity (%)	2023
Provision of appropriate electrification solutions for agricultural cooperatives and processing plants	Agricultural cooperatives and processing plants connected to appropriate electrification solutions	Proportion of agriculture cooperatives and processing plants connected to appropriate electrification solutions	2023
Provision of appropriate power solutions for water projects in Makueni County	Water projects utilising the appropriate power solutions	Proportion of water projects utilising the appropriate power solutions (%)	2023
Powering Irrigation schemes	Irrigation schemes powered with clean and affordable energy sources	Mapping and feasibility study	2023
		Proportion of irrigation schemes installed with solar power systems	2023

	Baseline Value	Mid Target	End Target	Source of data	Frequency	Responsibility	Reporting entity
	0	20%	50%	GMC	Annual	CO-Energy	GMC
	0	1	1	GMC	Annual	CO-Energy	GMC
	0	10%	50%	GMC	Annual	CO-Energy	GMC
	0	50%	100%	GMC	Annual	CO-Energy	GMC
	0	40%	70%	GMC	Annual	CO-Energy	GMC
	-	50%	80%	GMC	Annual	CO-Water	GMC
	-	30	60	GMC	Annual	CO-Water	GMC
	29.2%	40%	62%	KNBS	Annual	CO-Energy	GMC
	0	1	3	GMC/Ministry of Energy and Petroleum	Annual	CO-Energy	GMC
	0	2.45	25.1	GMC/Ministry of Energy and Petroleum	Annual	CO-Energy	GMC
	1	2	4	GMC	Annual	CO-Energy	GMC
	0.15	35	72.5	GMC	Annual	CO-Energy	GMC
	40.2%	30%	38%	KNBS	Annual	CO-Energy	GMC
	-	30,000	83,395	GMC	Annual	CO-Energy	GMC
	0	1	2	GMC	Annual	CO-Energy	GMC
	0	1	1	GMC	Annual	CO-Energy	GMC
	0	1	2	GMC			
	1	30	60	GMC	Annual	CO-Energy	GMC
	60	80	100	GMC	Annual	CO-Energy	GMC
	0	20%	70%	GMC	Annual	CO-Energy	GMC
	-	50	100	GMC	Annual	CO-Energy	GMC
	0	1	1	GMC	Annual	CO-Energy	GMC
	0	20%	50%	GMC	Annual	CO-Energy	GMC

Project	Key Output/ Outcome	Indicators	Baseline Year
Powering Cold storage facilities	Cold storage facilities powered with clean and affordable energy	No. of cold rooms connected to clean and affordable energy	2023
Development of PURE investment Prospectus (IP) for resource mobilisation	PURE investment Prospectus developed	No. of PURE investment Prospectus developed	2023
Bioenergy and Clean Cooking			
Promotion of commercial farming of bioenergy crops	Enhanced commercial farming of bioenergy crops	Proportion of farmers engaged in bioenergy crop farming	2023
		Number of bioenergy crop aggregation centres developed	2023
County landscape restoration and wood fuel development programme	Increased land restoration and sustainable use of wood fuel	Restoration opportunities and profile established	2023
Enhanced private sector participation in the bioenergy sector	Increased participation of local SMEs in the bioenergy sector	Training curriculum on clean cook stoves and alternative clean cooking fuels developed	2023
		Proportion of CTTIs offering training on adoption of clean cookstoves	2023
		Financing of local entrepreneurs to establish bioenergy enterprises	2023
	Enabling environment for SMEs in the bioenergy sector	Establishment of partnerships with development partners to fund feasibility studies	2023
		Development of incentives report to support in creation of an enabling environment for the bioenergy sector	2023
	Awareness campaigns organised and carried out	No. of awareness campaigns organised and carried out	2023
LPG Investment	40% of households using LPG by 2032	% of households	2023
Expansion of distribution chains for clean cooking fuels and technologies	Enhanced use of improved cookstoves among the HHs	Number of technology and fuel distributors per ward	2023

	Baseline Value	Mid Target	End Target	Source of data	Frequency	Responsibility	Reporting entity
	4	10	20	GMC	Annual	CO-Energy	GMC
	0	1	1	GMC	Annual	CO-Energy	GMC
	-	10%	20%	GMC	Annual	CO-Energy	GMC
	-	1	6	GMC	Annual	CO-Energy	GMC
	0	2	6	GMC	Annual	CO-Energy	GMC
	0	1	1	GMC	Annual	CO-Energy	GMC
	0	10	25	GMC	Annual	CO-Energy	GMC
	0	12	30	GMC	Annual	CO-Energy	GMC
	0	2	6	GMC	Annual	CO-Energy	GMC
	0	1	1				
	0	10	20	GMC	Annual	CO-Energy	GMC
	8%	25%	40%	GMC	Annual	CO-Energy	GMC
	-	1 distributor for each technol-ogy and fuel per ward	1 distributor for each technolo-gy and fuel per ward	GMC	Annual	Co-Energy	GMC

ANNEXES

A: BIOENERGY

A.1 Expression Used to Calculate biogas potential from sisal and mangoes

$$Q_{biogas\text{-}from\text{-}crop\text{-}residuals,\ solids} = TB_{Fresh\text{-}esidues\text{-}collected\text{-}per\text{-}year} * RF * FFC * DM * VS_{content} * BP_{Biogaspotential}$$

Where:

$Q_{biogas\text{-}from\text{-}crop\text{-}residuals,\ solids}$ is the amount of biogas that can potentially be produced annually from relevant crop residues

$TB_{Fresh\text{-}residues\text{-}collected\text{-}per\text{-}year}$ is the amount of residue (tonnes per year)

RF is the recoverable fraction of the total available residue biomass

FFC is the fraction of residue free from completion (and available for biogas production)

DM is the Dry matter content (% FFC)

$VS_{content}$ is the Volatile solids (VS) content (% RF)

$BP_{Biogas\ potential}$ is the Biogas potential for the substrate (m^3/t VS)

The equation below is used to determine the biogas potential from wastewater:

$$Q_{biogas\text{-}from\text{-}crop\text{-}residuals,\ wastewater} = QCC * RPR * COD_{wastewater} * COD_{degradability} * BP_{Biogas\ potential}$$

Where:

$Q_{biogas\text{-}from\text{-}crop\text{-}residuals,\ wastewater}$ is the biogas potential from wastewater

QCC is the crop-based commodity associated with the waste

RPR is the residue to product ratio

COD is the chemical oxygen demand in wastewater (g/l)

COD degradability (%) is the chemical oxygen demand degradability, as percentage

Biogas potential Nm^3/ton $COD_{removed}$ is the biogas potential in ‘normal cubic meter per tonne COD) removed

A.2 Summaries of the production of substrates and wastewaters together with the characteristics of parameters which can be used in deriving the potential biogas

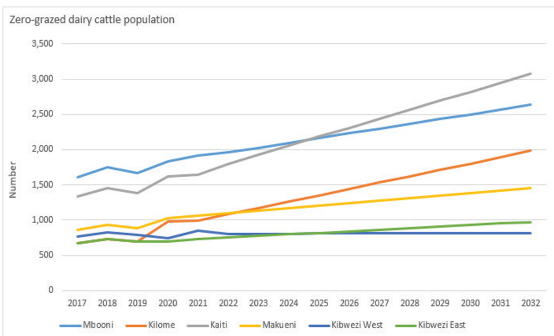
Table A1: Summaries of the production of substrates and wastewaters together with the characteristics of parameters that can be used in deriving the potential biogas

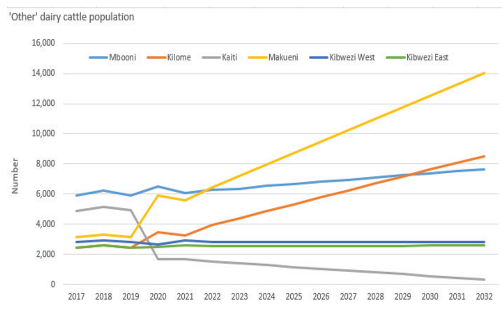
Crops	Residue (sub-strate)	RPR	Residue recovery factor	***Dry matter (DM) content (% of fresh matter, FM)	***Volatile solids (VS) content (% DM)	***Biogas potential (Nm3/t VS)	Biogas potential (Nm3/t fresh weight)	Volatile matter (weight %)
Mangoes	Peels, fibre, stone	*0.45 [45% processing residues: peels, fibre, stone]	*50 %	+14	+95	+550	*60	*75
Sisal	Sisal pulp	24 [24 ton of pulp produced for every 1 ton fibre produced]	**90 %	10	85	523	**56	**85

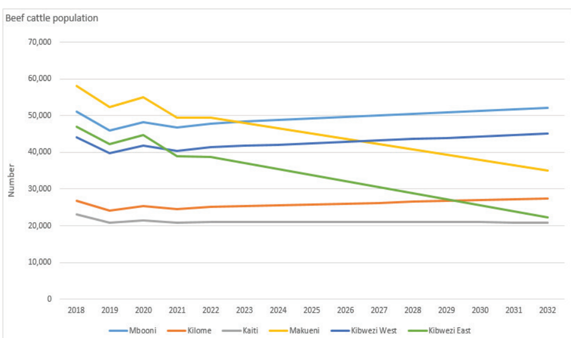
*Sources: * NIRAS-LTS, 2021a, ** NIRAS-LTS, 2021b, ***GIZ, 2010*

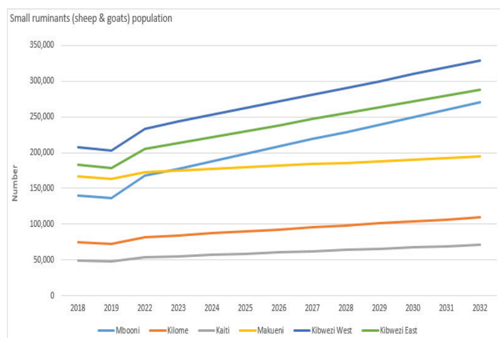
NB: + Because values for mangoes were not available, the values for pineapple solid wastes were used as surrogate.

A.3 Projection of Livestock Population in Makueni County









B: ENERGY ACCESS

B.1 Multi-Tier Framework

Table B-1: Multi-tier framework

ATTRIBUTES		TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Peak Capacity	Power capacity rating[28] (in W or daily Wh)		Min 3W Min 12Wh	Min 50W Min 200Wh	Min 200W Min 1.0Wh	Min 800W Min 3.4Wh	Min 2kW Min 8.2kWh
	OR Services		Lighting of 1,000 lmhr/day	Electrical lighting, air circulation, television, and phone charging are possible			
Availability (Duration)	Hours Per day		Min 4hrs	Min 4hrs	Min 8hrs	Min 16hrs	Min 23hrs
	Hours Per evening		Min 1hrs	Min 2hrs	Min 3hrs	Min 4hrs	Min 4hrs
Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration <2 hrs
Quality						Voltage problems do not affect the use of desired appliances	
Affordability					Cost of a standard consumption package of 365 kWh/year <5% of household income		
Legality						Bill is paid to the utility, prepaid card seller, or authorized representative	
Health & Safety						Absence of past accidents and perception of high risk in the future	

B.2 LCOE Calculation and data inputs for OnSSET

The LCOE from a specific source represents the final cost of electricity required for the overall system to break even over the project lifetime.

The Equation below gives the formula used for calculating LCOE for a particular technology considers:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + O\&M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

Where:

I_t: Investment expenditure for a specific system in year t,

$O\&M_t$: the operation and maintenance costs,

F_t: the fuel expenditures,

E_t: the generated electricity,

***r:** the discount rate,*

***n:** the lifetime of the system.*

The electrification options are divided into three main categories: grid-connected, mini grids and standalone systems (e.g.: Solar home systems or SHSs). The cost of generating electricity for all off-grid technologies is calculated according to renewable energy resource availability (e.g., Global Horizontal Irradiation) and the technical and economic parameters of generation technologies (e.g., capacity and capital cost factors). For mini grids, an additional cost for the distribution network is added. Then for each cell, the most cost-effective off-grid technology is selected.

OnSSET is a GIS-based tool and therefore requires data in a geographical format. In the context of the power sector, necessary data are shown in Table B-2:

Table B-2: Data required for OnSSET

Distribution of HV lines (current & planned)
Distribution of MV line
Location of Substations & Transformers
Road network
Global Horizontal Irradiation
Location of Substations & Transformers
Wind speed
Location of Small Hydropower potential sites
Land Cover
Night time light
Elevation & Slope
Administrative boundaries
Population distribution

B.3 OnSSET Scenarios Combinations

Table B-3: OnSSET scenario combinations

Scenario Parameters	Choice	Explanation of choice options
Population Growth	0, 1	Expected population in the country by the end year of the analysis; 0: low population growth, 1: high population growth
Target_electricity_consumption_level	0, 1, 2	0: low electricity demand target (e.g., U4R1), 1: high electricity demand target (e.g., U5R3), 2: use the custom residential demand target layer (from GIS)
Electrification_target_5_years	0, 1	0: low electrification target in the intermediate year (e.g., 35%), 1: high electrification target in the intermediate year (e.g., 60%)
Grid_electricity_generation_cost	0, 1	0: low generating cost for the grid (e.g., 0.047), 1: high generating cost for the grid (e.g., 0.059)
PV_cost_adjust	0, 1, 2	0: PV capacity cost as defined by the user, 1: PV capacity cost reduced by 25%, 2: PV capacity cost increased by 25%
Diesel price	0, 1	0: low diesel price, 1: high diesel price
Productive_uses_demand	0, 1	0: not including productive uses of electricity, 1: including productive uses of electricity
Prioritization_algorithm	0, 1, 2	0: least cost prioritization, 1: forced grid within 1km, 2: forced grid within 2km

B.4 Key Cooking Modelling Data and Assumptions

The following assumptions were used to project households, population, SMES and learning institutions

1. The Base year 2022's number of households is taken as 259,602HH projected from a population of 921,168 and 243,979 HH in 2019. The HH size is taken as 3.92, which reduces annually by 0.01%[1].
2. Projection growth rate for households from 2022-2032 is 2.62%[4].
3. Number of SMEs is 2,285 (Source: Government of Makueni County Statistics 2022)
4. Summary of the Learning Institutions Statistics[2] – Table 1

Table B-4: Data on Learning Institutions in Makueni County

Institution	Total number	Number of Students/Catering Capacity
ECDE (Public)	1,208	41,765
ECDE (Private)	210	
Primary (Public)	903	225,960
Primary (Private)	129	15,375
High School (public)	390	117,165
High School (private)	29	3,326
CTTI (Public)	3	4,698
TVET (Private)	10	-
University Campus	3	-
Total (excluding ECDE & public Primary)	-	140,564

Table B-5: Modelling data for Households

Source of Energy/ Technology	Annual Specific consumption (Kg/year)		Urban (Adoption Rate)			Rural (Adoption Rate)		
	Urban	Rural	2019[3] (%)	2023 (%)	2032 (%)	2019[1] (%)	2023 (%)	2032 (%)
6Kg Meko	60	48	39.1	16	-	15	8	-
LPG Cookstoves	60	60	9.25	61	-	1.15	16	-
Conventional charcoal cookstoves	192	372	4.6	41	-	8.6	35	-
Improved charcoal cookstoves	180	312	21.6	20	-	16.8	20	-
Three Stone Open Fire (TSOF)	372	1404	21.8	4	-	75.4	75	-
Improved wood cookstoves	900	1092	1.5	7	-	5.7	15	-
Kerosene (lts/year)	45	50	28	24	-	3.2	9	-
Biogas	-	$135M^3$		0	-		-	-
Electricity (hot plate/ induction cookers)[4]	1318kWh	1318kWh		-	-	-	-	-
Electric Pressure Cookers (EPC)	800kWh	800kWh		-	-	-	-	-
Bio-Ethanol[5]	3500MJ	3500MJ		-	-	-	-	-
Gasifiers (Biomass)[6]	150Kg	270Kg		-	-	-	-	-

Table B-6: Summary of Costs

S.no	Cooking Technology	Cost Range (Ksh)[7]
1.	Improved wood stoves	2,800 – 3,600
2.	Ordinary Charcoal Cookstove	300 – 500
3.	Improved Charcoal cookstove	2,990 – 5,300
4.	3 Kg Meko	2,000 – 3,000
5.	6 Kg Meko	3,500 – 5,000
6	Mixed LPG -Electricity stove	28,920 – 39,250
7.	Electric Hot plates	2,000 – 5,000
8.	Induction Cookers	9,500
9.	Electric Pressure Cookers	7,000-15,000
10.	Bio- Ethanol stoves	2,300 – 7,000
11.	Biogas (Digester and cooking accessories)	50,000 – 100,000
12	Gasifiers	11,000

Institutional LPG burners with 1Tonne of LPG tank ranges between Ksh1.5-2.0Million[8].

Rocket stove Ksh 500-1000 FGD plus installation Ksh. 2,500 Total Ksh. 3000 – 3500

Institutional Electric Pressure cookers (65L) USD 639[9] ex-works in China – Estimated final price USD 781

SME Electric Pressure cookers (33 L) USD 268[3] ex-works in China – estimated final price USD 410.

Commercial Charcoal stove (SME) Ksh. 9,000[10] – Jiko Koa

Biogas Costs[11]

Cost of a domestic Biogas digester for a HH with 5persons is 95,000K

Cost of Commercial Biogas system - T-Rex T30m^3 gas capacity of 15m^3 is Ksh. 750,000

T-Rex T50m^3 gas capacity of 25m^3 is Ksh. 1,250,000

T-Rex M100m^3 gas capacity of 50m^3 is Ksh. 1,850,000

C: ENERGY EFFICIENCY

C.1 KNEECS (2020) Strategies and Targets

Objectives	Indicators	Status (2019)	Target by 2025
Improve the energy efficiency of household electrical appliances	Electricity consumption of household appliances	961 GWh (6 kinds of appliances) a Projected target	3% annual increase in efficiency to the base case level in 2020
	Number of appliances covered by MEPS	6MEPS, covering motors, air conditioners, fridges, CFLs, magnetic ballasts, and fluorescent lamps	10 MEPS – Additional MEPS for LEDs, computers, TVs, and cookstoves
Improve the energy efficiency of household thermal energy	• MEPS for cookers & fuels • Testing lab for cookers and fuels • Communication and awareness strategy • Reviewed CAP • Bio Energy strategy formulated	70% households using biomass fuel	50% households utilizing clean energy

Improve fuel economy performance and reduce CO2 emissions in Kenya in the transport sector	Average fuel consumption (light duty vehicles) per 100 km travelled Average CO2 emission per km travelled	Average fuel economy = 7.5 L/100km Average CO2 emission = 181.9 g/km	6.5 L/100km 160 g/km
Increase the adoption of E-Mobility	Share of electric/hybrid vehicles in total vehicles imported into Kenya	0%	5% of imported electric cars annually
Develop Minimum Energy Performance Standards for Buildings	1 Minimum Energy Performance Standard developed and gazetted	0	1
Building Energy Use Index	Establish Baseline Energy Use Index for Buildings in Kenya	0	1
Improve the energy performance of new buildings in Kenya	Share of newly built floor area compliant with energy efficiency requirements in the total building stock	0	10%
Building cooling	Adopt American Society of Heating, Refrigerating and Air-Conditioning Engineers buildings energy conservation standards or equivalent for public and commercial buildings	0	2
Improve the energy efficiency of lighting in existing public buildings	Lighting load in public buildings	0	50%
Promotion of new green public buildings	Design and construction of energy-efficient/green public buildings	0	20
	Ensure 25% of buildings under affordable housing are green buildings	0%	25%
Increase the reach of successful industrial energy efficiency programmes	Number of audited facilities	1,800	4,000
Improve the acceptance of energy audits and implementation of energy audit recommendations	Number of certified energy efficiency professionals	70 licensed EE professionals	120 licensed EE professionals
Enhance the implementation of recommended EE measures	Estimated industrial energy savings	Current estimated annual savings level from programmes: 177,000 MWh/20MW demand/51m litres heavy fuel oil/1.8m litres industrial fuel oil	885,000 MWh/100MW demand/250m litres heavy fuel oil/9.0m litres industrial fuel oil
	No. of ESCOs created and undertaking EE projects	0	5
Improve EE in the agricultural value chain in off-grid areas	Demonstration projects for EE in Productive Use of Energy activities in agricultural value chain in off-grid areas. Target projects include pumping water systems, cold chains, and grain milling.	0	5

C.2 Summary of Kenya Green Buildings Design Guidelines

1. Building envelope insulation that isolates the building from the outside environment for passive cooling.
2. Using reflective or light-coloured walls and roofing materials or installing a roof garden to reduce heat flow into the building.
3. Building orientation that minimises façades facing east and west to reduce solar heat ingress.
4. Design windows with shading devices or roof overhangs to minimise solar heat ingress. Growing trees outside buildings helps in reducing solar heat ingress.
5. Use of high thermal performance glass such as double glazed or reflective film to shield external heat ingress.
6. Design for optimum natural lighting and cooling with window to wall ratio (WWR) of 30% and above.
7. Where artificial lighting is needed, then use of high efficacy LED lighting to be employed e.g., to attain a max of $3W/m^2$ per 100lux for offices.
8. Design for light zoning that allows specific lights to be switched on only where required. The use of lighting automation such as timers, motion and daylight sensors to be employed to operate lights when needed.
9. Design for natural draught ventilation. Where artificial ventilation and air conditioning is required, then high efficiency ventilation units to be employed.
10. Design to allow onsite electricity generation such as Solar PhotoVoltaic (PV).
11. Design buildings to allow for solar water heating installation
12. Design for water use efficiency that includes use of low flow faucets, rain water harvesting, grey water treatment and reuse.
13. Apply Energy Efficiency Management principles in buildings during operations that include energy monitoring, metering and sub-metering and efficient use of lighting, appliances and utilities.