UN environment programme

SUSTAINABILITY OF SUGARCANE BAGASSE BRIQUETTES AND CHARCOAL VALUE CHAINS IN KENYA

Results and recommendations from implementation of the Global Bioenergy Partnership Indicators

SUMMARY

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

SUSTAINABILITY OF SUGARCANE BAGASSE BRIQUETTES AND CHARCOAL VALUE CHAINS IN KENYA

Results and recommendations from implementation of the Global Bioenergy Partnership Indicators

SUMMARY

Disclaimer

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Environment Programme concerning the legal status of any country, territory, city or area or of its authorities, or concerning delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the United Nations Environment Programme, nor does citing of trade names or commercial processes constitute endorsement.

TABLE OF CONTENTS

TABLES AND FIGURES

TABLES

FIGURES

ACKNOWLEDGEMENTS

The United Nations Environment Programme (UNEP) supported the development of this report in Kenya in the framework of the project "Building Capacity for Enhancing Bioenergy Sustainability Through the Use of GBEP Indicators". The project was coordinated by Laura Williamson from UNEP's Economy Division for overall management, Kouadio N'Goran from UNEP's Africa Office for regional management and Dr. Maryse Labriet as indicator expert.

In Kenya the project was coordinated by Dr Rocio Diaz-Chavez from the Stockholm Environment Institute Africa Centre.

We would like to express our appreciation to Horst Fehrenbach, from the Institute for Energy and Environmental Research, for the training delivered in Kenya on the assessment of emissions from sugarcane bagasse briquettes and solid biomass.

The contributing researchers of the project, by participating organization, are as follows:

- Stockholm Environment Institute (SEI): Dr Rocio Diaz-Chavez, Hannah Wanjiru, Mbeo Ogeya, Natxo Garcia-Lopez.
- Kenya Forest Research Institute (KEFRI): Nellie Oduor, Peter Churchill Ogutu, Emily Kitheka, Dr Gabriel Muturi, Dr James Kimondo, Dr Mbae Muchiri, Dr Robert Nyambati, Dr James Ndufa, James Maina, John Ngugi.
- World Agroforestry Centre (ICRAF): Dr Mary Njenga, James Kinyua Gitau.
- Strathmore University: Prof Izael da Silva, Anne Wacera Wambugu, Prisca Atieno Ochieng.

We acknowledge the support and contribution to the discussions of Mr Peter Omeny from the Ministry of Energy, Directorate of Climate Change and Mr Cyrus Mageria from the Ministry of Environment and Forestry.

SEI acknowledges the administrative support of Elvine Kwamboka, Faith Saluu and Felix Akumu.

We also acknowledge the contribution of the different stakeholders who participated in the workshops and discussions and who provided data, including: Vishal Taank, Charles Odhiambo, White Coal Industries Ltd (Kisumu); the tea factories Mudete, Eberege and Makomboki; Beatrice Despioch, Eco-Charcoal; Edward Hewitt and Kevin Juma, The Nature Conservancy; George Oselu and John Lang'at, Kenya Tea Development Agency (KTDA); Geoffrey Wanyama, Farm Forestry Smallholder Producers Association of Kenya (FF SPAK); David Njugi, Kenya Association of Manufacturers (KAM); Erick Okola Lwambe and Mary Gondi, Agriculture and Food Authority, Sugar Directorate; Dr Martha Induli, Kenya Industrial Research and Development Institute (KIRDI); Stephen Mutimba, Climate & Energy Advisory; John Kioli, Green Africa Foundation; Ruth Gichuhi, Energy and Environment Development Advisory; Rachel Mwangangi, Kitui County; Nils Razmilovic, Tamuwa Ltd; Humphray Mbuga, Ragesh Bhargava, Transmara Sugar Company Ltd; Coline Ogada, WeCoal Ltd; Wambura Mwangi, Jomo Kenyatta University of Agriculture and Technology, Nairobi; Mathew Muma, Kenya Institute of Public Policy and Analysis (KIPPRA); Christoffer Boman, Robert Lindgren and Eleonora Borén, Umeå University; Gert Nyberg, Swedish University of Agricultural Sciences.

We would also like to thank Lisa Mastny for editing and proofreading the final version.

This work was made possible with the financial support of the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

FOREWORD

Dear Readers,

The following report, Sustainability of Sugarcane Bagasse Briquettes and Charcoal Value Chains in Kenya: Results and recommendations from implementation of the Global Bioenergy Partnership (GBEP) Indicators, assesses the current and future potential of Kenya's bioenergy sector. It outlines the consequences of the widening gap between supply and demand for wood fuel, with the current supply not matching demand in various parts of the country. The report also illustrates key factors that can shape the long-term and periodic monitoring of the sector.

Kenya Vision 2030 has identified energy as one of the enablers of the three pillars of its vision. The level and intensity of commercial energy use will be the key indicator of economic growth and development. Bioenergy, like other energy sources, will continue to play a role both in the traditional and commercial energy mix.

Kenya's Nationally Determined Contribution (NDC) includes four key climate change mitigation targets related to forestry and bioenergy: working towards 10 per cent tree cover of the land area of Kenya; promotion of clean energy technologies to reduce overreliance on wood fuel; employing low-carbon and efficient transport systems and using climate-smart agriculture (CSA) in line with the National CSA Framework.

The 24 GBEP indicators assess the environmental, social and economic aspects of bioenergy use. In this study two critical pathways were chosen: 1) use of sugarcane bagasse briquettes in the tea industry; and 2) household use of charcoal produced on woodlands and farmlands.

I hope that you will find the conclusions and the recommendations presented in this report informative, and that by better understanding the environmental, social and economic impacts of bioenergy use we will be able to sustainably manage this important national resource.

This work was undertaken by four research centres – Stockholm Environment Institute for Africa, Kenya Forestry Research Institute, Strathmore University and the World Agroforestry Centre – with the support of a multi-stakeholder working group. We are grateful for the technical support from the United Nations Environment Programme and for the financial support from the German Climate Initiative (IKI).

Dr Charles Mutai

Director, Climate Change Directorate
Ministry of Environment and Forestry Kenya

1. OVERVIEW OF THE PROJECT

The Global Bioenergy Partnership (GBEP) project provides technical assistance to government officials and experts in Ethiopia and Kenya to assess the sustainability of their bioenergy sectors and to build their capacity for long-term, periodic monitoring of these sectors. Work is structured around the application and interpretation of the 24 indicators to assess the environmental, social and economic impacts of bioenergy production and use. Results from the indicators can be used to inform the decision-making process.

The GBEP indicators evolved out of a collaborative process. The indicators are a result of consensus among a broad range of national governments and international organizations on the sustainability of bioenergy. The emphasis is on providing measurements useful for informing national-level policy analysis and development.

The GBEP indicators are unique in that they can be applied to all forms of bioenergy. As such, the indicators do not feature directions, thresholds or limits and do not constitute a standard, nor are they legally binding on GBEP members. The indicators have been tested in 14 countries to date, ranging from industrialized countries such as Germany to those heavily dependent on biomass like Ethiopia and Kenya.

In Kenya, the project was implemented by the Stockholm Environment Institute (SEI) in collaboration with the Ministry of Environment and Forestry and is anchored in Kenya Vision 2030 and Kenya's National Energy Policy as well as the country's Nationally Determined Contribution (NDC). The United Nations Environment Programme (UNEP) worked with the Ministry to implement this project with support from the International Climate Initiative (IKI) of the German government. The calculation and analysis of the 24 indicators applied to the two priority pathways was conducted by SEI, Kenya Forestry Research Institute (KEFRI), Strathmore University and the World Agroforestry Centre (ICRAF).

Based on collective consultation, two priority bioenergy pathways were selected:

1. Use of sugarcane bagasse briquettes in the tea industry; and
2. Household use of charcoal produced on woodlands and farmlands.

The national research team, with input from a multi-stakeholder working group, applied the 24 GBEP indicators to the above pathways. The results of this work are summarized in the following text. In-depth description of the national context and the calculation process for each indicator are detailed in the technical report, available online. https://bit.ly/2LFOZm3

This work is a starting point for increasing the sustainability of the bioenergy sector in Kenya. By establishing benchmarks, it is hoped that the national government will continue to engage in a regular process of assessing the evolution of the sector. Through continuous reporting, results from the indicator calculations will help to inform decision makers about the direction of national bioenergy policies with the ultimate goal of achieving sustainability of the nation's bioenergy sector.

The GBEP activities are managed by the GBEP Secretariat, housed at the Food and Agriculture Organization of the United Nations.

2. COUNTRY CONTEXT

Kenya, with a population of around 48 million people, is the fourth largest economy on the African continent. The country's gross domestic product in 2018 was $88 billion, or $1,202 per capita. The energy mix of Kenya is dominated by biomass (76 per cent), followed by oil and oil products (17 per cent), geothermal (6 per cent) and other renewables (below 6 per cent) (KNBS 2018a).

Biomass contributes a large share of Kenya's final energy demand, supplying more than 90 per cent of rural household energy needs. The main sources of biomass in the country include charcoal, wood fuel and agricultural waste. Sustainability of the bioenergy sector is central to Kenya's aspirations to achieve middle-income status by 2030 and to contribute to the Paris Agreement, as indicated in the country's Nationally Determined Contribution (NDC) as well as the Climate Change Act (2016).

The government has identified substantial potential for power generation using forestry and agro-industry residues, including sugarcane bagasse. The total potential for cogeneration using bagasse is 193 megawatts (MW). Opportunities within other sugar factories are estimated to reach 300 MW but have not been exploited. Other bioenergy uses in Kenya include biogas, fuelwood, briquettes, pellets, charcoal and, to a lesser extent, ethanol. The technical potential to achieve sustainable biomass production in the country is still under development (Diaz-Chavez 2016).

In Kenya, biomass use accounts for 68 per cent of the energy mix. Overall energy demand is rising due primarily to rapid economic growth. The country's biomass use, coupled with growth, has serious implications for the bioenergy sector, particularly as Kenya has no bioenergy sustainability framework. In addition, a lack of, or inconsistency in, the monitoring and evaluation of national bioenergy programmes makes it difficult to track the contribution of biomass use to national sustainable development objectives. Gaps in the expertise of national researchers and policymakers, the decentralized nature of biomass and a lack of financial resources for data collection and analysis generate additional barriers to achieving sustainability in the sector.

Furthermore, data are poor on the environmental, social and economic performance of national programmes. Data tend to come from research with a narrow scope, and results are not placed in the wider national sustainable development context. While awareness exists concerning bioenergy sustainability and some multi-stakeholder engagement, there is not yet a clear, agreed means of measuring the sustainability of bioenergy. A robust understanding among stakeholders of the multiple benefits of sustainable bioenergy is lacking.

3. BAGASSE BRIQUETTES AND CHARCOAL: TWO PRIORITY BIOENERGY PATHWAYS

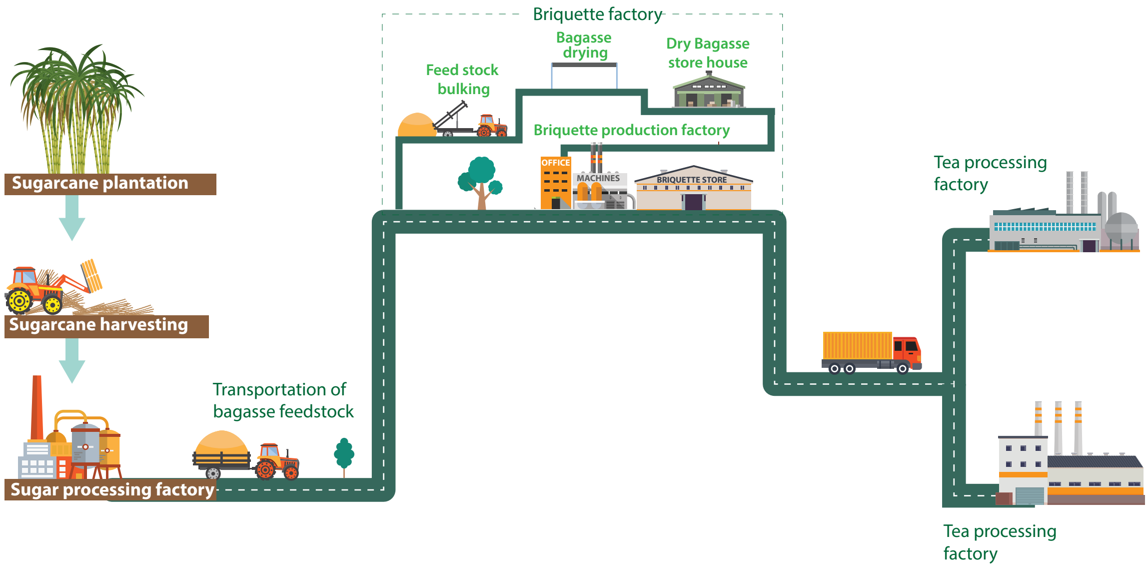
USE OF SUGARCANE BAGASSE BRIQUETTES IN THE TEA INDUSTRY

This bioenergy pathway focuses on the use of sugarcane bagasse briquettes in the tea industry in Kenya as an alternative to firewood (Figure 0.1).

The demand for firewood for use in the tea industry is around 1 million tons each year. The briquetting industry is picking up rapidly in the country as a potential source of livelihood as well as of fuel for industrial, institutional and domestic use. Major consumers of non-carbonized briquettes include the tea industry, schools and hospitals, the tobacco industry and the vegetable oil processing industry. According to the Sugar Directorate, the country's 12 sugar mills generate around 2.4 million tons of bagasse annually that remain unutilized.

Production of the briquettes begins with the collection of agricultural residues from millers and farmers. The feedstock is then dried either in the open air or in industrial rotary systems at high temperatures to reduce the moisture content to less than 15 per cent, and then is compressed at high pressure to form briquettes. The bagasse briquettes contribute to 5 per cent of the annual final energy demand of the tea industry, or an estimated 490 tons of wood equivalent per year (7,400 megajoules (MJ) per year). Although the use of briquettes saves around 490 tons per year of wood resource, the economic cost intensity of

Figure 0.1 Value chain of sugarcane bagasse briquettes



obtaining similar energy from briquettes is around three times more compared to firewood.

The indicators are reported for company X as a reference to a company based in Kisumu city in western Kenya that produces briquettes from sugarcane bagasse. The company produces 50 to 70 tons of briquettes from sugarcane bagasse, of which 40 per cent goes to tea factories. The tea industry is referred to as Y and uses the briquettes from company X as a source of energy for the heating process.

HOUSEHOLD USE OF CHARCOAL PRODUCED ON WOODLANDS AND FARMLANDS

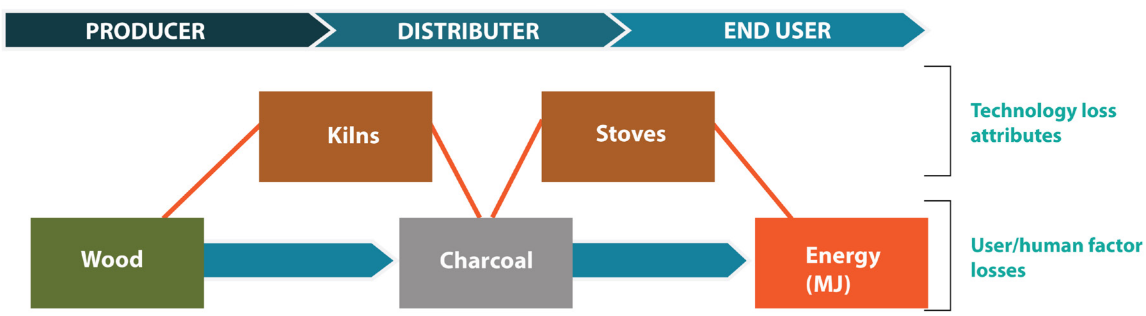
This pathway focuses on the production of charcoal on woodlands and farmlands that is used at the household level (Figure 0.2).

Demand for charcoal is increasing rapidly in Kenya as a result of population growth, increased urbanization and the development of cottage industries. Around 80 per cent of the population uses solid fuels for cooking, often in rudimentary and inefficient stoves with no or poorly operating chimneys. Around 39 million people, or 87 per cent of the population, are affected by household air pollution, which resulted in an estimated 13,900 to 15,140 deaths in 2016 (CCA 2019). Today an estimated 2.5 million tons of charcoal are produced in the country annually, up from 1.6 million tons in 2005. There are 253,808 charcoal producers nationwide, up 27 per cent from the estimated number in 2005 (Ministry of Environment 2013; Mutimba and Barasa 2005).

In Kenya, charcoal is produced mainly from arid and semi-arid lands, which includes the counties of Baringo, Elgeyo Marakwet, Garissa, Kajiado, Kilifi, Kitui, Kwale, Laikipia, Makueni, Mt Elgon, Narok, Nyandarua, Tana River, Tharaka Nithi and Turkana (KNBS 2018a). The tree species preferred for charcoal production are Acacia species. Nairobi is the county that consumes the most charcoal in Kenya, and 70 per cent of the charcoal consumed in this county is produced mainly in Kitui and Narok. This is the focus of the pathway analysed by the indicators.

Kenya introduced a ban on charcoal production in 2018, but charcoal is still produced from woodlands and farmlands. Nearly half a million people work in the charcoal sector, which generates more than $427 million annually but is not considered part of the formal economy of the country (Njenga 2018).

Figure 0.2 Charcoal value chain.



Source: Transrisk 2018

4. KEY FINDINGS FROM THE 24 INDICATORS

INDICATOR 1. LIFE CYCLE GREENHOUSE GAS EMISSIONS

DEFINITION

(1.1) Lifecycle greenhouse gas emissions from bioenergy production and use.

MEASUREMENT UNIT(S)

Grams of CO_2 equivalent per megajoule (gCO_{2eq}/MJ)

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- The spreadsheet-based life cycle analysis tool, developed by the Institut für Energie und Umweltforschung Heidelberg in partnership with the Global Bioenergy Partnership and UNEP, was used to quantify the carbon dioxide, methane and nitrous oxide emissions of each stage of the value chain.
- Emission factors are based on international literature and life cycle analysis databases and adapted to Kenya.
- In the case of the bagasse briquettes, the analysis was based on a case study of briquette-producing company X[1] supplying to tea industry Y[2] that uses briquettes as a source of input energy. The analysis scope included briquette production from sugarcane bagasse as well as its transport and combustion in the tea industry, as the reference encompassed wood harvesting and chipping, transport and combustion.
- In the case of charcoal, the focus is on charcoal consumed in Nairobi and produced in Narok and Kitui counties. Two cases were considered: highly efficient processes (high adoption of improved cookstoves and conversion kilns) and business as usual (a mix of inefficient stoves and kilns, as in the current situation).

Bagasse Briquettes

KEY FINDINGS

- Emissions increased by around 1 gCO_{2eq}/MJ (21 per cent) in the bioenergy pathway compared to the reference case (Table 1.1).
- Briquette transport contributed to around 64 per cent of emission intensity, and manufacture and combustion contributed to 28 per cent and 8 per cent respectively. In the reference case, harvesting and chopping of wood chips contributed to 72 per cent of total emissions, and transport and combustion yielded 15 per cent and 13 per cent respectively.

[1]Company X refers to a reference company based in Western Kenya region in Kisumu city that produce briquettes from sugarcane Bagasse. The company produces 50 to 70 tons of briquettes from sugarcane bagasse of which 40% goes to tea factories
[2]Tea industry Y uses briquettes from company X as source of energy for process heating

Table 1.1. Life cycle greenhouse gas emissions of the bioenergy pathway

	g CO_{2eq}/MJ Heat
Bagasse briquette (pathway)	5.9
Stem wood (reference)	4.9
Avoided emission in gCO_{2eq}/MJ heat	-1.0

Source: Own calculation

KEY MESSAGES

- The policy consideration is the use of briquettes as a form of sustainably produced bioenergy, used within a radius of 100 kilometres from generation.
- Spatial and temporal surveys are needed of the availability of agricultural and forest residues for briquette manufacturing within the tea-growing zones to provide the needed bioenergy.

MORE IN THE TECHNICAL REPORT

- Detailed assumptions of the pathway scope.
- Graphical representation of life cycle emissions resulting from reduced briquette transport distance.
- Practices and policies to improve sustainability.
- Future recommendations.

Charcoal

KEY FINDINGS

- In the case of highly efficient processes, the greenhouse gas emission intensity for Kitui and Narok reached 38.9 gCO_{2eq}/MJ and 38.7 gCO_{2eq}/MJ respectively, compared to 49.0 gCO_{2eq}/MJ and 48.5 gCO_{2eq}/MJ respectively in the business-as-usual case.
- Emission intensity related to transport is halved in the highly efficient case compared to the business-as-usual case, given the assumption that trucks are loaded with other goods once charcoal was delivered. Biogenic methane emissions constitute 81 per cent of greenhouse gas emissions. The implication is that both scenarios will continue to have substantial greenhouse gas emissions. Absolute emission savings in both cases (Kitui and Narok) is around 10 gCO_{2eq}/MJ heat, which translates to 21 per cent emission abatement.

KEY MESSAGES

- In the case of highly efficient processes, the greenhouse gas emission intensity for Kitui and Narok reached 38.9 gCO_{2eq}/MJ and 38.7 gCO_{2eq}/MJ respectively, compared to 49.0 gCO_{2eq}/MJ and 48.5 gCO_{2eq}/MJ respectively in the business-as-usual case.
- Emission intensity related to transport is halved in the highly efficient case compared to the business-as-usual case, given the assumption that trucks are loaded with other goods once charcoal was delivered. Biogenic methane emissions constitute 81 per cent of greenhouse gas emissions. The implication is that both scenarios will continue to have substantial greenhouse gas emissions. Absolute emission savings in both cases (Kitui and Narok) is around 10 gCO_{2eq}/MJ heat, which translates to 21 per cent emission abatement.

MORE IN THE TECHNICAL REPORT

- Detailed description of the two cases.
- Comprehensive list of datasets considered in the computation.
- Graphical representation of emission contribution from various process stages.
- Full description of policy recommendations.

INDICATOR 2. SOIL QUALITY

DEFINITION

(2.1) Percentage of land for which soil quality, particularly in terms of soil organic carbon, is maintained or improved out of total land on which bioenergy feedstock is cultivated or harvested.

MEASUREMENT UNIT

Percentage (%)

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- The methodological approach was adapted to the set of conditions found in Kenya. It was not possible to carry out direct soil surveys and consequent analyses of soil organic carbon and other parameters related to soil quality. Therefore, secondary data were retrieved from the relevant institutions in the country, and analyses were performed.
- Some limitations due to specific data scarcity were encountered. Information available from different governmental reports, national research institutions and institutions of higher learning on soil quality in Kenya was found to be insufficient to define the percentage of land for which soil quality is maintained or improved out of the total land devoted to bioenergy feedstock cultivation.

National level

KEY FINDINGS

- The difficulties encountered during the measurement of this indicator highlighted the need for harmonized time series of soil quality data for parameters of interest.
- Primary data collection activities (data collection campaign), soil sampling in the field, and in situ and laboratory analyses of the samples should be performed at appropriate intervals as proposed by the GBEP methodological approach.
- It is recommended to involve landowners/ managers and bioenergy producers in the collection of primary data in the field. This is particularly the case for soil organic carbon content in the soils used for bioenergy feedstock production, where the scarce literature that was found has presented inconsistent results.
- A systematic surveying of soil management practices is needed to determine whether risks to soil quality are being managed adequately and to gain a better understanding of how soil quality could be improved in areas of bioenergy feedstock production. This would require the compilation of good practices suited to specific soil and agroecological conditions and crops, building on what is already known within the sector.

KEY MESSAGES

- Unsustainable fuelwood collection and charcoal production may lead to deforestation and soil loss. The impact of deforestation and overexploitation of particular species such as Acacia has impacts on both biodiversity and land degradation.
- There are insufficient baseline data and monitoring of soil organic carbon and other key soil quality parameters, including soil management practices.
- Increased (and methodical) soil quality monitoring in key sugarcane and Eucalyptus areas would be advantageous.
- Organization of information on the implementation of good agricultural practices (GAPs) favouring soil quality (including soil

organic carbon) maintenance or increases would seem a cost-efficient alternative or complement.

- Site-specific techniques of restoring soil quality include conservation agriculture, integrated nutrient management and continuous vegetative cover such as residue mulch and cover cropping, and controlled grazing at appropriate stocking rates.

MORE IN THE TECHNICAL REPORT

- Soil type classification in Kenya by region.
- Detailed explanation of the impacts of deforestation on fuelwood and charcoal production.

INDICATOR 3. HARVEST LEVELS OF WOOD RESOURCES

DEFINITION

(3.1) Annual harvest of wood resources by volume and as a percentage of net growth or sustained yield, and the percentage of the annual harvest used for bioenergy.

MEASUREMENT UNIT(S)

Cubic metres per hectare per year (m^3/ha/year), tons/ha/year, m^3/year or tons/year, percentage

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Secondary data were used to determine the amount of wood residue that is used as fuel during the harvesting of plantations for timber and other products. While no removal of wood from natural forests is officially allowed, a large unquantified amount of firewood is removed by communities near forests.

KEY FINDINGS

- The total wood supply in 2012 was 31,405,060 m^3, compared with a demand of 41,700,664 m^3 (MEWNR 2013).
- Removals from natural forests are mainly in the form of firewood that is consumed at a household level and by local institutions including schools and hospitals. Small quantities are sold to tea factories.
- Removals from woodlands are typically not adequately controlled, as policing of these areas is by county governments that have insufficient law enforcement personnel.
- From the total of 855,399 tons of fuelwood consumed by tea factories (April 2019), the leftovers after plantation harvesting – including the bark, small stems, tops and branches – form the bulk of the fuelwood, comprising around 55 per cent of the total volume.

Table 3.1. Total wood supply (m^3) by product in Kenya in 2012

Timber	Poles	Firewood	Charcoal
7 363 41	3 028 907	13 654 022	7 358 717

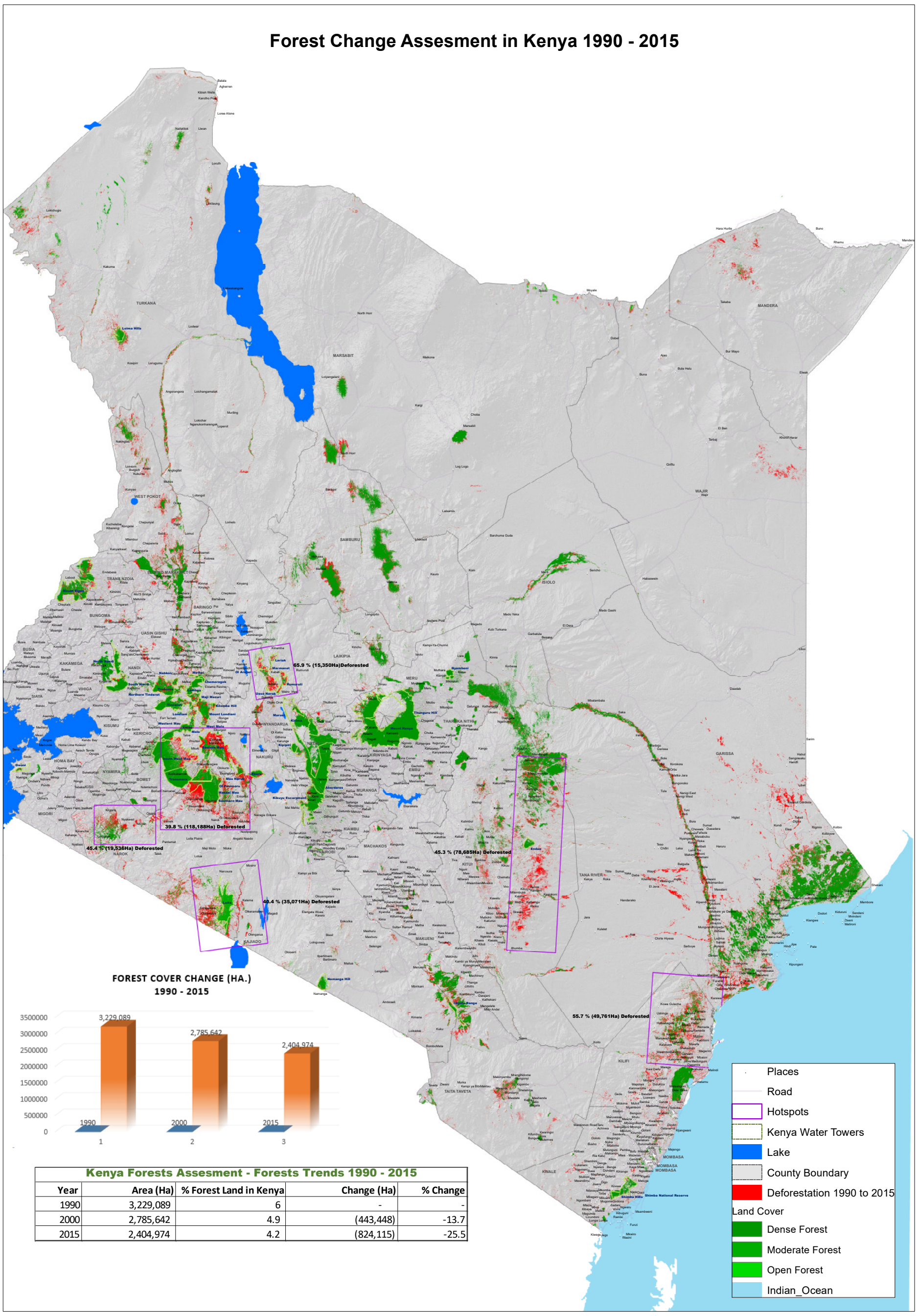
Source: MEWNR 2013

Table 3.2. Yields (m³/ha) for different forest types and products

Forest type	Rotation period	Wood products			
		Timber	Poles	Fuelwood	Total
Natural forests (public and community)	-	0.4	0.2	0.9	1.5
Public plantation forests	28 years	262.20	44.50	100.80	407.5
Community/Private plantations	21 years	88.17	140.66	178.52	407.35
Trees on farms	8 years	3.52	1.23	12.83	17.58

Source: MEWNR 2013

Figure 3.1. Key deforestation hotspots in Kenya



Source: WWF 2019

KEY MESSAGES

- Annual harvest data are difficult to find in Kenya. Production in cubic metres was found for the eucalyptus plantations used mainly in the tea industry.
- Considering the heavy reliance on firewood and charcoal, more plantations should be established in Kenya specifically to supply firewood and charcoal. However, access to woodlands as a source of wood for energy must be controlled in order to gather data on the amount harvested per year.
- While major efforts are geared towards obtaining accurate data on timber volume and ignoring the branches, tops and stumps, more studies are necessary to assess their contribution to fuelwood use. This would provide a better and truer value of trees in the country.

MORE IN THE TECHNICAL REPORT

- Area of forest land in Kenya.
- Estimated current amount and projected wood demand.
- Impact of fuelwood harvested for charcoal production.
- Impact of the tea factories on wood demand.

INDICATOR 4. EMISSIONS OF NON-GREENHOUSE GAS AIR POLLUTANTS, INCLUDING AIR TOXICS

DEFINITION

(4.1) Emissions of non-greenhouse gas air pollutants, including air toxics, from 1) feedstock production, 2) processing, 3) transport of feedstocks, intermediate products and end products, and 4) use; and comparisons with other energy sources.

MEASUREMENT UNIT(S)

Emissions of particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen oxides, sulphur dioxide and other pollutants in 1) milligrams per hectare (mg/ha), milligrams per megajoule (mg/MJ) and as a percentage; 2) milligrams per cubic metre (mg/m3) or parts per million (ppm); 3) mg/MJ; 4) mg/MJ

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- The spreadsheet-based life cycle analysis tool, developed by the Institut für Energie und Umweltforschung Heidelberg in partnership with the Global Bioenergy Partnership and UNEP, was used to quantify the carbon dioxide, methane and nitrous oxide emissions of each stage of the value chain.
- Emission factors are based on international literature and life cycle analysis databases and adapted to Kenya.
- In the case of the bagasse briquettes, the analysis was based on a case study of briquette-producing company X supplying to tea industry Y that uses briquettes as a source of input energy. The analysis scope included briquette production from sugarcane bagasse as well as its transport and combustion in the tea industry, as the reference case encompassed wood harvesting and chipping, transport and combustion.
- In the case of charcoal, , the focus is on charcoal consumed in Nairobi and produced in Narok and Kitui counties. Two cases were considered: highly efficient processes (high adoption of improved cookstoves and conversion kilns) and business as usual (a mix of inefficient stoves and kilns, as currently).

Bagasse briquettes

KEY FINDINGS

- The use of firewood by tea factories emits 0.04 grams of sulphur dioxide, 0.07 grams of nitrogen oxides, 0.09 grams of carbon monoxide and 0.01 grams of PM_{10} per MJ of heat.

- The use of bagasse briquettes emits 0.04 grams of sulphur dioxide, 0.09 grams of nitrogen oxides, 0.09 grams of carbon monoxide and 0.01 grams of PM_{10} per MJ of heat.
- Compared to firewood, the use of bagasse briquettes increases emissions of sulphur dioxide by 3.7 per cent, of nitrogen oxides by 31.9 per cent, of carbon monoxide by 4.2 per cent and of $PM_{2.5}$ by 2.8 per cent.

KEY MESSAGES

- There is a need to gather data on emissions from the use of sugarcane bagasse briquettes and firewood in tea factories.
- Emission data for the trucks used for local transport were missing and need to be compiled.
- The best mix ratio of firewood and briquettes needs to be determined to reduce the formation of clinkers/ashes, lower emissions of non-greenhouse gas air pollutants and enhance combustion efficiency.
- Transport of briquettes needs to be reduced by setting up briquette production facilities near to the tea factories.

MORE IN THE TECHNICAL REPORT

- Stages studied in the use of sugarcane bagasse briquettes and firewood in tea factories, the distances covered and the scenarios considered.
- Emission per stage of the pathway (transport, processing and use) for the improved scenario.
- Recommended practices for improved sustainability of briquette use.

Charcoal

KEY FINDINGS

In reference to the conventional practice of charcoal production, transport and use, the high-efficiency case reduces emissions of gases and particles (Table 4.1).

Table 4.1. Emission reduction by improved charcoal production system

Gas/Particle (g/MJ)	Kitui			Narok		
	Reference case	High-efficiency case	% reduction	Reference case	High-efficiency case	% reduction
Sulphur dioxide	0.0017	0.0009	47	0.0014	0.0007	50
Nitrogen oxides	0.0312	0.0210	33	0.0273	0.0191	30
Carbon monoxide	12.0368	12.0344	0.02	12.0359	12.0340	0.02
PM_{10}	0.0826	0.0823	0.38	0.0825	0.0822	0.36

Source: Own calculation

Table 4.2. Emissions per stage in the pathway from the improved system

Gas/Particle (g/MJ)	Kitui			Narok		
	Transport	Processing	Use	Transport	Processing	Use
Sulphur dioxide	0.00084	0.00003	0.00003	0.00067	0.00003	0.00003
Nitrogen oxides	0.01008	0.00197	0.00578	0.00813	0.00197	0.00578
Carbon monoxide	0.00231	6.96875	5.06250	0.00186	6.96875	5.06250
PM_{10}	0.00031	0.01563	0.06625	0.00025	0.01563	0.06625

Source: Own calculation

KEY MESSAGES

- All the gases and particle emissions are reduced by 1) shifting from using fresh wood with around 50 per cent moisture content to air-drying wood to 20 per cent moisture content, 2) shifting from low to high adoption of improved kilns (from 10 per cent to 80 per cent) and stoves (from 38 per cent to 80 per cent) and 3) reducing distance in transport.
- Non-greenhouse gas emissions are increased mainly by the transport system.
- For sustainable charcoal production in Kenya, tree management and replanting plans through a variety of contextualized agroforestry systems is critical, integrated with improved kilns and stoves and reduced distance in the transport of charcoal.

MORE IN THE TECHNICAL REPORT

- Details of the scenarios (conventional and improved) considered in charcoal production, transport and use.
- Efficiency of the kilns used in the carbonization process and stoves used with the charcoal.
- Recommended practices for sustainable charcoal production.

INDICATOR 5. WATER USE AND EFFICIENCY

DEFINITION

(5.1) Water withdrawn from nationally determined watersheds(s) for the production and processing of bioenergy feedstocks, expressed

(5.1a) as the percentage of total actual renewable water resources (TARWR) and

(5.1b) as the percentage of total annual water withdrawals (TAWW), disaggregated into renewable and non-renewable water sources;

(5.2) Volume of water withdrawn from nationally determined watershed(s) used for the production and processing of bioenergy feedstocks per unit of bioenergy output, disaggregated into renewable and non-renewable water sources.

MEASUREMENT UNIT(S)

(5.1a) percentage, (5.1b) percentage, (5.2) m^3/MJ or m^3/kWh, or m^3/ton for feedstock production phase if considered separately.

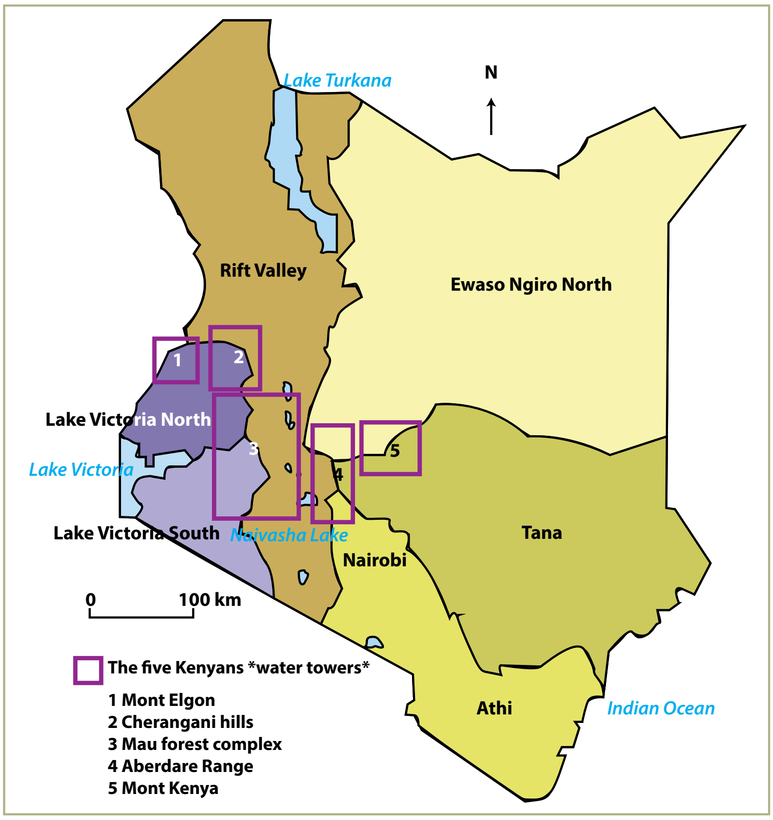
OVERALL METHODOLOGY OF THE IMPLEMENTATION

- The analysis was done at the country level. Briquettes and charcoal production do not use water.

KEY FINDINGS

- Agriculture and domestic use accounted for most of the total annual water withdrawal at 87 per cent, followed by livestock (8 per cent), industry (4 per cent) and wildlife and fisheries (1 per cent).
- The total annual renewable surface water in 2010 was an estimated 20.6 cubic kilometres (km^3) per year.
- Total available water is 586 m^3 per year per capita, based on the 2010 population, compared to the international benchmark of 1,000 m^3 per year per capita.
- Total water demand will increase from 3.2 km^3 per year in 2010 to 21.5 km^3 per year in 2030.
- The per capita water is 586 m^3 per year based on the 2010 population.
- Kenya has no specific crop grown for bioenergy production and relies on by-products of other crops.

Figure 5.1: Large catchments and main water towers of the Kenya



Source: Adapted from Rouille et al. 2015

KEY MESSAGES

- Kenya is a chronically water-scarce.
- Water demand will probably equal or surpass available water resources in the future. The Kenya Energy Act of 2019 encourages the uptake of renewable energy sources.
- Deforestation for fuelwood has affected water availability and is expected to have further impacts.

MORE IN THE TECHNICAL REPORT

- Description of Kenya's water resources by catchment area.
- Impacts of deforestation on water availability.
- Water demand by sector.

INDICATOR 6. WATER QUALITY

DEFINITION

(6.1) Pollutant loadings to waterways and bodies of water attributable to fertilizer and pesticide application for bioenergy feedstock production, and expressed as a percentage of pollutant loadings from total agricultural production in the watershed;

(6.2) Pollutant loadings to waterways and bodies of water attributable to bioenergy processing effluents in the watershed.

MEASUREMENT UNIT(S)

(6.1) Annual nitrogen and phosphorus loadings from fertilizer and pesticide active ingredient loading attributable to bioenergy feedstock production (per watershed area): in kilograms of nitrogen, phosphorus and active ingredient per hectare per year;

(6.2) Pollutant loadings attributable to bioenergy processing effluent: pollutant levels in bioenergy processing effluent in mg/litre.

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- A literature review of water quality in Kenya was performed, considering the impacts of piling bagasse as well as the soil impacts from deforestation for charcoal production.

Bagasse briquettes

KEY FINDINGS

- The backlog of bagasse is stacked in sugar mill yards before it finds its way to briquetting. Water pollution is caused by run-off from these bagasse piles.

KEY MESSAGES

- The bioenergy sector, especially briquette making, is relatively young, and no work has been done to quantify biochemical and chemical pollutants that emanate from this process that can be used as a reference point.
- Bagasse piling has a negative impact on water quality through acidification and eutrophication potential as well as photochemical oxidant creation.
- In the future, field research and monitoring activities should be carried out to assess the true extent of the indicator based on the selected pathway.

MORE IN THE TECHNICAL REPORT

- Secondary water quality data compiled across six catchments.
- Review of the quality of catchment water resources at a national level.

Charcoal

KEY FINDINGS

- Clearing of forest cover for charcoal production in the country increases soil erosion. The eroded material from soil and from the remnants of charcoal production moves downstream, causing sedimentation and siltation of waterways.
- Habitat modification through charcoal burning results in non-point pollution as degraded areas become prone to erosion.

KEY MESSAGES

- Data are limited on the impacts of deforestation on water quality.
- Deforestation in high mountains affects the water quality downstream due to solid material washed into rivers.

MORE IN THE TECHNICAL REPORT

- General water quality trends in the country.
- Data from studies conducted in Lake Victoria on pollutants from sugarcane production (although indirectly related to the pathway).

INDICATOR 7. BIOLOGICAL DIVERSITY IN THE LANDSCAPE

DESCRIPTION

(7.1) Area and percentage of nationally recognized areas of high biodiversity value or critical ecosystems converted to bioenergy production;

(7.2) Area and percentage of the land used for bioenergy production where nationally recognized invasive species, by risk category, are cultivated;

(7.3) Area and percentage of the land used for bioenergy production where nationally recognized conservation methods are used.

MEASUREMENT UNIT(S)

Absolute areas in hectares or square kilometres (km2) for each component and for total area used for bioenergy production. Percentages of bioenergy production area were calculated from these and given either separately for each relevant category (i.e., different types of priority areas for and specific methods) or as a combined total across such categories.

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- A review of secondary data (literature review, government reports, non-governmental organization reports, national figures) was performed.
- Biodiversity hotspot areas were reviewed, focusing on forestry and plant species by region, primarily in the sugarcane belt and in Narok and Kitui counties.

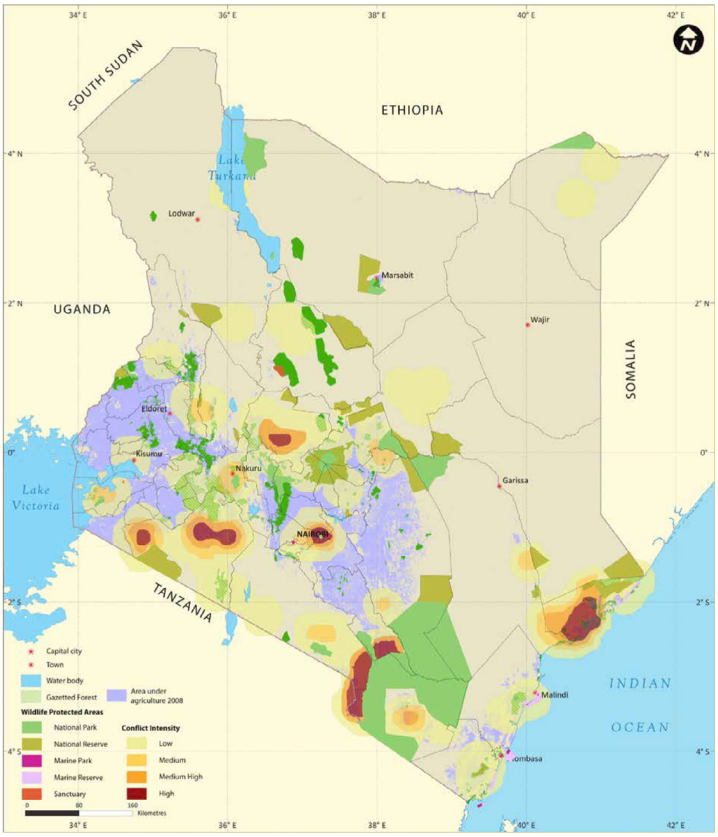
Bagasse briquettes

KEY FINDINGS

- The bulk of Kenya's biological diversity occurs in natural forests, game parks, nature reserves and private conservancies.
- The National Forest Program estimates that forest cover represents 7 per cent of the total land area (MENR 2016).
- Records from Kenya Wildlife Service estimate that terrestrial protected areas (game parks and nature reserves) represent 8.05 per cent of the total land area. The percentage of land that can be classified as biodiversity hotspots is around 15 per cent of the total land area.

- Biodiversity hotspots in areas near bagasse briquette production are related to the sugarcane production regions: sugar belt – Kisumu, Transmara, Migori, Kakamega (briquette production); tea industries in Kericho, Kisii, Nandi, Vihiga and Murang'a counties.
- The main impacts on biodiversity are from human-wildlife conflicts related to the expansion of agriculture, human settlements and roads, among others (Figure 7.2).

Figure 7.2. Human-wildlife conflict has increased with growing human pressure on land and wild species



Source: KWS in MEWNR, 2015

KEY MESSAGES

- A causal link between the use of biomass residues to produce briquettes in order to satisfy the energy needs of the tea industry may reduce the pressure on forests, with a gradual reduction in the consumption of primary wood biomass contributing to biodiversity conservation.
- Dedicated plantation of trees for the tea industry may allow for biodiversity improvements in areas where afforestation is needed.

MORE IN THE TECHNICAL REPORT

- Biodiversity hotspot regions in Kenya.
- National policies and international agreements promoting the conservation of biodiversity in Kenya.

Charcoal

KEY FINDINGS

- Biodiversity hotspots related to charcoal production are in Kitui and Narok counties, to provide charcoal to Nairobi.
- Charcoal production has impacts on indigenous species such as Acacia nilotica, Acacia xanthopholea, Euclea schimperi, Olea africana and Rhus natalensis, leading to conversion of woodlands into open grasslands.
- For Kitui county, charcoal production is more intense in Kitui East, North and South, with varied impacts on ecological and woodlands hectarage. These studies show evidence of 24 per cent woodland loss between 1986 and 2014 in parts of Kitui South. However, more work is required to measure trends in the change in coverage in all charcoal-producing hotspots.

KEY MESSAGES

- The indiscriminate exploitation of trees is generally higher on private land than in protected government forests.
- Historical trends indicate gradual loss of forest area, conversion of forests to bushlands and farm expansion.
- Data fitting the criteria defined in the biological diversity indicator are missing.

MORE IN THE TECHNICAL REPORT

- Policy instruments aimed at protecting biodiversity.
- Biodiversity risks in sugarcane production regions and in charcoal-producing regions.

INDICATOR 8. LAND USE AND LAND-USE CHANGE RELATED TO BIOENERGY FEEDSTOCK PRODUCTION

DEFINITION

(8.1) Total area of land for bioenergy feedstock production, and as compared to total national surface and (8.2) agricultural land and managed forest area;

(8.3) Percentages of bioenergy from: (8.3a) yield increases, (8.3b) residues, (8.3c) wastes, (8.3d) degraded or contaminated land;

(8.4) Net annual rates of conversion between land-use types caused directly by bioenergy feedstock production, including the following (among others):

- arable land and permanent crops, permanent meadows and pastures, and managed forests
- natural forests and grasslands (including savannah, excluding natural permanent meadows and pastures), peatlands and wetlands.

MEASUREMENT UNIT(S)

(8.1-2) hectares and percentages, (8.3) percentages, (8.4) hectares per year.

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Secondary data were used in addition to links to Indicator 3 on harvested area and Indicator 9 on allocation and tenure of land.
- The national level was reported but was focused on the forest area for charcoal production and eucalyptus plantations that are produced for the tea industry.

- The total area of land for bioenergy feedstock was calculated and pro-rated based on focused national charcoal demand, yield of biomass and estimated harvesting profile.

Bagasse briquettes

KEY FINDINGS

- In the case of the tea factories assessed, the factory uses 2 m^3 of wood per hour or around 22,426 m^3 of wet wood annually. As such, 30 per cent replacement of wood would yield 6,728 m3 of wood translating to land cover conservation estimated at 17 hectares of land annually.
- Forest plantations used by tea factories in Kenya over a 30-year period may increase forest land and contribute to land conservation.
- Replacing 30 per cent of firewood used in tea industries would reduce 342,000 m^3 of wood nationally per year required for tea processing.

KEY MESSAGES

- Biomass briquettes present an alternative use of bioenergy feedstocks in Kenya, which also provides an opportunity for forest conservation.
- Land use for private plantations may be incorporated into other programmes for afforestation.
- This indicator needs to be linked to Indicator 3 on harvested area and Indicator 9 on land tenure.

MORE IN THE TECHNICAL REPORT

- Details on land type and description of land management classification as considered by the Kenya Forestry Service.
- In-depth quantitative information on how waste conversion to energy could translate to sustainable bioenergy in the tea sector.

Charcoal

KEY FINDINGS

- Net additional land of 0.61 million hectares is needed to satisfy charcoal needs.
- The percentage of land for charcoal as a share of agricultural land (cropland and pastureland) and total national land cover was determined to be 4 per cent and 2 per cent respectively.

KEY MESSAGES

- As the population grows and urbanization increases, the demand for wood to produce charcoal will increase an estimated 55 per cent by 2030. Consequently, land required to produce charcoal will need to increase.
- Charcoal may need to be produced entirely from range land and restored degraded land to provided additional area and yields to satisfy the charcoal demand. This will need to be coupled with more-efficient kilns, cookstoves and particular tree species.

MORE IN THE TECHNICAL REPORT

- Further discussion on the implications of farm forestry for bioenergy feedstock.
- Detailed methodology for landcover analysis.

INDICATOR 9. ALLOCATION AND TENURE OF LAND FOR NEW BIOENERGY PRODUCTION

DEFINITION

(9.1) Percentage of land – total and by land-use type – used for new bioenergy production where: (9.1) a legal instrument or domestic authority establishes title and procedures for change of title; and (9.2) the current domestic legal system and/or socially accepted practices provide due process and the established procedures are followed for determining legal title.

MEASUREMENT UNIT(S)

Percentage

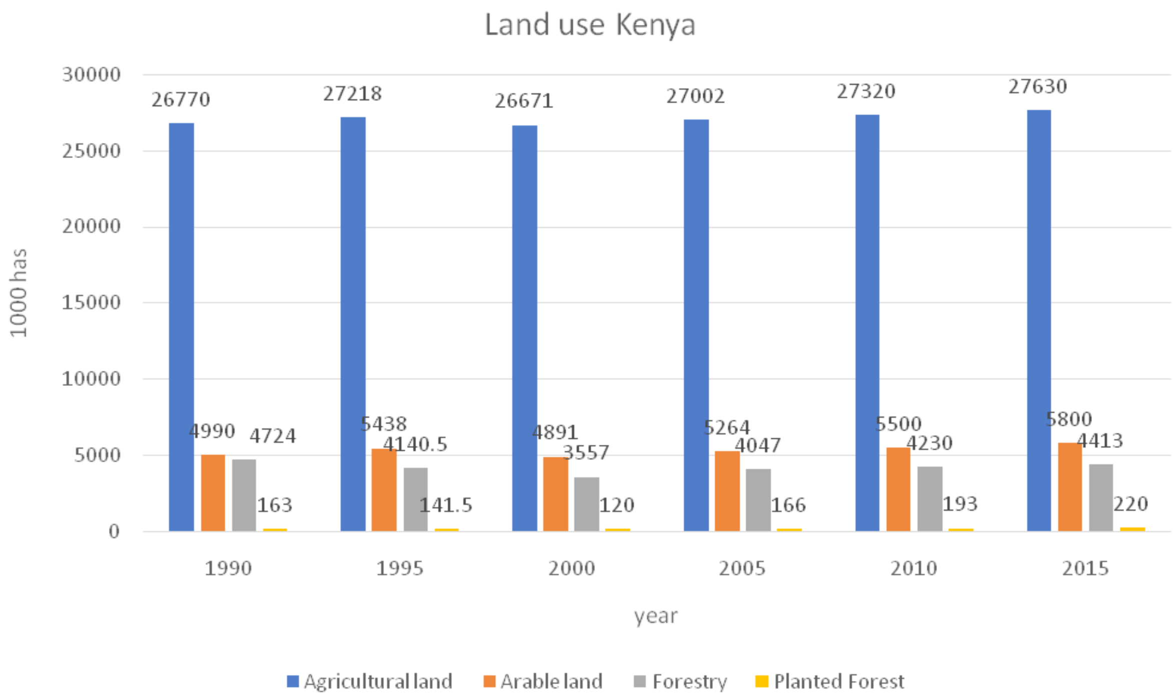
OVERALL METHODOLOGY OF THE IMPLEMENTATION

- A review of the literature (journals, non-governmental organization reports, government reports) and of national policies was performed.
- Links were made to Indicator 3 on harvested area and Indicator 8 on land use.
- No data were collected on the size or percentage of land under each type of property, except for forest land.
- This indicator is calculated at the national level.

KEY FINDINGS

- Public land in Kenya includes forest reserves, water bodies, national parks, townships and other urban centres, land reserved for government institutions and any other special category of land that may be acquired by the government for public use.
- The lack of data on land converted from private use to public use through compulsory acquisition is a problem in Kenya.
- An estimated 10 per cent of land in Kenya is categorized as public tenure (Kameri-Mbote 2016).

Figure 9.1. Land use in Kenya



Source: FAO 2019

- The surface cover of agricultural land, the main type of land use in Kenya, has not changed much in 25 years, from 267,700 hectares in 1990 to 276,300 hectares in 2015. Forestry land has changed during this period, and the planted area has increased significantly.
- Most of the forest land (77 per cent) is under community and private ownership, while the rest (23 per cent) is public.
- Regarding the links to bioenergy, private plantations cover 37 per cent of the total forest plantation area, which is almost equal to the area of stocked plantations under public management.

Gender and land tenure

- Customary practices in Kenya grant women only secondary rights to land and property through male relatives.
- Around 32 per cent of households in Kenya are headed by women, but only 1 per cent of land titles are held by women, and 5 per cent of land titles are held jointly with women and men (Mbugua 2018).
- In 2013, the country made some moves to strengthen women's land rights by passing the Matrimonial Property Act 2013, which reinforced the equal rights enshrined in the constitution for both spouses when they own property together and granted some new rights to women landowners. However, many obstacles still remain, including cultural tradition and lack of awareness.

KEY MESSAGES

- Overall the land tenure system in Kenya is clear and establishes the different types of property, although it does not favour some stakeholders, such as women, particularly in communal land.
- It is not possible to gather data on land by type of property.
- The enforcement system on land property continues to be a problem in Kenya.

MORE IN THE TECHNICAL REPORT

- Land-use classification.
- Explanation of land tenure types.
- Governance of land.

INDICATOR 10. PRICE AND SUPPLY OF A NATIONAL FOOD BASKET

DEFINITION

(10.1) Effects of bioenergy use and domestic production on the price and supply of a food basket, which is a nationally defined collection of representative foodstuffs, including main staple crops, measured at the national, regional and/or household level, taking into consideration:

- Changes in demand for foodstuffs, feed and fibre
- Changes in the import and export of foodstuffs
- Change in agricultural production due to weather conditions
- Changes in agricultural costs from petroleum and other energy prices
- The impact of price volatility and price inflation of foodstuffs on the national, regional and/or household welfare level, as nationally determined.

MEASUREMENT UNIT(S)

Tons; US dollars; national currency (Kenyan shillings); percentage

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Literature review and assessment was performed based on the Kenya National Bureau of Statistics horizontal analysis (2005-2015) on poverty and food and non-food expenditure using the national food basket.
- A family food basket is based on the prevalent food situation of a country, and the monetary value of it is based on minimum wages. It considers the quantity of food that should be included in the diet (Flores and Bent 1980).
- Welfare based on consumption expenditures was assessed, and the poverty line of Kenya was computed, including the food basket.
- A horizontal study was conducted at the national level (2005-2015) to see the evolution. It was particularly important to see the expenditure on fuels (charcoal).

KEY FINDINGS

- The main difference between the two food baskets (rural and urban) was that consumption of meat was more significant in urban areas.
- The food poverty rate in Kenya has decreased in 10 years, including by -12.4 at the national level, -13.7 in rural areas, -14.4 in peri-urban areas and -4.6 in core urban areas.
- In the agricultural sector, the supply of charcoal was an estimated 62,286.33 terajoules (TJ) and the supply of firewood was an estimated 846,441.85 TJ (KNBS 2018b). As a natural input for energy in 2017, biomass wood was reported to be 122,550.00 TJ in the manufacturing sector and 787,342.82 TJ for households.
- Considering the amount of biomass demand and use at the household level, and the poverty levels, the prices of charcoal affect affordability.

Table 10.1. First five items in the urban food basket

Food item	Share in basket	Kilocalories (100 g)	Median urban price (Kenyan shillings / 100 g)	Kilocalories per 100 Kenyan shillings	Kenyan shillings for 2,250 kilocalories
Unpackaged fresh cow’s milk	0.080	72	6.0	95.7	6.68
Sugar	0.072	375	10.0	268.5	6.00
Loose maize flour	0.064	264	5.0	336.5	5.34
Beef with bones	0.053	223	40.0	29.8	4.48
Cooking oil	0.052	900	15.8	293.1	4.32

Source: KNBS 2018a

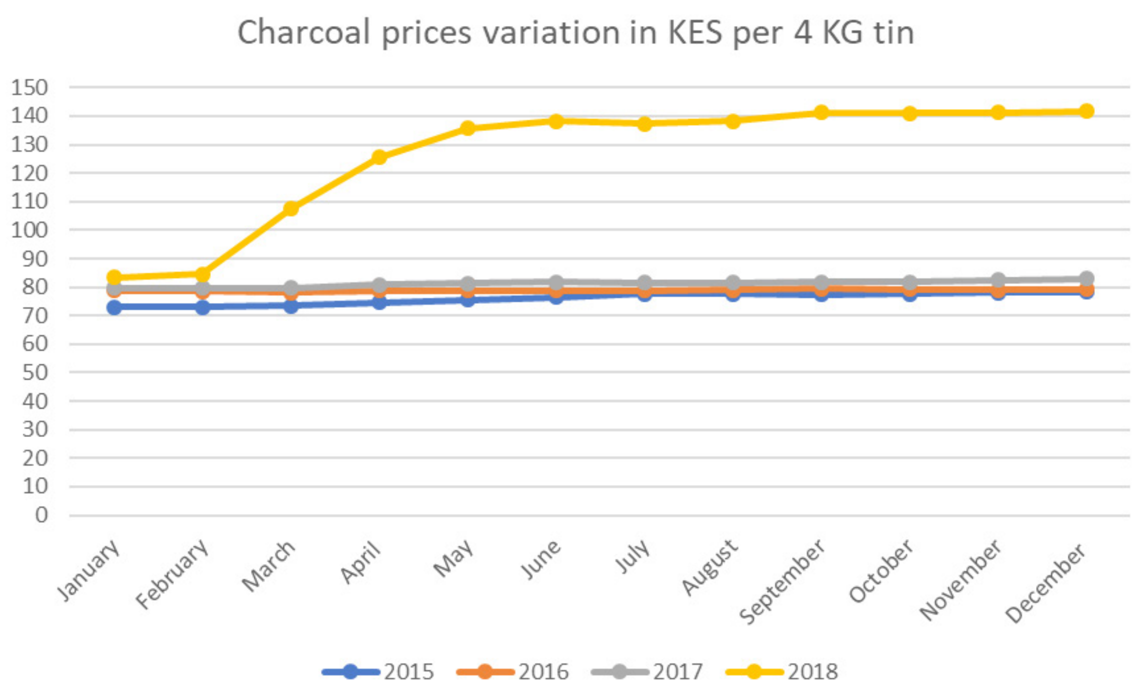
Table 10.2. First five items in the rural food basket

Food item	Share in basket	Kilocalories (100 g)	Median urban price (Kenyan shillings / 100 g)	Kilocalories per 100 Kenyan shillings	Kenyan shillings for 2,250 kilocalories
Loose maize flour	0.164	264	5.0	863.5	10.50
Unpackaged fresh cow's milk	0.105	72	5.0	150.5	6.71
Sugar	0.090	375	10.3	329.4	5.81
Beans	0.064	324	8.0	257.6	4.09
Loose maize grain	0.038	353	3.5	385.4	2.45

Source: KNBS 2018a

- Linking the food basket to energy consumption (in terms of prices) requires analysing the prices of the energy used at the household level. Three issues were analysed in this indicator: the food basket price, the urban and rural poor, and the prices of charcoal for cooking, as per Figure 10.1.

Figure 10.1. Charcoal price variation in Kenyan shillings per 4 kilogram tin



Source: KNBS 2018a

KEY MESSAGES

- Achieving sustainable charcoal production and other sources of energy with affordable prices should be part of an energy policy linked to the Sustainable Development Goals.
- Kenya has a well-established methodology for the food basket that can be used for monitoring it in future assessments

MORE IN THE TECHNICAL REPORT

- Full description of the methodology.
- The 10 main food items and differences between the rural and urban food baskets in prices as well as in the share of these items in the food basket.
- The methodology used by the Kenya National Bureau of Statistics.
- Statistics on charcoal prices for 2015-2018.

INDICATOR 11. CHANGE IN INCOME

DEFINITION

Contribution of the following to change in income due to bioenergy production:

(11.1) Wages paid for employment in the bioenergy sector in relation to comparable sectors;

(11.2) Net income from the sale, barter and/or own-consumption of bioenergy products, including feedstock, by self-employed households/individuals.

MEASUREMENT UNIT(S)

(11.1) local currency units per household/individual per year, and percentages (for share or change in total income and comparison);

(11.2) local currency units per household/individual per year, and percentages (for share or change in total income and comparison).

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- For bagasse briquettes, the indicator was based on a mixed methodology using literature review and data gathered from reports as well as interviews conducted in selected briquette manufacturing plants and in selected tea factories.
- Based on secondary data and interviews, wages were calculated for the main activities within the briquette factories and the tea factories.
- Due to the lack of detailed data on production costs for the different actors along the charcoal value chain, the net income per activity and per individual could not be calculated. Thus, only revenue values are presented for the charcoal pathway.
- Revenue values for each actor along the charcoal value chain are presented per amount of charcoal produced rather than on an individual basis. This is due to the lack of accurate information about the number of individuals involved in each of the activities in the value chain.

Bagasse briquettes

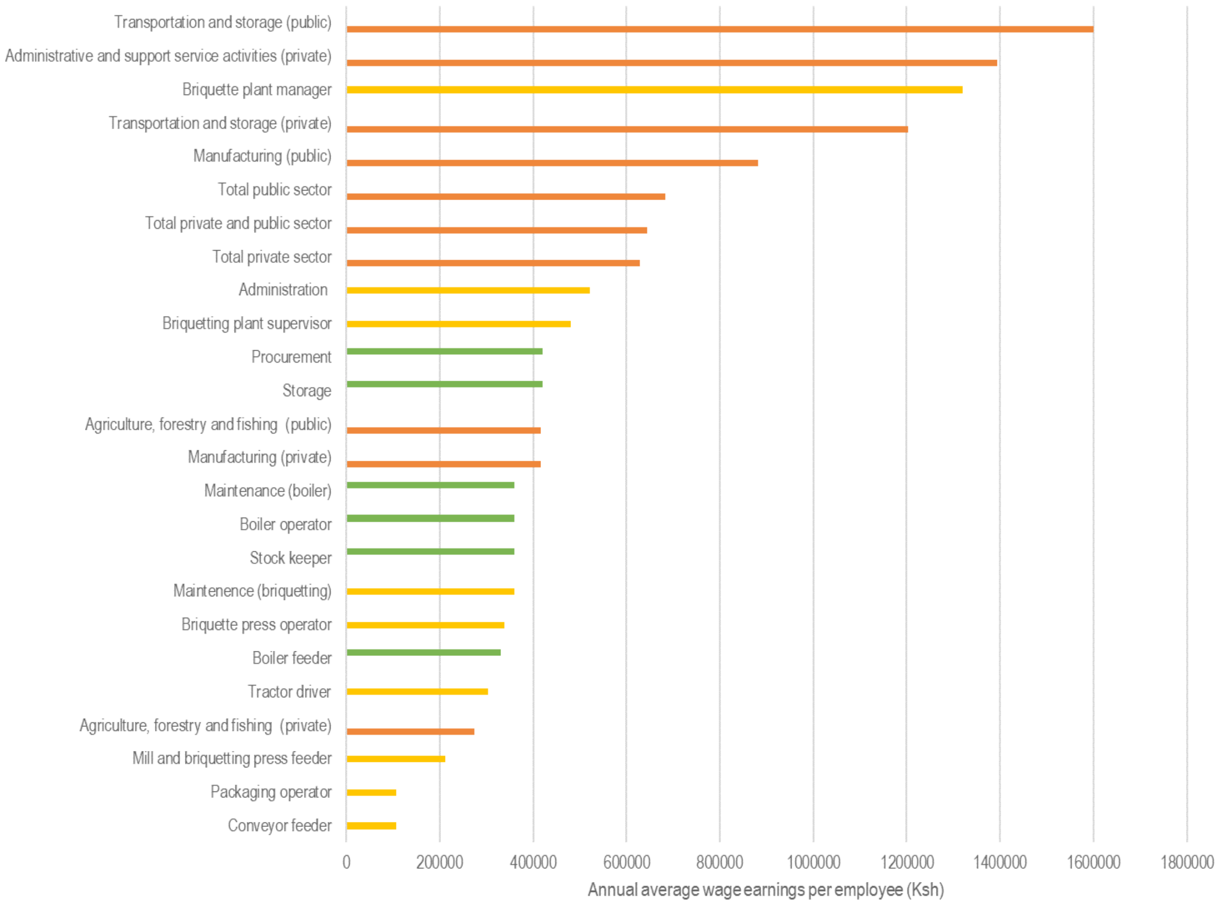
KEY FINDINGS

- Activities within the briquette factories that provide employment (formal and informal) and wages to employees include bagasse drying and briquetting.
- After briquette production, employment includes transporting the briquettes to the tea

factory, receiving and storing the briquettes at the tea factory, and boiler feeding and operation.

- Assessment of the annual wage earnings per employee in Kenya's main sectors during 2013-2016 showed that the average annual earnings per employee in the private and public sectors in 2016 was 645,035.2 Kenyan shillings and increased 5.9 per cent from 2015. The increase in average earnings in 2016 was slightly higher for the public sector (6.4 per cent) compared to the private sector (5.7 per cent).

Figure 11.1. Annual average wage earnings per employee for a selection of sectors in Kenya in 2016 (orange) and annual average reported wage earnings per employee for the workers from the three interviewed briquetting plants (yellow) and the three interviewed tea factories (green)



Source: KNBS 2018a

KEY MESSAGES

- Automation is generally low among Kenyan briquetting plants.
- Earnings for most of the workers in the interviewed factories are above those for workers in agriculture, forestry and fishing.
- Briquette plant managers are the only workers in the interviewed factories whose annual wage earnings are, on average, above the annual average earnings for the private and public sectors in Kenya.

MORE IN THE TECHNICAL REPORT

- Detailed description of the six income-generating activities within bagasse briquettes.
- Detailed conclusions and recommendations.

Charcoal

KEY FINDINGS

- There are 253,808 charcoal producers nationwide, up 27 per cent from the estimated number in 2005.
- The charcoal value chain provides revenue to all actors.

Table 11.1 Monthly revenue distribution among key actors along the charcoal value chain from the charcoal production reported in interviews with the charcoal producers associations (i.e., 25,000 bags of approximately 50 kg each)

Actors	Share values	Monthly revenue	
		Kenyan shillings	$
Wood producers	6%	2 405 080	23 792
Charcoal producers	16%	6 022 319	59 576
Transporters	37%	13 776 296	136 283
Wholesalers	13%	4 733 197	46 823
Retailers	28%	10 563 109	104 496
TOTAL	100%	37 500 000	370 971

Source: KNBS 2018

KEY MESSAGES

- Revenues in the charcoal value chain are concentrated among transporters and vendors.
- Bribery is a common practice in the charcoal sector.

MORE IN THE TECHNICAL REPORT

- Detailed description of the five key actors identified along the charcoal value chain.
- Detailed conclusions and recommendations.

INDICATOR 12. JOBS IN THE BIOENERGY SECTOR

DEFINITION

Net job creation as a result of bioenergy production and use, total (12.1) and disaggregated (if possible) as follows:

(12.2) Skilled/unskilled

(12.3) Permanent/temporary

(12.4) Total number of jobs in the bioenergy sector; and percentage adhering to nationally recognized labour standard consistent with the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work, in relation to comparable sectors (12.5).

MEASUREMENT UNIT(S)

(12.1) number and number per MJ or MW

(12.2) number, number per MJ or MW, and percentage

(12.3) number, number per MJ or MW, and percentage

(12.4) number and as percentage of (working-age) population

(12.5) percentages

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Literature review and interviews were conducted with three briquetting plants, three tea factories and one charcoal producer association.
- Reported job numbers were disaggregated into skilled/non-skilled and permanent/temporary where possible. Based on the bagasse calorific value, 18.3 MJ/kg (García López 2016), and the briquette production of each of the three briquetting plants, the number of employees per MJ was also estimated.

Bagasse briquettes

KEY FINDINGS

- In general, the informal sector is predominant in Kenya, accounting for around 80 per cent of the working population.
- All of the jobs identified in pathway 1 seem to follow the principles enumerated in the ILO Declaration on Fundamental Principles and Rights at Work.

Table 12.1. Qualitative data summarized from data collected during interviews with the briquetting plants and tea factories

Job category/description		Sub-Indicator 12.2		Sub-Indicator 12.3		Sub-Indicator 12.6	
		Skilled	Unskilled	Temporary	Permanent	Male	Female
Transport	Truck driver	X			X	X	
	Truck assistant		X		X	X	
Production	Bagasse sun drying		X	X			X
	Mill and press feeders		X		X	X	
	Press operator	X			X	X	
	Maintenance	X			X	X	
	Plant manager	X			X	X	
	Administrative	X			X		X
	Packaging		X		X	X	
Consumption	Procurement	X			X	X	
	Receiving		X		X	X	X
	Feeding		X		X	X	
	Boiler operator	X			X	X	
	Maintenance	X			X	X	

Source: Interviews

KEY MESSAGES

- The role of women is limited to bagasse sun drying in the bagasse briquette value chain and to kiln preparation and charcoal retail in the charcoal value chain.
- Indicator 11 provides more information regarding wages, and Indicator 21 provides detailed information about training and requalification of the workforce and its implications for job creation.

MORE IN THE TECHNICAL REPORT

- Compiled information on the number of jobs for the three briquetting plants and tea factories, disaggregated into skilled/unskilled, permanent/temporary and female/male.

Charcoal

KEY FINDINGS

- More than 200,000 people are directly employed in charcoal production, and an estimated 500,000 others are involved in the transport and vending of charcoal – who are believed to be supporting over 2.5 million dependents.

Table 12.2. Jobs related to income-generating activities in the charcoal sector from agroforestry and used in the household value chain

Income-generating activity	Jobs	Type of wage employment	
		Formal	Informal
Tree production	Planting	X	
	Pruning	X	
	Thinning/Harvesting	X	
Charcoal production	Kiln maker		X
	Kiln maker assistant		X
Transporter	Truck driver		X
	Truck assistant		X
Wholesaler	Trader		X
	Trader assistant		X
Retailer	Vendor		X
	Vendor assistant		X

Source: Analysis and interviews

KEY MESSAGES

- Charcoal producers in Kenya must organize into charcoal producer associations.
- The role of women in the charcoal sector is related mainly to charcoal production (kiln preparation) and retail, whereas transport and wholesaling are heavily dominated by men.
- Bribery is a common practice in the charcoal sector.
- Indicator 11 provides more information on wages, and Indicator 21 provides detailed information on training and requalification of the workforce and its implications for job creation.

MORE IN THE TECHNICAL REPORT

- Assessment of the proportion of jobs in the formal and informal sectors related to the charcoal value chain.
- Assessment of the gender gap in jobs and wages in the value chain.

INDICATOR 13. CHANGE IN AVERAGE UNPAID TIME SPENT BY WOMEN AND CHILDREN COLLECTING BIOMASS

DEFINITION

(13.1) Change in average unpaid time spent by women and children collecting biomass as a result of switching from the traditional use of biomass to modern bioenergy services.

MEASUREMENT UNIT(S)

Hours per week per household, percentage

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- This indicator was calculated only for the charcoal pathway.
- Several studies were reviewed for this indicator: five on sourcing firewood from forests, three on trees on farm and six on improved stoves. This was to determine the time saving by switching from sourcing firewood from the forest and using traditional three-stone open fires, to sourcing firewood from trees on-farm and using improved stoves.

Table 13.1. Distances covered and time spent in firewood collection

Site	Distance from forest (km)	Time spent collecting firewood (hours)		Source
		Forest	On-farm	
Kibugu, Embu	8	4	2	Njenga et al. 2019
Kereita, Kiambu	6	3	1	Njenga et al. 2019
Matuga, Kwale	N/A	3	1.4	Gitau 2019
Gazi Bay	1.8	3.1	N/A	Jung and Huxham 2018
Dadaab	N/A	8	N/A	Bizzarri 2010
Average	5.3	4.2	1.5	

Charcoal

KEY FINDINGS

- Case studies in Kenya show the distances and time spent collecting firewood (Table 13.1).
- If households that spent 3-8 hours (4.2 hours on average) or around 218 hours annually collecting firewood from forests shifted instead to sourcing firewood from trees on farms (spending 1-2 hours or 1.5 hours on average, or around 78 hours annually), this wwould save 64 per cent of the time on a weekly round trip.
- Time is saved (an amount not yet quantified) when pruning of trees on farms is carried out annually or once every two years and firewood is carried to homesteads in a few days or women carry firewood as they go home after working on the farm. Firewood from trees on-farm is well dried, reducing smoke in the kitchen.
- Shifting to improved stoves – resulting in fuel savings of 46-20 per cent or 33.2 per cent on average – would reduce the number of annual trips to forests from 52 to 35, reducing the number of hours spent each year collecting firewood from 147 hours from forests to 53 hours on farms.
- Collecting firewood once per week results in a loss of a labourer's day's income of 300 Kenyan shillings ($3), equivalent to 15,600 Kenyan shillings ($152) annually. Additionally, 100 Kenyan shillings ($1) per month or 1,200 Kenyan shillings ($12) annually is paid to Kenya Forest Service for one trip per day of firewood collection.
- With the use of improved stoves, the income lost by women for not working would be reduced to 10,500 Kenyan shillings ($105), and only 900 Kenyan shillings ($9) would be paid to Kenya Forest Service. Additional benefits are

unquantified, including the improved quality of life from not carrying heavy loads through rough terrain in forests and other associated risks.

KEY MESSAGES

- Sourcing firewood from trees on farms, integrated with efficient improved cookstoves, is a promising cooking system for reducing women's drudgery and opportunity cost in unpaid labour.
- Small-scale farmers should be trained on suitable multiple purpose trees, which, in addition to providing firewood, have other ecosystem benefits such as improved soil fertility.
- End users should be consulted and the initiative integrated into Kenya's agendas on gender equality, cleaner cooking and climate change.
- There is a need to grow agroforestry trees on household farms to reduce the necessity of going into the forest to collect firewood, which is a time-consuming and life-threatening exercise. Incentives should be given for enhanced uptake of such technologies with training and follow-up that considers the user's needs and preferences.

MORE IN THE TECHNICAL REPORT

- Full explanation of the case studies reported, and on both time savings and economic savings.
- Detailed conclusions and recommendations.

INDICATOR 14. BIOENERGY USED TO EXPAND ACCESS TO MODERN ENERGY SERVICES

DEFINITION

(14.1) Total amount and percentage of increased access to modern energy services gained through modern bioenergy (disaggregated by bioenergy type), measured in terms of (14.1a) energy and (14.1b) numbers of households and businesses;

(14.2) Total number and percentage of households and businesses using bioenergy, disaggregated into modern bioenergy and traditional biomass.

MEASUREMENT UNIT(S)

(14.1a) Modern energy services can take the form of liquid fuels, gaseous fuels, solid fuels, heating, cooling and electricity. A change in access to each of these forms of modern energy can be measured in MJ per year, and this is preferable in order to allow comparison of different forms of energy service, but each may also be measured in appropriate units of volume or mass per year, which may sometimes be more convenient, such as litres/year or MJ/year for liquid fuels, tons/year or MJ/year for solid fuels, etc.

(14.1b) number and percentage.

(14.2) number and percentage

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- A secondary data search was performed in addition to a calculation of annual bioenergy demand based on 2015 Kenya statistics. Data were sourced from various sources and surveys such as the Ministry of Environment and Forestry report for 2013 and the Kenya National Integrated Household Survey report of 2015.

- Results are based on national statistics and encompass four energy sources: electricity, liquefied petroleum gas (LPG), biogas, briquettes and pellets.

KEY FINDINGS

- Modern energy access in households is dominated by LPG. Modern bioenergy access by biogas, briquettes and pellets remains limited. Improved cookstoves could be considered to be modern bioenergy solutions if the efficiency of the stoves is high enough (higher than 20-30%) and if their flue gases are released distant from their users, according to the GBEP definition.

Table 14.1. Availability of cookstoves in households

	Households		Final Energy Intensity	
	Urban (%)*	Rural (%)*		
Traditional 3 stone	13.7	71.7	2093	kg wood/household/year
Improved wood stove	2.3	12.8	1675	kg wood/household/year
Traditional metal charcoal stove	13.5	5.7	593	kg charcoal/household/year
Kenya Ceramic Jiko	9.3	3.7	474.4	kg charcoal/household/year
Electric stove	2.0	0.3	459	kWh/household/year
LPG cookers	27.7	2.5	99.9	kg/household/year
Biogas stove	0.3	0.2	1093	cubic meter/household/year
Kerosene stoves	29.5	2.3	221.4	litres/household/year

* Total is more than 100% because some households own different types of cookstoves.

Source: KNBS 2018a; MoE 2002; MoEWN 2013b

KEY MESSAGES

- Whereas the adoption of modern energy services in urban areas has increased, rural areas remain highly dependent on traditional energy services, dominated by firewood. This slow growth in access in rural areas can be attributed to financial and technological challenges and to limited supply chain development.
- With exerted efforts, the trend towards the adoption of modern energy services in urban areas presents an opportunity for increased access. In rural areas, however, greater effort and policy streamlining are required.

MORE IN THE TECHNICAL REPORT

- Expanded description and definition of the indicator.
- Targeted policy recommendations.

INDICATOR 15. CHANGE IN MORTALITY AND BURDEN OF DISEASE ATTRIBUTABLE TO INDOOR SMOKE FROM SOLID FUEL USE

DEFINITION

(15.1) Change in mortality and burden of disease attributable to indoor smoke from solid fuel use;

(15.2) Changes in these as a result of the increased deployment of modern bioenergy services, including improved biomass-based cookstoves.

MEASUREMENT UNIT(S)

Percentages

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Literature review and secondary data assessment were performed.
- The units were changed to n: number of deaths.
- Data included age-standardized deaths per 100,000 people, age-standardized disability-adjusted life-years (DALYs) per 100,000 people, and reported sickness or injury by sickness related to household air pollution exposure by percentage of the population.

KEY FINDINGS

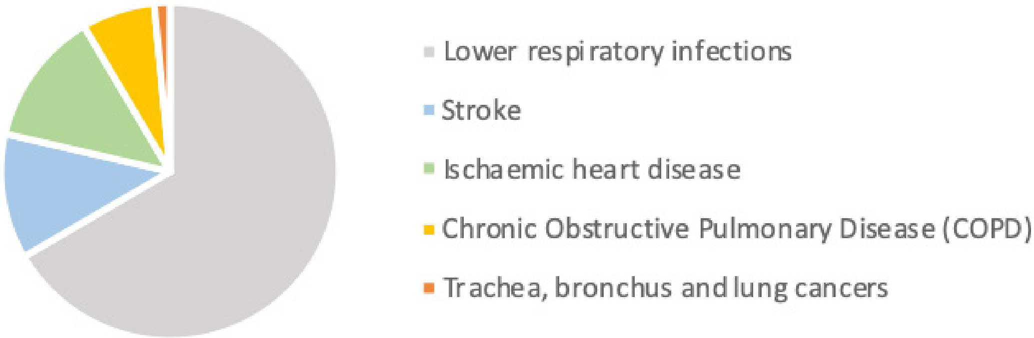
- Only an estimated 6 per cent of households rely mainly on clean fuels for cooking.
- An estimated 39 million people in Kenya, or around 87 per cent of the population, are affected by household air pollution.
- The Health Effects Institute reported 13,900 estimated deaths attributable to household air pollution, whereas the World Health Organization reported 15,140 for the year 2016 (Table 15.1).
- The reported number of deaths attributable to household air pollution for females was almost the same as for males, which was not expected.
- Age-standardized death and disability-adjusted life year (DALY) rates attributable to household air pollution have decreased sharply during the last couple of decades in Kenya.

Table 15.1. Deaths attributable to household air pollution in Kenya in 2016

Cause	Both sexes	Male	Female
Total	15 140	7 523	7 617
Lower respiratory infections	10 083 (66.6%)	5 125	4 957
Trachea, bronchus, lung cancers	229 (1.5%)	126	103
Ischaemic heart disease	1 954 (12.9%)	997	957
Stroke	1 810 (12%)	790	1 020
Chronic obstructive pulmonary disease	1 064 (7%)	484	580

Source: WHO 2019

Figure 15.1. Proportion of deaths attributable to household air pollution according to different acute and chronic respiratory diseases in Kenya in 2016



Source: Adapted from WHO 2019

KEY MESSAGES

- Advanced cooking solutions need to be adopted more widely to reduce exposure to indoor pollutants.
- Standards for cookstoves and other fuels such as carbonized briquettes are under development in Kenya.

MORE IN THE TECHNICAL REPORT

- Full description of the methodology used.
- Key findings on health statistics from international organizations (WHO) and national statistics for Kenya.
- Detailed conclusions and recommendations.

INDICATOR 16. INCIDENCE OF OCCUPATIONAL INJURY, ILLNESS AND FATALITIES

DEFINITION

(16.1) Incidences of occupational injury, illness and fatalities in the production of bioenergy in relation to comparable sectors.

MEASUREMENT UNIT(S)

Number/ha (for comparison with other agricultural activities); number/MJ or MW (for comparison with alternative energy sources)

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- A literature review and data collection were done for Narok county.
- Data on occupational injuries, illness and fatalities in Kenya are not available for public consultation, either because the data are inexistent or because organizations and companies are not willing to share them. ILOSTAT, the world's leading source of labour statistics, affiliated with the International Labour Organization, has no available data on safety and health at work for Kenya.
- Interviews were performed at the selected tea factories to gather data on occupational health and injuries.
- Charcoal production was considered as an alternative agricultural activity that is carried out on the farm with available resources, both material and human.

SUMMARY

Bagasse briquettes

KEY FINDINGS

- Fires in bagasse storage areas are common. When bagasse is heated by the sun, gases such as methane are emitted from the natural decomposition of the biomass, creating a suitable environment for starting fires.

- Bagasse sun drying takes place in big fields on which bagasse is spread to dry. Women walk on the bagasse, turning the material with their feet to accelerate the drying process. Although the dust concentrations are not as high as inside the briquetting factories, women are still constantly exposed to fine bagasse dust.

- Companies and organizations seem to have difficulties in sharing their experience regarding occupational safety and health and whether the relevant regulations are implemented.

Figure 16.1. (Top) A woman showing a handful of bagasse during sun drying. (Bottom) A group of charcoal producers supervising a traditional kiln in operation.

Photos by Natxo García López.

Table 16.1. Reported number of occupational injuries and fatalities in 2018 for the three briquetting plants and three tea industries interviewed

		Number of employees	Number of injuries	Type of injuries	Number of fatalities	Occupational safety and health policy	Annual audit
Briquetting plants	Case study 1	Permanent: 7 Casual: 50*	Not reported	Minor	0	Yes	Yes
	Case study 2	Permanent: 51 Casual: 40*	Not reported	Not reported	0	Yes	Yes
	Case study 3	Permanent: 26	Not reported	Not reported	0	Yes	Yes
Tea industries	Case study A	14	0	Not reported	0	Yes	Yes
	Case study B	9	0	Not reported	0	Yes	Yes
	Case study C	12	0	Not reported	0	Yes	Yes

* The number of casual workers varies by season. An average of 50 and 40 casual employees was considered for case studies 1 and 2, respectively.

Source: Interviews

KEY MESSAGES

- Despite the low numbers of reported injuries, the working environments in bagasse briquetting plants and tea factories have some particularities that might be worth considering during the design and formulation of occupational risk prevention plans and regulations.
- Having a functional and transparent occupational safety and health policy would contribute to better working environments.

Charcoal

KEY FINDINGS

- In the charcoal sector, injuries are common but are often not reported to relevant offices. They include injuries due to trees falling on people and injuries during loading and unloading, which are common during the harvesting and movement of wood resources.
- People are also at risk from snake bites as well as from exposure to smoke, dust and particulate matter during production and handling of charcoal, which contributes to increased cases of respiratory diseases.
- Burns are common during harvesting of charcoal, especially when kilns are dismounted when the charcoal is still hot.

Table 16.2. Compilation of the collected data on occupational injuries and on the number of charcoal producer groups

	Case study County 1 (Kitui)
Number of associations	9
Number of charcoal producer groups	126
Average number of members per charcoal producer group	35
Average monthly production per charcoal producer group (tons)	8.9
Monthly average of accidents per group	1
Number of accidents per MJ produced	3.4 X 10-6

Source: Interviews

KEY MESSAGES

- No data or very poor data and records exist on injuries, illness and fatalities related to charcoal production, transport and commercialization.
- The charcoal sector needs to be drastically remodelled if the aim of Kenya Vision 2030 is to be achieved.
- In general, personal protective equipment is not used.

MORE IN THE TECHNICAL REPORT

- Compilation of the specific risks for the two studied pathways.
- Detailed conclusions and recommendations.

INDICATOR 17. PRODUCTIVITY

DEFINITION

(17.1) Productivity of bioenergy feedstocks by feedstock or by farm/plantation;

(17.2) Processing efficiencies by technology and feedstock;

(17.3) Amount of bioenergy end product by mass, volume or energy content per hectare per year;

(17.4) Production cost per unit of bioenergy.

MEASUREMENT UNIT(S)

(17.1) Tons/ha per year;

(17.2) MJ/ton;

(17.3) Tons/ha per year, m^3/ha per year or MJ/ha per year;

(17.4) US dollars/MJ

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Data and information were extracted from both primary and secondary sources.
- In the case of charcoal, the focus is on the productivity of Acacia species and the comparison of traditional earth and improved earth kilns.

Bagasse briquettes

KEY FINDINGS

- Kenya's 11 sugar factories produced more than 1.7 million tons of sugarcane bagasse in 2017. Of this, around 510,000 tons remained unutilized and was available for briquette production and other products (AFA-SD 2017).
- One ton of crushed sugar cane produces 0.3590-0.3968 tons of bagasse, which normally has a moisture content of 12-14 per cent (AFA-SD 2018).
- Once the briquettes are produced, the useful

energy yield from bagasse briquettes delivered to industries is around 18,000 MJ per ton, with an ash content of 10-30 per cent.

- The cost of a ton of briquettes varies widely depending on the intended market but generally ranges between $0.01673 and $0.0239 per megajoule.

KEY MESSAGES

- The use of bagasse briquettes as fuel is a fairly new source of thermal energy and is gaining popularity in Kenya. Its adoption and use increased greatly following the ban on logging in 2018 that affected the tea industry, among others.
- More research needs to be done to better know the productivity of the value chain.

MORE IN THE TECHNICAL REPORT

- More detailed information on the productivity of bagasse and the amount produced by all the sugar factories.
- Amount of bagasse by mass, volume or energy content per hectare per year.
- Analysis of the production cost per unit of bagasse.

Charcoal

KEY FINDINGS

- Productivity rates for charcoal production vary according to different issues such as the tree species and the efficiency of the kiln.
- The most common tree used for charcoal production, due to its high quality and productivity, is Acacia drepanolobium, a native woodland species that can yield 0.18 tons per hectare of charcoal per year with a low-efficiency kiln.
- In contrast, Acacia mearnsii may produce 1.01 tons per hectare of charcoal per year when a low-efficiency kiln is used.
- The majority of charcoal producers (99 per cent) use traditional earth kilns, which have very low recovery rates.

KEY MESSAGES

- Adequate management of tree plantations and selected species may provide higher yields with improved kilns.
- No conclusive data and information are available on the production cost per unit of charcoal because the existing figures appear to be too low compared to the annual retail value, as estimated by various studies.

MORE IN THE TECHNICAL REPORT

- Productivity of Acacia species.
- Amount of charcoal end product by mass, volume or energy content per hectare per year.
- Production cost per unit of charcoal and the assumptions made during calculations.

INDICATOR 18. NET ENERGY BALANCE

DEFINITION

Energy ratio of the bioenergy value chain with comparison with other energy sources, including energy ratios of: (18.1) feedstock production; (18.2) processing of feedstock into bioenergy; (18.3) bioenergy use; and/or (18.4) life cycle analysis.

MEASUREMENT UNIT(S)

Ratios

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Data and information used in this indicator were gathered from both desktop research and field visits to the various tea industries.
- Very limited data were found on the net energy balance.

Bagasse briquettes

KEY FINDINGS

- Energy consumption in the value chain was considered mainly for the production and transport of briquettes.
- As per conducted field visits, the case study tea factory used 21,382 m3 (11,760 tons) of fuelwood, equivalent to 177,577 gigajoules.
- Switching to greater briquette use at the tea factories would increase the energy consumed in transport.

KEY MESSAGES

- Transport of briquettes should not go beyond a radius of 100 kilometres by road.
- Tea factories should automate the feeding of boilers to increase energy efficiency at the boiler section.
- Existing boilers should be improved technically to be compatible with the briquette characteristics.
- Information on the efficiency of the boilers used by the tea factories needs to be compiled for monitoring of this pathway in the future.

MORE IN THE TECHNICAL REPORT

- Full calculations of the energy consumed during the production of briquettes compared to the preparation of fuelwood for the tea industry.
- Full calculations and comparison of the energy consumed in the transport of briquettes and fuelwood to the tea factories.
- Detailed conclusions and recommendations.

Charcoal

KEY FINDINGS

- Charcoal production is done in situ (no transportation of wood), and additional energy is consumed if tools are used such as power saws. The main energy loss is related to the efficiency of the kiln.
- The other aspects to consider are the fuel consumed for the transportation of charcoal and the energy efficiency of the cookstoves.

KEY MESSAGES

- Transport of charcoal should not go beyond a radius of 100 kilometres by road.
- Communities should set a fixed location for charcoal production to make it easy for the government to employ high-efficiency production technologies.
- Reducing the massive waste during carbonization will contribute to reducing deforestation.
- During the production, transport, wholesaling and retailing of the charcoal, a significant proportion of it ends up as waste in the form of dust.

MORE IN THE TECHNICAL REPORT

- Full assessments of the energy balance for charcoal production, including using different kilns and cookstove efficiencies.
- Recommendations on sustainable technologies for charcoal production and use to be more energy efficient.

INDICATOR 19. GROSS VALUE ADDED

DEFINITION

(19.1) Gross value added per unit of bioenergy produced and as a percentage of gross domestic product.

MEASUREMENT UNIT(S)

The gross value added could be expressed both per unit of bioenergy produced and as a percentage of gross domestic product (GDP).

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- For bagasse briquettes, the indicator was changed from gross value added to cost savings that the tea industry can achieve by shifting to bagasse briquettes and plantations. This involved the collation of information on the contribution of fuelwood and briquettes to energy costs.
- For charcoal, although the analysis does not focus on the gross value added, it provides an overview of the contribution of the charcoal sector to the Kenyan economy.

Bagasse briquettes

KEY FINDINGS

- The use of bagasse briquettes can greatly reduce costs for the tea industry. Currently, around 2.4 million tons of bagasse generated by the country's 11 sugar mills remains unutilized. On average, tea factories that use bagasse briquettes consume around 1 per cent annually. Factories can be encouraged to increase this use to above 5 per cent if the quality of briquettes is guaranteed, and above 20 per cent with the introduction of mechanized boiler feeding solutions.
- The use of sugarcane bagasse would also increase the value of sugar cane, since bagasse is an automatic by-product of the production process whose value is not accounted for while sugar cane is being purchased.
- Compounded, this will have a significant impact on Kenya's GDP due to the scale of the industry's activities.

KEY MESSAGES

- Energy costs account for a large share of the tea industry's expenses and contribute to cutting of trees, and hence should be done more sustainably.
- Bagasse briquettes and plantations can greatly reduce energy costs in factories.
- Mechanization of boilers is needed to help increase the use of bagasse.
- Because plantations require considerable land, there is a need to enact policies to incentivize their set-up.
- The numerical values must be considered as illustrative-only since they are based on a case study, and data vary from factory to factory; hence a base factory was picked. This base factory is probably not representative of every tea factory.
- This analysis assumed that factories are close to their plantations. In future monitoring it is important to use models that simplify calculations and consider different factory distances.

MORE IN THE TECHNICAL REPORT

- Costs associated with ideal scenarios with 100 per cent briquettes and 100 per cent plantations.
- Scenarios showing how bagasse briquettes and plantations can reduce costs.
- Cost savings associated with a shift to plantations versus purchasing fuelwood.

Charcoal

KEY FINDINGS

- Charcoal activities in Kenya generate revenue of around $426 million annually.
- The charcoal industry contributes to government revenues through licences, transport and business permits and is a source of employment for 0.5-0.7 million Kenyans who support more than 2 million dependents.
- The price of charcoal is affected by the quality of charcoal and the availability of customers, which is intertwined with food security, size of market/town, weather and policy-related factors such as the logging ban.

KEY MESSAGES

- The average income generated per unit of charcoal production is 4,496 Kenyan shillings for producers, 11,298 Kenyan shillings for transporters and 7,503 Kenyan shillings for vendors.
- Production of cookstoves provides good business opportunities for producers and vendors and provides employment across the value chain.

MORE IN THE TECHNICAL REPORT

- Recommendations on practices and policies to improve sustainability in the charcoal sector.
- Further information on the charcoal sector nationally and in Narok county.

INDICATOR 20. CHANGE IN CONSUMPTION OF FOSSIL FUELS AND TRADITIONAL USE OF BIOMASS

DEFINITION

(20.1) Substitution of fossil fuels with domestic bioenergy measured by energy content (20.1a) and annual savings of convertible currency from reduced purchases of fossil fuels (20.1b);

(20.2) Substitution of traditional use of biomass with modern domestic bioenergy measured by energy content.

MEASUREMENT UNIT(S)

(20.1) MJ per year and/or MW per year;

(20.2) MJ per year

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- For bagasse briquettes, the indicator considered the substitution of firewood by sugarcane briquettes in the investigated tea factories.
- For charcoal, the indicator considered the shift from traditional firewood to modern charcoal. The study assumed 100 per cent replacement of traditional firewood use in urban areas.

Bagasse briquettes

KEY FINDINGS

- Switching from fuelwood to briquettes in the tea factories would potentially result in 40 hectares of forest stock being preserved.
- However, the cost intensity of obtaining energy from briquettes is around three times more compared to firewood.

Table 20.1. Energy cost saving due to substitution of bioenergy

	Wood	Briquette
Energy required in MJ	7 400	7 400
Cost at factory (Kenyan shillings)	1 623	5 117
Cost intensity (Kenyan shillings / MJ)	0.22	0.69

Source: Own calculation

- However, the cost intensity of obtaining energy from briquettes is around three times more compared to firewood.

Table 20.1. Energy cost saving due to substitution of bioenergy

	Wood	Briquette
Energy required in MJ	7 400	7 400
Cost at factory (Kenyan shillings)	1 623	5 117
Cost intensity (Kenyan shillings / MJ)	0.22	0.69

Source: Own calculati

KEY MESSAGES

- If the tea sector incorporates co-firing, using briquettes and fuelwood, a reduction in fuelwood consumption would contribute to forest stock conservation.
- On the other hand, plantations for the tea sector would improve afforestation benefits in Kenya.

MORE IN THE TECHNICAL REPORT

- In-depth analysis of costs savings and fuels in transitioning tea factories from fuelwood to sugarcane briquettes based on changes in consumption.
- Opportunities and challenges in implementation of the bioenergy pathway.
- Various cost elements undermining the effectiveness of the bioenergy pathway.

Charcoal

KEY FINDINGS

- Replacing traditional fuelwood with charcoal in modern and improved cookstoves (bioenergy) in urban areas would result in the equivalent of 22.8 million gigajoules being replaced with charcoal.

KEY MESSAGES

- Charcoal use in modern and improved stoves should remain a transitional fuel for effective sustainability achievement.
- Improved charcoal production and use will make it possible to move towards more sustainable use of bioenergy.

MORE IN THE TECHNICAL REPORT

- More-detailed results illustrating the business-as-usual and pathway scenarios to understand the dynamic of the change in wood requirement for final energy demand.
- Policy recommendations on charcoal utilization as sustainable bioenergy.

INDICATOR 21. TRAINING AND RE-QUALIFICATION OF THE WORKFORCE

DEFINITION

(21.1) Share of trained workers in the bioenergy sector out of total bioenergy workforce, and (21.2) share of re-qualified workers out of the total number of jobs lost in the bioenergy sector.

MEASUREMENT UNIT(S)

Percentage (per year)

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- For bagasse briquettes, interviews were conducted with the workers of three briquette plants and three tea factories.

- For charcoal, interviews were conducted with charcoal producer associations.
- Literature review and personal communications with Kenya Forestry Research Institute were conducted on training in charcoal.

Bagasse briquettes

KEY FINDINGS

- The workforce involved in the production, transport and use of bagasse briquettes has received low or non-existent training and re-qualification.
- When training is received, it is mainly for staff that is employed full-time and engaged in skilled work.

KEY MESSAGES

- Briquette factories provide training only for operators of the briquette machines.
- Tea factories provide technical training only for boiler operators. There should also be training in the combustion of agricultural residues for future briquette use in boilers.

MORE IN THE TECHNICAL REPORT

- Comprehensive key findings for training in the briquette pathways.
- Detailed conclusions and recommendations.

Charcoal

KEY FINDINGS

- Production of charcoal is an empirical activity that is learned in the villages.
- According to the interviewed charcoal producer associations, less than 15 per cent of the charcoal producers have received training on charcoal production in modern kilns.
- Two types of training were identified within the activities included in the charcoal value chain: basic training on the use of modern kilns, and licencing in the case of drivers involved in charcoal transport.
- Charcoal producers do not belong to a company but to charcoal producer groups, which in turn belong to charcoal producer associations.
- Charcoal production is rarely a full-time job but rather a complementary source of income for people living in rural areas.
- Standardization and regulation of the charcoal sector will promote the training of the workforce involved.

KEY MESSAGES

- Given that charcoal production is a complementary source of income and not a full-time job, the use of modern kilns and the need for training are not seen as required by the sector.
- Within charcoal production and commercialization, training on first aid and fire extinction and other basic training is non-existent. However, transport is a key element in the charcoal value chain, and the majority of the drivers have driver's licences, which is a basic training.
- Kenya Forestry Research Institute has conducted training on the use of modern kilns.

MORE IN THE TECHNICAL REPORT

- Comprehensive key findings for training in charcoal production.
- Detailed conclusions and recommendations.

INDICATOR 22. ENERGY DIVERSITY

DEFINITION

(22.1) Change in diversity of total primary energy supply due to bioenergy.

MEASUREMENT UNIT(S)

Index (in the range 0-1) and MJ bioenergy per year in the total primary energy supply (TPES)

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Information on energy diversity in Kenya and data required for calculation of the Herfindahl Index were retrieved from both national and international statistics.
- Calculation of the Herfindahl Index was done at the national level.
- Some references are indicated for the pathways.

KEY FINDINGS

- The total primary energy supply in 2017 was 27 million tons of oil equivalent (IEA 2019) and was largely dominated by biomass (64 per cent).
- At the national level, the Herfindahl index is 0.4646. A higher diversity of supply would result in a lower index.
- The tea industry consumes electricity, fossil fuels and biomass energy, used mainly for tea drying. Biomass, mostly firewood, represents more than 70 per cent of the energy consumed by the tea industry.
- At the household level, the energy diversity is even smaller since biomass represents 94 per cent of the energy consumed by the residential sector.

KEY MESSAGES

- The promotion of a larger portfolio of energy sources and types of stoves for cooking would increase the energy security of households.
- The use of bagasse briquettes by the tea industry contributes to the diversification of energy sources and therefore to the energy security of the industry.

MORE IN THE TECHNICAL REPORT

- Detailed analysis of the energy sector.
- Description of the energy sources of the tea industry.

INDICATOR 23. INFRASTRUCTURE AND LOGISTICS FOR DISTRIBUTION OF BIOENERGY

DEFINITION

(23.1) Number and (23.2) capacity of routes for critical distribution systems, along with (23.3) an assessment of the proportion of the bioenergy associated with each.

MEASUREMENT UNIT(S)

(23.1) number

(23.2) MJ, m3 or tons per year; or MW for heat and power capacity

(23.3) percentages

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- A review was conducted through perusal of official reports and literature regarding infrastructure for production and logistics for the distribution of bioenergy in the country. Field visits were conducted in the two hotspot charcoal-producing counties of Kitui and Narok.

- Field visits were conducted to selected tea factories and briquette plants to obtain data and information on the production and use of sugarcane bagasse briquettes in the tea industry.

Bagasse briquettes

KEY FINDINGS

- Logistics in the production and distribution of bagasse briquettes differ by the capacity of briquette plants, which has an impact on the cost and quality of the briquettes required by the tea industry.
- There are four main processes: 1) collection and transport of bagasse feedstock to briquette plants; 2) production of briquettes; 3) briquette transport and distribution; and 4) end use in tea industries.
- In 2017, Kenya's 11 sugar factories produced more than 1.7 million tons of sugarcane bagasse, accounting for around 30 per cent of the sugar cane crushed by the mills (AFA-SD 2017).
- More than 75 per cent of the briquette plants operate in the vicinity of sugar mills in western Kenya.
- For distribution, in the cases studied in this pathway, briquettes can be transported up to 334 kilometres, which (linking it to Indicator 1 on greenhouse gases) would have negative emissions.

KEY MESSAGES

- High costs in the logistics of feedstock preparation (especially drying), production and transport contribute to a higher price of briquettes. On the demand side, higher price and operational challenges, including clinkers in existing boilers, limit the use of briquettes by the tea industry.
- As consumption of briquettes is expected to increase in the near future, feedstock delivery directly from the sugar mills with shorter distances will likely become more reliable, thus reducing energy consumption and transport costs.
- For future monitoring, the briquette plants and tea factories will need to optimize their infrastructure and logistic systems to deal with this increased demand.

MORE IN THE TECHNICAL REPORT

- Annual bagasse production by sugar mills in Kenya.
- Annual firewood use by tea industries. Briquette production and use in tea industries in Kenya.

Charcoal

KEY FINDINGS

- Charcoal is a very informal sector in Kenya, and so are the logistics related to it. Charcoal is produced in strategic locations near feedstock sources, using a range of conversion technologies.
- Although charcoal producer associations have been established to formalize the operations in the sector, they do not control transport. The logistics of charcoal transport to Nairobi are complex and involve several supply chain actors. The lower-end actors (producers) have the shortest distance to collection centres, while the total transport distance to Nairobi is much longer with an average of 175 kilometres.
- Other key logistical challenges contribute to increases in the prices for charcoal in Nairobi, which consumes 10 per cent of the total charcoal volume in Kenya.

KEY MESSAGES

- Kilns for charcoal production are built in areas where feedstock is harvested. This is because the kilns are often mobile. Therefore, energy consumption is minimal and was not considered.
- There is a need to increase the stable raw material supply by introducing extension and technical assistance programmes to support the sustainable management of existing indigenous forests, woodlots and rangeland trees that are currently being used for charcoal production.
- For charcoal distribution, there is a need to introduce a modal split in transport including the establishment of central depots on the major all-weather roads in charcoal-producing areas. The short-haul – depot – long-haul mode could cut the cost of transport by at least 30 per cent.
- For future research work, there is a need for national institutions and county governments to make available the data and information on charcoal production.

MORE IN THE TECHNICAL REPORT

- Charcoal production, distribution and use in Nairobi.
- Distribution of charcoal for household use in Nairobi City County.

INDICATOR 24. CAPACITY AND FLEXIBILITY OF USE OF BIOENERGY

DEFINITION

(24.1) Ratio of capacity for using bioenergy compared with actual use for each significant utilization route;

(24.2) Ratio of flexible capacity which can use either bioenergy or other fuel sources to total capacity.

MEASUREMENT UNIT(S)

Ratio

OVERALL METHODOLOGY OF THE IMPLEMENTATION

- Regarding bagasse briquettes, primary data were collected through field visits, official statistics and the literature. In particular, data were compiled on the current share of use of sugarcane bagasse briquettes by the tea industries, and information was gathered related to the maximum level of briquettes/bioenergy blending with firewood that can be tolerated by the existing boilers without retrofitting.
- Regarding charcoal, the necessary information was collected through field studies, official statistics and the literature.

Bagasse briquettes

KEY FINDINGS

- According to a survey of four tea factories in Kenya, the current factories could run on bagasse briquette blends of at least 20 per cent, with 80 per cent firewood, without having to retrofit their boilers. This would result in annual savings of around 200,000 tons of bone-dry firewood, corresponding to 363.64 m3 of wood fuel in Kenya.

KEY MESSAGES

- Each year, the 113 tea industries in operation in Kenya use around 1 million tons of bone-dry firewood, or 4.4 per cent of national consumption.
- Tea factories are flexible, and bagasse briquettes can be blended with firewood in the ratio of 20 per cent without retrofitting the existing thermal boilers for tea processing.
- The future monitoring of briquettes used by the tea industries depends on the credibility of data on both briquette production and consumption.

- Additional data on optimal boiler efficiencies with bagasse briquettes are needed from tea factories, Kenya Tea Development Agency, Kenya Agriculture and Food Authority Tea Directorate, Kenya Industrial Research and Development Institute, Kenya Forestry Research Institute and universities / research institutions.

MORE IN THE TECHNICAL REPORT

- Annual bioenergy consumption by the tea industry in Kenya.
- Capacity ratios of bagasse briquettes sold, and the share in tea industries for selected tea factories and briquette plants in Kenya.

Charcoal

KEY FINDINGS

- In Kenya, charcoal plays an important role in contributing to the capacity and flexibility of bioenergy through the adoption of energy-efficient cookstoves.

KEY MESSAGES

- Research, development and dissemination work on improved charcoal stoves has resulted in the introduction of different stove models. The existence of charcoal and stove stacking within distributor outlets and kiosks gives flexibility to households when cooking.
- For Kenya to improve on the consumption of charcoal from sustainable sources, there is a need to consider fuel and stove stacking accompanied with incentives to accelerate the uptake of clean-stacking cooking.

MORE IN THE TECHNICAL REPORT

- Annual consumption of charcoal in Kenya.
- Stove utilization in Kenya.

5.CONCLUSION

GBEP INDICATORS AND SUSTAINABLE DEVELOPMENT GOALS

The 24 Sustainability Indicators for bioenergy from the Global Bioenergy Partnership (GBEP) have strong links to the Sustainable Development Goals. Implementation of the indicators in Kenya may strength this link and inform policymakers about the areas in which the country needs to move towards achievable modern bioenergy. This will make it possible to focus on one of the main concerns related to energy access in Kenya, which is access to clean cooking fuels.

Modern bioenergy through solid biomass for use in the industry sector is not common in sub-Saharan Africa, and this may lead to the discovery of additional linkages to the Sustainable Development Goals and to the GBEP indicators on poverty alleviation, health improvement, improved livelihoods and job creation, gender equity, and climate change adaptation and mitigation. As this innovation in the industrial sector starts to evolve, the improvement in the production and use of charcoal is a priority in Kenya, and application of the indicators will also contribute to achieving the Sustainable Development Goals and the goals of Agenda 2030.

POLICY INNOVATION AND GOVERNANCE

The monitoring of bioenergy in Kenya will provide better tools for policymakers not only in the energy arena, but also in the areas of avoiding further degradation and improving quality of life with more affordable energy for cooking and for industry (including agroindustry). Implementation of the GBEP indicators is a first step for the Kenyan government to foster a new business environment in the emerging briquette sector. This is a valuable opportunity to create an enabling environment for the establishment of briquetting companies through incentives such as tax exemptions on briquetting equipment, creating awareness, enforcing stringent laws on logging and easier business formalisation procedures.

MODERN BIOENERGY FOR COOKING

As the ban on charcoal continues to be enforced, the government should consider alternative approaches to stimulate afforestation and plantations that will be able to meet the increasing demand for cooking fuels in a clean manner. This will consider the scale-up of benefits of afforestation in terms of ecological restoration and carbon sequestration and a secure source of fuel at the farm level in rural areas.

The indicators also demonstrated the benefits of alternative use of modern bioenergy in urban areas through improved cookstoves and sustainable charcoal use. Monitoring the use of charcoal, particularly in Nairobi, will allow the government to plan for alternative fuels to use in the future – such as ethanol, which has already started to have an impact in the city.

RESEARCH AND DATA

The biggest challenge in analysing the indicators was the lack of data and the broad distribution of data among different organizations. Myriad organizations are working specifically with cookstoves and charcoal production, but the data continue to be disaggregated and disperse. Other organizations – both national and international – have not standardized the data related to the bioenergy sector.

At the end of this project, the first United Briquettes Producers Association of Kenya (UBPA) was officially created in July 2019 thanks to the support of MIT D-LAB and The Charcoal Project in partnership with the Clean Cooking Association of Kenya. The UBPA comprises 25 companies sustainably producing carbonized briquettes (micro enterprises, small and medium-sized enterprises) as well as representatives from government, academia, private sector, donor agencies, non-governmental organizations and individuals active in the sector. It represents a single, cohesive united front of the carbonized briquette sector for approaching the government, the donor community and consumers, but also for advocating policies, sharing best practices (technology, marketing, business models), increasing the demand and facilitating the supply system.

This indicates a willingness from the different actors to move towards a sustainable bioenergy sector.

6.REFERENCES

Agriculture and Food Authority, Sugar Directorate (2017). Year Bookof Statistics. Nairobi.

Agriculture and Food Authority, Sugar Directorate (2018). Year Book of Statistics. Nairobi.

Bizzarri, M. (2010). Safe Access to Firewood and Alternative Energy in Kenya: An Appraisal Report. World Food Programme and Women's Refugee Commission. Rome.

Clean Cooking Alliance (2019). Country Profiles Kenya. https://www.cleancookingalliance.org/country-profiles/21-kenya.html.

Diaz-Chavez, R. (2016). Kenya. In Intelligent Energy Europe, BioTrade2020plus: Supporting a Sustainable European Bioenergy Trade Strategy. Deliverable 2.1: Availability and Sustainable Potentials. https://www.biotrade2020plus.eu/images/BioTrade2020plus_Deliverable_2.1_final__2016.pdf.

Flores, M. and Bent, V.W. (1980). Family food basket. Definition and methodology. Archivos latinoamericanos de nutricion 30(1), 58-74. https://www.ncbi.nlm.nih.gov/pubmed/7447589.

Gitau, J.K. (2019). Assessment of Biomass Cooking Systems and Improvement through Micro Gasification in Small-Holder Farms: A Case of Kwale County, Kenya. PhD Thesis. University of Nairobi. Nairobi.

International Energy Agency (2019). Energy statistics of Kenya. International Energy Agency. https://www.iea.org/statistics/?country=KEN&isISO=true.

Jung, J., and Huxham, M. (2018). Firewood usage and indoor air pollution from traditional cooking fires in Gazi Bay, Kenya. Bioscience Horizons 11. https://doi.org/10.1093/biohorizons/hzy014.

Kameri-Mbote, P. (2016). Kenya Land Governance Assessment Report. The World Bank. 27 June 2016. P. 129. http://documents.worldbank.org/curated/en/829991504864783043/pdf/119619-WP-P095390-PUBLIC-7-9-2017-10-9-20-KenyaFinalReport.pdf.

Kenya National Bureau of Statistics (2018a). https://www.knbs.or.ke.

Kenya National Bureau of Statistics (2018b). Economic Survey 2018. Nairobi. P. 340.

Ministry of Environment, Government of Kenya (2002). Study on Kenya's Energy Demand, Supply and Policy Strategy for Households, Small-scale Industries and Service Establishments. Final report. Nairobi. P. 160.

Ministry of Environment and Natural Resources, Government of Kenya (2016). Technical Report on the National Assessment of Forest and Landscape Restoration Opportunities in Kenya. Nairobi.

Ministry of Environment, Water and Natural Resources, Government of Kenya (2013). Analysis of the Charcoal Value Chain in Kenya. Nairobi.

Mutimba, S. and Barasa, M. (2005). National Charcoal Survey: Summary Report. Exploring the Potential for a Sustainable Charcoal Industry in Kenya. Energy for Sustainable Development Africa.

Njenga, M. (2018). Resource recovery for briquettes and women's empowerment in humanitarian conditions in Kenya.

Njenga, M., Gitau, J. K., Iiyama, M., Jamnadassa, R., Mahmoud, Y., and Karanja, N. (2019). Innovative biomass cooking approaches for sub-Saharan Africa. African Journal of Food, Agriculture, Nutrition and Development 19(1), 14066-14087. DOI: 10.18697/ajfand.84.BLFB1031.

Rouillé, G., Blanchon, D., Calas, B. & Temple-Boyer, É. (2015). Environnement, écologisation du politique et territorialisations : les nouvelles politiques de l'eau (gire et pse) au Kenya. L'Espace Géographique 44(2), 131-146.

Transrisk (2018). Transition pathway and risk analysis for climate change projects. http://www.transrisk-project.eu. Accessed May 2019.

Water Resources Management Authority, Government of Kenya (2013). The National Water Master Plan 2030. Volume V. Sectoral Report (E) Agriculture and Irrigation. Nairobi.

World Health Organization (2019). "Global Health Observatory Data Repository". http://apps.who.int/gho/data. Accessed 24 May 2019.

WWF (2019). Kenya Deforestation Hotspots Map. https://www.wwfkenya.org/keep_kenya_breathing_/state_of_forest_in_kenya/. Accessed September 2019.

The Global Bioenergy Partnership (GBEP) project provides technical assistance to government officials and experts in Ethiopia and Kenya to assess the sustainability of their bioenergy sectors and build their capacity for long-term, periodic monitoring of these sectors. Work is structured around the application and interpretation of the 24 indicators to assess the environmental, social and economic impacts of bioenergy production and use. Results from the indicators can be used to inform the decision-making process.

The GBEP Indicators were developed in a collaborative process, led by the Food and Agriculture Organization of the United Nations, which currently hosts the GBEP Secretariat.

UN environment programme

United Nations Environment Programme
Economy Division
1 Rue Miollis, 75015 Paris, France
www.unep.org