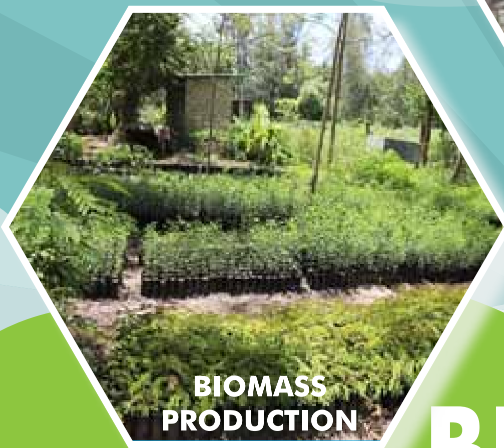
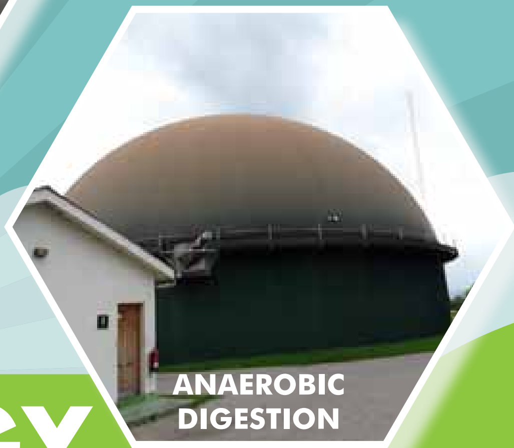
REPUBLIC OF KENYA

MINISTRY OF ENERGY





BIOENERGY STRATEGY

2020-2027

MINISTRY OF ENERGY

BIOENERGY STRATEGY

2020

On Farm Agroforestry for Biomass Production

FOREWORD

Bioenergy plays an important role in the domestic and industrial energy needs of Kenyans. It is renewable energy created from natural biological sources, and can be classified into solid, liquid and gaseous forms. Bioenergy in Kenya has not been exploited to its full potential despite numerous efforts that have been made in the past 30 years to address issues touching on its sustainable production, efficient conversion/processing and use.

The Government of Kenya is committed to achieving the target of its population enjoying access to modern bioenergy services, including 100% access to clean cooking, by 2028, two years ahead of the schedule set out in the Kenya Sustainable Energy for All (SEforAll) Action Agenda. Improvements in the bioenergy sector will play a critical role in achieving these targets through sustainable production and efficient use of biomass, waste to energy conversion and development of biofuels. The implementation of this strategy is the first step towards achieving the aspiration of Kenyans of having modern bioenergy solutions by 2030.

In this context, it is important to develop a comprehensive bioenergy strategy which will promote the sustainable production, distribution and utilisation of bioenergy as a clean source of energy. The strategy, therefore, aims to address the strengths, gaps, opportunities and foreseen challenges to enhance sustainable exploitation of bioenergy. This strategy will go a long way in supporting the realisation of the full potential of bioenergy development and assist the country in achieving the aspirations of the Sustainable Development Goals (SDGs), key among them being SDG 7 which aims to ensure access to affordable, reliable, sustainable and modern energy for all by 2030.

Hon. Charles Keter, EGH

Cabinet Secretary

MINISTRY OF ENERGY

ACKNOWLEDGEMENTS

I appreciate the leadership of the Ministry of Energy in providing policy direction throughout the process of formulating the bioenergy strategy. I also wish to express deep appreciation to all parties who have unreservedly offered support to develop the Sustainable Bioenergy Strategy. I note with concern that bioenergy technologies have not been given adequate consideration in the past, yet many Kenyans (74.7%) rely on biomass as their primary source of energy, mainly for cooking.

I wish to sincerely thank the National Bioenergy Committee (NBC) for providing strategic leadership in this exercise. Further, I appreciate the inputs from stakeholders and support from development partners. It is my hope that this partnership will continue as we enter the next phase of implementation.

The support received from GIZ, World Agroforestry (ICRAF) and the World Bank in the process of developing this strategy is acknowledged. There are numerous contributions from other stakeholders who had been consulted in one way or another during the preparation process of this elaborate document, and whose names may not have been captured. I wish to assure you that your contribution is valued, and you will be part and parcel of the implementation of this strategy.

Last but not least, personnel from the Directorate of Renewable Energy, led by the Secretary, Eng. Isaac N. Kiva, cannot be forgotten. They facilitated the process and ensured that the strategy meets the required standards.

I encourage all stakeholders to participate and implement the various sub-sectors in bioenergy to enhance development of this form of renewable energy in the country.

Dr. Eng. Joseph K. Njoroge, CBS

Principal Secretary

MINISTRY OF ENERGY

EXECUTIVE SUMMARY

Bioenergy is an important form of energy for Kenya, contributing 68% of the country's final energy demand for diverse needs, especially cooking and heating. As a renewable energy source, it can contribute to energy security in the country as espoused in the Energy Policy and Energy Act, and to meeting the country's other national goals covered under Vision 2030—such as agriculture, health and commerce—for which energy is an enabler. Bioenergy can also support the country in meeting its global commitments such as its Nationally Determined Contribution (NDC) under the Paris Agreement, Sustainable Development Goals (SDGs) including SDG 1 on poverty reduction, SDG 3 on improved health and wellbeing, SDG 7 on sustainable energy; SDG 13 on climate action; and SDG 17 on partnerships for development. Despite its significance to the country's growth, bioenergy development from biomass resources has not received adequate attention it deserves to optimise its potential contribution.

The strategy is founded on intelligence from global and regional trends in bioenergy production and consumption and an understanding of the local bioenergy industry status. The document aims to guide development and promotion of bioenergy as a formal industry that can be a vehicle for Kenya's economic development. It embodies the national and county governments' renewable energy priorities and intentions to deliver modern energy solutions from available bioenergy feedstock through innovation and consultation. The strategy will support the development of bioenergy to meet the long-term sustainable energy demand.

Being the inaugural bioenergy strategy for the country with no precedent, it sets forth guidelines and approaches, and further identifies strategic interventions that can promote the development and sustainable utilisation of bioenergy resources in Kenya over the 2020-2027 period. It identifies strategic interventions to be considered by able actors for implementation and that promise to fast-track the country along the sustainable-energy-for-all pathway. Three key features of the strategy that stand out are: a delivery and coordination mechanism at the Department of Renewable Energy to oversee overall implementation of the strategy; recognition of adaptive planning and multi-stakeholder consultations around innovation platforms; and the critical role of learning and feedback. It is worth noting that this strategy does not set hard quantitative targets (these will be determined by sub-sector stakeholders convening around their innovation platforms) but provides guidance on realisable outcomes over the short- (2020-2022) to medium-term (2023-2027).

The strategy is being launched at a time when the world is turning its attention to health concerns attributed to cooking fuels, both at household and institutional level. Kenya is a testimony of these, with respiratory-related diseases comprising 25% of the total burden of disease reported by the Economic Survey in 2019. The strategy also comes at a time when a range of financing opportunities are available locally and internationally in favour of clean cooking and climate finance. It is also noteworthy that energy-intensive industries are switching from furnace oil to biomass to power their boilers. It is incumbent upon the responsible stakeholders to ensure that an enabling environment for investment is established and nurtured in order for the vision of sustainable bioenergy for all citizens to be a reality by 2027 and beyond.

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DEFINITIONS OF TERMS

Biochar	Biochar is a charcoal-like substance that's made by burning biomass in a controlled process known as pyrolysis
Biodiesel	An alternative fuel, similar to conventional or fossil diesel, produced from straight vegetable oil, animal oil/fats and waste cooking oil
Bioenergy	A form of renewable energy that is derived from organic matter, including wood, agricultural products, organic wastes, municipal solid waste and other living cell materials
Biofuel	A fuel that is produced through contemporary biological processes
Biogas	A type of biofuel that is naturally produced from the decomposition of organic matter in an anaerobic (absence of oxygen) environment
Bio-slurry	The liquid discharged at the bio-digester outlet after gas has been tapped off
Briquettes	A compressed block of coal dust or other combustible biomass material such as sawdust, wood chips, peat or used paper
Clean cooking	Cooking fuels and technologies which are used without harm to the health of those in the household and which are more environmentally sustainable and energy efficient than inefficient biomass cookstoves and the three-stone fires
Incinerator	A waste treatment plant that involves combustion of organic substances contained in waste materials
Pellets	Biofuel made from compressed organic matter or biomass but smaller in diameter than briquettes

ACRONYMS AND ABBREVIATIONS

AA	Action Agenda
ABBP	African Biogas Partnership Programme
AFREPREN/ FWD	The Energy, Environment and Development Network for Africa
CBD	Convention on Biological Diversity
CCAK	Clean Cooking Association of Kenya
CCCF	County Climate Change Fund
CCNUCC	La Convention-cadre des Nations unies sur les changements climatiques
CDACC	Curriculum Development Assessment and Certification Council
CHEST	Clean Household Energy Solutions Toolkit
CIDP	County Integrated Development Plans
CO	Carbon monoxide
CoG	Council of Governors
CPA	Charcoal Producers' Association
DALY	Disability-Adjusted Life Years
DCD	Delivery and Coordination Desk
DCF	Decentralized Climate Finance
DRE	Directorate of Renewable Energy
EAC	East African Community
ECF	Ethanol Cooking Fuel
EfW	Energy-from-Waste
ESMAP	Energy Sector Management Assistance Program
FAO	Food and Agriculture Organisation of the United Nations
FIT	Feed-In-Tariff
GBV	Gender-Based Violence
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
GoK	Government of Kenya
GPS	Global Positioning System
HAP	Household Air Pollution
HEPA	Health and Energy Platform of Action
IAQ	Indoor Air Quality
ICRAF	World Agroforestry
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISO	International Organisation for Standardization
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KEBS	Kenya Bureau of Standards
KEFRI	Kenya Forestry Research Institute
KES	Kenya Shilling
KFS	Kenya Forestry Service
KIA	Kenya Investment Authority

KIRDI	Kenya Industrial Research and Development Institute
KNQA	Kenya National Qualification Authority
KPC	Kenya Pipeline Company
KT	Kilo Tonnes
LCA	Life Cycle Assessment
LCPDP	Least Cost Power Development Plan
LPG	Liquid Petroleum Gas
MCAs	Members of the County Assembly
MDAs	Ministries, Departments and Agencies
MECS	Modern Energy Cooking Services
MEWNR	Ministry of Environment, Water and Natural Resources
MoE	Ministry of Energy
MW	Mega Watts
NAMA	National Appropriate Mitigation Action
NBC	National Bioenergy Committee
NCCAP	National Climate Change Action Plan
NDC	Nationally Determined Contribution
NDMA	National Drought Management Authority
NGO	Non-Governmental Organisation
NIMES	National Integrated Monitoring and Evaluation System
NMS	Nairobi Metropolitan Services
NRM	Natural Resource Management
OECD	Organisation for Economic Co-operation and Development
PLWD	People Living With Disabilities
PM	Particulate Matter
PPA	Power Purchase Agreement
PPP	Public Private Partnership
R&D	Research and Development
REREC	Rural Electrification and Renewable Energy Corporation
SDGs	Sustainable Development Goals
SEforAll	Sustainable Energy for All
SME	Small and Medium Enterprises
TOR	Terms of Reference
TVET	Technical Vocational Entrepreneurship Training
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
USD	United States Dollar
VAT	Value-Added Tax
WHO	World Health Organisation
WTO	World Trade Organisation

Training on Emerging Biogas Technologies

1.0 Introduction

Biomass is renewable organic matter that comes from crops, trees, wood chips, aquatic plants, manure and municipal waste. Different forms of bioenergy include (i) solid biomass such as fuelwood, charcoal and agro-industrial solid wastes—including pellets and briquettes (ii) liquid biofuels such as bioethanol and biodiesel, and (iii) gaseous biofuels such as biogas, biomethane and syn-gas. These forms of energy are used in their natural state or processed as shown in Figure 1. According to the IEA (2019), bioenergy is the most common form of renewable energy in the world, supplying heat and electricity, as well as transport fuels, thus providing a huge potential to transition from fossil to cleaner fuels.

The Intergovernmental Panel on Climate Change (IPCC) Special Report on Climate Change and Land (IPCC, 2019) calls for a significant increase in the deployment of bioenergy for all the suggested 1.5-degree Celsius and 2-degree Celsius mitigation pathways. The seventh Sustainable Development Goal (SDG 7) on affordable and clean energy and the Sustainable Energy for All Initiative (SEforAll) (United Nations, 2015) stipulates that access to affordable, reliable and sustainable energy is an essential prerequisite to achieving social and economic wellbeing. Similarly, sustainable energy is at the forefront of the development plans of African nations, which recognise its crucial role for achieving all SDG targets and mitigating and adapting to climate change. Out of the 53 African nationally determined contributions (NDCs), 45 contain quantified renewable energy targets. This is an acknowledgement of the abundant opportunities offered by Africa's vast renewable energy potential to put the continent on a clean development path (IRENA, 2020).

The Kenya Vision 2030 identified energy as one of the infrastructure enablers of its socio-economic pillar. Sustainable, competitive, affordable and reliable energy for all citizens is a key factor in realisation of the vision. The overall objective of the Energy Policy is to ensure sustainable, adequate, affordable, competitive, secure and reliable supply of energy at the least cost geared to meet national and county needs, while protecting and conserving the environment. Furthermore, the Government's "Big 4 Agenda" – comprising Food and Nutrition, Manufacturing, Affordable Housing and Healthcare offers opportunity for accelerated investments in the bioenergy sector, while also addressing the sustainable household energy supply. Bioenergy is a major source of primary energy supply in Kenya, accounting for 68% of the total primary energy consumption. The country aspires to achieve universal access to modern energy for cooking, heating and productive uses by 2028. A bioenergy strategy is therefore, key to providing a framework of key interventions towards this goal. However, this sector is still in the very nascent stages, and will require transformation that will modernise, formalise and regulate it towards sustainability.

Various obstacles have stood in the way of sustainable bioenergy deployment resulting in serious health and ecological consequences. A few scattered and uncoordinated interventions have been pursued through initiatives by different institutions—both in the public and private sector. Some local universities for example, have been testing the viability of different biomass feedstock for biodiesel production; these findings could inform policy and practice.

The National Climate Change Action Plan (NCCAP) 2018-2022 proposes in several sections, options which pledges to take the bioenergy sector to greater heights of development if adopted and well implemented. Similarly, the Ministry of Energy in its Sustainable Energy for All (SEforALL) Action Agenda and Investment Prospectus for Kenya, has identified some activities for implementation under the Ministry's coordination. Considering the numerous actors needed to work collaboratively to deliver the national and global agenda, the diverse interests each of them carries, as well as the

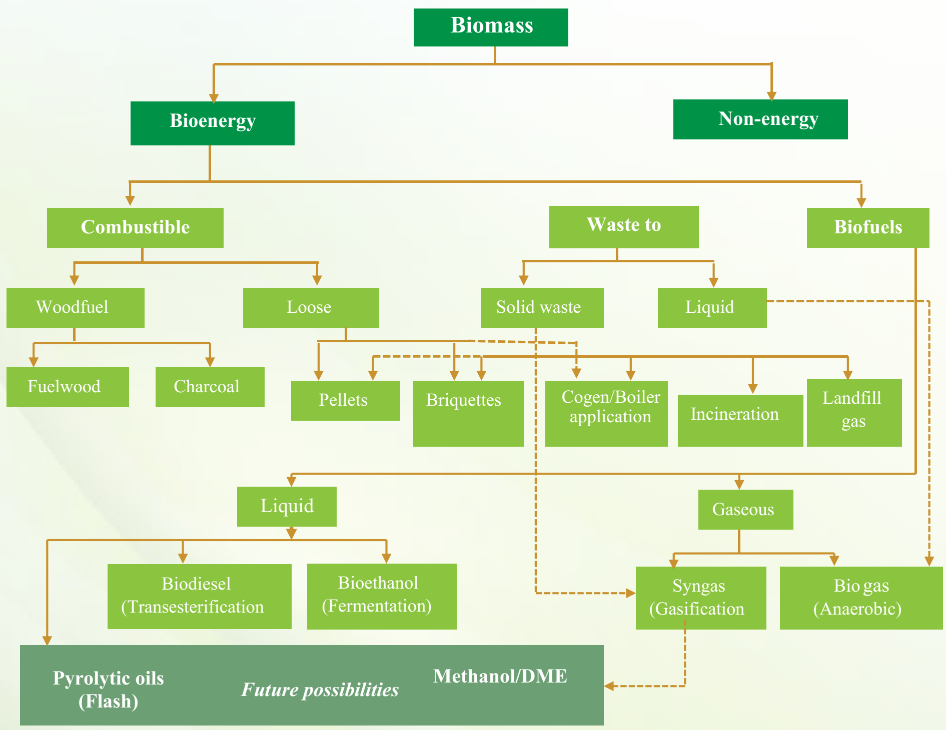


Figure 1: Conversion Process from Biomass to Different Bioenergy Forms

implications for more deliberate coordination and monitoring of the interventions, the need for a reference and guiding framework is apparent, hence the development of this Bioenergy Strategy to seal that gap.

The goal of this Strategy is "*sustainable bioenergy for all*" by 2028. Specific objectives comprise the following:

- To promote sustainable production and consumption of bioenergy;
- To accelerate transition to clean cooking technologies and fuels;
- To provide potential investors with requisite information on viable opportunities for bioenergy development in Kenya; and
- To serve as a framework for regional and international cooperation and trade in bioenergy and related feedstocks.

This strategy is the culmination of extensive and elaborate expert consultation and multi-stakeholder dialogue processes that commenced in 2018. It is therefore an important framework document that describes the current status of the sector, the goal that the sector needs to achieve and how to realise sustainable, low-carbon bioenergy deployment by defining priority interventions. Effective implementation of the strategy will support the Government to meet its various social and policy obligations including energy and climate change objectives, unlocking sustainable economic growth, while improving gender equality, human health and well-being. Bioenergy deployment therefore has the potential to lift millions of Kenyans out of poverty.

This strategy is structured as follows: Chapter 2 evaluates some current regional and global trends in bioenergy production and consumption, projections and factors propelling or hindering success. It also highlights the growing attention to clean cooking and health implications. Chapter 3 presents the current knowledge on supply and demand, and sustainability of different forms of biomass utilised in the production of different bioenergy forms. It also comments on the status of conversion technologies, key barriers to optimising bioenergy production and some current interventions in the sector. Chapter 4 lays out the conceptual framework underpinning the pathways to the desired bioenergy future. It also describes the approaches that can be used to overcome all the known barriers standing in the way of successful adoption of innovations, technologies and best practices for sustainable bioenergy production and consumption. Finally, Chapter 5 presents selected strategic interventions fit for this inaugural strategy, with emphasis on those for which the likelihood of securing an enabling environment for strategic bioenergy investments, as well as early gains in human health and well-being outcomes are assured.

Types of Biomass

It is envisaged that annual work plans will be formulated. This will outline specific actions and interventions which will partly be prioritised based on availability of requisite resources.

Global Clean Cooking Forum

2.0 Global and Regional Trends

Bioenergy is the largest source of renewable energy today, providing heat and electricity, as well as transport fuels (IEA & FAO, 2017). In 2017, 55.6 EJ of biomass was utilised for energy purposes – 86% of this was in the form of primary solid biofuels including wood chips, wood pellets, fuelwood for cooking and heating, etc. About 7% of the biomass was used as liquid biofuels. Biogas, municipal waste and industrial waste had almost equal share at 2-3% (World Bioenergy Association, 2019). An understanding of the global and regional trends and patterns of production and consumption, as well as projections and trade are critical in rationalising the factors that propel or retard progress in bioenergy development. It also helps identify technologies, policies and institutional issues as well as market features and opportunities for regional and international trade.

2.1 Trends in Bioenergy Production and Consumption

According to the International Energy Agency (IEA, 2019), global biofuel production increased by 10 billion litres in 2018 to reach a record 154 billion litres. Double the growth of 2017, this 7% year-on-year increase was the highest in five years. It is estimated that output will increase by 25% in 2024, an upward revision from 2018 owing to better market prospects in Brazil, the United States and especially China. Similarly, biofuels provided 93% of global renewable energy, the remainder being renewable electricity—mainly solar. By 2024, according to the same IEA report, the biofuel share of renewable energy in transport will be about 90%. These trends have been attributed to three main factors.

First, policy and regulatory reforms are behind much of this growth. The increased consumption in Europe, for example, is attributed to the mandatory 10% target for renewable energy in the transport sector under Europe's Renewable Energy Directive (Cogan, 2019). Brazil's Renovabio (National Biofuel Policy) is expected to further drive production beyond the 2019 record levels at 34.45 billion litres for ethanol and 5.8 billion litres for biodiesel (USDA, 2019). India's 2018 biofuels policy similarly widened the permitted feedstock base for ethanol and introduced subsidies to expand production capacity, thus establishing the foundations for ethanol output growth (IEA, 2019).

Second, rapid market development and technological leapfrogging is similarly playing a big role in the growth of biofuel production and consumption. China is, for instance, rolling out blends of 10% ethanol in gasoline from 11 to 15 provinces and new ethanol capacity is already in development. In Mexico and South Africa, transport biofuel industries are at an early stage of development and more deliberate market development and technological leapfrogging are needed. Third, rapid technological evolution around the world—driven by stricter standards and poor quality feedstock—is being achieved through significant investment in research and development mainly around biodiesel technologies. As a result, various add-on technologies are available today that improve fuel quality and make biodiesel production more cost-efficient.

Encouraging trends are also being observed in other bioenergy sources. Use of biomass for power generation (co-generation) is estimated to have increased by over 5% in 2019 globally (IEA, 2019). This growth is buoyed by recent positive policy and market developments in emerging economies, which indicate an optimistic outlook for bioenergy. Some examples of policy interventions by China include (a) the recently-introduced clean-heat initiative and (b) providing Feed-in-Tariff (FIT) support for investments using agricultural residues for bioenergy using both the Energy-from-Waste (EfW) and solid biomass-based electricity cogeneration. In addition to policy reforms, there is increasing feedstock from municipal waste generation owing to increasing urbanisation and economic development. These factors combined are expected to increase the deployment of biomass and waste-fuelled cogeneration plants (IEA, 2019).

The Cogen for Africa Project implemented by AFREPREN/FWD (afrepren.org/cogen) with support from UNEP, the African Development Bank and World Bank, found the cogeneration potential for an average Sub-Saharan African country to be 10% considering the sugar industry feedstock alone, and 40% considering the sugar industry and agro industries. The biggest challenge to growth in cogeneration were found to include inter alia, the absence of favourable FITs, standard Power Purchase Agreements (PPAs) and insecurity of feedstock in the sugar industry. A success story of a country that has surmounted most of these challenges is Mauritius, where 55% of the total power generation is from the sugar sector's cogeneration. A study by To et al. (2018) reveals how policies influenced the development of the bagasse cogeneration niche and changes in the sugar and energy regimes in Mauritius over time. They found that formation of independent power producers, centralisation of sugar mills, the use of complementary fuel (coal) during the off-crop season, and targeted financial incentives were important for the development of bagasse cogeneration in the country.

The feedstock available for sustainable production of biogas and biomethane are enormous, but only a fraction of this potential is used today. Every part of the world has significant scope to produce biogas and/or biomethane, and the availability of sustainable feedstock for these purposes is set to grow by 40% over the period to 2040 (IEA, 2019). This feedstock includes crop residues, animal manure, municipal solid waste, wastewater and forestry residues – for direct production of biomethane via gasification. Biogas and biomethane production in 2018 in OECD countries were around 35 million tons of oil equivalent (Mtoe), only a fraction of the estimated overall potential. Full utilisation of the sustainable potential could cover some 20% of today's worldwide gas demand. Biogas is projected to provide a source of clean cooking fuel to an additional 200 million people by 2040, half of whom will be from Africa.

Most countries are in the process of instituting legislation to regulate the biogas industry. Biogas is considered to be the future of renewable and sustainable energy (Korbag et al., 2020). Despite these challenges, extensive research is being done to move towards more efficient biomethane production systems (Cuffari, 2020). The major hurdles to the implementation of biogas technology in Africa are the cost implications, lack of communication, lack of ownership and the negative image as well as perceptions of the technology caused by past failures. Provision of loans, government assistance, community workshops, wide-scale communication and the implementation of prefabricated digesters could have a significant impact on the increased uptake of the technology in Africa (Roopnarain & Adeleke, 2017).

The special focus of the 2019 edition of the World Energy Outlook (IEA, 2019) on "The rise of the African energy consumer" is timely. More than half a billion people will be added to Africa's urban population by 2040. These urbanisation trends have profound energy implications. There is scanty data and statistics on biomass and bioenergy across most of the African continent, a factor that has negatively affected the quality of policy making and potential investments (African Union, 2018). A key strategic intervention that must feature in any progressive bioenergy strategy for the low- and medium-income countries should be development of biomass and bioenergy inventories across all feedstock available.

2.2 Trends in Clean Cooking Interventions

Solid biomass (fuelwood and charcoal) are the primary fuels used for cooking and heating in Sub-Saharan Africa, and may remain so for decades to come if a business-as-usual scenario is assumed. There is growing discourse around clean cooking which has picked up momentum since the Global Clean Cooking Forum hosted by Kenya in November 2019. Recent developments include the development and application of a comprehensive way of measuring progress towards access to modern cooking energy for all by the World Bank's Energy Sector Management Assistance Program (ESMAP) and partners (ESMAP, 2020).

A number of encouraging trends in favour of clean cooking have been reported in developing countries in general. First, the affordability of ethanol and biomass pellets is steadily improving and greater private sector participation with new business models, including decentralised ethanol distribution and increased microcredit access, have seen growing success, particularly in urban and peri-urban settings in most developing countries (ESMAP, 2020). These are opening up channels for increased accessibility, reliability, and affordability of sustainable bioenergy solutions. Accounting for and leveraging this early success is urgently needed to overcome the slow and, in some regions, stagnant progress to date.

Second, long-term funders of cooking interventions are increasingly moving their financial resources in the direction of access to sustainable energy solutions. These include the World Bank's recently announced USD 500 million Clean Cooking Fund, housed under the Energy Sector Management Assistance Programme (ESMAP). The fund will offer grants, primarily at national and sub-national scale, to help countries incentivize the private sector to deliver sustainable bioenergy solutions. The World Bank funded Kenya Off-grid Solar Access Project (KOSAP) currently being implemented in Kenya also has a clean cooking component.

The International Organisation for Standardization (ISO) has published new voluntary performance targets for cookstoves, defining benchmarks for efficiency, emissions, safety and durability (ISO 19867-1:2018). These are applicable to stoves used primarily for cooking or water heating in homes, small-scale enterprises and institutions. It has also published ISO 19869:2019 Clean cookstoves and clean cooking solutions on field testing methods for cookstoves. This provides quantitative and qualitative measurements of cooking system performance; guidance for measurements of household air pollution and personal exposure to PM2.5 and CO; and guidance for field assessments that compare cooking system performance metrics.

There is a shift in the focus and pitching of household energy projects. A key feature in past biomass energy interventions has been the use of energy efficiency and livelihood benefits—mainly monetary and time savings associated with the use of improved cookstoves—as the key incentives. Similarly, many improved cookstove-promoting organisations have pitched their promotional messages around the narrow definition of environmental sustainability—one primarily driven by the desire to mitigate greenhouse gas (GHG) emissions by relying on renewable biomass fuelling the improved cookstoves. In reality, however, it is difficult to achieve complete combustion and health goals when using solid biomass in household stoves, and more than 3.8 million lives are reportedly lost each year to smoke from cooking fuels (WHO, 2019). Indoor air pollution is influenced by fuel, stove, ventilation and user behaviour in managing the fireplace, hence these four factors need to be improved if clean cooking is to be achieved (Roth et al., 2014).

The UN World Health Organisation (WHO) has therefore been at the forefront of clean cooking issues with specific interests around household air pollution, and has developed tools and guidelines. In this respect, the WHO is developing a Clean Household Energy Solutions Toolkit (CHEST) to help health sector professionals and other decision-makers at both national and local levels to implement the recommendations in the WHO IAQ guidelines on household fuel combustion (WHO, n.d.). Similarly, the Health and Energy Platform of Action (WHO, 2019) launched by the World Health Assembly in May 2019 aims at strengthening the political and technical cooperation between the health and energy sectors at both global and country level. The initial focus is on clean cooking and energy for healthcare facilities.

2.3 Key Lessons for Kenya's Bioenergy Strategy

A number of insights have emerged from global and regional as well as the national situation analysis on bioenergy production and consumption trends. These could inform the choice of strategic interventions for Kenya. They include the following:

- There is value in investing in bioethanol and biodiesel production for blending to be used in the transportation sector.

This can be achieved by putting in place right policies and regulations, ensuring good economics, proactive market development, technological leapfrogging, and the necessary political will and support.

- Meaningful transformation of the bioenergy sector needs accurate biomass feedstock datasets as well as spatial and temporal biomass activity baseline information.
- Urban growth and population increases will continue to pose a challenge for municipal solid waste management, yet present an opportunity for energy production. Numerous success cases where such technologies could be adapted exist in other countries such as China and Canada.
- Research has improved technologies such as increased efficiency of bioenergy (mainly biodiesel and bioethanol) conversion, and lowered costs of production, among others. Further research is needed in some areas, e.g., feedstock assessments and municipal waste-to-energy harnessing. There is therefore, the strong justification to strengthen research capacity in key R&D institutions and among research partnerships through bioenergy innovation platforms that bring together multi-stakeholders to co-produce technological innovations and new knowledge.
- There is a shift towards prioritising health benefits when planning clean cooking access. Increased use of bioethanol and other clean fuels in the household energy mix promises enormous human and social benefits.
- There is increased funding from development partners towards clean cooking initiatives, hence the need for developing countries to strategise and leverage these opportunities to support activities. These include increased monitoring of HAP quality among rural and urban households, research around impact of exposure to fuel pollutants on children, support civil society efforts to sensitize communities on the dangers of unclean cooking and finally, lobbying through regional and national policy processes for enhanced attention to improved health through clean cooking.
- Transitioning to sustainable bioenergy production and use is costly, and achieving this goal will require enhanced incentives that will attract private sector investment. It is incumbent upon the government to embrace stronger partnership with the private sector in order to ensure faster adoption of sustainable bioenergy.

Well Managed Prosopis Juliflora Woodland Baringo. *Photo: Danyell Odhiambo ICRAF*

3.0 Status of Bioenergy in Kenya

A comprehensive inventory having reliable, regularly updated biomass supply and demand estimates is important to provide energy producers and investors with information for planning and development of new bioenergy opportunities. The country does not have a harmonised and comprehensive inventory. This chapter covers the current state of supply and demand of key bioenergy forms, estimates of projected supply, sustainability concerns as well as barriers against optimising the potential inherent in the sector.

3.1 Policy, Institutional and Regulatory Framework

3.1.1 International and Regional

The Bioenergy Strategy is aligned with various national, regional and international legal frameworks. The Sustainable Development Goals (SDGs), and SDG 7 in particular, aims to ensure access to affordable, reliable, sustainable and modern energy for all by 2030. SDG 7 encompasses the following targets: ensure universal access to affordable, reliable and modern energy services; double the global rate of improvement in energy efficiency; enhance international cooperation to facilitate access to clean energy research and technology; promote investment in energy infrastructure and clean energy technology; and expand infrastructure as well as upgrade technology for supplying modern and sustainable energy services for all, in developing countries. Other SDGs relevant to bioenergy are SDG 3 related to good health and well-being, SDG 5 on gender equality, SDG 9 on industry innovation and infrastructure, SDG 11 on sustainable cities and communities, SDG 13 on climate action and SDG 17 on partnerships for the goals.

Kenya is also a Party to a number of international conventions including the United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD), United Nations Convention to Combat Desertification (UNCCD), the Paris Agreement, WTO framework on trade in bioenergy products, the United Nations Forum on Forests (UNFF) and the Sustainable Energy for All (SEforAll) initiative. These conventions oblige the country to take actions that would promote sustainable utilisation of bioenergy. An example is reducing GHG emissions arising from deforestation or inefficient combustion of biomass fuels, and taking agricultural- and forestry-related measures to combat land degradation and desertification.

At regional level, Africa Bioenergy Policy Framework and Guidelines aim to inform national bioenergy policy formulation. The Customs Union Integration establishes free trade on goods and services within the bloc, and imposes a common external tariff (CET) on imports from non-EAC countries when sold to EAC partner states. New CET tariffs came into effect from 1 July 2018 and affected bioenergy use in various ways. In the cooking sector, for example, it led to zero-rating (0% import duty) of inputs and raw materials for use in the manufacture of energy-saving stoves, and imposition of a 35% import duty on complete sets of non-electric cooking appliances under one-year country-specific CET duty rates. Upon intervention from the Ministry and other stakeholders, the import duty was reviewed downward to 25% in 2019. The Common Markets Integration is yet another instrument that has an impact on the bioenergy sector. Through this, the EAC seeks to adopt "policies and mechanisms to promote the efficient exploitation, development, joint research and utilisation of various energy resources available within the region." Outputs attributed to this instrument include the launch of the East African Centre for Renewable Energy and Energy Efficiency. Similarly, Agenda 2063, the blueprint and masterplan for Africa's development transformation also recognises the important role of renewable energy that would include bioenergy. The goals and priority areas for the first 10 years of the Agenda include environmentally-sustainable and climate-resilient economies and communities (Goal 7), with renewable energy cited as one of the priority areas for development.

3.1.2 National Level Framework

Kenya recognises the vital role played by bioenergy and has put in place mechanisms to promote modern bioenergy services. The Kenyan Constitution of 2010 devolved the roles of county planning and development in energy regulation. The National Energy Policy 2018 recognises biomass fuels as the largest source of primary energy in the country. The policy further notes that wood fuel supply management is crucial to ensure sustainable supply to meet the growing demand. The Energy Act, 2019 sets forth the implementation framework for energy that includes bioenergy. The Act has provisions to make regulations for the licensing and management of renewable energy sources including biogas and biomass. The Cabinet Secretary is also required to develop and publish the Integrated National Energy Plan which will guide the country in the provision of clean and affordable energy. County governments are mandated with regulating and licensing of biomass production, transport and distribution, biogas systems, as well as charcoal production, transportation and distribution. The Act further provides for the promotion, development and use of renewable energy technologies including, but not limited to, biodiesel, bioethanol, charcoal and fuelwood, among other sources.

The National Climate Change Action Plan (NCCAP) 2018-2022 has identified key actions to transform energy with emphasis on enhanced adoption of renewable energy to assist the country achieve a low-carbon development pathway. The Action Plan outlines nine priority areas which include aspects on bioenergy such as promotion of clean cooking solutions (improved cookstoves, bioethanol and other alternative fuels), restoration of forests and agroforestry. The action plan also sets out the targets to be achieved for each mitigation measure. The Vision 2030 and Big 4 Agenda that set forth the government's priorities also identify energy as a critical enabler towards achievement of the vision. The following additional instruments are also relevant for the development of the bioenergy sector:

i) The Energy Regulations of 2013 (Improved Biomass Cookstoves) which sets out the classes and requirements for licensing for installation, maintenance, manufacture, importation and distribution of cookstoves;

i) The Forest Conservation and Management Act of 2016 which retains the licensing role of Kenya Forest Service, noting that they are to "*receive and consider applications for licenses or permits in relation to forest resources*" and to "*implement and enforce rules and regulations governing importation, exportation and trade in forest produce*." The Act provides specific regulations for production, transportation and marketing of charcoal;

i) The Forest (Charcoal) Rules of 2012 which were first gazetted in 2009 and revised in 2012, actualised the provisions of the Energy Act 2006, specifically regulating the sustainable production, transportation and marketing of charcoal. Charcoal producers and transporters must be licensed by the Kenya Forest Service (KFS); commercial charcoal producers must organise themselves into Charcoal Producers Associations (CPAs); and charcoal wholesalers or retailers should not trade with unlicensed producers.

Various standards have been put forward to guide bioenergy development. In the cooking sector, for example, there are biomass stove performance requirements; ethanol-fuelled cooking appliances and specifications for solid biofuels . The government has similarly undertaken the following measures in line with these commitments for the clean cooking sector:

- The country has formed a National Bioenergy Committee to oversee the development of the Bioenergy Strategy. The Energy Policy 2018 is in place;
- The Government has demonstrated dedication in efficient utilisation of bioenergy for cooking through removal of excise duty on ethanol (now zero-rated) and lowering of duty for clean cooking stoves. Locally manufactured cookstoves are zero-rated. These are fiscal incentives to encourage the adoption of clean cooking. There has also been the development of cookstove standards to promote efficient utilisation of biomass

through the Kenya Bureau of Standards (KEBS). To facilitate implementation of these standards, a Clean Cooking Laboratory has been established within the Kenya Industrial Research and Development Institute (KIRDI); and

- Other bioenergy forms including biogas waste-to-energy and co-generation for production, and woodlots are also encouraged by the existing policy framework.

3.2 Solid Biomass Fuels

3.2.1 Wood Fuel (Fuelwood and Charcoal)

The country is highly dependent on biomass energy, which comprises 68% of the total energy supply; fossil fuels and electricity account for 22% and 9% respectively, while other sources provide 1% of the overall energy requirements (Ministry of Energy & CCAK, 2019). About 55% of the biomass is derived from farmlands in the form of woody biomass, crop residue and animal waste, while the remaining 45% is derived from government and communal forests (Ministry of Energy, 2018). Other sources of biomass for wood fuel include use of invasive species such as *Prosopis juliflora*, commonly referred to as Mathenge (Bourne et al., 2020). National and county governments are working on integrated approaches that include control of the invasive species; a national strategy on the same is underway. The Ministry of Energy and CCAK Study (2019) on Clean Cooking shows that 64.7% (8.1 million) households in Kenya still use wood as their primary cooking fuel, followed by LPG at 19.0% (2.4 million) and charcoal at 10% (1.3 million) (Figure 2).

Table 1 presents the average annual consumption for common cooking fuels by households in rural and urban areas. These give an estimate of 9.6 Mton of fuelwood, 2.0 Mton of charcoal, 201 kton of LPG, 243 kton of kerosene, and 372 kton of crop residues (Ministry of Energy & CCAK, 2019). The country has continued to experience sustained deforestation and forest degradation since independence. Today, Kenya is among the countries with a forest cover of less than 10% of total land mass. Forest cover increased marginally from 4.18 million Ha (7.22%) in 2016 to 4.22 million Ha, (7.29%) in 2017 (KNBS, 2018).

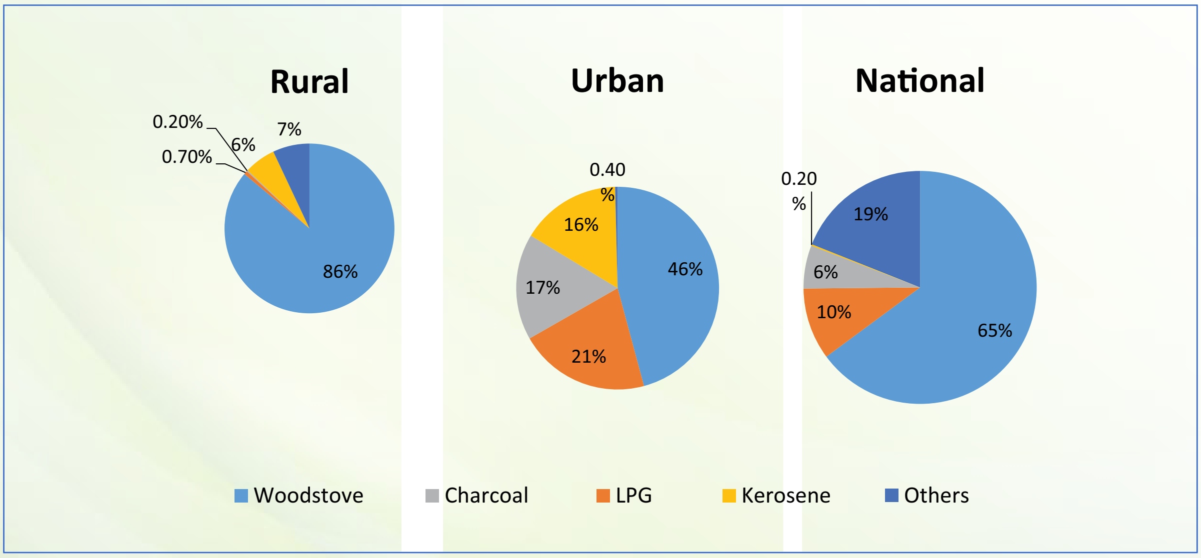


Figure 2: Primary Fuels used by Households in Kenya at Urban, Rural and National Levels. Source Moe/Ccak 2019

Table 1: Average Annual Consumption for Common Cooking Fuels by Households

Fuel	Urban			Rural			Total		
	%HHs using	Average (kg/yr)	95% CI (kg/yr)	%HHs using	Average (kg/yr)	95% CI (kg/yr)	%HHs using	Average (kg/yr)	95%CI (kg/yr)
Fuelwood	24%	1232	224	86%	1362	60	67%	1349	59
Charcol	46%	364	44	42%	411	29	44%	395	24
LPG	51%	68	3	15%	47	3	27%	57	2
Kerosene	29%	163	12	7%	78	10	14%	114	9
Crop Residue	3%	270	155	11%	421	61	9%	400	57

Source: (Ministry of Energy & CCAK, 2019)

Much of the increase in forest cover is attributed to the entry of private commercial plantations and natural expansion of sparsely populated woodlands. In 2017, the area under natural forests stood at 4.03 million Ha, while the area under Government forest plantations stood at 0.1351 million Ha (Economic Survey, 2018). Unsustainable logging to produce wood fuel (charcoal in particular) is a primary cause of deforestation in the country, alongside other negative effects such as degradation of land and destruction of major water catchment areas and carbon sinks.

With rapid population growth and urbanisation happening in Kenya, charcoal use is likely to remain high for decades to come (NCCAP 2018-2022) (Ministry of Environment and Forestry, 2018). In 2013, the charcoal sub-sector employed nearly 1 million people in production and trade, and was estimated to contribute about USD 1.6 billion per year (an amount equivalent to the national tea industry) to Kenya's economy then (MEWNR, 2013). This sub-sector operates informally and is at present outside of the fiscal system of the country. Often considered as an industry of the poor, one of the challenges that exists with regards to introducing new technologies into the sector is the need for these to be both affordable as well as offer optimal recovery of the wood fuel that is used (Ministry of Environment and Forestry, 2018).

Efficient Charcoal Production Kiln

An analysis of the National Census Report 2019 data (Bailis, 2020) highlights the fact that only 12% of Kenyans use charcoal as a primary fuel, 32% as their secondary fuel while 45% use charcoal for some cooking. The patterns are similar in both urban and rural areas, with the rural constituting 62% of the total population. It is worth noting that more rural than urban Kenyan households currently use charcoal.

The average consumption in 2019 was 30 kg per month per household, with the rural

Improved Cookstove

consuming about 12% more than the urban households. Primary users consume 40-50 kg/month while secondary users consume 20-30 kg/month. Similarly, 40% of primary firewood users and 33% of LPG users also use charcoal for some other cooking. There has been a gradual decline in the percentage of households using charcoal as a primary fuel since the last census in 2009, when the figure was about 19%.

The market value of charcoal consumed at the household level alone is estimated at KES 68 billion (Ministry of Energy & CCAK, 2019). For a long time, charcoal use in Kenya has been known to be a primary fuel for urban households; however, this is changing as more rural communities now consume it as their main fuel. Table 2 compares the weekly wood fuel consumption levels and related average expenditure. As families expand and farmlands are subdivided for shelter, fuelwood sources are getting scarcer and more expensive, hence the gradual change in source and fuel preference.

Majority of the households that cook with fuelwood still use the three-stone open fire. This exposes families, particularly women and children, to health damaging pollutants. Similarly, this practice has had a negative impact on the environment resulting in deforestation and denudation of farmlands and woodlands without replanting trees. Cases of respiratory infections reported in Kenyan healthcare institutions in 2019 are responsible for the total disease burden, with pneumonia among under-5-year-olds being the most prevalent (KNBS, 2019). Furthermore, 21,560 deaths that occur annually are attributed, in large part, to exposure to household fuel emissions.

A common intervention against use of inefficient cookstove technologies has been the dissemination of improved cookstoves over the past 30 years, initially through development partner-driven programmes and later through self-sustained adoption by households, albeit at low rates. There is an increasing number of private sector actors involved in the manufacture of charcoal and firewood stoves such as Burn Manufacturing, Envirofit and Biolite. There are very few nationally representative studies on the degree of penetration of clean cooking solutions.

Industries are also using wood for their thermal processes and the tea industry is one of the largest consumers of fuelwood. There are over 90 tea factories in Kenya consuming an average of 10,900 m^3 of fuelwood per year; about 550,000 tons every year. Some of the industries also use briquettes as a source of fuel. Other high consumers of fuelwood are the cottage industries which include brick-making, tobacco-curing, fish-smoking, jaggaries and bakeries. Though many of these industries are present across rural Kenya, inadequate data exists on their annual consumption and sources of fuelwood.

It is estimated that 97% of community institutions (schools, prisons, hospitals) in

Table 2: Weekly Wood Fuel Consumption and Average Expenditure Per Household

Fuel	Urban		Rural	
	Consumption (kg)	Cost (KES)	Consumption (kg)	Cost (KES)
Fuelwood	23.7	342	26.2	409
Charcoal	7	270	7.9	229

Source: MoE, 2019 Kenya Household Cooking Sector Survey

Kenya use fuelwood, where the penetration rate of improved institutional firewood cookstoves was above 80%. The MoE/CCAK study (2019) reported per capita average annual cost of fuelwood in these institutions to be KES 1500 while the per capita average annual cost of charcoal is KES 3,420. No estimates are available on the power generation potential from tree biomass, hence the need for a comprehensive assessment (NCCAP 2018-2022) (Ministry of Environment and Forestry, 2018).

In addition to the absence of reliable data on tree biomass production and consumption trends and patterns, other known barriers to sustainable resource use include lack of quality standards, and the high cost of improved stoves and their cleaner alternatives. Similarly, local traditions and cultural norms prevent behavioural change. Enhancing the enforcement or implementation of the range of policy and legal interventions which have been endorsed will lead to accelerated uptake of modern bioenergy.

3.2.2 Briquettes

There are two main sub-types of briquettes, namely the carbonized and non-carbonized briquettes. Carbonized briquettes are made from biomass raw materials that have undergone pyrolysis, which is then typically mixed with a binding element, moulded into various shapes then dried. Non-carbonized briquettes are processed directly from biomass sources through various casting and pressing processes, also known as compaction or solidification

and are mainly for industrial use. Briquette production in the country has huge potential for uptake, as majority of Kenyans still depend on solid biomass for cooking. In addition studies have shown that briquettes are in a price range that makes them competitive with charcoal (Okoko et al., 2018). However, they have very low rates of adoption (Kitheka et al., 2019; Mwampamba, 2007)demand for biomass energy has increased due to increasing population and urbanization and high cost of alternative energy sources. This coupled with use of inefficient production and utilization technologies, has led to increased deforestation, environmental degradation and increased health impacts. In Kenya, a number of improved technologies have been developed and promoted; however, adoption still remains low. This study sought to assess factors influencing adoption of biomass energy conservation technologies in four selected areas of Kitui County, Kenya. Data were collected using a structured questionnaire and guidelines for institutional and focus group discussions. Sampling was done through purposive and stratified random sampling. Results revealed three categories of biomass energy conservation technologies: energy saving stoves (46% because of variations in quality and burning characteristics. Briquette quality needs to be matched with utilisation (Njenga et al., 2013).

Briquettes

There are ongoing briquetting activities across the country mainly driven by the private sector. Biomass briquettes made from sustainable sources such as bagasse, sisal (*Agave sisalana*); waste, wheat (*Triticum* *aestivum)*; straw, rice (*Oryza sativa*); husks, pineapple (*Ananas comosus*); plant waste, coffee (*Coffea Arabica*); husks, coconut (*Cocos nucifera)*; husks and sawdust can offer alternative fuel for many domestic and institutional cooking and industrial heating processes. Some of the barriers to sustainable production and consumption of briquettes include inadequate biomass feedstock quantities, lack of capacity to fabricate and maintain briquetting machines and the high cost of briquettes compared to competition from other alternative and often cheaper forms of fuels (Mwampamba et al., 2013) or densified biomass that is subsequently carbonized. In spite of clear advantages of charcoal briquettes that include price, burn time, environmental sustainability and potential for product standardization, their uptake as a substitute for wood charcoal in Sub-Saharan Africa (SSA.

Actors in the briquette sub-sector have undertaken various initiatives in the country to build up the briquette value chain. These include policy interventions that create a favourable environment for development of the value chain, equipping existing Energy Centres with briquetting technology clearly showcased as one of the promising technologies, and disseminating knowledge on commercialisation of the technology. Technical and Vocational Education and Training (TVET) institutions across the country could also implement this through their curricula. There is also need for resource mobilisation aimed at up-scaling briquetting activities in the country.

3.2.3 Pellets

Pellets are a heating and energy fuel made from compressed wood fibres. Wood pellets are used in pellet stoves, boilers and furnaces to heat homes, businesses and commercial locations. Pellets are at a nascent stage of production and use in the country. It is estimated that about 0.1% of households use it as fuel for cooking (Ministry of Energy & CCAK, 2019). The fuel is being promoted as a clean cooking solution and modern energy, due to the fact that when used for cooking in a gasifier stove, there is a drastic reduction of indoor pollution. The results include improved health of citizens and environmental benefits.

The proposed feedstock for making pellets sustainably in the country are waste residues from agricultural and woody biomass, and energy crops. Due to the pressure already exerted on wood resources and dwindling forest cover, the use of these resources for pellets is not encouraged. The woody feedstock comprises woodchips, sawdust, wood shavings and other woody wastes. Non-woody feedstock includes agricultural residue from sugarcane, coffee husks, maize straws and stalks and rice straws and husks. About 7.4 million tonnes per annum of crop residue can be generated from the country, and there is a high potential of energy generation from crop residues, according to a study by Wekesa (2013). The challenges of pellet production include low awareness, high prices for cookstoves, low R&D and inadequate capacity. Others are low availability of pellets, lack of standards, high cost of stoves (the need for specialised household stoves), need to adapt cooking behaviour, high capital investment and lack of consistent and affordable fuel supply.

Pellets

3.2.4 Agricultural Waste for Cogeneration

Cogeneration is the generation of electricity and useful heat jointly, especially the utilisation of the steam left over from electricity generation for heating. The total installed electricity generation capacity in Kenya stands at 2,753 MW. The generation mix includes hydropower (829 MW), geothermal (783 MW), co-generation (26 MW), wind (336 MW) solar (50 MW) biomass (2 MW) and fossil fuel-based electricity (720 MW). Kenya's Sustainable Energy for all (SEforAll) policy envisions a target of 600 MW from co-generation, representing 4.08% of Kenya's target for renewable energy mix in power generation by 2030 (Government of Kenya, 2016). Under the SEforAll pathway, the capture and recycling of waste heat and the use of renewable energy sources in industrial and agricultural processes will be enabled by mandating agro-processing companies to upgrade their biomass-based cogeneration potential. This will involve feasibility studies on resource assessment to estimate cogeneration potential in the agro-processing companies; formulation of standards and regulations; continued review of the cogeneration power generation framework; and formulation and implementation of a national strategy.

One successful co-generation example in the country is Mumias Sugar Company in Western Kenya. It took advantage of its co-generation potential from sugarcane bagasse by installing a 38 MW capacity, out of which 26 MW is dedicated to the national grid. However, recent challenges facing the factory, including cane supply, have compromised reliability of supply from this source. According to the Least Cost Power Development Plan (LCPDP, 2019-2039) more than 2% of electricity demand will be covered by biomass cogeneration (MoE, 2019).Other than GHG emissions and potential leachates from bagasse to water tables if poorly managed, no major environmental or health concerns have been associated with co-generation in industrial plants. Some examples on power production from trees exist. In 2009 for example,, Tokyo Power constructed and commissioned a 10 MW gliricidia-fuelled plant in Trincomalee, Sri Lanka. Following its success, the company commissioned a second plant of 5 MW capacity in Mahiyanganaya in early 2014. There is a 500 kW plant in Thirappane (Anuradhapura) and a 15 MW plant in Embilipitiya (Garrity, 2015).

3.2.5 Medical and Other Industrial Wastes for Incineration

Medical and industrial waste carries significant potential for bioenergy production. This potential is already being exploited in the West where conversion technologies are mature. Currently, there is no reliable data to guide investment in bioenergy generation from this feedstock. Most hospitals run incinerators that do not recover heat—this could significantly cut the amount of money used on fuel oil water boilers in most facilities. A national assessment to determine the bioenergy potential from these sources is necessary to provide critical data for development planning, including potential investors.

3.3 Liquid Biofuels

3.3.1 Biodiesel

Biodiesel is a vegetable oil or animal fat-based diesel fuel consisting of long-chain alkyl esters made by chemically reacting with an alcohol in a process dubbed 'transesterification'. It can be derived from a variety of oil-bearing plants like castor (*Ricinus communis*), croton (*Croton megalocarpus*), jatropha (*Jatropha curcas*), sunflower (*Helianthus annuus*) and coconut (*Cocos nucifera*). Biodiesel contains between 88% and 95% as much energy as fossil diesel, but has advantage over diesel in that it improves the lubricity of the diesel and raises the cetane value, thereby making the fuel economy of both generally comparable. It also has a higher oxygen content which aids in the completion of fuel combustion, hence lower emission of particulate air pollutants, carbon monoxide and hydrocarbons (MoE, 2010). Biodiesel can be blended with traditional diesel fuel or burned in its pure form in ordinary compression ignition engines. The blends can range from 1% biodiesel and 99% diesel (B1), to 25% biodiesel and 75% diesel (B25). However, the most common blends are B5 and B20. A research on biofuels done in Kenya commissioned by GIZ and the Ministry of Energy recommended a B2 blend as the most feasible and sustainable.

Oil Extraction (for Biodiesel)

Major biodiesel feedstocks, and specifically those that can be sustainably produced without resulting in food crises, can be produced in some parts of the country (Ndegwa et al., 2011). Castor Seed Kenya Ltd with approximately 700 acres of castor seed under cultivation in the coastal region of Kenya, is an example of a biodiesel project. It is running through contract farming involving more than 400 low-income farmers. These could be scaled up in other geographically favourable regions. Edible vegetable oils and animal fats also command high prices as food (more than KES 200 per litre) and the country does not produce enough but rather depends on imports. As such, they are not available for economic production of biodiesel. Competition for land between energy crops and food crops is a potential challenge that could be overcome through proper land use planning and intercropping with food crops as is the case with jatropha and castor in the early years of growth (up to five years for jatropha). Other challenges include:

- High cost of raw material and production, making biodiesel less attractive than the readily-available fossil diesel, and therefore commercially uncompetitive;
- Lack of standards and regulations;
- Insufficient volumes of biodiesel resulting in low impact on the market, thus fails to command attention from consumer, government incentives and investors;
- Lack of awareness of the advantages of using biodiesel to run engines as compared to fossil diesel;
- Lack of market for the product;
- Lack of awareness on production of oil seeds, collection from forests and the market channels available; and
- Lack of access by farmers to proven quality seeds for different agro-ecological regions.

The Kenya Forestry Research Institute (KEFRI) has been undertaking research on jatropha varieties in various regions of the country. The Jomo Kenyatta University of Agriculture and Technology (JKUAT) has also carried out research studies that could inform bioenergy potential analysis, namely:

- Biodiesel production from croton, cotton and oleander seed oils;
- Production of biodiesel from animal fats and evaluation of its potential as an alternative fuel; and
- Development of sweet sorghum for food and energy production.

There is need to undertake research on sustainable production, marketing and consumption of biodiesel as part of baseline research for this strategy.

3.3.2 Bioethanol

Globally, various feedstocks are used to produce ECF, including molasses, sugarcane, corn, cassava and sorghum. In Kenya, ethanol is currently exclusively produced using molasses feedstock, a by-product of sugar production. Ethanol production is therefore inextricably linked to sugar production. Ethanol as a cooking fuel is still nascent with just 1.2 million litres produced annually. A constraint to production is the national shortage of molasses due to the inefficient performance of public mills and reduction in sugarcane farming.

The sector has faced many challenges in its recent past, including increased competition from foreign producers, a decline in productivity at the farm level and failure in institutional structures, inefficient processing, and lack of policy to address the issues. Most state-owned sugar companies have faced operational challenges and have since halted production; majority of the current producers of sugar are private sector companies. However, three companies currently producing ethanol domestically are Kisumu Molasses Plant, the Agro Chemical and Food Company and Mumias Sugar Company

Use of bioethanol-blended gasoline (gasohol) produced in Mombasa was popular in the 1980s but was discontinued in 1995 owing largely to economics-gone-wrong. Then, bioethanol from Agro Chemical and Food Company in Muhoroni would be transported by road to the Kenya Petroleum Refinery Limited in Mombasa. The market opportunity for fuel ethanol (anhydrous grade) remains large in terms of both volumes and profitability. Furthermore, the Kenya Bureau of Standards authorised the E10 blend, (10% ethanol-gasoline blend for the transport sector) in Kisumu, but this has not taken off despite infrastructure for blending being put in place in the Kenya Pipeline Company (KPC) Kisumu Depot and gazettement of supportive regulations. This has been attributed to insufficient ethanol supplies from the targeted sugar industry due to the low prices offered. A litre of table alcohol costs above KES 200 as compared with a litre of petrol at KES 112.8 in Nairobi.

Kenya's current gasoline consumption is estimated at 520,000 m^3 per annum. To meet the national target of 10% ethanol blend, the country's national production will need to double. Furthermore, fuel ethanol is not subject to excise taxes, petroleum regulation, petroleum development and road maintenance levies. (Afrinol, n.d.). State-owned sugar plants are set to be privatized from 2020. These plants, including Miwani, Chemelil, Nzoia, Muhoroni and South Nyanza have the potential to revive the gasohol industry by increasing the production of much-needed molasses.

Going into the future, the draft Ethanol Cooking Fuel (ECF) Masterplan (Dalberg, 2019) underscores that ethanol cooking fuel production will likely be sourced from molasses, sugarcane juice and cassava as the higher-potential sources of ECF in Kenya. On household cooking, bioethanol in the form of gel and liquid is emerging as a complementary fuel to LPG and urban households are shifting their primary cooking fuels from kerosene and charcoal to LPG and ethanol. Following the emerging trend towards cleaner fuels among households, the demand for ethanol as a primary cooking fuel is projected to increase significantly in the near future.

A private actor, KOKO Network, has successfully enabled 65,000 households to use bioethanol, through 600 agents and 700 outlets around Nairobi (Sapp, 2020). Affordability and availability, enabled by sufficient domestic production and supply chain development, as well as greater awareness of the health and environmental benefits of ethanol over traditional fuels, will be key to driving the demand. A low demand scenario for ethanol for cooking proposed in the draft Masterplan projects a demand of 8 million litres in year 1, and rising to 115 million litres by year 10 (Dalberg, 2019). The NCCAP (2018-2022) envisages development and distribution of 250,000 ethanol stoves by 2022.

The creation of a local ECF industry has the potential to create new opportunities across the value chain. It will also generate positive environmental and health impacts at both the individual and national levels. It should also be noted that there are potential social and environmental risks associated with ethanol production including potential risks linked to land use displacement. These risks will need to be assessed at the planning stage together with a defined and agreed set of safeguards. Dalberg (2019) estimates the potential impact of households switching to ECF on jobs, income, health, and the environment as reported in Table 3.

Table 3: Potential Impacts of Switching Households from use of other Fuels to ECF

Employment and earnings impact	• **Jobs:** Up to 370,000 jobs (with the majority in feedstock production) • **New income generated**: Up to KES 51 billion, with additional income of up to KES 180,000 per year for smallholder farmers
Environmental impact	• **Deforestation averted:** Up to 54 million trees saved • **GHG emissions:** Up to 13.5 billion kgs of CO_2equivalent saved
Health impact	• **Deaths averted:** ~3,700 deaths could be averted • **Disability-adjusted Life Years (DALYs) averted:** Up to 507,000 DALYs • **Economic value of deaths averted and DALYs saved:** ~KES 372 million in lost wages

Source: Dalberg, 2019

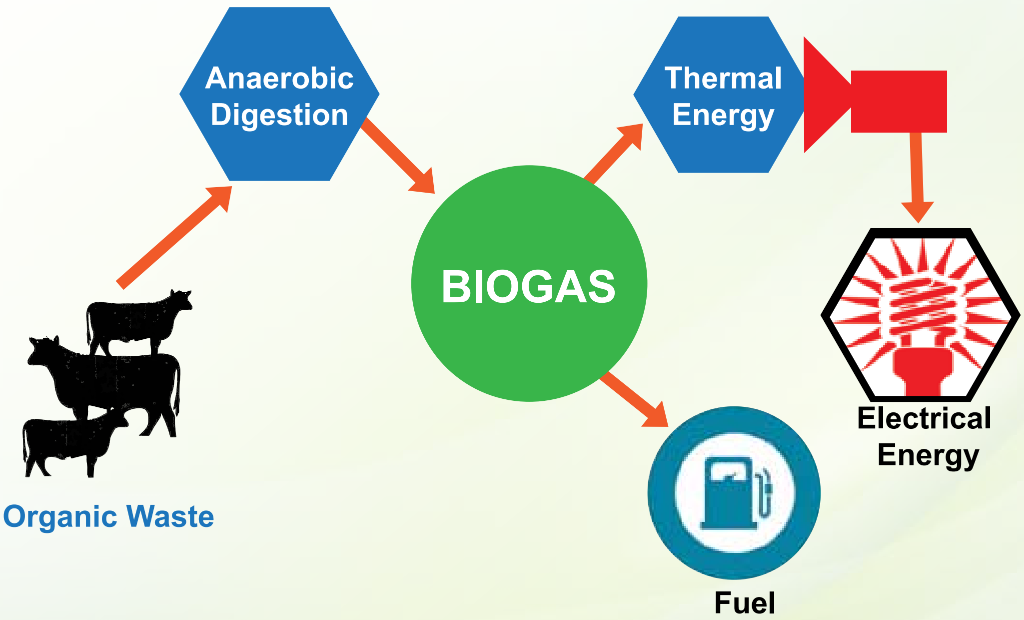
3.4 Gaseous Biofuels

3.4.1 Biogas

Biogas is produced through the anaerobic fermentation of biomass, animal dung and other organic waste. Historically, Kenya was among the first African countries to embrace biogas technologies in the early 1950s (ABPP, n.d.). In the past, the dominant biogas designs have been the floating drum and fixed dome. The pre-fabricated biogas type is increasingly gaining popularity in recent times. It is estimated that Kenya has 21,000 biogas digesters distributed through efforts from both the government and private sector. Use of biogas for cooking is projected to reach 0.8% by 2030, while electricity generation from biogas will be at 0.07% of the renewable energy mix. A feasibility study on biogas has established that it is possible to construct 6,500 biogas digesters annually in Kenya, and that the country has the potential to establish 2.3 million digesters.

Biogas-based electricity generation potential has been identified in municipal waste, sisal and coffee production, and is estimated at 29-131 MW. The Biojule plant in Naivasha, which produces 2 MW of power, is an example of a grid-connected biogas plant utilising flower-waste as feedstock. An increase in the adoption of biogas technology use by 80,000 households could lead to the abatement of 1.2 million tCO_2e by 2022. Similarly, an increase in adoption of biogas technology use by at least 200 abattoirs could result in the abatement of 0.8 million tCO_2e by 2022 (Ministry of Environment and Forestry, 2018).According to the Kenya Dairy NAMA, biogas adoption significantly reduces household expenditure on energy provisioning and chemical fertiliser use. For each biogas unit, direct financial savings are estimated at USD 204 per year. The proposed 20,000 units installed at household level will enable dairy farming households to realise USD 61.2 million in cost savings over the 15-year lifetime of these units. The units will also save 8.8 million hours of women's time each year, thus enabling them to use their time to engage in other economic activities. Biogas promotion will also reduce fuelwood and charcoal use, with installation of 20,000 units reducing an estimated 1.7 million m^3 of fuelwood use over the 10-year project period. This will contribute to Kenya's efforts to reduce deforestation and forest degradation.

The technical potential for biogas in Kenya – as indicated by households with sufficient water and livestock waste (manure) – has been estimated at 320,000 households. Estimates of current actual installed biogas units are only a small proportion of this potential. A number of demand-side barriers to successful adoption of biogas technology have been reported and include: high upfront investments for biogas units; many potential users are not aware of the technology; poor management and maintenance (due to household labour constraints); lack of quality control and standards, therefore clients and

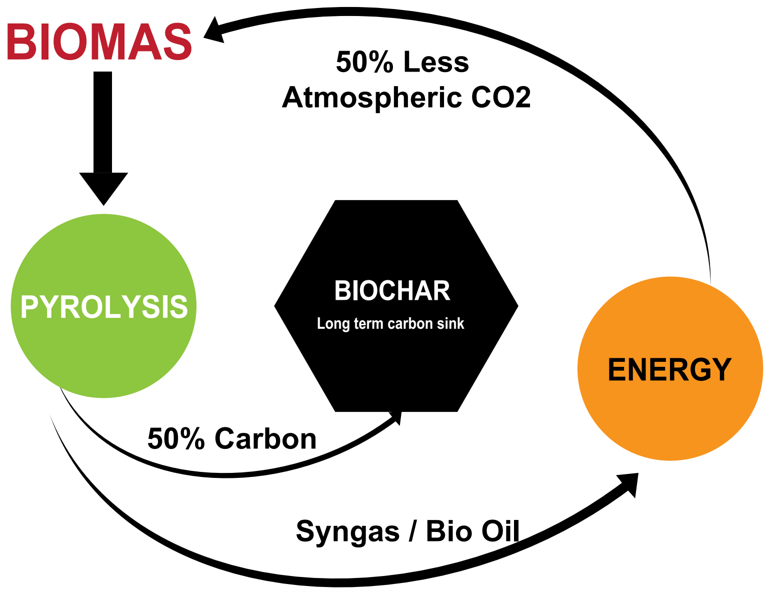


Anaerobic Digestion-Biogas Digester

financial institutions are unsure of product quality. Kenya has a number of biogas service companies, but in the absence of biogas subsidy programmes, most companies are supplying only 200-400 units per year. On the other hand, supply-side constraints include: lack of strategies and internal operational processes for service provision at scale by existing companies; lack of finance for up scaling service provision; and few skilled technicians to construct and provide maintenance services/post-installation support.

Investment costs for biogas units vary depending on the size and model. An evaluation of pilot extension of biogas systems in the context of an IFAD-funded dairy project in Kenya suggests average savings in energy costs and time spent on fuel provisioning of KES 1,445 per household per month. Other studies also report savings of KES 1,180 per household per month in direct energy expenditures (Dohoo et al., 2013) which generate biogas for cooking from the anaerobic decomposition of livestock manure, are an alternative fuel source. The objective of this study was to quantify the quality of life and health benefits of installing biogas digesters on rural Kenyan dairy farms with respect to wood utilisation. Women from 62 farms (31 biogas farms and 31 referent farms. There is need to grow the market for biogas in Kenya in order to transition the population from traditional biomass energy fuels for cooking to clean cooking. The Government of Kenya has continually undertaken several initiatives to develop biogas in the country. These include programmes to construct bio-digesters in several areas for use as demonstration and training centres. The Energy Centres in the Ministry of Energy have built bio-digesters for training and demonstration. The private sector has also been running programmes to establish bio-digesters across the country.

3.4.2 Gasification (Syngas)



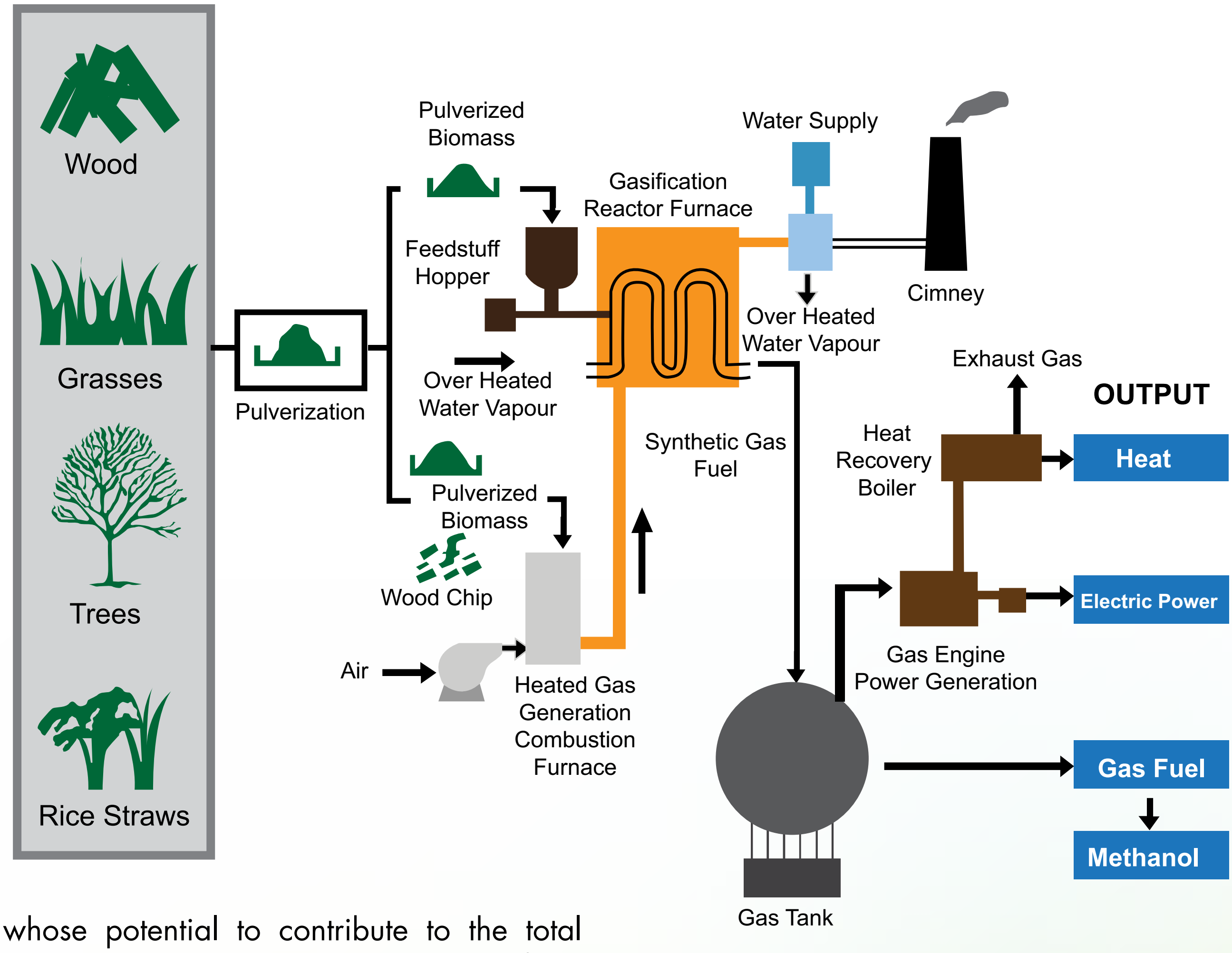
Pyrolysis (for Biochar, Gas and Oils)

Biomass gasification is the conversion of solid fuels like wood and agricultural residues into a combustible gas mixture technically known as Syngas. It is a fairly new technology in Kenya with most of the projects either at planning or demonstration stages. The technology has the potential to be used for electricity generation, allowing households and enterprises to access clean energy. Micro-gasification units also exist for cooking with gas from dry biomass (Roth et al., 2014). Studies are required to assess the potential of this technology as well as prerequisites for harnessing its potential.

3.4.3 Municipal Landfill Gas

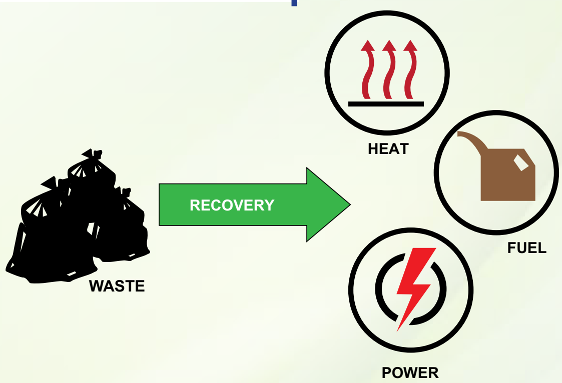
Municipal waste carries significant potential for bioenergy production. There is inadequate data to guide investment in large-scale bioenergy generation. Municipal landfills in most Kenyan urban centres are overflowing with solid waste,

Gasification Process



whose potential to contribute to the total bioenergy supply is enormous. Therefore, a national assessment of this potential is necessary to avail critical data to investors. The Hartland Landfill in Victoria, BC in Canada for instance, captures landfill gases through a series of underground pipes. The gas is collected, cooled, compressed and transported to a generating facility where it creates enough electricity for about 1,400 homes in the neighbourhood (British Columbia Bioenergy Strategy). According to the NCCAP (2018-2022) the volume of solid waste generated across Kenyan urban centres increased from 4,950 tonnes per day in 2011 to 5,990 tonnes per day in 2014, a rate that is higher than the country's urbanisation rate. Nairobi produces 3,000 metric tons of waste per day and is planning an initial waste-to-energy project of 25 MW (NMS, 2020).

Gasification Municipal Waste



4.0 Pathway to a Sustainable Bioenergy Future

A generic pathway to guide the adoption of priority sustainable bioenergy options is proposed in this section. It will direct the implementation of this Bioenergy Strategy over the 2020-2027 period. It puts emphasis on the role of adaptive planning and multi-stakeholder consultations as the foundation for achieving sustainable bioenergy for all.

4.1 Conceptual Framework Towards a Sustainable Bioenergy Future

To achieve a sustainable bioenergy future as envisaged under the SEforAll framework, there is need to put in place critical structures and an enabling environment that will address potential barriers to effectively deploy bioenergy. Figure 3 presents a proposed conceptual framework that will guide the identification, roll-out of sustainable production and consumption activities, and scale-up of priority bioenergy types or other strategic interventions identified and endorsed through this Bioenergy Strategy process.

The strategy proposal is that, for a given strategic bioenergy intervention to contribute towards the country's aspiration for universal access to modern energy for all, the framework anticipates that interested investors or end-users of the bioenergy will engage with relevant external actors through a multi-stakeholder innovation platform. This platform will provide an opportunity for planning, execution of projects and building of consensus on a case-specific theory of change, highlighting clear outcomes and success indicators. On this platform, the user or investor brings on board their local knowledge around the bioenergy under consideration. In addition, the external actors bring technical and other specialised knowledge and insights to support sustainable production and consumption of the energy. During the planning process, critical cross-cutting issues such as gender concerns, youth interests and opportunities, climate change impacts and communication strategies that are likely to influence success of the bioenergy project at scale will be considered. Similarly, agreement on key enablers must be secured. Key among these include financing mechanisms relevant to the project, requisite capacity development, policies and legislation, knowledge on markets and institutions, as well as political leadership necessary to ensure successful bioenergy project roll-out and scale-up in identified geographies and beyond.

After an established duration of implementation, a systematic monitoring and evaluation exercise should be conducted and the lessons learnt used to adapt the scale-up strategies and plans. Over the longer term, investors and end-users are able to sustainably produce and consume the bioenergy with attendant measurable health, economic and environmental benefits. However, the success of this framework solely depends on the effectiveness of the delivery and coordination mechanisms under the Ministry of Energy.

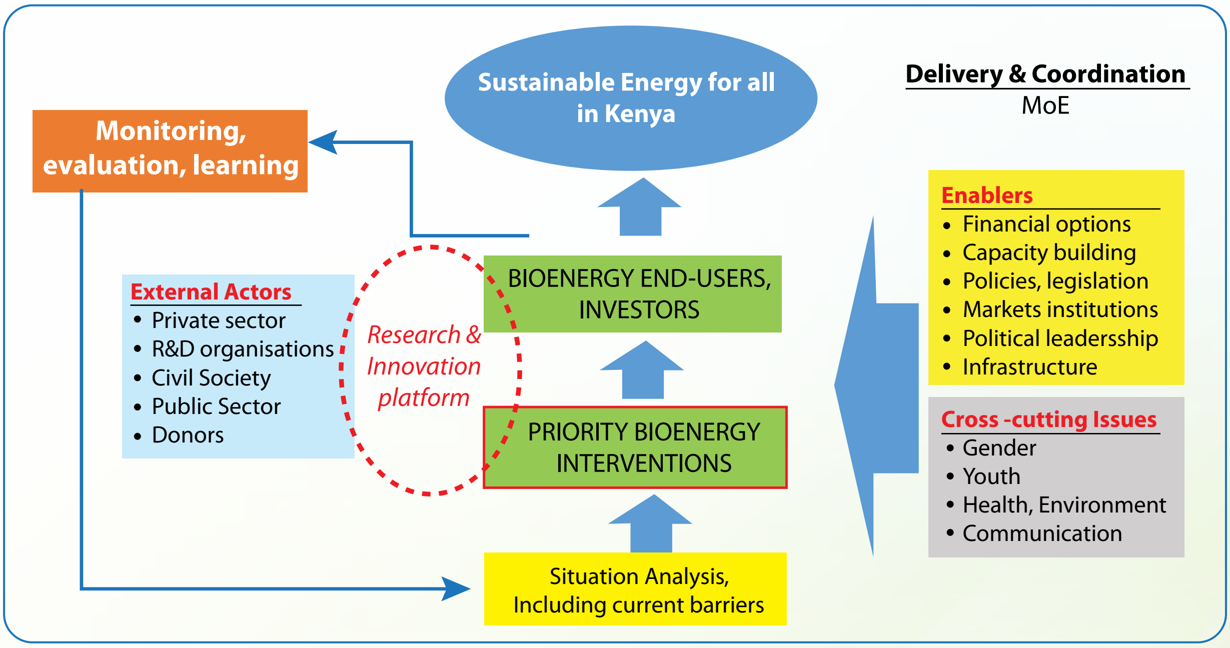


Figure 3: Conceptual Framework for Identifying, Adopting and Scaling-Up Bioenergy Interventions

4.2 Planning for Sustainable Bioenergy through Innovation Platforms

The National Energy Policy (2018) sets out its vision as "affordable quality energy for all Kenyans". Its mission is "to facilitate provision of clean, sustainable, affordable, competitive, reliable and secure energy services at least cost while protecting the environment". The SEforAll Action Agenda (AA) presents an energy sector-wide, long-term vision spanning the period 2015 to 2030. It outlines how Kenya will achieve her SEforAll goals of 100% universal access to modern energy services, increase the rate of energy efficiency and increase to 80% the share of renewable energy in her energy mix, by 2030. It also recognised the need for all stakeholders (particularly national and county governments, private sector, civil society and local communities) to play a leadership role. Further, the strategy acknowledges that truly holistic solutions require the participation of stakeholders across multiple sectors, ranging from energy, health, climate, industry, and finance to rural and urban development, gender, and social protection, among others (ESMAP, 2020). It also recognises that access to modern energy involves electricity and energy for cooking. It is important to bear all these elements in mind during planning.

The role of adaptive planning for bioenergy development to address supply and demand cannot be overemphasized. Upscaling is considered when bioenergy technology and innovations have been demonstrated to work at local levels, ranging from a few users to the entire community. By identifying barriers to wider adoption of a given bioenergy innovation at the planning stage, risks are mitigated and barriers overcome as part of the design process from the outset. Similarly, setting clear milestones that relate to scaling a given bioenergy technology via a well-defined theory of change helps to bring divergent views and options together.

Selection of bioenergy technologies and innovation must be based on the best-available evidence from research and local experience. While economics can drive key decisions, the social and cultural dimensions should not be overlooked when introducing new bioenergy technologies. In addition, participatory approaches should be adopted to bring on board multiple perspectives and dimensions of value. Before scaling up bioenergy options in a location, it is important to clarify historical and cultural contexts within which people's priorities and possibilities for innovations are set and bound (Carter & Currie-Alder, 2006). By assessing the bioenergy technologies to be disseminated against such cultural and historical boundaries, their suitability for adoption can be determined. Such interventions will be adapted to specific contexts and accommodate both indigenous and scientific knowledge.

Various stakeholder groups have unique incentives and abilities and will face different challenges in developing and scaling up bioenergy innovations. The investors or end users are the key beneficiaries in a sustainable bioenergy development and scale-up undertaking. They could comprise community members or small and medium enterprises (SMEs). External actors interested in bioenergy development could include development partners, government, researchers, civil society and the private sector. Each of these actors possesses uniquely diverse roles within an innovation system (Gressel, 2017). The progression of sector dialogue since the establishment of the SDGs points to a space where governments (national and county) development partners, policy makers, and enterprises, among many players, are brought closer together with a more consistent focus on outcomes (ESMAP, 2020).

Researchers including KIRDI, KEFRI, public universities, think-tanks and private consulting companies, could, for instance, be interested in situational analyses to frame the context for the new site where the modern innovation is desired. They could also explore various feedstocks to recommend appropriate alternatives for better bioenergy yields. Research must also be continuous in order to counter evolving climate change realities and contexts. Together with researchers, civil society needs to be active in disseminating their experiences (local innovation and behavioural change) to facilitate further scale up. Development partners financing projects in the bioenergy space will also align their support based on learning from the innovation platform. Any future pathway to universal access to modern energy cooking services (MECS) will require strong collaboration between public and private sectors in order to develop robust and modern energy markets for households (ESMAP, 2020).

Perspectives of development partner agencies, governments and other non-local actors do not necessarily coincide with local people's perspectives of their own needs. By bringing diverse stakeholders together through the innovation platform, an opportunity is provided to exchange ideas and build mutual understanding and trust—a critical ingredient for innovation. Inter-level participation is particularly crucial where local actors may interact with those at county, national and international levels (development partners and international NGOs working in the country can bring this perspective). The national and proposed county SEforAll committees could host the proposed innovation platforms as part of the county energy planning process. It is important to eliminate barriers which may hinder local stakeholders from freely participating and sharing information that is considered culturally sensitive or private to them. Fostering meaningful participation on these platforms also calls for capacity building of the disadvantaged groups, fostering trust among all partners and convincing powerful stakeholders to open the space for the disadvantaged groups to influence the agenda and nominate their own representatives (Ajayi et al., 2018).

The first step towards successful planning should involve developing a complete but evolving inventory of bioenergy resources and actors in Kenya, taking care to include current and potential resources. Strengthening existing and functional multi-stakeholder programmes on energy to host innovative platforms around clean cooking options is a logical step. The capacity building project for counties will help to solidify the county SEforAll committees which are currently non-existent, but are supposed to be established. Where they exist, Energy Centres in counties may also serve as conveners for specific innovation platforms. Scheduling of activities by an institutional champion appointed by the MoE's delivery and coordination mechanism is a third important step towards ensuring that strategic interventions proceed as planned.

4.3 Situation Analysis: A Prerequisite for Investment Planning

An assessment of the currently available biomass base for bioenergy development is crucial for policy planning and investment. Information on biomass supply and demand and accompanying projections to 2030 and beyond are urgently needed if this Bioenergy Strategy is to achieve its objectives. Data on historical, current and future bioenergy consumption rates and patterns in the country is also imperative. Market information including pricing and fluctuations across seasons is important. Further, the social, economic and environmental sustainability associated with the production and consumption of a given bioenergy, as well as documentation of key barriers to the effective harnessing of the potential in bioenergy from diverse sources should be documented. In addition, an assessment of bioenergy initiatives currently being implemented or proposed by different stakeholders that are contributing towards achievement of this strategy's goal and targets need to be undertaken. Chapter 3 of this strategy is the best assessment available for Kenya considering the various viable biomass-for-bioenergy resources and will inform the identification of priority or strategic bioenergy interventions that will be promoted over the strategy period 2020-2027.

4.4 Strategic Bioenergy Interventions

A myriad of opportunities exist for bioenergy development and these must be prioritised considering the level of capacities available to sustainably convert these to clean, affordable energy. Criteria to be used in narrowing down to strategic options include those that will improve the enabling environment for investment in the sector, contribute to youth employment and provide health benefits for women and children in particular, among others. Recommendations for action perennially made in public policy documents but not yet made effective require to be followed up and implemented. Finally, availability of feedstock, affordable conversion technology and ready markets for the bioenergy are additional criteria.

4.5 An Enabling Environment

4.5.1 Capacity Development

Capacity building encompasses activities at the level of individuals, institutions and systems. Scaling up bioenergy technologies requires capacity building across all scales from community members, the private sector to national and international policy makers. Once a decision is made that an intervention indeed has potential for scaling up, the limits or boundaries need to be defined such as a village, county or national scale. The capacity acquired enables individuals, organisations and societies to adopt and adapt the bioenergy options. Skilled workforce for the bioenergy sub-sector including personnel to operate and maintain production and consumption equipment is essential for successful deployment and development of bioenergy. Strengthening research capacity through training, mentorship, institutional visits where skills in planning participatory action research is essential. In addition, value chain analysis and systems thinking as well as designing products for the environment will be critical if research is to influence sustainable bioenergy adoption at scale. Changing mindsets among academic researchers to accept local communities as researchers in their own right will be particularly encouraged if the role of scientists in innovation platforms is to be meaningful.

Shortage of local experts in modern biomass conversion technologies have in the past been known to limit the choice of bioenergy projects that can be developed. This results in high operational and maintenance costs due to lack of local qualified personnel. Solutions could include introducing bioenergy technologies in the Technical and Vocational Education and Training (TVET) curriculum and working with the TVET-Curriculum Development, Accreditation and Coordination Council (CDACC) and the Kenya National Qualification Authority (KNQA) to develop competency-based curricula for building capacities in the bioenergy sector. Similarly, institutions such as Kenya Industrial Research and Development Institute (KIRDI) working in collaboration with the Council of Governors (CoG) and the Ministry of Energy (MoE) should pursue opportunities for technology and knowledge exchange with mature bioenergy markets. Counties interested in establishing new municipal landfill gas power generators should, for example, plan exchange missions with other successful municipalities across the world. More support for public- and private-sector investment in local capacity building is also encouraged.

4.5.2 Financing Mechanisms

Multiple countries in Sub-Saharan Africa—where financing could potentially have the greatest impact—have seen financing commitments more than halved (ESMAP, 2020). To reach universal access to MECS for instance, investment needs to be scaled up from the tens of millions, along with dedicated policies. Such investment includes not only the initial capital costs of stoves and deposit/connection fees, but also the energy infrastructure costs and additional subsidies required to make the clean-fuel costs affordable to the poorest consumers. Meeting the financial challenge for bioenergy technology development and promotion in Kenya will require innovations, cooperative actions and political will to urgently and adequately address current and projected shortfalls.

Financing could be obtained from public, private and other innovative sources such as crowd-funding, fintechs, bank guarantees and price-based mechanisms such as Feed-in Tariffs (FITs), market premiums and tax incentives. The approach to scaling up and out will typically need to be adapted to the funding model. Development partners for example have different priorities, which will influence the selection of bioenergy technologies and approaches likely to be promoted in upscaling. Accessing climate finance from global sources such as the Green Climate Fund (GCF) and the Global Environment Facility (GEF) has not been fully exploited mainly due to the stringent and bureaucratic nature of these funds. Therefore, local actors need capacity enhancement on how to apply for these funds. In addition, low cost financing avenues through public-private partnerships (PPPs) should be explored. Leveraging climate finance from National Treasury's Climate Fund is plausible.

This strategy encourages fundraising from domestic sources including from national budgets through parliamentary appropriation; remittances from the diaspora, which have fast gained currency as a key foreign exchange earner for Kenya; NGO funds—this sector controls a significant chunk of development partners funds towards climate action; and the private sector, most of whose members in the country are still struggling to understand their role in low emission development. Microfinance institutions and community-based savings and credit systems may also provide the much-needed alternative particularly to local communities. Decentralized Climate Finance (DCF) is becoming increasingly important, albeit targeting adaptation initiatives. An example is the County Climate Change Fund (CCCF) in Kenya by the NDMA.

4.5.3 Policy, Regulations and Institutions

The national and county policy framework, laws, regulations and norms have to be supportive if scaling up of bioenergy options is to succeed (Hartmann & Linn, 2008). Policy consists of treaties, laws, regulations, statements, administrative actions and funding priorities. Policy comprises the rules that establish who can do what and subject to what conditions. Some examples of policies that could constrain or advance scaling are those related to raw material duty and taxes. Institutions are rules and norms that enable human interaction to take place, and how they operate is critical for the achievement of economic development. These include property rights, regulatory institutions and social insurance. A bioenergy market is an institution through which multiple buyers or multiple sellers recurrently exchange a substantial number of similar commodities of a particular type. Markets involve legal and other rules that help to structure, organise and legitimize exchange transactions. They involve pricing and trading routines that help to establish consensus over prices, and often disseminate information regarding the products, prices, quantities, potential buyers and possible sellers (Johnson, 2009). The development of a comprehensive regulatory and legal framework, which includes a standard tariff-setting methodology and Power Purchase Agreements (in the case of electricity-generating bioenergy projects) will hence be imperative.

Sustainability standards are a major consideration in bioenergy development. Demand for bioenergy has its downside as it can pose a risk of loss of biodiversity, including loss of natural habitats. These mainly result from intensification of agricultural production for bioenergy and also the possibility of introduction of non-native invasive species. Demand for bioenergy can also exacerbate food price increases during seasons when they are high for other reasons. The demand can therefore have a negative impact if suitable environmental or social controls are lacking. Land and resource tenure issues will be discussed using existing policy and regulatory frameworks. There is need for an assessment of the likely impact of bioenergy demand, including hindering achievement of other objectives such as maintaining food security, biodiversity enhancement, achieving wider environmental outcomes or global development and poverty reduction. It is imperative to include sustainability criteria for bioenergy which relate to environmental, social or economic conditions, used to distinguish between desirable and undesirable forms of bioenergy. These criteria may be in two forms: mandatory and voluntary, with the former implying mandatory conditions that must be met to gain access to market support mechanisms, while the latter implies conditions to assess a programme or policy impact.

Sustainability standards place safeguards against direct land use changes in areas with high biodiversity value or high carbon stock such as indigenous forests, protected areas, peatland and wetlands. The government therefore envisions introducing sustainability criteria for proposed bioenergy feedstock. Besides sustainability criteria, Life Cycle Assessment (LCA) will be carried out to quantify total environmental impact of proposed bioenergy feedstock by considering all processes involved, from the production of raw materials, to the final use or disposal of products. The analysis aims at quantifying the impact of each of these stages.

4.5.4 Political Leadership and Support

One key way to ensure that leaders and institutions continue to pay attention to scaling up bioenergy programmes is to create an effective demand for it through the political system (Hartmann & Linn, 2008). The Wind Energy Project in Kipipiri Constituency, stalled as result of negative political campaigns in 2017, is an example. Social change needs to be embedded in a society and supported by political constituencies which do not generally emerge by themselves. They have to be created and nurtured. Political constituencies need to be actively engaged in the process, and leaders must be constantly reminded of the significance of adding the scaling up process to their political agenda. Advocacy often needs to be built around individual champions, but should aim to form broader coalitions down the line. African leaders in particular will need to deliver on their commitments such as those under the Nationally Determined Contributions (NDC) under the Paris Agreement (UNFCCC/CCNUCC, 2015).

The United Nations' Health and Energy Platform of Action (HEPA); the proposed High-Level Coalition of Leaders for Clean Cooking, Energy and Health; and other coalitions (e.g., Clean Cooking Association of Kenya – CCAK that is currently coordinating the Climate Change – Health and Energy Committee) are critical for raising the stakes for implementing measures to achieve SDG 7.1 and affirming cooking as an essential component of energy policy. Such coalitions generate the political will and incentives needed to embed cooking within cross-cutting, national policy-making and create a context for countries in transition to learn from each other and ensure coordinated action (ESMAP, 2020).

County governments will need to be more active in ensuring access to clean fuels for all their constituents if the vision of sustainable energy access for all is to be realised. Most 2018-2022 County Integrated Development Plans (CIDPs) shed some light of hope by referring to cooking sector improvements. Some counties (see Table 4) already have specific cooking sector goals. However, the success of these programmes depends on political will as the county executive and Members of the County Assembly (MCAs) need significant levels of awareness of the health, environmental and economic benefits of different technologies in order to effectively lobby and influence local budgetary allocations.

4.5.5 Infrastructure

The state of roads to allow access to biomass feedstock in remote places, the availability and access to water, and other infrastructure, are challenges that have implications on uptake of bioenergy. If this is not resolved, opportunities in areas with abundant bioenergy feedstock may be underexploited. Relevant county government departments are encouraged to develop risk management strategies to address production, storage, transportation and use of bioenergy. This could include training of service providers and professionals handling bioenergy and hazardous material. There is also need for actors to develop drying and storage facilities in the planning and positioning of the conversion plants. Similarly, investment in infrastructure including road networks, railways and water transport should be integrated into county development plans, where a mapping of bioenergy resource feedstock is identified.

Table 4: Some County-Specific Cooking Sector Targets for 2022

County	Development targets by 2022
	Biogas technology adoption
Makueni	20,000 households using biogas
Busia	500 digesters installed
Kisii	630 households using biogas
Trans Nzoia	125 biogas demonstration projects implemented
	Increase in energy-saving cookstoves
Isiolo	5 to 25% households
Kisii	15 to 75% households
Tana River	2000 improved cookstoves installed
Wajir	5 to 40% including clean fuels, e.g., LPG

Source: Constructed from data in MoE/CCAK 2019

4.6 Cross-Cutting Issues

4.6.1 Gender and Youth Mainstreaming in Bioenergy

Energy interventions impact men and women differently, as they have distinct roles, responsibilities and voices within their households, markets and communities. This leads to differences in their access, control and use of energy, as well as the impact of energy services on their lives. In Kenya, production and use of biomass fuels is the responsibility of women and children, particularly in rural areas. Most men are only involved when these activities are commercialized. It is most often women who spend much time and efforts to supply fuel for their household and productive needs. They travel long distances to collect energy resources which put their physical security at risk. They could be subjected togender-based violence (GBV) or attacked by wild animals(Prebble & Rojas, 2017).

Any shortage in fuel supply affects them most as they need energy for multiple tasks such as cooking, lighting and heating. More often they have to resort to using traditional biomass which tends to take atoll on their health. It is evident that the use of low quality energy options and inefficient devices pose health risks to households(Prebble & Rojas, 2017). Women and children are mostly exposed to large amounts of smoke from indoor fires which expose them to respiratory diseases. Lack of investment in low-cost energy supply systems compels women to continue using poor quality firewood for cooking and lighting, with the associated health and safety problems. Improved access to modern energy services can reduce both time and effort spent in reproductive and productive labour, leading to socio-economic development and environmental sustainability. Energy programmes, which include those that focuson cookstoves, do not always take gender issuesinto consideration. In most energy interventions, women are not involved in design, supply and demand. This hinders uptake and marketing.

Women, the youth, people living with disabilities(PLWDs) and the marginalised experience unequal access to resources and decision-making processes. Their access to decision-making within the household and community is restricted, thus limiting their ability to influence processes and resource allocation on many issues, including energy use and control. For instance, in some communities, it's a taboo for them to plant any trees, and they have no control over trees in the family. This posesa big challenge.

In most cases, women are not ready to take up the challenge of actively participating in the energy value chain as it is largely perceived as a man's domain. This has a negative effect on their level of empowerment in the energy market space. Cultural barriers hinder promotion of clean energy technologies as most communities becomeattached to traditional methods.

Gender imbalance in public awareness and sensitization on energy-related issues affect uptake and change of mindset. Most sensitization activities are attended by men, leaving out women who may have a significantimpact on the project's sustainability. For instance,use of a gas cylinder for lighting might not be common knowledge. We find that it is the woman who will be expected tolight it, yet the man is the one who could be sensitized on the same but might fail to share the informationwith his spouse.Energy plays a key role in enhancing adaptive capacity and resilience to climate change. Communities with access to clean energy can tap it for income-generating activities to boost their incomes, while at the same time conserving the environment. Modern forms of fuel such as renewable energy technologies can expand the options and allow women to become entrepreneurs both in the distribution (suppliers) of clean energy, as well as in its use (consumers).

4.6.2 Communications and Awareness

Scaling up local climate innovations depends on demonstrating their success and convincing non-local stakeholders to learn from these experiences. Development partners and research organisations have a role to play in dissemination of local bioenergy innovations and changing their own behaviour to facilitate further scaling up of local innovations. Training programmes conducted by international institutions (in cases where a technology is imported) and local universities represent an important channel for disseminating knowledge on how to use innovations, the principles on which they are based and their potential applications. The potential of traditional communication methods blended with modern approaches to social marketing should similarly be explored.

4.6.3 Health and Environment Concerns

Bioenergy development may lead to unsustainable use of bioenergy feedstock resulting in environmental degradation. These may include negative environmental impacts such eutrophication and contamination of water and land, in the process of yield improvement. This may be resolved through development of sustainability standards for all proposed feedstock that include regulating the use of fertilisers (if any are required in biomass production) and sound environmental management. Use of most solid biomass feedstock will produce household air pollutants that have serious consequences for human health. This concern must be considered right from the planning stage. Changes in biomass use will be resolved in consultation with the affected populations.

4.7 Monitoring, Evaluation and Learning

Successful scaling up of any strategic intervention selected requires regular feedback through monitoring and evaluation systems from all stakeholders including those whose views are harder to ascertain. It is essential to learn from success and failure alike in order to develop best practices in scaling up and out (Thomas et al., 2018). It requires a "learning-by-doing" culture among the innovators, one that values adaptation, flexibility and openness to change. While a solid process needs to be laid out, scaling up processes need to be adjusted regularly with an awareness that the needs and preferences of different groups may vary and conflict. This is to be expected and as far as possible, accommodated. Therefore, regular monitoring and evaluation as well as feedback from beneficiaries, communities, and field-based staff are important for learning and adjustment to take place.

Having champions facilitate learning among different stakeholder groups across scales (preferably on the bioenergy-specific innovation platform) is critical. Working in collaboration with stakeholders to enable continuous learning, such champions will improve uptake of bioenergy solutions. Local stakeholders (end users and investors in bioenergy) require building up of their confidence and skills to enable them share, learn, develop, adapt and apply appropriate knowledge, ideas, methods and tools within a given context. Non-local actors can foster learning among local actors by providing necessary interdisciplinary research and forums for knowledge sharing.

To modify issues of their concern or meet their priorities effectively, local stakeholders need to be aware of the complexities and interconnectivity of the systems on which they depend for energy and their livelihoods. Employees of non-local agencies (Development Partners, NGOs, government NRM agencies, among others) need to learn how to support and empower local stakeholders by designing and providing the required training, research and opportunities for knowledge sharing. Where good practices are identified, these need to be communicated widely to build expertise in scaling up across different contexts.

The Delivery and Coordination Desk (DCD) proposed to be established through deliberation among state agencies and domiciled at the Bioenergy Directorate of the Ministry of Energy will oversee the development of a comprehensive monitoring, evaluation and learning (MEL) framework within six months of launching the Bioenergy Strategy. This framework is expected to be consistent with the National Integrated Monitoring and Evaluation System—NIMES (Government of Kenya, 2015) and County Integrated Monitoring and Evaluation System Guidelines (Council of Governors, 2015) and have clear terms of reference for relevant stakeholders in data collection and reporting at all levels. Learning is a key element of this strategy's monitoring and evaluation framework. Annual learning review meetings will therefore be convened by the DCD. These will bring together the national and county delivery and coordination teams to share learnings and adapt respective action plans to integrate emerging issues and lessons.

4.8 Strategy Delivery and Coordination

The lack of coordination within and between institutions in countries has stymied cooking interventions from becoming high-impact policy priorities (ESMAP 2020). While governments may include accelerating access to modern cooking energy in their policy agendas, they often lack the required institutional leadership and incentives to make major progress. Furthermore, lack of integrated energy planning often isolates electrification programmes from cooking policies and interventions (ESMAP 2020). Scaling up bioenergy technologies and innovations cannot happen in a vacuum and requires leadership and process facilitation. There is need to engage a champion from one or more of the actor groups who can lead and link different levels and interests (Thomas et al., 2018). It is possible to work with champions including underrepresented groups such as women with limited education to develop an influencing/engagement strategy with key stakeholders, working where necessary, with influential intermediaries to build momentum for changes in policy or practice. Key roles of the champions include inter-level coordination (e.g., between county and national government) mobilising key stakeholders involved in the scale-up and out programme, and coordination of the decentralised scale-up governance framework (Cooley et al., 2006). The role of innovation intermediaries is also key. They facilitate interaction among isolated innovation networks, and between communities and researchers, policy makers and other industry actors. They can also be referred to as innovation "brokers". Key partners in scaling-up innovations must always be mobilised and brought on board (Jonasova & Cooke, 2012).

This strategy proposes the establishment of a delivery and coordination framework in the form of a National Bioenergy Committee (NBC) under the overall coordination of the Ministry of Energy. The roles and responsibilities will be deliberated by Ministries, Departments and Agencies (MDAs) responsible for agriculture, environment, energy, transport, infrastructure, industrialisation and enterprise development, land, water and irrigation, regulatory and support institutions at both the national and county governments. Figure 4 depicts the relationship between the two levels of coordination. The National Government through the Ministry of Energy and relevant MDAs will be responsible for policies, strategies and regulatory services.

At the county level, County Governments and local energy sector-associated MDAs will spearhead the implementation of locally-relevant strategies. Energy Centres (currently found in only 17 counties) will be strengthened to support county-level delivery and coordination. These centres will receive coordination support from the national level. There is need to fast-track establishment of additional Energy Centres in counties that have none.

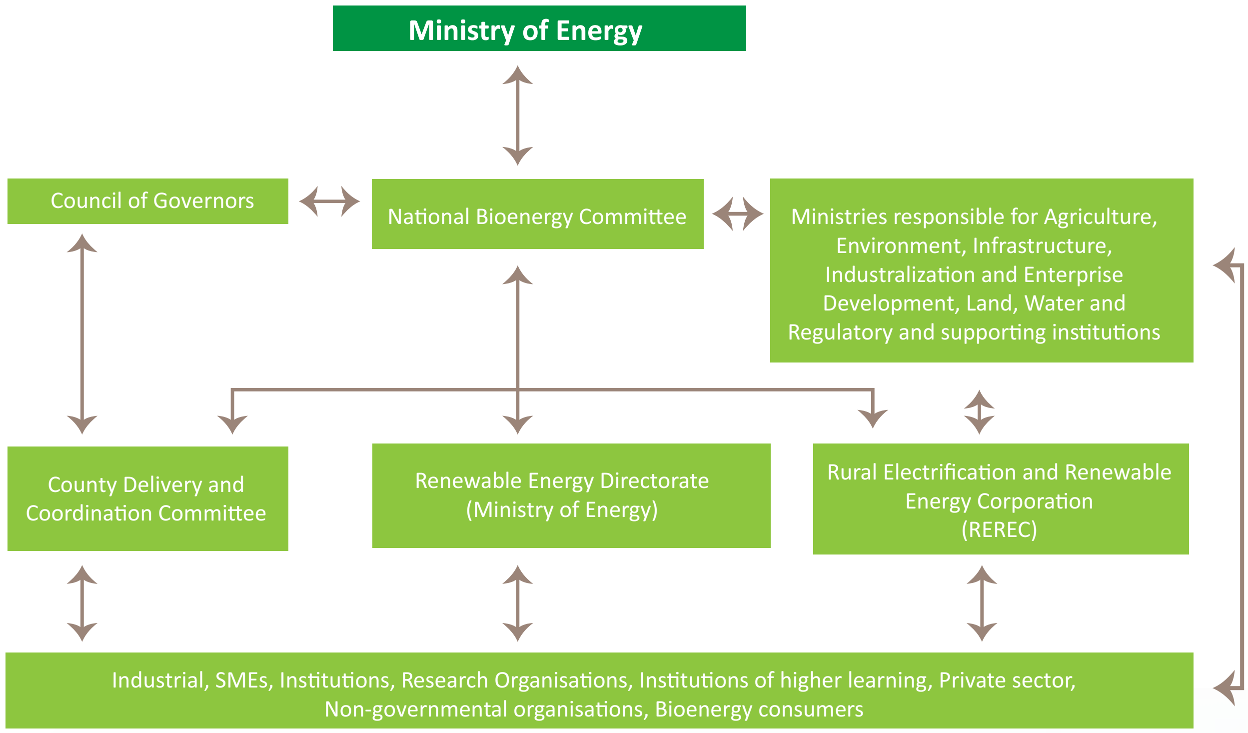


Figure 4: Roles for and Relationships between National and County Delivery and Coordination Desks

Sawdust Briquettes. *Photo: Mary Njenga*

5.0 Strategic Interventions

This strategy has defined where we are (the country's bioenergy status), where we want to go (the vision and objectives) and how we will get there (the pathway towards the future). This section presents the proposed strategic interventions and desired outcomes for the short (2020-2022) to medium-term (till 2027), with impacts to be felt beyond this period. These span increased bioenergy supply and demand, policy, regulatory and institutional reforms, capacity development and research. It therefore allows stakeholders interested in specific bioenergy interventions to self-converge around appropriate innovation platforms convened and coordinated by the Ministry's delivery and coordination mechanism to determine their relevant and specific activities, timelines and other enabling environments befitting their contexts. Considering the wide and variable stakeholder bases across bioenergy value chains, locations and sub-sectors, this strategy does not prescribe critical stakeholders, budget estimates and delivery timelines. Rather, it leaves that role to the innovation platforms which will be guided by the established delivery and coordination framework at national and county level.

5.1 Proposed Actions and Desired Outcomes

SHORT-TERM (2020-2022)

1. **Enhance policy, regulatory and institutional frameworks for effective delivery and coordination of bioenergy programmes. Desired outcomes include:**

   a.) The National Bioenergy Committee (NBC) strengthened, relaunched and gazetted;

   b.) Organisational mandates in bioenergy development as well as coordination and leadership in implementing policy and regulatory requirements are harmonised at national and county levels;

   c.) Clear Delivery and Coordination desk established at DRE, REREC and county government, and TORs developed and endorsed by all relevant government agencies;

   d.) Operational budget for DRE increased;

   e.) Capacities of national and county governments to implement programmes enhanced;

   f.) Collaboration Charter developed and endorsed by non-state actors and oversight provided by the NBC;

   g.) Bioenergy industry associations strengthened; and

   h.) Diverse actors—both non-state and state agencies – registered and coalesce around bioenergy-specific innovation platforms to champion bioenergy planning and deployment.

2. **Comprehensive mapping of the country's bioenergy resources with potential for bioenergy development. Desired outcomes include:**

   a.) Inventory established covering bioenergy feedstock resource, approximate volumes available annually and location (GPS), potential energy yield, economic value, uses, active players in resource development. Tree biomass, including wood chips and sawdust, municipal solid waste including sanitary waste, animal manure, bioenergy crops and agricultural waste, among others, mapped;

   b.) Online portal, as well as criteria for continuous update of the inventory by research organisations, independent consultants and government entities established;

   c.) Bioenergy portal and strategy among potential investors, research organisations, development launched and disseminated; and

   d.) Bioenergy sector-specific studies conducted.

3. **Enhance sustainable bioenergy feedstock production in urban, peri-urban and rural spaces. Desired outcomes include:**

   a.) Sustainable bioenergy feedstock production promoted. On-farm growing of energy trees and crops, and fast-growing tree plantations established in public places by county governments and private sector, including peri-urban areas;

   b.) Invasive tree/shrub species such as Prosopis spp managed for sustainable bioenergy supply;

   c.) Production of forest and non-forest biomass fuels;

   d.) Programmes for sustainable collection of animal dung and human waste for purposes of bioenergy development supported; and e.) Contribution made to the country's climate change and forest cover targets.

4. Evaluate the viability of reviving bioethanol blending with gasoline for transport sector consumption. Desired outcomes expected:

Ethanol Blending for Transport

a.) Expert report prepared recommending viability, economic value, technical steps and enabling environment towards sustainably reviving the bioethanol-gasoline blending industry;

b.) Biomass feedstock potential determined for sustainable production of bioethanol. Kenya's existing sugar factories and potential from her neighbours, Uganda and Tanzania, determined; and

c.) Evaluation report on innovations and technology assessment for sustainable bioethanol production, including molasses, fresh sugar juice or other feedstock produced.

SHORT- to MEDIUM-TERM (2020-2027)

1. Strengthen research capacity to better inform bioenergy policy and support sector development through assessment of existing gaps and opportunities. Desired outcomes include:

a.) Digital library or resource portal on bioenergy publications, reports etc. established;

b.) All ongoing projects in Kenya, including past researches at universities, research institutes, think-tanks and energy consulting firms documented;

c.) Database of bioenergy professionals developed and maintained;

d.) Research institutions with mandate for bioenergy development pursue strategic partnerships with leading bioenergy developers for technology development, transfer and capacity development;

e.) The Kenya Industrial Research and Development Institute (KIRDI), as the National Designated Entity (NDE) for the CTCN of the UNFCCC, guides researchers whose technology is mature but have not yet been deployed commercially, on the development of fundable proposals for pilot bioenergy development projects;

f.) Research on municipal solid waste and landfills, and different biodiesel feedstock development conducted and results communicated to potential investors and policy makers; and

g.) Innovation hub for bioenergy established and nurtured.

2. Transition to clean cooking fuels and technologies. Desired outcomes could include:

a.) VAT, import duty and other fiscal incentives on clean cooking solutions achieved;

b.) Clean cooking solutions financing options co-designed with development partners and the private sector;

c.) Capacity development carried out on more efficient carbonization technologies in line with charcoal regulations in partnership with Charcoal Producers Associations (CPAs) and other similar groups;

d.) Policy, regulatory, technical capacity and financing gaps related to individual bioenergy types documented and resolved;

e.) Women and youth gainfully engaged through entrepreneurial activities along the strategic bioenergy value chains; and

f.) Number of households and institutions using improved biomass cookstoves and cleaner fuels, including bioethanol, increased.

3. Mobilising financial resources for local bioenergy development. Desired outcomes include:

a.) Funding secured from multilateral organisations and feasibility studies on setting up bioenergy plants conducted;

b.) Development partner support attracted to leverage efficient sourcing from smallholder farmers;

c.) International partnerships built with local institutions to create opportunities for technology and knowledge transfers;

d.) Climate financing unlocked to develop the bioenergy ecosystem at different stages of the value chain; and

e.) Results-based financing that could enhance bioenergy enterprise economics deployed.

4. Strengthen the cooperation between the health and energy sectors for clean cooking[1]. Desired outcomes include:

a.) The Health and Energy Working Group established and supported;

b.) Meetings with the Cabinet Secretaries, county executive committee members, private sector leaders and other local leaders facilitated;

c.) County status reports on clean cooking and its impact on health, gender, development and climate prepared;

d.) Development and adoption of national clean cooking standards which account for and minimise adverse health impact facilitated and technically supported;

e.) Monitoring and evaluation of clean cooking and its impacts at national, county and project level enhanced;

f.) Technical support provided to national and county governments in the integration of strategies and policies that address interlinkages between health and energy; and

g.) Current awareness raising campaigns for clean cooking coordinated, integrated and amplified to make the "health", "gender" and "equity" argument for clean cooking.

5. Promote awareness and communication

a.) A communications and knowledge management plan developed for this strategy;

b.) Behaviour change communication, information and education campaigns

1 This Strategic Intervention implements the Work Plan of the global health and energy platform of action (HEPA) for 2020-2022.

on sustainable uptake of various sources of bioenergy promoted; and

c.) Awareness and communication campaigns to promote sustainable bioenergy expanded;

6. Support and facilitate private sector involvement in bioenergy development. Desired outcomes include:

a.) Ease of doing business improved;

b.) Private sector participation in bioenergy development strengthened;

c.) Standards and regulations for bioenergy technologies developed;

d.) Market with low-interest loans for local bioenergy producers stimulated;

e.) Fiscal and investment incentives developed and implemented; and

f.) The existing one-stop-shop within the Kenya Investment Authority (KIA) leveraged to support investors.

5.2 Monitoring and Evaluation of the Strategy Implementation

Table 5 describes the simplified version of the theory of change for the Bioenergy Strategy. It will be the basis for monitoring and evaluation of the strategy's performance over the 2020-2027 period. This will be refined by stakeholders coordinated by the delivery and coordination mechanism in place.

The theory of change for this Bioenergy Strategy is that IF investors and end users of bioenergy engage with external stakeholders through innovation platforms, are provided an enabling environment for sustainable production and consumption, and are supported by a dedicated delivery and coordination mechanism, and users' concerns such as youth opportunity, gender, health and environment are considered in bioenergy development and scale-up plans, THEN access to modern, clean, affordable and sustainable energy for all will be realised over the long term.

Table 5: Theory of Change for the Bioenergy Strategy

Inputs	Activities	Outputs	Outcomes	Development Goal
• Robust delivery and coordination mechanism at DRE • Strong multi-stakeholder partnerships organised around innovation platforms • Access to finance • Endorsed strategic interventions	• Adaptive planning and implementation of selected strategic bioenergy interventions • Establishing the enabling environment for respective interventions including mobilising funding, building capacity, setting policies and regulations, develop markets, solicit political will and assess infrastructure status • Mobilising sustainable feedstock production, waste management, and incentivizing private sector investment in rolling out clean fuels	• Policy options, regulations, sustainability standards and rules • Resource assessments and databases • New bioenergy markets • Innovation platforms • New bioenergy technologies • Innovative financing mechanisms and models	• Full transition to clean cooking with bioethanol and biogas by at least 50% of all households; complete switch to improved charcoal kilns; at least 50% households are lit with power from bioenergy systems by 2027 • Self-sustaining bioenergy businesses are running, thriving markets, green jobs in value chains, and increased incomes • Improved respiratory health outcomes among women and children, better social indicators • Increased biomass production, healthy ecosystems and cleaner local environments	Access to modern, clean, affordable and sustainable energy for all

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