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TRANSFORMING LANDSCAPES:

A Water, Food and Energy Nexus approach in Ecosystem Based Adaptation

CETRAD Centre for Training and Integrated Research in ASAL Development

PIK

MID-P Collective Action: Resilient Society

NDMA

SEI Stockholm Environment Institute

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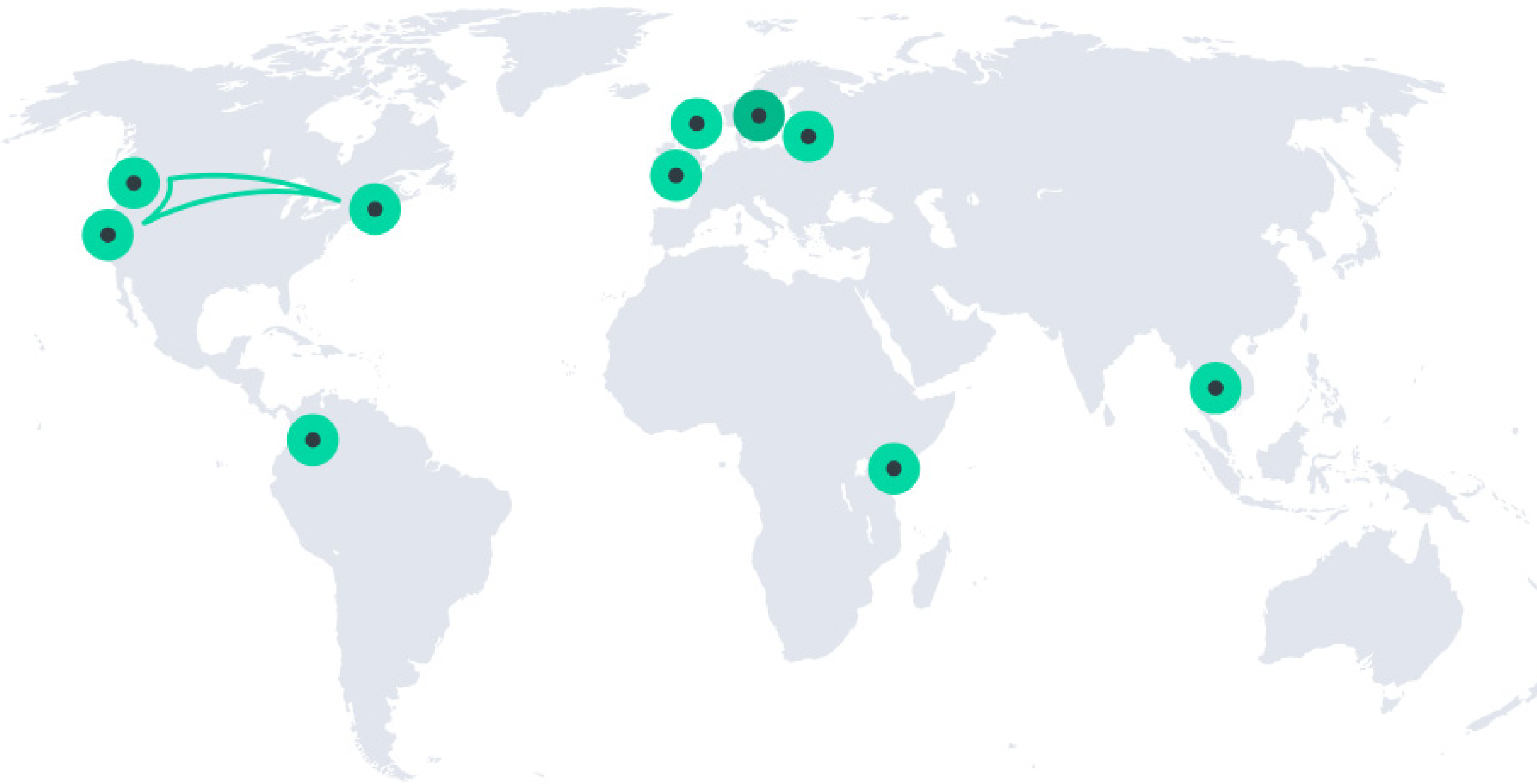

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About the Project

Applying the water-energy-food nexus to promote ecosystem-based adaptation in the Ewaso Ng'iro North Catchment, Kenya

This project seeks to support the Government of Kenya, five county governments (Laikipia, Samburu, Isiolo, Meru and Nyeri), local communities, and agro-based private enterprises to promote ecosystem-based adaptation practices and integrated planning for water, energy, agriculture and land use for resilient livelihoods in the Ewaso Ng'iro North Catchment Area.

The project seeks to apply ecosystem-based adaptation (EbA) and the nexus approaches to facilitate the co-production of resilient water-energy-food (WEF) knowledge with stakeholders (policymakers, local community groups, private sector, and non-governmental organizations) to inform decision and policymaking.

The project will contribute towards several development objectives which are in line with the Kenya Vision 2030 priorities, the Ewaso Ng'iro North Development Area (ENNDA) Integrated Regional Development Plan (2010-2040), the ENNDA catchment management strategy and the reformulation and implementation of CIDPs. These include increasing food security, especially pastoral livestock production; resilience through livelihoods diversification; employment creation through EbA solutions; agricultural growth; the conservation and safeguarding of critical habitats, including wildlife-protected areas and community wildlife conservancies. At the governance level, the nexus approach is expected to promote cooperation among actors and policy coherence across "policy silos", i.e. sectors, levels and scales and the key added value of the nexus approach is in integrating across the various plans and strategies, promoting synergies and generating co-benefits.

Expected results

- WEF nexus models and development scenarios for Ewaso Ng'iro North Catchment Area (ENNCA)
- Identification, validation, and promotion of innovative Ecosystem-based nexus solutions among key stakeholders in the ENNCA region
- Increased awareness of cross-sectoral interactions (water, energy, agriculture, and land) during the implementation, upscaling, out scaling, and transfer of ecosystem-based nexus solutions at the sub-national and national level

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LIST OF ACRONYMS

AGB	Above Ground Biomass
ASAL	Arid and Semi-Arid Lands
AGB	Above Ground Biomass
BAU	Business As Usual
BGB	Below Ground Biomass
BR	Bio-resource (contextual in Nexus scenario)
CCAP / NCCAP	National Climate Change Action Plan
CCRS / NCCRS	National Climate Change Response Strategy
CIDP	County Integrated Development Plan
CO	Chief Officer (context: county executives)
CSO	Civil Society Organization
CEP	County Energy Plan
CETRAD	Centre for Training and Integrated Research in ASAL Development
EbA	Ecosystem-based Adaptation
ECD	Early Childhood Development Centres
ENNCA	Ewaso Ng'iro North Catchment Area
ENNEbA	Ewaso Ng'iro North Ecosystem-based Adaptation
FAO	Food and Agriculture Organization
FRL	Forest Reference Level
GDP	Gross Domestic Product
GCP	Gross County Product
GoK	Government of Kenya
GHG	Greenhouse Gases (context: NDC emissions reductions)
ha	Hectares (used in land/forest metrics)
KOSAP	Kenya Off-Grid Solar Access Project
KPI	Key Performance Indicators
LEAP	Low Emissions Analysis Platform
LT-LEDS	Long-Term Low Emission Development Strategy
LPG	Liquefied Petroleum Gas
MIDP	Merti Integrated Development Programme / MID-P (organization working in ENNCA)
MW	Megawatt
m3/ha	Cubic meters per hectare (biomass estimation)
NDC	Nationally Determined Contribution
NAP	National Adaptation Plan
NGO	Non-Governmental Organization
PIK	Potsdam Institute for Climate Impact Research
PV	Photovoltaic
REREC	Rural Electrification and Renewable Energy Corporation
SEI	Stockholm Environment Institute
SMEs	Small and Medium Enterprises
TJ	Terajoules
TVET	Technical and Vocational Education and Training
UNFCCC	United Nations Framework Convention on Climate Change
WEAP	Water Evaluation and Planning
WEF	Water–Energy–Food

EXECUTIVE SUMMARY

The Ewaso Ng'iro North Catchment (ENNCA) sits at the heart of Kenya's arid and semi-arid lands (ASALs), supporting over three million people, extensive livestock systems, critical ecosystems, and the basin's only perennial river. Yet the region faces intensifying pressures from rapid population growth, land-use change, upstream agricultural expansion, climate variability, and competing demands for water, land, biomass, and energy. These dynamics combined with the ambitions of Vision 2030 and major infrastructure projects are accelerating ecosystem degradation and threatening water, food, and energy security.

This report presents the findings of a comprehensive Water-Energy-Food (WEF) Nexus and Ecosystem-based Adaptation (EbA) assessment conducted in five ENNCA counties: Laikipia, Meru, Nyeri, Isiolo, and Samburu. Implemented collaboratively by SEI, CETRAD, and MIDP, the study integrates systemic modelling, stakeholder co-production, and scenario analysis using SEI's LEAP (Low Emissions Analysis Platform) and WEAP (Water Evaluation and Planning) tools. The objective is to support counties in transitioning from siloed sectoral planning to coherent, evidence-based, cross-sector decision-making that enhances resilience and resource sustainability.

Methodological Approach

A multi-tiered engagement process comprising national inception meetings, county taskforce sessions, training workshops, and participatory mapping guided data collection, scenario building, and model validation. Key inputs included demographic and macro-economic drivers, energy demand and supply data, water system parameters, charcoal production flows, and FRL-based forest resource assessments. Stakeholders co-developed three major scenario pathways in addition to a baseline: County Plan, Climate Action, and Nexus scenarios.

Key Findings

1. Rising Energy Demand Under BAU

Total final energy demand across the five counties is projected to grow from 23,000 TJ in 2020 to 28,000 TJ in 2030, driven primarily by population and economic growth. Biomass remains dominant, constituting an average 90% of household energy demand with Meru and Nyeri recording the highest residential consumption levels.

2. Misalignment Between County Plans and National Climate Goals

County Plan Scenarios generally increase total energy demand to 30,500 TJ by 2030, reflecting ambitious industrial growth but limited commitments to clean cooking or energy efficiency. This contrasts sharply with the Climate Action Scenario, aligned to Kenya's NDC and NCCAP, which shows that aggressive adoption of clean cooking fuels, electrification, and energy efficiency could reduce energy demand by nearly 50% relative to BAU by 2030.

3. Nexus Trade-offs and Synergies

The Nexus Scenario highlights critical interactions:

- Expansion of hydropower and irrigation can constrain water availability for ecosystems and downstream users.
- Increased charcoal and firewood extraction intensifies forest degradation particularly in Isiolo, Samburu and Meru unless alternative energy transitions occur.
- Solarizing boreholes reduces diesel reliance but increases electricity demand, requiring coordinated planning between water and energy departments.

4. Spatial Variations in Resource Stress

FRL analysis shows notable degradation in forest and shrubland areas across the basin, with land conversion, charcoal production, and agricultural expansion acting as major drivers. Counties such as Meru and Nyeri show greater reliance on farm forestry, while others depend more heavily on surrounding natural ecosystems, elevating the risk of long-term resource deficits.

Implications for Policy and Planning

Adopting a WEF Nexus-EbA approach offers counties a structured pathway to:

- Reduce biomass pressure and forest degradation
- Strengthen resilience to droughts and floods
- Improve water reliability for households, ecosystems, and productive uses
- Align county plans with national climate targets
- Enhance sustainability of energy, water, and agricultural system
- Lower emissions and enhanced alignment with national climate commitments

Conclusion

The ENNCA is at a critical decision point. Without integrated planning, escalating pressure on water, land, and energy resources will compromise Vision 2030 ambitions and climate resilience. However, by adopting a WEF Nexus EbA framework supported by robust modelling, stakeholder participation, and cross-sector coordination, the five counties can safeguard ecosystems while enabling sustainable economic transformation. This report provides the evidence base, scenario pathways, and policy insights needed to drive that transition.

INTRODUCTION

Kenya seeks to achieve middle income status through the Vision 2030 development blueprint and to promote integrated climate change mitigation and adaptation to achieve the targets set in Nationally Determined Contributions (NDC). Several policies, strategies, action plans and programmes have been developed to enable the government and stakeholders (private sector, CSOs, local communities) to address climate change. These are anchored in the Climate Change Law of 2016 and Climate Change (Amendment) Act, 2023.

The Ewaso Ng'iro North Catchment (ENNCA) is located in the ASAL and is part of the Ewaso Ng'iro North Basin, the largest river basin in Kenya. Over 3 million people and large numbers of livestock, wildlife and ecosystems rely on the Ewaso Ng'iro north, the only perennial river in the basin. As a consequence of the Kenya Vision 2030 and its planned flagship infrastructure projects (a mega dam along the Ewaso Ng'iro River, the Isiolo Resort City, and the Lamu Port-South Sudan-Ethiopia-Transport Corridor), the prevailing competition among different water, land, biomass and energy users in the basin is projected to intensify. Additional pressures expected to arise from upstream commercial agriculture expansion, population and urban growth and climate variability and change. These factors in combination lead to increased abstraction of water, thereby critically reducing the water flow during the dry season, land degradation, deterioration of ecosystem health and eventually compromising water-, energy- and food security.

To address these challenges, a water-food-energy nexus approach in planning for resource allocation and use is encouraged. SEI, CETRAD and MiDP are collaborating to pilot a Nexus planning approach in five Counties in ENNCA - Laikipia, Samburu, Isiolo, Meru and Nyeri - where rapid transitions in agriculture, energy systems and water and land use are ongoing. The application of a combination of EbA and Nexus approach has the potential to enable and promote coordination and cooperation across sectors (water, energy, agriculture/land, and environment) and levels (local, sub-national and national) which is currently lacking in addressing integrated climate change adaptation and mitigation by local public and private sectors and civil society actors.

Background

The project uses as a key entry point the Kenya Vision 2030 – the development blueprint whose objective is to transform Kenya into a newly industrializing "middle income country providing a high quality of life to all its citizens by the year 2030" by among others, maintaining and sustaining a 10% annual economic growth to 2030, and Kenya's Nationally Determined Contribution (NDC). The potential negative impacts of climate change could however undermine the efforts towards the achievement of Vision 2030 goals; estimates suggests that climate change could lead to additional and potentially very large economic costs, equivalent to 3% of GDP by 2030 (SEI, 2009). The ASAL regions, which cover 83% of Kenya's land mass, and which host some of the most vulnerable ecosystems, have recently experienced severe climate effects manifested for example in the form of recurrent drought and floods.

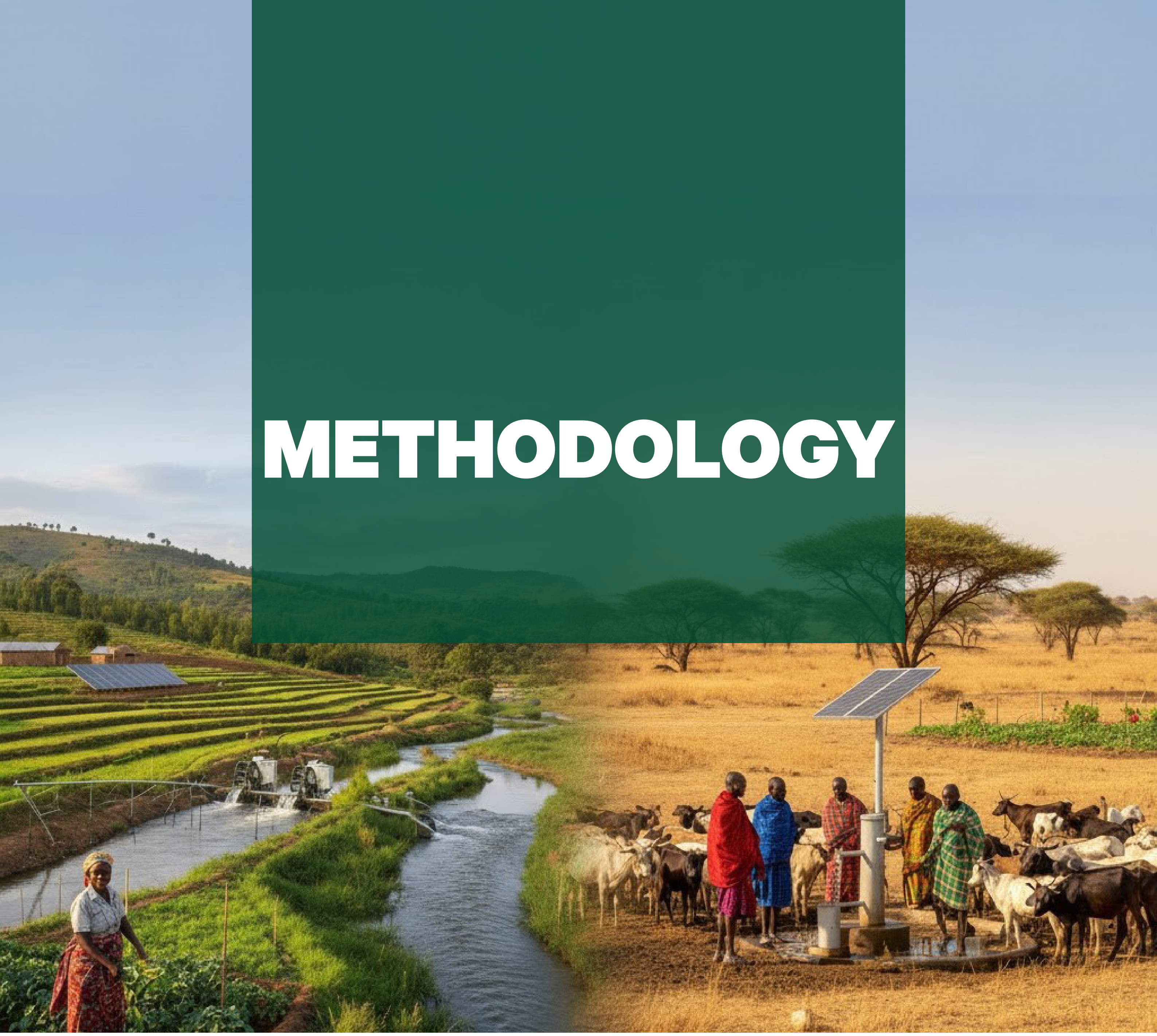
In response to the challenge posed by climate change, the Government of Kenya (GoK) has enacted the Climate Change Act (2016) and has developed the draft National Climate Change Framework Policy to provide the legal and policy framework for facilitating an effective response to climate change. Furthermore, the GoK has also developed the National Climate Change Response Strategy (NCCRS 2010), the National Climate Change Action Plan (NCCAP 2013-2017), and the Na-tional Adaptation Plan (NAP: 2016-2030), which provide a vision for low carbon and climate resilient development pathway. The NAP aims "to consolidate the country's vision on adaptation supported by macro-level adaptation actions that relate with

In Kenya, the ASAL regions, cover 83% of Kenya's land mass, and host some of the most vulnerable ecosystems. These regions have experienced severe climate effects manifested for example in the form of recurrent drought and floods. It is reported that there has been 45 flood disasters between 1990 and 2020 and some of the recent occurrences of drought were 2021-2022, 2016 – 2017 and 2008 – 2012 causing unprecedented effect on human and wildlife[1]. In response to challenges posed by climate change, the country has enacted policies, regulations and plans including the nationally determined contribution to the UNFCCC with ambitious targets in abetment of national contribution to GHG emission and created relevant institutions in spearheading climate change mitigation and adaptation priority actions. However, working in 'silos' often are ineffective or result to non-intended impacts on other sectors exacerbating climate change mitigation and adaptation efforts.

As such the nexus project aims at generating evidence and creating awareness for policy and decision making, that (1) coordination and cooperation across sectors (water, energy, agriculture / land, and environment / ecosystems) and scales (local and national) can promote synergies and bring benefits over and above taking a single sector approach; (2) that ecosystems can serve as "natural infrastructure"; and (3) that an EbA nexus approach can strengthen resilience.

Therefore, the project activities that fall in work package 2 which was co-led by SEI and the PIK, involve participatory nexus analysis and development and evaluation of participatory scenarios for different development pathways and interventions, the project elucidate the interactions between and among sectors, including synergies and trade-offs at the county level. It incorporates scenarios based on the county integrated development plans to assess levels and rates of resource extraction demonstrating strains or yields in Ewasongiro North catchment. The activities also include a rapid assessment, mapping of resources and a participatory appraisal of issues, trends, risks to eco-system services and vulnerabilities of social-ecological systems.

[1]MoEF, 2023; National Long Term – Low emission development strategy, 2022 - 2050



METHODOLOGY

The study was designed pragmatically with a mix of methods including systemic modelling, qualitative research and case studies. The study also adopted intensive stakeholder engagement for co-development and ease adoptability of the project result in influencing policy.

Literature review

Key national and county level literatures and documents were used to provide baseline information. This included such national statistical reports such as Economic survey reports, national census report and strategies, county level reports such as county gross domestic product and economic report, county energy plans and county integrated development plans as well as other strategies.

These literatures provide key information and statistics relevant for modelling such as historic population data, economic drivers to energy consumption, energy demand sectors and intensity of consumption and county relevant plans for scenarios development.

Stakeholders’ engagement

Stakeholders’ engagement was systematically organised to enhance co-creation of the WEF Nexus and adoption for policy influence at the county level. The engagements were designed to deliver the project in a multi-level approach.

High level engagement

Inception meeting

This included the inception workshop that brought together national government representatives from the three sectors – Water, Agriculture and Energy. The Directors and representatives from the three nexus sectors, county executives and chief officers discussed in details of the nexus project, the intersection between energy-food and water and cross county collaboration in the catchment with an aim to meet the needs of the counties while conserving the environment and adapting to the changing climate.

The inception meeting provided the critical county decision makers with a comprehensive overview of the WEF Nexus and its interconnections as well as a short introduction of the tools, establishing a foundational understanding essential for sustainable resource management in their counties. Counties represented included Meru, Laikipia, Nanyuki, Isiolo, and Nyeri.

Validation and Policy forum

Taskforce Meetings

Systematic taskforce meetings were designed to co-deliver design, data collection, modelling and analysis of the Nexus work.

The intense modelling work was to be preceded with task force training on both WEAP and LEAP. The training objectives were to enhance capacity of participants on the modelling tools - LEAP and WEAP – in developing county energy and water demand and supply and co-develop different scenarios and analyse development pathways using a nexus approach. The expected outcome is the counties adopting modelling approach and data in effective decision making. The list of the taskforce list is in the appendix 1.

The training followed the systematic approach described in the theory of change for the Water-Energy-Food Nexus to promote Ecosystem Based Adaptation. Output 1 of the proposal sought for different nexus development scenarios modelled, evaluated and compared using the Nexus toolkit. The main activities that led to the output included establishing baseline for ecosystem services, data collection, parametrisation and in a participatory approach apply LEAP and WEAP modelling with water and energy experts from county and national governments, develop scenarios jointly with stakeholders, Integrating WEAP and LEAP models to generate alternative scenarios enhancing resource conservation and building resilience and finally stakeholder engagement and assessing impacts of EbA nexus solutions.

These activities shall be achieved in three training sessions as summarised in table 1 below.

Table 1. LEAP/WEAP training roadmap for the ENNEbA project

LEAP training session	Corresponding activities	Key outputs and KPI
Session 1 LEAP/WEAP training: Introduction to LEAP/WEAP modelling tool and taskforce identification	Collect data, parameterize models, and apply the SEI nexus toolkit (WEAP and LEAP) for ENNCA, jointly with water and energy experts from county and national government agencies	30 officers from government, private and CSO trained on WEF nexus planning and 10 officers from the national and county level trained to basic user of LEAP tool Means of verification: Training report, list of attendance and LEAP user licenses application and granted
Session 2 LEAP/WEAP training: Participatory scenario building	Develop scenario narratives jointly with stakeholders, reflecting current policies and plans such as CIDP and CEP	LEAP Taskforce led scenarios development with national and county government officers. Means of verification: Training report, list of attendance, scenario analysis report (co-created)
Session 3 LEAP/WEAP training: WEAP -LEAP coupling for nexus analysis	Application of the SEI nexus toolkit (integrated WEAP-LEAP model), to generate and compare different scenarios for improving human securities and building resilience in the ENNCA region.	LEAP/WEAP integration assessing trad-offs and synergies for sustainable nexus scenario development. Means of verification: Nexus report, list of attendees

Session 1 training objectives

The LEAP training was delivered in 4-training days with the following training objectives:

- Learn how to use the LEAP tool to develop county energy demand and supply current account, baseline scenario projection and development pathway scenario analysis in a nexus approach.
- Understand how data available can be used to develop these analyses.
- To identify data gaps, consolidate relevant data and liaise with the SEI modellers to update county model.
- Describe the short term (based on CIDP) and long term (based on county long-term vision) development priorities in energy, agriculture, industrial and manufacturing and infrastructure and how they are likely to influence future transformation in the county.
- To understand how to build these scenarios in LEAP and generate useful information for decision making.

Session 2 LEAP training objectives

The second training was dubbed scenario workshop. The workshop core objectives was co-development of county plan scenarios and building understanding of resource flows. Specifically, the following key objectives were to be accomplished: -

- Learn how to use the LEAP tool to develop county energy demand and supply current account, baseline scenario projection and development pathway scenario analysis in a nexus approach.
- Participatory scenarios development for energy demand and supply
- Discuss scenario results in a nexus perspective implication of the plans on water, forest and agriculture

Session 3 LEAP training objectives

The third training was dubbed Nexus and climate workshop. The workshop core objective was to: -

- To demonstrate using the WEAP-LEAP tutorial on instances when Water and agricultural planning would affect energy generation and when energy generation would also affect water availability for other purposes. It showed the trade-offs and synergies between sectors and using the tool to stimulate discussion and nexus planning approaches that reduces trade-offs and increase synergy
- To work in county teams to assess policy coherency analysis using simple adjacency matrix where experts argue relationship between policies and strategies in the three sectors. N x n matrix was used to discuss policy relationships. A simple matrix illustration is as in Table 2
- To present climate change scenarios of the Ewaso Ngiro North catchment

Table 2.. Adjacency matrix for policy coherency analysis

		Energy		Agriculture		Water	
		10,000 Clean energy appliances by 2027 (Assuming the appliances included energy efficienct lighting- 10,000 LED bulbs to 2000 households).	Distribution of 55 energy saving jikos in school by 2027	800+ poultry farmers in 4 MVs in Ntarami, Kangeta, Ng'onyi and Mbaaria			
Energy	10,000 Clean energy appliances by 2027 (Assuming the appliances included energy efficienct lighting- 10,000 LED bulbs to 2000 households).						
	Distribution of 55 energy saving jikos in school by 2027						
Agriculture	800+ poultry farmers in 4 MVs in Ntarami, Kangeta, Ng'onyi and Mbaaria						
Water							

Water Energy and Food Nexus Modelling

The nexus modelling used Low Emission Analysis Platform (LEAP) and Water Evaluation and Planning (WEAP) toolkits. The SEI tools were designed and developed to support policy makers in assessing energy and water supply and demand. Additional capabilities have since been incorporated in the two tools making them versatile for policy makers, using evidence-based approach in planning and decision making.

LEAP modelling

LEAP (the Low Emissions Analysis Platform) is a widely adopted software tool developed by the Stockholm Environment Institute for energy policy analysis and climate change mitigation planning. It is used by thousands of organizations across more than 190 countries, including government agencies, academic institutions, NGOs, consulting firms, and energy utilities. LEAP has been applied at various scales from local cities and states to national, regional, and even global levels.

LEAP is valued for its intuitive and transparent interface, which simplifies complex energy system concepts for users. It is also highly adaptable, catering to a broad range of users from global experts developing and demonstrating policy impacts to decision-makers, to trainers building capacity among early-career analysts learning to navigate the intricacies of energy systems.

Rather than representing a fixed model of any specific energy system, LEAP serves as a flexible platform for building custom models tailored to the unique data and structure of different energy systems. It supports diverse modelling approaches ranging from bottom-up, end-use methodologies to top-down macroeconomic models. LEAP works on two conceptual levels: at one level, it automatically performs core calculations for energy, emissions, and cost-benefit analysis; at the other, it allows users to input spreadsheet-style formulas to define time-varying data and create advanced, multi-variable models, including econometric and simulation techniques.

LEAP is built around the principle of scenario analysis, enabling users to construct self-consistent narratives about how an energy system might develop over time. By modelling and comparing alternative scenarios, analysts can evaluate energy needs, social and economic costs, and environmental impacts. This scenario-based approach helps policymakers understand the effects of individual policies and the synergies or trade-offs when multiple measures are combined[2].

WEAP modelling

The Water Evaluation and Planning (WEAP) system is a software tool designed to support, rather than replace, the work of skilled water resource planners. It offers a comprehensive, adaptable, and user-friendly platform for integrated water resources planning and policy analysis.

At its core, WEAP is based on the principle of water balance and is suitable for a wide range of applications from municipal and agricultural systems to single watersheds and complex transboundary river basins. The system can simulate both natural processes and engineered infrastructure, including rainfall-runoff relationships, baseflow, groundwater recharge, water demand and conservation, water rights and allocation priorities, reservoir operations, hydropower generation, water pollution, quality monitoring, ecosystem needs, and vulnerability assessments. Additionally, its financial analysis module enables cost-benefit evaluations of different projects and policy options.

Users model the system by defining its key components: water sources (such as rivers, creeks, groundwater, reservoirs, and desalination facilities), infrastructure (for withdrawal, transmission, and treatment), demand sectors, pollution sources, and ecological requirements. The tool's structure and level of detail can be easily tailored to suit the specific needs and data availability of a given region or study.

WEAP serves multiple functions:

- Water balance database: It helps manage and organize data on water supply and demand.
- Scenario modeling tool: It simulates how water demand, availability, runoff, streamflow, storage, pollution, treatment, discharge, and instream water quality might evolve under different conditions.
- Policy analysis tool: It supports the evaluation of various water development and management strategies, accounting for the competing and interconnected uses of water resources[3].

[2] https://leap.sei.org/default.asp?action=introduction

[3] https://www.weap21.org/index.asp?action=201

Forest resource analysis, the FRL approach

Carbon stock depletion of enhancement is one of the sustainability analyses in the land use land use change analysis. Degradation of forested and shrub land is a precursor to climate change, loss of biodiversity and land degradation thereby directly affecting livelihoods and poor ecosystem services. This degradation is a consequence of conversion of forest lands to crop-lands, degradation of forest land through logging or charcoal burning to shrubland and grassland and expansion of settlements and other land uses to forest, shrub and grassland. IPCC frameworks estimate carbon stock change between two points of time by using either of the following, difference between two independent stock estimation, direct estimation of change by remeasurement of the same plot, estimation by proportionate crown cover and demonstration of “no-decrease”(IPCC 1996).

In 2018, the country adopted Forest Reference Level (FRL) analysis to estimate change in forest land between 2002 to 2018 in a four-year time interval that uses the approach three of the IPCC – estimation by proportionate crown cover and demonstration. The FRL approach uses satellite imagery and land cover mapping in estimating the change in land use patterns. The land cover maps stratify forests into four strata including montane forest / western rainforest/ bamboo, coastal forest and mangroves, dry land forest and plantation forests (Ministry Environment and Forestry 2020). A second level stratification on the three strata based on ecozones (Dryland Forest areas, Montane & Western Rain Forest areas and Coastal & Mangrove Forest areas) was done based on canopy closure. The resultant canopy classes are: 15-40 % (Open), 40-65 % (Moderate), and above 65 % (Dense) as discussed in the FRL report.

The data was recorded in the matrix of forest conversion between two interval time period as exemplified in Figure 1. The rows define the land use categories while the columns define the change in land use read from row verses column e.g. dense forest land in 2002 degraded to moderate forest in 2006 was 558ha. In other words, a sum of row transformation gives total land area of land type before change in 2002 and sum of column land transformation results to the land area in 2006.

For the five Ewaso Ng’iro North based counties there are no Coastal and Mangrove Forest categories hence no land use changes available.

Figure 1. Land use change matrix based on FRL estimation

			2006													
			Montane Forest / Western Rain			Coastal Forest and Mangroves			Dryland Forest			Plantation	Cropland	Grassland	Wetland	Settlement and Other land
			Dense	Moderate	Open	Dense	Moderate	Open	Dense	Moderate	Open					
2002	Montane Forest / Western Rain Forest / Bamboo	Dense	19,475	558	122								523	9,164	5	0
		Moderate	746	196	72								280	794	1	0
		Open	246	36	117								206	1,170	0	0
	Coastal Forest and Mangroves	Dense				0	0	0					0	0	0	0
		Moderate				0	0	0					0	0	0	0
		Open				0	0	0					0	0	0	0
	Dryland Forest	Dense							3,266	163	107		57	4,098	19	0
		Moderate							709	914	210		26	1,452	5	0
		Open							375	110	838		72	3,457	15	0
	Plantation											0	0	0	0	0
	Cropland		501	16	80	0	0	0	74	12	41	0				
	Grassland		5,921	331	590	0	0	0	4,777	1,664	4,481	0				
	Wetland		24	0	0	0	0	0	209	62	0	0				
	Settlement and Other land		1	0	0	0	0	0	0	0	0	0				

Enhancement

Deforestation

Land type remaining land type

Plantation farming

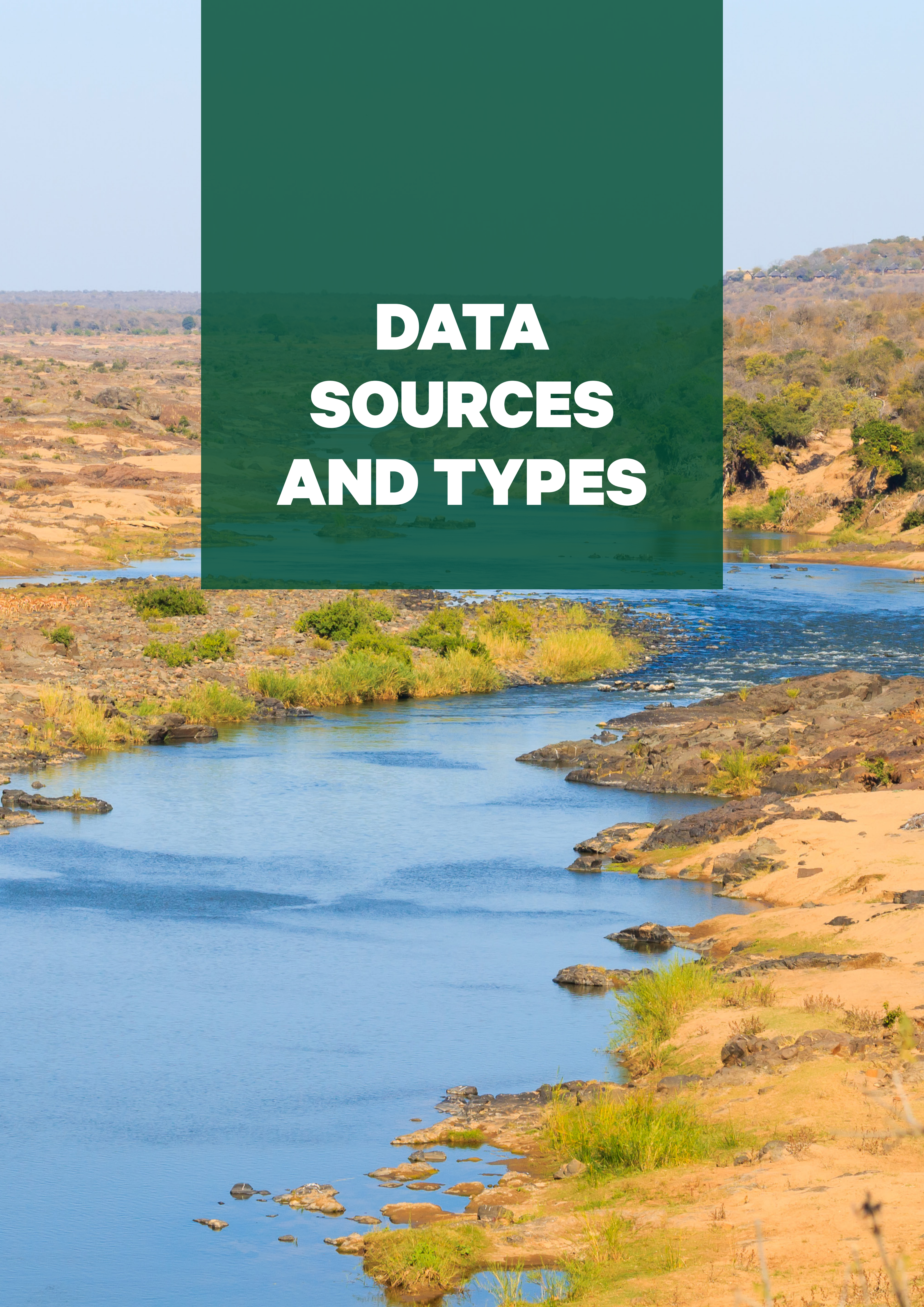
Degradation

The FRL methodology defines the above and below biomass stock per hectare is illustrated in Table 3.

Table 3. Default assumptions of biomass stocks by land type category

Class	Canopy coverage	Volume (m3/ha)	Above Ground Biomass (AGB)		Below Ground Biomass (BGB)	
			Biomass stock (ton/ha)	Carbon stock (ton/ha)	Biomass stock (ton/ha)	Carbon stock (ton/ha)
Montane Forest & Western Rain Forest	Dense	441.99	345.99	162.62	93.42	46.71
	Moderate	70.92	58.43	27.46	15.78	7.89
	Open	26.44	23.13	10.87	6.25	3.12
Coastal forest & Mangrove Forest	Dense	99.57	94.09	44.22	27.65	13.82
	Moderate	64.53	60.45	28.41	13.64	6.82
	Open	42.14	35.37	16.62	7.5	3.75
Dryland Forest	Dense	100.42	80.36	37.77	31.72	15.86
	Moderate	39.88	34.5	16.21	12.99	6.49
	Open	16	14.26	6.7	3.85	1.93
Plantation		286	231	108	62	31
Agroforestry		106.98	74.23	34.89	20.04	10.02

DATA SOURCES AND TYPES



This section describes the data that was used in LEAP modelling. Attention was paid to county data based on county specific surveys and reports. In areas where such data were inadequate, national attribution was made.

Drivers of demand

Demand drivers include the demographic and macro-economic data set. LEAP is built upon the premise that energy demand changes and is directly proportional to changes in national economic and demographic growth.

Macro-economic levers

Gross Domestic Product (GDP)

Table 3 is a time series of national GDP in million Kenya shillings. In commercial and industrial sectors where we had inadequacy of data, national attribution of energy consumption per Unit GDP was determined. This intensity was then translated to county commercial and industrial energy demand by multiplying with the gross county product (GCP) as illustrated in Table 5.

Table 4. Time series of GDP for the last five years by sector category

	2018	2019	2020+	2021+	2022*
Agriculture, Forestry and Fishing	1,897,475	2,135,709	2,432,613	2,583,190	2,829,505
Small commercials and services	2,898,839	3,120,517	3,242,476	3,594,787	3,945,230
Manufacturing and Construction	1,399,932	1,512,675	1,640,883	1,827,055	2,120,362
Public administration, Education and Health	1,178,975	1,280,087	1,311,411	1,501,132	1,589,431
Hotels, restaurants and local eateries	100,019	119,581	77,843	133,678	147,342
TOTAL commercial and Industrial	7,475,240	8,168,569	8,705,226	9,639,842	10,631,870
Transport and Storage	1,056,264	1,202,830	1,156,921	1,391,614	1,653,557
GRAND TOTAL	8,531,504	9,371,399	9,862,147	11,031,456	12,285,427

Proportion GDP contribution by sector category

GDP contribution by sector (Percentage)	2018	2019	2020+	2021+	2022*
Agriculture forestry and fisheries	25%	26%	28%	27%	27%
Small commercials and services	39%	38%	37%	37%	37%
Manufacturing and Construction	19%	19%	19%	19%	20%
Public administration, Education and Health	16%	16%	15%	16%	15%
Hotels, restaurants and local eateries	1%	1%	1%	1%	1%

Table 5. Sub-classification of manufacturing sector GDP contribution

	2018	2019	2020+	2021+	2022*
MANUFACTURING	1,399,931	1,512,675	1,640,883	1,827,055	2,120,362
Food, Beverage and Tobacco	452,182	467,200	467,412	499,252	575,130
Construction and cement	614,563	703,422	826,555	941,422	1,074,073
Others	333,186	342,053	346,916	386,381	471,159
Hotels, restaurants and local eateries	1%	1%	1%	1%	1%
Proportion by sub-sector	2018	2019	2020+	2021+	2022*
Food, Beverage and Tobacco	32%	31%	28%	27%	27%
Construction and cement	44%	47%	50%	52%	51%
Others	24%	23%	21%	21%	22%

Gross County Product (GCP)

Gross county product represent the country contribution to national GDP in Million Kenya shillings. Table 5 present the GCP for the five counties in 2022 (base year) as Figure 1 illustrates the differences in the county's economic activities. Agriculture and forestry are the greatest economic contributors of Nyeri, Laikipia it is a mix of small commercials and agricultural activity while Isiolo and Samburu it is public admin education and health. Meru economic earner is agricultural activities.

Table 6. Gross county product for the five counties in 2022

	Nyeri	Laikipia	Isiolo	Meru	Samburu
Agriculture, Forestry and Fishing	87,052	23,401	4,543	211,033	4,891
Manufacturing, construction and Mining	18,227	13,533	4,024	30,707	2,603
Public Admin, Education and Health	31,219	17,727	11,080	40,809	12,714
Hotels and restaurants	2,378	2,201	544	936	1,643
Small commercials and other services	57,381	27,824	7,583	56,081	6,741
Total Commercial and Industrial	**196,257**	**84,686**	**27,774**	**339,566**	**28,592**
Transport and Storage	28,108	15,515	1,840	39,267	2,466
GRAND TOTAL	**224,365**	**100,201**	**29,614**	**378,833**	**31,058**

Figure 2. Gross County Product (GCP) for the five counties proportion by sector categories

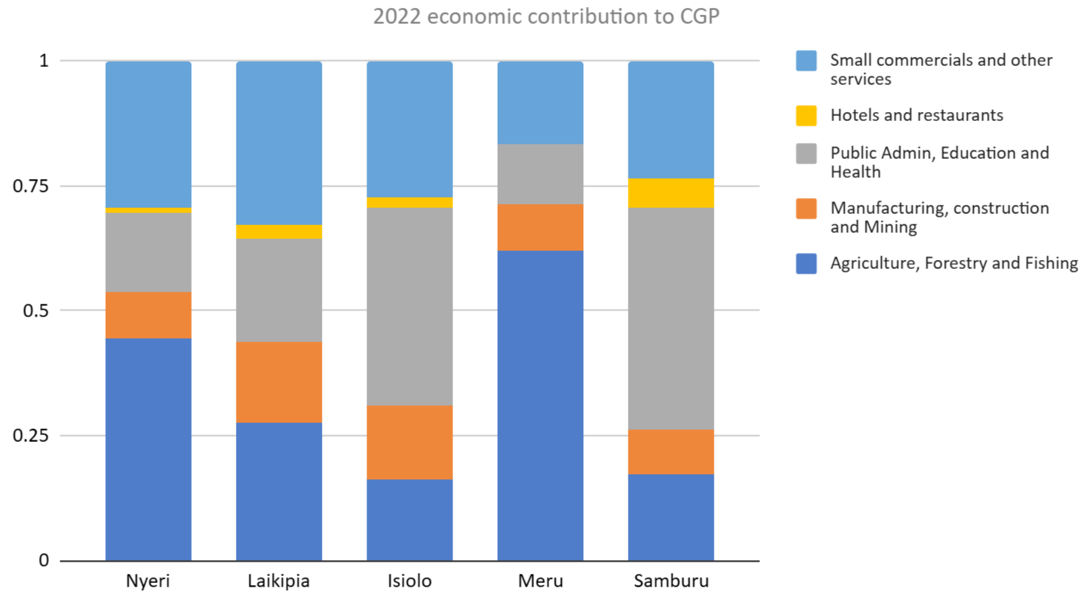


Table 6. is a time series of total county GCP for the five counties. Albeit that it is only five years time series, average GCP growth rate that was used for economic growth projection was obtained for the five counties.

Table 7. Time series of total GCP contribution by county for five years

	GCP Current price Adjusted excluding transport and storage					
	2018	2019	2020	2021	2022	Average
Nyeri	148739	169143	183364	196257	212588	3.6%
Laikipia	68401	74741	79985	84687	101060	3.7%
Isiolo	21260	23495	24905	27776	29530	4.4%
Meru	239558	275066	295774	339565	365189	3.2%
Samburu	22257	25735	26780	28591	31209	4.6%

Table 8.Population distribution in the five counties in 2019

Demographics	Census 2019				
	Nyeri	Laikipia	Isiolo	Meru	Samburu
Total population	752695	513879	267997	1535635	307957
Total households	248050	149271	58072	426360	65910
Household size	3.03	3.44	4.61	3.60	4.67

Table 8.Population distribution in the five counties in 2019

	Population in Thousand											
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Nyeri	752.7	768.1	783.4	798.8	812.7	826.6	840.5	855.0	869.5	884.4	898.9	913.4
Laikipia	513.9	525.7	537.6	549.4	561.2	572.1	583.0	594.3	605.6	617.5	629.0	640.4
Isiolo	268.0	281.6	295.1	308.7	315.9	323.2	330.5	338.2	345.9	359.1	368.6	378.0
Samburu	308.0	318.4	328.8	339.3	349.7	360.1	370.6	381.8	393.1	402.9	413.5	424.1
Meru	1,535.6	1,565.8	1,595.9	1,626.0	1,639.4	1,652.9	1,666.4	1,686.1	1,705.9	1,731.3	1,751.4	1,771.6
Total	3,378.2	3,459.5	3,540.8	3,622.1	3,679.0	3,734.9	3,790.9	3,855.4	3,919.9	3,995.2	4,061.3	4,127.5

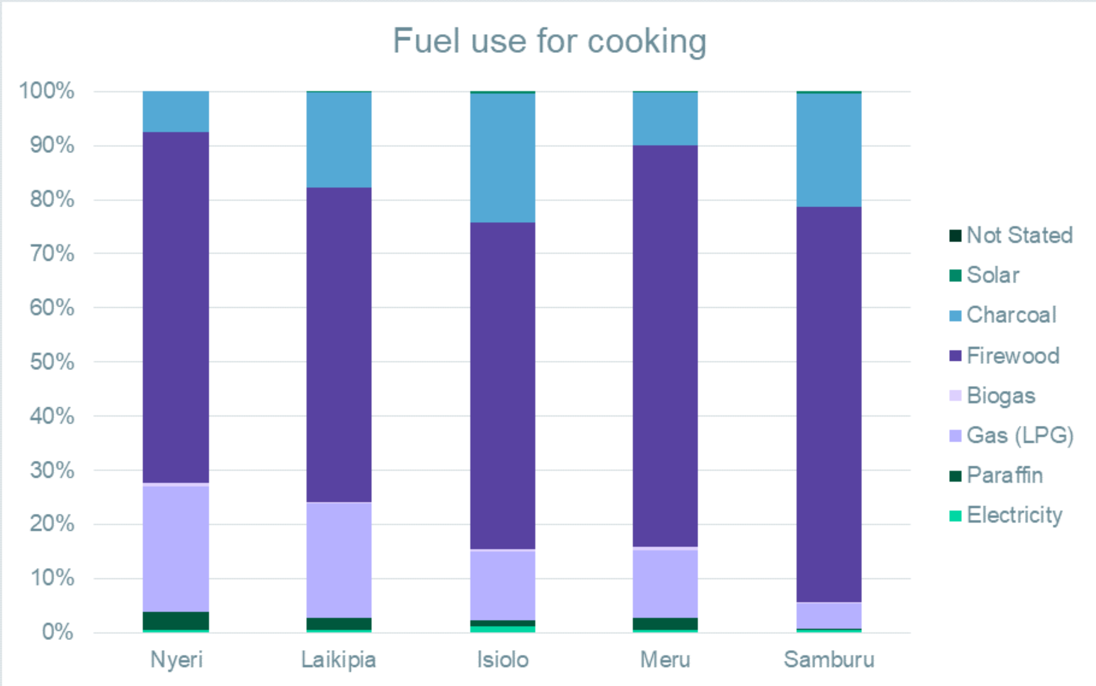
Household Cooking

The residential data requirement is derived from the common services in the household. This include, cooking, lighting and other appliances. The census reports explicitly provide the proportion of households using a given technology. Other reports such Ministry of Energy household cooking survey, the clean cooking strategy, e-cooking action plan and the Kenya Household and Integrated Survey 2022, provided the data needed to argument typical fuel used in Kenyan households and intensity. The census report provided the data to the county level of the proportion of households using given cooking and lighting device as presented in Table 9 and Figure 2. The analysis assumed that whereas the number of people using some fuel for cooking in year "x" may change, without any policy influence the change will not be significant enough to alter the proportion of fuel adoption.

Table 10. Percent proportion of Grid connected households using type of cooking fuel in the five counties in 2019

	Nyeri	Laikipia	Isiolo	Meru	Samburu
Electricity	0.5	0.4	1.2	0.5	0.5
Paraffin	3.3	2.3	1.1	2.2	0.3
Gas (LPG)	23.2	21.2	12.6	12.6	4.5
Biogas	0.5	0.3	0.5	0.5	0.4
Firewood	64.8	58	60.5	74.3	73
Charcoal	7.5	17.7	23.9	9.8	21.1
Solar	0	0.1	0.3	0.1	0.3

Figure 3. Proportion of household using a given fuel for cooking in 2019



The non-grid connected households is proportions is a harmonised data by eliminating the grid connected households who use electricity for cooking. Table 10 is a harmonised proportion reflecting proportion of household using fuel "X"

Table 11. Percent proportion of non- grid connected household using cooking fuel

	Nyeri	Laikipia	Isiolo	Meru	Samburu
Paraffin	3.3	2.3	1.1	2.2	0.3
Gas (LPG)	23.2	21.2	12.6	12.6	4.5
Biogas	0.5	0.3	0.5	0.5	0.4
Firewood	64.8	58	60.5	74.3	73
Charcoal	7.5	17.7	23.9	9.8	21.1
Solar	0	0.1	0.3	0.1	0.3

Any fuel is combusted in a given cooking technology. Kenya household use different conversion technologies. Because of inadequacy of this information at the county level, the technology level assessment adopted a national assumption of typical household technology use by fuel and energy intensity as illustrated in Table 11.

Table 12. Fuel conversion technologies adoption in Kenya

COOKING	KIHBS (2015/16)		MoE, 2019		Energy use intensity (Kg/hhd/year)
	rural	urban	rural	urban	
Firewood	84.3%	16.2%	90%	26%	
Traditional firewood 3 stove	84.9%	85.6%	81.4%	82.9%	1349
Improved fixed wood stoves	15.1%	14.4%	15.3%	14.8%	1079
Improved portable biomass	0.0%	0.0%	2.6%	1.5%	1079
Branded firewood stove	0.0%	0.0%	0.6%	0.8%	674.5
Gasifier stove	0.0%	0.0%	0.0%	0.0%	
Electricity	0.3%	2.0%	1%	7.0%	
Mixed LPG-Electricity stove	100%	100%	60.0%	62.0%	533kWh/hhd/y
Microwave			40.0%	27.8%	
Electric coil stove			0.0%	10.1%	
Electric induction stove			0.0%	0.0%	
LPG	2.5%	27.7%	18%	54%	
6kg complete cylinder	60.0%	60.0%	86.7%	67.9%	68kg/hhd/year
12kg cylinder - LPG stove (multiple burner)	40.0%	40.0%	11.6%	23.6%	68kg/hhd/year
12kg cylinder - Mixed LPG-Electricity stove	0.0%	0.0%	1.7%	8.5%	68kg/hhd/year
Biogas	0.2%	0.3%	0.20%	0.10%	180m3/hhd/yr
Kerosene	2.3%	29.5%	3.20%	27.70%	72l/hhd/yr
Others (Twigs, agriresidue, dung)	1.5%	2.5%	0.00%	0.00%	Like wood
Traditional firewood 3 stove	84.9%	85.6%	81.4%	82.9%	
Improved fixed wood stoves	15.1%	14.4%	15.3%	14.8%	
Improved portable biomass	0.0%	0.0%	2.6%	1.5%	
Branded firewood stove	0.0%	0.0%	0.6%	0.8%	
Gasifier stove	0.0%	0.0%	0.0%	0.0%	
Charcoal	8.9%	22.0%	40%	47%	
Traditional charcoal stove	60.6%	59.2%	20.4%	9.5%	395kg/hhd/year
Improved Charcoal stove	39.4%	40.8%	73.0%	82.4%	347.6kg/hhd/yr
Branded modern charcoal stove	0.0%	0.0%	7.4%	6.6%	217.3kg/hhd/yr
Nyama Choma Grill	0.00%	0.00%	0.0%	0.6%	

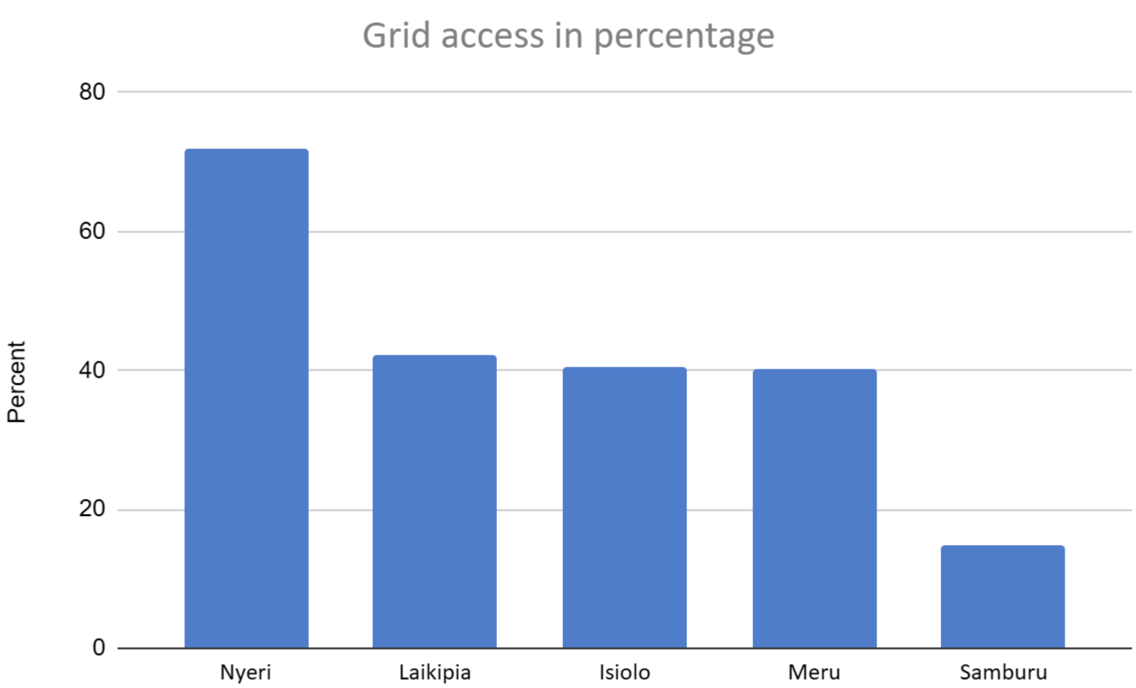
Household lighting

Lighting as key component of household energy demand. Like household cooking, the data was obtained from national statistics – the census report – that gave proportion of population using given energy source for lighting as illustrated in Table 12. From the data it was assumed that the level of electricity access by county is similar to the number of households reported to be using electricity for lighting. As such Figure 3 illustrates the level of electricity access per county.

Table 13. Proportion of households using type of energy device in 2019 (Percent share)

	Grid electricity	Pressure lamp	Lantern	Tin Lamp	Gas lamp	Firewood	Solar	Torch/ Sport light charged	Torch Dry cell	Candle	Battery Charged	Generator
Nyeri	71.8	0.4	8.1	8.1	0.1	0.1	8.4	1.2	0.7	0.8	0.3	0
Laikipia	42.2	0.3	8.4	9.1	0.1	3.8	26.4	5.3	2.3	1.2	0.7	0.2
Isiolo	40.6	0.3	3.8	3.7	1.2	6.7	9.1	9	24.6	0.7	0.2	0.1
Meru	40.2	0.5	11	13.9	0.2	1.5	18.8	3.6	8.3	1.5	0.5	0
Samburu	14.8	0.3	3.3	5.5	0.3	36.3	13.3	9.6	15.7	0.6	0.3	0

Figure 4. Grid access by counties in 2019



Industrial Sector energy demand data

In the unavailability of the county specific data, the sector was modelled based on attribution. National statistics report annual petroleum demand and consumption by sector as illustrated in Table 14. This demand results in national throughput interims of GDP. The national GDP is directly proportional to the total energy consumption in the country - petroleum product and electricity. Its intensity is represented as energy used to produce a unit of a country's GDP (i.e. GJ/KES). The national gross domestic product (GDP) can be disaggregated into county GCPs proportional to the economic activities within the counties. As such each county GCP constitutes the economic drivers of the county. Therefore with the knowledge of the energy intensity per economic unit, it was possible to model the industrial and commercial energy demand. This was preceded with energy balance for petroleum and electricity consumption in the commercial and industrial sector. As illustrated in Table 13 the country imports 5134k ton of fossil fuel in 2022, larger proportions are gasoline and light diesel oil accounting for 30% and 43% respectively. LPG and fuel oil accounted for 7% and jet fuel accounted for 12%. Other fossil fuel products such as Kerosene and aviation spirit only accounted for 2% and 0.02% respectively.

Based on Table 14 retail pumps and roads (mainly gasoline and diesel) accounted for 75% of total fossil fuel demand and aviation fuel accounting for 11%. This is a clear indication that the biggest proportion of fossil fuel is consumed in the transport sector. Specifically, industrial and commercial sectors consume 8.7% and power generation 3.7%. The electricity consumption analysis considered electricity sales to small commercial and commercial and industrial who account for about 69% of total electricity demand in Kenya in 2022. However, there are industrial and commercial sectors purchasing diesel from the retail pumps. As such careful energy balance corroborating specified energy consumptions, GDP contribution and suitability logic was used. Example of suitability logics included, 100% of gasoline was attributed to road transport, example of specified user is train transport use diesel, and all illuminating kerosene used in residential, finally example of balancing heavy fuel oil in the industrial sector is a balance of total imports less HFO used in electricity and in marine.

Table 14. Fossil fuel demand and supply table

Demand '000' tons	2016	2017	2018	2019	2020	2021	2022
Liquified petroleum gas	151.7	189.3	222.3	312.1	326.2	371.4	333.8
Motor gasoline (premium and regular)1	1227.2	1267.4	1359	1438.4	1,395.3	1,554.4	1,561.3
Aviation spirit	4.8	3.8	18.8	10.2	1.9	1.4	0.9
Jet/Turbo fuel	619.2	649.7	674.4	699.4	394.8	506.8	592.3
Illuminating Kerosene	371.7	448	339.4	168.3	127	111.3	89.0
Light diesel oil	2318.3	2086.2	2173.1	2198.7	2,157.6	2,305.7	2,219.7
Heavy diesel oil	0.5	1.2	0.2	1.3	1.8	0.8	0.0
fuel oil	350.9	525	402	382.8	273.9	340.3	337.1
TOTAL	**5044.3**	**5170.6**	**5189.2**	**5211.2**	**4678.5**	**5192.1**	**5,134.1**

User	2016*	2017	2018	2019	2020	2021	2022
Agriculture	35	57	60	26	24.8	26.6	29.0
Retail pump outlets and road transport	3718	3541	3743	3752	3,650.50	3,937.80	3,849.3
Rail transport	43	12	12	19	11.4	19.4	19.0
Tourisml	5	9	10	14	6.5	6	4.9
Marine (excl. naval forces)	2	6	5	6	1.1	2.1	1.5
Aviation (excl. government)	598	645	671	711	392.7	499.4	570.3
Power generation	15	45	34	29	75.8	147.5	189.9
Industrial, commercial and others	616	837	635	636	494.4	530.5	446.3
Government	11	19	19	16	21.5	22.8	23.8
Balancing item	0	0	0	0	0	0	0.0
Total	**5044**	**5171**	**5189**	**5207**	**4679**	**5192**	**5,134.1**

Similarly electricity consumption in different sectors were assumed from the annual sales. Commercial and industrial electricity consumption was assumed to be total sales of small commercial and commercial and industrial as illustrated in Table 15

Table 16. National electricity sales by sector

	Electricity sales in GWh						
Type of customer	2016	2017	2018	2019	2020	2021	2022
Domestic customer (DC)	2007	2138	2335	2366	2508	2630	2728
Small Commercial (SC)	1153	1201	1222	1,250	1262	1326	1474
Commercial and Industrial (CI)	4104	4266	4225	4,462	4308	4514	4851
Off-peak Interruptible (IT)	26	41	33	0	0	0	0
Street lighting (SL)	40	55	66	68	76	84	95
Total	7330	7701	7881	8146	8154	8554	9148

Biomass use in public administration, hospitals and schools is illustrated in Table 16. Hospital, secondary and primary schools are the greatest consumers of firewood and hospitals are the highest consumers of charcoal.

All these energy systems are augmented on their contribution to a unit of GDP and then computed with county GCP to determine energy demand in the commercial and industrial sectors in the counties.

Table 17. Biomass use in public administration, hospitals and schools.

Wood	**Qty in tons**
Hospitals	380000
Secondary	490000
Colleges	50000
Universities	50000
Primary	430000
Charcoal	
Hospitals	35000
Secondary	7000
Colleges	**5000**
Universities	**3000**
Primary	**2500**

Source: C&E, 2019

Electricity supply

Kenya electricity system is centralised with four regional blocks, Nairobi, Western, Mt. Kenya and Coastal regions. The county specific generation for the analysis of electricity supply was based on the off-grid systems that supply decentralised communities. While most of these decentralised systems are in the form of mini-grids and based on solar PV Meru and Nyeri counties have hydropower mini grids as illustrated in Table 17. Isiolo and Samburu have one solar PV operational while the rest of the Solar-diesel hybrid plants are planned under Kenya Off-grid Solar Access project (KOSAP). Most of the power plants did not state the number of beneficiaries, however based on literature review community project are often capped at 100watt per household. With this assumption, the possible beneficiaries was computed for the projects that didn't specify the targeted number of beneficiaries.

Table 18. Mini grids in Ewaso Ng'iro North Catchment

County name	Name of Mini grid	Technology type	Installed Capacity (kW)	Percent Availability	Year of Installation	Ownership	Number of households connected
Nyeri	Kiangurwe Micro Hydro Power Project	Hydropower	100	90%		Community	333*
Nyeri	Kangocho Micro Hydropower	Hydropower	1.1	90%		Community	11*
Nyeri	Gikiria	Hydropower	514	90%	2016	Power Technology Solutions	Connected to grid
Nyeri	Gura	Hydropower	5800	90%	2017	Public	Connected to grid
Nyeri	Sagana Falls	Hydropower	1500	90%		Public/ Private	Connected to grid
Meru	Mutunguru United Mini Hydro	Hydropower	7800	90%		Community	5000
Meru	Tungu Kabiri Micro Hydropower	Hydropower	14	90%		Community	47*
Meru	Ndurumo Hydro Electricity Power Project	Hydropower	320	90%		private investor and community-based company	1067*
Meru	Imenti	Hydropower	900	90%		Public	3000*
Isiolo	REREC / MERTI	Solar	10	25%	2011	GoK/REREC	33*
Isiolo	Garfasa	Solar/diesel hybrid	115	90%	2025	GoK/KOSAP	648
Isiolo	Badana	Solar/diesel hybrid	62	90%	2026	GoK/KOSAP	263
Isiolo	Rapsu	Solar/diesel hybrid	45	90%	2026	GoK/KOSAP	227
Isiolo	Bassa	Solar/diesel hybrid	105	90%	2025	GoK/KOSAP	524
Isiolo	Leparua	Solar/diesel hybrid	50	90%	2026	GoK/KOSAP	270
Isiolo	Eras Ha Boru	Solar/diesel hybrid	115	90%	2026	GoK/KOSAP	637
Isiolo	Oldonyiro	Solar/diesel hybrid	80	90%	2026	GoK/KOSAP	347
Isiolo	Athibohol	Solar/diesel hybrid	110	90%	2026	GoK/KOSAP	553
Isiolo	Kipsing	Solar/diesel hybrid	95	90%	2026	GoK/KOSAP	327

Isiolo	Kombolla	Solar/diesel hybrid	45	90%	2026	GoK/KOSAP	200
Isiolo	Malkadaka	Solar/diesel hybrid	45	90%	2026	GoK/KOSAP	229
Isiolo	Malkaghala	Solar/diesel hybrid	50	90%	2026	GoK/KOSAP	261
Samburu	REREC / Baragoi	Diesel	240	90%	2011	GoK/REREC	473
Samburu	Opiroi	Solar/diesel hybrid	55	90%	2026	GoK/KOSAP	190
Samburu	Kirimon	Solar/diesel hybrid	65	90%	2026	GoK/KOSAP	368
Samburu	Tuum	Solar/diesel hybrid	94	90%	2026	GoK/KOSAP	475
Samburu	Sereolipi	Solar/diesel hybrid	119	90%	2026	GoK/KOSAP	699
Samburu	Barsaloi	Solar/diesel hybrid	92	90%	2026	GoK/KOSAP	466
Samburu	Ngurnit	Solar/diesel hybrid	60	90%	2026	GoK/KOSAP	327

Note. *this are computed cells

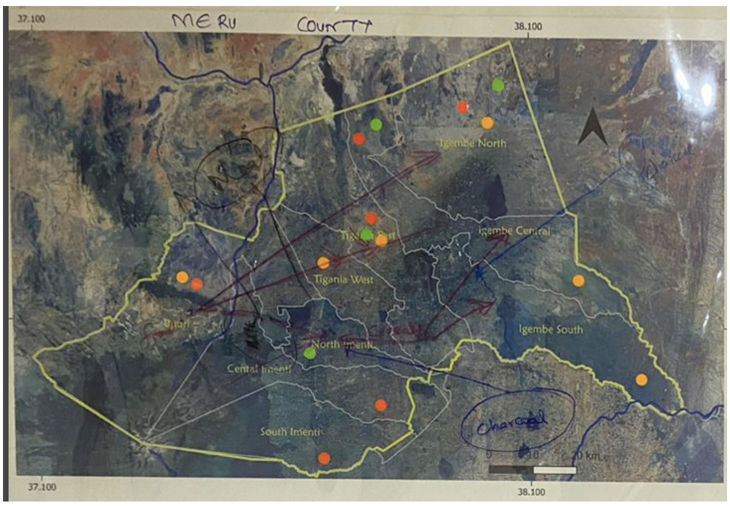
Resource flow mapping

This was a qualitative mapping excessive to map resource flow across the Ewasongiro region. The energy resources that was considered was charcoal production and trade across the region. While it can be argued that charcoal produced in a region can be exported to regions beyond the Catchment neighbouring counties, the modelling assumed that the greater majority is exported to the neighbouring counties.

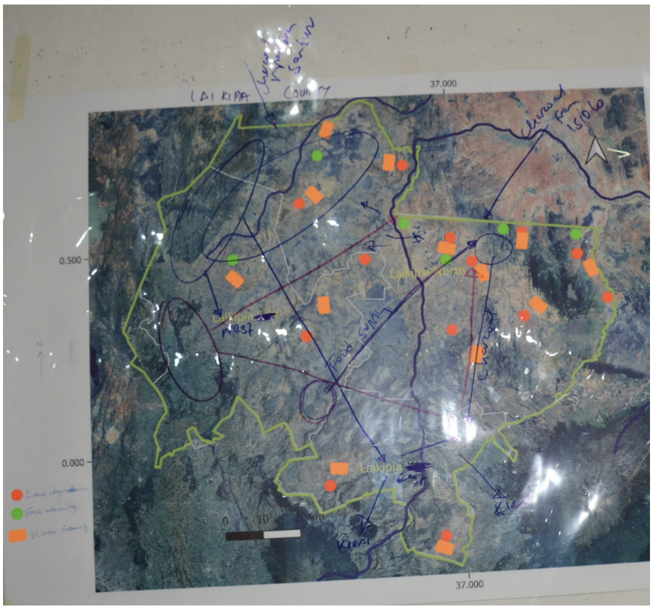
In the participatory resource mapping approach, the members of the county representatives worked in groups and identified the source of resource and end-users as illustrated in Figure 4.

Figure 5, Participatory mapping of areas of resource constraints and charcoal trade across counties

a. Meru County

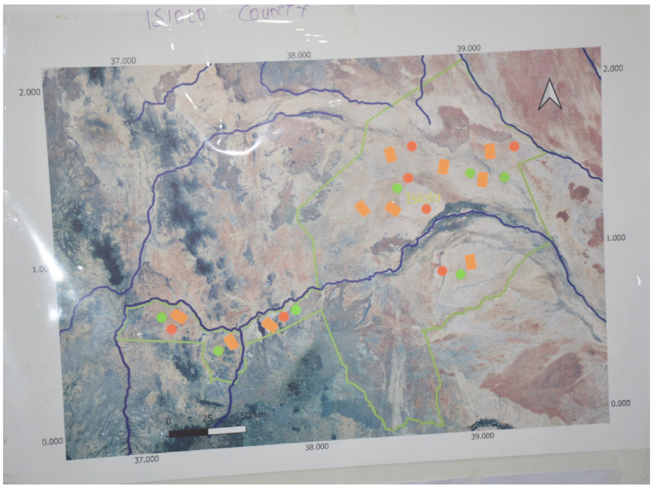


b. *Laikipia county*



c. *Samburu county*

d. *Isiolo County*



e. *Nyeri County*

Charcoal production analysis

Charcoal consumption in the Ewasongiro basin is significant. LEAP tool provide for charcoal production modelling linked to county demand. The five Key parameters input into the model include resource trading and quantitative data on proportion that is traded across the region, the regional import fraction, process dispatch rule, process efficiency and process share. In Kenya, wood-to-charcoal conversion efficiency rates range between 10-15 % with only a few cases achieving rates above 20% (Bailis, 2009). According to FAO, bagged charcoal is bulkier than loose charcoal which "settles" during transport with a volume loss of 2-5%. In the modelling we adopted a 5% loss during transportation. In an ideal case the import fraction would be accompanied by primary data collection from vendors through survey and interviews on the sources of their charcoal and also the transporters on destination. This study however relied on experts' knowledge on the final destinations of the charcoal produced in a region. Table 18 illustrates data input fields for charcoal production and regional trade.

LEAP tree structure

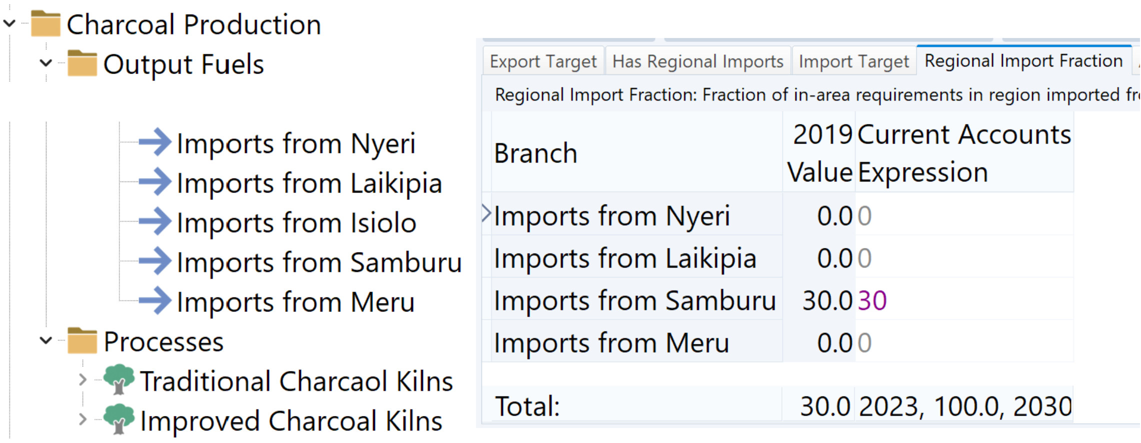


Table 19. Regional Charcoal trade

	Indigenous production (%)	Import from region (%)				
		Nyeri	**Laikipia**	**Meru**	**Isiolo**	**Samburu**
Nyeri	90%					10%
Laikipia	40%				20%	40%
Meru	90%					10%
Isiolo	80%					20%
Samburu	100%					

MODELLING KEY ASSUMPTIONS

Scenarios in LEAP is a consistent story line on how the future is likely to evolve. Often it is guided with logical assessment of historic changes in the sector using the changes in landscape factors such as macro-economics and demographic. Other scenarios would be guided by national, regional or international policies with significant influence in the sector. Additionally, the area can test various hypothesis based on the ambitions of the governance of a region.

In this modelling work four scenarios are discussed, Baseline scenario assuming historic trends, county plan scenario co-developed with county representatives and based on county policies and strategies, climate action policy mostly adopt national climate action with significant impacts that need to implement locally to yield national impacts and finally the Nexus scenario that assesses trade-offs and synergies in WEF nexus interventions. Figure 5 summaries the four scenarios assessed in the WEF nexus analysis.

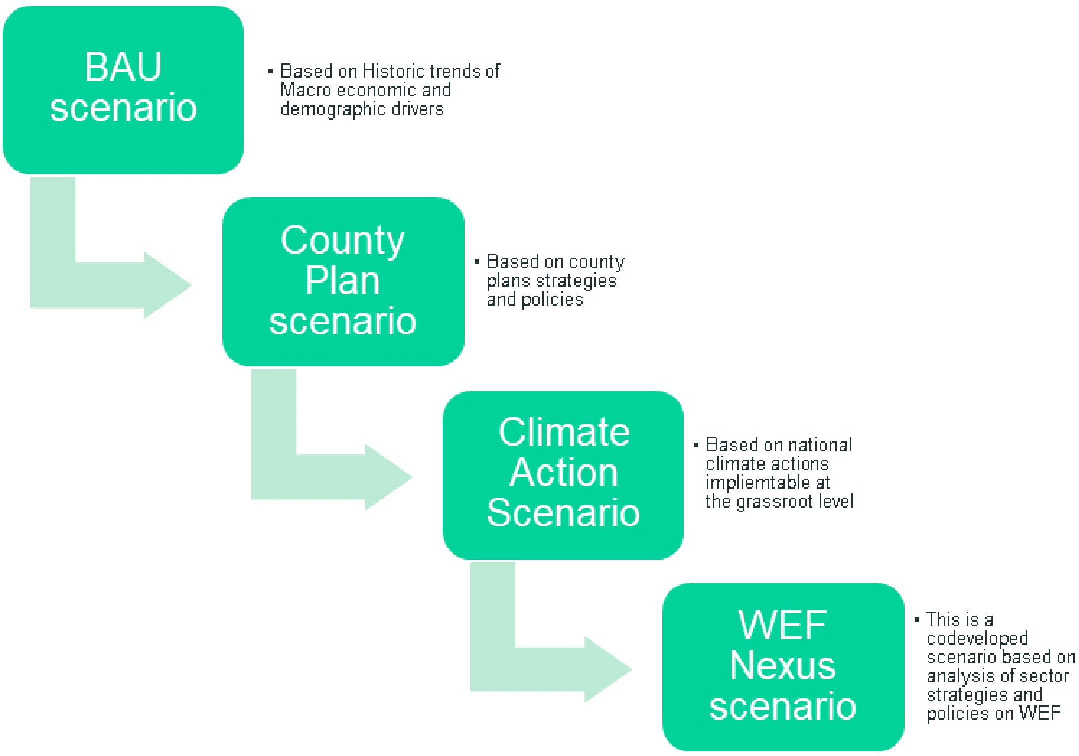


Figure 6. Summary of scenarios in the WEF nexus analysis

Key Baseline assumptions

Baseline scenario assumes that demand will increase based on historic trends. As such main drivers of growth are mainly demographic and macro economic projected based on average historic growth trends. The population growth projection was obtained from the various county's CIDP's between 2023 – 2027 and forecast made to 2030. The applied Gross County Product growth rate was adopted from the average historic GCP between 2018 - 2022. Computed average county level GCPs as follows, Meru GCP growth rate was 3.2%, Samburu 4.6%, Isiolo 4.4%, Laikipia 3.7% and Nyeri 3.6%. Electricity connectivity was projected based on intercensal grid connection such that in the baseline scenario the counties assumed grid extension is as illustrated in Table 19 below.

Table 20. Intercensal grid electricity connection

	Actual Intercensal grid connections		Projected
	2009	2019	2029
Nyeri	26%	71.80%	85%
Laikipia	18%	42.20%	60%
Isiolo	19%	42%	60%
Samburu	6.20%	14.80%	21%
Meru	14%	40.20%	60%

County plan scenario

These are scenarios developed and discussed with stakeholders from the five implementing counties mostly drawn from the county's main development documents such as CEPs and CIDPs. The county plan scenarios have adopted multiple sub-scenarios including off-grid electricity development, energy transition, street lighting program, County development scenarios, water supply scenarios and energy conservation scenarios. Table 20 summarizes the description of the various sub-scenarios. The sub-scenarios are all inherited under the overall county plan scenario. Note that not all counties will have all the sub-scenarios.

Table 21. Sub-scenario descriptions under the County Plan Scenario

County plan – Sub-scenarios

Energy transition	The sub-scenario assumes transition from one energy source to another to deliver a service. This would include increased adoption of renewable energy technologies to replace conventional energy sources such as adoption of LPG, biogas, bioethanol etc.
Energy Conservation	Energy conservation sub-scenario accounts for energy efficiency measures at the residential or commercial and industrial level. For example, adoption of improved cookstoves at the household or institutional level.
Water Supply	This is a scenario that is specific for county expansion of water supply projects such as boreholes, water pumping initiatives etc.
County Development	County development sub-scenario accounts for all activities that would be defined as development plans such as establishment of SMEs and manufacturing activities. Example is the proposal to develop industrial parks
Street lighting	Most counties seek to implement county lighting programs, the sub-scenario implement counties ambition to electrify public places
Off-grid electricity development	The off-grid electricity development account for decentralized electricity supply development. A typical example is the development of micro-hydro projects and solar mini-grids development.

Table 21 summarizes the various county plan assumptions for the five counties in Ewaso Ngoro North catchment.

Table 22. Sub- scenario assumptions by county

Sector	Description of the scenario	Sub. Scenario name	Implementable Targets	Period of implementation
Meru County				
Energy	Energy conservation and sustainable energy adoption through enhanced energy efficiency	Energy conservation	Promotion of 10,000 clean energy appliances. This will include distribution of 10,000 LED bulbs to replace incandescent bulbs in 2000 households in Meru County.	2023 - 2027
	Modern energy transition through promotion of biogas technologies.	Energy transition	The county will promote adoption of 2300 biodigesters in 2300 households	2023 - 2027
	Enhancing rural and urban electrification through street lighting and flood lighting	Street lighting program	The county targets 250 street lighting and low mast 230 Floodlighting and 75 High mast flood light	2023 - 2027
	Institutional energy efficient stoves in the county	Energy conservation	Distribution of 55 energy saving jikos by 2027, Implementing these targets have p-potential of reducing firwood use intensity by 15%	2023 - 2027
	Capacity building and training on clean cooking. Conduct 46 ward energy sensitization forums by Sensitizing households on clean cooking energy techniques and green economy	Energy transition	Estimated transition to modern energy by 20% across the county increasing the adoption of LPG and another 5% adopting ethanol fuel replacing kerosene use. The use of electricity for cooking will also increase from 0.5% to 1% in 2030.	2023 - 2027
Water access	Energy for water pumping for domestic use and irrigation systems with solar energy, wind energy and hydro power	Water supply	Increase water access level to 30%	2023 - 2027
	Solarization of boreholes at county level	Water supply	26 solar powered boreholes	2023 - 2027
Health	Enhanced health facility through electrification of Level II hospitals	County Dev.	Model demonstration in 15 health level II facilities each demanding 11kW electricity under small commercial category	2023 - 2027
Agriculture	Electricity for chicken rearing	County Dev.	Support 800 farmers in the model villages with backup generators and 100 farmers provided with egg incubators (96 egg capacity incubators) each incubator demand ?? kW electricity	2023 - 2027
Nyeri County				
Energy	Enhancement of Energy efficiency in institutions	Energy conservation	60 Institutional Jikos in 60 institutions,	2023 - 2027
			1000 improved cookstoves adoption in the residential sector	2023 - 2027
	Enhanced transition to modern energy services	Energy Transition	Promotion of 100 biogas units for 100 households	2023 - 2027
	Increasing access to street and market lighting services	Street lighting program	10000 Units of streetlights	2023 - 2027

Health	Solarization of health facilities	Renewable energy transition	10% of health facilities solarized	2023 - 2027
Industry	Livestock value addition through construction of common manufacturing facility	County dev.	1 facility	2023 - 2027
	Construction of industrial parks	County dev.	5 industrial parks	2023 - 2027

Isiolo County				
Energy	Energy conservation measure at the residential level through increased adoption of efficient tech	Energy conservation	5900 Households will be accessing improved cooking technologies; assumption is that this households are distributed based on the proportion of population connected to electricity and non-electrified homes. In Isiolo about 41% of the population have access to electricity and 59% are not connected to electricity. However, in 2030 there is opportunity to increased electrification to about 60% based on intercensal projection. Thus this population will increase in the grid connected households	2023 - 2027
	Installation of biogas systems in public institutions	Energy transition	3 Government facilities equipped with biogas	2023 - 2027
	Adoption of renewable energy technologies by increasing access to affordable, reliable and modern energy services	Energy transition	29 facilities equipped with solar power system	2023 - 2027
	Institutions and Households connected to the renewable energy	Energy access	500 households connected through OGS	2023 - 2027
	Institutions and Households connected to the renewable energy	Energy access	16 public facilities solarized	2023 - 2027
health	Providing affordable health care while reducing the burden of violence	Energy transition	Solarization of 38 health facilities scenario	2023 - 2027
Water	Install boreholes with solar energy To Increase coverage and access to potable water services for both rural and urban households	Water Supply	55 solar boreholes	2023 - 2027

Samburu County				
Industries	milk processing plant establishment	County Dev.	240000 liters of milk per day capacity	2023 - 2027
	Animal feeds processing plant	County Dev.	45000, bales of hay per month, 40 bags acacia pods and 60 bags of feedblocks	2023 - 2027

	Establishment of SME parks	County Dev.	6 model factories	2023 - 2027
Energy	Clean cooking promotion	Energy transition	2782 additional adopting LPG	2023 - 2027
	Enhancing energy efficiency	energy conservation	2700 households adopting improved biomass,	2023 - 2027
			8% SMEs adopting energy efficient technologies	2023 - 2027
Water	Enhancing water access by pumping	water supply	This project is targeting to drill and equip 65 boreholes across the entire county. The borehole will be powerd by solar powe and generators (Water access project)	2023 - 2027
Health	Establishment of health facility to enhance adequate health care in the county	County Dev.	60 health facilities developed across the county	2023 - 2027

Laikipia County				
Energy	Enhanced adoption of clean cooking	Energy transition	100 biogas technologies installed to 100 households. The target is so low and hence in model 200 new households implemented. This is only 0.2%	2023 - 2027
	Public institution adoption if improved cookstoves	Energy conservation	100 cookstoves in institutions, and	2023 - 2027
	Residential adopting improved cookstoves	Energy conservation	750 improved cookstoves to 750 households	2023 - 2027
	Enhancing renewable electricity to grid		40MW solar PV to grid	2023 - 2027
	Industrial energy conservation	Energy conservation	1250 demo facilities. Assume that 1250 is about 50% of total industries in Laikipia	2023 - 2027
	Institutional energy transition	Energy transition	443 ECD centers adopting LPG. 50% of institutions adopting LPG but interms of overall energy contribution will account for 25% of total energy demand	2023 - 2027
	Institutional energy conservation	energy conservation	443 institutions using energy saving jikos. We can assume that 443 institutions constitute 50% of the total institutional establishments. With a possibility of achieving 15% energy saving, then overall this will mean 7.5%	2023 - 2027
	residential access to electricity	County dev.	500 more households connected. This ambition is very low compared with the trend. Projecting the trend there would be about 18%	2023 - 2027
		Energy transition	255 existing boreholes rehabilitated and solarized	2023 - 2027
Water	Borehole sinking and pumping	Water supply	120 boreholes solarization	2023 - 2027
industry	Expansion of TVET centers		10 TVET centers established	2023 - 2027

Climate Action Scenario

Climate action scenario draws from national climate change policies - the national climate change action plan (NCCAP, 2023 – 2027) and the Countries Nationally Determined Contribution. It argues that for the country to achieve its NDC, the nationally defined ambitions has to be implemented at the local level. The scenario thus builds generally on the key energy scenario defined at the national level and implemented at the county level.

Key assumptions under this scenario are defined in three sub-scenarios that are inherited in the overall climate action scenario. The sub-scenarios include are summarised in Table 22.

Table 23. Climate Action sub-scenarios

Climate Action – Sub-Scenarios	
Transition to clean cooking	Access rates: 50% (LPG stoves), 30% (bioethanol) 10% (electricity) 3% (biogas technology), 7% (low emission/clean burning sustainable biomass e.g., briquettes and pellets).
National Energy Efficiency	15% reduction in energy use intensity by 2025 and 30% energy saving by 2050 through state-of-the-art equipment and processes as stipulated in the LT-LEDS
Universal Access to electricity	The national plan seeks for 100% electrification by 2030. Kenya realizes that universal electrification will not only be achieved by grid electricity, but also standalone solar, distributed systems and mini grids will play a role in electrification. Samburu and Isiolo counties have been identified as some of the undeserved counties and are benefiting from Kenya Off grid Solar Project (KOSAP).

Nexus Scenario

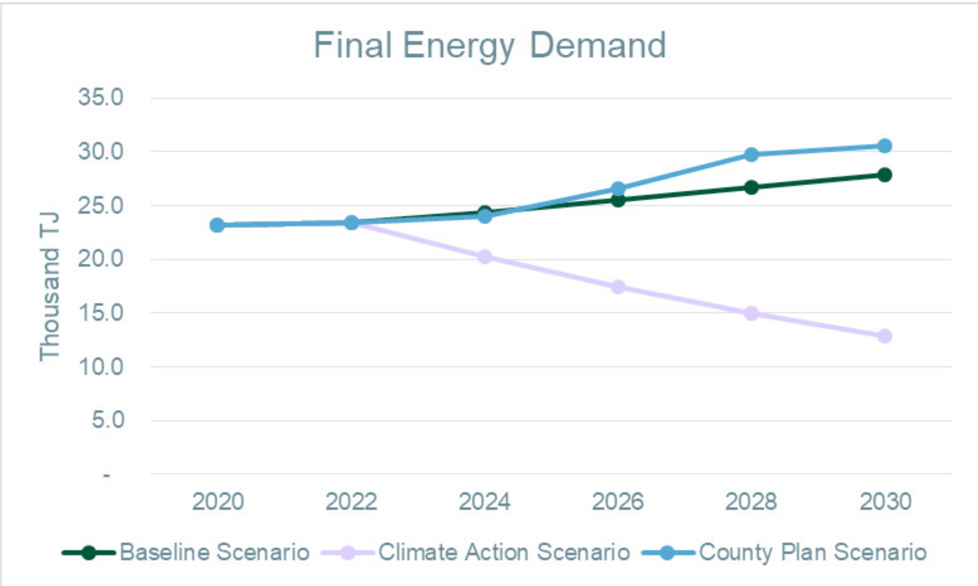
The WEF Nexus scenario probs the conflicts arising from implementation of water development targets on energy supply, energy demand on natural resource flows and effect of natural resource competition on energy supply. Two key sub-scenarios in this respect are Water for hydropower development vs natural resource balance and ecosystems services and bio-resource for firewood and charcoal and ecosystem services.

The ecosystem services take priority and the balance resource is what is provided for energy planning.

ENERGY DEMAND ANALYSIS IN ENNCA IN THREE SCENARIOS

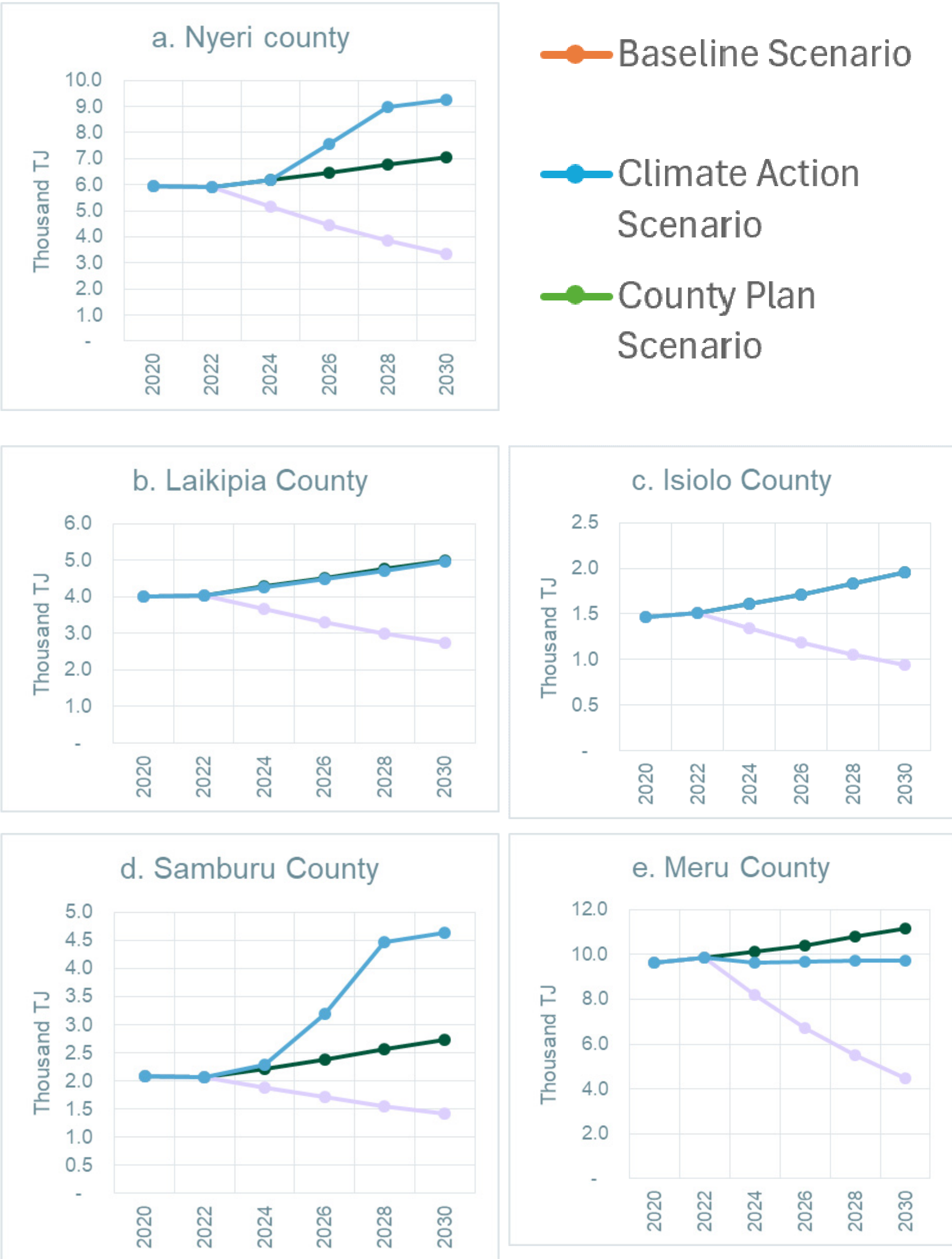
The energy demand was analysed in respect to the three scenarios and summarily presented in Figure 6. Generally, in the BAU/baseline the final energy demand is expected to increase from 23 thousand TJ in 2020 to 28 thousand TJ, It is observed that the county plan scenario projection shows an increase in energy demand by 2030 to 30.5 thousand TJ in 2030. The increase in energy demand in the county plan scenario is arguably due to inadequate ambition in energy transition and conservation and while increasing ambition on commercial and industrial development. However, the climate action scenario shows reduced final energy demand to projection from 23 thousand TJ in 2020 to about 13 thousand TJ in 2030. This would be attributed to the high energy transition ambition from tradition and convention technologies to clean and efficient energy technologies. These two results are in conflict as county development is expected to align to national plan strategies and climate actions.

Figure 7. Summary final energy demand in three scenarios



Analysis on county specific projections, the counties with higher energy demand against the BAU scenario is Nyeri, Samburu and Meru. While Laikipia and Isiolo doesn't show any significant change in energy consumption patterns between the county plan scenario and the BAU. All the counties however demonstrate energy saving opportunity in transitioning to modern energy services and enhancing energy efficiency in residential, commercial and industrial sectors. Specifically, Nyeri county would reduce its final energy demand by about 50% against BAU in 2030, Laikipia saving 46%, Isiolo county 51%, Samburu 48% and Meru 59%. Figure 7 illustrate the projected energy demand in the five counties. Further analysis of these trends are in the sub-sequent chapters.

Figure 8. County summary of energy demand in three scenarios



Business as Usual (BAU) Scenario analysis

A medium-term projection to 2030 was made. This is in line with the country's vision 2030, the sustainable development goals target year and the Paris agreement first commitment period (2015 – 2030). This projection forecasting would provide a sense of local action leading to national targets in climate change actions while focusing to the bigger picture of national development.

Final energy demand in Ewaso Ngiro counties in BAU

The total energy demand for all the five counties assessed from the residential, commercial and industrial sectors was 23 thousand Terajoules in 2020 and would increase to about 28 thousand Terajoule by 2030. The increase in energy demand is attributed to the counties economic and population growth. Overall, the residential sector accounted for about 70% of total energy consumed in the region while commercial and Industrial sectors accounting for the reminder of the final energy demand.

Comparing the counties, Meru accounts for the highest consumption accounting for 42% of the final energy demand in the region. Nyeri account for 26%, Laikipia, 17% and Samburu and Isiolo accounting for 9% and 6% respectively. Figure 9a illustrate the differences in final energy demand in the five counties. This is mainly attributed to the population difference between the counties. Even so, further analysis and comparison of baseline energy intensity per capita present close to similar energy intensity between Nyeri and Laikipia – 7.40GJ/capita per year and 7.37GJ/capita per year respectively and Samburu and Meru per capita consumption of 6.09 and 6.05 respectively. The county with the least final energy

Figure 9. Final energy demand projection

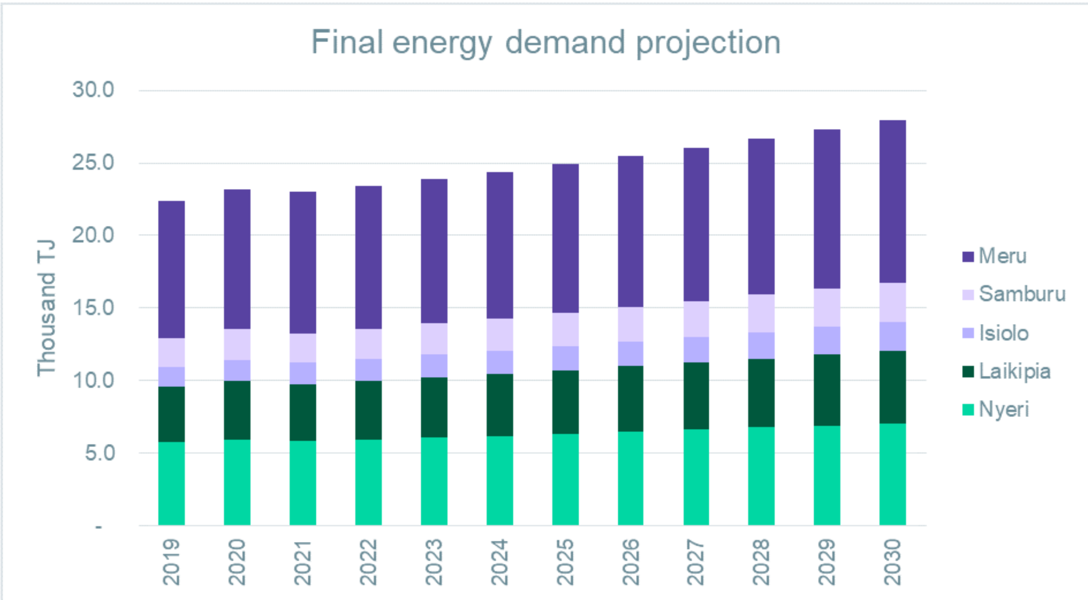
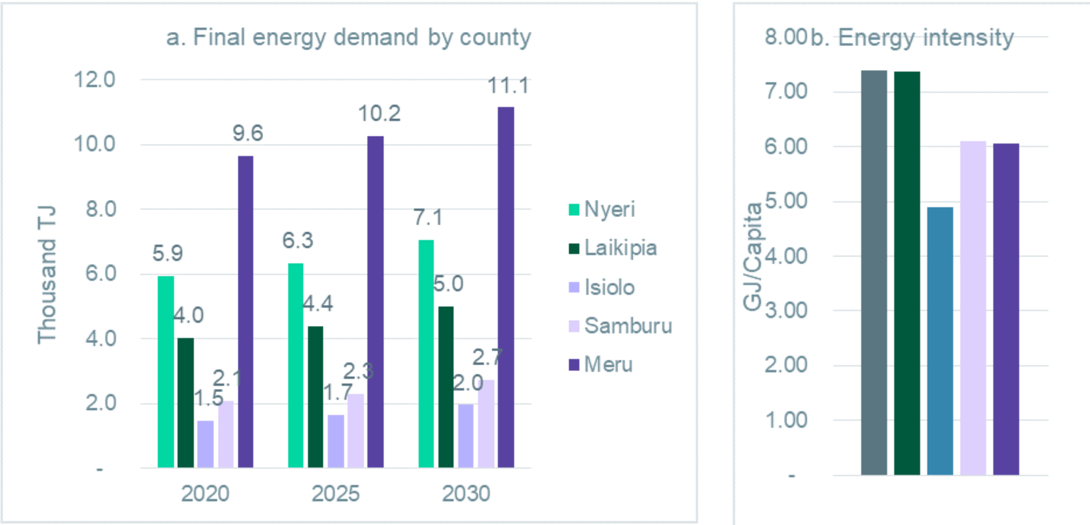


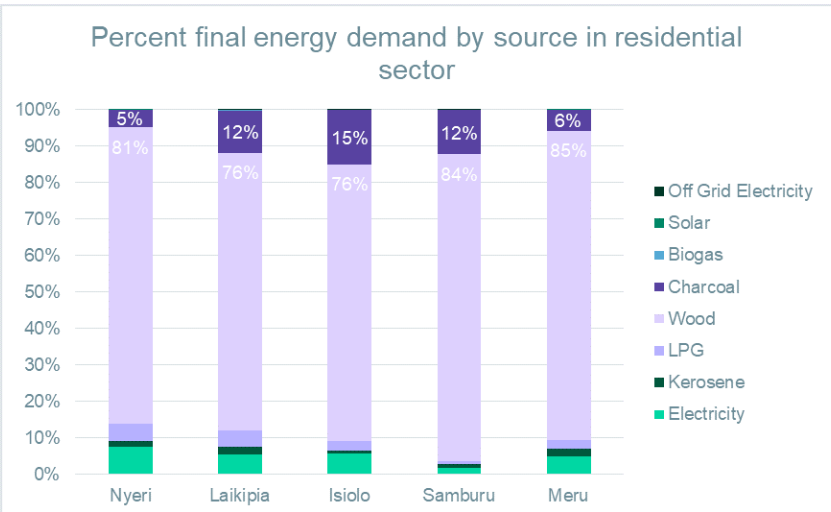
Figure 10. Final energy demand by county



Residential Sector Energy Demand

Residential final energy demand rose from 16.2 thousand TJ in 2020 to 19.3 thousand TJ in 2030. As aforementioned, the residential sector accounts for about 70% of total energy demand in the ENN catchment counties. From the analysis biomass contribute to on average 90% final energy demand in the counties. This makes biomass a significantly important resource and the same time a potential challenge to environmental sustainability. In Nyeri, 86% of total energy requirement is from biomass energy. However, an interview with the county representative, 100% of this fuel comes from on farm plantations. On the other hand, biomass accounts for 88%, 91%, 96% and 90% of Laikipia, Isiolo, Samburu and Meru final energy demand respectively. Unlike Nyeri, these counties derive some of the biomass they use from national forests, grassland and conservancies presenting environmental flows challenges.

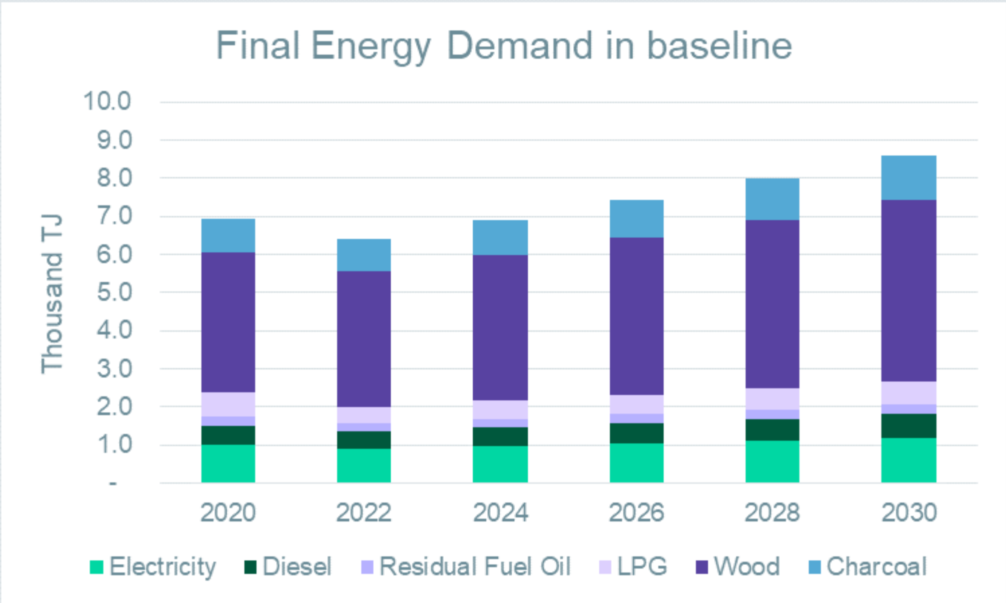
Figure 11. Residential sector energy demand



Commercial and Industrial Sector Energy demand

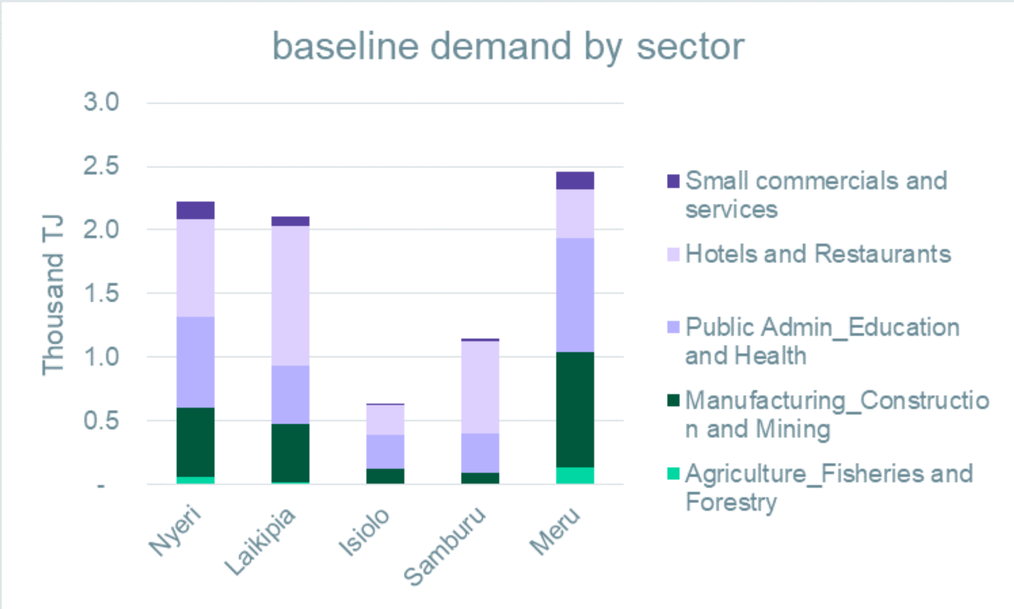
The commercial and industrial energy demand rose from 6.9 thousand TJ in 2020 to 8.6 thousand TJ in 2030 as illustrated in Figure 11. Like the residential sector, biomass is the highly demanded source of energy. In 2022, 68% of final energy demand was from biomass (wood – 55% and charcoal – 13%). Electricity accounted for 14% while diesel and LPG accounting for 7% and residual fuel oil accounting for 3%.

Figure 12. Industrial and commercial sector final energy demand projection



In terms of sub-sectors, final energy demand varied by counties due to the different economic activities attributed to the various counties. However, the top three sub-sectors contributing to the county GCP are hotels and restaurants, public admin, education and health and manufacturing. In Nyeri county, the projected final energy demand in 2030 is 2.2 thousand TJ and the top 3 sub-sectors are Hotel and restaurants, public admin and education and health and manufacturing accounting for 34%, 32% and 24% respectively. The hotel industry also is seen to perform high in Laikipia and Samburu accounting for 52% and 63% of the respective county final energy demand. Meru county highest consumer of energy is the manufacturing and public admin and health accounting for 37% each of final energy demand. This would arguably be attributed to the agro-based industries in Meru - coffee and tea industries and the Mount Kenya dairy and the level 5 Meru referral hospital boosting the high energy demand in Meru. Isiolo's top two sub-sectors are Public admin, schools and hospitals that account for 42% of their total energy consumption and hotels and restaurants accounting for 35% final energy demand. Figure 12 illustrate final energy demand in the five counties by sub-sectors.

Figure 13. Commercial and Industrial final energy demand by sub-sectors



Analysing the energy intensity level of the commercial and industrial sector, Meru County uses the least amount of energy to produce a unit of GCP (5.6 MJ/KES) while Samburu uses the highest amount of energy 28 MJ/KES. It is therefore important for Samburu, Isiolo and Laikipia to heighten energy efficiency program within its commercial and industrial sector. As Meru and Nyeri strives to ensure optimised energy consumption in its manufacturing and commercial sector. Figure 13 illustrate the energy intensity in the commercial and industrial sectors per county.

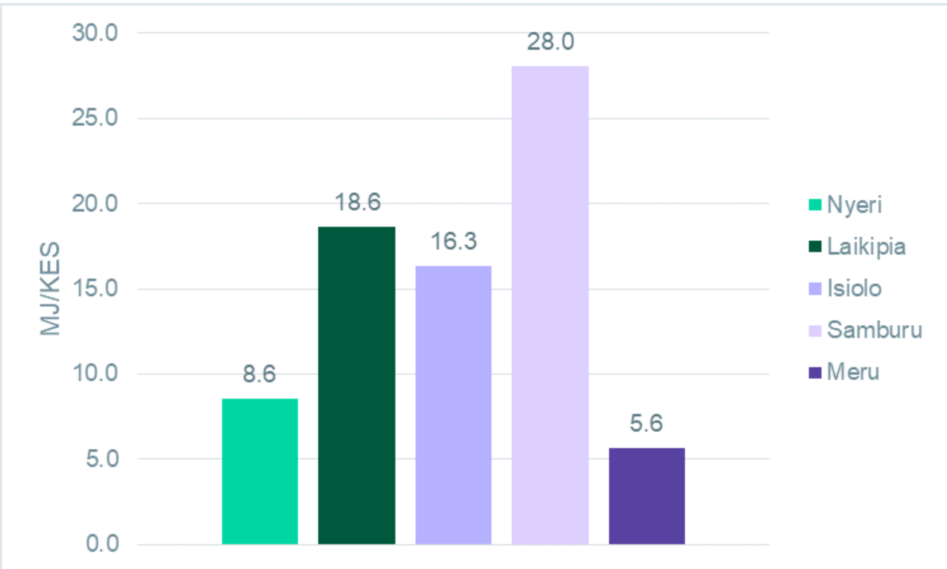


Figure 14. Commercial and Industrial energy intensity

Final Unit, biomass energy demand

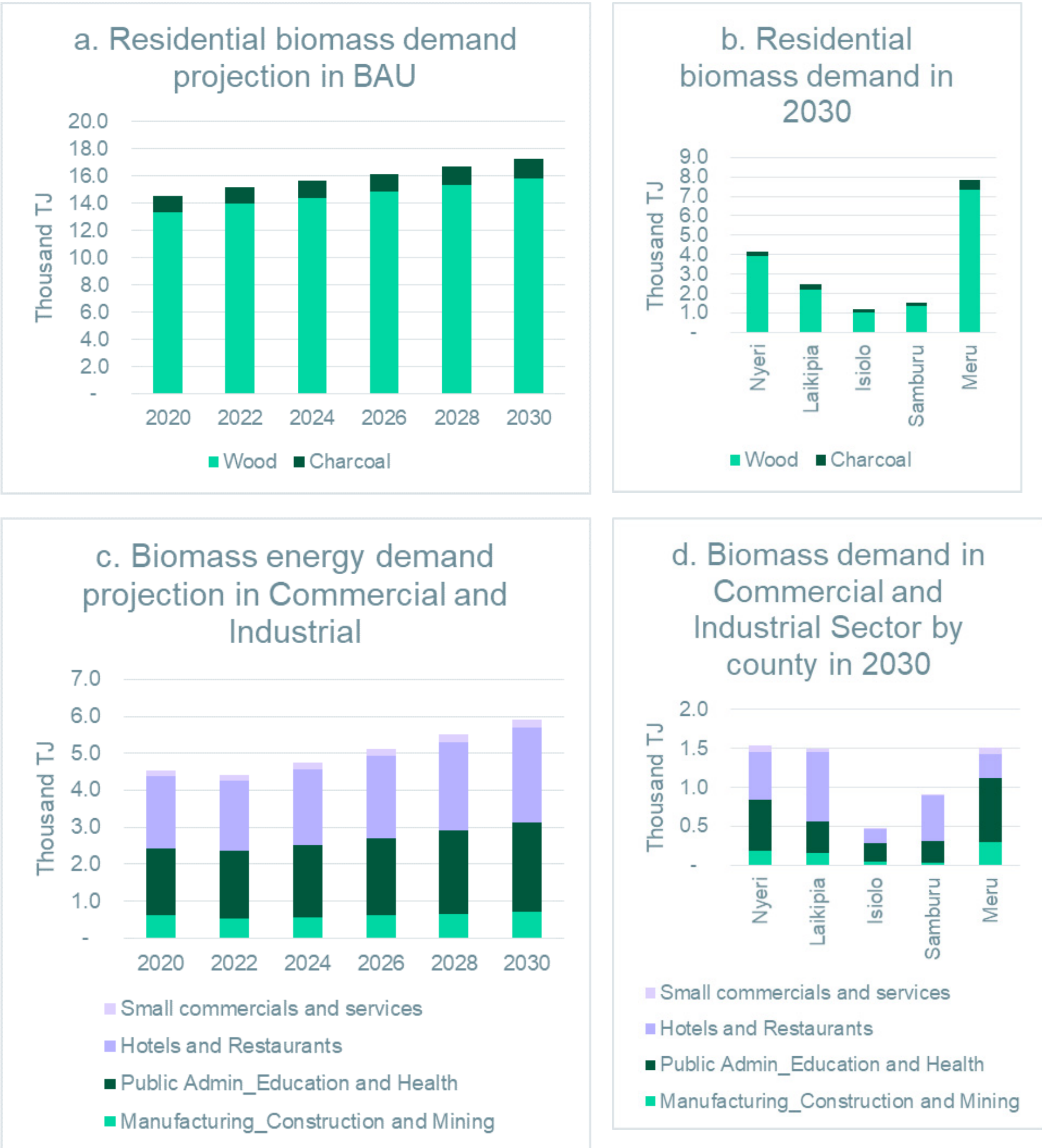
Biomass remain to be the highly demanded energy source in the region accounting for 83% of the final energy – firewood accounting for 74% and charcoal accounting for 9%. Electricity contributes to 8% of final energy demand while LPG contribute to 4% of the final energy demand. Other fuels such as diesel, residual fuel oil and kerosene account for 2% and 1% respectively. In the business-as-usual scenario, biomass demand is expected to rise from 1231k tons of wood equivalent in 2020 to 1494k tons of wood equivalent in 2030 depicting 21% increase in demand. This is evidence of over relance on biomass energy with very low consumption of clean energy sources. Table 23 illustrate the growth in biomass demand projection between 2020 – 2030.

Table 24. Charcoal and wood demand projection in Ewaso Ng'iro North Catchment

	2020	2022	2024	2026	2028	2030
Wood (Thousand-ton Wood eq)	1,098.9	1,131.2	1,174.8	1,222.0	1,275.1	1,328.1
Charcoal (Thousand-ton Wood eq)	131.9	134.8	141.8	149.4	157.7	166.3
Total (Thousand-ton Wood eq)	1,230.8	1,266.0	1,316.7	1,371.3	1,432.8	1,494.3
Charcoal (Thousand-ton charcoal)	70.5	72.1	75.8	79.8	84.3	88.9

Residential sector biomass demand was projected to rise from 14.5 Thousand TJ in 2020 to 19.2 thousand TJ in 2030, while the commercial and Industrial energy demand is expected to increase from 4.5 thousand TJ in 2020 to 5.9 thousand TJ in 2030. Comparing county demand levels in 2030, the demand levels are proportional to county population. Meru accounting for the highest demand in the residential sector accounting for 46% of total energy demand. However, the commercial and industrial biomass demand is attributed to the hotels and restaurants activities and the public admin, school and health sector activities in the respective counties. In this case, Nyeri, Laikipia and Meru demand about 1.5thousand TJ of biomass in 2030 while Samburu account for 0.9thousand TJ and Isiolo 0.5 thousand TJ. The high demand in Laikipia is attributed to hotels and restaurants while the high consumption in Meru is attributed to public admin and health sectors, while Nyeri has more less equal demand in restaurants and hotels and in public admin, schools and health sector as illustrated in Figure 15d.

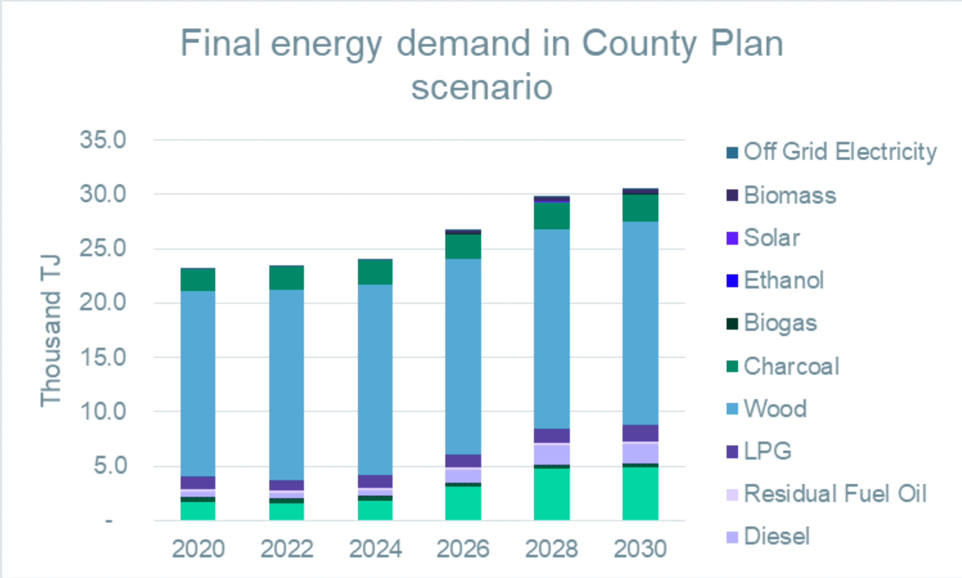
Figure 15. Biomass (wood and charcoal) projection for residential and commercial and industrial by county



County plan scenario analysis

County plan scenario is a mix of activities including energy transition, energy conservation and county development activities such as development of industrial parks and common manufacturing facilities. The final energy demand in county plan scenario is expected to increase by 32% point from 23 thousand TJ in 2020 to 30.5 thousand TJ in 2030. Like baseline scenario, biomass dependency still accounts for 70% of total energy demand. However, there is a more adoption and use of electricity hence the electricity demand more than doubles.

Figure 16.Final energy demand in County Plan Scenario

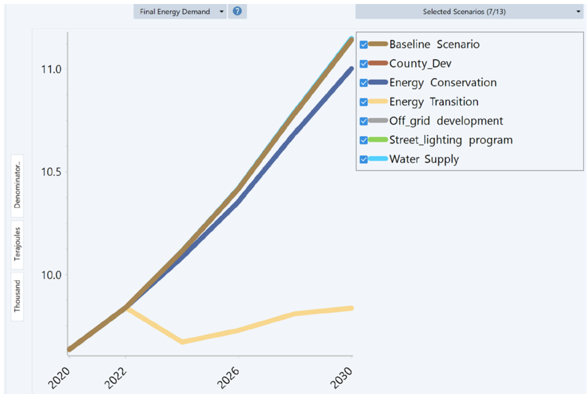


In Nyeri, county development activities such as 1 value addition on livestock product (assumed to be establishment of dairy facility) and the establishment of 5 industrial parks are the main drivers for higher energy demand rise in 2030 against the BAU (9.3 thousand TJ against 7.1TJ in the BAU in 2030). The greatest change being higher demand of electricity. The energy transition and conservation ambition are too low to bring significant change in final energy consumption. For example, targeting 100biogas plants and 1000 improved cookstoves in residential sector by 2027 in proportion of total population is a 0.1% adoption of biogas and about 1% proportion of households adopting energy conservation measures. These targets I are not ambitious to make significant change in county energy consumption.

In Laikipia, there is very small change in energy demand on scenarios in respect to baseline as illustrated in Figure 17. The energy demand is projected to rise from 4 thousand TJ in 2020 to 5 thousand TJ in 2030. The county plan sub-scenarios including development of 100 biogas in 100 households is only account for 0.2% of the total households in the county. Disseminating 750 improved cookstoves is barely 2% of total population and whereas 443 ECD and other institutions were assumed to account for about 50% of the total institutions in the county the potential saving on final energy demand is barely 10%. Compounding this to county energy demand is very low to ensure significant change. On the other hand Meru County projection shown in Figure 16b demonstrated some significant result in energy conservation and energy transition sub-scenario. The energy conservation ambitions would deliver a 0.1 thousand TJ saving while the energy transition would deliver 1.3 thousand TJ energy saving.

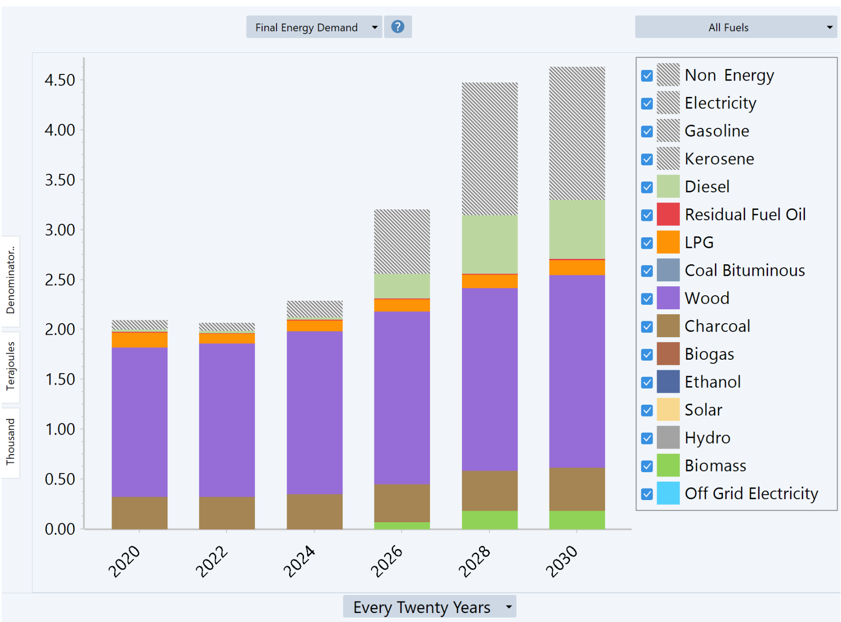
a. *Laikipia County demand projection*

b. *Meru county demand projection*



Finally, while Samburu demonstrated high energy demand rise – from 2.1 thousand TJ in 2020 to 4.7 thousand TJ in 2030, Isiolo didn't demonstrate any significant change in energy demand in the county plan scenarios. Like Nyeri, Samburu county industrial transformation and ambition on developing 60 health facilities, one milk processing plant of capacity 240,000liters per day and animal feed production plant with a yield of 45,000 bales hay per month, 40 bags acacia pods and 60bags feed blocks inflated the final energy demand in the county. An upward serge of electricity demand, diesel requirement and biomass use is observed as illustrated in Figure 17

Figure 18. Energy demand in Samburu county in county plan scenario



Climate change scenario

The climate scenario presented on average about 50% reduction in final energy demand in all counties in Ewaso Ngiro North catchment. While biomass still dominated the share proportion of energy demand in 2030 (accounting for 46%), firewood demand reduced significantly from 17thousand TJ in 2020 to 4.5 thousand TJ in 2030, similarly charcoal final energy contribution reduced from 2 thousand TJ to only 1.5 thousand TJ. On the flip side the use of electricity and LPG more than doubled. Table 24 illustrate final energy demand in climate change scenario

Table 25. Final energy demand projection in the Climate change Scenario in thousand TJ

	2020	2022	2024	2026	2028	2030
Electricity	1.7	1.6	1.8	2.0	2.3	2.6
Kerosene	0.4	0.5	0.3	0.2	0.1	-
Diesel	0.5	0.5	0.5	0.5	0.6	0.6
Residual Fuel Oil	0.2	0.2	0.2	0.2	0.2	0.2
LPG	1.2	1.0	1.3	1.6	2.0	2.4
Wood	17.0	17.5	13.9	10.5	7.3	4.5
Charcoal	2.0	2.1	1.9	1.8	1.6	1.5
Biogas	0.0	0.0	0.0	0.1	0.1	0.1
Ethanol	-	-	0.2	0.5	0.8	1.1
Solar	0.0	0.0	0.0	0.0	0.0	0.0
Off Grid Electricity	0.0	0.0	0.0	0.0	0.0	0.0
Total	23.2	23.4	20.2	17.4	15.0	12.9

PRIMARY RESOURCE FLOW ANALYSIS

Biomass is one of the primary resources with significant impact to environmental sustainability. Harvesting of biomass for charcoal and firewood have significant impact on the environment and human health. It affects the hydrological cycle and also impact on global climate change as a source of emissions through deforestation and land degradation.

From participatory mapping approach, and drawing from expert opinions, Samburu and Isiolo are the main charcoal producing hubs which is consumed in Laikipia, Nyeri and Meru. From the stakeholder's opinion, it was estimated that Samburu County exports 10% of charcoal produced to Nyeri, and Meru, 20% to Isiolo and 40% to Laikipia above charcoal produced for local consumption. It is therefore logical that whereas Samburu County demands the least charcoal, it is the highest producer of charcoal to serve the region as illustrated in Figure 18. Charcoal supply in three scenarios by region in 2030. Table 25 illustrate wood resource requirement in the three scenarios.

Figure 19. Charcoal supply in three scenarios by region in 2030.

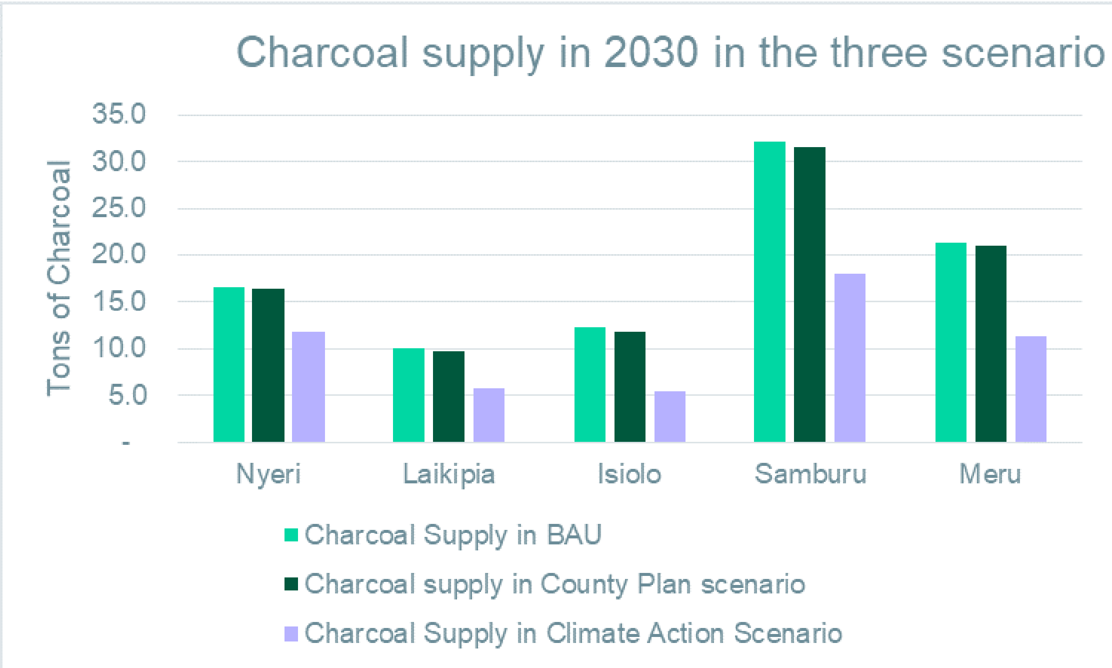


Table 26. Wood resource requirement in three scenarios in Ewaso Ngiro North counties

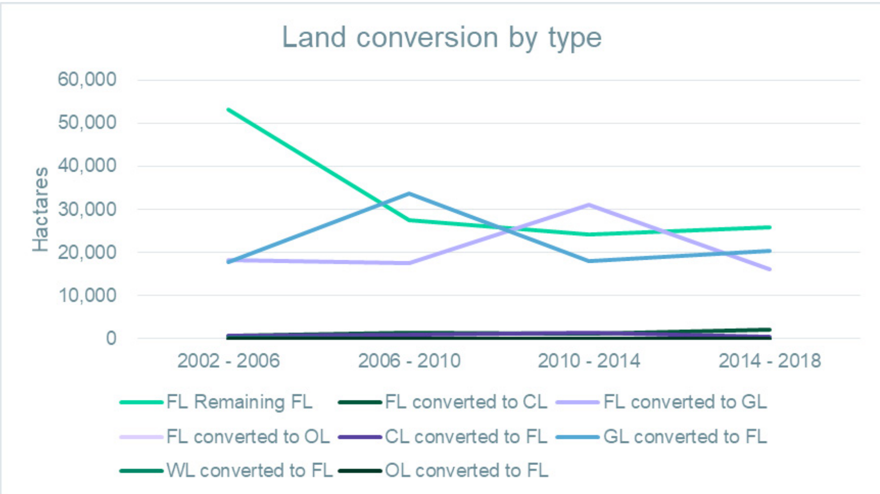
Million tons of Wood						
	2020	2022	2024	2026	2028	2030
Baseline wood resource requirement	1.6	1.7	1.8	1.8	1.9	2.0
County plan scenario	1.6	1.7	1.7	1.8	1.8	1.9
Climate Action Scenario	1.6	1.7	1.4	1.1	0.9	0.7

Forest resource use assessment

Laikipia County

As illustrated in Figure 20 Laikipia county forest degradation has been steady from 53k hectare of land in 2002 to 26K hectare of land in 2018. While the grassland transforming to forest land is very minimal 17k hectare in 2002 to 20k hectare in 2018. Similarly slow rate of agroforestry is recorded with transformation between 2002-2006 was 724ha and between 2014 – 2018 recording only 367ha. Thus, the resultant effect is land degradation. This is attributed to multiple factors such as over stocking of livestock, charcoal burning and agriculture. Forest land area converted to cropland and grassland remained rather steady an average of 22k hectares of land in the four intervals.

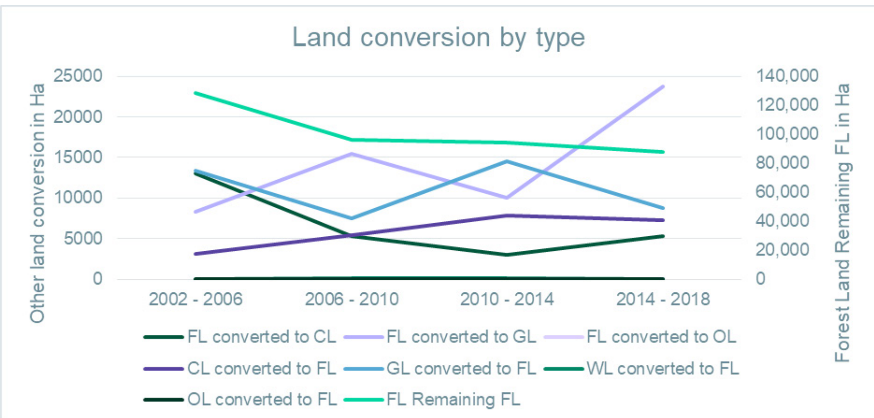
Figure 20. Land use change in Laikipia county



Meru County

While Meru County also showed decreasing in forest land, unlike Laikipia the Meru Forest land remaining forest land changed from 128k hectare in 2002 to 88k hectare in 2018 implying 40k hectare deforested. This would highly be attributed to either logging or charcoal production as forest land converted to grass land sharply rose from just 8k hectare in 2002 to about 23k in 2018 as illustrated in Figure 21.

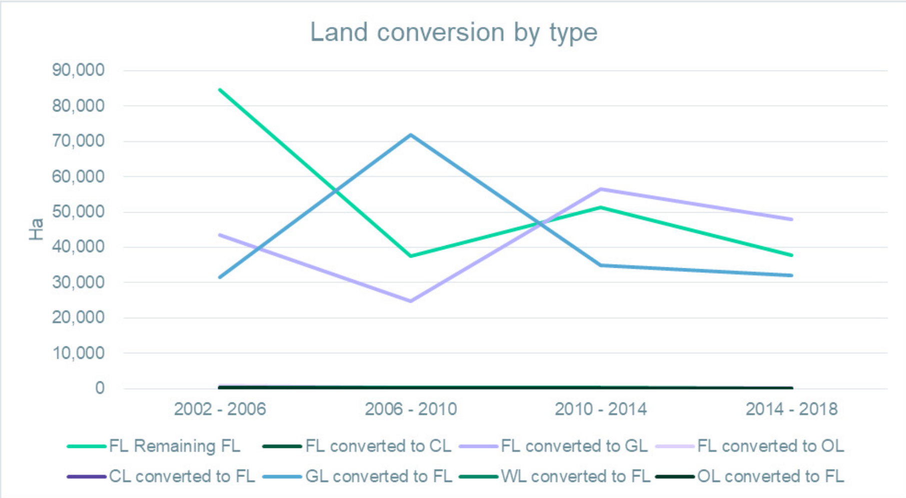
Figure 21. Land use change in Meru County



Isiolo

Like Laikipia, Isiolo forest land has reduced by more than half. In 2002, forest land area was about 86k hectares and by 2018, the forest land had reduced to about 38k hectares. This is attributed to the high forest conversion rate to grassland averaging 43k hectares in the analysis periods or more than 10k hectares degraded annually as illustrated in Figure 22. While the afforestation rate has also been experienced (grass land converting to forest land), the rate is much lower than the degradation rate. The average conversion from grass land to forest land was estimated at 33k hectares between the estimation periods.

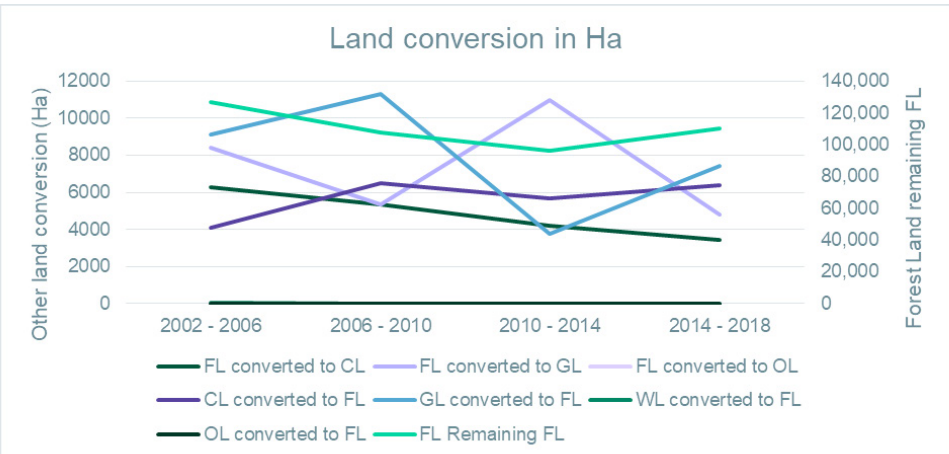
Figure 22. Land use change in Isiolo county



Nyeri

Nyeri is considered the most forested of the five counties as illustrated in Figure 23. The level of deforestation is quite low with forest land in 2002 was 127k hectares and in 2018 it was 111k hectare – only 16k hectare deforested in a period of 16 years. Moreover, the rate at afforestation (3389 ha/year) is slightly higher than the rate of deforestation (3048ha/year). The balance has managed to maintain the forest ecosystem.

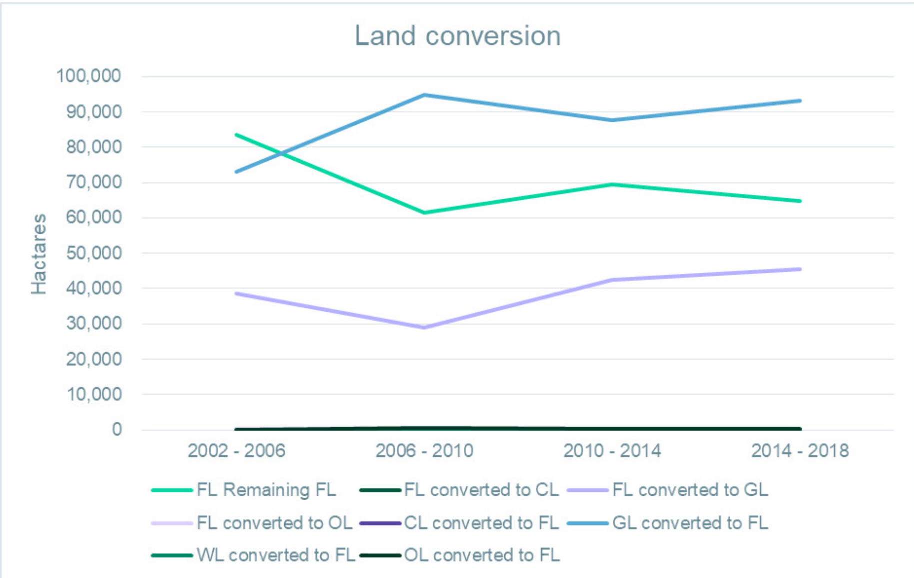
Figure 23. Land use change in Nyeri county



Samburu

Samburu is considered as the major supplier of charcoal in the Ewaso Ngiro north catchment. The community is pastoralist and hunters, and the ecosystem is rather more of shrub vegetation. Based on the FRL estimation, the forest land reduced from 84k hectares in 2002 to 65k hectares of land in 2018. While the deforestation is very high (forestland converting to grassland at an average of about 10k hectares of land annually) the rate of afforestation (grassland converted to forest land) is much higher at a rate of 22k hectares annually. There is limited or negligible change of cropland either to forest land or other lands to agricultural land, partly due to the culture and economic activity of the community. Figure 24 is an illustration of land conversion in Samburu County.

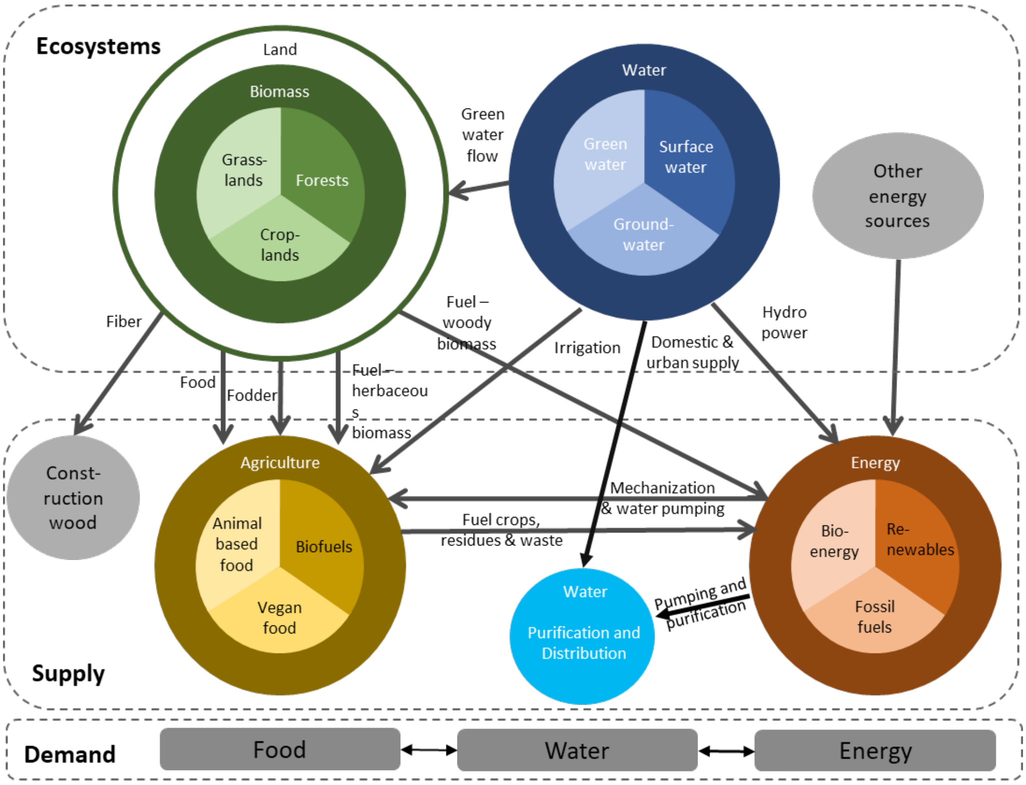
Figure 24. Land use change in Samburu



NEXUS ANALYSIS

Nexus analysis is underpinned on the interrelation between sectors and that different human systems compete for limited resources. Human system demand food, energy and water that is supplied through three main ecosystem services – agriculture, water and energy primarily within two key ecosystems – the land ecosystem and the water ecosystem as illustrated in Figure 25. Agricultural activity provide food that is demanded by human and animals but also supply energy as herbaceous biomass – straws, dungs and crop residues as sources of bioenergy. On the other hand biomass constitute high residential energy demand. This could be in the form of woody biomass, liquid biofuels and fossil fuel. Energy is a core requirement for food processing and mechanisation and is sourced from agricultural activities, water and land and forest ecosystem. While demand for land for agricultural production and land for forest continue to press, the county land area is not changing. Hence sustainable utilisation of this finite resource is critical.

Figure 25. Food – water and Energy Nexus schematic



The nexus analysis focused on hydropower resource for off-grid electricity generation. Nyeri and Meru relies on Micro-hydropower generators to supply more than 30000 households with electricity. On the other hand, population is in the increases and demand for water for domestic consumption and agriculture both up and down stream continues to soar. Moreover, this hydropower systems are run-off the river schemes hence highly sensitive to human behaviours and climate change impact. The reality of competition would put pressure on the finite water resource constraining power generation. This would in turn have direct and in-direct impacts on local production, hence impaired local economy and reduced livelihoods.

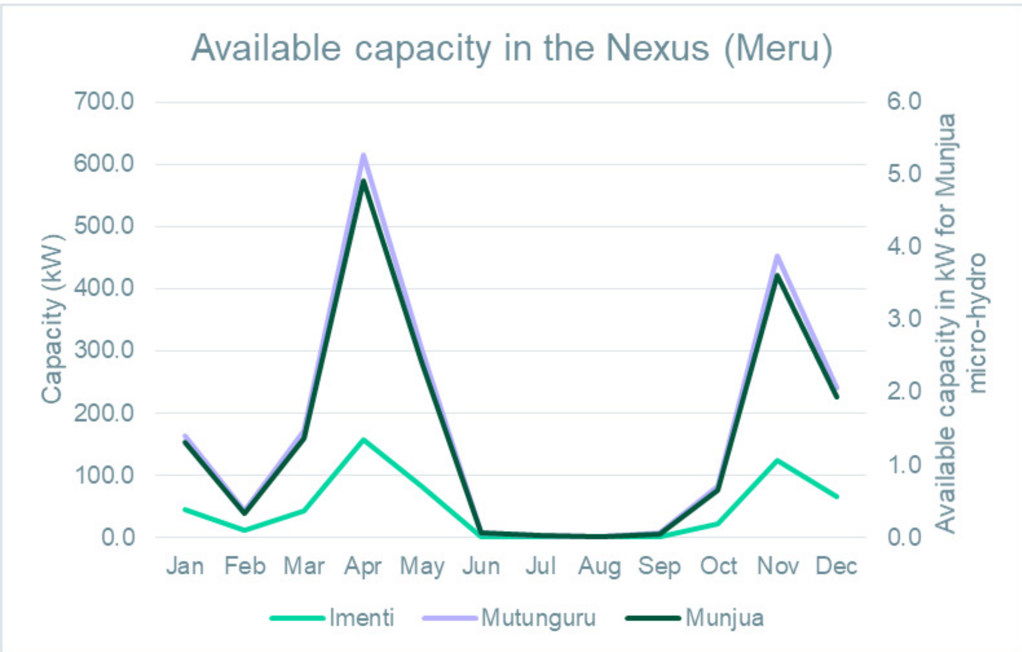
While the Tana River catchment plays a critical role in Kenya electricity sector. The 7 forks dams (Kiambere, Gitaru, Kindaruma, Kamburu and Masinga dams) are the major hydropower dam supplying Kenya with about 600MW capacity of hydroelectricity. In the same river in the upper catchments in Meru and Nyeri communities also benefit from small off-grid hydropower systems supplying over 30000 households with electricity.

The analysis prioritises water for domestic consumption and agriculture and assess hydropotential across the year for the four micro-hydropower systems in Nyeri and three micro-hydropower system in Meru.

Water-Energy Nexus analysis in Meru

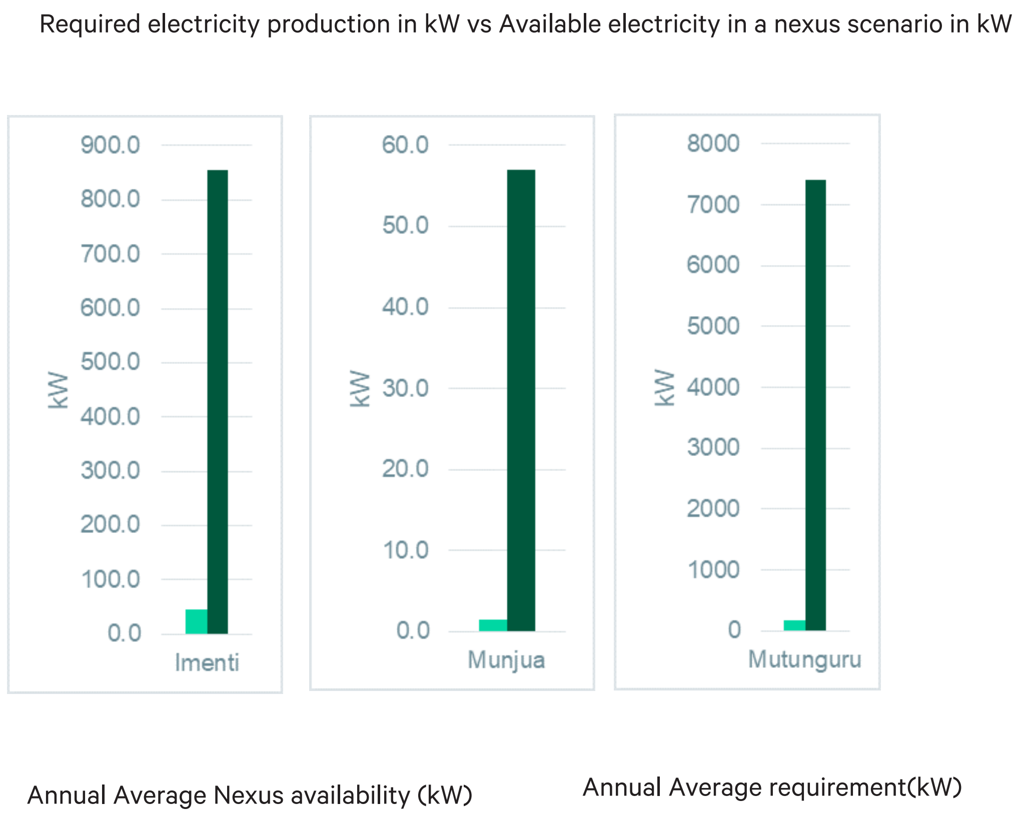
Meru county has three micro-hydro power plants that supply electricity to the community and support local development. They include Imenti, Mutunguru and Munjua. All the three micro-hydropower illustrate high and low availability as per the rainfall patterns. March, April and May are high rainfall seasons (GoK 2022) in Kenya and hence the demonstration of high hydropower availability while between June to September are dry months with low or no hydropower availability in the domestic and agricultural demand prioritisation. The short rains come in October and end in December hence increased availability. Figure 26 illustrate micro-hydropower availability in Meru.

Figure 26. Hydropower availability across the year in Meru



While the trend is major concern, further analysis showed that the average available capacity is barely 10% of the design capacity as illustrated in Figure 27. This is a point of decision making as it reflects unreliability of the micro-hydro power depicting high load shading and power rationing.

Figure 27. Average availability in low priority scenario



Water – Energy Nexus analysis in Nyeri County

Like Meru, the micro-hydropower availability in Nyeri also follows the rain fall pattern with high generation between March – May and elevated production between October and December as illustrated in Figure 28. Also, compared to the design capacity, most micro-hydropower in Nyeri can only generate about 30% of the design capacity with adverse implications as illustrated in Figure 29.

Figure 28. Micro-hydropower availability in Nyeri County

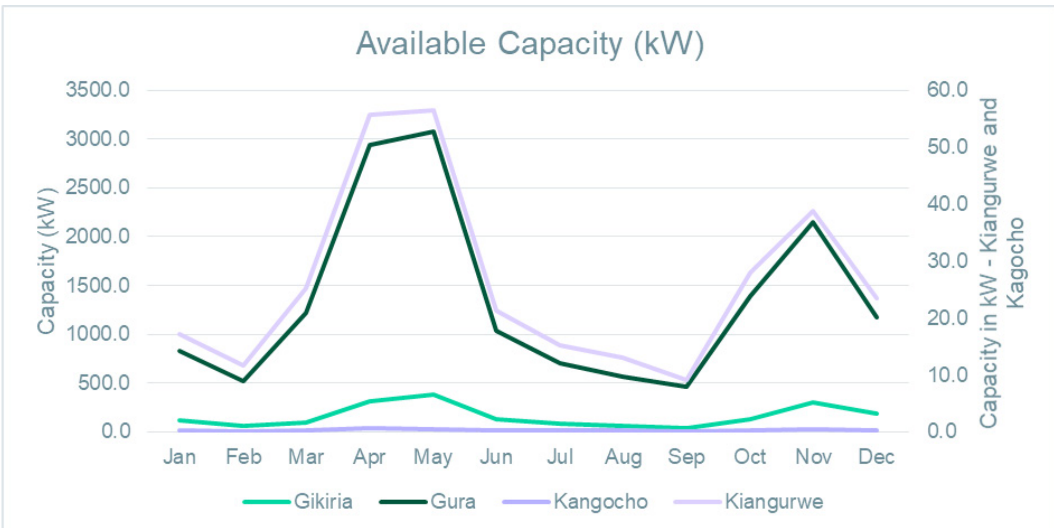


Figure 29. Average capacity available in low priority scenario against design capacity

CONCLUSION

The Water–Energy–Food (WEF) Nexus and Ecosystem-based Adaptation assessment across the five counties of the Ewaso Ng'iro North Catchment (Nyeri, Laikipia, Isiolo, Meru and Samburu) demonstrates that resource demands especially for water, biomass energy and land are increasing rapidly, driven by population growth, expanding economic activities and persistent dependence on biomass. Final energy demand in the region is projected to rise from 23,000 TJ in 2020 to 28,000 TJ by 2030 under business-as-usual, with biomass accounting for roughly 70–90% of residential and commercial energy use. This continued reliance places substantial pressure on forests, rangelands and ecosystem services, especially in counties where biomass is sourced from natural forests and conservancies rather than on-farm plantations.

Scenario analysis reveals that current county development trajectories (County Plan Scenario) increase energy demand significantly due to industrial parks, TVET centres, and other growth plans, but provide limited ambition for energy transition or efficiency, resulting in higher consumption than BAU. In contrast, the Climate Action Scenario aligned with NDCs and the NCCAP demonstrates transformative potential, cutting final energy demand by up to 50–59% across counties through adoption of clean cooking, universal electrification, and strong energy efficiency measures. This highlights a major gap between national climate ambitions and actual county implementation pathways.

The study's WEF Nexus analysis underscores the interdependence of resources. Water availability especially for micro-hydropower in Nyeri and Meru varies strongly with rainfall patterns, with most plants delivering 10–30% of their design capacity, signaling chronic unreliability and risks to community electrification. Simultaneously, competition for water between agriculture, domestic use, and energy is expected to intensify under climate variability.

Overall, the findings show that without integrated resource planning and enhanced coordination, counties risk deepening resource conflicts, accelerating ecosystem degradation, and missing both development and climate goals. The Nexus approach and EbA provide a pathway to harmonize sector actions, optimize trade-offs and build resilient systems capable of supporting inclusive development and climate adaptation.

RECOMMENDATIONS

1. Strengthening Cross-Sectoral Coordination and Institutional Mechanisms

- Establish formal Nexus coordination units or committees linking Water, Energy, Agriculture, Environment and Lands departments at county level.
- Integrate EbA principles and WEF Nexus indicators into county planning, CIDPs and sector budgets.
- Create harmonized guidelines for cross-county collaboration given shared ecosystems, water sources and biomass supply chains.

2. Accelerate the Transition to Modern and Clean Energy Technologies

- Implement ambitious county-level clean cooking strategies aligned with the national NDC target (LPG, bioethanol, electricity and improved biomass technologies).
- Expand access to electricity through grid extension, mini-grids and standalone solar systems, especially in Isiolo and Samburu.
- Introduce incentives for energy efficiency technologies in households, public institutions and industries.

3. Reduce Biomass Dependency Through Sustainable Resource Management

- Promote on-farm woodlots, agroforestry, and fast-growing tree species to reduce pressure on natural forests and conservancies.
- Develop county-wide charcoal production and trade regulations, including improved kilns and certified charcoal value chains.
- Strengthen monitoring of biomass flows using LEAP outputs to inform forest management plans.

4. Enhance Water Resource Management for Resilience and Equity

- Prioritize water allocation for domestic and priority agricultural uses while ensuring ecological flow requirements.
- Invest in water storage, riverbank protection, watershed restoration and catchment rehabilitation as EbA measures.
- Expand data collection and monitoring of water abstraction, hydropower performance and groundwater stress.

5. Improve the Reliability of Micro-Hydropower and Explore Alternative Renewables

- Reassess micro-hydropower investment viability given highly variable seasonal availability (10–30% of design capacity).
- Undertake rehabilitation, sediment control and flow regulation where feasible.
- Diversify local renewable energy options including hybrid solar–hydro systems to stabilize supply.

6. Align County Development Plans with National Climate Commitments

- Ensure county activities industrial parks, agricultural expansion, infrastructure are evaluated against NDC targets for clean cooking, energy efficiency and electrification.
- Adopt the Climate Action Scenario assumptions in county energy plans to avoid the projected rise in demand under the County Plan Scenario.
- Use LEAP and WEAP modelling output continuously for policy updating and impact tracking.

7. Strengthening Data Systems and Modelling Capacity

- Institutionalize periodic data collection on energy use, biomass production, water flows and ecosystem change.
- Support counties to operationalize LEAP and WEAP models for annual planning and investment decisions.
- Establish data-sharing agreements among counties, national agencies and research institutions.

8. Invest in Community Awareness and Stakeholder Engagement

- Expand awareness programmes on clean cooking, energy efficiency and sustainable land management.
- Empower local communities through participatory resource mapping, community forestry and rangeland management groups.
- Ensure women, youth and pastoralist groups are integrated into Nexus decision-making processes.