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REPORT

Urban Briquette Making Pilot

Urban Briquette Making Pilot Study

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Acronyms

AFA	Agriculture and Food Authority
AFDB	African Development Bank
ASR	Automotive Shredder Residue
ATL	Above the Line Marketing
BAT	British American Tobacco
BAU	Business-as-Usual
BMH	Biogas Marketing Hub
BMS	Business Model Canvas
BOD	Biological Oxygen Demand
BTL	Below the Line Marketing
CARE	Capital Access for Renewable Energy Enterprises
CARE	Capital Access for Renewable Energy Enterprises
CBO	Community-Based Organisation
CCAK	Clean Cooking Association of Kenya
CET	Custom External Tariff
CI	Cost Insurance and Freight
COC	Certificate of Conformity
COD	Chemical Oxygen Demand
COMESA	Common Market for Eastern and Southern Africa
CPF	Central Production Facility
CTCN	Climate Technology Centre and Network
DEEP	Developing Energy Enterprises Project
E4I	Energy 4 Impact
EAC	East African Community
EACREEE	East African Centre for Renewable Energy and Energy Efficiency
ECA	Economic Commission Africa
EE	Energy Efficient
EEP	Energy Environment Partnership
EEP	Energy and Environment Partnership
EMCA	Environmental Management and Coordination Act
EU	European Union
FAO	Food and Agriculture Organization
FGD	Focus Group Discussions
GDP	Gross Domestic Product
GHG's	Greenhouse Gas Emissions
GIZ	Gesellschaft für Internationale Zusammenarbeit
GKIT	Greening Kenya Initiative Trust
GVEP	Global Village Energy Partnership (currently, Energy4impact)
IAC	Indoor Air Concentration
ICS	Improved Cook Stoves
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
IWA	International Workshop Agreement
KCJ	Kenya Ceramic Jiko
KEBS	Kenya Bureau of Standards
KEFRI	Kenya Forest Research Institute
KES	Kenya Shillings
KG	Kilo Gram
KIRDI	Kenya Industrial Research and Development Institute
KM	Kilo Meters
KOSAP	Kenya Off-Grid Solar Access Project
KPCU	Kenya Planters Co-operative Union
kWh	Kilowatt-hour
LCM	Lean Curves Model
LED	Light Emitting Diode
LPG	Liquid Petroleum Gas
MFI	Micro Finance Institutions
MJ/kg	Megajoules per Kilogram
MoE	Ministry of Energy
MSW	Municipal Solid Waste
Mton	Metric ton
NAWASSCO	Nakuru Water and Sanitation Services Company Limited
NCCAP	National Climate Change Action Plan

NCSP	Nakuru County Sanitation Programme
NCWSC	Nairobi City Water and Sewerage Company
NDC	National Designated Contribution
NDE	National Designated Entity
NEIP	National Expanded Irrigation Program
NEMA	National Environmental Management Authority
NGO	Non-governmental Organisation
PCB	Print Circuit Board
POPs	Persistent Organic Pollutants
PPP	Public Private Partnerships
QTM	Quality Test Method
RBF	Results Based Financing
RE	Renewable Energy
REREC	Rural Electrification and Renewable Energy Corporation
RKTC	Regional Testing and Knowledge Centres
RPR	Residue to Product Ratio
SACCO	Savings and Credit Cooperative Organisation
SDG	Sustainable Development Goals
SEFA	Sustainable Energy for Africa
SME	Small and Medium Enterprises
SNV	Netherlands Development Organization
TOC	Total Organic Carbon
UBPA	United Briquette Producers Association
UNDP	United Nations Development Programme
USA	United States of America
USD	United States Dollar
VAT	Value Added Tax
VEI	Vitens Evides International
WEEE	Waste from Electrical and Electronic Equipment
WIRE	Women in Renewable Energy
WtE	Waste to Energy
WTO	World Trade Organisation

Executive Summary

According to the Ministry of Energy's 2019 Kenya Household Cooking Sector study, less than 1% of all households reported having used briquettes in the 12 months preceding the survey. Despite the seemingly great potential, the briquette sector's contribution to the national energy mix remains negligible. The Climate Technology Centre and Network (CTCN) is providing technical assistance to Kenya through its National Designated Entity (NDE). The support is towards promoting the uptake of briquette use as part of its Nationally Determined Contribution (NDC).

The objective of the study is to gather knowledge that can be used to inform and guide the development of the briquette sector in the country. Multiple data collection approaches were conducted, including literature and data reviews, surveys with briquette manufacturers, biomass waste suppliers and briquetting machine fabricators and importers (both formal and informal), geo-spatial analysis and key informant interviews with sector experts.

The report covers the following areas: inventory of raw materials of high potential, briquette making technologies, analysis of the supply chain and identification of potential scenarios for scaling the briquette value chain, and the assessment of the policy environment influencing the briquettes sector.

less than

1%

of all households reported having used briquettes in the 12 months preceding the survey

Briquette production in Kenya

The study revealed that there are two main classes of briquettes produced in Kenya: carbonised and non-carbonised briquettes. Carbonised briquettes are made from biomass that has undergone pyrolysis while non-carbonised briquettes, on the other hand, are processed directly from biomass sources through various casting and pressing processes. Relative to non-carbonised briquettes, carbonised briquettes have a higher calorific value, burn with minimal smoke, contain lower ash content, and cannot be destroyed by insects such as termites. For these reasons, they are preferred for cooking and space heating (e.g., poultry farming). Non-carbonised briquettes are cheaper (per unit mass) and burn longer (up to 6 hours). They are preferred by industrial and institutional users such as factories, schools, hospitals and prisons.

Briquette producers can be grouped into sole entrepreneurs, limited companies, and Community Based Organisations (CBO) with most of those interviewed being limited companies (11/20). The informal and artisanal small-scale producers constitute a significant number in the industry and are mainly in carbonised briquettes production. However, it is difficult to exhaustively profile them, their businesses and product since they do not have an online presence. Their products are not standardized nor are they labelled. For example, about 11 businesses, 55% of the producers interviewed, reported taking their briquettes for independent testing either at KEBS (4 businesses) or KIRDI (7 producers).

Although most of the briquette producers who were interviewed for the study had started their operations in the last five years (12/20). It was noted that others such as Kings Biofuels, Eversafe Limited, Lean Energy and Chardust have been in the market for the last decade.

It was observed that women and youth are active in the sector with 11/20 and 10/20 businesses being owned by women and youth respectively. It was also observed that 69% of all employees are youth (less than 35 years). Men formed a higher proportion of full-time employees (62%) with women working on temporary basis. This might be explained by the fact that most large producers hire temporary workers to help with activities such as sorting of waste, drying of the raw material and briquette drying which are often performed by women.

In regard to management, the proportion of men in managerial positions was slightly higher at 51 % compared to women at 48%. It was also observed that more than half (53%) of employees in managerial positions were youth.

Charcoal dust was the most common type of feedstock with 9/20 producers (CBOs and sole proprietors) using it as the main feedstock. This could be explained by the fact that the waste is already carbonised and can be acquired for free or at a minimal cost of about KES 1 per kilogram making it a desirable raw material for small-scale producers. Charcoal dust was also used prominently by producers who target households, small hotels or poultry farmers who require carbonised briquettes. Bagasse and sawdust were the most common raw materials for limited companies who produce non- carbonised briquettes. The map below shows location of different briquette producers identified by the study.


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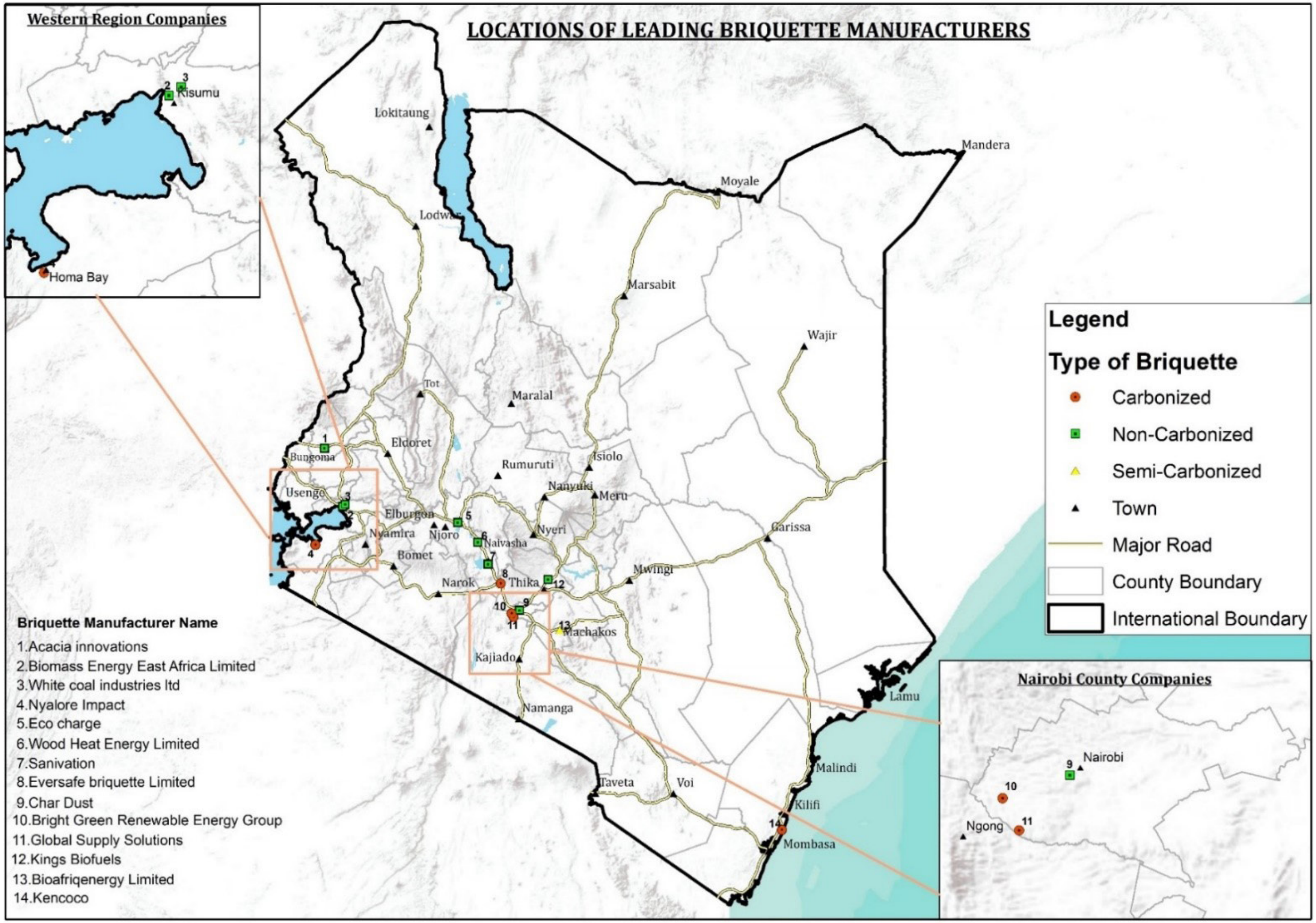
LOCATIONS OF LEADING BRIQUETTE MANUFACTURERS
Western Region Companies
Kisumu
Homa Bay
Nairobi County Companies
Nairobi
Ngong
Legend
Type of Briquette
Carbonized
Non-Carbonized
Semi-Carbonized
Town
Major Road
County Boundary
International Boundary
Lokitaung
Lodwar
Moyale
Mandera
Marsabit
Wajir
Tot
Maralal
Eldoret
Bungoma
Usenge
Rumuruti
Isiolo
Nanyuki
Meru
Elburgon
Nyamira
Njoro
Naivasha
Nyeri
Garissa
Bomet
Narok
Thika
Mwingi
Machakos
Kajiado
Namanga
Lamu
Malindi
Taveta
Voi
Kilifi
Mombasa
Briquette Manufacturer Name
1.Acacia innovations
2.Biomass Energy East Africa Limited
3.White coal industries ltd
4.Nyalore Impact
5.Eco charge
6.Wood Heat Energy Limited
7.Sanivation
8.Eversafe briquette Limited
9.Char Dust
10.Bright Green Renewable Energy Group
11.Global Supply Solutions
12.Kings Biofuels
13.Bioafriqenergy Limited
14.Kencoco

Assessment of raw materials that can be used for making biomass briquettes

Kenya has a considerable number of feedstocks from municipal waste, agricultural residues and forest residue that can be used for briquette production. However, the selection of a suitable feedstock is largely governed by the following key factors: (i) quantities available against competing uses, seasonality and ability to congregate the waste in a central location; (ii) quality of waste where the key factors include ash content, moisture content and calorific value and; (iii) cost of the raw material. Using these three main factors as the selection criteria, 28 potential wastes for briquette production were assessed on their suitability for briquette production. Five types of waste were considered for further analysis which include: bagasse, sawdust, organic waste, charcoal dust and faecal matter.

Ideally, the most suitable raw material for briquette production should be available in large quantities and easy to collect i.e., large quantities in a central location. Bagasse was found to tick most of these boxes. Sawdust, although a good briquetting material for non-carbonised briquettes, has limited supply compared to bagasse. Its cost is also relatively high. It was found that using sawdust to produce carbonised briquettes was not economically viable because of the losses of the raw material during the carbonisation process or thermal decomposition. Charcoal dust was found to be an ideal raw material for the production of carbonised briquettes but it is difficult to obtain it in large quantities in a single location. It is, therefore, recommended for small-scale producers of briquettes.

Faecal matter was found to be available in large quantities but the downside is that it must be blended with other types of raw material to make it usable. This requires a high level of investment. In addition, there are other challenges regarding the use of faecal matter that need to be addressed such as public health concerns and cultural inclinations.

Household waste would be ideal but, in Kenya, waste is not sorted at the household level. In that case, the producer must be ready to invest in sorting the waste. Market places were identified as sources of the homogenous waste but it was found that other competing uses and the level of investment required make it economically unsuitable for briquette production.

Identification of briquette making technologies

Three types of technologies for briquette production were identified;

1. **Low pressure technology,** which uses manpower to drive the process (hand-made briquettes and manual machines)
2. **Medium pressure technology,** (screw extruders, agglomerator, roller drums, and hydraulic presses)
3. **High pressure technology,** which is used in production of non-carbonised briquettes (e.g., heated-die screw, ram/piston, and hydraulic presses).

The advantage with low-pressure technology is that it is low cost and needs the least start-up capital and technical operating skills. The downside of the technology is that it is only applied for small-scale production of briquettes, is time consuming and exposes the producer to dust and dirt. Production capacity per day is also low as it is highly dependent on the person who is manually running the machine.

Medium-pressure technology requires minimum labour and maintenance. The machines are readily available in the local market. However, their quality is doubtful. Most of them are poorly fabricated resulting in frequent breakdowns which interferes with the production output.

High-pressure machines are imported and are suitable for large scale briquette production. Although they have a high production rate, they require high initial capital (between KES 10 million to 50 million) due to the skilled manpower and spare parts which have to be sourced overseas. They are also associated with high power consumption which increases the cost of briquette production.

Supply chain of the briquette making processes

The key factors that briquette producers consider in selecting the most suitable feedstock for briquette production are quantities available, cost and quality. Transportation of the feedstock from the source to the point of production varied across the different types of feedstock.

For instance, producers utilising bulky feedstock such as bagasse or faecal matter were located near the source of the feedstock to reduce the cost of transportation. This is contrasted with other feedstocks such as sawdust or charcoal where producers are willing to cover longer distances to source the raw material. For example, one producer reported occasionally (three times annually) sourcing charcoal fines from as far as 400 km to supplement their supply.

Midstream activities included packaging and transportation of briquettes. The packaging sizes ranged from 1 kg to over 25 kg. The latter was mostly utilised by industrial and factory consumers. Producers distributing through supermarkets were required to seek certification from the Kenya Bureau of Standards. The cost of the briquettes was dependent on the type of briquette but the average cost of carbonised briquettes ranged from KES 25 - 30 per kg. Non-carbonised briquettes mostly utilised by industries and mid-scale entities were priced at KES 10 – 15 kg. Although majority of the producers reported purchasing feedstock on credit, there was a variation in their supply dynamics to consumers. That is, they offered credit terms, more so, for institutions and factories.

Policy and the regulatory environment

The study revealed that there is no overarching institutional framework that could anchor and inform the briquette sector's development. Recognising this, the Ministry of Energy developed an all-encompassing Bioenergy Strategy that will form the basis for transformation change within the sector moving from the incremental initiatives of the past. Briquettes and pellets are some of the cooking fuels covered under this strategy.

Another hurdle that complicates coordination of efforts is the disjointed institutional framework which disseminates functions across various public institutions. For example, the feedstock supply falls under the Ministry of Forestry and Environment and Ministry of Agriculture depending on the source, while promotion of technologies falls under Ministry of Energy and Ministry of Industrialisation, Trade, and Enterprise Development. Transportation of charcoal, which is the main source of charcoal dust used in briquette production falls under the Ministry of Environment and Forestry while the sale of briquettes could be influenced by the County governments or Ministry of Finance.

Scenarios of briquette production

Three scenarios to promote briquettes uptake in the country were developed. An ideal scenario would be one where; (i) the feedstock is readily available, affordable, accessible (ii) briquette making machines are available in the market and affordable (iii) the briquettes have a ready market.

The first scenario aims to explore the possibility of working with already existing producers who already have an established value chains and the other two scenarios explore how an ideal value chain would look like by setting up a central production facility for briquettes with bagasse as the main feedstock. Under the first scenario, the key components of the programme would include; (i) recruiting the briquettes producers to the programme; (ii) setting the standards for briquettes to be produced under the programme; (iii) creating an enabling environment by facilitating access to finance and fiscal incentives, facilitating access to the suitable technologies, awareness creation, supporting development of policies and clear institutional frameworks that support uptake of briquettes (iv) linking the producers to ready markets. The cost of setting and running the programme for the first 5 years was estimated at USD 2,346,160.

The second scenario explore the use of bagasse for production of carbonised and non-carbonised briquettes. The production unit would be located in Western Kenya where most of the sugar companies are located. Scenario analysis indicated that production of non-carbonised briquettes from bagasse would be more ideal than carbonised briquettes from bagasse in terms of cost and quality. The estimated cost of setting up and running a 20,000 tonnes per year production facility is estimated at USD 2,192,200 with that of non-carbonised briquettes is estimated at USD 1,380,720.

Scenario 3 provides a case for exploring the possibility of other raw materials such as faecal matter that can be used for briquette production to address the challenge of inconsistent availability of raw materials. It was however noted that faecal matter can only produce carbonised briquettes and advanced technology is a prerequisite to handle the faecal waste. The cost estimation of setting up the facility compares with the cost of setting up the facility for carbonised briquettes under scenario 2.

It is noteworthy that more than one type of scenario can be implemented at ago in a hybrid manner but that will be dependent on the environment it is being set-up. For example, the formation of a central briquette production facility would greatly benefit from the activities under the national briquette programme.

Barriers

Several challenges hindering the growth and development of the briquette sector were identified. These include lack of an overarching institutional framework to govern the briquette sector, lack of enforceability of the existing policy instruments, legal instruments and standards to guide the briquette sector, lack of awareness of existing standards by the manufacturers, distributors and programme implementers and, lack of awareness of briquette products by end users, limited fiscal incentives to attract substantial private sector investments, especially to produce briquettes for household consumers. Briquettes for households have competing fuels that are affordable, consistently available and of a higher quality, (e.g., LPG and charcoal). Additionally, the more affordable and most commonly used stoves such as the Kenya Ceramic Jiko (KCJ) is noted to be unsuitable for burning briquettes. The well adaptable stoves to briquettes are relatively expensive retailing between KES 3,000- 5,000, compared to the KCJ, which is KES 500-700.

Conclusions and Recommendations

The briquette market is still at a nascent stage and therefore taxation and lack of fiscal incentives will continue to cripple the sector. Comparing carbonised and non-carbonised, briquettes for industrial use provided a more feasible business opportunity compared to carbonised briquettes. Carbonised briquettes are preferred for households and small-scale enterprises such as hotels, have to contend with other fuels such as charcoal and LPG which are readily available, affordable and of high quality. Relative to carbonised briquettes, non-carbonised briquettes have a ready market as some users are conscious on cost, environmental benefits of using briquettes over furnace oil and being energy secure due to unplanned disruption of the grid. Non-carbonised briquettes are less costly to produce compared to carbonised briquettes, which require longer processes including carbonisation, use of binders, drying and small-scale packaging of the briquettes. In the production of non-carbonised briquettes, all these processes are eliminated from the production process. Additionally, there are greater gains in mitigation of greenhouse gases as the non-carbonised briquettes would replace fossil fuels and not biomass as is the case for briquettes meant for household use.

Recommendations on how to address the various hurdles along the briquette production landscape were identified and discussed. These include promotion of voluntary standards and labels for briquettes, strategic awareness creation, provision of fiscal incentives, creation of demand and briquette production hubs, access to finance for briquette producers and mainstreaming gender into energy policies. To realise the expected transformation in the sector, these recommendations must be implemented in concert. One way this can be achieved is through the design and implementation of a national programme mandated to promote the uptake of briquettes in Kenya. The programme will work with already existing briquette producers to help them grow their businesses by addressing the various challenges in the sector. The programme will be housed at the Renewable Energy Directorate in the Ministry of Energy. Under the umbrella of this programme, the following would be implemented: strategic awareness creation, creation of an enabling environment by facilitating access to finance and fiscal incentives; facilitating access to suitable technologies; supporting development of policies and clear institutional frameworks that support uptake of briquettes and linking the producers to ready markets. This is extensively explained under Scenario 1 in Chapter 6.

1 | Introduction

1.1 State of cooking in Kenya

The Ministry of Energy (MoE) (2019) *Kenya Household Cooking Sector Study* estimates that 75% of all households in Kenya still use solid biomass as their primary cooking fuel – 38% and 93% in urban and rural households respectively as shown in Figure 1 below[1] – the definition of primary cooking fuel being the cooking solution that is most frequently used.

As shown in Figure 1 above, the choice of cooking solution varies greatly between urban and rural households. The use of traditional non-commercial solutions is prevalent in rural areas as expected. Urban users depend more on cooking solutions that use charcoal, LPG and kerosene. It is for this reason, that urban households are seen as a potentially significant market for briquettes which could supplement or substitute fuels such as charcoal. Table 1 below highlights the main cooking fuels used by households within Kenya's largest urban areas (population of more than 250,000) as reported in the 2019 census[2]. The data is reported at the sub-county level for some urban areas. As seen, LPG, paraffin, firewood and charcoal are the primary cooking fuels in Kenya's urban areas.

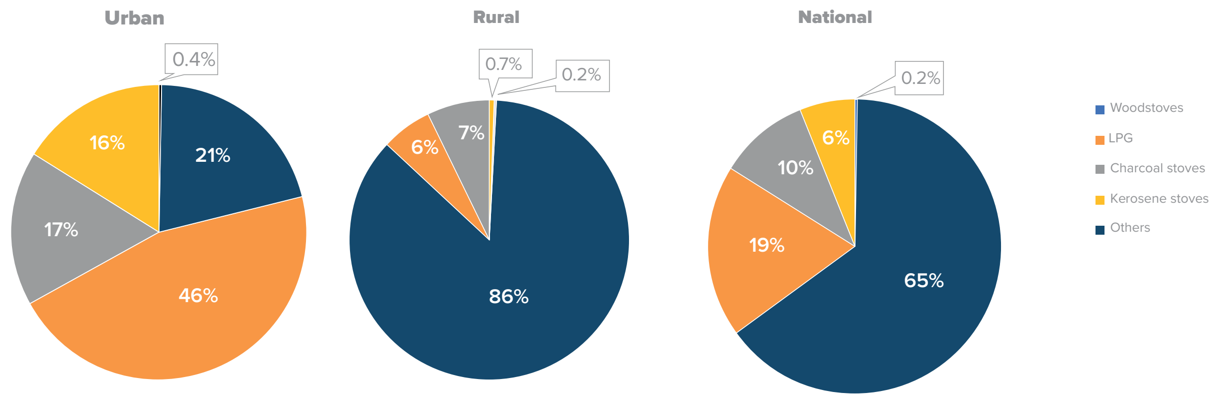

Figure 1 Household level primary cooking fuels – urban, rural and national (Data from MoE, 2019)

Table 1 Main types of cooking fuels in Kenya's largest urban areas

Urban Area	Sub-county	Urban Population	# of HH	Electricity	Paraffin	Gas (LPG)	Biogas	Firewood	Charcoal	Solar
Nairobi City	All Sub-counties	4,397,073	1,494,676	2.3	26.5	67.2	0.6	0.7	2.7	0.0
Mombasa County	All Sub-counties	1,208,333	376,295	1.4	32.1	37.6	1.1	4.7	23.2	0.0
Nakuru		570,674								
	Nakuru East		60,066	0.9	8.9	61.1	0.5	3.6	25.0	0.0
	Nakuru West		64,429	1.0	14.1	43.3	0.6	7.7	33.2	0.0
Ruiru	Ruiru Sub-county	490,120	127,910	1.2	15.1	79.2	0.5	2.3	1.6	
Eldoret		475,716								
	Soy		53,758	0.6	5.2	13.0	0.3	65.3	15.2	0.3
	Turbo		71,587	1.2	10.0	28.2	0.4	35.8	24.3	0.1
	Moiben		46,602	1.0	3.4	29.5	0.3	48.3	17.3	0.1
Kisumu	Kisumu Central	397,957								
Kikuyu	Kikuyu	323,881	60,619	0.7	7.5	61.0	0.4	18.1	12.2	0.0
Thika	Thika West	251,407	89,089	0.8	17.6	76.3	0.5	2.6	2.3	0.0

1 Ministry of Energy (2019), Kenya Household Cooking Sector Study

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

Further, stacking of cooking solutions is common practice among Kenyan households. Stacking refers to the use of multiple devices and fuels to meet and optimise a household's cooking energy needs practiced by 51% of households, (MoE, 2019). The MoE, 2019 report notes that most of the households using LPG as their primary cooking fuel also use traditional cooking fuels like wood (17%), kerosene (18%) and charcoal (47%). 53% of households in urban areas practice cookstove stacking. Among these, 34% and 7% use charcoal and wood stoves respectively. As such, the use of biomass stoves is more prevalent than the 38% that report using these as their primary stoves (MoE, 2019). It is therefore imperative to look beyond primary cooking behaviour for any intervention that seeks to displace use of solid biomass in cooking. The MoE, 2019 report estimates that 9.6 metric tonnes (Mton) of fuelwood and 2.0 Mton of charcoal are consumed by Kenyan households annually, with urban areas responsible for 1.3Mton and 0.7Mton of fuelwood and charcoal respectively. While urban households are seen as the obvious market for briquettes and other charcoal substitutes, these statistics demonstrate that up to 65% of charcoal consumed in households is consumed in rural areas.

Comparing the cost per unit mass of fuels across the four main cooking fuels in Kenya can be elusive. As such, we also consider cost per energy output as shown in Figure 2 below (the asterisk on charcoal indicates statistically significant differences between rural and urban areas with 95% confidence). In terms of cost per kg, firewood is the least costly fuel followed by charcoal[3]. Additionally, LPG is the costliest fuel of the four types of fuels and is closely followed by kerosene. However, if you consider energy content, kerosene is the least costly fuel followed by LPG. There is a slight difference in the price of fuels in rural and urban areas.

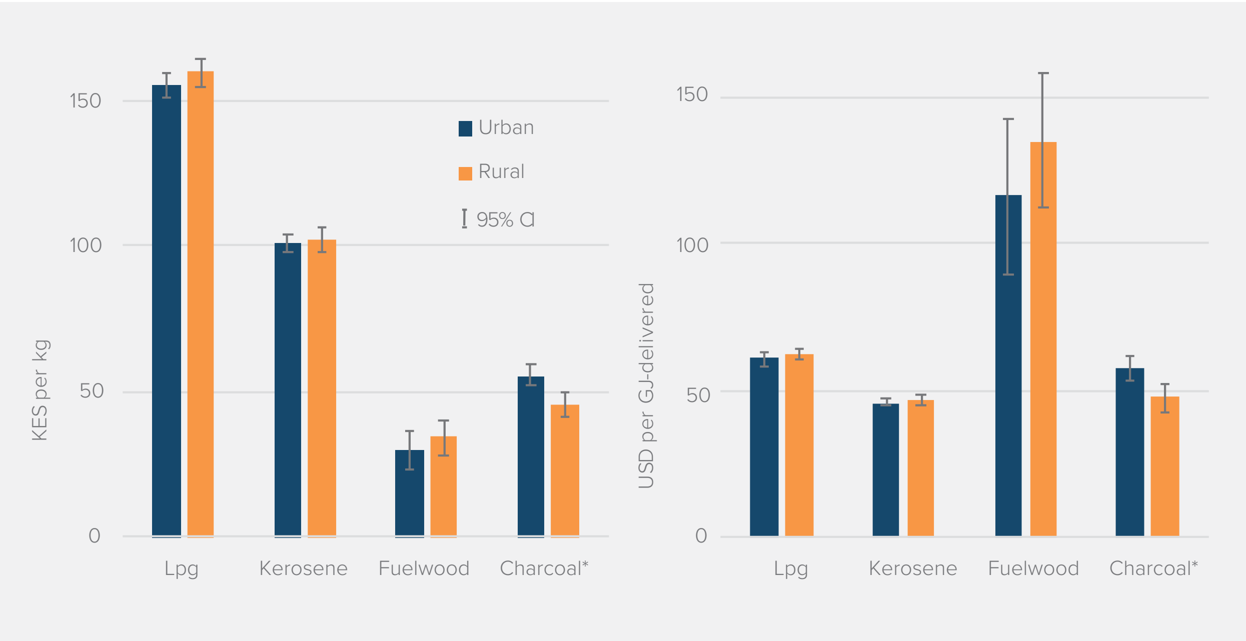

Figure 2 Fuel price per unit mass (left) and energy delivered (right) for major commercial fuels

3 Ministry of Energy (2019), Kenya Household Cooking Sector Study

1.2 Urbanization and demand for cooking fuels

Kenya has recorded rapid population growth, with the total population having expanded more than four times over the last 50 years; from 10.9 million in 1969 to 47.6 million in 2019[4]. Further, Kenya is characterised by rapid urbanisation and urban population growth though this rate is not as high as much of the rest of Africa, with the World Bank noting that this pace of urbanisation may be considered manageable[5]. Basing their definition of urban population as the 'core urban' population, Figure 3 summarises the growth in share of urban population in total population as reported by the World Bank. For comparison, the 2019 Kenya census data has the rate of urban population at 31.2% (14.8 million people) where urban centres are those that have a population of 2,000 and above[6].

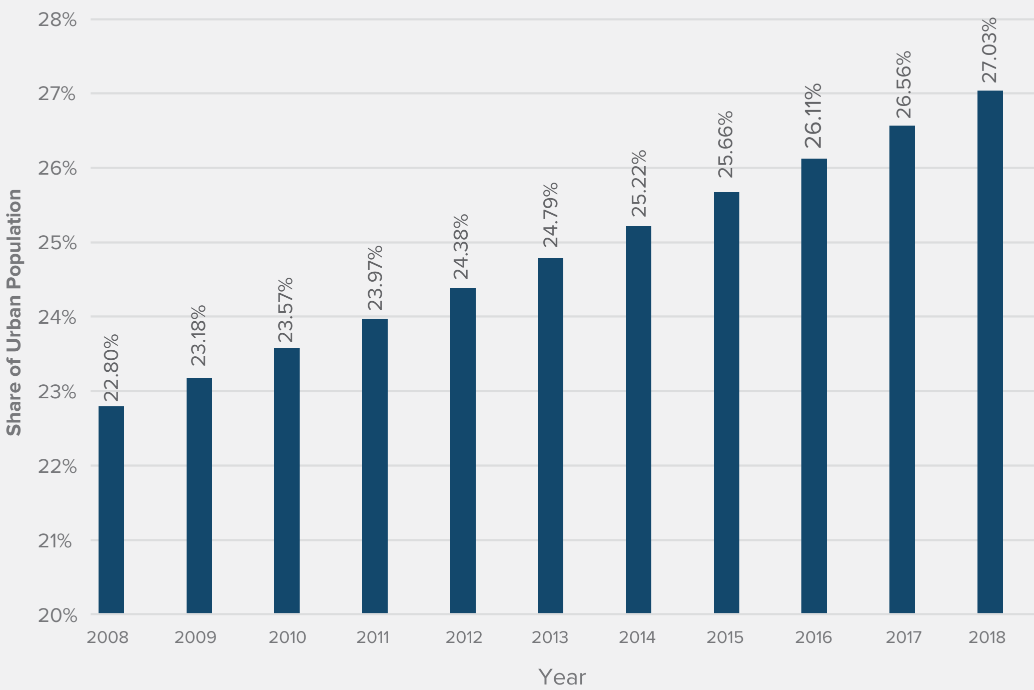

Figure 3: Share of urban population in total population (Source: World Bank Data)

A review of Kenya's GDP growth shows Kenya's urbanisation being driven more by a rural push than by an industry pull – while the urban population has been growing, the share in GDP of industry and services has remained quite stable[7]. Consequently, the urban economy is increasingly informal as jobs within the formal sector remain limited compared to demand.

In these dynamics are two key impacts on the energy sector. First is that the growing population is a major contributing factor to the increase in demand for cooking fuels. As presented in the previous section, solid biomass represents a significant source of energy for both rural and urban Kenyan households and, unless a fundamental shift is realised, the use of these fuels will remain prevalent over the coming years. Second, the informality of most jobs within urban areas, coupled with high unemployment rates, translates to low-income levels for most urban dwellers. Consequently, the cost of fuel (aggregate costs per volume, but more so, ability to pay in small quantities) becomes a key consideration in selecting cooking solutions.

4 KNBS (2019), Kenya population and housing census results, Kenya National Bureau of Statistics, Ministry of Planning, Kenya
5 The World Bank (2016), Republic of Kenya: Kenya Urbanization Review
6 KNBS (2019), 2019 Kenya Population and Housing Census Volume II: Distribution of Population by Administrative Units
7 The World Bank (2016), Republic of Kenya: Kenya Urbanization Review

In this population growth, however, is a potential energy resource – municipal solid waste. Municipal waste (such as paper and organic waste), agricultural and forestry residue have been used as potential sources of energy through various approaches such as the briquetting technology. Increase in population results in an increase in the amount of waste generated in the urban areas. In Nakuru County for instance, a 2017 feasibility report by the World Bank[8] found that the county generates an average of 523 tonnes of waste per day of which 80% is biodegradable material (e.g., organic food, paper, cardboard, textile). Nairobi County, on the other hand, is estimated to produce about 2,400 tonnes of waste per day; Kisumu county produces an estimated 500 tonnes of waste per day Kisumu County; Mombasa County produces 875 tonnes of municipal solid waste per day[9]. Recognising that most urban areas are limited in their capacity to collect waste[10], this is a resource that could be utilised to address the increasing energy demand driven by population growth. From a feedstock perspective there seem to be the potential to use the waste generated as input into fuel production. Briquetting is one of the options that can utilize this potential.

1.3 Introduction to briquettes


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The term "briquette" is a composite term used to identify a wide range of biomass-based fuels that vary in terms of composition, shape, size, energy density and price[11]. This variety is largely determined by the feedstock options and the process of production. Feedstock options used to create briquettes can be classified into four main groups: organic municipal waste, agricultural residue (e.g., coffee husks, sugarcane bagasse, rice husks, macadamia nuts, wheat straws), forestry residue (e.g., sawdust, chips, offcuts) and charcoal dust. Processes of production results in two main classes of briquettes; carbonised and non-carbonised briquettes. Carbonised briquettes are made from biomass that has undergone pyrolysis while non-carbonised briquettes, on the other hand, are processed directly from biomass sources through various casting and pressing processes also known as compaction or solidification. The raw material is typically compressed under high pressure, which releases the lignin in the biomass enabling the binding process that forms the non-carbonised briquettes[12].

Relative to non-carbonised briquettes, carbonised briquettes have a higher calorific value, burn with minimal smoke, contain lower ash content, and cannot be destroyed by insects such as termites[13]. For these reasons, they are preferred for cooking and space heating (e.g., poultry farming).

8 World Bank (2017), Nakuru Integrated Solid Waste Management PPP Project: Feasibility Study Report and PPP Implementation Plan

9 Oyake-Onbis, Leah (2017), Awareness on Environmentally Sound Solid Waste Management by Communities and Municipalities in Kenya

10 ibid

11 Ministry of Energy (2019). Kenya Household Cooking Sector Study: Assessment of the Supply and Demand of Cooking Solutions at the Household Level. https://www.eedadvisory.com/wp-content/uploads/2019/11/moe-2019-cooking-sector-study-.pdf

12 Nikolaisen, L.S., and Jensen, P.D. (2013). Biomass feedstocks: categorisation and preparation for combustion and gasification. Biomass Combustion Science, Technology and Engineering (pp. 36 -57). Woodhead Publishing Series in Energy. https://doi.org/10.1533/9780857097439.1.36

13 Hu, J., Lei, T., Wang, Z., Yan, X., Shi, X., Li, Z., He, X., Zhang, Q. (2014). Economic, environmental and social assessment of briquette fuel from agricultural residues in China – A study on flat die briquetting using corn stalk. Energy 64, 557 -566.

Non-carbonised briquettes are cheaper (per unit mass) and burn longer (up to 6 hours)[14], therefore preferred by industrial and institutional users such as factories, schools, hospitals and prisons. The ability to burn for long reduces the number of times the fuel must be loaded to the boilers thus reducing the cost of energy for end-users. These two briquetting processes are explained under Section 2 of this report. In addition to these two main classes of briquettes, there is a third but uncommon class known as semi-carbonised briquettes formed through a process known as torrefaction[15]. These are briquettes whose outer layer (2-4 millimetres) is carbonised while the inner section is non-carbonised. The approach to production includes manual (artisanal), mechanical and electrical processes and varies from micro-scale production (e.g., hand-made briquettes) to large-scale production (e.g., assembly line industrial scale based).

While recognising the diversity in input material, types of producers, process of production and scale of production, this report will outline the technologies under each of the main steps along the production process. The main processes are divided into; i) pre-processing, ii) pyrolysis and carbonisation, iii) mixing, iv) binding and compaction and v) drying as shown in Figure 4 below.

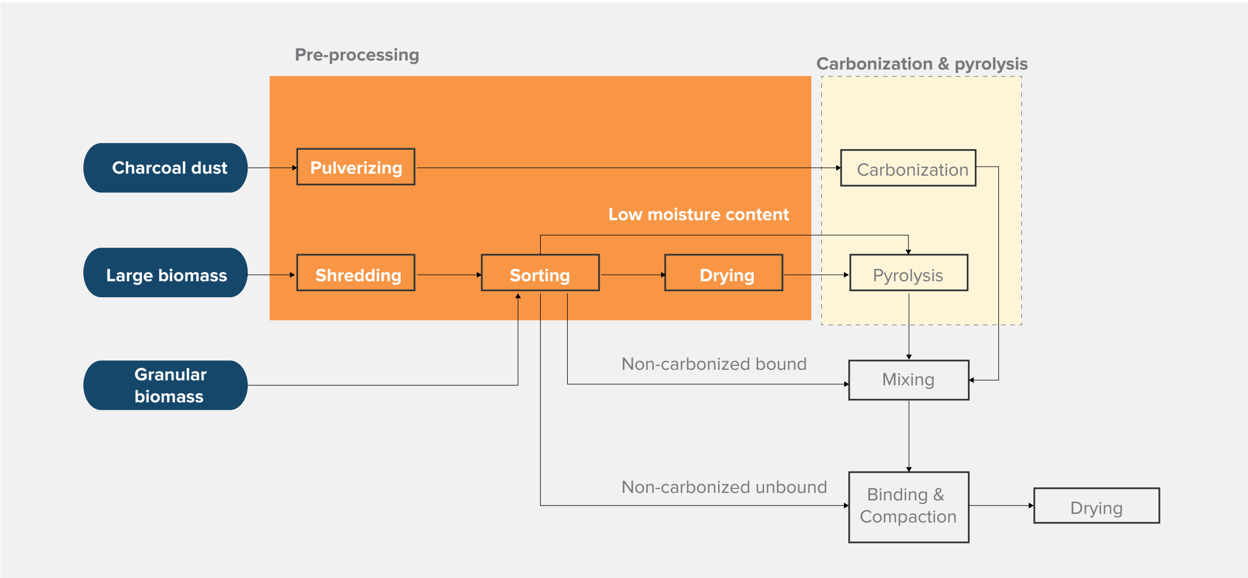

Figure 4: Main step along the production process

1.4 Summary of past initiatives and current producers

Two of the earliest briquette-making plants in Kenya were installed in the 1980s with the goal of meeting energy demand for industries and reducing the high dependence on imported oil [16]. The need for self-reliance was driven in part from the lessons and inconvenience of the 1973 global oil crisis[17]. One of the most prominent briquetting plants was set up by the Kenya Planters Co-operative Union (KPCU) in 1981 to supply consumers who depend on charcoal in urban and peri-urban areas of Kenya and for export to Saudi Arabia[18]. About 200 tonnes of charcoal a month was produced from 400 tonnes of coffee husk during the earlier years. The project was informed by the various studies that had predicted a shortage in the supply of wood and an increase in the rate of deforestation if alternative sources of fuels were not promoted. Between then and now, there have been several initiatives led by development agencies, research institutions, Government departments, non-governmental organisations. Table 2 below provides a summary of key initiatives that have been implemented in Kenya.

14 Key informant Interview

15 Stepien, P., Pulka, J., Bialowiec, A. (2017). Organic Waste Torrefaction – A Review: Reactor Systems, and the Biochar Properties. Pyrolysis Intechopen http://dx.doi.org/10.5772/67644

16 FAO. (1990). The briquetting of agricultural wastes for fuel; Part 3 Country Reviews. http://www.fao.org/3/t0275e/T0275E06.html

17 Issawi, C. (1978). The 1973 Oil Crisis and After. Journal of Post Keynesian Economics, 1(2), 3–26. https://doi.org/10.1080/01603477.1978.11489099

18 FAO (1985). Unasylva – International journal of the forestry and food industries. Food and Agriculture Organisation of the United Nations, Rome – Italy.

Table 2: Summary of key initiatives promoting briquetting technologies

#	Organisation	Name of the initiative	Activities
1	Energy 4 Impact	Developing Energy Enterprises Project (DEEP) Capital Access for Renewable Energy Enterprises (CARE2) Project (2008-present)	• Business and technical advisory services • Market development • Financial linkages to purchase machinery • Improve quality of briquettes through product design • Promote gender diversity and inclusion
2	Practical Action East Africa	Briquette Commercialisation Project (2011-2015)	• Technical advisory on the technology • Assistance on setting up the business
3	Netherlands Development Organisation (SNV)	Improved Charcoaling Technologies and Briquetting using Agricultural Waste (Jan-Sept 2013)	• Technical advisory on the technology • Assistance on setting up the business
4	Middlesex University, Kenyatta University, Terra Nuova	Fuel from Waste Network (2010-2012)	• Formed a network of briquette producers • Facilitated knowledge sharing • Create awareness of the technology/best practice
5	Kenya United Briquette Producers Association (UBPA)	Supporting the expansion and replication of briquetting businesses in East Africa[19]	• Supporting technical, financial, and policy innovations.
6	Hivos in partnership with the Greening Kenya Initiative Trust (GKIT)	The National Biomass Briquette Programme (2018-2022)	• Establish standards for production of domestic and industrial briquettes • Support community-based enterprises to create sustainable income while safeguarding the environment
7	NAWASSCO in partnership with SNV, Umande Trust and Vitens Evides International	Nakuru County Sanitation Programmeme (2018)	• Formed a subsidiary company Nawasscoal for producing carbonised briquette from the combination of sawdust and faecal matter collected in Nakuru county
8	Kenya Bureau of Standards (KEBS)	Quality assurance	• Development of the briquette standards • Enforcement and monitoring for compliance
9	Kenya Industrial Research and Development Institute (KIRDI)	Research and Development	• General research on briquettes • Testing facilities
10	Jomo Kenyatta University of Agriculture and Technology	Research and Development	• Research in low-cost briquette-making machines
11	University of Nairobi	Research and Development	• Testing facility • Research in briquettes
12	The Kenya Forestry Research Institute (KEFRI)	Research and Development	• Research on improved carbonisation methodologies
13	Ministry of Energy	Energy Centres	• Demonstration and training hubs in sustainable energy. • Training and awareness creation of briquetting technology.
14	Energy and Environment Partnership (EEP)	Research and Funding	• Research into briquette markets • Grant programmes

19 The Charcoal Project. (2019). New Carbonised Briquette Producer Association Created in Kenya. https://newsite.charcoalproject.org/kenya-briquette-manufacturers-association-to-hold-first-general-meeting-july-23rd/

Other organisations that have been active in the sector include; Rotary International who partnered with Energy 4 Impact to provide grants for purchasing of briquetting; Green Africa Foundation who were involved in trainings and facilitating acquisition of machines for the manufacturers; Legacy Foundation that was involved in the production of the wood press machines and user manuals; Kiva which provides loans to business start-ups including briquette producing enterprises, and the Green Belt Movement who partnered with AMREF to train manufacturers in Kajiado on briquette production. Even with the years of experience and demonstrated technical potential and appropriateness, perennial barriers still hinder the uptake of briquettes as a mainstream cooking solution within households. Key among these is the relatively high cost of the fuel, constrained feedstock supply, disjointed or non-existent supply and distribution networks, and competition from alternative sources of cooking fuels[20].

1.5 Purpose of this study

It is within this context that Kenya, through its National Designated Entity (NDE), has sought technical assistance from CTCN to support the development of the briquetting sector as part of its objectives under the NDC and NCCAP. Production of briquettes is viewed as an opportunity to sustainably address the increase in demand for energy and the need to effectively manage solid biomass waste from the growing urban populations. This request requires an evaluation of the sector with a focus on charcoal dust, saw dust and organic municipal solid waste and their potential as viable feedstock options to produce briquettes. Based on the *Technical Assistance Response Plan – Terms of Reference* submitted by the NDE, this assignment also aims to assess the briquetting value chain ranging from sourcing of raw materials, briquette production technologies, supply chains and the policy environment in the sector. For each of these tasks, the output is a standalone report. This report combines a series of six reports presented as chapters as shown in the Table 3. Additionally, a chapter on barriers and recommendations is added to enrich the discussion.

Table 3: Series of reports

#	Report	Title
1	Part 1	Inventory of raw materials that can be used for making biomass briquettes
2	Part 2	Identification of biomass waste-based briquettes making technologies
3	Part 3	Assessment of the existing briquettes production chain
4	Part 4	Identification of scenarios for briquettes value chains
5	Part 5	Review of legal frameworks related to briquette production in Kenya
6	Part 6	Development of a training manual

20 Ministry of Energy (2019), Kenya Household Cooking Sector Study

2 | Approach and Methodology

2.1 Approach

Information and data used in this report was collected through literature review and primary data analysis. This was then analysed and synthesised into a unitary report. Figure 5 below summarises the main approaches and methods used.

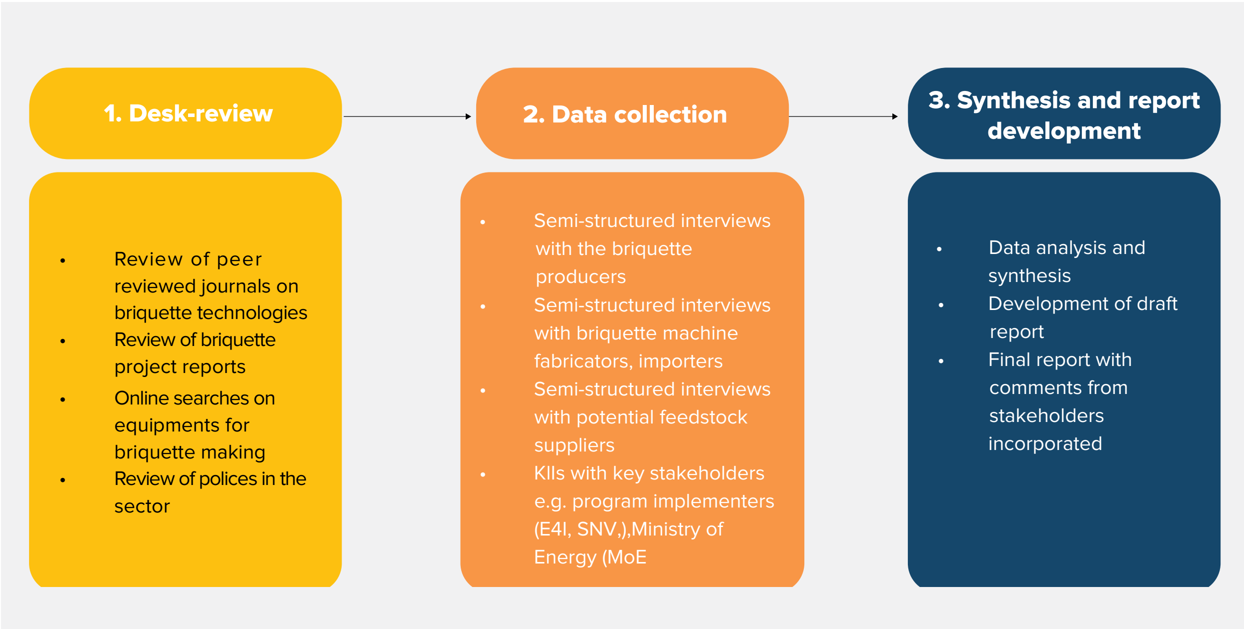

Figure 5: Summary of approach and methodology

2.2 Methodology

2.2.1 Literature and secondary data review

Literature and secondary data review included the appraisal of relevant literature on briquetting technologies, policy, legal and institutional frameworks from peer reviewed journals, grey literature, Government reports and various data depositories. A summary of the main reports published in the recent past and data depositories that were reviewed is provided in Table 4 below.

Table 4: List of prominent reports

#	Author/ Institution	Title	Key findings
1	GVEP (now Energy 4 Impact)	Assessment of the briquette market in Kenya (2013)	• Survey covered 35 briquette entrepreneurs. • Categorised the briquetting technologies into handmade, manual machines, locally fabricated electric machines and imported machines. • Charcoal dust was the most common type of feedstock (26/35 respondents). • Charcoal was the most preferred fuel compared to briquettes due to quality issues.
2	George Ngusale	Briquette Making in Kenya; Nairobi and Peri-Urban Areas (2014)	• Survey covered 18 briquette entrepreneurs. • Charcoal dust was the most common feedstock for briquette production. • Consumers are the schools, churches, hotels and some households. • Barriers identified included; technological challenges (lack of briquetting machines, low quality binders and lack of appropriate feedstock), lack of finance to grow the business, and lack of briquette standards.
3	Mary Njenga	Evaluating Fuel Briquette Technologies and their implications on Greenhouse Gases and Livelihoods in Kenya (2013)	• Study of briquette production methods in Nairobi and surroundings. • A Focus Group Discussion (FGD) with eight self-help groups and one private company was carried out. • Additionally, laboratory experiments on ash contents, volatile matter and calorific values for the different types of briquettes were conducted. • Fuel briquettes made from charcoal dust and soil as the binder performed the best in terms of combustion and emission qualities. • Type of tree species determine the quality of charcoal dust produced during charcoal production. • Carbonising sawdust increased calorific value of the briquette by 40%, reduced Indoor Air Concentration (IAC) of CO by 67% and P.M 2.5 by 98%. • Adopting improved wood production and wood carbonisation systems will result in additional cooking fuel supply and reduced Global Warming Potential. • Trainings to community groups were recommended to aid in improving the quality of briquettes produced.

4	Article on Energy for Sustainable Development (Mwampamba,T., Owen. M. and Pighart. M)	Opportunities, challenges and way forward for the charcoal briquette industry in Sub-Saharan Africa (2012)	• Study covered charcoal producers in Kenya, Rwanda, Uganda, and Tanzania. • Briquettes have displaced only small volumes of charcoal demand. • Main barriers in the sector include; low prices of wood charcoal, fiscal requirements for briquette producers, and supply-driven (versus market-led) approaches to industry development.
5	European Union	Biomass Use and Potential for Export from Kenya to the European Union 2015 – 2030	• Biomass feedstock assessment. • Feedstock quantification. • Feedstock characterisation.
6	FAOSTAT Database	Food and Agriculture Data (2018)	• Crop production.
7	Agriculture and Food Authority (AFA)	Year Book of Sugar Statistics 2019	• Sugar quantities produced for year 2019. • Bagasse quantities and characterisation. • Characterisation of the sugar sector in Kenya.
8	Chardust Ltd and Spectrum Technical Services	The Use of Biomass to Fabricate Charcoal Substitutes in Kenya. Feasibility Study: Forming Part of the Shell Foundation-Supported Project on Charcoal Briquetting in Kenya (2004)	• Assessment of the biomass for briquette production. • Characterisation of the biomass. • Quantification of the biomass.

2.2.2 Primary data collection

Primary data collection involved conducting interviews with briquette producers, briquette making equipment fabricators and distributors, and a select set of opinion leaders and experts in the sector. From a long list of 60 briquette producers a representative short list of 25 producers was created. This sample included a mix of carbonised and non-carbonised briquette producers; small, medium and large-scale producers; sole entrepreneurs, community-based organisations and limited companies; and a regional representation of producers. Three interviews were held with local fabricators, 1 importer and 1 international manufacturer. A list of the respondents is provided in Annex 3, 4 and 5. To access raw materials for briquetting primary data collection involved conducting interviews with selected possible suppliers of the raw materials for briquette production. Spot visits were also conducted within timber yards, furniture production hubs and charcoal vendors in Nairobi County and telephone interviews with saw millers. These include:

- Two retail charcoal vendors in Kawangware,
- Two charcoal wholesalers in Parklands area,
- A timber yard in Kawangware
- Furniture production hub along Ngong Road
- Two saw-millers (one in Iten and one in Nakuru)

Key Informant Interviews

Key Informant Interviews were conducted with policy and regulation experts and briquette programme implementers and financiers. Policy and regulation experts, for example government officials from the Ministry of Energy, Energy and Petroleum Regulatory Authority and Kenya Bureau of Standards, were interviewed to gather opinions on how briquette production can be fostered and regulated. Other key stakeholders including programme implementers such as SNV, Energy 4 Impact and the Clean Association of Kenya were consulted on their experience with the briquette sector. A full list Key Informants interviewed has been provided in the annex.

2.2.4 Synthesis

Report synthesis focused on aggregating and analysing qualitative and quantitative data to develop the various reports on biomass availability, technologies for briquette production, legal and regulatory environment for briquette production, baseline and proposed briquette value chains, the training manual for briquette production, closure and data collection report and revision of the CTCN impact description document.

3 Inventory of Raw Materials for Making Biomass Briquettes in Kenya

There is no single universal definition of waste, as the definition remains quite subjective. What is considered waste for one process can be a resource for another activity. Different countries adopt different definitions and classifications of waste according to the purpose and message intended to be passed across. The Kenya National Sustainable Waste Management Bill (2018), defines waste as *"any substance, material or object, that is unwanted, rejected, abandoned, discarded or disposed of, or that is intended or required to be discarded or disposed of, by the holder of that substance, material or object, whether or not such substance, material or object can be re-used, recycled or recovered and includes all wastes as municipal waste, domestic waste, waste from agriculture, horticulture waste, aqua culture waste, forestry waste, biomedical, hazardous, industrial waste, pesticide and toxic substances".* Common classification of waste includes[21]; (i) physical state-solid, liquid or gaseous waste, (ii) source of waste - domestic, industrial, commercial, forestry or agricultural waste and; (iii) impact to the environment- hazardous or non-hazardous waste. Waste generation has always been a concern for countries since the pre-historical period. However, in the recent past population growth and urbanization in developing countries have increased the quantities of waste generated resulting to limited land to absorb the large volumes of waste in cities. Kenya for instance, has recorded rapid population growth, with the total population increasing more than four times over the last 50 years; from 10.9 million in 1969 to 47.6 million in 2019. Kenya is also characterized by rapid urbanization and urban population growth which has an impact on the quantities of waste generated in urban areas. Most urban areas in Kenya are limited in their capacity to collect and dispose of waste[22]. This has given rise to indiscriminate littering and open dumpsites such as the popular *Dandora* dumpsite in Nairobi and *Kachok* dumpsite in Kisumu. These dumpsites pose a significant risk not only to public health but also to the environment. Recognising that there is an increase in waste generated in urban areas and a challenge in waste management, this chapter aims to explore the various opportunities for investment in waste management with a focus on waste to energy scenario and specifically the use of waste for production of briquettes. This is geared towards addressing the increasing energy demand driven by population growth and waste management. This report is part of a series of outputs under the CTCN Technical Assistance to Kenya on *Urban Briquette Making Pilot Project.* The report presents an assessment of the different types of waste with the aim of identifying the most suitable raw material for briquette making in Kenya. An overview is provided on the impacts of waste to the environment in a Business-as-Usual Scenario (BAU), various ways of waste management are discussed and an assessment of the most viable waste for briquette production is conducted. The study focuses on the following categories of waste:

- ***Municipal solid waste (MSW)*** is defined as all solid domestic refuse, and non-hazardous wastes such as commercial and institutional wastes, street sweepings and construction debris[23]. Typically, the material composition includes organic waste, paper, glass, plastic, metal, charcoal dust and others (hazardous household waste, diapers and textiles, among others). For production of briquettes organic waste is prioritized for this study. The potential of faecal matter as a potential briquetting material is also assessed.

- ***Agricultural waste*** is waste resulting from rearing of livestock and the production and processing of food and fibre. Examples include; crop residues, animal manure (poultry houses and slaughter-houses), dead animals, harvest waste, and fertilizer runoff that contributes to contamination of the environment[24]. This study focuses on crop residues such as bagasse from sugar cane, rice husks from rice, coffee husks from coffee, maize cobs from maize, etc.

21 Amasuomo, E and Baird J. (2016). The Concept of Waste and Waste Management. Journal of Management and Sustainability 6 (4). http://dx.doi.org/10.5539/jms.v6n4p88

22 ibid

23 Magutu P.O and Onsongo C.O. (2011). Operationalizing Municipal Solid Waste Management. Integrated Waste Management – Volume II. Integrated Waste Management DOI: 10.5772/16457

24 OECD. Glossary of Statistical Terms. Retrieved from https://stats.oecd.org/glossary/detail.asp?ID=77

- ***Forestry waste*** is a by-product of harvesting wood or processing of forest resources e.g., saw-dust.

3.1 Impacts of municipal solid waste to the environment in a BAU scenario

Due to the non-engineered sanitary landfills, discharge (leachate) and emissions emanating from the waste is released into water, soil and air. The source of pollutants from the commingled waste arises from i) microbial decomposition of organic waste and biomass ii) infiltration of water, iii) heavy metals and iv) open burning of waste. The initial degradation phase of organic waste materials (food residues, paper and biomass), hydrolysis, is aerobic, however, after oxygen depletion the degradation continues anaerobically through acetogenesis and methanogenesis. The latter leads to the production of greenhouse gases (methane and carbon dioxide)[25] and other trace gases (hydrogen sulphide and ammonia) which cause air pollution. Additionally, the chemical, microbiological and physical processes lead to transfer of pollutants to water emanating from groundwater underflow, surface runoff and precipitation, which leads to production of landfill leachate. This is further elaborated in the section below.

3.1.1 Surface Water and Groundwater Contamination

The exact chemical composition of landfill leachate depends on the waste composition, climatic conditions, age and degradation of solid waste. Typical constituent concentrations indicate high ammonia-nitrogen and organic nitrogen, which cause eutrophic conditions in surface waters when in high concentrations[26]. Other pollutants include Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Biological Oxygen Demand (BOD), specific organic compounds and heavy metals[27]. Currently, the operational open dumpsites in Kenya are not engineered to contain or treat leachate, which percolates to lower soil layers leading to contamination of groundwater, and residual soil. A study of Nairobi River and groundwater around *Dandora* dumpsite indicated high concentrations of COD and heavy metals (Cadmium (Cd), Lead (Pb)) as shown in Table 5.

Table 5: Mean concentration of heavy metals, BOD and COD for Dandora Dumpsite Leachate compared to effluent discharge permissible levels issued through NEMA Water Regulations

Contaminant	Mean Range Concentration of Leachate (mg/l)	Effluent discharge permissible levels (mg/l)
Lead (Pb)*	3 – 4*	1.0
Cadmium (Cd)*	1.5 -2.0*	0.5
Chromium (Cr)	0.5 – 1.5	2.0
Zinc (Zn)	0.5 – 1.5	5.0
Antimony (Sb)	3.5 – 4.0	-
BOD	403	500
COD*	10,700*	1,000

*Concentrations surpassing permissible levels (Data sourced from Odhiambo 2017[28], NEMA Water Quality Regulations)

Whereas city residents do not depend on the river water for daily use, risk of exposure exists through consumption of livestock reared and vegetables irrigated using contaminated water as well as crops grown on contaminated land. An assessment of the metal extent in blood of livestock from Dandora dumpsite indicated high levels of Cadmium (0.17 – 4.35 µg/kg dry-wt) and lead poisoning (90 – 2710 µg/kg) suggesting human exposure through livestock consumption was likely. Additionally, charcoal dust, which accumulates in the charcoal selling points is disposed to the drains or burnt. This results to blockage of the drainage and emissions from burning[29].

3.1.2 Greenhouse gases and other hazardous gases

According to the Kenya Climate Change Action Plan, greenhouse gas production from the waste sector under a business-as-usual model was estimated at 2.4 $MtCO_2$-eq in 2015 and projected to increase to 4.7 $MtCO_2$-eq in 2030[30], of which solid waste accounts for 75% of the emissions[31].

25 Bhalla B., Saina M.S., and Jha M.K. (2018). Effect of Age and Seasonal Variations on Leachate Characteristics of Municipal Solid Waste Land-fill. International Journal of Research Engineering and Technology 2(8)

26 Stefanakis A., Akratos C., Tsihrintzis V. (2014). Vertical Flow Constructed Wetlands: Eco-engineering Systems for Wastewater and Sludge Treatment. (CHAPTER 7: Treatment of Special Wastewaters in VFCWs pp 145-164) ISBN 9780124046122

27 ibid

28 Odhiambo H. (2017). Survey on Environmental Impact caused by Dandora Dumpsite and Proposal of Mitigation Measures. (Master Thesis).

29 Njenga,M., Karanja,N.and Iiyama,M. (2013). Implications of Charcoal Briquette Produced by Local Communities on Livelihoods and Environ-ment in Nairobi- Kenya. International Journal of Research and Development DOI: 10.14710/ijred.2.1.19-29

30 Ministry of Environment and Natural Resources (2017). Kenya's Nationally Determined Contribution (NDC): Update of Kenya's Emission Baseline Projections and Impact on NDC Target. Nairobi; Kenya

31 Kenya's Climate Change Action Plan: Mitigation Chapter 9: Waste

Besides the decomposition of waste additional emissions are released through open burning of waste at landfills and dumpsites, which is one of the main modes of waste volume reduction in Kenya[32]. Open burning is typically a poor combustion process and is a significant source of persistent organic pollutants, (POPs, such as dioxins and furans). It generates 7% of the national releases of persistent organic pollutants[33], particulate matter and heavy metals.

3.1.3 Implications on health

Decomposing organic waste is a rich medium for the growth of numerous microorganisms which are linked to gastro-intestinal infections (gastro-enteritis, typhoid fever, and helminths) if poorly handled. As earlier stated, burning of waste in an open field is a major source of air pollution.

Dioxins, Furans, Mercury and Polychlorinated Biphenyl's are linked to skin lesions such as chloracne, dark patches on the skin, altered or reduced liver capacity. Long-term exposure leads to respiratory diseases including asthma, weakened immune system, central nervous system, endocrine system conceptive capacities and cancers.

Indirect hazards posed by the current disposal methods include environmental contamination due to flooding. Waste disposal sites that are located in lowland areas close to residential areas pose a long-term risk of potential environmental contamination due to inundations. This can potentially increase the transmission of the following communicable diseases such as water-borne diseases such as typhoid fever, cholera, leptospirosis and hepatitis A and Vector-borne diseases such as malaria, dengue hemorrhagic fever, yellow, and West Nile Fever.

3.2 Opportunities for waste management

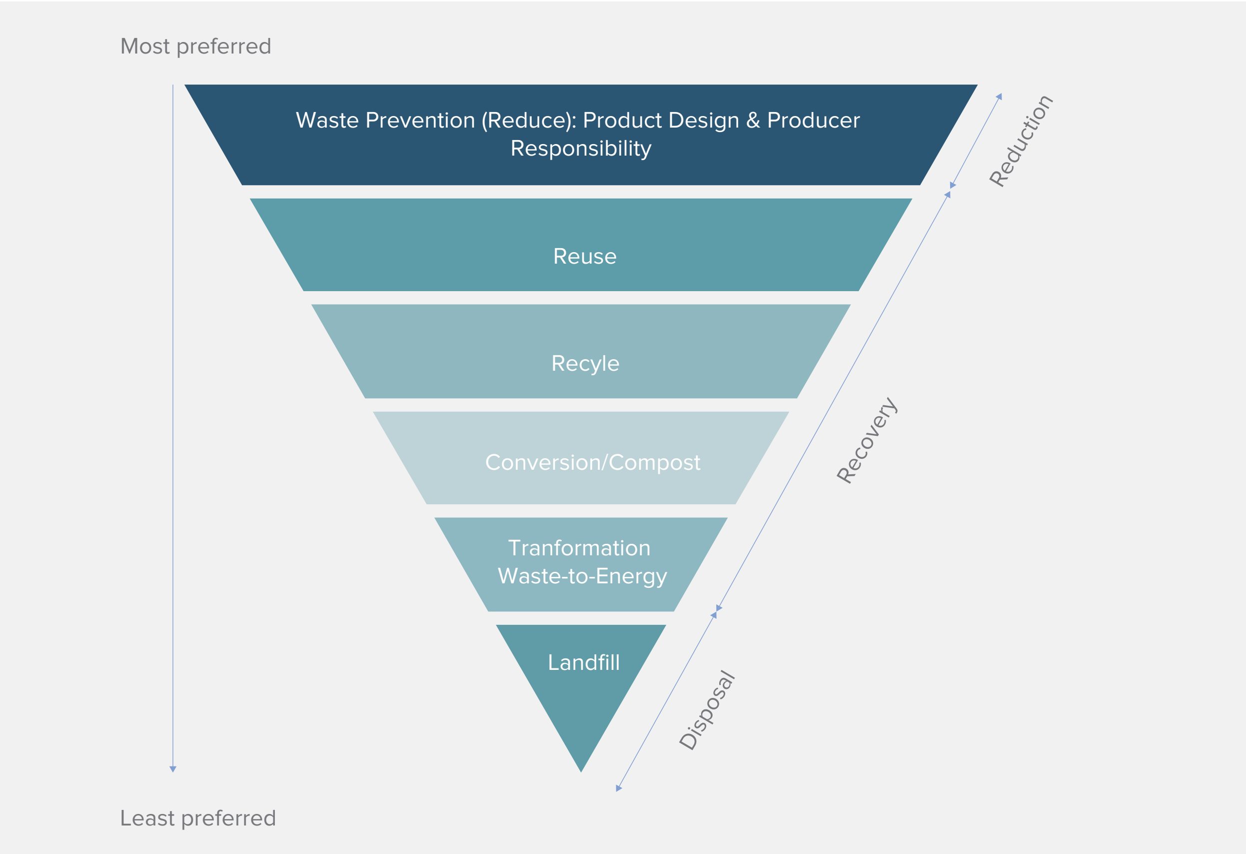

Figure 6: Waste Management Hierarchy

32 MoEWNR (2012). Inventory of Mercury Releases in Kenya. Nairobi; Kenya

33 MoEWNR (2014). Kenya National Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants 2014 – 2019. Nairobi:Kenya

The waste management hierarchy (Figure 6) is premised on reducing the volume of waste produced while allowing for the lowest cost of waste management and the most environmentally friendly option for disposal of waste. Waste prevention (reduce) provides the least amount of generated waste hence the most desired option of disposal while engineered sanitary landfills provide the least preferred option due to the volumes generated and disposed and cost involved. Therefore, waste, depending on the treatment and quality, remain viable sources of energy, nutrient recovery and soil conditioners. These options are reviewed below.

3.2.1 Waste to energy

Waste to energy (WtE) refers to any process that creates energy in the form of electricity and or heat or processing of fuels from a waste source. There are several pathways of biomass conversion and WtE technologies currently commercialized as shown in Figure 7. Ultimately, the technology adopted depends on the amount of waste, local technical expertise, financial implications and the policies available[34].

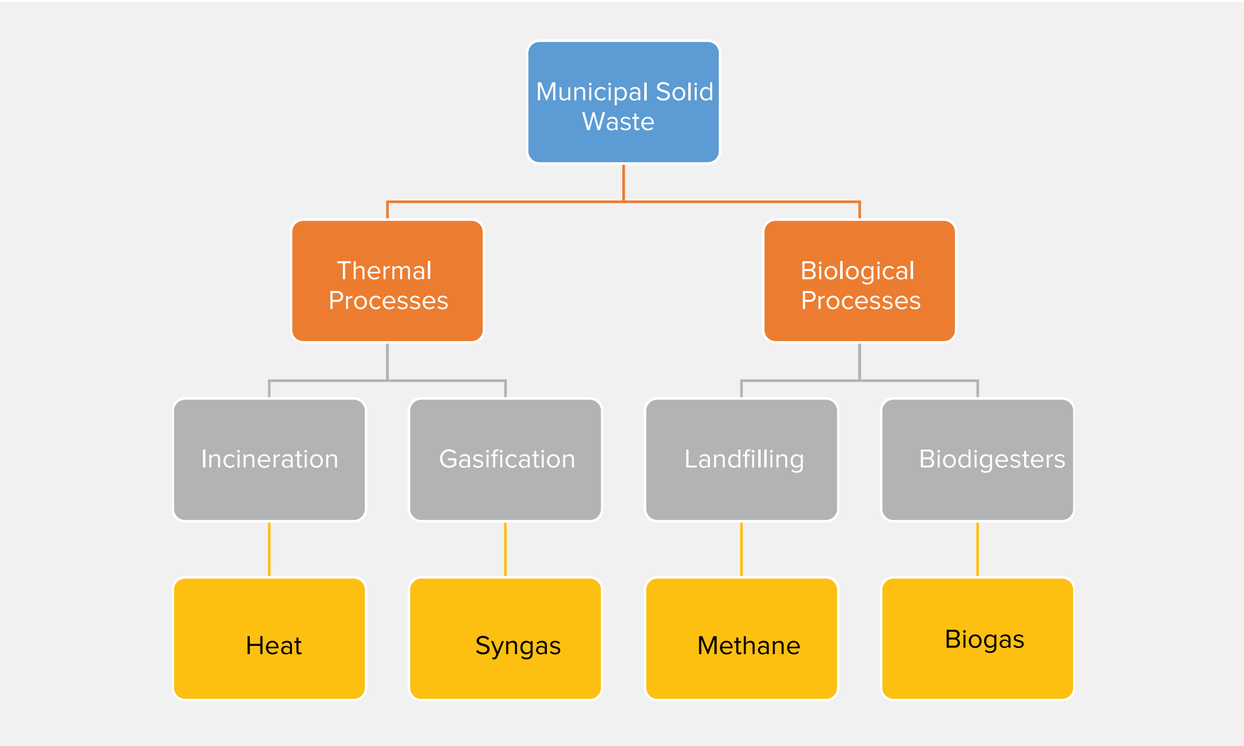

Figure 7: Waste to Energy Technological Options (Adapted from Coelho et al., 2020)[35]

The most commonly used WtE arises from the thermal process of incineration in a combined heat and power (CHP) plant. The range of net electric generation depends on the quality and calorific value of the MSW. Typically, the high content of organic waste, high moisture content, low combustible waste such as plastics, and inconsistency of composition due to the lack of sorting for developing countries leads to a lower net electric generation, 300 – 400 kWh per ton compared to 500 – 600 kWh per ton for developed countries[36]. The annual waste generated in Nairobi (approx. 2,400 tonnes/day or 876,000 tonnes / yr.) would be suitable for large-scale incinerators[37]. For these volumes of waste, and approximate power production at 30% power generation efficiency is estimated at 177,184 kWh per day (excluding plastics and inorganics)[38].

34 Coelho S.T., Bouille D.H, Mani S.K., Stafford W.H.L., (2020). Introduction. Multiple Solid Waste Energy Conversion in Developing Countries, 1 - 7.

35 Coelho S.T., Bouille D.H, Mani S.K., Stafford W.H.L., (2020). Introduction. Multiple Solid Waste Energy Conversion in Developing Countries, 1 -7.

36 Yan M., Waluyo J., and Agamuthu P. (2020). Challenges for Sustainable Development of Waste to Energy in Developing Countries. Waste Management & Research Vol. 38 (3) 229 – 231.

37 Williams P.T., (2005). Waste Treatment and Disposal (2nd Ed). John Wiley & Sons, Ltd, England.

38 Khamala E. M., and Alex. A. A. (2013). Municipal Solid Waste Composition and Characterisation Relevant to the Waste-To-Energy Disposal Method for Nairobi City. G.J.E.D.T Vol. 2 (4): 1-6.

It should be noted that collection of waste stands at approximately 40% (350,400 tonnes / yr.) and the capital investment is high. Technical and legislative frameworks and their subsequent enforcement outlining the emissions standards should also be stringent to avoid pollution through Persistent Organic Pollutants (POPs) such as dioxins and furans which bio accumulate in human tissue and cause adverse health impacts.

Typically, the generation of energy from biological processes arises from the conversion of waste to biogas or bio methane which can be used for powering vehicles, energy for cooking and heating. Biodegradation of the organic fraction, also referred to anaerobic decomposition, leads to the production of biogas (methane and carbon dioxide) for landfilling and biogas / organic compounds for bio digesters. The main factors / parameters influencing anaerobic digestion include the absence of oxygen, substrate composition and temperature. The characterisation of organic matter is of great importance in determining or predicting the efficiency of the anaerobic digestion process. The higher the percentage of organic matter presents in the waste, the greater the biogas production potential[39]. The current biological conversion is happening on a small-scale as community projects. According to studies, Skylink Innovators enterprises and SimGas enterprises are a few private sector biogas initiatives where customers are responsible for their own organic waste and which feed into movable biogas digesters[40].

Asticom Kenya with funds from Sustainable Energy for Africa (SEFA), aims to operate WtE facilities in Sub-Sahara Africa including Kenya. The project aims to use municipal solid waste (from urban areas), agricultural crop residues (western counties) and livestock waste or manure for generation of bio methane, ethanol and electricity. They have set up a pilot in Kibera with a capacity of 260 tons/day and 75,000 tons per annum[41].

Organic municipal waste, agricultural residue (e.g., coffee husks, sugarcane bagasse, rice husks, macadamia nuts, wheat straws etc), forestry residue (e.g., sawdust, chips, offcuts) and charcoal dust are used as feedstock for production of briquettes. Briquettes are biomass-based fuels that are considered as alternatives to charcoal and fuelwood.

3.2.2 Composting

Composting is a simple process where optimization efforts are used to increase the rate of decomposition, minimize nuisance potential, and produce a clean and readily marketable finished product, soil conditioners. Composting in Nairobi is observed to happen on a small-scale by private collection companies such as Taka Taka solutions and community-based organisations (CBOs) mostly located in the low-income residential areas and informal settlements[42]. Taka Taka solutions ensures separation of organic waste from the source to improve the quality of product while CBOs source their waste from the markets and farms. The current demand for compost is in excess of 100,000 tons/year while actual production stands at <10,000 tons/year[43]. Sanergy Limited collects, treats and converts faecal matter from low-income areas to organic fertilizer.

39 Garcilasso V. P., and Oliveir F.C. (2020). Best Available Technologies (BAT) for WtE in Developing Countries. Multiple Solid Waste Energy Conversion in Developing Countries, 63 - 105.

40 Muok Ben (2020). WtE Project in Kenya. Multiple Solid Waste Energy Conversion in Developing Countries, 208 – 209.

41 Asiticom website. https://www.asticom.org/index.php/about-us

42 Onduru D.D, Waarts Y., Jager A., and Zwart K (2009). Inventory and Analysis of Users, Producers and Markets for Compost, Biogas and Livestock Feeds in Urban and Peri-Urban Areas of Nairobi. Converting City Waste into Compost Pilot Nairobi.

43 ibid

3.3 Assessment of raw materials for briquette manufacturing

There exists an array of raw materials that can be used for briquette production. However, a briquette producer must identify the most suitable raw material for briquette production. Identification of the most suitable raw material was guided by these three main factors: (i) quantities available, (ii) quality of the raw material and (iii) cost of the raw materials. Additionally, national and global trends which may affect availability of suitable raw materials, were also considered. A list of 28 possible sources of raw materials was developed (from literature review and interviews with the briquette producers) and an elimination criterion developed to allow elimination of waste with the least potential for briquette production as summarized in Figure 8.

- **Pyrethrum**
- **Rapeseed**
- **Sesame**
- **Beans**
- **Pigeon Peas**
- **Sorghum**
- **Sugarcane**
- **Cassava**
- **Coconut**
- **Cotton**
- **Groundnut**
- **Sweet Potatoes**
- **Irish Potatoes**
- **Macadamia**
- **Barley**
- **Cashew**
- **Millet**
- **Coffee husks**
- **Pineapple**
- **Rice husk**
- **Sisal**
- **Flower waste**
- **Sawdust**
- **Charcoal dust**
- **Faecal matter**
- **Organic waste**
- **Maize**
- **Coconut**

The guideline is a funnel-shaped approach beginning with all the potential feedstocks at the top, but as they are subjected to the evaluation criterion the list decreases and only the most suitable raw material is left at the end of the funnel. The elimination process is discussed below.

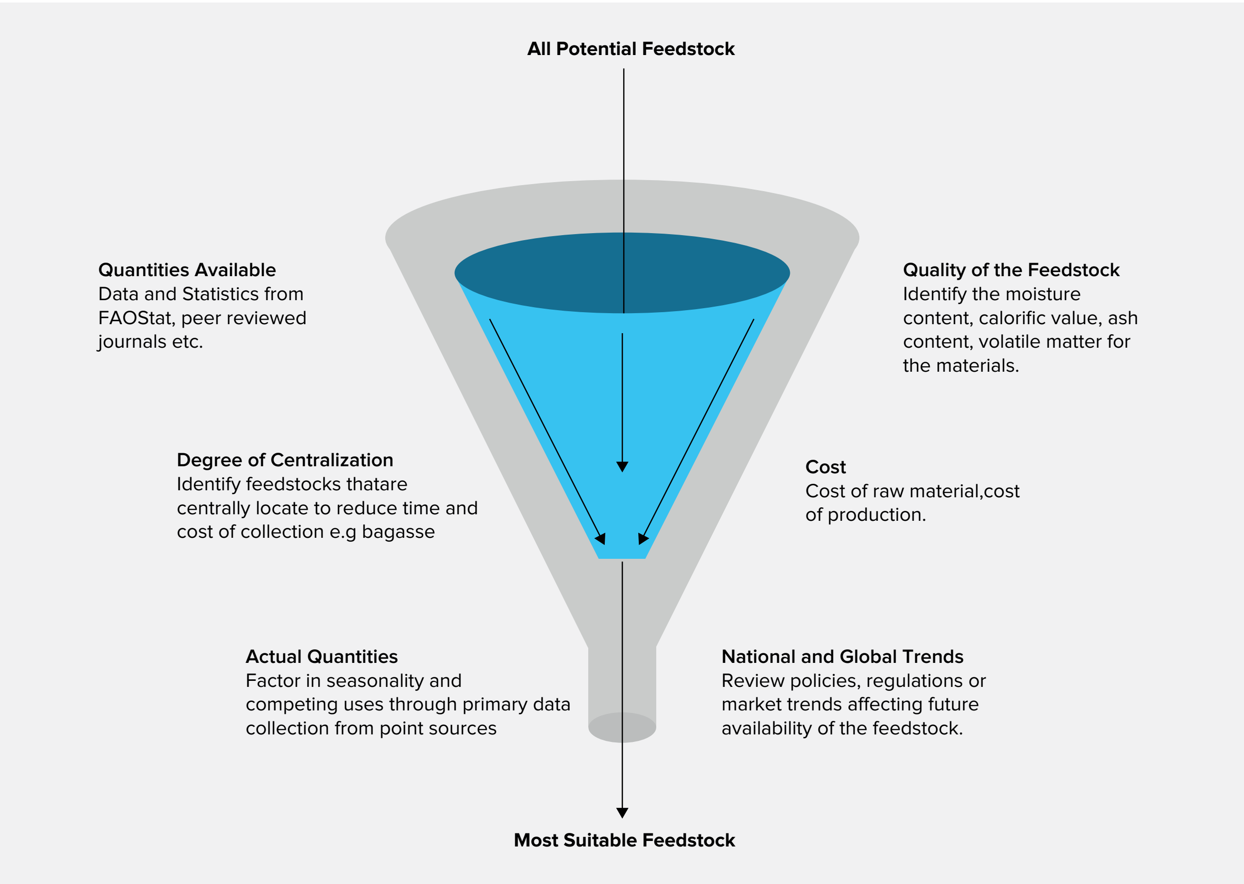

Figure 8: Summary of Feedstock Assessment methodology

3.3.1 Quantities available

One of the key factors to consider when choosing a raw material for fuel production is the annual quantities available. Availability of raw material is affected by; (i) seasonality of crop production (for the case of agricultural waste), (ii) competing uses, and (iii) centrality of the raw material. Although, it is difficult to precisely estimate the quantities of biomass residue volumes in Kenya given the informality of trade and the lack of available databases, there exists methodologies that can aid in estimating approximate quantities. For example, agricultural residue (waste) was estimated based on the residue to product ratio (RPR) which describes the amount of residue produced per crop. Using the methodology adopted in the assessment of the available agricultural residues in Kenya by the EU for prominent agricultural products, which was based on production, yield, area of production, and a residue to product ratio (RPR), quantities of waste generated per crop was estimated. This was further supplemented by FAO statistics on the available residues production in Kenya. Literature review was used to estimate the quantities of municipal waste, charcoal dust and sawdust. Table 6 and Table 7 below provides a summary of estimates of waste quantities available before factoring in competing uses.

Table 6: Summary of quantities available for agricultural waste, forestry waste and charcoal dust[44]

Agricultural Residues	Mass of Residue of (Field and Process) (t)
Bananas	2,649,000
Beans	1,122,000
Cashew	15,036
Cassava	518,000
Coconuts	41,763 – 193,000
Coffee	13,357
Irish Potatoes	1,050,000
Macadamia	15,071
Maize	16,063,000
Mangoes	5,564,000
Pigeon & Cow Peas	193,000
Pineapples	109,305
Rice	182,472 – 312,000
Sisal	675,294 – 800,00
Sorghum	692,000
Sugarcane	1,789,748 – 2,416,000
Sweet Potatoes	310,000
Wheat	538,204 – 654,000
Wood waste (off cuts, timber rejects and sawdust[45])	15,600
Charcoal dust (urban areas)[46]	70,000-105,000

44 IIED (2015). Biomass Use and Potential for Export from Kenya to the European Union 2015 – 20130. EU

45 Ministry of Environment, Water and Natural Resources (2013). Analysis of Demand and Supply of Wood Products in Kenya. Nairobi. http://www.kenyaforestservice.org/documents/pdf.

46 0.7 Mtons of charcoal are consumed in urban areas (MoE,2019). 10-15 % is converted to charcoal dust

Pyrethrum, rapeseed, sesame and cotton were not considered for further analysis because the annual crop production is less than 10,000 tonnes[47].

Table 7: Estimates for municipal waste generated for Nairobi, Kisumu and Mombasa

Data Source	Estimated waste generated in Nairobi, Kisumu and Mombasa					
	Nairobi		Kisumu		Mombasa	
	Nairobi (t/day)	Approximate Organic Fraction (t/day)	Kisumu (t/day)	Approximate Organic Fraction (t/day)	Mombasa (t/day)	Approximate Organic Fraction (t/day)
Oyake – Ombis 2017[48]	2,400	1440	500	300	875	525
NAMA 2017[49]	3,030	1818	395	237	602	361.2
MoEF 2019[50]	2,400	1440	1000	600	2000	1200
NCC, 2010[51]	3,200	1920		-	-	-

Centrality of the waste

A raw material can be available in large quantities but highly decentralized in terms of point sources. As a result, there is need to determine the degree of centrality of the raw material. From the list above, there are crops whose processing is done at a farm level and others at an industrial level. Processing of the crops at the farm level results in the waste being highly decentralized and the producer has to source the raw material from multiple suppliers. The procurement process for multiple suppliers is tedious and can at times be costly compared with dealing with one supplier. For this reason, crops like beans, peas, bananas, millet, potatoes, mangoes, sorghum, rice straws, coconut husks, and maize, though have high residue capacities, were dropped from the list of potential crops for consideration because they are not centrally located.

Seasonality of the raw material

For continuous briquette production, the ideal raw material should be available throughout the year. If the raw material has low and peak seasons, it is important that the briquette producer is aware of these periods to plan accordingly. For example, sawdust maybe in limited quantities during the rainy seasons when milling of timber is limited, coffee is a seasonal crop and therefore unavailable in certain times of the year. Although coffee husks have low moisture content and a calorific value of 12.38 MJ/kg, which is within the range of many feedstocks for briquette making, they are unavailable between May-July. Coffee husks are also a source of thermal heat for the Kenya Clay Works and Bidco Oil Refineries. Other seasonal crops include wheat, maize and beans which may have one or two planting seasons. Even though coffee is seasonal, the waste can be collected at central locations thus it was still considered for further analysis. As for beans, maize, potatoes which are not only decentralized but also seasonal, they were eliminated from the list of potential feedstocks for briquetting.

Competing uses

It is important to establish the existing uses of the waste in determining the actual amounts available for a given crop residue. A feedstock may exist in large amounts but has an alternative use that is more preferred or of a higher economic value than briquette making. For example, wheat straws are available in large quantities, but most farmers prefer to use them as animal feedstock or as manure for their farms. In such an instance, the price of buying the straws from the farmers would have to offer better economic returns for them to consider it.

47 FAOSTAT. (2017). Crops. http://www.fao.org/faostat/en/#data/QC

48 ibid

49 UNDP. (2017). Nationally Appropriate Mitigation Action on a Circular Economy Solid Waste Management Approach for Urban Areas in Kenya.

50 Government of Kenya. (2019). National Sustainable Waste Management Policy 2019 (Revised Draft). Nairobi Kenya

51 I Ngau P, von Harro B. (2020). Integrated Solid Waste Management Plan for Nairobi 2010.

Sisal waste has the potential of being converted to electricity production[52], however, sisal balls are cut and left in the field as manure. If they were to be utilised in briquetting, there would be need to factor in the expense and logistics involved in collecting the waste into a central location. In addition, sisal fibre has found application in the furniture industry where it is used as a stuffing material. Coconut coir is preferred for weaving of ropes, mats, door mats while coir peat is used as compost. Coconut shells are mainly used in boilers by oil producers and other companies leaving minimal amounts for briquetting. Pineapple waste from one of the largest producers (Delmonte (K) Limited) is utilised by a briquette making company in Kenya (Global Supply Solutions) which has already acquired a patent in Kenya and other countries[53]. Flower waste is currently used by the flower farms as a compost for their farms and as such, no quantities are available for supply. From the analysis on competing uses, waste from pineapples, flowers, coconut and sisal were not considered for further analysis.

Cost of the raw material

The price of the fuel is a key determinant on its rate of adoption at the household level[54]. The cost of briquettes should be more competitive than the other types of fuels in the market that it is replacing. The price at which the briquettes will be sold is in turn determined by the cost of raw material, transport cost for both raw material and the briquettes, processing, packaging etc. As such, the cost of the material is important in determining the economic viability of a given raw material. For example, macadamia nuts and cashew nuts have high calorific value and low moisture content and thus a desirable raw material for briquetting[55]. However, these two raw materials can still provide the required energy content without the need for briquetting. Briquetting of these material is thus not economically viable and as a result thermal intensive industry such as tea factories, Bidco, Clay works, and Bamburi Cement Limited etc. use both in their raw forms. Over the years, there has been a rise in demand for these raw materials by thermal intensive industries such as oil refineries, cement manufacturers, tea factories given their desirable qualities. Some of the costs per tonne identified for this study include; coffee husks costs KES 6,500 + VAT, sawdust KES 3,000 - 6,000, charcoal dust KES 6,000[56], macadamia nuts KES 5,000 - 20,000 and bagasse KES 0-600. At this point, some of the materials that were already in limited volumes, seasonal and had a high cost were eliminated from the list. For coffee husks, macadamia nuts and cashew nuts, purchasing process is through bidding which is announced in the daily newspaper every end of season and thereafter annual contracts to successful bidders. Briquette start-ups might not be as competitive and in some of the mills, they already have established customers. For this reason, macadamia nuts, cashew nuts and coffee husks were eliminated from the list.

3.3.2 Quality of the raw material

The potential raw materials were subjected to a proximate analysis, which assesses the physical characteristics of the feedstock that will affect the combustion characteristics of the resulting briquettes. The following characteristics of the feedstocks were considered:

1. ***Fixed carbon*** is the remaining residue after subtracting the volatile matter, moisture content and ash content during the heating process[57]. Materials with high levels of fixed carbon are preferred for briquette production. Lower levels of fixed carbon mean that you require high amounts of the material to achieve a given heat output. A high percentage of fixed carbon increases the heat value of the raw material.

2. ***Moisture content*** is the percentage of moisture (water) in a sample of raw material in its original state before drying or being subjected to environmental elements such as precipitation. Raw materials with high moisture content must be dried

52 Julia Terrapon-Pfaff, Manfred Fischedick, Heiner Monheim. (2012). Energy potentials and sustainability—the case of sisal residues in Tanzania. Energy for Sustainable Development, (16) 3,312–319: DOI: 10.1016/j.esd.2012.06.001

53 Global Supplies Limited. Retrieved from https://www.globalsupply.co.ke/about/

54 Ministry of Energy. (2019). Kenya Household Sector study.

55 Chardust Ltd and Spectrum Technical Services. (2004).The Use of Biomass to Fabricate Charcoal Substitutes in Kenya. Feasibility Study; Forming Part of the Shell Foundation-Supported Project on Charcoal Briquetting in Kenya. Nairobi; Kenya

56 Calculated from a sack of 50 kg being sold at KES 300.

57 Dipak K.Sarkar. (2015). Fuels and Combustion. Thermal Power Plant: Design and Operations. Elsevier,91-137. https://doi.org/10.1016/B978-0-12-801575-9.00003-2

therefore the producer has to invest in drying equipment. Additionally, there is a loss in mass after drying of the raw materials and the cost of transporting wet raw material is high compared to dry raw materials.

3 ***Volatile matter*** is the percentage of material that burns in a gaseous state. Lower volatile matter in the biomass is desirable[58] as it improves the efficiency of combustion of the resulting briquette.

4 ***Ash content*** is the incombustible residue after the burning of raw material. The higher the ash content in the waste the lower the calorific value of the raw material.

5 ***Calorific value*** is the heat content of the raw material. The higher the calorific value the higher the heat output during combustion.

6 ***Bulk density*** is the weight per unit volume of a material[59]. Biomass with high bulk densities is desirable as the material is able to compact easily. Although the transport of bulk materials is costly.

To determine the optimal quality for feedstock, the following qualities from Asamoah (2016) study[60], were used as a guide (see Table 8).

Table 8: preferred qualities for briquetting materials

Properties	Unit	Requirement
Fixed Carbon	%	9 – 25
Volatile Matter	%	50 – 90
Ash Content	%	Less than 4%
Moisture Content	%	6 – 14%
Bulk Density	kg/m3	More than 50
Calorific Value	MJ/kg	12 – 20
Particle Size	Mm	1 -10 mm size with 10 -20% powdery

58 Miller.B. (2013). Fuel considerations and burner design for ultra-supercritical power plants. Ultra-Supercritical Coal Power Plants Materials, Technologies and Optimisation. Woodhead Publishing Series in Energy,57-80. https://doi.org/10.1533/9780857097514.1.57

59 S. Clarke, P.Eng., and F. Preto. (2011). Biomass Densification for Energy Production. http://www.omafra.gov.on.ca/english/engineer/facts/11-035.pdf

60 Asamoah, B., Nikiema, J., Gebrezgabher, S., Odonkor, E., and Njenga, M. (2016). A Review on Production, Marketing and Use of Fuel Briquettes. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Programme on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

Table 9 below provide a summary of the quantities and properties of the key raw materials considered for briquette production.

Table 9: Summary of the quantities and properties of selected waste

Feedstock	Quantities			Properties						
	Quantities available	Degree of centrality	Competing uses that are more viable than briquette production	Fixed Carbon (%)	Volatile Matter (%)	Ash Content (%)	Moisture Content (%)	Bulk Density (Kg/ m3)	Calorific Value (MJ/ kg)	Sources
Bagasse	1,611,011	Centralized at the sugar milling companies	Cogeneration and other briquette producers	13.6	82.1	4.3	50.0	N/A	13	Lopez (2016)[61]
Cassava stem	1,221,051	Decentralized	Animal feed	30.0	59.0	4.9	7.2	N/A	N/A	Adebisi (2017)[62]
Coconut shells	11,759	Food companies such as Malindi Industries, Navida Natural Foods	Used as fuel in boilers by oil producers	17.0 – 20.7	76.0 – 81.4	0.5 – 7.0	6.9 – 18.1	0.1	15.5 – 23.0	Asamoah et al. (2016), Adeyi (2010)[63]
Cashew nut shells	15,087	Centralized at the processing companies	Used as fuel in thermal intensive industries such as Bamburi, Bidco etc	20.48	72	1.05	6.47	NA	25.9	Muhammad et al (2015)[64]
Groundnut (Shell)	10,612	Centralized at the processing companies	Used as fuel in thermal intensive industries such as Bamburi, Bidco etc	17.1 – 19.5	77.5 – 81.5	1.5 – 1.9	1.6	NA	19.0	Asamoah et al (2016)
Macadamia (Shells)	14,668	Centralized to nut companies	Used as fuel in thermal intensive industries such as Bamburi, Bidco etc	23.7	76.0	0.4	N/A	N/A	21.01	
Coffee husks	13,357	Centralized to coffee milling companies	Used as fuel in thermal intensive industries such as clay works, Bidco etc	15.0 - 20.3	68.8 - 74.4	1.8 - 5.3	14.5	N/A	N/A	Lopez 2016, Chen et al (2012)[65]

61 Lopez (2016). Biomass utilization for energy purposes in Kenya. Fuel characteristics and thermochemical properties.

62 Adebisi, J., Agunsoye, J., Bello, S., Kolawole, F., Munyadziwa, M., Daramola, M., and Hassan, S. (2017). Extraction of Silica from Sugarcane Bagasse, Cassava Periderm and Maize Stalk: Proximate Analysis and Physico-Chemical Properties of Wastes. Waste Biomass Valor. http://dx.doi.org/10.1007/s12649-017-0089-5

63 Adeyi, O. (2010). Proximate composition of some agricultural wastes in Nigeria and their potential use in activated carbon production. J. Appl. Environ. Manage, 14 (1), 55 -58

64 Danish, M., Naqvi, M., Farooq, U., and Naqvi, S. (2015). Characterization of South Asian agricultural residues for potential utilization in future 'energy mix'. Energy Procedia 75, 2974 – 2980. doi: 10.1016/j.egypro.2015.07.604

65 Chen, W., Lu, Ke-Miao and Tsai, C. (2012). An experimental analysis on property and structure variations of agricultural wastes undergoing torrefaction. Applied Energy ,100, 318 – 325.

Feedstock	Quantities			Properties						
	Quantities available	Degree of centrality	Competing uses that are more viable than briquette production	Fixed Carbon (%)	Volatile Matter (%)	Ash Content (%)	Moisture Content (%)	Bulk Density (Kg/ m3)	Calorific Value (MJ/ kg)	Sources
Rice Husks	18,715	Centralized to coffee milling companies	Used as fuel in thermal intensive industries. Used as soil conditioners by farmers. A board production factory is on the pipeline for production of boards from rice husks as an alternative to timber	14.2 – 17.5	56.1 – 66.3	7.9 -23.5	5.1 – 15.5	327.0	14.2 – 17.5	Asamoah et al (2016)
Maize (stover/husk/ straw)	16,063,000	Decentralized	Animal feed	6.7- 16.8	72.2 – 84.3	4.6 – 11.8	7.0 – 9.3	1, 017.2	17.1 -18.4	Asamoah et al (2016), Muhammad et al (2015)
Sawdust	15,600	Centralized at timber yards, furniture shops and saw milling points	Production of boards. Fuel for boilers in companies. Briquette production. Poultry farming as floor cover. Charcoal stove insulator in hotels.	2.2 – 21.6	77.7 – 88.6	0.2 – 5.6	1.8 – 9.8	133.0 -210.0	2.2 – 21.6	Asamoah et al (2016)
Faecal sludge	N/A	Centralized in sewerage companies	Composting Briquette production	6.9 -8.6	36.1 – 53.0	38.40 – 57.1	80.0 – 97.0	NA	13.0	Asamoah et al (2016)
Paper-Waste	N/A	Centralized in dumpsites and waste collection companies	Recycling	NA	65.5	1.2 – 15.5	7.4 – 12.6	NA	NA	Asamoah et al (2016)
Organic waste (market place)	N/A	Market places	Composting Power generation	12.8	87.2	25.9	22.3			
Organic waste (households)	N/A	Waste collection companies	Composting Power generation	16.9	83.1	37.0	63.1	N/A		
Charcoal dust (urban areas)	70,000-105,000	Charcoal venders	Briquette production			11.3	14.9		28.35	Charcoal properties

The desirable calorific value for the raw material for briquette production falls between 12-20 MJ/Kg. Table 9 above shows all the raw materials under consideration that fall within that range. Cashew nuts, macadamia, groundnuts and coffee husks are among the top materials with high calorific value but they are available in small quantities as they are used as fuel for thermal intensive industries such as cement manufacturers and oil refineries. This makes it difficult for briquette producers to compete with other users who use the raw material in its unprocessed state. As a result, these four raw materials were eliminated from the list. Cassava stem has the highest value for fixed carbon but its production is in small-scale and heavily decentralized. Sourcing the raw material from many different suppliers is tedious and may be costly. This also applies to the maize cobs and stovers which, even though they exist in large quantities, are decentralized, seasonal and are preferred as animal feed. As a result, these two raw materials were dropped from the list.

The advantage of using rice husks as a raw material for manufacturing briquettes is that they are dry and they do not require shredding given their small size[66]. However, the husks have high silica content, which wears out briquetting machines, thus increasing maintenance and operation costs. They also produce high ash content, which affect the combustion efficiency of the briquettes. Rice husk has found application in boilers of thermal intensive industries and as soil conditioners for farmers to improve productivity. Additionally, if the plans for setting up the board production factory in Kirinyaga follows through, limited quantities will be available for briquette production. For these reasons, rice husks were dropped from the list.

Bagasse, faecal matter, sawdust, charcoal dust and organic waste were considered for further analysis. The reasons why the five raw materials were selected for further analysis are summarized in Table 10 below.

Table 10: Reasons for selecting the five materials for further analysis

No	Type of waste	Reason for consideration for further analysis
1	**Bagasse**	• High quantities of waste • Can be obtained from central points • Cost is relatively low compared to the other raw materials
2	**Sawdust**	• Several point sources in urban areas • A preferred material for production of non-carbonised briquettes because of the high proportion of lignin, which acts as a natural binder during the pressing process resulting to dense briquettes
3	**Charcoal dust**	• An urban waste • Already carbonised so preferred for making carbonised briquettes
4	**Organic waste**	• An urban waste that may not be well managed
5	**Faecal waste**	• Available in large quantities • Unless there are competing uses, the raw material will always be available with the existence of the human race • It's an emerging raw material for briquetting and we have companies piloting the suitability of this raw material for briquette production

66 S. Suryaningsih, O. Nurhilal, Y. Yuliah and E. Salsabila. Fabrication and Characterization of Rice Husk Charcoal Bio Briquettes. AIP Conference Proceedings 1927, 030044 (2018); https://doi.org/10.1063/1.5021237

Although, baggase and faecal waste have high moisture content of 50% and 98 % they were still included for further analysis as the waste exists in large quantities at central locations and the calorific value falls within the desired range. Faecal sludge also has the lowest fixed carbon and high ash content but since it is an emerging raw material in Kenya for briquette production, there are companies using it for briquette production, hence it was considered for further analysis.

3.4 Analysis of the selected raw materials

For this section, we focus on the top five raw materials that were considered for further analysis. These are bagasse, faecal matter, sawdust, charcoal dust and organic waste. These raw materials are further discussed below focusing on the cost of raw materials and specific areas to source the feedstocks. Other factors that may affect the availability of the waste were also examined.

3.4.1 Bagasse

Bagasse is a waste generated from the processing of sugarcane. Sugarcane in Kenya is mainly grown in western Kenya around Nyando, Migori, Mumias, Busia, Nandi and the Coastal region. It is estimated that there are at least 250,000 farmers who supply sugarcane to at least 15 sugar manufacturers (government owned and private companies)[67]. Bagasse is available in large quantities and is centrally located. It has a calorific value of 13 MJ/Kg, which is within the required value for briquette production. Table 11 below shows quantities of bagasse produced in the last 10 years[68].

67 Bancy M. Mati1, Michael K. Thomas .(2018). Overview of Sugar Industry in Kenya and Prospects for Production at the Coast. Agricultural Sciences, 10, 1477-1485.Retrieved from https://www.scirp.org/journal/as

68 Agriculture and Food Authority. (2019). Year Book of Sugar Statistics 2019. Nairobi: Kenya.

Table 11: Bagasse production for the last 10 years (Source: Agriculture and Food Authority)

Company	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total (per company)
Chemelil	212,158	147,124	135,463	115,391	192,939	159,289	112,289	84,625	97,834	19,232	1,276,344
Muhoroni	193,369	137,319	172,836	149,914	201,625	158,403	133,060	124,444	89,113	73,166	1,433,249
Mumias	870,462	760,608	751,100	696,525	539,116	511,902	395,343	109,642	35,785	N/A	4,670,483
Nzoia Sugar Company Ltd.	251,975	239,604	269,206	289,439	263,671	266,143	305,921	154,213	135,630	79,265	2,255,067
South Nyanza Company Ltd.	205,122	228,259	181,307	239,439	224,785	264,974	262,029	163,121	180,079	83,094	2,032,209
West Sugar Company Ltd	258,570	229,424	206,658	341,687	295,690	410,869	326,935	305,800	315,699	327,586	3,018,918
Sony Sugar Limited	4,896	4,243	6,763	7,500	--	-	-	-	-		23,402
Kibos Sugar & Allied Industries	140,620	161,517	179,487	251,125	192,815	350,088	338,320	254,125	355,113	255,914	2,479,124
Butali Sugar Company Ltd	-	107,583	147,857	141,760	200,103	182,273	300,862	182,097	262,596	209,659	1,734,790
Transmara Sugar Company Limited	-	-	60,680	129,705	177,023	178,687	282,105	138,800	241,516	244,697	1,453,213
Sukari Industries Ltd	-	-	73,855	108,853	131,838	126,148	166,330	118,151	180,267	217,342	1,122,784
Kwale International Sugar Company	-	-	-	-	-	-	114,720	70,130	61,857	6,141	252,848
Olepito Sugar Company Ltd	-	-	-	-	-	-	-	-	18,086	37,238	55,324
Busia Sugar Company Ltd	-	-	-	-	-	-	-	-	-	57,677	57,677
Total per year	**2,137,172**	**2,015,681**	**2,185,212**	**2,471,338**	**2,419,605**	**2,608,776**	**2,737,914**	**1,705,148**	**1,973,575**	**1,611,011**	

Data presented in Table 11 above indicate that even though there is a decline in the quantities of bagasse available since 2017, there are still substantial quantities that can be utilised for briquette production. Using 2019 as the base year, the top 5 sugar milling companies with high amounts of bagasse are: West Sugar Company Ltd (327,586 tonnes), Kibos Sugar & Allied Industries (255,914 tonnes), Transmural Sugar Company Limited (244,697 tonnes), Sukari Industries Ltd (217,342 tonnes) and Butali Sugar Company Ltd (209,659 tonnes). These can be the first options to consider as points of purchase for bagasse. In some of these sugar companies, the waste is a nuisance and they would be looking for a way to dispose of the waste, as a result, the producers may get it at a no cost or at a cost of KES 0-600 per tonne.

Factors affecting availability of bagasse

The sugar industry in Kenya has been facing various challenges that have seen a decline in the yields from 66.4 t/ha in 2015 to 55.1 t/ha in 2018. Table 12 below shows the trend of production of sugarcane from 2014 to 2018.

Table 12: Sugar production from 2014-2018[69]

#	Sugarcane Area and production	2014	2015	2016	2017	2018
1	Area under cane ('000 Ha)	211.3	223.6	220.8	191.2	202.4
2	Area harvested ('000 Ha)	72.2	77.8	85.8	67.7	73.1
3	Total Production ('000 tonnes)	6409.9	7164.8	7151.7	4751.6	5262.2
4	Production non-contracted farms ('000 tonnes)	1977.1	1995.8	1816.7	1004.3	1233.1
5	Average yield (tonnes/ha)	61.4	66.4	62.2	55.3	55.1

This has led to the country having to import sugar to meet the deficit in supply from local production. The decline in yields has been attributed to the low quality of sugarcane varieties, high production cost, poor crop management, delayed harvesting (18 months compared to 14 months for varieties in other countries) and disillusionment from the industry[70]. The strained relationship between the farmers and the millers has seen farmers switch to other crops due to delayed payment and the low prices of the sugarcane. This has led to the closure of some of the major state-owned millers in the country such as Miwani (which was closed 20 years ago), Mumias sugar, which was closed for 20 months but was, reopened early 2020 and Chemelil has not been milling for the last 8 months[71]. Another challenge in the sugar sector is the global treaties that Kenya is party to (COMESA, ECA and WTO) which allow the importation of sugar from member countries to have zero or minimum tariffs[72]. Since the production, cost is low in these countries and the sector is greatly subsidized by their governments, the price of locally produced sugar is unable to compete with the imported sugar at local and foreign market.

The government in a bid to investigate the reforms that can be implemented to revive the sector, created a task force. The task force report was completed and presented to the president in February 2020 with key recommendations being: the re-introduction of the sugar levy, privatization of public sugar mills to enhance their efficiency and the enactment of the Sugar Act[73]. The farmers are however opposed to one of the recommendations that introduces zoning of sugar producing regions. This restricts the farmers from selling their produce to the highest bidder and those who pay promptly. As such, they are threatening to uproot their sugarcane and utilize the land for other economic activities. If these grievances are addressed and the reforms addressed, then the sector may be revived in a few years to come. Otherwise, we will continue to witness a decrease in the land area under sugar production.

69 Bancy M. Mati1, Michael K. Thomas. (2018). Overview of Sugar Industry in Kenya and Prospects for Production at the Coast. Agricultural Sciences, 10, 1477-1485. https://www.scirp.org/journal/as

70 Ibid

71 As reported by the local newspaper

72 Philip Kariuki. Nd. The Sugar Sub-sector. Challenges and Opportunities.http://www.kenyalink.org/sucam/documents/Sugarsub1.html

73 Soko Directory. (2020). March Monthly Report. Retrieved from https://sokodirectory.com/wp-content/uploads/2020/03/March-Soko-Monthly-Report-1.pdf

Availability of baggase from the state-owned mills is not assured as their operations are on and off due to reasons discussed above. Unlike the state-owned mills, privately owned mills are well managed and may be a point source for baggase. In addition, if the government follows through with the recommendations of the taskforce to privatize the sugar mills, we might see an increase in the amounts of bagasse available.

The competing uses for bagasse include: co-firing in the sugar mills boilers, briquette manufacturers (e.g Tamua Ltd) who sell their briquettes to industries such as tea factories, British American Tobacco Kenya (BAT) and institutions. The daily residue for bagasse contains almost 50% moisture content and to make briquettes, the baggase has to be dried to 12-14% moisture content[74]. This is to mean that, the total amount produced by a mill reduces after drying and this introduces a drying cost. The other challenge with the use of briquettes produced from bagasse is the formation of clinkers (incombustible residue), which block the air, vents of the boilers (for industries) which results in inefficiencies in its operation.

3.4.2 Sawdust

Sawdust is a by-product of wood and timber industries. In Kenya, there are approximately 850 saw millers who are grouped into large-scale mill (process more than 10,000 m^3 of trees annually), medium scale millers (process 2,000 m^3 - 10,000 m^3 of trees annually) and small-scale miller (process less than 2,000m^3 of trees annually). The small-scale millers form the largest group accounting for 77% of the saw millers. The small and medium scale saw millers in the country are spread out within the central, rift and western regions. Most of the millers obtain their trees from government forests in which the Kenya Forest Service provides guidelines for exploitation of the raw material[75]. Briquette producers can source the raw materials from three main points (timber yards, furniture shops and saw-millers). Key informant interviews with the suppliers of saw millers were held and the information gathered discussed below.

Small-scale millers form the largest group accounting for

77%

of the saw millers

74 KICIC. (2017). Sugarcane Bagasse as an Alternative Renewable Energy Solution. Retrieved from https://www.kenyacic.org/news/sugar-cane-bagasse-alternative-renewable-energy-solution

75 Ototo., G. and Vlosky.(2018). Overview of the Forest Sector in Kenya. Forest Products Journal 68(1):6-14; DOI: 10.13073/0015-7473.68.1.4

1 *Furniture shop*

One source of sawdust is furniture workshops in urban areas. Ngong Road furniture hub in Nairobi County was visited. This is because the sawdust quantities in a furniture hub are higher compared to stand-alone furniture workshops. Four suppliers of sawdust were identified in this production hub. They collect the sawdust from the furniture shop and accumulate it along the road. Figure 9 below shows the sawdust accumulated.

They collect two types of waste from furniture workshops: fine sawdust and wood shavings. The wood shavings are more preferred for poultry farming. In a week, they can collect 20 bags of sawdust, each 20 kgs. In a typical week, the 4 suppliers accumulate approximately 1,600 kgs (20 bags x 20 kgs per bag x 4 suppliers) of sawdust. This is sold to customers on a first come basis. Each bag of 20kg is sold for KES 150. The sawdust is sold to briquette producers, hotels within the vicinity to add to the charcoal stoves for heat retention and poultry farmers. These quantities however, are quite low considering large-scale production of briquettes. Availability is also highly uncertain as it is sold on a first come basis. The status and performance of the business also has an impact on the amounts generated i.e. when business is low less furniture will be made and therefore low quantities of the sawdust and vice versa.

©Ngong Road furniture workshop

Figure 9: Sawdust from a furniture production hub

2 *Timber Yard*

A timber yard in Kawagware area (Nairobi County) was visited. In a week, they can collect 5-10 bags, each 50kgs which sums up to 250-500 kgs in total. A bag goes for KES 150. They sell on a first come basis. Some of their customers include households who use it as a fuel, farmers who use it as mulch and animal bedding and hotels as floor covering and a heat insulator for the charcoal stoves.

3 *Saw-millers*

In terms of actual amounts available, large and medium scale (e.g. Comply and Raiply) millers are not potential suppliers as they use their sawdust to heat boilers, make plywood, poles and particleboards. The focus is more on the small-scale millers who are spread out within the central, rift and western regions. Key informant interviews with sawdust suppliers were carried out with two suppliers located in Iten (Elgeyo Marakwet County) and Nakuru town. From the information gathered, it is clear that it is difficult to estimate the exact amount of sawdust at a given time. Unlike in the past where the sawdust was abandoned in heaps, currently sawdust has multiple uses and therefore less amounts are readily available. Most of the suppliers have established customers such as Bidco Oil refineries in Nakuru and Thika and briquette producers. Some of these customers pre-pay for the sawdust as a way of securing supply. The available sawdust is sold on a first come basis. Milling in the area has also been affected by the closure of the forests after the government issued a logging ban in 2019 (this is elaborated further in the section below). It is estimated that on a typical day a saw miller can produce up to 30 tonnes of sawdust. However, since the closure of the forests, the highest that can be achieved is 10 tonnes per day.

©Kawangware timber yard

Figure 10: Sawdust at a timber yard in Kawagware

The supplier at Nakuru estimates that there are approximately 50 saw millers in his area of operation with the assumption that each mill 10-30 tonnes a day, the sawdust generated is estimated at 500- 1,500 tonnes per day. The supplier at Iten estimates that in a day he can collect up to 100 tonnes of sawdust. The cost of sawdust is determined by the moisture content of the waste. The typical moisture content for sawdust is 30-40 % immediately after milling. This is sold at KES 3,000 per tonne. If the sawdust is dried, the cost doubles to KES 6,000 per tonnes.

For sourcing of sawdust by the briquette producers, it is recommended that they identify a broker[76] who will be mandated with collecting the sawdust from the various saw millers. This is seen as more efficient approach as the brokers are well versed with the dynamics of sawdust availability in their area of operation. This saves time compared to collecting the sawdust from multiple saw millers. In addition, brokers are able to arrange for transportation of the sawdust that is more affordable (e.g. use of trucks that have no load on their return trip) than if, the producer was to arrange for the transport. It is also advisable that the production site be closer to the sawdust since, the farther you are from the raw materials, the higher the transportation cost. For example, transporting 7- 10 tonnes of sawdust to Nairobi could cost KES 8,000 (if you identify a return truck for transporting goods) and can be as high as KES 20,000 if a truck is hired just to transport the sawdust.

The cost of sawdust is determined by the moisture content of the waste. The typical moisture content for sawdust is

30-40%

immediately after milling.

Factors affecting availability of sawdust

The government from time to time issues a ban on logging due to over-exploitation of the forest or in instances when the rate of reforestation is slow. For example, in 1982 a ban was given on the exploitation of Camphor Wood, this was followed by a ban on exportation of indigenous timber in 1984 and in 1985 a ban was extended on exploitation of all timber unless the Office of the President issued special clearance[77]. Another ban on logging was issued from 1999 to 2012 and it resulted in a sharp decline in saw milling in the country. In February 2018, a 90-day ban on logging was imposed on public and community forests to curb the water shortage that the country was experiencing due to decrease in water level in rivers[78]. After expiry of the 90 days, the ban was extended to 6 months and after the 6 months it was further extended for another 12 months. This is aimed to help the country meet the 10% forest cover target by 2022. This on and off bans on harvesting trees from the community and public forests have a great impact on the total amounts of sawdust available. To address the deficit created by the ban, the government removed the 10% import duty imposed on imported raw timber[79]. Another contributor to reduced amounts of sawdust is the push by the government for millers to use wood mizer[80] in their milling process, which is more efficient than the chain saw, and the circular bench saw and therefore produces very little sawdust.

Sawdust is a good briquette material because it contains a high proportion of lignin, which acts as a natural binder during the pressing process resulting to dense briquettes. Sawdust briquettes are preferred to other types of briquettes because they have high energy density, burn for a long time, less costly and produce less ash content[81].

76 A broker is an individual or firm that charges a fee or commission for executing buy and sell orders submitted by an investor (definition by investopidia).

77 George M. Muthike, M., G, Shitanda., D., and Kanali., C., L. and Muisu, F, N. (2010). Chainsaw Milling in Kenya. ETFRN News 52: December 2010.

78 Ministry of Environment and Forestry. (nd). Government Suspends Logging as Country faces water crisis. http://www.environment.go.ke/?p=4598

79 ALN.Key highlights of the 2019-2020 National Budget Statement. Retrieved from https://www.africalegalnetwork.com/legal-alert-key-highlights-2019-2020-national-budget-statement/

80 Government of Kenya. (2016). Forest Conservation and Management Act 2016. Nairobi: Kenya

81 Ajibade, F., O. Lasisi, H.,K. and Babatola. (2017). Production of Sawdust Briquettes as Alternative Household Fuel Using Water and Cow Dung as Binders. African Journal of Renewable and Alternative Energy.

3.4.3 Charcoal dust

Figure 11: Charcoal distributor in Parklands area in Nairobi County

Briquette enterprises in urban and peri-urban areas (mostly small-scale manufacturers with exemption of Chardust Ltd) use this waste as a raw material because it is readily available, it is already carbonised, could complement charcoal if a good quality binder and mixed in the right ration is used[82] and is low cost compared to sawdust and bagasse. To help estimate the quantities available for charcoal dust, charcoal venders in Nairobi were interviewed. One of the charcoal vendors interviewed is based in parklands area where they sell on retail and wholesale (see Figure 11).

Although, there exists large quantities of charcoal being sold in these locations, charcoal dust quantities remain limited. This is because the charcoal is sold in wholesale and is delivered for distribution when it is already packed in sacks as shown in the figure above. The charcoal dust they collect is from the charcoal sold on retail is not much. They have a briquette producer who collects this waste but would be willing to sell on a first come basis. This is also because the city council fines them if they find the charcoal dust accumulated on their site[83]. A sack of charcoal dust of about 50 Kgs goes for KES 300 or KES 400 depending on the vendor. The maximum they can accumulate in a week is five sacks (50 Kg) of charcoal dust. However, this is not always the case as some charcoal may have limited or no charcoal dust at the point of delivery. Charcoal with low quantities of charcoal dust is preferred by both vendors and final consumers as it has less waste.

The second type of charcoal vendors visited are the small-scale traders who sell the charcoal on retail (see Figure 12 below). From the information gathered, it is difficult to accumulate one sack of charcoal dust in a week. Each sack is sold at KES 350.

Charcoal dust although available, is highly decentralized. While the number of charcoal vendors may be high, the quantities available per charcoal vendor are limited. It would be ideal for small-scale production of briquettes, where the briquette producer identifies the main suppliers of the charcoal dust within the vicinity of the business. Reliability of the raw material is highly uncertain, as there are cases where the charcoal may have limited or no charcoal dust at the point of delivery.

82 Tanui, J.K., Kioni, P.N., Kariuki, P.N. et al. (2018). Influence of processing conditions on the quality of briquettes produced by recycling charcoal dust. International Journal for Energy Environment and Engineering 9, 341–350. https://doi.org/10.1007/s40095-018-0275-7

83 Information gathered from a charcoal vendor in Parkland area in Nairobi

©Kawangware charcoal vendors

Figure 12: Small-scale vendors of charcoal

Issues associated with the use of charcoal dust as briquetting material

From an environmental point of view, charcoal briquettes are viewed as additional fuel, which slows down the rate of deforestation and reduces the Greenhouse Gas Emissions (GHGs)[84]. Although this is contrasted with the fact that most of the charcoal dust in Kenya is from unsustainable charcoal production[85]. It can also be argued that in the absence of charcoal (which the charcoal briquettes are aiming to displace) then there will be no raw material for the briquettes. However, if the goal is for the two types of fuel to complement each other, charcoal is produced sustainably and with the expectation that biomass will be the primary source of energy in Sub-Saharan Africa for several years to come[86] then charcoal briquettes could provide additional fuel to the energy mix at a household level. Availability of the waste is affected by the on-and-off bans in the production of charcoal and logging bans. For example, in 2018 there was a ban on charcoal production in the charcoal production hotspot counties due to environmental degradation[87].

3.4.4 Municipal solid waste

Municipal waste that can be used for the manufacturing of briquette include organic waste (vegetables, legumes, tubers, grains, fruits, and other biodegradable materials), bio-degradable paper, plastic and human waste (faecal matter).The sources of these wastes include households, small food stalls, markets, restaurants, institutions (schools, offices etc) among others. Presently, wastepaper is the most commonly used waste stream for briquetting. However, to maximize the potential of municipal waste for briquetting (wastepaper, organic waste and faecal matter) is blended with other types of biomass wastes in the form of carbonised rice husk, sawdust etc. The mixing of these materials in different ratios will yield briquettes of different quality. Briquettes mixed in the following proportions: Paper Briquette 1 (100%); Briquette 2 Paper (50%) and Sawdust (50%); Briquette 3 Paper (50%); Sawdust (25%) and Carbonised rice husks (25%) yield characteristics as indicated in Table 13[88].

Table 13: Quality of briquettes produced from varied mixture proportions of wastepaper, sawdust and carbonised rice husk

#	Parameters Measured	Briquette 1	Briquette 2	Briquette 3
1	Heating value (MJ/kg)	15.01	16.68	13.69
2	Ash Yield (% dm)	21.0	14.6	31.0
3	Moisture (%)	5.6	7.1	5.8
4	Bulk Density (kg/m3)	485.41	390.06	459.01

It should be noted that briquettes require a heating value of about 11.66 MJ/kg to sustain combustion.

84 Njenga., M.Yonemitsu.,A. and Karanja.,Nancy. (2014). Implications of Charcoal Briquette Produced by Local Communities on Livelihoods and Environment in Nairobi- Kenya. Journal of Cleaner Production: 10.14710/ijred.2.1.19-29

85 Ngusale, G. (2014). Briquette making in Kenya: Nairobi and peri-urban areas Renewable and Sustainable Energy Reviews 40:749-759. Retrieved from https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.rser.2014.07.206

86 Gitau, J.K, Mutune, J., Sundberg, C., Mendum, R., and Njenga, M.(2019). Implications on Livelihoods and the Environment of Uptake of Gasifier Cook Stoves among Kenya's Rural Households. Applied Sciences, 9, 1205.doi:10.3390/app9061205

87 The conversation. (2018). Banning charcoal isn't the way to go. Kenya should make it sustainable. https://theconversation.com/banning-charcoal-isnt-the-way-to-go-kenya-should-make-it-sustainable-95610

88 ibid

Other biomass raw materials and mixing ratios currently used in Kenya include: charcoal dust and waste paper (2:1); Sawdust, coffee husks (2:1) with waste paper as the binder; sawdust, char dust, waste paper, wood shavings (no particular ratio) and waste paper, clay, and sawdust (sawdust to clay 4:1) with waste paper as the binder[89].

Vegetable market waste (organic waste) has also been used as a raw material for briquetting. Vegetable market waste has a high initial moisture content and would need drying and size reduction to be suitable for briquetting. Different types of vegetable waste have varying calorific values. A study[90] of briquetting from four food wastes i.e. cauliflower/cabbage leaves, coriander stalks and leaves, field beans and green pea pods indicated calorific values ranging from 10.26 – 16.60 MJ/kg, the calorific value, bulk density and ash content for the individual feedstocks are indicated in Table 14 Additionally, the feedstock did not require binding material.

Table 14: Quality of Briquettes produced from dried and powered vegetable feedstocks

#	Parameters Measured	Cauliflower	Coriander Stalk	Field Beans	Green Pea
1	Heating Value (MJ/kg)	12.39	13.70	16.60	10.26
2	Ash content (% db)*	18.15	3.47	4.22	6.27
3	Bulk Density	509	747	685	557

*physical characteristic of the dried vegetable market wastes powder.

Plastics may also be used in combination with biomass to increase the calorific value of briquettes. A combination of sawdust, waste from electrical and electronic equipment (WEEE) i.e. halogen free wire and print circuit board (PCB) and automotive shredder residue (ASR) residues from end of life vehicles were used to make briquettes through varied waste proportion, pressure and temperature. The net calorific value of briquettes produced ranged from 16.6 – 18.9 MJ/kg. It was noted the use of sawdust and PCB yielded consistently higher calorific value of 18.9 MJ/kg[91] Table 15.

Table 15: Net Calorific Values of briquettes formed from varying mixtures of sawdust, ASR, and halogen free wire

#	% Biomass	% Waste	Net Calorific Value (MJ/kg)
1	90% sawdust	10% Wire	18.2
2	80% sawdust	20% Wire	17.5
3	70% sawdust	30% Wire	16.8
4	90% sawdust	10% ASR	18.9
5	80% sawdust	20% ASR	18.9
6	70% sawdust	30% ASR	18.9
7	90% sawdust	10% PCB	18.1
8	80% Sawdust	20% PCB	18.9
9	70% Sawdust	30% PCB	16.6

Other studies highlight the potential of mixed plastic waste mixed with corn stover. The mixed plastics were obtained from a dumpsite and the corn stover was obtained from the field after a harvest season. The briquettes from corn stover (100%) were compared to a mixture of plastics (55%) and corn stover (45%), the calorific value of corn stover ranged between 15.64 -16.60 MJ/kg, carbon content 52.17 – 53.72 % and ash content 8 – 9% while the mixture briquettes had a calorific value of 26.4 -28.9 MJ/kg (as high as charcoal Table 4), carbon content 82.83 – 86.65 %, moisture and ash content of 6.10 – 7.02 %[92]. It should however be noted that burning of plastic emits toxic fumes, making them not ideal for briquette production.

Although both the organic and non-organic fractions of solid waste can be utilised for production of briquettes, the organic fraction, which will be referred to as biowaste, is recommended. Biowaste is mainly comprised of kitchen waste (food scraps and peeling residues), market and yard waste, wood residues and food processing residues. Burning plastic in open systems, where emissions are not captured or treated, as observed during cooking will lead to the increase of household and ambient air pollution for domestic and industrial settings, respectively. For this reason, plastics were not considered as a suitable waste for briquette production.

89 Ngusale G., Luo Y., and Kiplagat J.K., (2014). Briquette making in Kenya: Nairobi and peri-urban areas. Renewable and Sustainable Energy Reviews 40 749-759.

90 Olugbemiro, M.A. and Olorunnisola, A.O.(2018). Potential of Briquetting as a 90. Waste-Management Option for Handling Market-Generated Vegetable Waste in Port Harcourt, Nigeria. Recycling, 3,11. doi:10.3390/recycling3020011

91 Garrido M.A., Conesa J.A., and Garcia M.D. (2017). Characterization and Production of Fuel Briquettes Made from Biomass and Plastic Wastes. Energies 10,850.

92 Auprakul U., Promwungkwa A., Tippayawong N., and Chaiklangumauang S. (2014). Densified Fuels from Mixed Plastic Wastes and Corn Stover. Advanced Materials Research Vols. 931-932, pp 1117-1121.

Challenges in the utilization of municipal waste for briquette production

One of the main challenges at present is obtaining non-contaminated biowaste feedstock from municipal solid waste. Contamination of domestic waste in developing countries arises from the lack of sorting and segregation at source. The use of biowaste from domestic sources for briquetting will therefore need to take into consideration sorting machinery into desirable fractions or training and equipping personnel to separate waste. Additionally, this waste will include both raw and cooked leftovers. The latter is unsuitable for briquetting due to low calorific value. Although the raw material cost is lower than other feedstocks such as macadamia shells or coffee husks, the cost of treatment and processing of waste before use should not be overlooked.

Alternatively, sourcing of organic waste can be done directly from homogenous sources such as open markets such as Marikiti in Nairobi and Kongowea in Mombasa among others. A comparison of the physical-chemical properties of specific fraction biowaste – market / yard waste and organic domestic waste is indicated in Table 16.

Table 16: Physical and Chemical Characteristics of Biowaste Fractions[93]

#	Feedstock	Moisture (wt%)	Ash (wt%)	Volatile (wt%)	Fixed Carbon (wt %)
1	Yard and Market Waste (municipal)	22.3	25.9	87.2	12.8
2	Organic Domestic Waste	63.1	37.0	83.1	16.9

The moisture content of domestic organic waste (63.1%) is almost thrice that of organic fraction from market and yard sources. The higher moisture content will require additional drying to reduce content to an optimum of 10-14%.

It should be noted that the market waste would vary depending on the specific dietary patterns of a region. A report on the retail vegetable vendors in Kenya, indicated that at least 90% of retail vendors experience vegetable waste either while receiving / sorting vegetables from suppliers or waste on the shelf[94]. Therefore, waste can be "intercepted" at different stages of the value chain. Either before sale to a retail seller (from supplier) or waste not purchased by retail customer (from seller). The wastage from shelf was higher than that of receiving and sorting. The retailers highlighted five vegetables with the most wastage: potatoes peelings, tomatoes, snow peas, French beans and sugar snaps. Further assessment of the physical-chemical properties of the individual components of market waste are included in Table 14.

Another hurdle in obtaining adequate resource is other competing uses of the waste. Waste paper has a robust recycling system, which limits the availability of the raw material. Organic waste recovery through composting and gasification is a focal point of implementation in the integrated solid waste management plan of Nairobi. Vegetable waste from markets or groceries kiosks in low income areas are used as animal feed (e.g pig food). Large-scale projects on waste management such as that being implemented by ASTICOM K Ltd and the plans by KenGen and Nairobi City Council on generating electricity from garbage pose a threat to availability of municipal solid waste.

3.4.5 Faecal waste

Faecal matter was assessed as a raw material for briquette production. As highlighted earlier, faecal sludge has moisture content of 80-97 %, ash content of 38.40-57% and a calorific value of 13MJ/kg. The sludge contains high amounts of pathogens such as bacteria and other disease-causing microorganisms including Salmonella, Shigealla, Escherichia coli (E. coli), Ascaris Lumbricoides and Sclustosoma mansonic eggs[95]. Due to the high amounts of pathogens, the sludge has to be pre-treated before briquetting. This is done through carbonisation of the dried sludge in temperature of between 450^{0}C-600^{0}C[96] (using a carbonisation oil drum or furnace). Carbonisation is also carried out to increase the fixed carbon of the raw material, which then increases the calorific value of the resulting feedstock. Due to the high moisture content, advanced drying methods such as the use of greenhouse is recommended. The sludge is channelled to the greenhouse drying beds and left for 1-3 days. Due to its high ash content, the faecal sludge is blended with other types of biomass.

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93 Lohri, C., R., Rajabu, H., Sweeney, D., J., and Zurbrugg, C., (2016). Char fuel production in developing countries – A review of urban bio-waste carbonisation. Renewable and Sustainable Energy Reviews, 59, 1514 -1530. https://doi.org/10.1016/j.rser.2016.01.088

94 Ibid

95 D. M. Nyaanga, P. A. Kabok, J. Mbuba, S. O. Abich., R. Eppinga and J. Irungu. (2018). Faecal matter-saw dust composite briquette and pellet fuels: production and characteristics. Transformation Towards Sustainable and Resilient Wash Services: 41st WEDC International Conference, Egerton University, Nakuru, Kenya, 2018

96 Ibid

A study by Nawasscoal concluded that blending faecal sludge with sawdust at a ratio of 50:50 produced a briquette with a calorific value of 18.8 MJ/kg, which is above the minimum recommended value for briquettes (17.5 MJ/kg). The use of the faecal sludge for briquette production is viewed as a solution to the challenge of sanitation in urban areas and a source of alternative cooking solution for low-income households.

The faecal sludge can be obtained from water and sewerage companies in the main cities such as Nairobi City Water and Sewerage Company (NCWSC), which collect faecal sludge from households connected to the company's sewer system. NCWSC strategic plan for 2018/2019 aimed to collect, convey, treat and dispose 400,000 M^3 /day of wastewater in an environmentally friendly manner[97]. Sludge from households is the most suitable as it is not contaminated with heavy metals as is the case for industrial sludge. The sludge can also be collected from septic tanks and pit latrines in urban areas and delivered to the briquette production site using bowsers.

In the recent past, briquette producers have been exploring the use of faecal waste for production of briquettes. Sanivation Limited has been producing briquettes from faecal matter for household uses in Kakuma refugee camp and low-income areas of Naivasha. Nakuru Water and Sanitation Services Company is involved in faecal sludge management through its subsidiary company Nawasscoal that produces carbonised briquettes for household and small enterprises consumption.

Challenges in the use of faecal matter for briquetting

Faecal sludge must be blended with other carbonised biomass to produce briquettes of desirable quantities. Examples include use of charcoal dust and sawdust whose availability is not reliable due to on-and-off bans on charcoal production and logging in Kenya and the competing uses for the sawdust. However, further research is recommended on conversion of other types of biomass (e.g bagasse) into charcoal dust to be used together with the sludge for briquette production.

Another challenges with the use of faecal sludge for briquette production is people's perception on using briquettes made from faecal matter for cooking. Most communities consider this to be a taboo. However, this can be addressed by extensive awareness creation, demonstrations on the use of the fuel and households sampling the briquettes. Having a KEBs label of quality may also aid in gaining consumer confidence.

In addition to business permits, the briquette producer has to acquire public health permits on handling of faecal matter. The testing of briquettes must also include the testing for pathogens, which is a more elaborate than testing for briquette properties (ash content, moisture content etc). In case the briquette producer decides to acquire the sludge from Water and Sewerage Company then these companies must be willing to form partnerships. If they are unwilling, the raw material may have to be sourced from households.

3.5 Comparative analysis of the selected raw materials

This section of the report aims to compare the five types of raw materials discussed above and identify the most suitable raw material for briquetting. Several factors were considered in determining the most suitable raw material. For example, is the aim to produce carbonised or non-carbonised briquettes? Is it large-scale or small-scale production of briquettes? If the aim is to produce carbonised briquettes, then raw materials that are already carbonised rank highest (e.g. charcoal dust). If the material has to be carbonised then the raw materials that are in large quantities and low in cost are preferred as almost 70% of the raw – material will be lost during the carbonisation process. In regards to the scale of production, large-scale production of briquettes requires a raw material that is available in large quantities and in a central location.

In comparing the raw materials, it is clear for all the five feedstocks assessed, their calorific value falls within the desired range for briquette production. Additionally, for carbonised briquettes, the calorific value of the raw material is improved through the process of carbonisation. Therefore, the calorific value of the raw material was not a key factor for consideration when assessing the most suitable raw material for briquetting. The selection of the suitable material was mainly centred on quantities available and the cost of the raw material. Charcoal dust is a suitable material for producing carbonised briquettes

97 Nairobi City Water and Sewerage Company Limited. (2014). Strategic Plan 2014/15 – 2018/19. Retrieved from https://www.nairobiwater.co.ke/images/strategic_plan/NCWSC_2014-15_to_2018-19_Strategic_Plan.pdf

as it is already carbonised. However, its availability to a large extent is decentralized. From the data collected, most of the charcoal vendors are small-scale traders and collecting a sack (50 Kg) of charcoal dust in a week is already a challenge. For the wholesalers of charcoal, the charcoal packed from source and therefore have limited charcoal dust to sell. From the vendors interviewed, the maximum they can gather in a week is five sacks (50 Kgs). This means the producer will have to identify several charcoal vendors for the supply of the charcoal dust.

Sawdust quantities when compared with other raw materials such as bagasse and faecal waste was found to be limited. This is especially the case if it is sourced from timber yards or furniture shops. Moreover, if the aim is to produce carbonised briquettes, then approximately 70% of the waste will be lost through the carbonisation process. This is costly for the producer considering the cost of the sawdust per tonne (KES 3,000-6,000). The remaining two raw materials, faecal matter and bagasse are available in large quantities. They can also be sourced from a central location. Bagasse is not only centrally located (from sugar mills), it is also cost-friendly compared to the sawdust. Depending on the supplier and the agreement between the briquette producer and the sugar mill, the bagasse can be obtained at no cost or cost ranging from 100-600 per tonne.

Bagasse can be obtained at no cost or cost ranging from

100-600

per tonne.

Depending on the supplier and the agreement between the briquette producer and the sugar mill

Faecal matter is also available in large quantities but other factors such as collecting the sludge from homes or forming a partnerships with the Water and Sewerage Companies come into play. The need to acquire permits to handle the faecal matter and extensive testing can significantly raise the capital requirement for the production of briquettes which maybe a constrain for a start-up.

The other challenge with faecal matter is that it has to be blended with another type of biomass. Factors affecting the selected material to be blended with the faecal matter must also be considered when evaluating faecal matter as a potential feedstock. Other factors to consider are competing uses of the faecal waste that might be more economically viable than the production of briquettes, for example, organic fertilizer. Organic waste for briquette production has to be carbonised especially if the aim is to make household briquettes. This reduces the quantities greatly. Organic waste is also a preferred animal feed for pigs, which further reduces the quantities of waste available. For carbonised briquettes, charcoal dust is ranked as the first option but only for small-scale production of briquettes.

For large-scale production of carbonised briquettes, bagasse is ranked as the first option due to the large quantities available and relatively low cost and low investment compared to the use of faecal matter. Faecal matter is ranked as the second option given the need for preparation before use and organic matter is ranked as the last option mainly because the investment required in terms of collection of the waste, sorting and drying of the waste before briquetting may prove to be economically unviable compared to other uses such as animal feed where no processing of the waste is required.

For the production of non-carbonised briquettes, faecal waste and organic waste were not considered. This is mainly because, the faecal matter must be treated (mainly through carbonisation) and thus is more suited for carbonised briquettes. Organic waste was omitted due to the reasons discussed above.

Two raw materials are considered for the production of non-carbonised briquettes: sawdust and bagasse. The downside of using bagasse to sawdust is the high moisture content of 50% and the formation of the clinkers (incombustible residue resulting from the burning of bagasse briquette). The moisture content of sawdust is between 30-40% at the point of milling. However, in terms of quantities available and cost, bagasse is more preferred.

The difference in moisture content is also not a wide range and therefore for both sawdust and bagasse the producer will have to invest in drying techniques. For the formation of clinkers, the boilers can be retrofitted to address this challenge of using bagasse briquettes. The use of bagasse is still ranked as the most preferred raw material for the production of non-carbonised briquettes especially for large-scale production of briquettes. Sawdust is ranked as the second most suitable raw material mainly due to the cost and the quantities available.

Table 17 below compares the five raw materials.

Table 17: Comparison of the waste

#	Raw material	Advantages	Disadvantages
1	**Bagasse**	• Available in large quantities (for 2019, 1,611,011 tonnes of briquettes were produced). • Available in central locations. • Cost is relatively low compared to other types of raw materials (KES 0-600 per tonne).	• High moisture content. • Formation of clinkers.
2	**Sawdust**	• A preferred raw material for non-carbonised briquettes due to high levels of lignin thus allowing proper compacting. • It can be used as an additional raw material to other types of feedstock e.g. faecal matter.	• High cost ranging between KES 3,000-6,000 per tonne. • Requires drying before use. • Availability of the raw material is not reliable due to high competing uses and restrictions such as bans on logging.
3	**Charcoal dust**	• Recommended for carbonised briquettes as it is already carbonised. • No drying is required unless the charcoal dust has been exposed to environmental elements such as precipitation. • Ideal for small-scale producers of briquettes.	• The quantities are to large extent decentralized. A producer would be required to identify multiple charcoal vendors to obtain the desired quantities. • Availability is not reliable as some charcoal maybe delivered with low quantities of charcoal dust. • Availability may be affected by charcoal bans that are issued from time to time.
4	**Faecal matter**	• Available in large quantities and in centralized locations.	• Capital intensive, in regards to drying techniques (98% moisture content), carbonisation (treatment of the waste), testing of the briquettes for presence of pathogens. • Negative perception from potential users towards use of briquettes made from human waste. • Faecal matter has to be blended with other raw materials such as carbonised sawdust, which also adds to the cost of production.
5	**Organic waste**	• Contributes to cleaner environments.	• Lack of sorting of waste at the household level makes it difficult to have a homogenous waste, and therefore investment in sorting techniques have to be considered. • High moisture content also requires investment into a drying method. • Organic waste would require carbonisation if the briquettes are for household use, which greatly affects the availability of the quantities available. • Use of the waste as compost or as an animal feed may be more economical than the heavy investment required for briquette production.

Based on the discussion above, the five raw materials are ranked as shown in Table 18 below. From the most to least suitable material for carbonised briquettes. For non-carbonised briquettes, the choice is between sawdust and bagasse and bagasse ranked first as the most suitable raw material because of its availability in large volumes, low cost and the centrality (large volumes in sugar mills).

Table 18: Ranking of the raw material for production of carbonised briquettes

#	Feedstock	Rank
A	Charcoal dust	1
B	Bagasse	2
C	Faecal matter + sawdust	3
D	Sawdust	4
E	Organic water	5

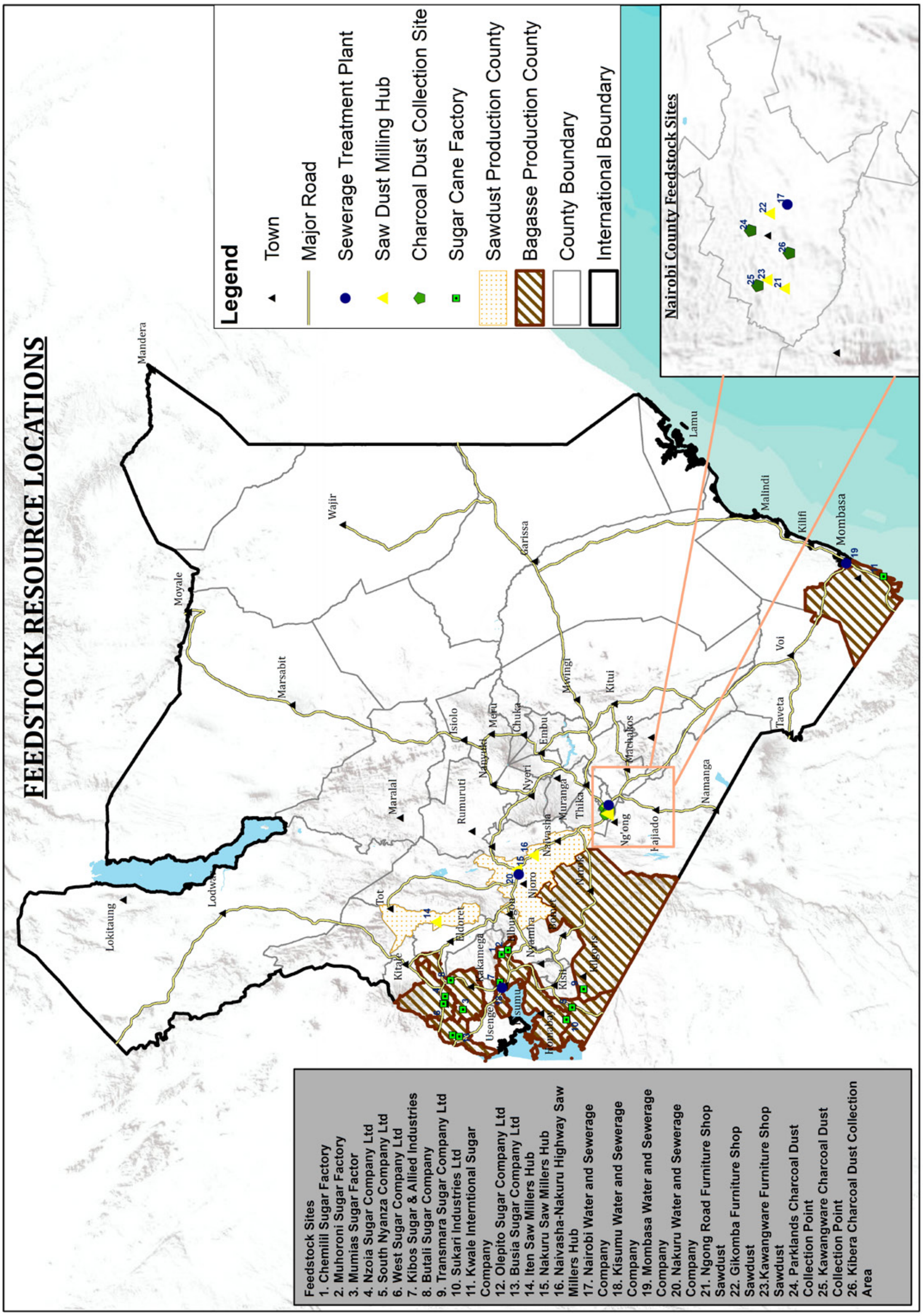

Figure 13: Potential Sources of Briquette Feedstock in Kenya

4 Identification of Biomass Waste-based Briquettes Making Technologies

Identification of the most suitable briquetting technology is essential when starting a briquette production enterprise. There are three main briquetting technologies; low-pressure technology where production is done manually, medium pressure technology, and high-pressure technology all of which use mechanical means to run briquetting equipments. This chapter describes the steps in the briquetting process, the different briquetting equipments at each step, compares the different technologies in terms of cost, expertise required, factors hindering its implementation. The chapter commences by characterizing the different briquette producers that were interviewed. Two cases are provided, one from Kenya (use of faecal matter for briquette production) and the second one from Uganda.

4.1.1 Profiles of producers interviewed

Briquette producers can be grouped into sole entrepreneurs, limited companies, and Community Based Organisations (CBO). Out of the 20 interviews carried out, 11 were limited companies and these include Kings Biofuels, Eversafe Limited, Sanivation, Nyalore Impact, Biomass Energy East Africa Limited, White coal industries limited, Bioafriqenergy Limited, Eco Charge, Kencoco, Acacia Innovations, and Wood Heat Energy Limited. Although most of them (12 out of 20) started operations in the last five years, other companies such as Kings Biofuels, Eversafe Limited, Lean Energy and Chardust have been in the market for the last decade. The sector is however dominated by informal and artisanal small-scale producers, who do not: label their products nor supply them in standardized units; belong to a formal or registered association or a production hub, and do not have an online presence making it difficult to exhaustively profile them, their businesses and products. Many of these are opportunistic, resulting in inconsistent production patterns and produce briquettes as a supplementary product.

Out of the 20 respondents, 14 of them have their business registered as a company or a CBO, 11 of the businesses are owned by women and 10 of the businesses are owned by youths (less than 35 years). Fourteen (14) of the businesses are fully operational, 4 are partially operational and 2 had closed their businesses. Details of the businesses interviewed are provided in Figure 14.

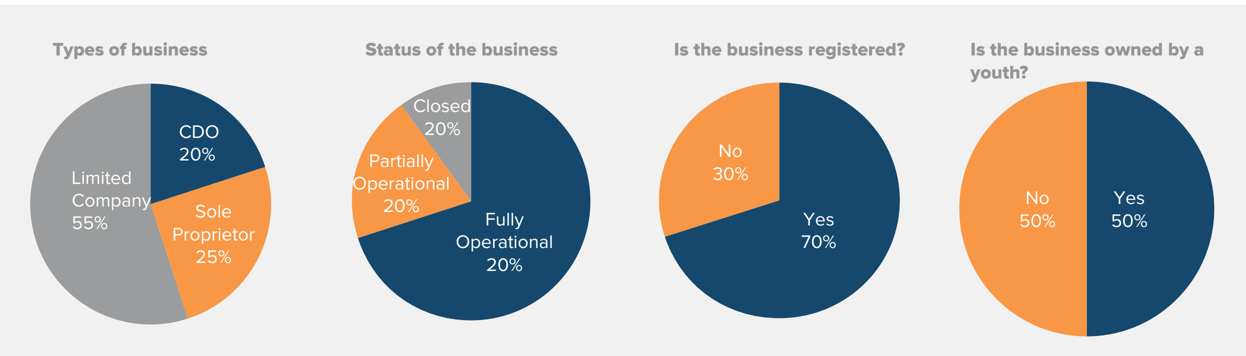

Figure 14: Profile of the briquette producers interviewed

The 20 businesses interviewed for this survey employ a total of 332 employees with women being more (55 %) than men (45%). It is also observed that youths are active in the sector with 69% of all employees being youths. Men form a higher proportion of full-time employees (62%) with women working on temporary basis. This might be explained by the fact that most large producers hire temporary workers to help with activities such as sorting of waste, drying of the raw material and briquette drying which are often performed by women. In regard to management, the proportion of men in managerial positions are slightly higher at 51 % compared to women at 48%. It is also observed that more than half of the employees in managerial positions are youths (53%). Further details are provided in the Table 19 below.

Table 19: Employee composition of the 20 producers

#		Men	Women	Youth
1	Total	45%	55%	69%
2	Permanent	62%	38%	68%
3	Temporary	27%	73%	71%

4.1.2 Feedstock and type of briquettes

As discussed above, there are 3 types of briquettes. From the interviews conducted with the briquette producers, all the 3 types were identified in this study. Carbonised briquettes are common among the CBOs and sole proprietors while non-carbonised are mainly produced by limited companies. Only one of business produces semi-carbonised briquettes. A summary of type briquettes per business is provided in the Figure 15 below.

Macadamia nut shells, sawdust, charcoal dust, baggase, maize cobs and paper waste were identified as the main type of feedstock used by the producers interviewed. Charcoal dust was the most common type of feedstock with 9/20 producers (CBOs and sole proprietors) using it as the main feedstock. This may be explained by the fact that the waste is already carbonised and can be acquired for free or at a cost as low as KES 1 per kilogram making it a desirable raw material for small-scale producers. Charcoal dust is also used prominently by producers who target households, small hotels or poultry farmers who require carbonised briquettes. Bagasse and sawdust were the most common raw materials for limited companies who produce non- carbonised briquettes. For producers who use more than one type of biomass, the following combinations were identified; sawdust and coffee husks, sawdust and charcoal dust, charcoal dust and macadamia shells, charcoal dust and coconut waste, faecal waste and sawdust.

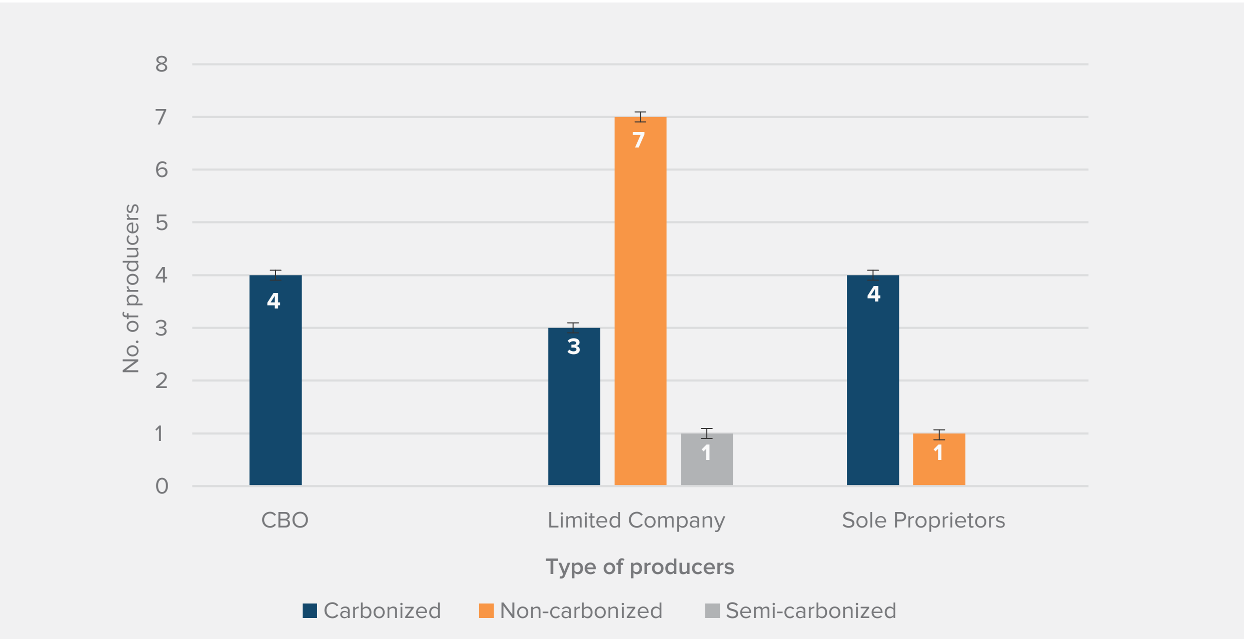

Figure 15: Types of briquettes produced

4.1.3 Production and type of end-users

To estimate the production capacity, the producers were asked to estimate the tonnes of briquettes produced for 2019. The production capacity for 2019 was classified into 3 groups based on quantities produced. Further analysis per group on type of business, type of briquettes produced, and main consumers was carried out and is summarized in Table 20 below. From this analysis it is evident that large quantities of briquettes were produced by limited companies who specialize in non-carbonised briquettes for industrial, institutional and small enterprises such as eateries. Small quantities produced were targeted at households, small enterprises such as eateries and space heating for poultry farmers.

Table 20: Production capacity for 2019[98]

#	Production Range (tonnes/2019)	Type of businesses	Type of briquettes	Main end-users
1	1,000-2,500	Limited Companies (4 companies)	• Non-carbonised	• Factories • Public institutions • Small enterprises e.g. Kiosks
2	200-700	Limited Companies (3 companies)	• Non-carbonised • Carbonised	• Factories • Public Institutions • Households
3	5-100	CBOs (2 CBOs) Sole Proprietors (3 producers) Limited Companies (1 company)	• Carbonised • Non-carbonised • Semi-carbonised	• Households • Small enterprises e.g. Kiosks • Poultry farmers

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98 Note that 25 % of the producers did not provide information on production quantities for 2019

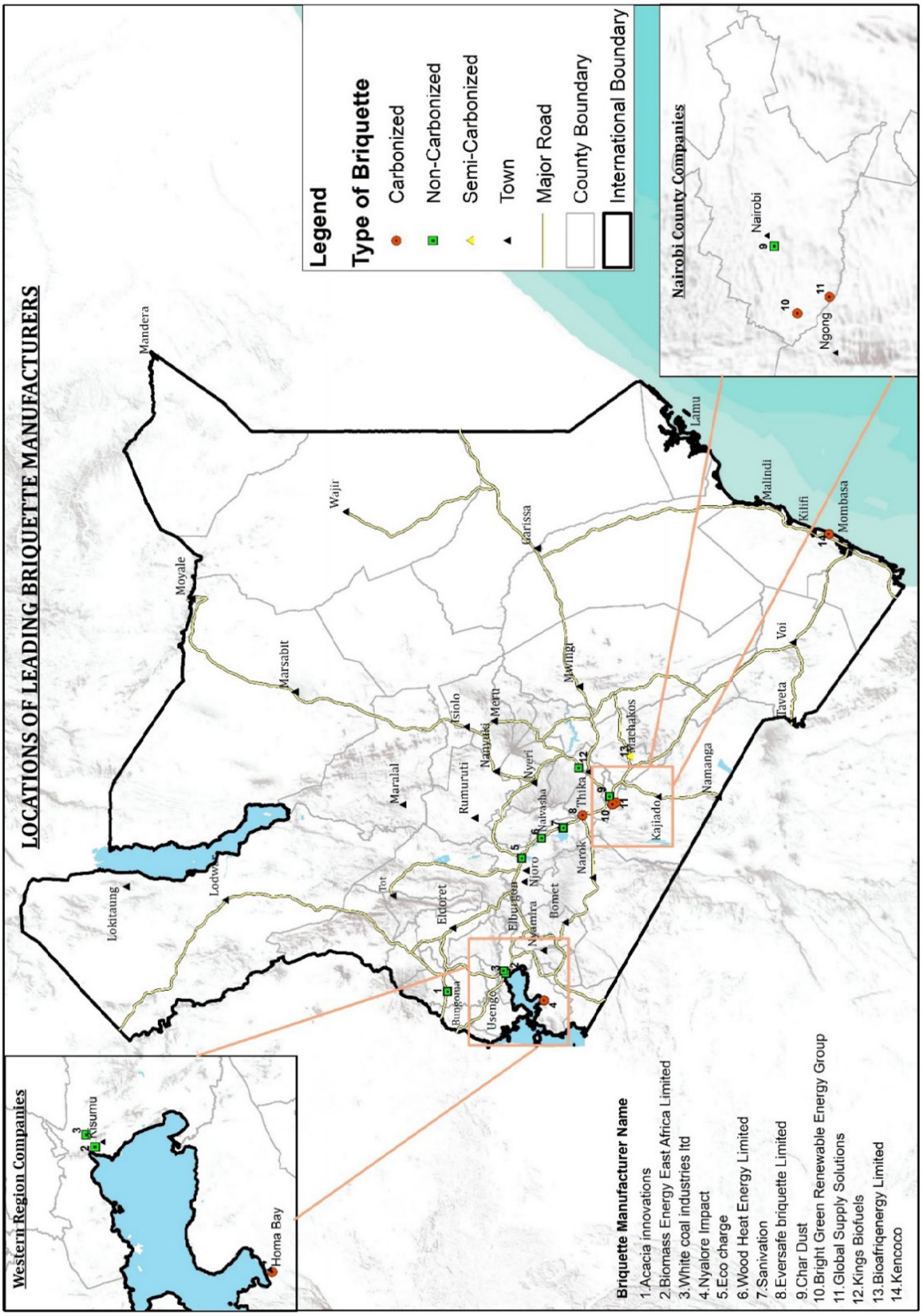

Figure 16: Location of briquette manufacturing companies in Kenya

4.2 Description of the processes

4.2.1 Pre-processing

Producers have to first identify a suitable feedstock. This choice is driven by various factors including proximity to a source, proximity to markets, availability of technology options and cost considerations. The preparation of raw materials includes drying, sorting and separation, shredding, grinding, pulverizing and milling. Factors including type, moisture content and size of the raw material will determine the pre-processing method. For example, to produce high quality non-carbonised briquettes, the moisture content of the raw material must be between 6% and 16%[99]. This is important since compaction will not occur at high moisture content. Sugarcane bagasse may have moisture levels of up to 50% which requires sufficient levels of energy for drying as part of the pre-processing[100]. Other feedstock options including charcoal dust and macadamia nuts start off with low moisture content and may not require any drying[101]. However, the hard outer shell of the macadamia nuts may require crushing or milling to facilitate proper compaction. Paper waste, wheat straws and sugarcane bagasse may require shredding. The drying process includes open air sun drying, use of solar drying where the raw materials are dried in an enclosed structure similar to a greenhouse covered with high density transparent polythene sheet that allows radiation into the room, or the use of blowers and driers powered by electricity or fossil fuel[102]. Sorting or in other cases waste separation is required when the feedstock has high levels of foreign materials and other impurities that may interfere with the briquetting process. Handpicking and use of sieves are the most common methods [103]. Some materials require grinding before the compacting process. This is done through a hammermill driven by either an electrical or a diesel engine[104]. The diesel driven hammermill is much preferred in areas where the electricity grid has not reached or is unreliable.

Collection and processing of centrally located feedstock is preferred although many of the producers have to source from several points which can be tedious and costly. Coffee husks for instance, is sourced from coffee milling companies such as Kofinaf Coffee millers, Central Kenya Coffee Mill Karatina, Thika Coffee Mill; sugarcane bagasse from the sugar factories including Chemelil Sugar Company, Kibos Sugar and Allied Factory and; pineapple waste from pineapple growers and processors such as Delmonte Limited. Sawdust can be sourced from saw millers who are mostly located along the Nakuru-Nairobi Highway, timber yards and furniture workshops. Charcoal dust is mainly collected from charcoal wholesalers in urban areas. Municipal solid waste sources include organic waste (vegetables, legumes, tubers, grains and fruits), bio-degradable paper, plastic and animal residues and waste. Dumpsites such as the Dandora in Nairobi and Kachok in Kisumu are prominent collection points. Collection of municipal waste requires a waste handling permit. Key competitors for organic waste include the manufacture of organic fertilizer and animal feed, especially pig feed.

Briquette producers are commonly located near the source of the raw material. For instance, producers using sugarcane bagasse are mainly in the sugar-belt region of Kenya where the sugar processing companies are located. One of the producers interviewed reported moving his production site from Kiambu County to the Flyover trading centre along the Nakuru-Nairobi highway to be close to the source of sawdust in order to reduce the cost of transportation. Some producers however have to travel long distances to collect the feedstock and can go as far as Uganda (approximately 700 kilometres from the site of production). Purchased feedstock can be obtained through i) competitive tendering processes, ii) direct sourcing or spot purchases and iii) use of brokers.

4.2.2 Pyrolysis and carbonisation

Carbonisation or pyrolysis of the biomass feedstock, which is the conversion of raw materials into carbon in the absence of air, is only done in the production of carbonised briquettes.

99 Nikolaisen, L.S., and Jensen, P.D. (2013). Biomass feedstocks: categorisation and preparation for combustion and gasification. Biomass Combustion Science, Technology and Engineering (pp. 36 -57). Woodhead Publishing Series in Energy. https://doi.org/10.1533/9780857097439.1.36

100 KCIC (2017). Sugarcane Bagasse as an Alternative Renewable Energy Solution. https://www.kenyacic.org/news/sugarcane-bagasse-alternative-renewable-energy-solution

101 Chardust Ltd., and Spectrum Technical Services (2004). The Use of Biomass to Fabricate Charcoal Substitutes in Kenya. Feasibility Study; Forming Part of the Shell Foundation-Supported Project on Charcoal Briquetting in Kenya. Nairobi; Kenya

102 Rane, M.V., Kata Reddy, S.V., Essow, R.R. (2005). "Energy Efficient Liquid Dessicant-based Dryer". Applied Thermal Engineering (pp 5-6).

103 UN- HABITAT (2014). Charcoal Briquette Production - A Practical Training Manual. Nairobi Kenya

104 Temmerman, M. (2019). Recycling of Organic Waste for Energy and Smallholder Livelihood in The Gambia; Briquette Production manual - Basic and Advanced Technology. CTCN

Pyrolysis involves thermo-chemical decomposition of organic material under high pressure, in high temperature of between 200 °C and 1,500 °C, in the absence of oxygen[105]. The product of the pyrolysis process is carbon residue. Not all raw materials have to go through this process as some like charcoal dust is already carbonised. The general requirement is that raw material must be dried before carbonisation, if not, some of the material will have to burn to produce the energy for drying feedstock before carbonisation begins. This significantly reduces the amounts of biomass feedstock that is converted into briquettes[106]. High temperatures are a requirement for pyrolysis, but because most of the biomass is both a fuel and the material that is being carbonised, a balance must be maintained between producing heat and releasing carbon material. Hence, air flow must be carefully restricted at the optimum time when the proper temperature is reached.

For example, at 270°C[107] most of the agricultural waste remains unburned (sawdust is 250°C) and can be converted to carbonised briquettes[108]. From the surveys with producers, use of an oil drum remains the most common mode of carbonisation. This finding is similar to the briquette study done in Nairobi peri-urban areas by Ngusale (2014)[109] that reported that the affordability of recycled oil drum (KES 1,000), its availability at a local market, portability and low area footprint made it a popular carbonisation method. It was observed that the carbonisation plants were powered by firewood bringing to question the issue of promoting briquettes as an alternative fuel with the goal of reducing the rate of deforestation in the country.

4.2.3 Mixing

Binders are a necessity in the manufacturing of carbonised briquettes. They are added to the raw material to enhance bonding and to attain stable briquettes[110]. They are used in instances where high temperatures and high pressure are not achievable which is the case with carbonised briquettes. Non-carbonised briquettes use machines that can densify and bond the materials under high temperatures and pressure and therefore do not require a binder. A good binder is one that is effective in holding the briquette together, has low ash content, burns without smoke and has a high energy out-put[111]. Examples include gum arabica, fine clay, cassava flour, wheat flour, molasses, soaked wastepaper and red soil[112]. Clay, red-soil and waste papers produce smoky briquettes. As such molasses, gum arabica and binders made from cassava and flour are more preferred because of their high calorific value. For this study the most common binder (7 out of 11 businesses using binders) was starch from cassava and maize. One manufacturer reported having settled for gum arabica even though it is more expensive compared to molasses, as it improves the quality of the briquette and consumers preferred the briquettes made from this binder.

4.2.4 Compaction

The type of material, moisture content, fraction size, pressing temperature and compacting pressure are the key determinants of quality when manufacturing briquette. Compacting is key as it dispels entrapped air which is the main cause for loose briquettes. The latter are of a lower quality and deteriorate while in storage. From literature review, compaction in Kenya is carried out either manually or with compaction machines such as motorized screw press machine, mold-box press machine, wooden press and the ram piston[113]. The ram piston and motorized screw press are fabricated from locally available materials and are therefore, commonly used. For this study we identified 3 briquette machine local fabricators, 1 importer and 1 international manufacturer from Denmark. Imported machines are either from Europe, India or China. Although the machines from Europe are expensive compared to the rest of the machines in the market, it was reported to have several advantages including:

105 Hub pages. (n.d). How to Make Fuel Briquettes – Charcoal Dust – Carbonisation and Pyrolysis of Biomass. http://ngureco.hubpages.com/hub/How-to-Make-Fuel- Briquettes-Charcoal-Dust-Carbonisation-and-Pyrolysis-of-Biomass

106 Wondwossen Bogale. (2009). Preparation of Charcoal Using Agricultural Waste. file:///C:/Users/TBC/Downloads/56314-Article%20Text-95679-1-10-20100708.pdf

107 Ibid

108 KII with the briquette manufacturers

109 Ngusale. (2014). Briquette making in Kenya: Nairobi and Peri-Urban areas. Renewable and Sustainable Energy Reviews (pp 749 - 759)

110 World Agroforestry Centre (2016). A Review on Production, Marketing and Use of Fuel Briquettes. CGIAR Research Programme on Water, Landand Ecosystems (WLE), International Water Management Institute (IWMI)

111 GVEP (2013). Assessment of the Briquette Market in Kenya. GVEP International Africa Regional Office, Nairobi Kenya.

112 Ngureco (2011). How to make fuel briquettes – Charcoal Dust Carbonatization and pyrolysis of biomass. https://hubpages.com/technology/How-to-Make-Fuel-Briquettes-Charcoal-Dust-Carbonisation-and-Pyrolysis-of-Biomass

113 GVEP 2013. Assessment of the Briquette Market in Kenya. GVEP International Africa Regional Office, Nairobi Kenya.

high quality, high efficiency, less breakdowns and they can be automated reducing the number of employees required in a production site. Another key determinant of cost of machines is the machine's production capacity per hour with machines of high production capacity being more costly. Most machines are bought directly from fabricators rather than dealers with a typical price range as follows: manual presses for KES 11,400 -11,700, electrical presses for KES 80,000 – 200,000, imported presses with a starting price of KES 10 million and can even be as high as KES 50 million[114,115,116]. None of the briquette producers interviewed currently use manual presses. Most of them (80%) use electric machines that are either imported (56%) or locally fabricated (44%). The machine sellers reported that most manufacturers consider the cost of technology before quality. As such, they buy the less expensive machines that are of poor quality and are prone to breakdowns and have a high maintenance cost. Four (4) of the producers reported to have purchased the machine on loan while seven (7) bought with their own financing. Local fabricators also reported that most customers buy the machines on loan and may take long to pay or in some cases may not make the full payment of the loan.

When considering the technological issues, the enabling conditions include having numerous options available for different levels of production. However, for large scale production, machinery must be imported, in which a highly qualified technician is needed to adjust machine settings to local conditions and lastly, adjustments or newly designed stoves may be necessary for the efficient briquette combustion[117].

4.2.5 Drying

This applies to carbonised briquettes. Due to the favourable climatic conditions in Kenya, the sun drying remains the most common means of drying wet briquettes at a temperature of 25°C which typically takes 3–5 days. This is done by placing the briquettes on drying racks or on laying them gently on the ground. The drying racks can be built to allow stacking of several trays or can be simple from a wire mesh. Other methods adopted include; solar drying, where the wet briquettes or materials are dried in a greenhouse, the drying takes 1–3 days; use of driers (e.g. flash driers) and drying ovens. From the surveys conducted, 10 out of the 13 producers who dry their briquettes use open air method for reducing moisture in their briquettes while one uses a greenhouse and 2 use drying racks. After drying, briquettes are stored at room temperature 20°C. A comparison between the various methods for drying is provided under chapter 3.

©Nawasscoal

114 Cohen, Y., and Marega, A. (2013). Assessment of the Briquette Market in Kenya. GVEP International

115 Ngusale (2014). Briquette making in Kenya: Nairobi and Peri-Urban areas. Renewable and Sustainable Energy Reviews 40 (pp 749 – 759)

116 Data from this study

117 Ibid

4.3 Description of the technologies

4.3.1 Inventory of locally available options

Table 21: Pre-Processing

A	PRE-PROCESSING		
#	Technology/ Appliance	Description	Cost
i	SORTING		
a	Sorting sieves  (Source: Local briquettes producers)	These are fabricated by mounting a coffee mesh roll on a rack. The roll is purchased from local stores. This is ideal for when small size raw materials of 2mm are required. Large particles are sorted and then crushed.	The coffee roll which is the main component of the sieve is purchased per meter. I Meter- KES 300.
b	Hand picking  (Source: www.pixabay.com)	This type of sorting is done manually. No cost of machine and technical skill required. This is used mainly to remove foreign materials from the waste.	The only cost associated with this method is cost on labour.
ii	SHREDDING		
a	Electrical shredder  (Source: Wood-Pellet-Mill.Com)	This is purchased from local stores in Kenya. It is similar to those used for shredding animal feeds. Depending on the size you want to achieve one can adjust the sieve size. For small size particles the sieve sizes are small.	KES: 75,000.
iii	MILLING		
a	Hammer mill  (Source: Camco Machinery)	Imported by Camco Machinery. This is used for crushing or milling raw materials to achieve the desired particle sizes and to reduce the size of the hard-raw materials such as groundnut shells. This is like similar to those used for milling corn to flour. Capacity production Kg/ hour ranges from 900-1,000 Kg/ hour.	Cost ranges from KES 120,000 -450,000.

Table 22: Pyrolysis and Carbonisation

B	PYROLYSIS AND CARBONISATION		
#	Technology/ Appliance	Description	Cost
i	PYROLYSIS		
a	Drum-oil carbonizer  (Source: Hubpages Link)	Recycled oil drum can be bought from local jua Kali markets. Load the raw material into the drum and close the lid. Place the drum on a three stone open fire and allow to burn in limited air.	KES: 1,000-1500.
b	Constructed concrete kiln  (Source: Kencoco Limited)	Constructed using available raw materials. The structure has steel on the inside for support and a loading opening. During pyrolysis the holes are closed to make the kiln air tight.	The cost of construction varies. One manufacturer reported to have used KES 150,000 for the construction of the kiln.

Table 23: Mixing

C	MIXING		
#	Technology/ Appliance	Description	Cost
a	Rotating mixers  (Source: Nawasscoal)	Available from local fabricators e.g Jaffidian Enterprise Limited. Raw materials are added to the rotating drum from the upper end, heat is introduced in the low side, which forms the countercurrent contacting allowing the materials to mix to form the briquettes. Varying production capacity that can go up to 1,000 Kgs a day.	A capacity of 1,000 Kgs per day go for KES 250,000.

b	Electrical mixers (Wheel mixer) 	Imported through online platforms such as Alibaba. Has spindles that move from side to side to cause mixing of the raw materials.	Cost. KES: 120,000-340,000.
c	Manual mixing  (Source: Practical Action)	Mostly done by the owner of the business so no labour costs. Used for small-scale production.	No cost.

Table 24: Compaction

D	COMPACTION		
#	**Technology/ Appliance**	**Description**	**Cost**
i	**SCREW PRESSES**		
a	Manual screw press  (Source: Isaiah Maobe(Local fabricator))	Mechanical co-centric saw dust screw briquetting machine. Fabricated by a local briquetting expert Isaiah Maobe in 2003. It is a manual machine which is ran by peddling. Depending on the effort of the person running the machine it can produce 600 Kgs per day.	KES: 450,000.

b	Motorized screw press  (Source; Kendubay Machinery)	Locally fabricated motorized -screw machine. Local fabricators include Kendubay Machinery, Kejofra Engineering and Benmah Product Company. There are two types the one fitted with a gear and one without. The gear fitted machine improves compatibility of the raw material thus produces higher dense briquettes. Run using electricity and production capacity is dependent on the power rating of the machine. A motor of 750 watts produces can produce up to 7,000 tonnes per day when using charcoal dust as the raw material.	Fitted with a gear: KES 85,000 No gear: KES 65,000
c	Mechanical co-centric  (Source: Isaiah Maobe(Local fabricator)	Mechanical co-centric saw dust screw briquetting machine. Fabricated by Maobe, 2003. The motor is rated 750 watts and can produce between 4,000- 5,000 Kgs per day. Ran using electricity.	KES: 450,000
ii	**PISTON PRESSES**		
a	Hydraulic Briquette Pressing Machine  (Source: C.F. Nielsen)	Manufactured and distributed in Kenya by C.F. Neilsen. Production capacity of 30kg to 1,500 Kgs per hour.	500 Kgs per hour capacity is KES 7 million
b	Extruder Briquetting Press  (Source: C.F. Nielsen)	Manufactured and distributed in Kenya by C.F. Neilsen. Production Capacity of 500 Kgs per hour. Used to produce household briquettes.	KES: 12 million

c	Mechanical briquetting machines  (Source: C.F. Nielsen)	Manufactured and distributed in Kenya by C.F. Neilsen. Different models and production capacity. Production can be as high as 7,000 Kgs per hour.	Cost ranges from KES 10 Million to 50 Million
iii	**HAND PRESSES**		
a	Wooden press  (Source: Local fabricator Isaiah Maobe)	Fabricated locally. Production capacity is dependent on man-power it ranges between 100-150 Kgs per day. Not popular nowadays as producers have moved towards improved machines.	KES:15,000
iv.	**OTHERS**		
a	Agglomerator  (Source Eco-consulting Link)	The machine is motor-driven, and the common capacity is 25-50 kg/hour. Purchased from local fabricators.	KES:450,000

Table 25: Drying

E	DRYING		
#	**Technology/ Appliance**	**Description**	**Cost**
a	Open air drying (ground)  (Source: Briquette Producers)	Spread the briquettes or raw materials depending on spread sheets on the ground. The number of tonnes that can be dried using this approach is dependent on availability of space.	Labour cost for spreading the briquettes

b	Open air drying (elevated)  (Source: Briquette Producers)	This is done either using drying trays and racks. The manufacturer can acquire the necessary materials (mesh and pools) from local stores and fabricate the rack.	The coffee roll which is the main component of the sieve is purchased per meter. I Meter- KES 300
c	Solar drying (use of greenhouses)  (Source: Nawasscoal)	In solar drying, wet briquettes or materials are dried in an enclosed structure which is a typical greenhouse covered with high density transparent polythene sheet that permits radiation into the room. Various greenhouse installers in Kenya e.g. PEGWA Enterprises and Amiran. Drying is fast, can take 1-3 days.	Cost is dependent on size of the greenhouse for example; 6M by 12 M - KES 150,000 24M by 12 M- KES 800,000
d	Driers e.g vertical driers  (Source: Maxton Engineering China)	Imported from Maxton Engineering China. The capacity per hour is dependent on the machine power rating. A 37 KW drier can dry between 15-20 tonnes of briquettes per hour. Applied for large scale production of briquettes.	Cost ranges based on power ratings KES 1 million to 10 million

4.4 Comparative analysis

It is critical for a producer to identify the right technology for the briquette production process. The technologies for the different raw materials are usually similar with the main difference being the preparation process employed for the feedstock. For instance, while a hammer mill can be used for crushing both macadamia shells or milling wood chips, availability and reliability of electricity would determine if a manufacturer settles for a diesel-powered hammer mill or an electric mill. This section compares the different technologies available under selected steps of the briquette production process with the aim of comparing the advantages and disadvantages of each technology.

From the discussion on compaction of briquettes, it can be concluded that there are 3 types of technologies for compacting; (i) low pressure which uses manpower to drive the process (hand-made briquettes and manual machines), (ii) medium pressure, and (iii) high pressure technology which is used in production of non-carbonised briquettes.

- **Low pressure technologies** include manual presses which are fabricated locally and do not require complicated skill to operate. These machines are either operated by hand, or foot and include simple single or twin hand and pedestal piston extruders, wooden lever, hand screw, small pipes. The advantage with this technology is that it is low cost and needs the least start-up costs and technical operating skills. The producer can also take care of breakdowns with little guidance from the fabricator. The downside of the technology is that it is only applied for small-scale production of briquettes, it's time consuming and exposes the producer to dust and dirt. Production capacity per day are highly dependent on the person running the machine.

- **Medium pressure compaction** machines include screw extruders, agglomerator, roller drums, and hydraulic presses which run on mechanical means. The machines can be fabricated locally. Production capacity can range between 250 Kgs to 5,000 Kgs of briquettes per day for the locally fabricated machines. The technology needs minimum labour and maintenance costs. The main challenge with locally fabricated machines is poor quality. Poorly fabricated machines result in poor quality briquettes and frequent breakdowns which halt production.

- **High Pressure Compaction** machines used in this category include heated-die screw, ram/piston, and hydraulic presses, and all are mechanically driven to compact granular biomass materials into non-carbonised biomass briquettes of different shapes and sizes. These, machines are imported and are suitable for large scale briquettes for factory consumption. Production capacity per hour can be as high as 7,000 Kgs per hour. Although they have high production rate, they are have high initial cost (between KES 10 million to 50 million) require skilled manpower, spare parts may not be locally available, and are associated with high electricity bills, maintenance costs, and replacement of worn out machines with new ones compared to the low and medium pressure technologies. Table 26 below provides a comparison between the available technologies under compaction.

Table 26: Comparison of the compacting technologies for briquette production

#	Compacting technologies	Advantages	Disadvantages
1	Low pressure technologies	• Low start up-cost • Minimum technical skills required for operations • The producer can easily take care of the breakdowns	• Low volume production • Variable quality • Requires high manpower
2	Medium pressure technologies (e.g. screw extruders, agglomerator, roller drums, and hydraulic presses)	• Technology is locally available • Spare parts can be sourced locally • Higher production volumes compared to low pressure technologies • Higher quality compared to the low-pressure technologies • Minimum labour is required	• Local machines are of poor quality and are therefore prone to breakdowns • Require electricity to run • Compared to low pressure technologies the cost is higher (cost ranges between KES 65,000- 500,000)
3	High pressure technologies (heated-die screw, ram/piston, and hydraulic presses)	• High production volumes • Less labour is required as most work is automated	• High initial cost (between KES 10 million to 50 million), • Requires skilled manpower, • Spare parts may not be locally available, • High electricity costs and maintenance cost compared to medium and low-cost technologies

The low and medium pressure compacting technologies requires the use of binders and drying of briquettes. Comparing the different binders available in the market, gum arabica and molasses have better burning qualities from clay, red-soil and waste papers which produce smoky briquettes. In addition to quality, availability, cost and alternative use of the binder are key factors to consider when selecting a binder. In some instances, quality supersedes the cost of the binder. For example, one manufacturer based in Naivasha reported that they use gum arabica which is costlier than molasses because of its high quality. The high cost of gum arabica is due to the fact that it has to be transported from Northern Kenya. One manufacturer in Kilifi reported having to switch binders from cassava to imported non-edible corn starch due to complaints from locals on the use of 'food' for briquette manufacturing.

As discussed, drying of briquettes can either be through open air drying (use of racks or spread on the ground), use of driers, greenhouses and ovens. Open air drying requires space to spread the briquettes out, while use of driers, the cost of purchase and operating auxiliary requirements such as electricity are inhibitive. Use of ovens requires an external source of thermal energy such as firewood which comes at a cost. Relying on the sun for drying of briquettes may halt production during the rainy seasons if an alternative drying method is not available. A producer can have more than one type of drier and utilize it on a need basis. The different drying methods are compared in Table 27 below.

Table 27: Comparison of the drying methods

#	Drying technologies	Advantages	Disadvantages
1	Open air drying	• Low initial cost. Drying racks can easily be fabricated at site and spreading the briquettes on the ground requires no equipment (3-5 days)	• Requires space to spread out the waste • Depends on climatic conditions with production coming to a stop during the rainy days • Require a larger work-force
2	Driers	• Takes less time to dry (1 hour) • smaller work-force required	• Requires high initial cost • Electricity bills for running of the machines or diesel costs • Associated with maintenance cost
3	Solar drying through greenhouse	• Convenient for waste with high moisture content e.g. sludge • Less days required for drying (1-3 days)	• High initial cost • Space for setting up the green house
4	Oven	• The briquette takes less time to dry	• High cost compared to open air drying • An external source of heat is required e.g. firewood


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4.5 Case studies

4.5.1 Nawasscoal – Utilizing municipal waste

Nawasscoal Company is a subsidiary of the Nakuru Water and Sanitation Services Company Limited (NAWASSCO), that produces briquettes from a combination of faecal matter, sawdust and molasses as a binder[118]. It was formed as part of the Nakuru County Sanitation Programmeme (NCSP) whose main objective was to demonstrate a commercially viable sanitation value chain that would benefit the peri- urban communities in the low- income areas of Nakuru. It was co-funded by the European Union and implemented by NAWASSCO in collaboration with Umande Trust, Vitens Evides International (VEI), SNV Netherlands Development Organisation, Egerton University and University of Nairobi.

Human waste, which is the main raw material used to produce the briquettes, is acquired from the NAWASSCO treatment plant. Availability of the feedstock is not a challenge as the plant collects 2,000 cubic meters of sludge every day and only utilizes 100 cubic meters per day [119]. About 98% of the sludge composition is water and 2% is biosolids as such the first step is dewatering. This is achieved using drying beds greenhouses where the sludge is left to dry for 2-3 weeks. The sludge is further dried through solar driers to achieve a moisture content of about 20% which is the required moisture content for carbonisation. The dry sludge is then carbonised at a temperature of 400°C. The carbonisation process also acts to sanitize and sterilize the sludge through flaring /the harmful gases, killing the pathogens and removing the bad oduor. The second raw material is sawdust. Sawdust is collected from the different saw millers in Nakuru County. It is prepared by removing the foreign materials through hand picking. The raw material has a moisture content of 40% and is sun dried to 20%.

The next step is milling of the two raw materials to achieve fine particles. This is done using a hammer mill. The two are then mixed in equal proportion and fed into a rotating drum machine and molasses is (binding agent) added as a binder to form ball shaped briquettes of 2.5 cm in diameter. This is done using drying racks in greenhouses for 3-4 days. The dry briquettes are weighed and packed in bags of 2kg, 5kg, 10kg and 25kg. These are sold either directly from the company or indirectly through their stockists (six in Nakuru, two in Nairobi and one in Kisii). The cost per Kg is currently at KES 30. The company produces 15 tonnes of briquettes per month. The briquettes have gone through a series of test including; ash content, calorific value, moisture content and test on presence of pathogens. Figure 17 below shows a summary of the process.

One of the challenges faced by the company is people's perception in using briquettes made from human waste for cooking. Most communities considered this to be a taboo. However, with the community trying out the briquettes and ascertaining that they do not smell, and that they burn longer than charcoal, they have been more receptive of the briquettes. Having the KEBs label of quality also helped in regaining consumer confidence. The other challenge faced at the commencement of the project was the absence of laws on handling of faecal matter in the production of the briquettes. The project partners were able to lobby the Nakuru County Assembly to develop a public health bill that stipulates how to handle human waste. The company is aiming to scale production to 10 tonnes per day through the purchase of high capacity briquetting machines.

One of the challenges reported by some of the manufacturers is constrained feedstock. Bans on logging and charcoal production and the seasonality of coffee for instance are factors that contribute to limited raw materials. Faecal waste provides an alternative feedstock which is available in large quantities and at all times and with the right technologies can be utilised to produce briquettes. This case study by Nawasscoal demonstrates the potential of such waste as a possible raw material in the process of briquette making.

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118 Nakuru County Sanitation Programmeme (2018). Sanitation Value Chains: Unlocking Opportunities in Sanitation. https://nawasscoal.co.ke/nawasscoal_uplds/2020/06/2018-ncspbooklet-selectedpublicationsjournalcontributions.pdf

119 Figures presented in this case study were provided in the Key Informant Interview with Nawasscoal

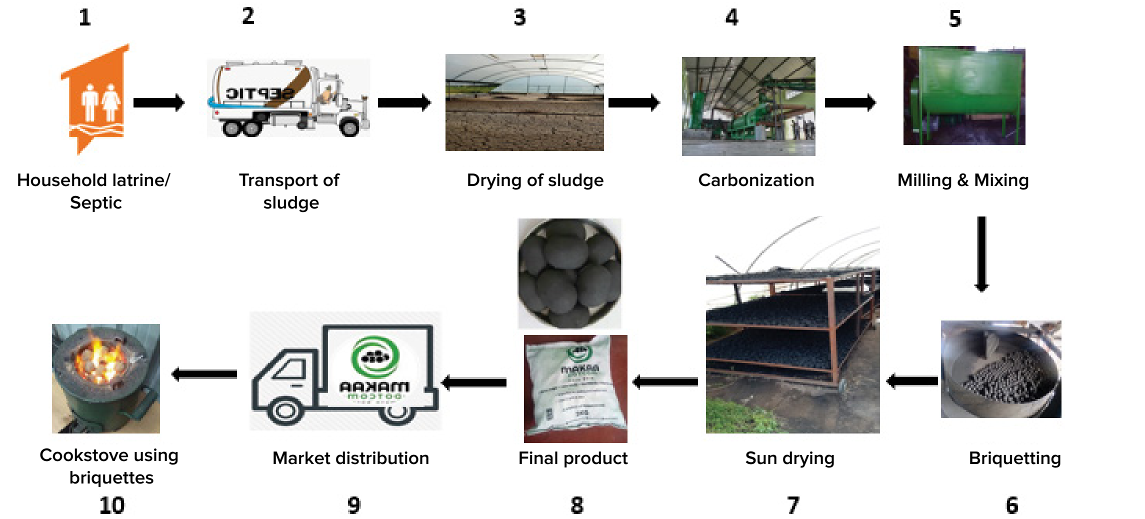

Figure 17: Summary of the briquette production process

4.5.2 Josa Green Technologies

Josa Green technologies Limited is an energy solution enterprise based in Wakiso District in Uganda which is 10 Kms from Kampala. It was founded in 2014 with the aim of providing a range of energy products and services such as energy saving cook stoves for both institutions and household, briquettes, biogas digesters, ovens, brooding kit etc. They produce carbonised briquettes from charcoal dust, agricultural waste, wood cuts and organic waste. The raw material is carbonised from source. They identified women groups and individuals who collect waste and carbonize it before selling to briquette producers. Clay is added to the mixture of raw materials as a filler and cassava starch as a binder. Once the waste is in the factory, it is sorted using a sieve, the large particles crushed using a crusher, the raw materials mixed in the right proportions and compacted with an automatic honeycomb using a press machine. In addition to the automatic electric briquetting machines they have a manual press that is used when there are power outages. The following methods are employed in drying the briquettes; use of dryers, ovens powered by briquettes and sun drying.

Their business model has evolved with time as they better understand the market. At the start their target market was households. However, they quickly Realised that since the honeycomb briquettes require custom made stoves to burn efficiently, and these stoves are expensive, low income households could not afford them. They started to produce stick briquettes which can burn on any type of stove. They also increased their customer base to include institutions, small hotels and roadside kiosks and poultry farmers. They deliver the briquettes to institutions at a cost and also have 8 outlets in Kampala that end-users can purchase the products from. In terms of volumes sold, institutions and briquettes for productive use are their largest customers base. The main challenge currently experienced is market saturation from large scale producers who are purchasing all the feedstock. In years to come the small-scale producers will be kicked out of the market.


Figure 18: Types of briquettes produced by Josa Green Technologies

For the sustainability of briquette making businesses there is need to diversify the consumer base. Josa Greens Technologies started out by targeting household end-users but quickly Realised that uptake of the fuel was low. While still addressing the low uptake of the fuel by households they changed their business model to incorporate institutions, small hotels and roadside *kiosks* and poultry farmers to avoid being thrown out of business. Another key lesson from Josa Green Technologies is the introduction of a group of actors in the supply chain who not only collect the waste but carbonize it before selling it to the producer. This could potentially reduce the start-up costs of briquette producing businesses by removing the cost of carbonisation equipments for carbonised briquettes. It can also be a source of employment for youths and women.

4.6 Gender and the briquetting

The findings of this study show that the proportion of women in briquette making is relatively high. Similar conclusions were made in a study by GVEP international on the assessment of briquette production in Kenya [120]. In this study, business ownership was disaggregated between women, men, youths and group ownership. Out of the 20 manufacturers interviewed, 11 of the businesses were owned and managed by women (7 limited companies, 3 sole proprietors and 1 Community Based Organisation), while half of the businesses are owned and managed by youths[121]. It is also noted that more than half of the women owned businesses (a total of 7) were formally registered. Two of the women briquette manufacturers have been in the business for the last ten years. Most of the businesses owned by women operate throughout the year (8/11) and partial operations are due to limited demand from the market and raw materials. In terms of the machines used for briquetting, only 3 out of the 11 interviewed were making handmade briquettes, the rest use electric machines. No men were found to be using hand pressing for briquetting. This may be interpreted to mean that although we have a considerable number of briquette businesses that are owned by women and with large and medium scale producers, we still have a portion of them who run informal businesses and using poor technologies for briquetting.

All briquette businesses had more youths as full time (at 69%) employees. Additionally, there are some women and youth-owned businesses where they are the only worker. Out of the 332 employees across the 20 businesses interviewed women are more (at 55 %) than men (at 45%). Although we have women spread across the different activities of briquette making, more of them were casual workers (73%) involved in drying of the briquettes and sorting of waste. One manufacturer said that the women are keen on

120 Cohen, Y., and Marega, A. (2013). Assessment of the Briquette Market in Kenya. GVEP International, Africa Regional Office.

121 A person below who is 35 years and below

picking out the foreign materials. Opinions towards women in briquetting are varied across the different manufacturers. One female respondent observed that if the women run the briquetting machine the breakages are minimum. She explained that women were keen on ensuring that the raw material is well sorted thus objects such as nails do not end up in the machine leading to un-screwing of the machine. Another respondent reported that in one instance he hired female workers to aid in the activities in the briquetting process but did not stay for long. He explained that the lifting of loads was prohibitive to the women. Another explained that although the business could not hire women for the manual activities in the briquetting process the people in charge of fund-rising and marketing of the briquettes were woman.

The study finds that there are great business opportunities for women and youths to generate income through briquette making; women can be catalysts for change agents and not just users of different energy technologies; and there is need to leverage women groups and other social institutions to scale the briquetting business.

5 | Analysis of the Supply Chain of the Briquette Making Processes

This chapter presents an analysis of the supply chain of the briquette making processes in Kenya with the specific objectives of assessing of existing briquettes production chain to give an overview of material availability, quality, standardization and market price estimation, energy costs and wood fuels price estimations, transport costs estimations for raw materials and briquettes. This activity will also include an analysis for the demand for charcoal/wood fuels that can be substituted with briquettes.

5.1 Demand for charcoal and wood fuels in Kenya

In 2013, Kenya had a reported sustainable supply potential of 7,358,717 m^3 for charcoal and a demand of 16,325,810 m^3 translating to a 55% deficit[122]. A 20-year projection indicated a 16% increase in supply and an 18% increase in demand by the year 2032 signifying an increasing deficit[123]. Firewood demand on the other hand stood at 18,702,748m^3 against a potential supply of 13,654,022m^3 in 2013[124]. The supply of firewood was projected to increase by 15% by 2032 compared to an increase in demand of 16%, also signalling an increasing deficit. See Figure 19 below.

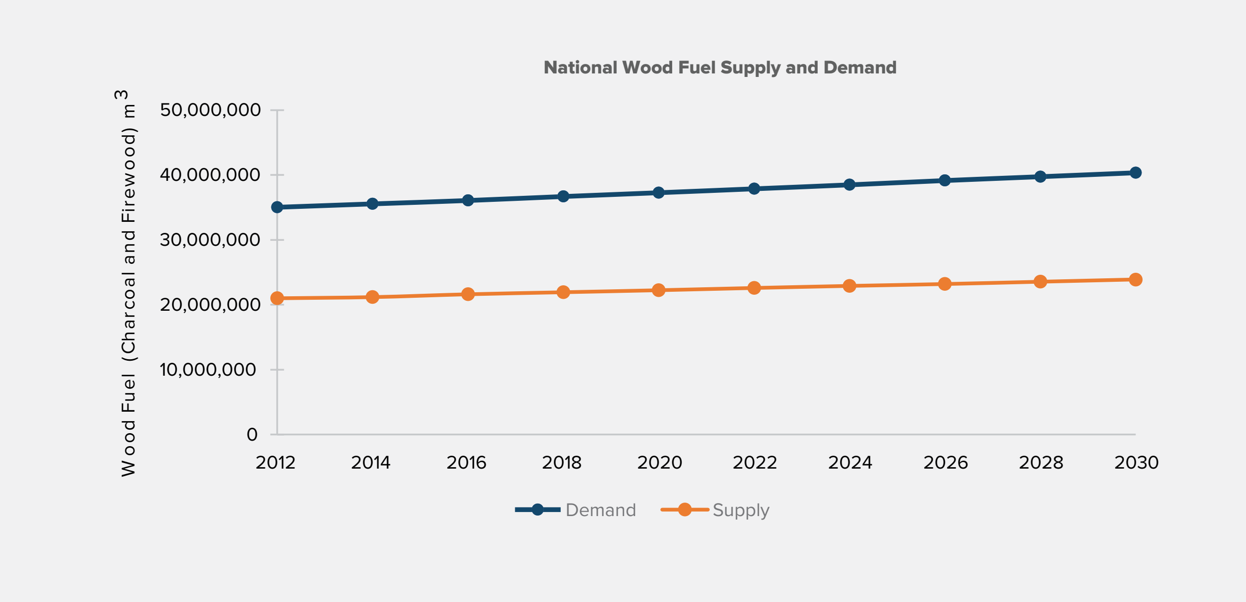

Figure 19: National Projected Supply and Demand of Wood Charcoal and Firewood

122 Ministry of Environment, Water and Natural Resources (2013). Analysis of Demand and Supply of Wood Products in Kenya. Nairobi. http://www.kenyaforestservice.org/documents/pdf.

123 Ibid

124 Ibid

Further, a national survey in 2013 indicated that the country had experienced a 5% annual increase in charcoal consumption between 2004 and 2013, a growth from 1.6million t/year to 2.3million t/year[125]. Kenya's rapid population growth, which has expanded more than four times over the last 50 years from 10.9 million in 1969 to 47.6 million in 2019[126], slow growth of alternative fuels, accessibility and affordability are contributing factors to the increase in demand for solid wood fuel.

The population growth is also translating to increasing urbanization rates – the urbanization rate for Kenya was 22.8% in 2008 compared to 27.0% in 2018[127]. However, the increase in charcoal consumption between 2004 and 2013 was higher than the urbanization rate for the same period[128]. Unless a fundamental shift is Realised, the use of solid biomass fuels in both urban and rural areas is projected to remain prevalent over the coming years, and a continuing threat to the sustainability of the country's forestry resources. Briquettes present a possible alternative. It is, however, important to understand demand across the different types of consumers to identify the low hanging fruits for briquette adoption. Below is a presentation of the charcoal and fuelwood use at the household, institution and industrial level in Kenya.

5.1.1 Household use of charcoal / firewood

The Ministry of Energy (2019), *Kenya Household Cooking Sector Study,* estimates that 75% of all households in Kenya use biomass as their primary cooking fuel – 38% of urban and 93% of rural households respectively. The definition of primary cooking is based on frequency of use, that is, the cooking solution that is most frequently used. This data is comparable to the 66.7% of households that reported using either firewood or charcoal as their main type of cooking fuel from the 2019 Kenya census – 26.9% and 91.8% in urban and rural areas respectively.

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75%

of all households in Kenya use biomass as their primary cooking fuel-38% of urban and 93% of rural households respectively.

125 Iiyama, M., et.al., (2014) Achieving sustainable charcoal in Kenya: Harnessing the opportunities for cross-sectoral integration. Technical Brief. Nairobi, Kenya.

126 KNBS (2019). Kenya population and housing census results, Kenya National Bureau of Statistics. Ministry of Planning, Kenya

127 Data from World Bank Data

128 Iiyama, M., et.al., (2014) Achieving sustainable charcoal in Kenya: Harnessing the opportunities for cross-sectoral integration. Technical Brief. Nairobi, Kenya.

On charcoal consumption, 47% of Kenyan households in urban areas use some form of charcoal based cooking solution compared to 40% in rural areas; 17% of urban dwellers use charcoal as their primary cooking fuel, compared to 7% in rural areas (see Figure 20)[129]. The mean annual national charcoal consumption among households that use charcoal was estimated at 395.2 kilograms per household per year[130] in 2019. These households level consumption rates translate to an annual residential consumption of an estimated 2Mton of charcoal, putting the annual market value of charcoal consumed at the household level alone at about KES 68 billion[131]. At a national prevalence rate of 34%, the KCJ (Kenya ceramic jiko) remains the most commonly used charcoal stove; branded charcoal stoves (such as those by BURN, Envirofit and Ecozoom) have a prevalence rate of 3%[132].

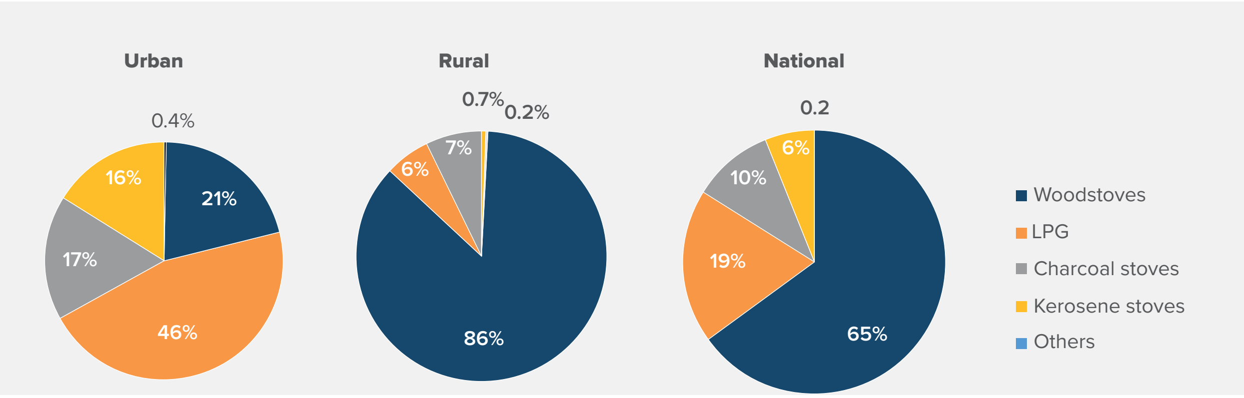

Figure 20: Household level primary cooking fuels – urban, rural and national (Data from MoE, 2019)

Firewood remains a significant source of energy among Kenya's rural households with 86% of them reporting using some type of woodstoves as their primary cooking solutions compared to 21% in urban areas. Additionally, the three stone open fire is the most commonly used firewood-based cooking solution at a 58% prevalence rate – 75% among rural households and 22% among urban households. This high prevalence of firewood as a cooking fuel translates to an annual residential consumption of an estimated 10.3Mton of firewood with the mean annual national firewood consumption being 1,349 kilograms per household per year among households that use firewood[133].

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5.1.2 Institutional use of charcoal /firewood

A majority of institutions in Kenya rely on solid wood fuel for their thermal energy needs. A 2018 study on use of biomass cookstoves and fuels in institutions in Kenya[134] found that charcoal, firewood and LPG represented the majority of fuels for cooking based on a sample of 705 institutions representing primary and secondary schools, colleges and universities, hospitals and prisons. Specifically, prisons are wholly reliant on firewood for cooking. Primary and secondary schools are heavily reliant on firewood, at 74% and 70% respectively, with some use of charcoal and LPG based solutions representing the highest need for alternative energy sources. Is mix in Kenya's institutions.

Table 28 provides a summary of the cooking fuels mix in Kenya's institutions.

129 Ministry of Energy (2019). Kenya Household Cooking Sector Study
130 ibid
131 ibid
132 ibid
133 ibid
134 Climate and Energy Advisory Ltd (2018). Study on Use of Biomass Cookstoves and Fuels in Institutions in Kenya (unpublished)

Table 28: Cooking fuels mix in Kenya's institutions

Fuel	Primary School	Secondary School	Colleges	Public Univ.	Private Univ.	Private Hospitals	Public Hospitals	Prisons
Firewood only	74%	70%	33%	-	-	9%	24%	100%
Charcoal only	2%	-	-	-	-	18%	4%	
Biogas only	1%	-	-	-	-	-	-	
LPG only	1%	1%	-	-	-	36%	20%	
Firewood +Charcoal	14%	11%	22%	33%	-	9%	12%	
Firewood +Charcoal +LPG	3%	5%	28%	33%	-	9%	12%	
Firewood + LPG	2%	6%	6%	33%	33%	-	24%	
Charcoal + LPG	1%	-	6%	-	17%	18%	4%	
LPG + Electricity	-	-	-	-	50%	-	-	
Other fuel mix	2%	7%	5%	1%	-	1%	-	

Source: Climate and Energy Advisory, 2018

It is observed that some institutions are already embracing a transition to briquettes as an alternative to firewood-based cooking solutions. Musingo High School in the Western part of Kenya, for instance, is reported to have fully transitioned to using non-carbonised briquettes while Kaimosi Girls High School and St. Mary's Hospital have also embraced briquettes as a transitional fuel while exiting the use of firewood[135]. Jamhuri High School in Nairobi is also reported to have shifted to biomass-based briquettes made from organic waste such as sawdust and sugarcane stalks[136].

5.1.3 Industrial use of charcoal / Firewood

Tea Industries

The tea sector is a high consumer of firewood with estimations that production of 1kg of tea consumes around 1.9kgs of firewood[137]. Kenya, the third largest tea exporting country with exports valued at USD 1.17 billion in 2016[138], has an annual production of around 415.68 million kilograms[139] of tea produced by 113 tea factories[140]. A key component of the tea production process is the withering and drying of green tea leaves, a process that demands high thermal energy. It is estimated that almost 99 % of this thermal energy comes from firewood and other biomass sources, while the remaining 1 % is from fuel oil[141]. According to the Agriculture and Food Authority -Tea Directorate, in 2018, the tea factories in operation consumed around 904,000 tons of firewood, accounting for around 4.4 % by volume of firewood consumption per year in Kenya[142]. Table 29 shows firewood consumption volumes by tea factories for the period 2014 – 2018[143].

135 Climate and Energy Advisory Ltd (2018). Study on Use of Biomass Cookstoves and Fuels in Institutions in Kenya (unpublished)

136 WRI (2018). Cleaner-Burning Fuels at Kenyan Schools Feed Students and Protect Forests. https://www.wri.org/blog/2018/11/cleaner-burning-fuels-kenyan-schools-feed-students-and-protect-forests

137 UN Environment (2017). Improving efficiency in forestry operations and forest product processing in Kenya: A viable REDD+ policy and measure?

138 MoALFI (2019). Agricultural Sector Transformation and Growth Strategy: Toward sustainable agricultural transformation and food security in Kenya 2019.

139 Xinhua (2019). Kenya's tea production expected to drop 12% in 2019. http://www.xinhuanet.com/english/africa/2019-02/12/c_137815978.html

140 UNEP (2019). Sustainability of sugarcane bagasse briquettes and charcoal value chains in Kenya

141 ibid

142 ibid

143 ibid

Table 29: Production capacities and bioenergy used in Kenya's tea factories 20114-18

	2014	2015	2016	2017	2018
Number of tea factories	104	104	107	108	113
Green leaf processed (kg)	1,869,439,883	1,676,687,741	1,986,647,561	1,847,402,504	2,070,594,637
Processed tea produced (kg)	445,104,734	399,211,367	473,011,324	439,857,739	492,998,723
Firewood used (m^3)	1,483,682	1,330,704	1,576,704	1,466,192	1,643,329
Bone-dry firewood (tons)	816,025	731,888	867,187	806,406	903,831

Cottage Industry

Among other key industries that are reliant on firewood and charcoal to a significant extent include brick making, tobacco processing, milk processing, fishing and fish smoking, bakeries and restaurants and kiosks. A 2002 Study[144] indicated that i) firewood is significantly more likely to be used for thermal energy requirements in small-scale industries than charcoal, and ii) Kiosks and restaurants account for the largest consumers of biomass-based energy sources in these small-scale industries. Table 30 is a summary of the numbers.

Table 30: Charcoal and firewood demand among small-scale industries

Source of energy	Firewood (tonnes / year)	Charcoal (tonnes / year)
Brick making	55,772	-
Tobacco	78,365	-
Milk processing	4,900	540
Fishing and fish smoking	17,960	-
Jaggary	180,000	-
Bakeries	20,665	622
Restaurants / kiosks	1,276,155	428,025

Some of the industries have recognized the need for increased efforts towards environmental sustainability and are implementing measures for energy conservation through use of alternative fuels. BAT (British American Tobacco) – Kenya, for instance, has partnered with Platinum and South Nyanza Sugar Company to utilize their excess sugarcane bagasse to produce high energy briquettes that can be used in place of firewood[145].

5.2 Assessment of the existing briquettes production chain

Briquettes have the potential to greatly reduce dependence on woodfuel where the enabling environment is strong. Part of the drive to realise the change is the sustainability of briquettes when compared to woodfuel. Briquettes hold the appeal of a diversified feedstock from agricultural, municipal and industrial waste[146].

The value chain for briquettes will vary largely depending on the scale of business, input material used, type of briquettes produced and the target market segment[147] however, the supply chain for the briquette making processes in Kenya may be loosely categorized into three key classes as summarized in Figure 21: 1) Upstream activities, 2) Midstream activities and 3) Downstream activities. These are discussed in the sections that follow.

144 Republic of Kenya (2002). Study on Kenya's Energy Demand, Supply and Policy Strategy for Households, Small-scale Industries and Service Establishments

145 BAT Kenya (n.d.). Environmental Sustainability. http://www.batkenya.com/group/sites.

146 Asamoah, B., Nikiema, J., Gebrezgabher, S., Odonkor, E., and Njenga, M. (2016). A Review on Production, Marketing and Use of Fuel Briquettes. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Programme on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

147 Asamoah, B., Nikiema, J., Gebrezgabher, S., Odonkor, E., and Njenga, M. (2016). A Review on Production, Marketing and Use of Fuel Briquettes. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Programme on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

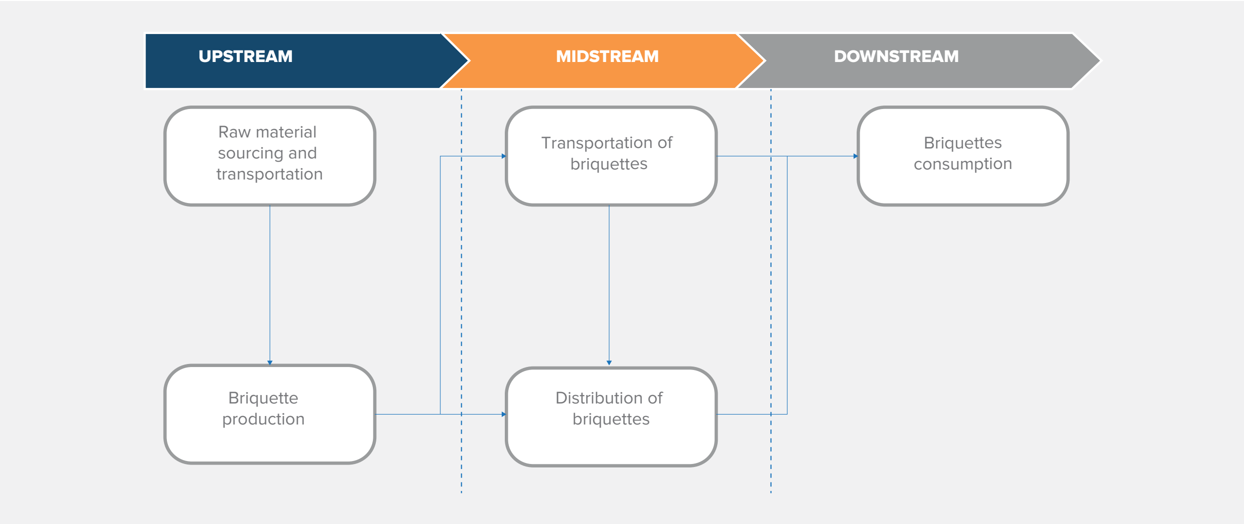

Figure 21: Summary of the supply chain of the briquette making processes

5.3 Upstream activities

These pertain to activities tied to sourcing, transportation and production of briquettes. As earlier stated, these will vary depending on the operations of the individual briquette producer. The fundamental differences are noted during the sourcing of raw materials and the sale of the product. Whereas a producer utilizing coconut husks feedstock in Kilifi will source raw materials directly from farmers, companies utilizing faecal matter will require an agreement with county governments to handle faecal sludge[148].

5.3.1 Sourcing of raw materials

5.3.1.1 Availability of feedstocks

The availability of feedstock is a key consideration during the evaluation of sustainability for briquettes production. With consideration of the existing feedstocks, a critical assessment of the available types is essential before commencing briquette production[149]. The main biomass sources emanate from three sectors: agriculture, forestry and municipal solid waste (MSW).

Agricultural wastes consist of lignocellulosic biomass which includes rice straw, wheat straw, corn stover / comb and plant residues. These are characterised by a high carbon-to-nitrogen ratio (> 50), the higher the lignocellulosic biomass, the higher the energy potential[150]. For this study, the forest product residues considered are sawdust and charcoal dust. Sawdust is a good briquetting material because it contains a high proportion of lignin, which acts as a natural binder during the pressing process resulting in dense briquettes for the case of non-carbonised briquettes.

Charcoal fines and dust arise from the production, transportation and handling of charcoal. The fines have the advantage of being already carbonised (rich in fixed carbon) and therefore have a high energy content.

Municipal waste for briquette production is also characterized by lignocellulosic biomass, mostly uncooked vegetable waste from markets and faecal sludge. The focus on market waste is due to its homogenous state when compared to domestic waste which is not sorted at source in Kenya. Industrial waste suitable for briquette production includes wastepaper and sewage sludge[151].

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148 KII's with briquette producers

149 Asamoah, B., Nikiema, J., Gebrezgabher, S., Odonkor, E., and Njenga, M. (2016). A Review on Production, Marketing and Use of Fuel Briquettes. Colombo, Sri Lanka: International Water Management Institute (IW#MI). CGIAR Research Programme on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

150 Stepien, P., Pulka, J., and Bialowiec, A. (2017). Organic Waste Torrefaction – A Review: Reactor Systems, and the Biochar Properties. Intechopen. http://dx.doi.org/10.5772/67644

151 Asamoah, B., Nikiema, J., Gebrezgabher, S., Odonkor, E., and Njenga, M. (2016). A Review on Production, Marketing and Use of Fuel Briquettes. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Programme on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

A three-step criterion focusing on i) quantities, ii) centralization and competing needs, and, iii) quality is used to further assess the most suitable feedstock, further discussed below.

1 Quantities

Agriculture is the mainstay of Kenya's economy contributing more than 25% of the gross domestic product (GDP) and employing 75% of the population[152]. As a result, there exists numerous quantities of agricultural residues that can be utilised for briquettes production. However, it is worth noting that for the residues to be used for briquettes making they must be available, accessible, economically viable and of suitable quality to produce briquettes that meets the user needs. Agricultural waste originates from rearing of livestock and the production and processing of foods and fibres. Examples include; crop residues, animal manure (poultry houses and slaughterhouses), dead animals, harvest waste, fertilizer runoff which contributes to contamination of the environment[153].

A non-exhaustive list of agricultural feedstocks available in Kenya includes:

- Pyrethrum
- Rapeseed
- Sesame
- Beans
- Pigeon Peas
- Sorghum
- Sugarcane
- Cassava
- Pyrethrum
- Coconut
- Cotton
- Groundnut
- Sweet Potatoes
- Irish Potatoes
- Tobacco
- Macadamia
- Barley
- Coconut
- Cashew
- Millet
- Coffee
- Pineapple
- Rice husk
- Sisal
- Sunflower
- Maize
- Cashew

Definitively estimating the biomass residue volumes in Kenya is nearly impossible due to the informality of trade and the lack of available databases. However, different robust methodologies including primary data collection from large scale suppliers and agricultural associations (e.g. Sugarcane Board of Kenya) and literature sources were used to estimate available mass quantities.

A recent assessment of the available agricultural residues in Kenya by the EU for prominent agricultural products was based on production, yield, area of production and a residue to product ratio (RPR). The latter describes the amount of residue produced per crop and was considered for both harvest (e.g. corn stover / straw) and processing operations (e.g. rice husks). This is further supplemented by FAO statistics on the available residues production in Kenya. The volumes of production for each feedstock revealed a substantial viability of main waste types whose mass residues estimates are summarised in Table 31[154].

Table 31: Estimated Agricultural Feedstock Mass Residue from Field and Process Activities

Agricultural Residues	Mass of Residue of (Field and Process) (t)
Bananas	2,649,000
Beans	1,122,000
Cashew	15,036
Cassava	518,000
Coconuts	41,763 – 193,000
Coffee	13,357
Irish Potatoes	1,050,000
Macadamia	15,071
Maize	16,063,000
Mangoes	5,564,000
Pigeon & Cow Peas	193,000
Pineapples	109,305
Rice	182,472 – 312,000
Sisal	675,294 – 800,00
Sorghum	692,000
Sugarcane	1,789,748 – 2,416,000
Sweet Potatoes	310,000
Wheat	538,204 – 654,000

Source (IIED 2015, FAO 2017)

152 USAID (2020). Kenya Agriculture and Food Security. https://www.usaid.gov/sites/default/files/documents/1860/Kenya_Agriculture_and_Food_Security_Feb_2020.pdf

153 OECD. Glossary of Statistical Terms. https://stats.oecd.org/glossary/detail.asp?ID=77

154 IIED (2015). Biomass Use and Potential for Export from Kenya to the European Union 2015 – 20130. EU

Sawdust is a by-product of wood and timber industries. In Kenya, there are approximately 850 saw millers who are grouped into large scale millers (process more than 10,000 m^3 of trees annually), medium scale millers (process 2,000 m^3 - 10,000 m^3 of trees annually) and small-scale miller (process less than 2,000m^3 of trees annually). Approximations on the total wood waste consumption is approximately 15,600 tons equivalent to 23,088 m^3 estimated from industrial by-product production (sawdust, timber rejects, off-cuts)[155].

Charcoal waste amounts to 10% – 15% of total charcoal production which produces between 70,000 and 105,000 tonnes of charcoal dust for urban areas in Kenya annually[156]. Due to the higher use rate of charcoal in urban areas, charcoal dust use is likely to be focused in urban areas.

Waste collected from Nairobi ranges from 2,400 to 3,200 t/day, only 33 % is collected[157,158]. Mombasa generates between 602 to 2,000 t/day, of which, only 50 % is collected[159] and Kisumu generates between 395 to 1,000 t/day of which, only 20 %[160] is collected (Table 32). Once collected, the waste is disposed at designated sites, Dandora, Kachoka and Mwakirunge for Nairobi, Kisumu and Mombasa respectively.

Table 32: Waste generation estimates for Nairobi, Kisumu and Mombasa from various literature sources

Data Source	Estimated waste generated in Nairobi, Kisumu and Mombasa					
	Nairobi		Kisumu		Mombasa	
	Nairobi (t/day)	Approximate Organic Fraction (t/day)	Kisumu (t/day)	Approximate Organic Fraction (t/day)	Mombasa (t/day)	Approximate Organic Fraction (t/day)
Oyake – Ombis 2017[161]	2,400	1440	500	300	875	525
NAMA 2017[162]	3,030	1818	395	237	602	361.2
MoEF 2019[163]	2,400	1440	1000	600	2000	1200
NCC, 2010[164]	3,200	1920		-	-	-

Previous studies characterising Nairobi household waste, which can be used as a proxy for urban waste in Kenya, indicate the organic component accounts for 58.8%165. The gross available organic waste in Nairobi ranges from 1440 – 1920 t/day, 237 – 600 t/day for Kisumu and 525 – 1200 t/day for Mombasa (Table 33). However, there are various competing uses of organic waste such as feeds for pigs and composting manure present a challenge in estimation of available waste that could be used for briquetting. It should also be noted that since the waste is not segregated at source, the comingling with other waste types leads to contamination. For this reason, domestic organic waste is not a feasible source under the current structure of collection and disposal. Concerted effort will have to go into ensuring waste is segregated at source as is the case with some collectors such as Taka Taka Solutions. Alternatively, the focus should shift to sources of homogenous organic waste such as markets.

155 Ministry of Environment, Water and Natural Resources (2013). Analysis of Demand and Supply of Wood Products in Kenya. Nairobi. http://www.kenyaforestservice.org/documents/pdf.

156 0.7 Mtons of charcoal are consumed in urban areas (MoE,2019). 10-15 % is converted to charcoal dust

157 Muok Ben (2020). Wte Project in Kenya. Multiple Solid Waste Energy Conversion in Developing Countries, 208 – 209.

158 Ali A.A. (2009). Characterisation, management and improvement strategies for household waste in Nairobi (Doctoral dissertation). University of Nairobi, Nairobi, Kenya.

159 Oyake-Ombis L. (2017). Awareness of Environmentally Sound Solid Waste Management by Communities and Municipalities in Kenya.

160 Munala G., & Moirongo B. O. (2011). The Need for an Integrated Solid Waste Management in Kisumu, Kenya. JAGST, 13 (1)

161 ibid

162 UNDP (2017). Nationally Appropriate Mitigation Action on a Circular Economy Solid Waste Management Approach for Urban Areas in Kenya.

163 National Sustainable Waste Management Policy 2019 (Revised Draft)

164 Integrated Solid Waste Management Plan for Nairobi 2010

165 Ali A.A. (2009). Characterization, management and improvement strategies for household waste in Nairobi (Doctoral dissertation). University of Nairobi, Nairobi, Kenya.

Municipal waste in the form of faecal sludge is another biomass resource. Sewerage plants are available in 32 urban centres across 21 counties[166]. Out of these, it is only NAWASCO that is piloting the use of sewage sludge for making briquettes. Therefore, a lot of research needs to be undertaken to further assess the viability and possibility of scaling to the rest of urban centres.

2 Centrality and Competing Needs

Maize is a staple food crop in Kenya making up more than half of the smallholder household production. This is cultivated alongside millet, cassava, potatoes and beans. In addition to crops, these farmers also rear livestock for ploughing and manure[167]. Therefore, although quantities from maize (16,063,000t), irish potatoes (1,050,000t), beans (1,122,000t), and cassava (518,000t) are substantial, production of these feedstocks is largely decentralized. Furthermore, due to the livestock rearing, majority of these residues are used as animal feed. The process of procuring sufficient volumes will require a tedious process of engaging multiple suppliers and therefore these feedstocks are dropped from the list. Wheat straws (654,000t) are also used as animal feed and also dropped from the list. Mango (5,564,000t) waste was also dropped from the list due to the lack of a central production point.

The sisal subsector is driven by ten estates located in the Coastal regions, Baringo and Mogotio. Part of the sisal residue (sisal bogas) is used as a fertilizer substitute due to its high nutrient content by majority of the large-scale producers[168]. Therefore, only the sisal ball (the trunk of the plant after harvest) is available as waste. It is partially set aside as fertilizer or burnt; however, the exact ratios were not explicitly ascertained.

Production of sugarcane occurs along the Western Belt of the country. According to the Sugar Directorate, 2.4 million tons of bagasse, produced annually from 12 sugar millers, remains unutilised[169]. This is estimated to account for 40 – 71% of the total bagasse production at national level. The main competing use is as a substrate in cogeneration plants (producing both electricity and heat)[170]. Molasses are used for ethanol production and animal feeds and directly sold to companies utilizing the latter.

Aside from the centrality of location and large-scale production, sisal, sugarcane and coffee are noted to also have a definitive ownership cut.

At least 60% of the total rice production in Kenya in centred in Kirinyaga county[171]. Approximately 65% of the rice straws are sold to farmers for livestock feeds while the remainder is utilised as manure. The rice husks (approx. 8%) is commonly used by households and local industries for either reducing the acidity of the soil or production of bricks. Coconut production is centrally located in the coastal region. A review of the coconut husk subsector estimates 14 – 18% of the annual husk production is used for mulching and a further 10 – 30% is used by locals for firewood[172]. Coconut shells are used as fuel for boilers by oil producers and other companies. Pineapples waste from the largest producer in the country, Delmonte (K) Limited is used by a briquette making company that have a long-term contract with. The demand for coffee husks emanates from two main uses, i) improving soil quality (approx. 20%) and ii) at least 60% is sold to cement and bricks manufacturing companies. Coffee pulp is used as soil conditioner and fertilizer substitute due to its high nutrient content.

Macadamia nuts and cashew nuts have high calorific value and low moisture content and thus a desirable raw material for briquetting[173]. They have high demand in thermal intensive industries such as oil refineries, cement manufacturers, tea factories due to their high energy content and they are readily used without briquetting. The high competition coupled with relatively low available quantities drops them from the list.

166 WASREB (2020). Impact: a performance report of Kenya's Water Services Sector – 2018/2019

167 FAO (2015). The Economic Lives of Smallholder Farmers: An analysis based on household data from nine countries

168 EU (2016). BioTrade2020plus Supporting a Sustainable European Bioenergy Trade Strategy: Assessment of Sustainable Lignocellulosic Biomass Potentials from Kenya for export to the European Union 2015 – 2030. IEE/31/577/S12.675534.

169 UNEP (2019). Sustainability of Sugarcane Bagasse Briquettes and Charcoal Value Chains in Kenya: Results and Recommendations from Implementation of the Global Bioenergy Partnership Indicators.

170 EU (2016). BioTrade2020plus Supporting a Sustainable European Bioenergy Trade Strategy: Assessment of Sustainable Lignocellulosic Biomass Potentials from Kenya for export to the European Union 2015 – 2030. IEE/31/577/S12.675534.

171 ibid

172 EU (2016). BioTrade2020plus Supporting a Sustainable European Bioenergy Trade Strategy: Assessment of Sustainable Lignocellulosic Biomass Potentials from Kenya for export to the European Union 2015 – 2030. IEE/31/577/S12.675534.

173 Chardust Ltd and Spectrum Technical Services. (2004). The Use of Biomass to Fabricate Charcoal Substitutes in Kenya. Feasibility Study; Forming Part of the Shell Foundation-Supported Project on Charcoal Briquetting in Kenya. Nairobi; Kenya

Table 33: Available Quantities of agricultural feedstocks after competing needs

Crop	Agricultural Residue	RPR	Mass of Residue (Field and Process) (t)	Competing Needs (%)	Available quantities (t)
Coconuts	Coconut husks	0.33	28,712	52	13,782
	Coconut shells	0.15	13,051	N/A	N/A
Coffee	Coffee husks	0.30	13,357	80	2,671
Pineapples	Pineapple crown	0.22	41,247	N/A	N/A
	Pineapple pulp	0.33	68,058	N/A	N/A
Rice	Rice husk	0.20	18,715	8	17,218
	Rice straw	1.75	163,757	65	57,315
Sisal	Sisal ball	4.7	110,588	N/A	N/A
	Sisal pulp	24	564,706	N/A	N/A
Sugarcane	Bagasse	0.30	1,789,748	30	1,252,824

The government has instituted bans on logging with the aim of increasing forest cover or to conserve the water towers which govern water supply throughout the country. The latest ban was in February 2018, a 90-day ban on logging was imposed on public and community forests to curb the water shortage that the country was experiencing due to decrease in water level in rivers[174]. After expiry of the 90 days, the ban was extended to 6 months and after the 6 months it was further extended for another 12 months. This is to meet the 10% forest cover target by 2022. The Ministry of Environment was directed to form an inter-agency committee that will assess the trees in the various forests that were mature for harvesting and report the findings in April 2020. This on and off bans on harvesting trees from the community and public forests have a greatly impacted on the total amount of sawdust available. To address the deficit created by the ban, the government removed the 10% import duty imposed on imported raw timber[175]. Supply of sawdust is therefore greatly constrained and that which is available, is experiencing competition from manufacturers of boards such as chipboards and plywood. In terms of actual amounts available, large and medium scale millers are not potential suppliers as they use their sawdust to heat boilers, make plywood, and particle boards. The focus will be more on the small-scale millers and the timber sales workshops within Nairobi that could serve as a source of sawdust. Sawdust is also used as a household fuel, mulch, animal bedding and for floor covering in hotels and bars. There's opportunity to source from the small-scale millers, however, the exact quantities available are not yet ascertained.

Charcoal fines, if not utilised, are disposed to waterways or burnt which causes environmental pollution especially in urban and peri-urban areas where there is a high use of charcoal. Briquettes enterprises in urban and peri-urban areas (mostly small-scale manufacturers with exemption of Chardust Ltd) use this waste as a raw material for briquette making. However, the availability of this feedstock is also affected by perpetual bans in the charcoal industry. For example, in 2018 there was a ban on charcoal production in the charcoal production hotspot counties due to environmental degradation[176].

174 Ministry of Environment and Forestry. Government Suspends Logging as Country faces water crisis. Retrieved from http://www.environment.go.ke/?p=4598

175 ALN.Key highlights of the 2019-2020 National Budget Statement. Retrieved from https://www.africalegalnetwork.com/legal-alert-key-highlights-2019-2020-national-budget-statement/

176 The conversation. 2018.Banning charcoal isn't the way to go. Kenya should make it sustainable. https://theconversation.com/banning-charcoal-isnt-the-way-to-go-kenya-should-make-it-sustainable-95610

Therefore, from our assessment, sugarcane bagasse, rice husks, coffee husks, faecal sludge and solid waste hold the greatest potential for future sustained production based on the current supply and use rate. But this does not nullify the use of other feedstocks supplies especially for small-scale briquette production.

5.3.2 Quality of raw materials and feedstocks

The key characteristics of feedstocks are evaluated based on the proximate analysis which indicates the potential efficiency and durability / combustion characteristics of the briquettes to be produced,[177] as derived from various literature sources. The analysis provides the percentage of material that burns in a gaseous state (volatile matter), in the solid state (fixed carbon) and the percentage of inorganic waste material (ash). Generally, higher fixed carbon content leads to higher charcoal yield whereas the volatile and ash content leads to lower charcoal yield[178]. This equally relates to the burning characteristics where higher fixed carbon and low volatile and ash content is desirable for the briquette feedstock. Other parameters that are also quantified include moisture content, bulk density, particle size and calorific value.

A review of the qualities of the agricultural, municipal and industrial waste identified is indicated in Table 34.

Table 34: Physical and Chemical Characteristics of Selected Biomass Residues Available in Kenya

Feedstock	Properties						
	Fixed Carbon (%)	Volatile Matter (%)	Ash Content (%)	Moisture Content (%)	Bulk Density (Kg/m3)	Calorific Value (MJ/kg)	Sources
Sugarcane	13.6	82.1	4.3	50.0	N/A	N/A	Lopez (2016)[179]
Cassava	30.0	59.0	4.9	7.2	N/A	N/A	Adebisi (2017)[180]
Coconut	17.0 – 20.7	76.0 – 81.4	0.5 – 7.0	6.9 – 18.1	0.1	15.5 – 23.0	Asamoah et al. (2016), Adeyi (2010)[181]
Cotton	5.0	81.8	7.1	6.9	NA	19.0	Muhammad et al (2015)[182]
Groundnut (Shell)	17.1 – 19.5	77.5 – 81.5	1.5 – 1.9	1.6	NA	19.0	Asamoah et al (2016)
Macadamia (Shells)	23.7	76.0	0.4	N/A	N/A	N/A	
Coffee	15.0 - 20.3	68.8 - 74.4	1.8 - 5.3	14.5	N/A	N/A	Lopez 2016, Chen et al (2012)[183]
Rice Husks	14.2 – 17.5	56.1 – 66.3	7.9 -23.5	5.1 – 15.5	327.0	14.2 – 17.5	Asamoah et al (2016)
Maize (stover/ husk/straw)	6.7- 16.8	72.2 – 84.3	4.6 – 11.8	7.0 – 9.3	1, 017.2	17.1 -18.4	Asamoah et al (2016), Muhammad et al (2015)
Water Hyacinth	1.90 - 14.5	61.3 -87.3	10.8- 24.2	90.0	14.0	N/A	Lopez (2016)
Sawdust	2.2 – 21.6	77.7 – 88.6	0.2 – 5.6	1.8 – 9.8	133.0 -210.0	2.2 – 21.6	Asamoah et al (2016)

177 ibid

178 Nunes, L., Matias, J., and Catalao, J. (2017). Torrefaction of Biomass for Energy Applications: From Fundamentals to Industrial Scale. https://doi.org/10.1016/C2015-0-04530-0

179 Lopez (2016). Biomass utilization for energy purposes in Kenya. Fuel characteristics and thermochemical properties.

180 Adebisi, J., Agunsoye, J., Bello, S., Kolawole, F., Munyadziwa, M., Daramola, M., and Hassan, S. (2017). Extraction of Silica from Sugarcane Bagasse, Cassava Periderm and Maize Stalk: Proximate Analysis and Physico-Chemical Properties of Wastes. Waste Biomass Valor. http://dx.doi.org/10.1007/s12649-017-0089-5

181 Adeyi, O. (2010). Proximate composition of some agricultural wastes in Nigeria and their potential use in activated carbon production. J. Appl. Environ. Manage, 14 (1), 55 -58.

182 Danish, M., Naqvi, M., Farooq, U., and Naqvi, S. (2015). Characterization of South Asian agricultural residues for potential utilization in future 'energy mix'. Energy Procedia 75, 2974 – 2980. doi: 10.1016/j.egypro.2015.07.604

183 Chen, W., Lu, Ke-Miao and Tsai, C. (2012). An experimental analysis on property and structure variations of agricultural wastes undergoing torrefaction. Applied Energy ,100, 318 – 325.

Feedstock	Properties						
	Fixed Carbon (%)	Volatile Matter (%)	Ash Content (%)	Moisture Content (%)	Bulk Density (Kg/m3)	Calorific Value (MJ/kg)	Sources
Faecal sludge	6.9 -8.6	36.1 – 53.0	38.40 – 57.1	80.0 – 97.0	NA	13.0	Asamoah et al (2016)
Paper-Waste	NA	65.5	1.2 – 15.5	7.4 – 12.6	NA	NA	Asamoah et al (2016)

In their study to characterise the most optimal quality for feedstock, Asamoah (2016), deduced the following qualities (Table 35).

Table 35: Physical and Chemical Characteristics of Biomass Required for Briquette Making

Properties	Unit	Requirement
Fixed Carbon	%	9 – 25
Volatile Matter	%	50 – 90
Ash Content	%	Less than 4%
Moisture Content	%	6 – 14%
Bulk Density	kg/m^3	More than 50
Calorific Value	MJ/kg	12 – 20
Particle Size	Mm	1 -10 mm size with 10 -20% powdery

Source (Asamoah et al 2016)

Macadamia and Cassava have the highest fixed carbon content detected (23.68% and 30%). Water hyacinth and faecal sludge have relatively low fixed carbon content at 1.90% and 6.9% respectively. The fixed carbon content is the amount of solid mass yield after carbonisation process[184] or the proportion of carbon available for char combustion after volatile matter is removed from the biomass [185]. Majority of the remaining feedstocks fall within the optimal fixed carbon content as shown in table 7 above. A higher fixed carbon content will enhance the heat value. Lower values may indicate lower heat values more suited to production of non-carbonised briquettes which tend to utilize briquettes of a lower heating value.

It should be noted that though biomass with a lower fixed carbon content may be carbonised to increase the heating value, there will be a considerable loss in the biomass due to the lower fixed carbon content, which depending on the available, quantities of the feedstock may not be sufficient to sustain production.

Volatile matter is the proportion of carbon, hydrogen and oxygen in the biomass which will be converted to vapour on ignition. Higher volatile matter is indicative of a higher ignition rate[186]. Faecal sludge was noted to have relatively lower volatile matter content in comparison to the other feedstocks. The remaining feedstocks were observed to have values within the optimal range of 50 – 90% indicated in Table 35.

Ash is the non-combustible component of the biomass; the higher the ash content the lower its calorific values[187]. Coconut husks, macadamia shells, coffee husks, sawdust and ground nut shells have the lowest ranges of ash content, with some of the measured values falling below 4%. Water hyacinth, faecal sludge and rice husks have considerably higher ash content which has the effect of corroding metal surfaces[188]. This is due to the formation of slag and deposition which increases the rate of corrosion on metal surfaces. A few briquette producers using rice husks (ash content of upto 23.5%) as raw material pointed to corrosion of briquetting machinery as a major disadvantage[189]. As for burning devices, residual ash, if not removed after burning will affect the flow of clean air[190] and the slagging inhibits the combustion process by supporting overheating of the burning device.

184 Asamoah, B., Nikiema, J., Gebrezgabher, S., Odonkor, E., and Njenga, M. (2016). A Review on Production, Marketing and Use of Fuel Briquettes. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research Programme on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

185 Tamilvanan, A. (2013). Preparation of Biomass Briquettes using Various Agro-Residues and Waste Papers. Journal of Biofuels 4 (2) 47 – 55.

186 Tamilvanan, A. (2013). Preparation of Biomass Briquettes using Various Agro-Residues and Waste Papers. Journal of Biofuels 4 (2) 47 – 55.

187 ibid

188 ibid

189 Survey with briquette producers

190 ibid

High moisture content in feedstocks increases the cost of production as moisture has to be reduced to about 12% for optimal briquette production. For example, faecal sludge contains upto 90% moisture, bagasse and water hyacinth equally have high moisture contents of 50% and 90% respectively. Majority of the briquette producers use sun drying methods which compromises on output through the year. Few have invested on mechanical drying.

High bulk density will lead to increased costs in transporting the raw material[191]. Alternatively, the feedstocks may be bailed where applicable to reduce the volume and lower transportation costs. The calorific value determines the amount of energy released during complete combustion of a unit mass of briquette[192]. Higher calorific values are desirable especially for household fuel use. Sawdust briquettes are preferred to other types of briquettes because they have high energy density, burn for a long time, less costly and produce less ash content[193].

According to studies,[194] the average value of moisture content for Municipal Solid Waste (MSW) in Nairobi is 68.9%, the average bulk density is 289 kg/m3. The average calorific values of MSW categorized into individual components with organic waste at 15.7 MJ/Kg and papers at 17.10 MJ/Kg. It should be noted that the briquettes require a heating value of about 11.66 MJ/kg to sustain combustion. Therefore, heterogenous municipal organic waste is a viable feedstock from the heating value. The high moisture content would require drying to attain optimum values of 6 – 14% from 68.9%. As earlier stated, market waste is the most viable option as it is not contaminated with other hazardous household wastes.

Overall, high fixed carbon mass and calorific value and low moisture content, volatile matter and ash content are most desirable. However, different preparation methods can be used to improve the quality of feedstock before densification, thereby improving the quality of briquettes.

5.3.3 Cost of feedstocks

The price of fuel is one of the key determinants on its rate of adoption at the consumer level[195]. The cost of briquettes should be more competitive than the types of fuels it is replacing. The price at which the briquettes will be sold is determined by cost of feedstocks, transport cost for both raw material and the briquettes, processing, packaging etc. As such the cost of feedstocks as the core raw materials is important in determining the economic viability of briquette production businesses. For example, macadamia nuts and cashew nuts have high calorific value and low moisture content and thus a desirable raw material for briquetting[196]. These two raw materials can provide the required energy content without the need for briquetting. Briquetting of the material is not economically viable and as a result thermal intensive industry such as tea factories use it in its raw form[197]. Over the years, there has been a rise in demand for these raw materials that can be used to provide thermal energy in their unprocessed state by thermal intensive industries such as oil refineries, cement manufacturers, tea factories etc. As a result, their cost has increased and in some cases their procurement is through pre-bids where these residues are sold to the highest bidder or to those with a long-term arrangement with the suppliers (Table 36). Additionally, coffee husks are a premium feedstock as indicated by a relatively high fixed carbon mass and low ash content (see section 3.1.2), however, its expensive and mostly used to blend other raw materials of lower calorific value rather than act as the main feedstock.

Primary data collection through a survey with briquette producers was carried out to further ascertain the costs of biomass residue. A total of 20 briquette producers with different profiles in terms of ownership, production scale, biomass feedstock used, type of briquette produced (carbonised and non-carbonised) were interviewed.

191 ibid

192 Asamoah, B., Nikiema, J., Gebrezgabher, S., Odonkor, E., and Njenga, M. (2016). A Review on Production, Marketing and Use of Fuel Briquettes. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Research

193 Ajibade, F., O. Lasisi, H., K. and Babatola. (2017). Production of Sawdust Briquettes as Alternative Household Fuel Using Water and Cow Dung as Binders. African Journal of Renewable and Alternative Energy.

194 Khamala E. M., and Alex. A. A., (2013). Municipal Solid Waste Composition and Characterisation Relevant to the Waste-To-Energy Disposal Method for Nairobi City. G.J.E.D.T Vol. 2 (4): 1-6.

195 Ministry of Energy (2019). Kenya Household Sector study.

196 Chardust Ltd and Spectrum Technical Services (2004). The Use of Biomass to Fabricate Charcoal Substitutes in Kenya. Feasibility Study; Forming Part of the Shell Foundation-Supported Project on Charcoal Briquetting in Kenya. Nairobi; Kenya

197 Key Informant Interview with Makomboki Tea Factory

There is no standard price for the feedstocks as reported by various briquette producers hence giving a wide price range as shown in Table 36. Charcoal dust had initially been treated as waste and only gained value as demand for use in briquetting increased, the most frequently reported average price was KES 4/kg. The most expensive feedstocks reported were coffee husks and macadamia shells with KES 3/kg and KES 12/kg respectively.

Majority of the producers, 90% of the businesses acquired their feedstock through payment by cash from the various suppliers. The repayment period for the 10% paying by credit varied from 1 to 2 weeks.

Table 36: Approximate prices per kg for selected biomass residue feedstocks in Kenya[198]

Feedstock	Price Range (KES/kg)
Charcoal Dust	1 -4
Bagasse	0-3
Coconut husk	3
Coffee husks	1 -5
Macadamia Shells	1 -12
Maize Cobs	0.5
Sawdust	1 – 5

5.3.4 Transportation of feedstock

The cost of feedstocks transportation is dependent on the distance to the briquettes production location. The briquette producers reported various distances between point of sale of the feedstocks and production site as indicated in the boxplot, Figure 22. The mean distances travelled are represented by x, the median values are represented by the lines and the outliers for the shortest or longest distances for each feedstock as indicated by the whiskers. For example, though most producers sourced sawdust over a range of 0km – 120km, one of the producers sourced their feedstock from a distance as far as 200km. Similarly, the range for bagasse falls within the window of 0km – 300km but one producer traverses 400 km to source bagasse.

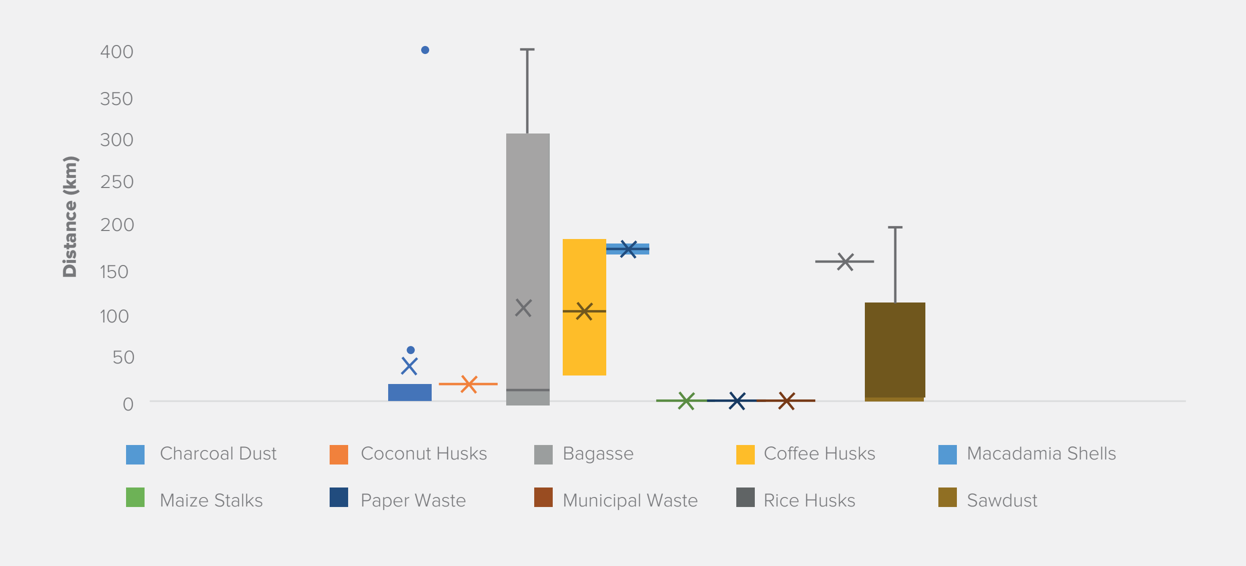

Figure 22: Distances from point of sale of feedstock to briquette production sites

198 Survey with briquette producers

Charcoal dust was the most commonly used feedstock reported and noted to have relatively similar shorter distances (0 – 60 km) between the source and production site as indicated in Figure 22. That may partly be attributed to ubiquity of charcoal making operations throughout the country. One of the charcoal producers indicated sourcing from a distance of 400km, 3 times a year, when they need to supplement their supply. Coconut husks, maize stalks, paper waste, municipal waste also indicated relatively short distances (less than 50 km). Macadamia shells and rice husks were sourced from distances greater than 150 km. Locating production sites closer to feedstock would reduce the transport costs however, most producers locate their production sites closer to their target markets. An advantage to centrally located feedstock is the availability of feedstock in sufficient amounts, however, if located further from the intended market and production site, then longer distances and higher costs will be incurred. Sawdust was sourced from a range of distances, 0 – 200 km.

Five means of transport were identified, pick-up, lorries, motorcycles, handcarts and headloads. Lorries were the most commonly used for covering distances ranging from 0 – 400km. Motorcycles, handcarts / wheelbarrows and headloads were used to traverse shorter trips of less than 10 km. Pick-ups were used to cover distances of 0 – 20 km.

Briquette producers reported a variation in the means of transport employed over different distances. Two briquette producers using lorries reported a similar distance, 190 km and 200 km, but paid KES 10,000 and KES 35,000, respectively. The use of pickups was mostly for shorter distances ranging from 1km – 20km for KES 500 - 1000 with the exception of one respondent who reported a distance of 152km for KES 4,000. The average cost for use of lorries was KES 112/km; KES 35/km for the pickup; KES 20/km for the motorbike; and KES 70/km for a headload.

Table 37: Average Cost of Transportation by mode of transport and distance travelled

Distance (Km)	Transportation	Cost (KES)
200	Lorries	35000
190	Lorries	10000
152	Pickups	4000
100	Lorries	10000
20	Pickups	1000
15	Pickups	1000
5	Motorbikes	100
1	Pickups	500
1	Headloads	70

5.3.5 Production of briquettes

The general briquette making process includes the i) collection and preparation of raw biomass ii) carbonisation of biomass (where applicable) iii) mixing with a binder (where necessary) iii) compaction of biomass material and iv) drying of wet briquettes mainly for carbonised type[199]. The preparation of raw biomass covers the sorting, separation, collection, transportation and resizing of materials. After resizing, non-carbonised briquettes are compacted using a high-pressure machine that melts the lignin material to act as a binder. For carbonised briquettes, the feedstocks are first thermally combusted in the absence of oxygen through a process called pyrolysis[200] which helps to enrich the fixed carbon content in the raw materials.

Definitively estimating briquettes production in Kenya is an uphill task, as majority of the sector players have remained largely informal and high turn-over with few businesses surviving the 5-year window before closure[201]. As is the norm with the informal sectors, data on exact operations and specifications is rare as it is undocumented. However, a survey of different market producers as well as literature sources are used to approximate output for the sector.

Producers reported a range of 15,625 – 2,400,000 kg annual production for the year ended 2019. The production capacities according to the type and size of business are indicated below (Table 20).

199 Ngusale (2014). Briquette making in Kenya: Nairobi and Peri-Urban areas. Renewable and Sustainable Energy Reviews 40 749 - 759

200 Lohri C.R, Rajabu H.M., Sweeney D.J., Zurbrugg C. (2016). Char fuel production in developing countries – A review of urban biowaste carbonisation. Renewable and Sustainable Energy Reviews 59 1514 – 1530. http://dx.doi.org/10.1016/j.rser.2016.01.088

201 Survey results

Table 38: Production capacity for 2019[202]

#	Production Range (tonnes/2019)	Type of businesses	Type of briquettes	Main end-users
1	1,000-2,500	Limited Companies (4 companies)	Non-carbonised	• Factories • Public institutions • Small enterprises e.g. Kiosks
2	200-700	Limited Companies (3 companies)	Non-carbonised Carbonised	• Factories • Public Institutions • Households
3	5-100	CBOs (2 CBOs) Sole Proprietors (3 producers) Limited Companies (1 company)	Carbonised Non-carbonised Semi-carbonised	• Households • Small enterprises e.g. Kiosks • Poultry farmers

About 11 businesses, (55%) of the producers interviewed reported taking their briquettes for independent testing either at KEBS (4 businesses) or KIRDI (7 producers). The 9 businesses which did not seek any sort of testing had different reasons for omitting the process, 3 reported not being aware of where to test their products, 3 reported not finding a need to test as their customers were comfortable with the quality and 2 reported that the process was too expensive. The highest reported price for testing was KES 200,000 which was related to the testing of faecal matter. Time to get results on the test varied from 0.5 to 12 weeks. The 12 weeks was also related to the testing of briquettes from sludge. More precautionary tests are required to ensure the faecal matter is sanitized.

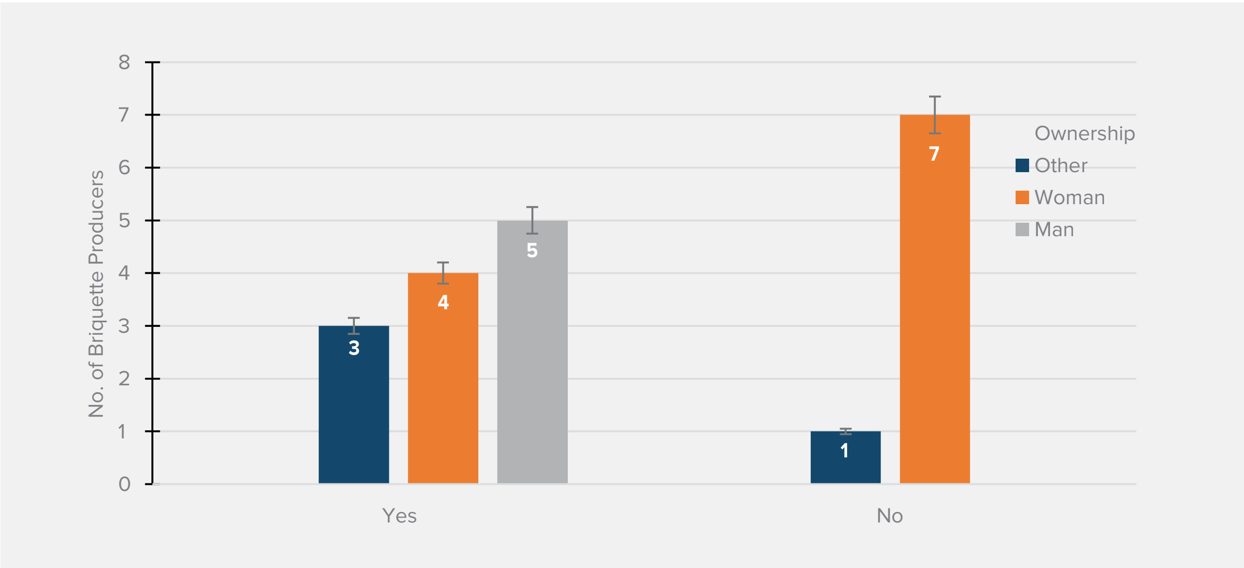

Figure 23: Number of briquettes producers aware of briquette standards in Kenya disaggregated by gender ownership of the businesses

202 Note that 25 % of the producers did not provide information on production quantities for 2019

Only 60% of the businesses (12) were aware of the briquette standards which are currently under development in Kenya (Figure 23). These producers learned of the standards through various channels, briquette producers (15%) and government officials (10%) and social media were the most prominent sources of information. Only one business reported learning of the briquette standards from a briquette forum and one through training from an NGO / CBO.

5.4 Midstream activities

5.4.1 Packaging of briquettes

Beyond the quality and testing, the final step of briquettes production is the product packaging. The type of end-users determines the type of packaging to be employed by the producers. Briquettes for large-scale users of briquettes (non-carbonised) such as industries and institutions require no defined packaging as the fuel is loaded onto either the pick-ups or the lorries. Briquettes for household use are mainly packed in 2kg, 5kg and 10kg bags (brown bags). For producers selling through supermarkets, having their briquettes labelled and with a KEBs standardization mark is a requirement on their packages. Nawasscoal also labels their products to win the consumer confidence since they produce briquettes from human waste. For small enterprises as hotels the briquettes are packed into 50 kg bags (similar to the 50 kg sugar sacks).

Most of the producers reported using more than one packaging size to suit either domestic or institutional demand. Of the 20, 11 businesses reported packaging in bags of weight greater than 25kg. About 10% (2 businesses), reported selling briquettes in tonnes. For the small sizes, 7 businesses used 1 kg bags, 17 businesses used 2 kg bags, and 3 businesses used 10 kg packages. The prices of the briquettes varied according to type; Carbonised briquettes were priced at KES 25 – 30 per kg while the non-carbonised briquettes were sold at 10 – 15 per kg. The latter was mostly sold to industries. Briquettes costing for industrial and household use is cheaper than charcoal, which is approximately, KES 45 – 50 (for both household[203] and industrial [,204,205] applications).

The average cost of firewood is KES 25 for firewood[206]; fuelwood for industry is approximately KES 1500 – 1800 / m^3 or approximately KES 3 - 5[207], supported by a CCAK study on the use of biomass cookstoves and fuels in institutions which reported KES 3 - 5 per Kg for firewood[208].

5.4.2 Distribution channels of briquettes

As earlier stated, the value chains will vary depending on briquettes production scale, type of briquettes produced (carbonised vs. non-carbonised), and the distribution channel which will also vary depending on the target market segment. Additionally, certification from KEBS will also have an influence on the channels for sale available to the producer.

In order to better comprehend the workings of the production and distribution process, a total of 20 briquette producers with different profiles in terms of ownership, production scale, feedstock used, type of briquettes produced (carbonised and non-carbonised) were interviewed. For components on distribution channels, the questionnaire captured the locations for sale (urban vs. rural), market segment (households vs. institutions), the means of sale (direct, door – door, supermarkets/market sales). Approximately, 70% of the producers targeted urban markets while only 30% were focused on rural settings. Of the 20, 9 producers (45%) targeted households, 30% targeted industries and factories (tea factories and Poultry farmers), 10% targeted institutions (schools, hospitals etc.) and 5% targeted small-scale enterprises such as food kiosks.

About 90% of the producers reported engaging in direct sales to consumers rather than relying on brokers or middle-men. A further 5% of the producers were noted to directly market their products to the consumers through door to door sales through hired agents or community members. Only 3 producers, (15%) utilised supermarkets or market stalls as their main distribution channel. Majority of the producers (85%) do not stock their producer in supermarkets. This is despite having 55% of the producers seeking independent testing through KEBS or KIRDI.

203 MOE 2019. Kenya Household Cooking Sector Study: Assessment of the Supply and Demand of Cooking Solutions at the Household Level.

204 MOE 2019. Kenya Household Cooking Sector Study: Assessment of the Supply and Demand of Cooking Solutions at the Household Level.

205 CCAK 2018. Study on Use of Biomass Cookstoves and Fuels in Institutions in Kenya.

206 MOE 2019. Kenya Household Cooking Sector Study: Assessment of the Supply and Demand of Cooking Solutions at the Household Level.

207 EED Advisory 2018. Kenya Biomass Availability Assessment (unpublished)

208 CCAK 2018. Study on Use of Biomass Cookstoves and Fuels in Institutions in Kenya.

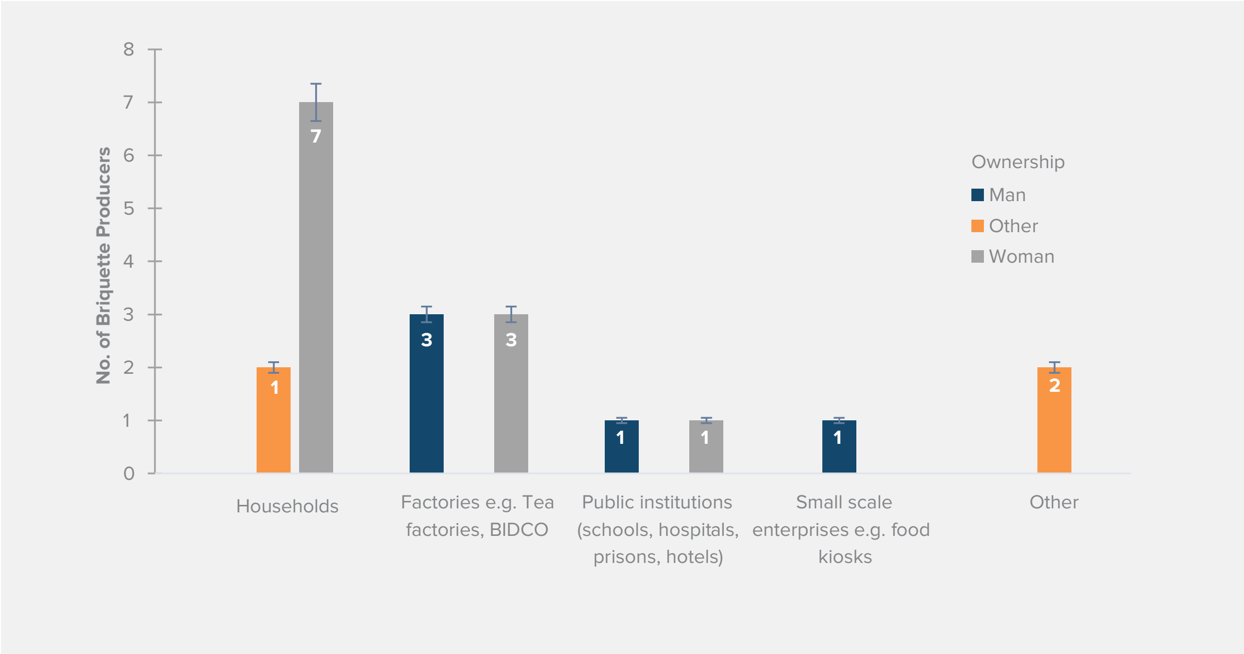

Figure 24: Target Market Segmentation disaggregated by the briquette producers' gender. Other represents businesses owned by groups such as Community Based Organisations, CBO.

After production the producers incur additional costs of transporting the briquettes to the point of sale. About 4 business reported using pick-up for transportation, 5 businesses reported using lorries and 2 business reported using a motorbike. Of the 20, 3 producers reported carrying out direct sales from the production site. The mode of transport is dependent on the market which ranges from households, institutions and industries.

5.5 Downstream activities

The main end users are identified according to the type of briquettes purchased. The large-scale producers supply non-carbonised briquettes to factories, public institutions and small enterprises while mid-scale briquette producers supply to factories, public institutions and households. Sole proprietors and CBOs produced both carbonised and non-carbonised briquettes for households, small kiosks and poultry farmers.

The main mode of payment offered to consumers was reported as cash. The average price for a kg of briquettes was indicated as 24 KES. About 15 businesses, 75% reported accepting cash as their main mode of payment and 15% of the business accepted credit payment (Figure 25). The payment window through credit varied from 3 weeks up to 2 months. The producers also indicated that industrial / institutional consumers often received the credit terms. For example, chicken coups or schools would receive credit and offer payment after maturation and sell of chicken / end of the school term.

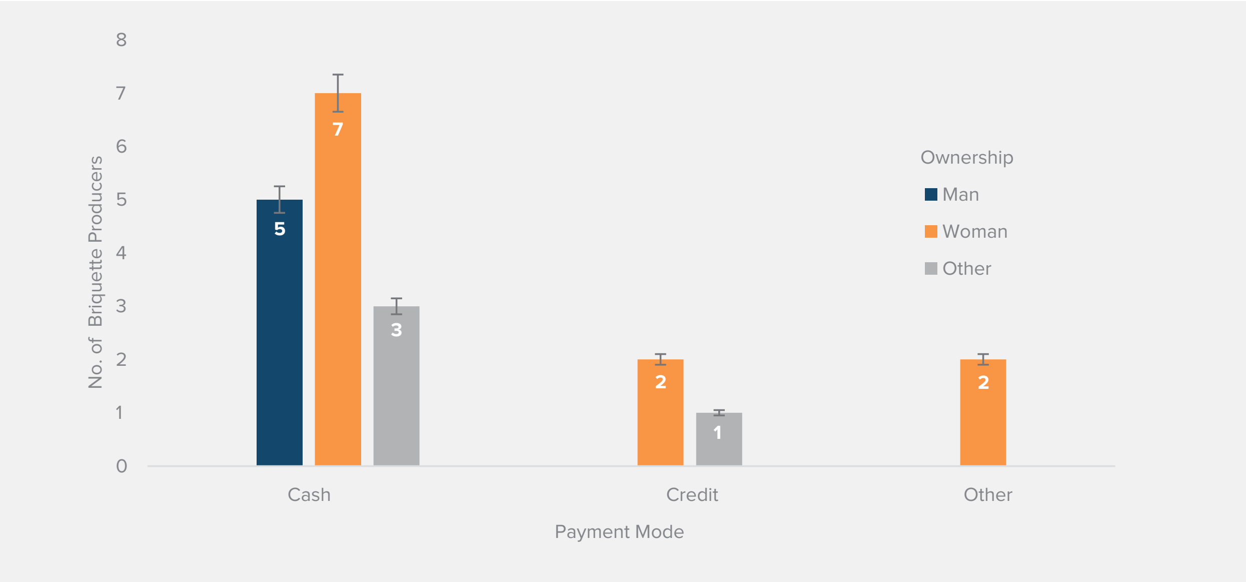

Figure 25: Main mode of payment offered to consumers by briquette producers disaggregated according to gender ownership

6 Identification of Scenarios for Briquettes Value Chains.

Sustainable briquette production is one of the proposed pathways under the National Climate Change Action plan (NCCAP) 2018-2022 to reduce greenhouse gas (GHG) emissions in the country by up to 0.45 MtCO2e by 2022[209]. Briquettes are promoted as alternative and transitional fuels to other clean cooking solutions such as LPG, electricity and ethanol. The action plan also proposes a holistic approach to forest management with uptake of briquettes being a proposed solution to forest degradation. This report seeks to develop possible scenarios under which briquettes would be promoted in Kenya to realise this objective as stipulated in the NCCAP. Although, the plan does not focus on industrial and institutional briquettes, considering that these consumers use large quantities of firewood and have a more significant effect on the forests than households, we seek to look at both briquettes for household and other large-scale users of solid biomass. The scenario development process was guided by data collected from the briquette producers, information from interviews with sector experts, secondary data on feedstock availability and quality and data from suppliers of raw materials for briquette production. The first step seeks to answer the following questions discussed below.

1 Target number of consumers or tonnes of briquettes in each scenario

The NCCAP does not provide the number of households targeted to start using briquettes as an alternative fuel by 2022. The first step was to develop a target number of households to transition to briquettes use. Since briquettes are promoted as an alternative fuel for charcoal in urban areas, a target group of 10% (242,386 households) of the total number of urban households (2,423,860) using charcoal was picked as a target to be attained for the promotion of briquettes[210]. This was used as the target for the period of the interventions under the scenarios that was set at five years since the 2022 is a short timeframe for the proposed activities. Using the mean annual national charcoal consumption among households of roughly 395.2 kg/ per year[211] and with the assumption that this is equivalent to what annual briquettes consumption will be, the production capacity of the scenarios was estimated at 100,000 tonnes. The scenarios targeting households will use this annual production target of 20,000 tonnes as the basis for formulating the type of interventions and resources required.

For industrial use of the briquettes, industries have increased efforts towards environmental sustainability and are implementing measures for energy conservation. One example of such industries are the tea factories. The annual firewood required for the tea industries is one million tonnes of dry firewood[212]. Using 10% as a target for the pilot of this would be 100,000 tonnes for industrial or institutional use for the 5-year period proposed under the scenarios.

209 Government of Kenya. (2018). National Climate Change Action Plan 2018-2022: Towards Low Carbon Climate Resilient Development (volume 1). Ministry of Environment and Forestry, Nairobi, Kenya

210 Ministry of Energy. (2019). Kenya Household Cooking Sector Study

211 Ibid

212 UNEP (2019). Sustainability of sugarcane bagasse briquettes and charcoal value chains in Kenya

2 Current supply of briquettes in the market

Several challenges were encountered in an attempt to estimate the tonnes of briquettes produced in Kenya. First, informal and artisanal small-scale producers, who do not belong to a formal or registered association or a production hub, and do not have an online presence dominate the sector. This makes it difficult to identify them, estimate their numbers and the quantities they produce. Second, some of the producers do not keep records on quantities produced or are not willing to share that information. Out of the 20 briquettes producers, 75% (15) of them produced 8,673 tonnes of briquettes in 2019. The highest reported briquettes produced by an individual company was 2,400 tonnes and the lowest 5.4 tonnes. Using this data, the average annual briquette production per briquette manufacturer was calculated and the average used to estimate the tonnes of briquettes produced in 2019. Using the average quantities per producer and the initial list of 60 producers, the total quantities produced for 2019 was determined to be approximately 37,180 tonnes. Most of the briquettes sold were non-carbonised for industries and institutions. Small quantities of carbonised briquettes produced were sold to households, small enterprises such as eateries and space heating for poultry farmers. It can therefore be concluded that the supply for briquettes is low compared to possible demand described above and household markets are either not attractive to the producers of briquettes or the fuel is not popular among the household users.

3 What barriers need to be addressed in order to meet the expected demand?

Comparing the possible demand for briquettes with what is supplied, it is evident that there is a huge deficit and low appetite for briquettes at the household level. The third question to consider was what challenges hinder the growth of the briquette sector from both the supply and demand side? For instance, some of the major challenges on the demand side include: poor quality of briquettes, lack of consistent supply, lack of awareness and lack of the suitable cooking stove to burn the briquettes, and readily available and affordable alternatives like charcoal.

On the other hand, briquette producers have limited access to finance to grow their businesses, lack of consistent consumers especially for households, inconsistent availability of feedstock and lack of technological knowhow to produce briquettes[213]. With the understanding of the objective of the scenarios and the barriers in the sector, the following three scenarios were developed to promote briquettes uptake in the country. An ideal scenario would be one where (i) the feedstock is readily available, affordable, accessible (ii) briquette making machines are available in the market and affordable (iii) the briquettes have a ready market. The first scenario aims to explore the possibility of working with already existing producers who already have an established value chain and the other two scenarios explore how an ideal value chain would look like by setting up a central production facility for briquettes.

213 A detailed description of the barriers is explained under review of policy and enabling environment part 1 of 5

6.1 Scenario 1: Design and implementation of a national briquette production programme

This scenario proposes the design and implementation of a national programme mandated to promote the uptake of briquettes in Kenya. The programme will work with already existing briquette producers to aid them grow their businesses by addressing the various challenges in the sector. The programme will be housed at the Renewable Energy Directorate in the Ministry of Energy. A similar approach was adopted by Lighting Global solar sector to promote the uptake of Pico solar products under Lighting Global programme led by the World Bank Group. Since its inception in 2009, the programme reports that over 42 million quality verified products have been sold since in Africa, Asia and Pacific region[214]. Another example of a similar approach is the Kenya Biogas Programme, which employs a Marketing Hub model (BMH) for promotion of biogas. The model targets formally organised groups such as SACCOS, MFIs (Micro Finance Institutions) and cooperative societies as their last mile marketing hubs. Activities carried out in these groups (known as marketing hubs) include creating awareness among members, sales, monitoring and verification of the systems, and training. The first phase of the programme managed to install 19,000 units of biogas systems (2009-2013)[215].

This approach would concentrate its efforts to address the market needs of the target groups. The key components of the programme would include (i) recruiting the briquettes producers to the programme (ii) setting the standards for briquettes to be produced under the programme (iii) creating an enabling environment by facilitating access to finance and fiscal incentives; facilitating access to the suitable technologies; awareness creation; supporting development of policies and clear institutional frameworks that support uptake of briquettes (iv) linking the producers to ready markets. Figure 26 below illustrates the different components of the programme.

To be able to implement the activities of the programme, the directorate will coordinate with the various actors in sector. For example, the Ministry of Finance is in charge of fiscal incentives, which are reflected in the annual national budget. As such, the programme implementers will lobby for fiscal incentives for the imports of the briquette technologies and VAT exemption for briquette producers. The programme will also coordinate activities under standard and testing with institutions such as KEBs and KIRDI. At the County level, the programme can engage the Energy Centres for educating the public on the use of briquettes.

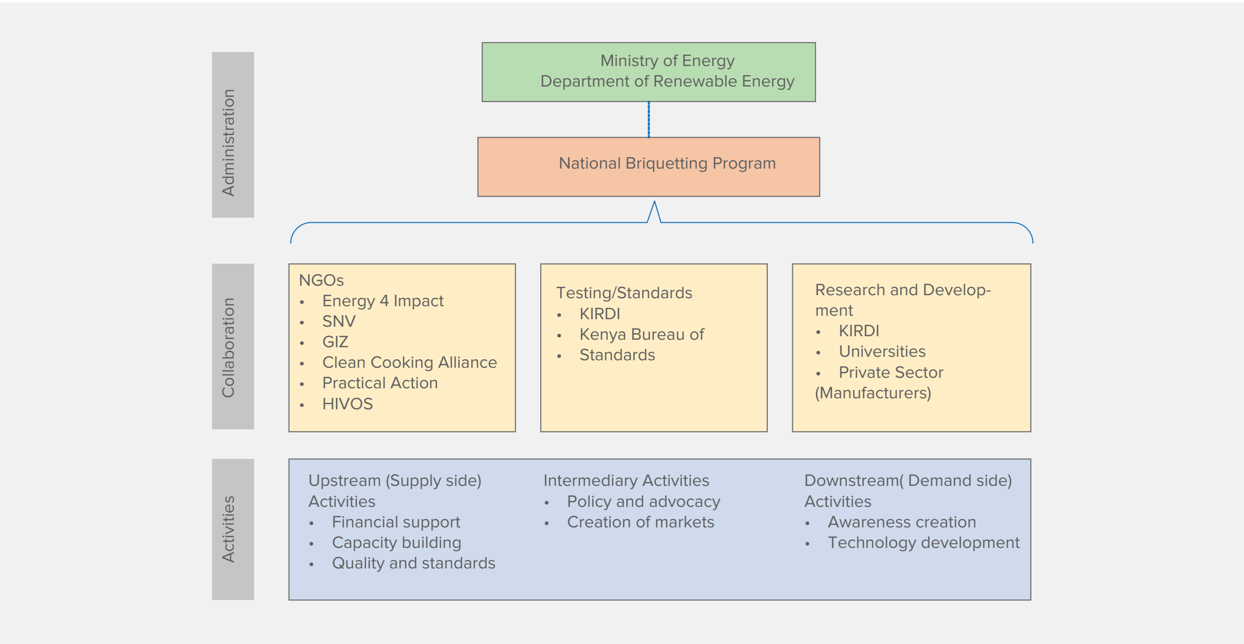

Figure 26: Summary of components of the programme

214 Lighting Global website. (n.d). About. Retrieved from https://www.lightingglobal.org/about/

215 Ministry of Energy. (2019). Kenya Household Cooking Sector Study

6.1.1 Recruitment of briquettes producers

The programme will cover producers of both carbonised and non-carbonised briquettes. It is advisable to recruit briquette producers who have been in existence for at least two years and who demonstrate potential to scale. This is because they already have sources of raw materials and established clients, and are aware of the existing challenges in the sector. The programme will be complimenting their already established efforts. Newly formed businesses may not be resilient to the hurdles in the sector. Some may be opportunistic producers who join the programme with the hope of benefiting from donor money and quickly lose interest when faced with challenges. Participants to the programme can be identified from organisations that have, in the past, implemented briquette programmes such as Energy 4 Impact, Practical Action and Netherlands Development Organisation (SNV) and the recently formed United Briquette Producers association (UBPA) and online searches. These producers will be approached directly and provided with information about the programme. Alternatively, a national campaign will be launched to sensitise the producers about the programme through forums, advertisement (radio, television, websites, and social media platforms). Participation will be voluntary and gender quotas will be applied in the recruitment process where at least half of the producers will be women and individuals under 35 years (youths).

6.1.2 Standards for briquette produced under the programme

One of the key barriers to uptake of briquettes, especially at the household level, is the quality of briquettes produced. To this effect, the programme will aim to address this challenge but ensure that the producers recruited to the programme produce briquettes that meet the approved Kenya standard. Kenya Bureau of Standards is currently developing regulations to guide briquette production in the country: *DKS 2912:2020 Solid biofuel — Sustainable Charcoal and carbonised briquettes for household and commercial use — Specification.* The standard specifies requirements for sustainable production of charcoal and carbonised briquettes from a range of feedstocks including wood and by-products of wood processing, agricultural waste and solid waste. They provide metrics such as moisture content, volatile matter, ash content etc. In addition to this, Kenya Bureau of Standards adopted the ISO standards on solid biofuels Part 1-7 in 2015 to provide guidelines on production of non-carbonised briquettes from both wood and non-wood-based feedstock. The producers will have to meet these standards to participate in this programme. The programme will facilitate producers to test their briquettes by subsidising the cost of testing at the beginning of the programme and gradually reducing the subsidy as more and more producers join the programme. For the briquettes that do not meet the standard, information on procedures to employ during the production process will be provided to help them achieve the specified standard.

6.1.3 Linking producers to ready markets

A key concern raised by the large-scale consumer is lack of a large consumer base that can take up their briquettes. Though some producers are willing to take loans to expand their businesses, they remain hesitant for lack of an assured market. As recommended in the policy assessment report[216], the government can push institutions to start using briquettes towards providing 10% of their thermal requirements. The 10% share will gradually be increased based on the observed uptake and lessons learnt. These institutions include hospitals, schools, training institutions and prisons. For households, the government can regulate charcoal production in the country by ensuring only charcoal that is sustainably produced is available for sale. This would limit the quantities of charcoal in the market and consumers would be forced to explore other alternative sources of cooking solutions. It is, however, important to note that regulation of charcoal may not necessarily translate to uptake of the briquettes as consumers can opt for other cooking solutions such as LPG as has been observed in the past.

6.1.4 Facilitating access to finance

Expanding their scale of production to meet the demand created by activity (2.1.3) above will require finances for purchasing more efficient briquette-making equipment and maintenance, testing and labelling of the briquettes and purchasing of the

216 This one of the proposed recommendations under the review of policy and regulatory report part 1 of 5

additional feedstock. Depending on the scale of production, and with the assumption that the business will embrace automation of the production processes, the initial cost of scaling up production can range from KES 500,000 to KES 50,000,000. While most large-scale producers have access to different forms of finance including loans and grants, it remains a hurdle when it comes to small-scale producers. These entrepreneurs are often not able to meet the requirements for financing including collateral in the case of debts. Financing can be advanced through varied forms such as Results Based Schemes (RBF). The programme can push for policies that allow inclusion of briquette producers to on-going initiatives such as Kenya Off-Grid Solar Access Project (KOSAP, component 2). The programme will also have aspects of capacity building by training the producers in writing bankable proposals which were reported as a hurdle for small-scale producers.

6.1.5 Facilitate accessing the right technologies

Another key challenge to be addressed by the programme is the availability of appropriate briquetting equipment. Briquette producers reported encountering low or absence of local technological capacity to fabricate densification equipment especially for non-carbonised briquettes. Of the four commonly used densifying equipment, that is, agglomerator, screw extruder, pillow briquettor and ram/piston press, only the screw extruder and the agglomerator are locally manufactured. The ram/piston/hydraulic press and pillow briquettors are imported from Europe, China or India[217]. Ultimately, the cost of importation is prohibitive making it difficult for emerging briquette producers to procure quality machines. This challenge can be addressed in two ways; promoting local production and providing fiscal incentives (tax exemptions) to companies such as C.F. Nielsen and Camco Machinery that import briquette-making machines. Companies under the programme that would like to import their own machines can be provided with this incentive of tax exemption. For local production, the programme will identify the local manufacturers with quality machines that they can supply to briquette producers under the programme and offer maintenance services for the machines.

6.1.6 Creation of awareness

After addressing the main impediments in the supply side of briquette production, the next step will be to create awareness among the end-users. Briquette end-users are broadly grouped into domestic (households), commercial-institutional (small/medium businesses, educational and health institutions) and industrial consumers (large thermal energy users including tea factories). A consumer education programme will be developed with a clear strategy on how to reach the different types of the end-users. The technique to be applied in awareness creation will be determined by the target group. For example, large-scale end-users such as manufacturers will be approached directly while households can be reached through road shows, television advertisements, billboards and fliers. In low-income areas, awareness campaigns can be held in the Community-Based Organisations (CBOs), women groups and youth groups. During their monthly meeting sessions, information dissemination and demonstrations on the use of briquettes can be carried out. The programme objectives would be to (i) create awareness of different briquettes types (ii) highlight the benefits of briquettes relative to other fuels (iii) demonstrate how briquettes are best used and the right technologies (e.g., stoves) to use the briquettes.

Additionally, the programme can use the Energy Centres as avenues to create awareness of the use of briquettes as an alternative fuel, its benefits and conduct demonstrations on how to use the fuel. The centres can also be demonstration points for the different briquette production technologies to the briquette producers.

6.1.7 Cost Estimation of the project

Table 39 below provides the cost estimation per component of the programme with assumptions to the costing.

217 Mwampamba T.H., Owen M. and Pigaht M. (2013). Opportunities, challenges and way forward for the charcoal briquettes industry in Sub-Saharan Africa. Energy for Sustainable Development 17 158 – 170.

Table 39: Estimation of the cost of the programme

#	Activity	Unit Cost (USD)	Quantities	Days	Total Cost (USD)	Comments
1	Design of the programme	1,000	3	30	90,000	Hire a team of consultants to design the activities of the programme, timelines etc. Cost is estimated at 30 working days at a rate of 1000 USD per day
2	Creation of awareness (Demand side)	10,000	2	12	240,000	Hire a consulting firm to handle the component of awareness creation that will apply both the below the line (BTL) and above the line marketing (ATL)techniques
3	Programme fund	50,000	35	1	1,750,000	Loans capped at 5 million. Facilitation of testing and labelling of products Programme working with 30 briquette producers
4	Training (Technical & Enterprise)	100	60	6	36,000	Training carried out three times in a year Cost per head is estimated at 100 USD to cover training venue and expert fee
5	Mentorship _Technical and business	200	60	6	108000	Entails follow-up with entrepreneurs to advise and guide on identified challenges This will be done by professional enterprise and technology experts
6	Research and development	50,000	2	1	100,000	Working collaboratively with universities, testing facilities and manufacturers to improve quality of briquettes and to address technological hurdles in the sector
7	Administration cost				234,616	10% of the total cost
	Total cost				**2,346,160**	

6.1.8 Risks and weaknesses of proposed Scenario

1 Availability of funds

Successful implementation of the programme is highly dependent on availability of funds to finance the various components of the programme. The initial funding for the programme can be from the annual budget allocation for the energy sector. Active lobbying will be required in order to increase the proportion of funding allocated to the cooking sector. Additional financing can be sourced through proposal writing to funding institutions such as the Green Climate Fund, World Bank, African Development Bank (AFDB), Netherlands Development organisation (SNV), The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH GIZ) etc.

2 Time frames

The design and implementation of the activities under the programme will require time and coordinated efforts from other departments of government. For instance, the passing of policies requiring institutions to take up briquettes, KEBs for standards and labelling and KIRDI for testing of the briquettes, may take long as there are several stakeholders to be engaged. The successful implementation of the programme is dependent on the level of commitment of these institutions to the programme. Given it is a multi-stakeholder engagement; there are risks in delayed decision-making and actual progression of the project.

6.2 Scenario 2: Setting a briquetting facility

Under this scenario, we explore the possibility of a Central Briquette Production Facility (CPF). Drawing from the analysis of the most suitable raw materials, bagasse was identified as the most suitable raw material for the CPF due to the following reasons;

i. Approximately 2.4 million tonnes of bagasse are produced annually and remain un-utilised[218]

ii. The cost of the feedstock is affordable compared to other types of feedstock. One manufacturer stated that since the waste is a nuisance to the sugar mill, they collect the waste at no cost or at a low cost of KES 600 per tonne

iii. Sugarcane is also perennial crop that is available and harvested throughout the year. This enables continuous production of bagasse throughout year.

iv. The quality of briquettes produced will be mainly determined by the procedure employed by the producers. This is because for most crops the calorific value does not vary widely but ranges from 12 to 16 MJ/kg.

The key challenge with the use of bagasse is the high moisture content. At the point of production, the moisture content is as high as 50%.

Two possible pathways were considered under this scenario; production of carbonised briquettes for household use and non-carbonised briquettes for industrial and institutional use.

6.2.1 Carbonised briquettes for household use

The CPF would be ideally located in Kisumu County as most of the sugar mills are located in the western region of the country. This is to reduce the transport cost associated with moving waste from generation source to the production site. According to the yearbook of sugar statistics for 2019, the top five performing mills were West Kenya (1,048,270 tonnes of sugar), Transmural (760,176 tonnes), Kibos (653,443 tonnes), Sukari (633,229 tonnes) and Butali (574,338 tonnes)[219]. Their total sugar production was 3,669,456 tonnes, which translated to 1,255,198, tonnes of bagasse that can be used for briquette production. A pilot producing 20,000 tonnes in the first year is proposed and depending on the success of the pilot, production can be scaled up to cover a wider consumer base. To calculate the production cost under this scenario we discuss the assumptions and recommended technologies under the steps of briquette production below.

218 UNEP. (2019). *Sustainability of sugarcane bagasse briquettes and charcoal value chains in Kenya*

219 Agriculture and Food Authority. (2019). Year Book of Sugar Statistics 2019.Nairobi; Kenya

1 Sourcing of the feedstock

Under this step, the cost of the feedstock and transportation is estimated. With the assumption of 70% loss of feedstock in the carbonisation process (for carbonised briquettes) approximately 34,000 tonnes of bagasse would be required to produce 20,000 tonnes of briquettes (approximately 1,500 tonnes of briquettes per month). This translates to approximately 3,000 tonnes of bagasse every month. Different miller will have different prices for the waste with some giving it at no cost. To calculate the estimated cost of the feedstock we use the highest quoted value, which was KES 600 per tonne[220]. Transportation can be either by CPF own vehicles or by hiring a transport company. The latter is more affordable as sourcing of the feedstock is not a daily affair and thus transfers the logistical concerns to the hired company. Cost of transport will be highly determined by the exact location of the CPF and how many of the sugar mills will be supplying the bagasse. To estimate this, we assume that the CPF will hire transport services weekly at KES 20,000 for the transport of the bagasse to the production site.

2 Preparation of the bagasse

As discussed earlier, bagasse has a high moisture content of 50%. The CPF can either use sun drying or purchase a dryer to ensure the feedstock attains the required moisture content. A dryer is recommended as it takes less time to dry the waste (4 tonnes of briquettes per hour)[221] compared to sun drying (takes 1-3 days). It is also independent of the seasonality meaning briquettes can be produced throughout the year without disruption. The upfront cost of purchasing the dryer is high and the operational cost of electricity but is highly efficient in large-scale production of briquettes. The driers will also be used in drying the briquettes.

3 Production site

The CPF will require space for setting up the briquetting machines, storage of the feedstock and briquettes, and for drying among briquettes and feedstock among other things. The CPF can first lease a piece of land during the pilot phase and if the pilot is successful, it can explore the cost of purchasing land. From online searches, a commercial property in an industrial area can range between KES 100,000-500,000 per month. We use the upper limit to estimate the cost of leasing land for one year.

4 Briquetting process

The following activities will be carried out; (i) carbonisation of bagasse; (ii) mixing of the feedstock with a binder; (iii) compacting of feedstock to briquettes; (iv) drying of the briquettes and; (v) packaging of briquettes. Since the aim is to have large-scale production of briquettes, the briquetting equipment recommended at each step are those of high efficiency and most of them must be imported. The range of equipment required include: carbonisation furnace, an electrical mixer, an extruder briquetting press (manufactured and distributed by C.F Nielsen) for compacting of the feedstock and, a briquette-packaging machine. The briquettes will be packed into 2 kg and 5 kg branded packets to build consumer confidence.

5 Cost of Labour

The CPF will require both permanent and temporary workers. To estimate the annual cost of salaries it is assumed that this facility is a medium sized industry less than 250 employees)[222]. Since most of the operations will be mechanized, we estimate that on average the facility will have 100 employees with an average monthly salary of KES 50,000. Technical experts and skilled personnel will be required to oversee the production and administrative process while semi-skilled will be required in the operating machines, packaging and distribution of briquettes.

6 Distribution of briquettes

Various methods of distributing the briquettes can be employed. Direct sales for the households close to the CPF; use of agents e.g., mini-shops that are already in existence and sell other commodities; door-to-door agents and a mobile distribution truck that sets up

220 Key Informant Interviews

221 Costing and specification of the equipments Retrieved from WWW.Alibaba.Com

222 OECD data. Retrieved from https://stats.oecd.org/glossary/detail.asp?ID=3123

during a designated market day and digital marketing on different platforms. The door-to- door agents will be common during the initial time of the project but as people become more aware of the briquettes and more stockists start to take up the fuel, they will be gradually eliminated.

7 Creation of awareness

Extensive creation of awareness to households must be conducted as explained under section 1.1.6. The creation of awareness should aim to ensure that; (i) consumers are aware of different briquettes types, (ii) highlight the benefits of briquettes relative to other fuels, (iii) demonstrate how briquettes are best-used i.e., easy ways to light the briquettes and, (iv) the right type of stoves to use the briquettes in. This will be done through use of roadshows, radio adverts and billboards.

8 Other costs

Other costs considered in the costing of the scenario include administration cost, briquette testing costs and acquisition of the KEBs standardization mark. This is estimated at 1 % of the total cost of this scenario.

Following the steps of production explained above Table 40 below provides estimates for production of carbonised briquettes.

Table 40: Estimate of the setting up the CPF for carbonised briquettes and operation cost for the first year

#	Item	Quantity	Unit Cost (USD)	Total Cost (USD)	Assumptions
1	Bagasse	34000	6	204,000	70% loss during carbonisation
2	Trips per year	52	1,00	5,200	One trip per week
3	Leasing of land/ month	12	2,0S00	24,000	Monthly rent for the production site
4	Carbonisation furnace	8	15,000	120,000	Capacity of the furnace 12 tonnes and takes 6-8 hours to carbonize.
5	Electric mixer	1	20,000	20,000	Mix 40 tonnes of the waste per hour
6	High-capacity briquetting machine	1	100,000	100,000	22 tonnes per hour
7	Cost of packaging machine	2	7,000	14,000	Packed into 2 Kg packets for household use
8	Drier (vertical)	1	35,000	35,000	4 tonnes per hour capacity
9	Branded packets	10,000,000	0	1,000,000	Labelled packets to win consumer confidence
10	Cost of labour	100	6,000	600,000	Most of the operations will be mechanized
11	Creation of awareness			70,000	5 roadshows each at USD 10,000 Billboards- USD 2,000 per month for 5 months 10,000 Radio adverts etc- USD 1000 per week, 10 times 10,000
12	Administration cost			350,810	10% of the operational total cost
13	**Total Cost**			**2,192,200**	

6.2.2 Non-carbonised Briquettes for industrial use

An alternative pathway under this scenario is the production of non-carbonised briquettes for industrial or institutional use. Thermal intensive factories have been keen on reducing the use of firewood by substituting it with briquettes. The fluctuating costs of furnace oil have led to these factories looking for alternative sources of thermal energy. Tea factories are among these end-users of solid biomass. Unlike carbonised briquettes, production of non-carbonised briquettes does not require carbonising equipment, binders and mixers are not required. Since the briquettes are sold to large scale consumers of briquettes no packaging machines or associated packaging cost is required. Extensive consumer awareness required for household briquettes which is costly is also eliminated under this pathway. This reduces the cost of production by 80% as shown below.

Table 41: Estimate of the setting up the CPF for non-carbonised briquettes and operation cost for the first year

#	Item	Quantity	Unit Cost (USD)	Total Cost (USD)	Assumptions
1	Bagasse	21,000	6	126,000	95% conversion rate of bagasse to briquettes
2	Trips per year	52	1,000	52,00	One trip per week
3	Leasing of land/month	12	2,000	24,000	Monthly rent for the production site
4	Mechanical briquetting machines	1	500,000	500,000	7 tonnes per hour, operation of 10 hours
5	Cost of labour	100	6,000	600,000	Most of the operations will be mechanized
6	Administration cost	21,000	6	125,520	10% of the total cost
7	Total cost			1,380,720	

6.2.3 Risks for the scenarios

1 **Availability of bagasse**

The volatility of the sugar industry in Kenya may influence the availability of bagasse. The strained relationship between the farmers and the millers has resulted to farmers switching to other crops due to delayed payment and the low prices of the sugarcane in the past. This has seen the closure of some of the major state-owned millers in the country such as Miwani (which was closed 20 years ago), Mumias Sugar, which was closed for 20 months but was, reopened early 2020 and Chemelil had closed for 8 months[223]. The government, in order to investigate the reforms that can be implemented to revive the sector created a task force. The task force report was completed and presented to the president in February 2020 with key recommendations being; the re-introduction of the sugar levy, privatization of public sugar mills to enhance their efficiency and the enactment of the Sugar Act[224]. The farmers are however opposed to one of the recommendations that introduces zoning of sugar producing regions. This restricts the farmers from selling their produce to the highest bidder and those who pay promptly. As such, they are threatening to uproot their sugarcane and utilize the land for other economic activities. If these grievances are addressed and the reforms addressed, then the sector may be revived in a few years to come. Otherwise, the sector will continue to witness a decrease in the land area under sugar production. Further, sugarcane farming in the country is rain fed and hence the quantities produced depend greatly on the prevailing weather conditions

223 As reported by the local newspaper

224 Soko Directory. 2020. March Monthly Report. Retrieved from https://sokodirectory.com/wp-content/uploads/2020/03/March-Soko-Monthly-Report-1.pdf

6.3 Scenario 3: Experimenting with new raw materials

The common raw materials used for briquette production include; macadamia nut shells, sawdust, charcoal dust, bagasse, maize cobs and paper waste (producers interviewed for this study). Use of faecal waste as a raw material for briquette production is a new concept in Kenya. This study established two companies (Sanivation and Nawasscoal) that use faecal matter as one of their raw materials for briquetting. From literature review, municipal waste has also been viewed as a possible raw material for briquette production. This scenario explores the emerging raw materials for briquette production.

Municipal solid waste that can be used for the manufacturing of briquette include organic waste (vegetables, legumes, tubers, grains, fruits and other biodegradable materials), biodegradable paper, plastic and human waste among others. The sources of these wastes include households, small food stalls, markets, restaurants, institutions (schools, offices etc) among others. Wastepaper is the most commonly used waste stream for briquetting. One of the main challenges at present is obtaining quality feedstock from municipal solid waste. The contamination is due to the lack of sorting and segregation from source. Another hurdle in obtaining adequate resource, is other competing uses of the waste. Wastepaper has a robust recycling system which limits the availability of the raw material. Organic waste recovery through composting and gasification is a focal point of implementation in the integrated solid waste management plan of Nairobi while plastics though essential in raising the calorific value of briquettes may cause pollution during combustion and use, thus further investigation on emissions is necessary to ensure that their use in briquetting is safe. Large-scale projects on waste project such as that being implemented by ASTICOM K Ltd[225] and the plans by KenGen[226] and Nairobi City Council on generating electricity from garbage pose a threat to availability of the waste.

In the recent past, briquette producers have been exploring the use of faecal waste for production of briquettes. Sanivation Limited has been producing briquettes from faecal matter for household users in Kakuma refugee camp and low-income areas of Naivasha. Nakuru Water and Sanitation Services Company is involved in faecal sludge management through its subsidiary company Nawasscoal that produces carbonised briquettes for household and small enterprises consumption. This is viewed as a solution to the challenge of sanitation in urban areas and a source of alternative cooking solution for low-income households[227].

Considering the hurdles involved in the use of municipal waste for briquette production (discussed above), this scenario seeks to explore the possibility of large-scale production of briquettes using faecal waste. The type of briquettes to be produced are carbonised briquettes for household use. This scenario is a build-up to the second scenario and the steps to be followed in the production process are similar to those described under section 2.2.1 with the major difference discussed in the section below.

1 Feedstock

Every day, water and sewerage companies such as Nairobi City Water and Sewerage Company (NCWSC) collect faecal sludge from households connected to the company's sewer system. NCWSC strategic plan for 2018/2019 aimed to collect, convey, treat and dispose 400,000 M^3 /day of wastewater in an environmentally friendly manner[228]. Ideally, the raw material for briquetting should be centrally located and thus sewerage companies form an ideal source of this waste. Sludge from households is the most suitable as it is not contaminated with heavy metals as is the case for industrial sludge. The waste must be carbonised to increase the energy content and reduce the ash content.

225 Astitcom. Waste to Energy Project Summary. Retrieved from http://asticom.org/index.php/about-us#:~:text=ASTICOM%20K%20Ltd%20was%20established,and%20livestock%20waste%20or%20manure.

226 Brian Ngugi. (27 August 2020). KenGen, Nairobi Metropolitan Service (NMS) pen deal to tap power from garbage. Business Daily.

227 Njenga, M. Karahalios. T and Berner, C . (2018). Human Waste-to-fuel Briquettes as a Sanitation and Energy Solution for Refugee Camps and Informal Urban Settlements.

228 Nairobi City Water and Sewerage Company Limited. (2014). STRATEGIC PLAN 2014/15 – 2018/19. Retrieved from https://www.nairobiwater.co.ke/images/strategic_plan/NCWSC_2014-15_to_2018-19_Strategic_Plan.pdf

The waste must also be treated to kill the pathogens[229]. However, availability of these two raw materials (charcoal dust and sawdust) in Kenya is intermittent due to on and off bans on charcoal production and logging, competing uses for the sawdust. However, given the high quantities of bagasse, options of carbonizing it and using it together with the sludge for briquette production can be explored.

2 Production process

The production process for carbonised briquettes using the human waste is similar to the one described under scenario 2 with the only difference being in the pre-processing of the waste. For instance, the sludge has high moisture content of approximately 98%, requiring heavy investment in the drying of the waste. Solar drying through greenhouses is ideal type of drying. Extensive testing of the faecal matter to ensure that the briquettes are free of pathogens must be conducted during the initial stage of setting up the production facility. The facility must also acquire permits on handling of faecal matter in the production of the briquettes. Partnerships would also need to be formed between the CPF and the water and sewerage companies on how the acquisition of the sludge similar to the partnership between Nakuru Water and Sewerage Company (NAWASCO) and Nawasscoal.

3 Cost of production

As discussed above the production process is similar to those described in scenario 2 for carbonised briquettes. As such, the cost of production for a CPF based in Kisumu utilizing either sawdust, charcoal dust or carbonised bagasse is comparable to the budget under scenario 2 (carbonised briquettes USD 2,192,200) as the steps and technologies are very similar.

6.3.1 Risks for the scenarios

Most communities consider cooking with fuel from human waste a taboo. This can be mitigated through extensive public awareness creation. Demonstration and distribution of samples for testing by households to ensure that they do not smell and burn as normal charcoal should be part of the public awareness creation process.

6.4 Comparative Analysis of the Scenarios

This section compares the different scenarios described above with the aim of identifying the best pathway to promote briquette production and uptake in Kenya. This is achieved by evaluating the advantages and disadvantages of each scenario; cost of briquette production under the scenarios presented with the cost of charcoal and wood production and; market for carbonised and carbonised briquettes.

1 Carbonised briquettes vs non-carbonised briquettes

The cost of large-scale production of carbonised briquettes is high compared to that of non-carbonised briquettes holding all factors constant (e.g., feedstock, location of the CPF etc) as demonstrated under scenario 2. This is explained by the fact that additional processes such as carbonisation of the feedstock, mixing of the feedstock with the binders, packaging of the briquettes and awareness creation to a large consumer base are added to the production chain of carbonised briquettes. The use of additional distribution points to reach consumers who may be located further from the CPF requires the cost of the briquettes to marked-up for the distribution agent to earn a profit margin. These factors influence the pricing of the briquettes and may result in higher prices for the briquettes, making them less competitive to the cost of charcoal. Though few, consumers of non-carbonised briquettes take up large quantities of briquettes. This makes it easy to supply the fuel to them as they can directly source the briquettes from the production facility and extensive awareness creation is not required as in the case of household users.

From a point of use, briquettes for households have competing fuels that are affordable, consistently available and of a higher quality, (e.g., LPG and charcoal). Additionally, the more affordable and most commonly used stoves such as the Kenya Ceramic Jiko (KCJ) is noted to be unsuitable for burning briquettes. The well adaptable stoves such as improved charcoal stoves are relatively expensive retailing between KES 3,000-5,000, compared to the KCJ, which is KES 500-700. Since the aim is to replace charcoal fuel, the briquettes must compete with charcoal in terms of cost, availability and quality.

229 Asamoah, B., Nikiema, J, J, Gebrezgabher, S, Odonkor, Elsie and Njenga, M. (2016). A Review on Production, Marketing and Use of Fuel Briquettes. CGIAR Research Programme on Water, Land and Ecosystems (WLE), International Water Management Institute (IWMI).

This would partly be solved by ensuring the standards under development are adhered to during the production of the briquettes and proper labelling is done to allow consumers to identify the briquettes from the Central Production Facility (CPF). Fuel handling habits of consumers such as shaking and poking charcoal to improve aeration or using water to extinguish fire are noted to cause disintegration when applied to briquettes. Consumer awareness needs to extend to the appropriate handling of briquettes during use and the appropriate stove for burning the briquettes[230].

Demand for industrial briquettes is already in existence as industries aim to be energy secure. The need to be certified as environmentally conscious businesses is an incentive for industries such as tea factories as their products are more acceptable if sustainable production methods are employed in the processing of tea. The challenge with the use of briquettes for industrial use is that some types of briquettes (e.g., bagasse briquettes), form clinkers (resulting residue from unburnt biomass) which block the air vents of the boilers, which result in inefficiencies in its operation and add cost in cleaning the boilers. Industrial boilers would need to be retrofitted or new boilers installed that can efficiently burn the bagasse briquettes adopted. Table 42 below compares the two types of briquettes.

Table 42: Comparison of the types of briquettes

#	Type of briquettes	Target market	Strengths	Weakness
1	Carbonised briquettes	• Mainly Households • Small enterprises such as eateries and hotels	Added solution to the energy options at the household level	• Relatively expensive to produce compared to non-carbonised briquettes • Requires improved charcoal stove to burn without smoke is costly compared to the traditional charcoal stove • Existing competing fuels that are readily available, affordable and of high quality
2	Non-carbonised briquettes	• Industrial (tea factories) • Institutions (schools, prisons etc)	• Less cost of production compared to production cost of carbonised briquettes • Ready market as industries add sources of thermal energy to their energy mix to be energy secure due to volatility of the oil prices • Existence of incentives in the uptake of products that are sustainably produced e.g., tea	• Industrial boilers may need to be retrofitted or new boilers that can efficiently burn briquettes acquired.

230 Mwampamba T.H., Owen M. and Pigaht M. (2013). Opportunities, challenges and way forward for the charcoal briquettes industry in Sub-Saharan Africa. Energy for Sustainable Development 17 158 – 170.

2 Analysis of the scenarios presented

The sustainability of the scenarios is determined by the ability of the proposed interventions to be self-sustaining. For instance, scenarios 2 and 3 the central production facilities' profit margins should be sufficient to run their daily operations after the first three years (assuming they break even by the third year) of being in business.

The strengths of scenario 1 is the fact that the programme is working with briquette producers who have been in the sector for a while and have already established their niche. However, the successful implementation of the programme will be determined by the support accorded to the programme by the key actors in the sector and all the different components must be implemented in unison. For example, creation of demand should be implemented together with adherence to production of quality briquettes and production of quality briquettes should be complimented with creation of awareness. Implementation of parts of the programme will not result to realisation of the set objectives. The producers under the programme should also be able to out-last the period of the programme.

Scenario 2 and 3 present a case where large quantities of briquettes are injected to the market. This would address the huge deficit in the supply of briquettes in the country. Scenario 3 also provides a case for exploring the possibility of other raw materials that can be used for briquettes production to address the challenge of inconsistent availability of raw materials. The risk to this scenario 2 and 3 is that successful implementation of the CPF may lead to some of the small medium sized briquette producers being put out of business. This was one concern raised by one of the producers interviewed indicating that introduction of funded businesses destabilizes the market as they offer low priced briquettes that other producers cannot compete with. In case the funding is depleted and the business is not self-sustaining then supply of the briquettes is impacted. Table 43 below provides a summary of the three scenarios.

Table 43: Comparison of the proposed scenarios

#	Scenarios	Strengths	Weakness
1	Design and implementation of a national briquette production programme	• Working with already existing briquette producers increases the chances of success • The programme aligns with the government goal of promoting local manufacturing under the Big Four Agenda • The cost of implementation is lower compared to the other scenarios	• The success of the programme is tied to implementation of all the components described in the programme description e.g., creation of demand must go hand in hand with quality briquettes • Different actors have to buy into the idea. From briquette producers to policy makers, distributors and manufacturers of briquette equipment etc.
2	Setting a centralised briquetting facility	• Large quantities of briquettes are added to the market • Job creation for both women and youths	• Household briquettes face competition from alternative fuels and the business may fail if unable to compete with these fuels
3	Experimenting with new raw materials	• Large quantities of briquettes are added to the market • Job creation for both women and youths • A chance to identify a raw material that is available in large quantities • Improved sanitation • Can be replicated in other urban areas • Circular economy by promoting resource recovery from waste	• People's perception on briquettes from faecal matter may lead to disqualification of the briquettes before testing • Household briquettes face competition from alternative fuels and the business may fail if unable to compete with these fuels

3 Comparison of production cost for briquettes, wood and charcoal

It is difficult to compare the cost of wood and charcoal production with that of briquettes. For example, wood for household use is mainly from family farms (at no cost) and in most cases, the households use dry twigs as opposed to felling a tree. Factories that require wood sources it from private farms or acquire it from government forests Kenya Forest Service. Charcoal production is an informal sector in Kenya and is not capital intensive as briquette production. The pre-processing, drying of waste, mixing with a binder and compacting are mechanized processes in briquette production and taxations adds to the capital for start-up businesses and the daily operation of the business. For this reason, briquettes prices are unable to compete with charcoal and wood as currently constituted, however, if the charcoal regulations of 2009 are enforced, there is an opportunity for the briquette sector to compete effectively.

6.5 Conclusion

The three scenarios described above present opportunities that can be employed to grow the briquettes sector. It is a requisite for the prevalent barriers in the sector to be addressed first for the scenarios to be successful. For example, if the issue on quality of household briquettes is not adequately addressed, adoption of the fuel to the energy mix will still be low. Producing quality briquettes without creation of awareness about the products will not result to the required uptake of briquettes for household use.

Production of briquettes for industrial use is less costly and the risk of failure is low compared to carbonised briquettes for household use. There is a ready market for industrial briquettes as industries seek to be more energy secure due to the fluctuating oil prices. On the other hand, scenarios with briquettes for household use have to navigate through the various hurdles in the sector limiting their chances of success. However, if the briquettes for household use are able to withstand the challenges in the sector then there will be greater impact in terms of cleaner cooking solutions at the household level.

More than one type of scenario can be implemented. For example, the formation of a central briquette production facility would greatly benefit from the activities under the national briquette programme.


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7 Assessment of the Policy Framework for Briquette Production in Kenya

The discussion on policies that govern briquette production in the country has been structured such that it begins from a broad perspective and narrows down to the specific policies and standards for the sector. This is achieved by discussing policy, legal and institutions framework that influence the briquettes subsector, cascading from the international, to regional, to national and finally to the sub-national level. Policy, legal and institutional frameworks discussed are those that can have direct impact in the production of briquettes such as those that affect availability of feedstock by limiting their generation and transportation or indirectly such as those that promote the general use of alternative fuel sources. These are reviewed to identify gaps and opportunities that can be recommended to encourage investment in and/or uptake of briquettes making and use. Policy and regulation experts for example, government officials from the Ministry of Energy, Energy and Petroleum Regulatory Authority and Kenya Bureau of Standards were interviewed to gather opinions on how briquette production can be fostered and regulated. Other key stakeholders including programme implementers such as SNV, Energy 4 Impact and the Clean Association of Kenya were consulted on their experience with the briquette sector. A full list Key Informants interviewed has been provided in the annex.

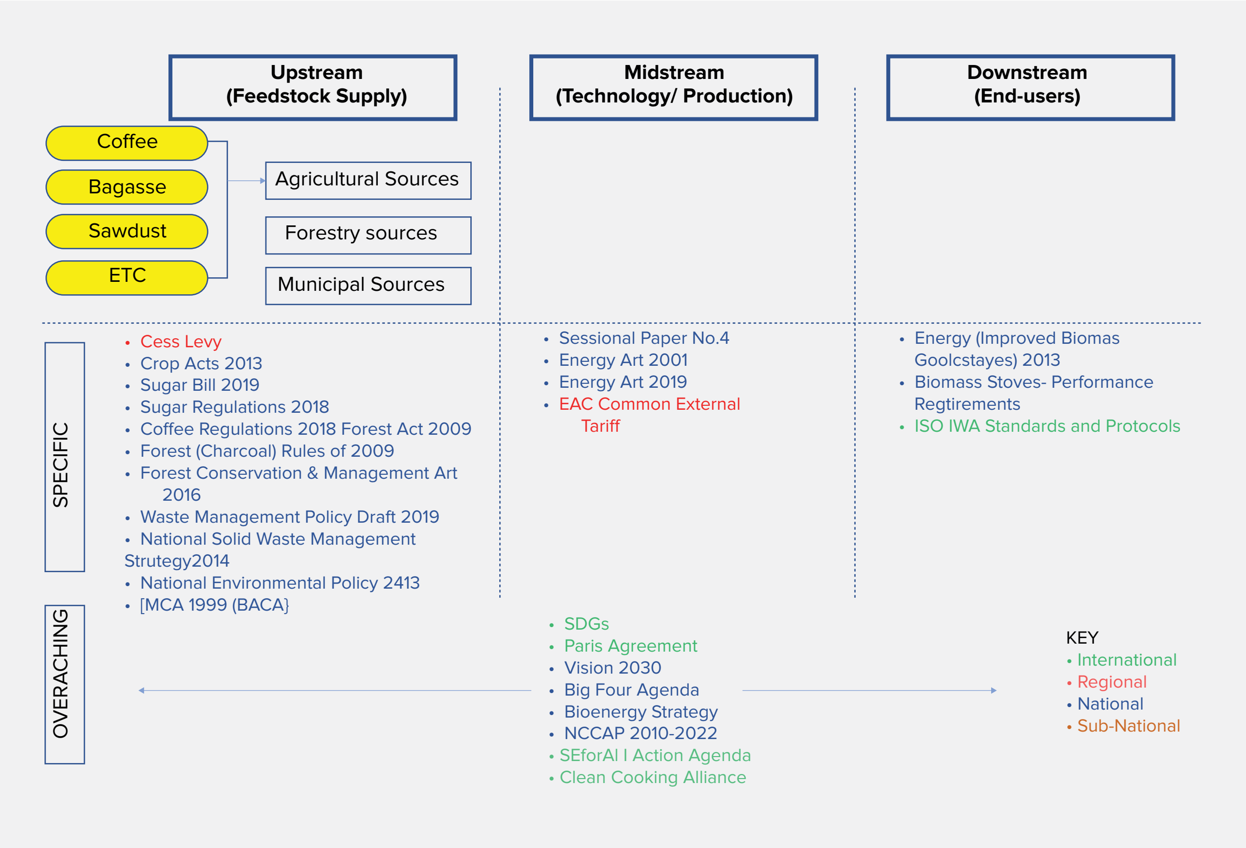

Figure 27: Summary of Polices and Frameworks Governing Briquette Production and Use in Kenya

7.1 International Frameworks

7.1.1 Sustainable Development Frameworks (SDGs)

The Sustainable Development Goals is a universal call of action to end poverty, protect the planet and ensure that all people enjoy peace by 2030. SDG 7 goal recognizes the importance of access to energy in both economic development and in improved leaving standards. This goal aims to ensure access to affordable, reliable, sustainable and modern energy for all. Upon this basis countries have developed the Sustainable Energy for All Action Agenda, detailing the transition to clean energy for lighting and cooking and subsequent investments that would be required. For instance, Kenya under its SEforALL Action Agenda has set a target of achieving a 100% access to modern cooking solutions by 2030 with 2013 as the baseline year. This target will be achieved partly through increased adoption of improved clean cookstoves and fuels and through reviewing and developing the biomass strategies[231].

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

7.1.2 Paris Agreement

Adopted in 2015, this environmental accord provides a framework to address the impacts of climate change by substantially reducing greenhouse gas emissions while limiting the global temperature increase in this century to below 2°C. Ratified by 189[232] countries, the agreement provides for individual commitments by countries in reducing GHG emissions in the form of nationally determined contributions (NDC). Kenya submitted its INDC in 2015 with an ambitious target of abating its GHG emissions by 30% by 2030 relative to the business-as-usual scenario of 143 MtCO2eq. Moreover, under its Climate Change Action Plan, the government has identified the energy sector as one of the most important sectors in meeting this target. Within the energy sector, transition to clean cooking has been highlighted as a priority action with great environmental and health benefits. The plan also promotes green manufacturing for waste management and resource efficiency including sustainable briquette production.

CLEAN COOKING ALLIANCE

Clean Cooking Alliance

The Clean Cooking Alliance is a global network of partners that was established in 2010 with a mandate to promote the development of clean cooking markets for the three billion people still using traditional cooking technologies[233]. The partners are from governments, private sector, Non-Governmental Organisation (NGOs), donors, humanitarian organisations, multilateral, civil society, and academic institutions. The Alliance's work is centred around the following three pillars[234]:

- Driving consumer demand for cleaner cooking solutions (stoves and fuels) by supporting behaviour change and raising consumer awareness;
- Mobilizing investment to build a pipeline of scalable businesses capable of delivering affordable, appropriate, high-quality clean cooking technologies and;
- Promoting an enabling environment for industry growth by advocating for effective and predictable policies, providing trusted, relevant data, and serving as the convener and champion of the clean cooking sector.

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231 Ministry of Energy and Petroleum. 2016. Sustainable Energy for All (SEforALL) Kenya Action Agenda. Retrieved from https://www.seforall.org/sites/default/files/Kenya_AA_EN_Released.pdf

232 United Nations Framework Convention on Climate Change (n.d) Paris Agreement-Status of Ratification retrieved from https://unfccc.int/process/the-paris-agreement/status-of-ratification

233 The Clean Cooking Alliance. About Us. Retrieved from https://www.cleancookingalliance.org/about/

234 Ibid

Under the practice line of technology and fuels, the Alliance; strengthens national policies that support the standards and testing protocols for stoves and fuels to foster innovation; provides information on testing protocols for the different stoves and fuels; provides support to the Regional Testing and Knowledge Centres (RKTC) and; provide information on the cookstove designs, prices, manufacturers and stove performance on an on-line clean cooking catalogue. Under research and evaluation, the Alliance provides evidence to demonstrate that uptake of clean cooking solutions impacts on the health of the population[235]

ISO Standards and Test Protocols

The international Organisation for Standardization (ISO) which is a worldwide federation of national standards and bodies has developed several standards on fuels and technologies. In particular ISO developed ISO 17225 (Solid biofuels — Fuel specifications and classes) series in 2014 to provide unambiguous and clear classification principles for solid biofuels. Divided into seven parts, the series covers both pellets and briquettes. Part 3 is specific to non-carbonised briquettes from graded wood including forest, plantation and other virgin wood; by-products and residues from wood processing industry and chemically untreated used wood while Part 7 is on non-carbonised briquettes from graded non-woody including herbaceous biomass-which is biomass from plants that have non-woody stems such as grains and or seeds crops from food production and their by-products such as cereals; fruit biomass, aquatic biomass or biomass blends and mixtures .

International Standards Organisation (ISO) International Workshop Agreement (IWA) on Cookstoves in 2012 led to several resolutions on cookstove testing including using multiple options from a set of internationally-recognized laboratory protocols most appropriate for the stove and performance indicator being tested rather than using a single test. Additionally, IWA established tiers of ranking stove performance based on four criteria: efficiency, total emissions, indoor emissions and safety. To measure and monitor these parameters, ISO developed the *ISO 19867-1:2018- Clean cookstoves and clean cooking solutions — Harmonized laboratory test protocols — Part 1: Standard test sequence for emissions and performance, safety and durability* which Kenya has adopted and uses as the basis for carrying out performance tests for biomass cookstoves in the country.

Table 44:ISO-IWA Five tiers of stoves

#	Tier	Description
1	Tier 0	No improvement over open Fire/Baseline
2	Tier 1	Measurable improvement over Baseline
3	Tier 2	Substantial Improvement over Baseline
4	Tier 3	Currently achievable technology for Biomass stoves
5	Tier 4	Stretch goals for Targeting Ambitious Health and Environmental Outcomes

7.2 Regional policies and frameworks

East African Community regional bloc is keen on promoting economic development among its member countries and operate across four integration pillars: customs union, common market, monetary union and political federation. The Common Markets Integration pillar provides freedoms and rights for movement of all factors of production within the EAC. EAC acknowledges that Energy is at the centre of economic development and has set it up as one of the sectors under the common market pillar. To this effect, the EAC has, among other things developed the Regional Strategy on Scaling Up Access to Modern Energy Services. Adopted by EAC Council of Ministers in November 2016, promotes adoption of high impact, low-cost scalable approaches. Among other things, the plan targets to increase access to modern cooking practices for 50% of traditional biomass users. Though well intended, the strategy proved to be limited in terms of enforcement and funding and it also failed to provide a clear roadmap on how implement the strategy for member states. EAC also established East African Centre for Renewable Energy and Energy Efficiency (EACREEE) in 2016 (legally registered in March 2018) which develops and promotes adoption of policies, legal and incentive frameworks, capacity development, and mobilization and implementation of infrastructure that promotes renewable energy and energy efficiency.

235 The Clean Cooking Alliance. Retrieved from https://www.cleancookingalliance.org/resources/463.html

Under the Customs Union Integration Pillar which establishes free trade on goods and services within the bloc, EAC amended custom duties and the custom external tariff (CET) with the new tariffs coming into effect from 1 July 2018. Relevant to the cooking sector was the zero-rating (0% import duty) of inputs and raw materials for use in the manufacture of energy saving stoves imported by gazetted users in all EAC Parties except Tanzania. Additionally, the policy includes country specific CET duty rates effective for one-year period starting from 1 July 2018 that have been approved to address country specific economic needs. Among these duty rates is the imposition of a 35% import duty on complete sets of non-electric cooking appliances including stoves for Kenya. This change in tax policies revised the government's 2016 decision to reduce import tax on complete stoves and parts from 25% to 10%. Tax on parts for manufacturing stoves was, however, maintained at 10%. These revisions have significant effect on the adoption of the cooking appliances in question.

7.3 National policies and frameworks

These have been broadly categorized into three groups: (i) Development Initiatives, which focuses on strategies that promote sustainable economic development within the country; (ii) Policies and regulations that govern feedstock supply such as policies on waste management, agriculture and forestry; energy access and development and (iii) Regulations of fuels and cooking technologies including standards for briquette production and for biomass cookstoves. These are further discussed below.

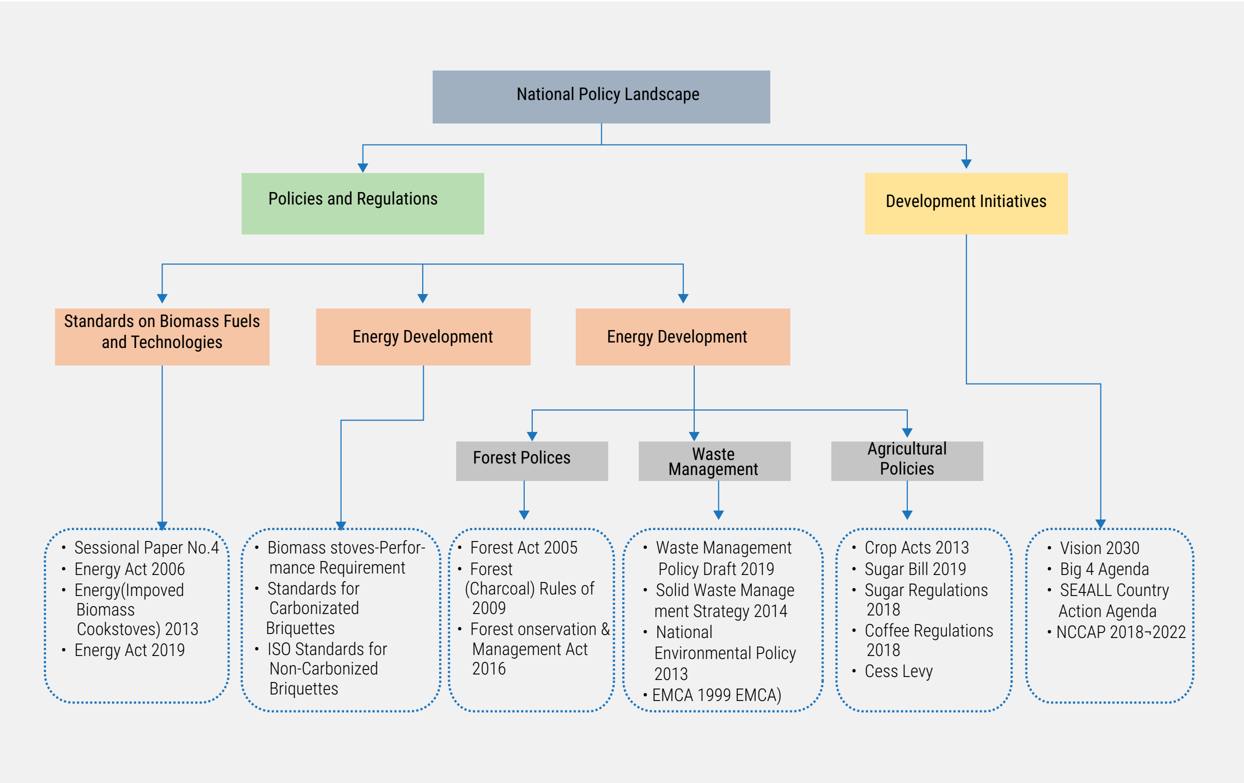


Figure 28: Summary of National Policies Governing Briquette Production in Kenya

7.3.1 Development Initiatives

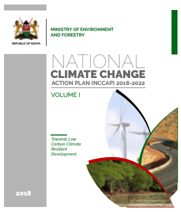
Vision 2030

Kenya's blueprint for development, Vision 2030 aims to transform the country a middle-income industrialized country by 2030. Under its economic pillar it identifies agriculture as one of the sectors to drive economic growth in the country. Expanding land under irrigation is one of the initiatives to increase agricultural output in the country. According to the Plan, at least 404,800 hectares were to be put under irrigation by 2017 especially in the Arid and Semi-Arid areas. Data on progress from the Medium-Term Plan III, indicates that an additional 51,600 hectares of land is under irrigation through the Galana-Kulalu flagship project; National Expanded Irrigation Programmeme (NEIP); and Community Based Smallholder Irrigation Projects[236].

Additionally, the Development Plan also seeks to create a manufacturing sector that is robust, diversified and competitive with the main objective of increasing the contribution of the sector to the GDP by 10% per annum. It underscores the importance of the Small and Medium Enterprises (SMEs) subsector in the country's industrial transformation agenda and is keen on developing SME industrial parks to promote local manufacturing.

This Plan further takes into consideration the need of a clean, secure and sustainable environments as necessity even as the country industrializes. Under its flagship projects it included the development of Solid Waste Management systems in five major cities: Mombasa, Kisumu, Eldoret, Nakuru and Thika. As of 2018, a national framework for solid waste management had been developed and county governments are using this as the basis for developing their environmental laws. Moreover, at least three waste management and pollution control plans have been developed at the county level and their implementation is ongoing.

These projects are expected to increase the feedstock supply from agro-based sources and from municipal waste for briquette production and also support growth of the enterprises within the sector through the provisions to promote the SME subsector.



National Climate Change Action Plan, 2018-2022

The MoE, 2019 report estimates that total annual greenhouse gas (GHG) emissions from residential cooking fuels is 13.6 MtCO2e (excluding black carbon, organic carbon and nitrogen oxides). In line with Kenya's Nationally Determined Contributions (NDCs) which aims to reduce greenhouse gas (GHG) emissions by 30% by 2030 relative to the business as usual (BAU) scenario of 143 MtCO2e, the National Climate Change Action Plan 2018-2022 (NCCAP) prioritizes clean cooking as high potential GHG abatement source. Strategic Objective 4 of the NCCAP on increasing forest/tree cover to 10% of total land areas highlights a key challenge to be reliance on biomass for cooking which contributes to deforestation and forest degradation. Among its actions to address this challenge, the NCCAP aims at "developing alternative technologies to reduce demand for biomass, such as clean cooking, briquetting and efficient charcoal production." Clean Cooking is also prioritized under Climate Change Priority 7 which aims to support a "transition to clean cooking through uptake of LPG, ethanol, and other alternative fuels in urban areas, and uptake of briquettes…" The cooking sector is therefore a significant sector in meeting Kenya's NDCs, and the place for briquettes is clearly outlined in the country's strategic documents. The Action Plan further highlights the potential benefits of using briquettes including cost saving on energy expenditures by households. It estimates that to cook a meal of maize and beans for a family of five, it would require charcoal briquettes worth KES 3 compared to KES 26 and KES 45 for charcoal and kerosene respectively.

236 Government of Kenya, The National Treasury and Planning: Third Medium Term Plan (2018-2022). Retrieved from https://planning.go.ke/wp-content/uploads/2018/12/THIRD-MEDIUM-TERM-PLAN-2018-2022.pdf

In addition to the energy sector, the Action Plan also identifies waste sector as a contributor of the national greenhouse gas emissions (GHG) and projects that about 3% of Kenya's GHG emissions from 2015 to 2030 will be from the waste sector, mostly as a result of methane generation from solid waste dumpsites, sewage and wastewater disposal. This represents an increase in GHG emissions from the waste sector from 2 MtCO2e per year in 2010 to 4 MtCO2e in 2030. The Plan aims to achieve reductions of up to 0.72 MtCO2 e by 2022 through mitigation actions to reduce and recycle solid waste, green buildings, and exploring options for methane capture and power generation. The use or conversion of this waste has the potential of significantly reducing the GHG attributed to this sector. The manufacturing of briquettes is one way of utilising this resource.

THE BIG 4

Big Four Agenda and Medium-Term Plan (MTP) III (2018-2022)

The Big Four Agenda, which is President Uhuru Kenyatta's development blueprint covers four priority areas: manufacturing, food security, housing which have been highlighted and frontloaded under the vision 2030. Under the food and nutrition security, the government targets to achieve universal food security by 2022. To achieve that, several strategies will be employed including enhancing large scale agricultural production, advancing small holder productivity and reducing the cost of food.

As part of expanding large scale production, an additional 700,000 acres of land through public private partnership (including idle arable land) will be put under maize, potato, rice, cotton, aquaculture and animal feed production. This will be completed by strengthening of the value chain through increasing the number of SMEs that could add valued to the primary product. The plan targets to set up about 100 enterprises in this regard[237]. Specific attention has been given to staple food crops such as rice, potatoes and maize. The government targets to increase production of maize from 40 million bags annually to 67 million bags; rice from around 125,000 metric tonnes currently to 400,000 metric tonnes and potatoes from the current 1.6 million tonnes to about 2.5 million by 2022[238].

The Agenda also recognizes the role of SMEs in *providing goods and services, value addition, enhancing competition, fostering innovation and generating employment leading to alleviation of poverty*[239]. To support the development of this sector, the agenda proposes three strategies, two of which are[240]:

i) Facilitating business compliance with regulations to formalize the informal economy by

- Promoting simplification of business startup procedures;
- Encouraging informal industries and associations to register with Micro and Small Enterprise Authority (MSEA) and use this body to voice the concerns and ideas of the sub-sector;
- Establishing incubation centres for SMEs in all 47 counties in order to resolve issues such as product design, access to technology, production innovation and patenting;
- Reducing barriers to registration through formulation of a policy that simplifies and spells out the registration process; and provide
- Corporate tax relief for start-up SMEs for the first three years of operation

ii) Enhancing credit and market access to SMEs by

- Rethinking and updating risk assessment tools, especially when assessing SMEs;
- Offer loan guarantees to SMEs;
- Incentivize commercial banks to provide low interest rate loans targeting manufacturers and SMEs;
- Encourage Kenya Credit Reference bureaus to work closely with manufacturers in determining credit worthiness.

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237 Government of Kenya. 2017. "The Big Four"-Immediate Priorities and Actions

238 Parliamentary Service Commission: Eye on the 'Big Four', Budget Watch for 2018/2019 and the Medium Term. Retrieved from http://www.parliament.go.ke/sites/default/files/2018-09/Budget%20Watch%202018.pdf

239 Kenya Association of Manufacturers. 2018. Manufacturing Priority Agenda 2018. Retrieved from https://kam.co.ke/kam/wp-content/uploads/2018/02/2018-Manufacturing-Priority-Agenda.pdf

240 Ibid

The Medium-Term Plan III (2018-2022) which builds on the achievements of the first and second MTPs, has been designed to serve as the conduit for achieving the Big Four initiatives. The plan targets to irrigate 1.2 million acres to increase the area under crop production.

The planned agricultural expansion will ultimately result in increased generation of feedstock from the scheduled crops i.e. rice, maize and potatoes that could be used in briquette production. Further, the strategies to promote SMES's outlined above could also be instrumental in formalizing businesses in the briquette sector which are mostly informal and small-scale.

SEforALL Country Action Agenda

In response to the SE4ALL initiative launched in 2011, Kenya through the Ministry of Energy and in consultation with a wide range of stakeholders developed the SE4ALL Action Agenda that, among others, set energy sector under the three core areas: Energy Access, Renewable Energy and Energy Efficiency. Under this Action Agenda, Kenya aims to achieve universal access to modern energy for cooking by 2030. To achieve this the government is advocating for increased uptake and use of improved technologies and cleaner fuels in the country as has been highlighted under the National Climate Change Action Plan (2018-2022). Some of the relevant initiatives that were put forth in the Action Agenda in growing the cooking sector include[241]:

- Improving coordination across agencies, private sector, CSOs and NGOs with the aim of fostering an enabling environment by promoting standards and rigorous testing protocols; promoting industry standards for efficiency, safety, and emission reduction, based on testing and certification for clean cooking appliances, such as ICS and supporting continuous research on consumer use and demand for efficient stoves and on the design of products that meet user needs.
- Human and institutional capacity development for cookstoves including conduct awareness campaigns on the benefits of clean cooking appliances and fuels for remote/isolated populations and raising general awareness to the public about the available clean cooking technologies
- Innovative finance, to support financial closure and financing access to energy services and clean cookstoves such as developing financing schemes to provide credit to households that cannot afford the upfront costs of access to modern energy services and providing regulatory support for scalable and sustainable business and financial models.

Some of these initiatives are already being implemented such those touching on testing protocols and standards but there's room to do more especially awareness creation which has been cited as a major hurdle in the uptake of briquettes by households in Kenya.

7.3.2 Policies and regulations

Feedstock Supply

These are regulations and polices that directly or indirectly affects the availability, supply and quality of feedstock suitable for briquette production, and the transportation of inputs and finished products.

Waste Management Laws and Policies

Over the years there has been a remarkable evolution in the laws governing solid waste management in Kenya; from the initial Penal code of 1948 to more structured and devolved laws such as the draft National Sustainable Waste Management Policy, 2019. These national policies and frameworks have been supported by other by-laws and sectoral laws in governing the environment. Table 45 below summarizes the relevant policies and outlines their impacts on briquette production.

241 Ministry of Energy and Petroleum. 2016. Sustainable Energy for All (SEforALL) Kenya Action Agenda

Table 45: Summary of Waste Management Policies and their impact on briquette production

Policy	Highlights	Impact
Environmental Management and Coordination Act 1999 (EMCA)	• Provides a framework for environmental governance. • Established the National Environmental Management Authority (NEMA) • Provides guidelines on the transportation and re-use of solid waste (Section 87 part (2)	Encourages waste minimization and recycling
National Environmental Policy 2013	• Formulated by the Ministry of Environment, Water, and Natural Resources • Seeks to provide the framework for an integrated approach to planning and sustainable management of natural resources in the country. • Proposes three ways in which the government can deal with the growing solid waste in the country: i) developing an integrated national waste management strategy, ii) promoting use of economic incentives to manage waste and, iii) promoting establishment of facilities and incentives for cleaner production, waste recovery, recycling and re-use.	Provides an opportunity for briquette production as a way of recycling
National Solid Waste Management Strategy, 2014	• Developed by NEMA • The long-term goal of the strategy is to achieve approximately 80% waste recovery (recycling, composting, and waste to energy and 20% landfilling in a Sanitary landfill (inert material) by 2030. • Establishes the preferred order of solid waste management alternatives as follows: waste reduction, reuse, recycling, resource recovery, incineration, and landfilling.	Puts emphasis on waste reduction creating opportunity for recycling
Waste Management Policy Draft 2019	• The draft policy also acknowledges the: i) need to minimize waste at the source to reduce the amounts to be disposed ii) roles and the contribution of county governments in waste management in the country iii) benefits of economic incentives in waste management. • Under the re-cycling policy measures, it requires the national government to ‘initiate a mechanism for exempting recycling business and materials recovery sector from presumptive tax, turnover tax and recycled materials from VAT’.	Tax exemptions can spur more recycling for businesses that manufacture briquettes.

Agricultural Law and Policies

These regulations, policy and legal instruments, and strategies are all directed towards increasing agricultural production and in turn they determine the amounts of feedstock that can be generated from the agricultural sector.

Table 46: Summary of Agricultural Policies and their impact on briquette production

Policy/Regulation	Highlights	Impact
Agricultural Sector Transformation and Growth Strategy, 2019-2029	• Provides a road map in realizing the objectives on food security set forth under vision 2030, Big Four Agenda and Medium-Term III Plan. • Under its flagship projects it aims to have an additional 40,000 acres under irrigation for small-scale farmers and 150,000 for large private farms. • It also plans to unlock 50 new large-scale private firms with land sizes greater than 2,500 and to set up least six large scale agro-processing hubs through Public Private Partnerships • It gives prominence to Maize as a significant crop given its role as a staple food in the country	Increase in available feedstock due to increased food production and processing.
Agriculture, Fisheries and Food Authority Act and Crops Act 2013	• Provide the legal framework for the agricultural sector • The Agriculture, Fisheries and Food Authority Act of 2013 under section 3 established the Agriculture and Food Authority (AFA) • Agricultural Food Authority (AFA) oversees the sector and among other things is in charge of promotion and regulation of scheduled crops which include barley, wheat, maize, rice, sugarcane among others • Crops Act 2013 provide for the growth and development of agricultural crops and for connected purposes	Agriculture and Food Authority (AFA) can give directives to increase production of a particular crop hence affecting the amount of waste/feedstock available.
Crops (Sugar) (General) Regulations, 2018	• Outlines the functions of the sugar directorate created through the Crops Act 2013 • The directorate is charged with responsibilities that include but not limited to: i) regulating, developing and promoting the industry; ii) formulating and implementing overall policies and plans for the development of the industry; iii) regulating the export and import of sugar and the by-products of sugar into the country.	Increased importation of sugar could lead to decrease in the amounts of bagasse available for briquette production and the other uses.
Sugar Bill 2019	• Reinstates the Sugar Board that had been repealed and transformed into a directorate under the Agriculture and Food Authority by the Crops Act 2013 and proposes that the board should act independent of AFA; • It re-introduces the sugar development levy on both domestic and imported sugar and gives growers a right to management of the sugar factories- 51% shareholding of all privatized sugar factories.	The Bill could lead to a revival of the sugar industry hence increasing production with a resultant effect of increased feedstock for possible briquette production
Crops (Coffee) (General) Regulations, 2018	• Provides regulation for coffee industry in Kenya • The Food and Agriculture Authority and the county government are ‘to develop and promote strategies for the coffee industry’	Increased production of coffee could lead to more coffee husks which is already being used as a feedstock in production of briquettes.

Forest Management Laws and Policies

These policy and legal instruments are geared towards sustainable management of forests and to a great extent defines the amount of logging and harvesting activities from both public and private forests, and therefore the quantities of residues from wood processing. Charcoal production is also governed by these policies.

Table 47: Summary of Forest Management Policies and their impact on briquette production

Policy/Regulation	Provisions	Impact
Forest Conservation and Management Act 2016	• This policy promotes sustainable management of forests. • Among other things the Act regulates the production, transportation and marketing of charcoal. • According to the Act, anyone who "makes or is found in possession of charcoal in a national, county or provisional forest; or in community forest, private forest or farmlands without a license or permit of the owner" commits an offence. • Other campaigns such as use of woodmizers by sawmillers imposed by KFS and the ongoing logging ban are some of the strategies in place to meet the objectives of the Act.	Charcoal ban has led to reduction in the quantities of charcoal produced and subsequently charcoal dust Use of efficient wood processing technologies has also led to reduction in the quantities of available sawdust.
The Forest (Charcoal) Rules of 2009 and revised in 2012	• The Kenya Forest Service shall be the authority responsible for the issuance of licences for the production and transportation of charcoal • The regulations further require all commercial charcoal producers to organize themselves in charcoal producer associations • Advocates for sustainable production of charcoal through efficient kilns and woodland management/ reforestation • Charcoal wholesalers or retailers should not trade with unlicensed producers and should keep records of their sources of charcoal; charcoal producers are prohibited from use of endangered or threatened plant species in charcoal production	The associations are to ensure sustainable production of charcoal KFS currently requires permits for transportation of more than 3 bags of briquette
Forest Act 2005	• This has been replaced by the Forest Conservation and Management Act 2016 • Provides for the establishment, development and sustainable management, including conservation and rational utilization of forest resources for the socio-economic development of the country • Makes provision for the conservation and management of public and private forests and areas of forest land that require special protection.	Regulates forest utilization thus determining availability of waste such as wood waste and sawdust.

Energy Development

Several energy policies and laws remain supportive of renewable energy development including biomass sources and promote cleaner sources of fuel for cooking in Kenya. These are highlighted in Table 48 below:

Table 48: Summary of Energy Policies and their impact on briquette production

Policy/Regulation	Highlights	Impact
Sessional Paper No.4 on Energy, 2004	• It acknowledges the need to promote sustainable biomass harvesting using innovative technologies • It also acknowledges the potential that exists in the use of forestry residue, agricultural waste and municipal waste to generate electricity that can be fed into the grid • Proposes adoption of waste to energy management strategies as a means for waste management. • Promote private sector participation in energy production, distribution and marketing	Though the focus is on generation of electricity, it provides a basis for utilization of biomass for cooking through innovative technologies.
Energy Act 2006	• Established the Rural Electrification Authority (now Rural Electrification and Renewable Energy Corporation) whose mandate is to promote the use of renewable energy such as biomass, wind, solar, hydro among others • Mandates minister for energy to provide an enabling framework for the efficient and sustainable production, distribution and marketing of biomass. • This has been replaced by the Energy Act 2019 (below)	REREC could promote research on briquettes as alternative fuels for households
Energy (Improved Biomass Cookstoves) Regulations 2013	• The regulations are intended for manufacturers, importers, distributors, technicians, and contractors of improved Biomass Cookstoves, and institutions using biomass fuels for cooking and heating purposes. • It makes provision in regulating: i) Licensing of manufacturers, importers, distributors, technicians, and contractors of improved biomass cookstoves, ii) Warranties to customers and iii) Disposal of stoves following other prevailing national environmental laws	
Energy Act 2019	• Provides for the use of renewable energy such as biomass and provides for an enabling framework for the efficient and sustainable production, distribution and marketing of biomass. • It also establishes the Rural Electrification and Energy Corporation and tasks it to develop, promote and manage the use of renewable energy and technologies, including biomass-biodiesel, bio-ethanol, charcoal, fuel-wood, biogas • It also outlines the functions of county governments which include: i) Developing and submitting a county energy plan of its energy requirements; ii) Regulating and licensing of biomass production iii) Transport and distribution and regulating and licensing of charcoal production, transportation and distribution.	• REREC could promote research on briquettes as alternative fuels for households • County governments have the opportunity to identify and suitable energy sources for cooking in collaboration with REREC.

Bio-energy Strategy 2019 (Still under development)	• The strategy aims to support the country in meeting its NDC under the Paris Agreement • Provides renewable energy priority and action to deliver modern energy solutions at the National and County governments • Briquettes are part of the technologies to be promoted • Outlines 4 main areas of interventions which are Bioenergy supply and demand management; Bioenergy policy and regulatory framework and Financing for bioenergy programmemes and projects • Acknowledges the need for collaborative actions by various actors including National and County Governments. • Covers communication and knowledge management for the sector	• Communication will help create awareness for the briquettes • Collaboration with the different actors in the sector will enable address the different barriers across the value chain

Fuels and Technology

Kenya is making strides to regulate the cooking sector to ensure quality products are sold to the consumers while stimulating market growth and transformation. While the focus is on briquette fuels, this report also reviews standards on biomass cookstoves given most households burn their briquettes in these stoves. The current regulations on briquettes and related cooking technologies are discussed below:

Biomass stoves – Performance Requirements-DKS 1814:2019 (Third Edition)

Though still under development this standard provides specifications for production of both domestic and institutional biomass stoves. The specifications speak to the various components of a biomass stove including the cladding, the ceramic liners, the size of the pots that can be supported, and the insulation material between the liner and the cladding among others.

The standards further specify thermal and emission performance requirements for stoves. When tested according to ISO 19867-1, the thermal efficiency requirement for domestic stoves natural draft biomass stoves is at least 30% for charcoal ceramic stoves and 35% for other stoves. For institutional stoves, the standard requires that thermal efficiency should be at least 45% for all designs and sizes

A minimum of 45% efficiency is expected from forced draft domestic biomass stoves and all types of institutional biomass stoves. Regarding emissions, the performance requirement charcoal stoves are 137 mg/MJd and 25g/MJd for $PM_{2.5}$ and CO respectively.

The standard also touches on packaging and branding of stoves including information on the manufacturer, product name, manufacture date, serial number, thermal efficiency and the KEBS standardization mark. Stove delivery to the customer should include an instruction manual, packing list and warranty.

Briquette Standards

Kenya Bureau of Standards is currently developing regulations to guide briquette production in the country: *DKS 2912:2020 Solid biofuel — Sustainable Charcoal and carbonised briquettes for household and commercial use — Specification.* The standard specifies requirements for sustainable production of charcoal and carbonised briquettes from a range of feedstock including wood and by-products of wood processing, agricultural waste and solid waste.

From the standard some of quality requirements for the briquettes include

- Moisture content of sustainable charcoal and carbonised briquettes shall not exceed 10%;
- The volatile matter content shall not exceed 20% in the case of sustainable charcoal, and in the case of carbonised briquettes shall not exceed 25%;

- The ash content of sustainable charcoal shall not exceed 5% in the case of charcoal, and in the case of carbonised briquettes shall not exceed 27%;
- Fixed carbon content of sustainable charcoal shall not be less than 75 % in the case of charcoal, and 44% in the case of carbonised briquettes;
- The proportion of the contents that passes through a test sieve of aperture size 9.5 mm shall not exceed 5 % (by mass);
- The proportion of the contents that passes through a test sieve of aperture size 9.5 mm shall not exceed 7.5 % (by mass).

In addition to this, Kenya Bureau of standards adopted the ISO standards on solid biofuels Part 1-7 in 2015 to provide additional guidelines covering the non-carbonised briquettes from both wood and non-wood based feedstocks. These have been discussed under the ISO standards in section 2.2.4.

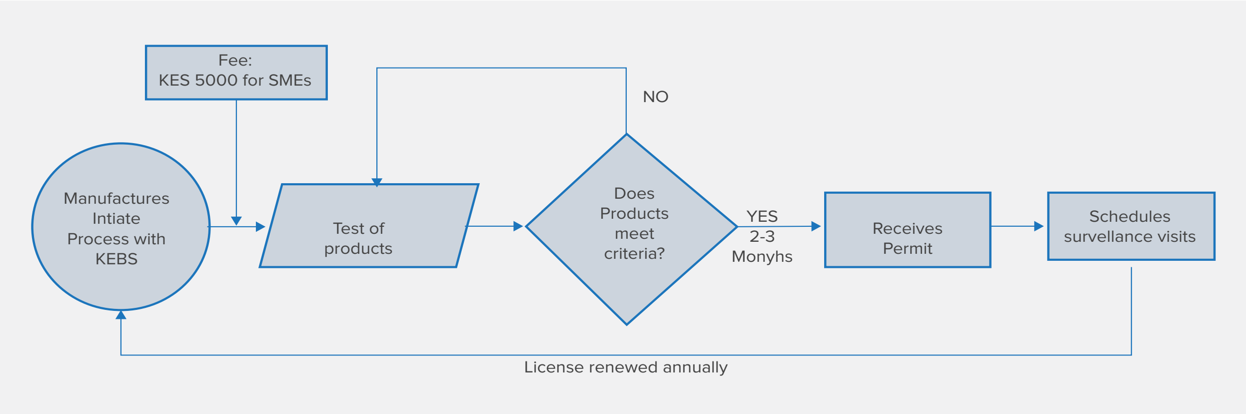

Figure 29: Process of obtaining KEBS Certification

7.4 Sub-national frameworks

Chapter eleven (11) of the constitution of Kenya creates a decentralized system of governance with the creation of 47 counties. The county governments constitute of a county assembly and county executive with the former having the following responsibilities:

- Exercising the powers of enacting laws at the county level;
- Acting as an oversight instrument on the county executive;
- Approval of plans and policies for smooth operation and management of resources and county institutions;

Devolution is further exemplified in laws and policies as can be seen from the Energy Act 2019, where among other things, the county governments are mandated with developing and submitting a county energy plan to the Ministry of Energy as part of the bottoms-up approach in national energy planning; regulating and licensing of biomass production; regulating and licensing of charcoal production, transportation and distribution. Additionally, the Waste Management Policy 2019, stipulates that among other things, county governments will: provide well managed central collection centres for materials that can be harvested from waste that can be reused; support waste management initiatives of the formalized groups through County Waste Funds; put in place mechanisms to ensure and enhance the participation of the youth and vulnerable groups in sustainable waste management. Through the County Integrated Development Plans, counties can advocate for preferred sources of energy that are readily available or matches their need.

Besides devolution, the constitution also gives directives on environmental management and conservation. Article 42 of the 2010 constitution states that 'every person has the right to a clean and healthy environment, which includes the right to have the environment protected for the benefit of present and future generations through legislative and other measures. This is further amplified under Article 70, which provides an enforcement of the right where it is being or is likely to be, denied, violated, infringed or threatened. Part 2 of the fourth schedule also explicitly provides that the County Governments shall be responsible for; refuse removal, refuse dumps and solid waste disposal. These efforts are all geared towards achieving a clean and healthy environment that is a target under the Vision 2030.

The County government is also in-charge of Cess levy which is a form of tax charged on movement of agricultural produce by local authorities. It was set under the Local Government Act cap of 1977 as a source of revenue for maintaining roads and other services related to the sector from which the Cess monies were levied[242] Though well intentioned, the levy is administered arbitrarily, and the rate varies from one locality to another. Moreover, county governments are taking advantage and are charging Cess levy not only on agricultural produce transported across counties but on all commodities as a general source of revenue. The result is increased cost of transportation of feedstock for briquette manufacturing

7.6 Gender perspectives

Women and men have different energy needs and demands; they have different access and control and play different roles in the energy sector. To ensure equitable and inclusive energy outcomes, gendered differences need to be mainstreamed in energy policies and programmemes. Women as primary stakeholders in the energy sector need to be involved to guide project design, so that their interests are considered in a sector which has been skewed more towards the needs of their male counterparts. To reach the hard-to-reach households with modern energy solutions, we need to tap into their different networks. In this section we review gender gaps and opportunities in energy policies and other international organisations.

7.6.1 Sessional Paper No 4 on Energy 2004

The sessional paper No 4 on Energy 2004 recognized the role of women, men and children in the production and use of biomass energy, while acknowledging the

242 Kenya Markets Trust (2016) The Burden of Produce Cess and Other Market Charges in Kenya: Retrieved from https://www.kenyamarkets.org/wp-content/uploads/2019/10/Agri-Summary-Report-The-Burden-of-Produce-Cess-and-Other-Market-Charges-in-Kenya.pdf

fact that men got involved only if it was commercialized. Women and children are noted to spend more time fetching fuelwood and other biomass fuels with little time for other productive activities; leading to limited study-time particularly for the girl child and health risk due to indoor pollution. In addition, structural barriers such as the land tenure system inhibit women's access to biomass fuels. Also, men dominated the management positions in the energy sector. Recommendations were to; mainstream gender issues in policy formulation - focus on production and use, provide public education and awareness on how social norms hinder women access to biomass fuel resources, public health education on appropriate use of biomass fuels, promote the use of fuel efficient biomass cook stoves and redress in balance in energy management. Here women, men and children were considered more as users and beneficiaries and not change agents.

7.6.2 Energy Act 2006 and Energy Act 2019

The Kenya energy Act No.12 of 2006 sought to promote energy efficiency and conservation, upgrade existing infrastructures, mobilize financial resources to meet service demands and diversify sources of supply in a cost-effective manner, so all can have access to energy. This has since been replaced by the Energy Act of 2019. The new act has a grand objective of meeting universal electrification by 2030 and is keen on promoting renewable energy; exploration, recovery and commercialization of geothermal energy; petroleum regulation and coal activities; regulation, production, supply and use of electricity and other energy forms. This Act is gender neutral, and only mentions gender balance, regional and ethnic diversity which is required only for the management positions of the nuclear power and energy agency. The government being cognisant of this challenge set out to address the gender gaps in the energy sector by formulating the gender policy in the energy sector and is currently developing the bioenergy strategy which incorporates gender issues into the energy initiatives. The implementation of the gender policy and the bioenergy strategy will complement the current energy act as the country gears towards universal access to clean, sustainable, affordable, and reliable energy services by2022 (SDG 7). The gender policy and bio-energy strategy are discussed below.

7.6.3 Draft Bioenergy Strategy 2019

The Bioenergy strategy acknowledges the fact that men and women have different roles and responsibilities within the household and community and so are impacted differently by energy interventions. Also, that men and women have different access, use and control of energy as a result of socio-cultural norms; where women have low decision-making power and are underrepresented in projects activities. Though women are important actors in the bioenergy sector, their interests are hardly considered even in cases where cook stoves are manufactured, leading to low adoption. Targets and data are not represented across the genders but often provided in aggregate terms and thereby fails to capture the disparities across the genders. Women often face the adverse effects of unsustainable harvesting of bioenergy more than their male counterparts. In Kenya, like other developing countries the production and use of biomass fuels is the responsibility of women and children. The role of men is heightened in cases where the energy product is commercialized including charcoal and sold firewood. In some instances, women and children have experienced gender-based violence when collecting firewood (IUCN 2017; Winther et al., 2020[243]). Additionally, the use of firewood and other traditional biomass affects their health as a result of air pollution.

Unequal access to large assets and resources, was also noted due to structural barriers and cultural norms. Where men own trees and women need permission to access and cannot possibly sell it; and decision making is mainly the due of the man who is the head of the household and so control energy use and access (Winther et al., 2020)[244]. Thus, improved access to modern energy can reduce time and create spaces for women to do more productive activities (starting an enterprise), which would contribute to increase income, empowerment and social economic development and environmental sustainability. Providing equal opportunities for men and women would reduce gender inequalities as more women participate in trainings and acquire information to guide their access to and use of energy. To be able to identify gaps and opportunities, a gender analysis must be conducted to consider all the necessary information to make an informed choice.

243 Winther, T., Ulsrud, K., Matinga, M., Govindan, M., Gill, B., Saini, A., Brahmachari, D., Palit, D. and Murali, R., 2020. In the light of what we cannot see: Exploring the interconnections between gender and electricity access. Energy Research & Social Science, 60, p.101334.

244 Ibid

This strategy proposes a social relational analysis, where data is collected on gendered production, use, market access of the bioenergy value chain for gaps and opportunities identified and a policy framework developed to support the gender agenda.

7.6.4 National gender policy in the energy sector

The development of the gender policy comes at a time when energy is considered the central factor in poverty reduction as per vision 2030 and the enactment of new energy policy – Energy Act 2019. In addition, this policy enactment also meets the country's commitment to meet the Sustainable Development Goals (SDGs) and Constitution of Kenya to advance gender equality and empowerment of women; through gender awareness and attitude change that would engender energy sector's work culture. The Gender Policy provides a framework to mainstream gender in all segments, projects and programmes in the Ministry and by all partners linked to the energy sector. It was developed with the State Department for Gender and the Ministerial Gender Committee and funded by Energia-International, KENGEN and Practical Action.

Access to modern energy is the key enabler for women empowerment. It would also reduce the drudgery for women, giving them more time to carry out productive activities that can generate income. In addition, provide better health and wellbeing of the family. Using clean cooking energy would also curb Green House Gas Emissions (GHG), contributing to climate change (UNDP 2015)[245].

Women make most decisions in the choice of cooking technology to use and so their input is needed in the design of these technologies. Men should also be included because they are often the main decision makers in most households and sometimes provide the money to purchase the technologies and fuel (Winther et al., 2020)[246]. Even though women understand the cultural context in which they operate the power holders are men in the households and communities, and they hold the position that can change behaviours and attitudes of the people (Senay Habtezion et al 2016). An aspect mentioned in this policy to achieve gender equality is gender budgeting which is not mentioned in the other policies and strategies, but very important. In addition, there is need to sideline all gender-neutral projects in order to move towards gender responsive energy sector, where gender is integrated in all energy related projects.

To mainstream gender in the energy, sector the government has undertaken various initiatives with development partners, non-governmental organisations, academia and research institutions including Energia, KOSAP, EnDev, SEforALL, Hivos, SNV, Practical Action, Power Africa to increase access to modern energy services, thereby reducing carbon emissions, indoor air pollution, clean cooking solutions, and industrial output for all.

245 UNDP. 2015. Gender, Policy and Energy: A review of energy policies in east and Southern Africa. UNDP, USA

246 Winther, T., Ulsrud, K., Matinga, M., Govindan, M., Gill, B., Saini, A., Brahmachari, D., Palit, D. and Murali, R., 2020.

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8 Gaps, Conclusions and Recommendations

8.1 Gaps and barriers

8.1.1 Lack of an overarching institutional framework

Even though biomass remains the leading source of fuel used at the household level, this policy analysis reveals that there is no overarching institutional framework that could anchor and direct the sector's development. Recognising this, the Ministry of Energy is currently developing an all-encompassing Bioenergy Strategy that will form the basis for transformation change within the sector moving from the incremental initiatives of the past. Briquettes and pellets are some of the cooking fuels covered under this strategy. A perennial challenge that complicates coordination of efforts is the disjointed institutional framework which disseminates functions across various public institutions. For example, and for briquettes specifically, feedstock supply falls under the Ministry of Forestry and Environment and Ministry of Agriculture depending on the source, while promotion of technologies falls under Ministry of Energy and Ministry of Industrialisation, Trade, and Enterprise Development. Transportation of charcoal, which is the main source of charcoal dust used in briquette production falls under the Ministry of Forestry and Environment while the sale of briquettes could be influenced by the local County governments or Ministry of Finance. While such distribution of roles across institutions is not unique to the biomass energy sector, the institutional structure is particularly disjointed in this sector. This situation is compounded by the fact that biomass energy is a suite of energy options with varied value chains rather than a singular solution.

8.1.2 Predominance of informal and dissimilar players

The briquette sector constitutes of numerous and diverse players along the value chain with different motivations and incentives structures. Upstream players include the producers or collectors of feedstock sources, to midstream players including transporters and manufacturers of briquettes and finally downstream players who deliver the product across the last mile. Sources of feedstock vary greatly in terms of type, seasonality and geographic location. The same applies to the process of manufacturing. What is common is that most of the players are informal, itinerant and sometimes opportunistic. 82% of all cookstove manufacturers in the sector are sole proprietors running informal enterprises[247]. The spectrum of potential stakeholders and stakeholder types makes the process of consultation, formulation and enforcement extremely difficult. Even with robust policy and legal instruments, the process of ensuring compliance will remain a challenge. Many of the entrepreneurs do not have registered businesses, official physical addresses or formal bank accounts. Their engagement in the briquette processing, manufacturing, or sale of briquettes is complementary to other income generating activities. The landscape of players is a major barrier to creating a replicable or standardised approach to promoting the sector. The informal and dissimilar players produce equally diverse products that in many instances require bespoke policy solutions and approaches. The creation of interventions to promote the manufacture of briquettes or pellets will inevitably have to content with this barrier.

8.1.3 Lack of enforceability

As mentioned above, there exist policy instruments, legal instruments and standards to guide the briquette and pellets sector. The briquette sector has been in existence for at least 40 years in Kenya and discussions on improving quality of end products and reducing market spoilage has been in place for at least 30 years. One of the cyclic challenges that has been encountered is institutional and technical limitations in enforcement. This is based on two main factors. The first is that the agencies mandated to enforce these regulations or standards do not have the capacity to do this effectively due to limited resources. However, this is a secondary reason.

247 Kenya Climate Innovation Centre. 2016 (KCIC). Sector Mapping and Market Assessment on the Improved Cookstoves (ICS) Sector in Kenya. Retrieved from https://www.kenyacic.org/sites/default/files/publications/KCIC%20ICS-3.pdf

Primarily, the incentive to rigorously enforce these regulations especially in artisanal setting such as among low-earning entrepreneurs in urban informal settlements is not socially appealing. Trying to enforce standards on manufacturing and charging penalties among, for example, women groups creating briquettes from charcoal dust in Kibera is morally challenging. The second reason is that for the regulations or standard to truly achieve the intended purpose, there needs to be basic infrastructure that supports its operationalisation. For example, the sieve analysis, as required in the charcoal and carbonised briquette standards, cannot be carried out because the associate equipment is not readily available in the Kenyan market. There are few testing centres in Nairobi, which makes it difficult for entrepreneurs scattered across the country, many of whom are in the informal sector, to access these facilities. The agencies charged with enforcement acknowledge this but are not as strict when ensuring compliance. Further, cost of compliance including licensing and permitting are often too high and restricts the proportion of entrepreneurs that can meet these requirements. This creates a self-supporting cyclical loop since most regulations are not enforceable, many entrepreneurs do not comply meaning the incentives to comply are further eroded since most entrepreneurs know that their competitors are also non-compliant.

8.1.4 Lack of awareness

Literature review and interviews with key actors reveal that lack of awareness continues to be a hurdle to growth of the briquette sector. Lack of awareness manifests itself at two levels: awareness of existing standards by the manufacturers, distributors and programme implementers and, awareness of briquette products by end users. The former, has a negative impact on the quality of products in the market while the latter affects demand and perceptions of users. From literature, it is evident that consumers are not aware of the existence of the types of briquettes in the market and the associated benefits relative to other cooking solutions[248,249]. This is made worse by the fact that briquettes do not exist in standardised categories and they vary greatly within and across groups. Even carbonised briquettes vary in the carbon and ash content from vendor to vendor and sometimes, products from the same vendors are different. The lack of consistency is a major deterrent to potential repeat clients. There are hardly any quick and easy ways to determine the quality of briquettes in the market, especially in informal markets which form the largest segment.

8.1.5 Limited fiscal incentives for entrepreneurs

There are very limited fiscal incentives to attract substantial private sector investments in the briquette sector, especially to produce briquettes for household consumers. Briquettes and pellets manufacturing and distribution often require additional incentives beyond the expected profit margins which are typically quite low. Apart from a few grant making competitions, there are hardly any sector-wide fiscal incentives to promote the sector. Unlike other upcoming fuels such as ethanol that benefit from zero-rating or a reduction in taxes for the raw materials, end-product or associate technology for manufacturing or use, the sector has not benefitted from such. Commercial financial institutions are also averse to providing various financial services to entrepreneurs in the sector. This is due to a limited understanding of the sector, limited understanding of the risk profiles of projects, lack of positive precedence and lack of viable scalable business models. A key risk is the unpredictability and exposure to the feedstock supply fluctuation and changing prices. Since this is key input to the business and many manufacturers are not the producers of the feedstock, the risk exposure is perceived to be high and, in some cases, unacceptable for providers of financial services.

8.1.6 Competing alternatives and uses

Briquette producers must contend with competing uses of raw materials. For example, coffee husks are predominantly used as manure by the same coffee farmers. Rice husks are a target for large thermal energy consumers such are edible oil manufactures and cement processors. They are also raw materials for animal feed. Flower cuttings are increasingly used for biogas production, limiting availability. Macadamia nuts are uses for construction purposes making them very expensive for briquette manufacturing. From the end product, briquettes and pellets have to compete with other, cheaper and readily available energy fuels including charcoal and firewood. The viability of the sector is constrained by these two factors.

248 Energy 4 Impact.2013. Assessment of the Briquette Market in Kenya. Nairobi Kenya

249 Ngusale, G., K., Luo, Y., Kiplagat, J., K.2014. Briquette making in Kenya: Nairobi and peri-urban areas. Renewable and Sustainable Energy Reviews (750-756). Retrieved from http://dx.doi.org/10.1016/j.rser.2014.07.206

8.1.7 Inadequate gender mainstream in energy policies and processes

The government of Kenya has made some strides in developing gender responsive energy policies in the country especially with the development of the National Gender Policy which provides a framework to mainstream gender in energy projects and programmes. Besides the draft Bioenergy strategy that has taken into consideration gender concerns, most energy policies do not explicitly address gender issues in access to energy for clean cooking. As indicated in the Bioenergy strategy, women have, in the past, not been actively involved in design of energy interventions hence limiting uptake of new technologies. They have also been excluded from most public awareness and sensitisation related to energy issues. In the context of clean cooking, this to a given extent, would limit their awareness on existing alternative fuels and cooking technologies and eventually the choice of the same. If briquette is to find its way into households as an alternative fuel, there is need for a conscious and deliberate effort to ensure the key agents for change, who are women and children, are integrated into the briquette production value chain.

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8.2 Conclusions

To realise positive outcomes in the briquette sector, concerted efforts are a pre-requisite at the policy and sectoral level. This would ensure that the various hurdles at the different stages of the briquette value chain are addressed.

The first step to effectively promoting technologies is identifying appropriate technologies. There are two types of briquettes and they are suited for different end-users. Carbonised briquettes burn with minimal smoke, contain lower ash content, have high calorific value, and are therefore ideal for household use or space warming in (poultry farming or hotels). Non-carbonised briquettes are cheaper (per unit mass), burn longer (up to 6 hours), and therefore preferred by larger consumers of briquettes such as institutions (schools, prison etc.).

In addition to matching the appropriate briquette type to the target group, the next step is identifying appropriate solutions for burning the briquettes. For instance, at the household level, improved charcoal stoves are associated with effectively burning carbonised briquettes. Retrofitting industrial boilers is necessary for non-carbonised briquettes to burn efficiently. Additionally, since the improved charcoal stoves are costly compared to the traditional charcoal stove, considerations should be made on ways of making the stoves affordable especially since the target market is the low-income households. Industrial boilers may need to be retrofitted or new boilers installed to efficiently burn non-carbonised briquettes especially if there is formation of clinkers (incombustible residue) as in the case of bagasse briquettes.

Production of quality briquettes is another important factor when promoting them. The first step, is to identify the appropriate raw materials. The most suitable material for briquette production may vary from country to country. However, the methodology for identifying the most suitable material can be adopted in other countries. The key considerations are quantity, quality and cost. Quality of raw materials is key in production of quality briquettes while quantity and cost play a major role in determining the economic viability of the briquette enterprise. Parameters used to determine the quality of the raw materials include energy content, moisture content, bulk density, ash content and volatility of the material. An ideal raw material has high-energy content, low moisture content (approximately 10%), high bulk density and low volatile matter. The next consideration is the type of briquetting equipment. Use of low-quality briquetting machine will result in briquettes that have not effectively compacted. Development of standards and enforcement through the voluntary approach is a pathway that can be explored to promote quality briquettes in the market.

Strategic creation of awareness for new technologies is essential for growing demand of quality products. The level of awareness on briquettes at the household level is still very low. Quality assurance and awareness creation have to work hand in hand for the increased uptake of briquettes. Quality products without consumer awareness will not result in the anticipated market transformation in the sector. This is also true for creation of awareness for products that are of low quality. Consequently, the two have to work together under the umbrella of the briquette programme described in this report.

Comparing the economic viability of the two types of briquettes, carbonised briquettes were identified as the most viable briquettes. The key factors in determining the viability of the briquettes were cost of production and availability of a ready market. In terms of production, cost of the two types of briquettes, non-carbonised briquettes are relatively less costly to produce than carbonised briquettes. This is because carbonisation, drying and the use of a binder are eliminated from the production process. In regards to demand, the market of non-carbonised briquettes have a ready market such as industries. Additionally, there exist incentives in the uptake of products that are sustainably produced e.g., tea factories are a potential market non-carbonised briquettes. In addition, large quantities of firewood are consumed by institutions (schools, prisons, thermal intensive companies etc.) compared to households. For instance, in 2018, the tea factories alone consumed around 904,000 tons of firewood. Although, roughly households consume 10.3 Mton of fuelwood, it may not directly translate to felling of a tree as households may harvest the dry parts of the tree. It can therefore be concluded that, since the non-carbonised briquettes have a ready market, low production cost would provide a better alternative source of energy to large consumers of firewood hence more focus should be directed to this target group if greater impacts (CO2 mitigation and curbing of deforestation) are to be realised.

Briquettes are promoted as an alternative fuel at the household level. There exist competing fuels that are more accessible, affordable and of higher quality (e.g., charcoal). Briquettes have to be equally competitive in terms of cost and quality for uptake at the household level. Availability should also be consistent. The following are possible ways to enhance the competitiveness of briquettes:

i. Enhancing R&D on briquettes through establishments of briquettes research platform in research institutions such as KIRDI to produce quality briquettes appropriate for specific use. For example, for household use, heating poultry houses, institutional use etc.

ii. As the market is still at nascent stage, removal of taxation such as VAT on products and introducing fiscal incentives will accelerate the sector development, for example, removal of import duty on briquettes equipment and machineries.

Briquette producers should gather market information for their products before commencement of their businesses. Information on the market size, existing and competing alternatives, supply and distribution channels, willingness and ability to pay, current and projected demand are necessary to inform on appropriate business models to adopt.

8.3 Recommendations

8.3.1 Voluntary approach for standards and labels

The significance of standards and labels for any industry cannot be understated. When designed appropriately and implemented effectively, standards and labels have the potential of strengthening domestic markets by advancing product differentiation, spurring innovation and diversity of products, conveying lifetime costs, and creating a criterion for allocating fiscal support e.g. through subsidy programmes[250]. Adherence to the current set of standards and labels in the cooking sector is mandatory where failure to comply attracts a penalty which can be in the form of withdrawal of products from the market, seizing of products or prosecution in a court of law. Mandatory approaches have the advantage of ensuring compliance but may not be ideal for marginally used products such as the briquette and pellets that are largely based on informal value chains. Such approaches work more effectively in formal, mature and competitive markets that support enforceability. Based on lessons from market transformation programmes such as the World Bank Lighting Africa/Global and considering the reality of the current landscape of players this report recommends the initial adoption of voluntary self-regulating light-touch approaches as a testbed before implementing mandatory measures. This recommendation aligns with those presented by CLASP in the *Transforming the Cookstoves Market through Standards & Labeling in Kenya* report[251].

In Kenya, successful implementation of a voluntary programme has been demonstrated in the solar sector, particularly Pico solar products under Lighting Global programme led by the World Bank Group. Since its inception in 2009, the programme reports that over 42 million quality verified products have been sold since in Africa, Asia and Pacific region[252]. This programme has valuable lessons that can be borrowed when designing a voluntary programme. Its success has been attributed to the quality assurance framework adopted for the implementation of the programme which was designed around three main elements as is discussed below [253];

1 Development of a minimum standard and test methods

This element determines the metrics (e.g., durability, lumen maintenance etc.) and the testing methods that will be used to measure the stipulated metrics. The Minimum Quality Standards (IEC/TS 62257-9-5) stipulates the metrics that the energy products are required to meet and the test methods to be applied for testing compliance of the products to the set standards[254]. These metrics include truth-in-

250 Global Alliance for Clean Cookstoves .2013. ISO International Workshop Agreement Guidance for Clean Cookstoves. Retrieved from http://ethoscon.com/pdf/ETHOS/ETHOS2013/LectureHall/SaturdayAM/Review_ISO_International_WorkshopAgreement_CookstoveGuidance.pdf

251 CLASP. 2014. Transforming the Cookstoves Market through Standards & Labeling in Kenya. Retrieved from https://clasp.ngo/publications/transforming-the-cookstoves-market-through-standards-labeling-in-kenya

252 Lighting Global website. n.d. About. Retrieved from https://www.lightingglobal.org/about/

253 Lighting Global. 2014. Lighting Global Quality Assurance Framework Past, Present, and Future Support for the Off-Grid Energy Market. Retrieved from https://www.lightingglobal.org/wp content/uploads/2013/12/LightingGlobal-QualityAssurance-Roadmap_Feb2014-v4.pdf

254 Lighting Global. n.d. Quality Assurance Programme. Retrieved from https://www.lightingglobal.org/quality-assurance-programme/our-standards/

advertising, durability, quality, lumen maintenance, and warranty terms. For instance, under lumen maintenance after using the energy product for 2,000 hours, the light output must not drop below 85% of the initial value[255]. These specifications were designed after an extensive market study that aimed to establish the minimum standard that end-users look out for when seeking to purchase the lighting products[256].

2 Testing and verification of the products

This second element prescribed a simple and clear method to be used by the manufacturers when applying for certification of their products. This also included the monitoring approach to ensure that the manufacturers adhere to the quality standards. To effectively implement this process, the programme created a network of testing laboratories located in Nairobi Kenya, United States of America (USA), China, Hong Kong and India[257]. The laboratories were accredited by Lighting Global before participating in the programme[258]. The manufacturers are expected to contact the test laboratories, negotiate a fee and sign a contract that, among other things, addresses any potential conflict of interest. Products that meet the minimum requirements are then published on the Lighting Global website. Lighting Global supports manufacturers whose products do not meet the minimum requirement to improve their offering. All applicants are issued with reports clearly indicating the performance for the products whether they qualify or not. During the formative stages of the programme, manufacturers were offered Quality Test Method (QTM) testing at a discounted cost. However, this has gradually been reduced over time from a discount of 90% to 10%[259] with the eventual aim of eliminating the subsidy[260].

3 Communication and marketing of the standard

The programme has divided the different actors in the value chain into four main categories and developed targeted methods of disseminating information on products that meet the minimum criteria.

Table 49: Key Stakeholders along the value chain and the proposed Communication Strategy

#	Stakeholders	Communication Strategy
1	Consumers	• Advertising campaigns • Consumer education conducted by regional programmes • Standardized Specification Sheets and website in cases where consumers have access
2	Manufacturers	• Test reports • Standardized Specification Sheets • Direct outreach by personnel associated with the Lighting Global
3	Distributors, Finance and Microfinance, Retailers, Bulk Purchasers, NGOs	• Standardized Specification Sheet • Website

Additionally, the issuance and publication of standardized specification sheets and verification letters on the Lighting Global website builds consumer confidence on the products which in turn builds demand for verified products. This provides a self-regulating market where low-quality products are excluded from the mainstream market. The aim is to promote brands that have a good reputation among consumers. This has significantly reduced market spoilage as consumers who do not purchase certified products implicitly accept the risk associated with their choice thus creating a separation between high quality products and the grey market.

255 Lighting Global. 2014. Lighting Global Quality Assurance Framework Past, Present, and Future Support for the Off-Grid Energy Market. Retrieved from https://www.lightingglobal.org/wp content/uploads/2013/12/LightingGlobal-QualityAssurance-Roadmap_Feb2014-v4.pdf

256 Key Informant Interview with a representative from Lighting Global

257 Lighting Global. n.d. Testing Laboratory Network. Retrieved from https://www.lightingglobal.org/quality-assurance-programme/test-laboratory-network/

258 Lighting Global. 2018. Lighting Global Product Testing and Laboratory Eligibility Policy. Retrieved from https://www.lightingglobal.org/wp-content/uploads/2018/08/LG_Product-Testing-and-Lab-Eligibility-Policy_v3.1.pdf

259 Key Informant Interview with a representative from Lighting Global

260 Lighting Global. 2014. Lighting Global Quality Assurance Framework Past, Present, and Future Support for the Off-Grid Energy Market. Retrieved from https://www.lightingglobal.org/wp

Although commendable gains have been achieved, wide use of uncertified products remains but the unpredictable performance of these products does not impact the entire market. Other incentives under the programme include the availability of networking platforms where manufacturers, distributors, financiers and consumer groups can interact. These forums also provide market intelligence, support to business planning and technical designs, and access to finance. These incentives crowd-in manufacturers and products at the commencement stages with the aim of gradually withdrawing the incentives as the market matures and eventually adopting mandatory approaches.

Based on these lessons and demonstrated transformation, this report recommends i) formation of briquette/pellets manufacturing groups especially for the informal players ii) development of sector-approved minimum standards indicating the particular performance parameters to be monitored and tested for, the appropriate testing methods for each parameter iii) development of a strategy to create awareness of these standards.

8.3.2 Strategic awareness creation

Awareness creation across the sector should happen at least at two levels: i) awareness of products targeting end-users ii) on standards and regulations for manufacturers, distributors, and implementers of programmes and consumers. Briquette end-users can be broadly grouped into domestic (households), commercial-institutional (small/medium businesses, educational and health institutions) and industrial consumers (large thermal energy users including tea factories). A consumer education programme would need to be developed with a clear strategy on how to reach the different types of the end-users. The programme objectives would be to; (i) create awareness of different briquette types as alternative or supplemental cooking fuels (ii) highlight the benefits of briquettes relative to other fuels (iii) demonstrate how briquettes are best used.

It is also necessary to develop a communication strategy targeting different stakeholders in the supply chain to ensure the standard is known and accepted widely to ensure long-term effectiveness[261]. Creation of awareness implemented as an independent intervention will not necessarily result in market transformation. This will always remain a complementary approach to other measures. For instance, before creation of consumer awareness, the products in the market must be of good quality, affordable and available to the end-users (i.e., developed supply chains creation of awareness). There is therefore a need to design a programme that is coordinated, for example, by the Clean Cooking Association of Kenya (CCAK) or the Ministry of Energy that would address the different barriers and gaps in the supply chain. A similar approach to that of Lighting Global discussed above would be effective. Under this scenario, creation of awareness becomes part of a broader programme that is addressing the different barriers in the sector.

It has been urged that existence of quality products with no consumer awareness[262] or development of a standard without communication to the manufacturers will have minimal impact in the sector. Creation of awareness of the benefits of certified products should be done together educating end-users of the risk associated with uncertified products in order to differentiate the products empowering the consumers to make informed choices. This has been reported by some producers where briquettes from some producers are of low quality leading to bad reputation of briquettes among end-users. To this effect, accurate information and verified products should be the centre of the awareness creation programme.

The type of method to apply for the awareness creation is determined by the target group. For example, in rural areas, radio advertisement would be effective as opposed to websites or television advertisement. A study on quality communication carried out in Kenya indicated that 48% of the respondents reported that radio advertisements in the local language was the most effective means of advertising, followed by road shows (24%), television advertisements (18%), and fliers (10%)[263].

261 Wiel, S. and Mcmahon, J., E. 2005. Energy-Efficiency Labels and Standards: A Guidebook for Appliances, Equipment, and Lighting, 2nd Edition. CLASP Washington D.C USA

262 Lighting Global. 2017.Building Awareness is Critical to Building Markets Retrieved from https://www.lightingglobal.org/news/change-minds-activate-markets/

263 Ibid

48%

of the respondents reported that **radio advertisements** in the local language was the most effective means of advertising.

In rural areas, awareness campaigns can be held in the Community-Based Organisations (CBOs), women groups and youth groups. During their monthly meeting sessions, information dissemination and demonstrations can be carried out.

The approach to reach the different manufacturers/ distributors would be informed by the type of manufacturer. For example, large-scale manufacturers have websites which have contact information while small-scale manufacturers are scattered across the different counties and do not have an online visibility. Programme implementors would need to come up with innovative ways of reaching these producers. They can leverage on the different initiates under development agencies (Practical Action, Energy 4 Impact etc.), the recently formed United Briquette Producers Association (UBPA), television and radio advertisement, roadshows, fliers and brochures. Through these platforms they can be invited for workshops aimed to raise awareness of the standard and trainings on how to attain the specification under the standard. Reports on the performance of their products after testing should be made available and suggestions on how to improve their production process if their products do not meet the requirements of the standard communicated. Other actors such as NGOs, government officials can be reached through direct engagements by the programme officials, invitation to training and awareness creation workshop.

An example of a successful consumer awareness campaign is the 'Songa Mbele na Solar (move ahead with solar)" under the Lighting Africa Kenya programme that started in 2010[264]. The campaign was only for products that had passed the quality check. Activities included direct campaigns through road shows where there was dramatisation and demonstration of how to use the solar products, quizzes and dances to attract participants, posters and billboards. Another unique tool applied was through local TV programmes (Makutano Junction) and radio talk shows. Also, leveraging on the penetration of the use of mobile phones, through a text message, consumers could access information on the available quality solar products in the market. Information was also provided on how manufacturers would get in touch with the Lighting Africa team implementing the programme for participation in the programme. It was reported that, by 2013, 29 million Kenyans had been reached by the campaign[265].

8.3.3 Regulation requiring public institutions to use briquettes for at least 10% of their thermal applications

The push and pull theories have often been used in most contexts to explain how technological changes occur in a market. The technology-push occurs when there is discovery of new scientific ideas leading to innovation or invention of new products. The demand-pull on the other hand is driven by the societal needs and hence products are designed to address these specific needs. Over time, researchers have discovered that these two theories are not as linear as they appear but rather there are several factors interacting at the market level that influences technology uptake. According to Christiansen (2001), it's becoming increasingly evident that the choice of technology is not only being determined by its technical or economic performance measures but also by other factors such as the prevailing socio-political cultural norms, rules and preferences. For example, the existing legal structures in a sector have the capacity to promote or hinder the development and adoption of new technologies. Bringing this to the briquette sector, it is evident that the drive is mostly technology-push, as demand remain quite low among households.

264 Lighting Africa. Songa Mbele na Solar. Retrieved from https://www.lightingafrica.org/wp-content/uploads/2014/03/Songa-Mbele-Na-Solar_Daily-Nation_2011.pdf

265 Lighting Africa Kenya. 2018. A Thriving Off-Grid Market – With a New Focus on Underserved Areas Retrieved from https://www.lightingafrica.org/country/kenya/

There is need to develop and implement policies and strategies that would combine both the technology-push and the demand-pull. These can typically be in three forms; regulations, economic instruments or information[266]. Regulations are restrictive and ensure a behavior is observed or a pattern is maintained; economic instruments can include tax and import duty exemptions, tax holidays or even direct funding for research and development and information can be in the form of persuasion and reasoned arguments to motivate certain patterns of behavior or behavioral change. In addition to the ongoing conversation on tax exemption for briquettes and related technologies, we propose that the Government should come up with a policy that requires public institutions to use briquettes towards providing 10% of their thermal requirements for a start and gradually increasing this share based on the observed performance. Institutions in this case include hospitals, schools, training institutions and prisons. This policy should target briquettes that meet a prescribed minimum standard which will send a strong signal to the market players. The success of this strategy, however, will be dependent on effective enforcement of standards to ensure availability of quality briquettes in the market.

8.3.4 Fiscal Incentives for briquette manufacturers

One way to ensure quality briquette production in Kenya is by eliminating costs associated with importation of manufacturing equipment and parts/components. The impact of such actions by the government is evident in the solar sector which has greatly benefitted from the VAT exemption as from 2014. As it were, tax exemptions are applied to "specialised equipment for the development and generation of solar and wind energy, including deep cycle batteries which use or store solar power upon the recommendation of the Cabinet Secretary responsible for matters relating to energy"[267]. The resultant effect was a reduction in the price of solar equipment leading to increased affordability and uptake of solar products by consumers. The tax exemption has seen the country become a market leader in pico solar products with total number of products sold by the second quarter of 2019 coming close to 1 million (944, 511)[268] and being the highest in Sub-Saharan Africa.

The cooking sector has, to some extent, also benefited from incentives including tax exemptions/zero rating on[269]:

- **"Taxable goods** locally purchased or imported by manufacturers or importers of clean cooking stoves for direct and exclusive use in the assembly, manufacture or repair of clean cook stoves"
- "**Inputs or raw materials** locally purchased or imported by manufacturers of clean cook stoves approved by the Cabinet Secretary upon recommendation by the Cabinet Secretary for the time being responsible for energy" from tax exemption.
- "**Plastic bag biogas digesters;** Biogas; Leasing of biogas producing equipment."
- "**The supply of liquefied petroleum gas** including propane."

The Financial Bill of 2020, however, had several amendments including introducing 14% VAT on all the above products. Active lobbying spearheaded by the Clean Cooking Alliance of Kenya has ensured that these products continue to benefit from tax exemptions. Tax reductions on manufacturing components has the benefit of increasing the profitability of the organisations without necessarily increasing prices for consumers. There's need to continually engage Treasury to make them understand the value of such incentives towards achieving the objectives of Big Four Agenda and Vision 2030 on transforming the manufacturing sector; creating employment and reducing the environmental health impact as a result of clean cooking.

Long-term approaches in addressing barriers to financial access for private sector would be in testing out new financing models. The renewable sector has made remarkable progress in bridging the financial gap for investors by creating facilities that not only provide technical assistance but extend financial services to actors in the sector. Some of these facilities include KawiSafi Ventures Technical Assistance Facility, Green Mini-Grids Technical Assistance Facility and African

266 Ibid

267 Government of Kenya, Finance Act 2018. Retrieved from https://www.kra.go.ke/images/publications/Finance-Act-2018.pdf

268 GOGLA (2019) Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data. July to December

269 Government of Kenya, Finance Bill 2018. Retrieved from http://kenyalaw.org/kl/fileadmin/pdfdownloads/bills/2018/TaxLawsAmendment-Bill2018.pdf

Clean Energy Technical Assistance Facility. There are several lessons the sector can learn in designing appropriate programmes to enhance access to finance to briquette manufacturers.

8.3.5 Energy centres for promoting briquette

Energy Centres (16 in number) were established in 1980s as the technical outreach arm of the Ministry of Energy[270]. With the new Energy Act 2019, however, they have been transferred to the newly established Rural Electrification and Renewable Energy Corporation (REREC). With this mandate, the energy centres have now been transferred to REREC and they are to establish more energy centres across the other 31 counties. According to the Act, they are to "develop, promote and manage in collaboration with other agencies, the use of renewable energy and technologies, including but not limited to biomass (biodiesel, bio-ethanol, charcoal, fuel-wood, biogas) municipal waste, solar, wind, tidal waves, small hydropower and co-generation but excluding geothermal". This role aligns well with the functions of the energy centres which include:

- Development of Renewable Energy (RE) & Energy Efficiency (EE) county energy plans
- Training, demonstration and extension on RE & EE technologies;
- Research and trials on agro-forestry systems;
- Dissemination of RE & EE technologies;
- Establishment and maintenance of database on renewable energy technologies in the country;
- Monitoring and evaluation of renewable energy projects in collaboration with the technical divisions of the directorate;
- Undertaking Research and development activities

From the discussions with key informants, it is clear that most households are not aware of briquettes and neither do they understand their benefits. The Ministry of Energy can use these centres as resource houses to educate the public on alternative fuels and technologies for cooking through demonstrations. These centres should also be open to schools for visits and for education forums as they are vital channels in propagating information and influencing choice of fuels for cooking.

8.3.6 Mainstreaming gender in energy policies

The downside of having gender neutral energy policies is a sector that discriminates on women-differentiated energy needs and may fail to incorporate their experience, expertise and capacity which is essential in the development of the sector. Women, as primary stakeholders in the energy sector, need to be involved to guide project design, so that their interests are considered in a sector which has been skewed more towards the needs of their male counterparts. To reach the hard-to-reach households with modern energy solutions, we need to tap into their different networks. Mainstreaming gender in energy policies requires a paradigm shift that recognizes women's contributions as agents and not only beneficiaries of energy products. The first step towards formulating energy policies that are more gender aware is to conduct a gender analysis on the existing energy policies (like the one conducted in this study). This would aim to understand how existing policies and practices within the energy sector reinforce gender inequalities, stereotypes, and what can be done to enable gender equality. The analysis would also provide information on critical gender gaps in existing energy policy formulation and implementation; allowing for development of a more gender-aware policy. The policies should ensure that the following considerations are made in the energy sector to ensure gender equality;

- A dual approach is adopted in reducing the equality gaps in the energy sector through gender mainstreaming and, specific gender targeted interventions.
- Data collected in the energy sector (national studies on demand side assessment for energy for cooking and lighting) should be disaggregated by sex and age at the bureau of statistics, ministries of finance and energy institutions and agencies, and gender indicators monitored, tracked and recommendations proposed for further refinement of existing policies or development of new ones.

270 Philip Mwakio (2019, June 25). REREC now eyes partnerships with counties to establish energy centres. Standard Media. Retrieved from- https://www.standardmedia.co.ke/article/2001331392/rerec-now-eyes-partnership-with-counties-to-establish-energy-centres

- Gender responsive budgeting is critical to make sure activities are carried out and results generated
- Gender quota should be instituted when hiring in the sector energy and increasing the number of women in leadership positions especially in the energy management boards, expert panels and advisory groups
- Women should also be involved in the design of energy projects and implementations; where evidence is used to develop inclusive gender energy policies
- Train personnel of energy-related institutions and partners on the importance of integrating gender in the energy sector
- Train women and youth on the development, production, use and marketing of low-carbon energy technologies like briquettes
- Build the capacity of women to establish and run clean energy business initiatives
- Engage with financial service providers to ease access to credit for women energy entrepreneurs to grow their businesses or start up new ones to increase economic empowerment.

8.3.7 Aggregation of informal supply

The briquette sector is characterised by small-scale producers who are opportunistic and are scattered across the country. This makes it hard to coordinate their activities to ensure production of quality briquettes. To effectively provide services to these enterprises requires a form of pooling. One approach to aggregate small producers into central production hubs could be modelled around the use of energy centres that are to be established in every county. This can be through formation of co-operatives or associations. Co-operatives have found application in various sectors of the economy with agriculture being the leading sector. Through co-operatives, small-scale farmers in Kenya, who form the majority of producers, have eliminated middlemen and fetched better prices for their produce. Further, regulating quality of products becomes easy as it becomes the responsibility of the organisation to ensure their products meet the required standard.

Research indicates that co-operatives are instrumental in reducing business failure. Nembhard, in his research on benefits and impacts on cooperatives in the United States, reports that co-operatives have lower failure rates than traditional corporations and small businesses. From the assessment, only 10% of co-operatives fail after the first year compared to 60-80% of the traditional businesses.


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The high survival rate of co-operatives has been attributed to the high number of people required in starting a cooperative and support from the community where they are established. From this briquette study, it was evident that businesses in the briquette sector are quite short-lived with 60% (12 out of 20) businesses interviewed formed within the past 5 years.

Co-operatives also have the additional advantage of addressing market failures including access to finance. The structure of co-operatives positions them well to receive different funding types such as grants and loans, which are not readily available for independent businesses. Other benefits of aggregation would include better bargaining power, low cost of production due to increased scale, improved marketing strategy including packaging and branding, accumulation of assets and human capital.

8.3.8 Promote local manufacturing

Despite the efforts underway to improve the quality of briquettes produced in the county, one of the main impediments is the availability of appropriate briquetting equipment. Briquette producers reported encountering low or absence of local technological capacity to fabricate densification equipment especially for non-carbonised briquettes. Of the four commonly used densifying equipment -- agglomerator, screw extruder, pillow briquettor and ram/piston press -- only the screw extruder and the agglomerator are locally manufactured. The ram/ piston press and pillow briquettors are imported from China or India. Ultimately, the cost of importation is prohibitive making it difficult for emerging briquette producers to be able to procure quality machines. Addressing these challenges would be through promoting local production. This can be anchored on the Big Four Agenda which is keen on transforming the manufacturing sector in Kenya. According to the Agenda, government is keen on increasing access to finance through increasing loan guarantees to SMEs and also incentivising commercial banks to provide low interest loans for manufacturing industries. With increased access to cheap capital (in the case of reduced interest rates) manufacturing companies are able to increase their production capacities hence lowering the cost of the final consumers thus creating demand.

Additional support to the sector can be unlocking innovation through financing research and development spearheaded by the government in partnership with private sector. This initiative is key in addressing the rising concerns by briquette producers such as high rates of wear and tear of locally manufactured machines as compared to imported machinery which drive up the cost of operation and maintenance.

8.3.9 Access to finance

Setting up a briquette-making business is a capital-intensive venture. The purchase of equipment, and maintenance, testing and labelling of the briquettes, marketing the briquettes, acquiring a premise and purchasing of the feedstock are activities along the landscape of briquette businesses that are expensive. Depending on the scale of production, and with the assumption that the business will have to use a type of machine for briquetting, the initial cost of setting up can range from KES 500,000 to KES 50,000,000. While most large-scale producers have access to different forms of finance including loans and grants, it remains a hurdle when it comes to small-scale producers. These entrepreneurs are often not able to meet the requirements for financing including collateral in the case of debts or to meet the conditions stipulated in other forms of grants for example, in one a case, was required to use cleaner modes of transport (EVs) instead of conventional engine drives. Further, for debt, there is need to demonstrate constant cash flow which is an indicator of the firm's capacity to repay the loan in time. In the case of businesses operating on credit models (especially those serving institutions), this becomes unattainable as their cash flows remain erratic and is hard to track over time. As is with start-ups, these enterprises require patient capital (such as concessional loans and grants) before breaking even. These can be advanced through varied forms such as Results Based Schemes (RBF). For example, under Component 2 of the Kenya Off-Grid Solar Access Project (KOSAP), the government is providing subsidies scheme through an RBF mechanism to promote uptake of improved biomass stoves. Similar strategies can be implemented for uptake of alternative fuels such as briquettes. As businesses mature, they can tap into other sources of financing including debt and venture capital.

The second layer of limitation in access to finance is lack of skills in writing fundable proposals for grant funding. While producers have an understanding and experience in the technical aspects of briquette production, lack of capacity in writing bankable proposals was reported as a hurdle for small-scale producers. Trainings offered to businesses such as one conducted by E4I under the Women in Renewable Energy (WIRE) programme are a good starting point to help businesses develop good business plans that they can use to seek funding. Instead of isolated projects, different players in the sector with similar programmes can collaborate to equip entrepreneurs with requisite skills in financial modelling, pitching business ideas, grant application and general fundraising.

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ANNEXES

Annex 1: Briquette production Manual

1. Background

Municipal waste (such as paper and organic waste), agricultural and forestry residue have been used as potential sources of energy through various approaches such as the briquetting technology. Increase in population results in an increase in the amount of waste generated in urban areas. In Nakuru County, for instance, a 2017 feasibility report by the World Bank[271] found that the county generates an average of 523 tonnes of waste per day of which 80% is biodegradable material (e.g., organic waste, paper, cardboard). Nairobi County on the other hand is estimated to produce about 2,400 tonnes of waste per day; Kisumu County produces 500 tonnes and Mombasa County 875 tonnes of municipal solid waste per day. Recognising that most urban areas are limited in their capacity to collect and manage waste, this is a resource that could be utilised to address the increasing energy demand driven by population growth and the need for a cleaner environment. Briquettes have been promoted as alternative fuels to charcoal at the household level and firewood or furnace oil in thermal intense industries such as tea factories. Use of charcoal and firewood is a major contributor to environmental degradation through deforestation and greenhouse gas emissions (GHG) as it is mainly sourced unsustainably. Furnace oil is a fossil fuel and therefore also contributes significantly to greenhouse emissions. In addition to addressing the energy and environmental concerns, development of sustainable briquette production businesses could potentially contribute to job creation along the value chain. This includes suppliers of raw materials, manufacturers of the briquetting technologies, employees at the production site, and distribution agents.

Being cognisant of the environmental and social-economic benefits that can be accrued from the use of briquettes, Kenya, through its National Designated Entity (NDE), has sought technical assistance from CTCN to support the development of the briquetting sector as part of its objectives under the Nationally Determined Contribution (NDC) and National Climate Change Action Plan (NCCAP). Production of briquettes is viewed as an opportunity to sustainably address the increase in demand for energy and the need to effectively manage solid biomass waste from the growing urban populations. This request requires an evaluation of the sector with a focus on charcoal dust, sawdust, agricultural waste and organic municipal solid waste and their potential as viable feedstock options to produce briquettes. Based on the Technical Assistance Response Plan – Terms of Reference submitted by the NDE, this assignment also aims to assess the briquetting value chain ranging from sourcing of raw materials, briquette production technologies, supply chains, the policy environment in the sector and develop a briquette production manual. For each of these tasks, the output is a standalone report. This briquette production manual is part 4 of a series of 5 reports under the technical assistance.

1.1 About the manual

Objectives

The main objectives of this manual are:

i. Contribute to the production of quality briquettes by guiding the briquette producers to choose the most suitable briquette making technology and equipment;

ii. Guide briquette producers in determining the viability of their businesses before setting up and guide existing business on identifying opportunities to improve their businesses;

iii. Point briquette producers to local fabricators, importers and distributors of briquetting machines while providing a guide on how to import the briquette machines;

271 World Bank. (2017). Nakuru Integrated Solid Waste Management PPP Project: Feasibility Study Report and PPP Implementation Plan

Scope

i. Steps in the production of the two main types of briquettes are discussed with the various technologies under each process compared (in terms of merits, demerits and cost) to enable the producer select the most suitable briquetting equipment and techniques for producing quality briquettes.

ii. Business models for start-ups and existing businesses. The Lean Canvas Model (LCM) is a tool for start-ups to quickly and effectively develop suitable business models and a Business Model Canvas (BMC) for already existing briquetting businesses to assess opportunities for improving their business models.

Target audience

The manual is designed to be used for training aspiring briquette producers and already existing producers who would wish to improve and scale their briquette production processes. This manual covers the production processes for both carbonised and non-carbonised briquettes using varied raw materials such as charcoal dust, sawdust, bagasse, municipal waste etc.

1.2 Introduction to briquettes

The term "briquette" is a composite term used to identify a wide range of biomass-based fuels that vary in terms of composition, shape, size, energy density and price[272]. Various types of feedstock can be used to create briquettes and can be classified into four main groups:

i. Organic municipal waste (e.g., waste paper, sludge);

ii. Agricultural residue (e.g., coffee husks, sugarcane bagasse, rice husks, and macadamia nuts);

iii. Forestry residue (e.g., sawdust, chips, offcuts);

iv. Charcoal dust.

There are two types of briquettes;

Carbonised briquettes made from biomass that has undergone pyrolysis. The feedstock is mixed with a binding agent then pressed to form briquettes. Carbonised briquettes have a higher calorific value, burn with minimal smoke, contain lower ash content, and cannot be destroyed by insects such as termites[273]. For these reasons, they are preferred for use by households for cooking and space heating (e.g., poultry farming).

Non-carbonised bri*quettes* processed directly from biomass sources through various casting and pressing processes also known as compaction or solidification using high-pressure machines. They are cheaper (per unit mass) and burn longer (up to 6 hours)[274] as compared to carbonised. Therefore, industrial and institutional users such as factories, schools, hospitals and prisons prefer them.

While recognising the diversity of input materials, types of producers, process of production and scale of production, this manual outlines the production processes for the two main types of briquettes; carbonised and non-carbonised briquettes with a focus on mechanised technologies (e.g., electrical machines) that have a higher production output (from 500-7,000 kg/hour) and produce well compacted briquettes. The main processes are divided into; i) pre-processing, ii) pyrolysis and carbonisation, iii) mixing, iv) binding and compaction and v) drying as shown in Figure 30 below.

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272 Ministry of Energy (2019). Kenya Household Cooking Sector Study: Assessment of the Supply and Demand of Cooking Solutions at the Household Level. https://www.eedadvisory.com/wp-content/uploads/2019/11/moe-2019-cooking-sector-study-.pdf

273 Hu, J., Lei, T., Wang, Z., Yan, X., Shi, X., Li, Z., He, X., Zhang, Q. (2014). Economic, environmental and social assessment of briquette fuel from agricultural residues in China – A study on flat die briquetting using corn stalk. Energy 64, 557 -566.

274 Key informant Interview

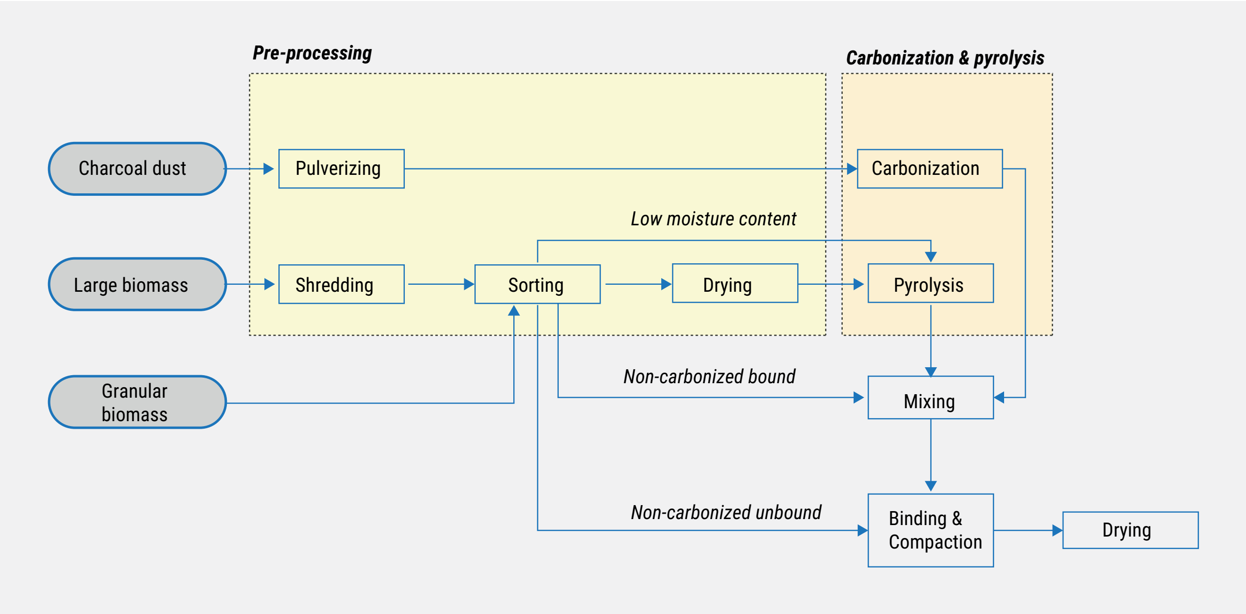

Figure 30: Main step along the production process (EED Advisory)

2. Production processes

2.1 Activities before production

2.1.1 Selecting a briquetting enterprise

The first step before setting up a briquette production unit is to decide on the type of briquettes to produce. As discussed earlier there are two main types of briquettes; carbonised and non-carbonised and their production processes differ slightly. The determinant factor of the type of briquette to produce is the target market. The business has to be demand-driven as opposed to supply driven. It is highly recommended that the producer first identifies potential buyers of the briquettes before setting up the business. Non-carbonised briquettes are recommended if the target market is institutions (schools, hospitals, prisons) or for industrial use and carbonised briquettes for households, space heating in hotels and poultry farming. For new enterprises, it is recommended to begin with small-scale production and gradually grow their production capacity as demand increase. Figure 31 and Figure 32 below show the different types of briquettes.


Rod-shaped briquettes


Honeycomb briquettes


Ball-shaped briquettes

Figure 31: Carbonised briquettes for households, poultry farming and hotel industry

Figure 32: Non-carbonised briquettes for industrial and institutions

2.1.2 Guidance on site selection

To identify the ideal site to set up the production unit, these factors should be put into consideration:

i. Location of source of the raw material and the briquette consumers – the ideal location would be one that is near the raw material and consumers. However, this may not be possible to attain and the producer has to decide between transporting the raw material and transporting the briquettes based on the cost associated with each of the two activities;

ii. Availability of water- water is very important in the production of carbonised briquettes during the mixing of a binder and the raw material. The producer must therefore ensure that there is access to a constant water supply at the site;

iii. Site should have adequate space for the set-up of briquetting production line, storing the feedstocks and briquettes. Figure 33 below[275] provides an illustration of how the production site would look like.

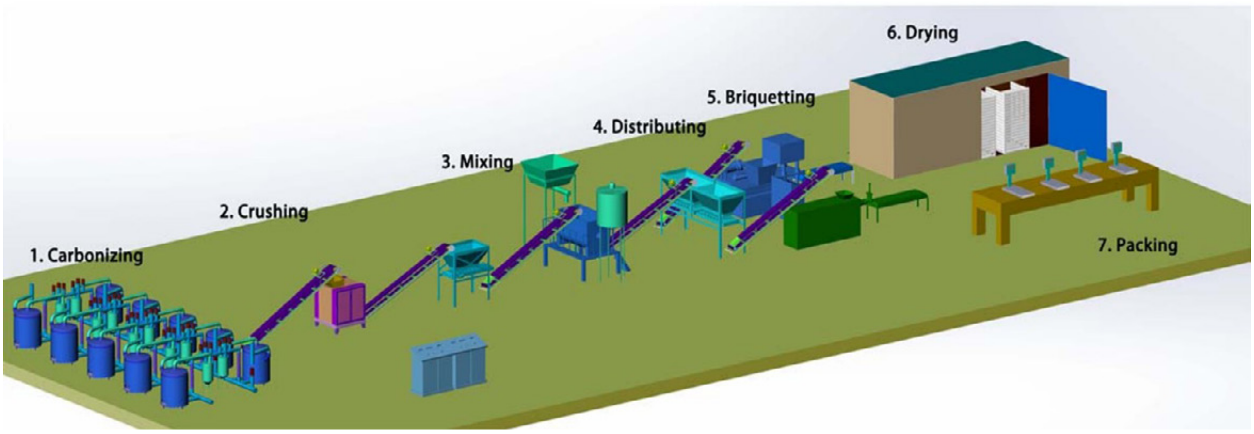

Figure 33: Example of a site layout adopted from FUYU Machinery Co.Ltd

275 FUYU Machinery Co.Ltd. https://www.fuyu-machinery.com/

2.1.3 Layout and construction of briquetting structures

The briquetting production line is to be arranged in an east-west direction if possible, for efficient aeration[276]. The ideal structure plan comprises of security fence and flood lights, lawns, offices, shade for raw materials, crushing/milling unit, maintenance workshop, cloak rooms, power room, storage facility, sanitation rooms, internal gangways, and pathways and automobile routes/ parking bays, and a security gate room.

In the case of meeting production requirements, the whole production line should be tidy and machinery/ equipment well installed than being spread far apart to reduce walking and waste of production time. However, there should be safe space to ensure equipment maintenance and smooth movements during maintenance/servicing of machinery/ equipment.

Construction plans for a briquettes manufacturing factory is a major undertaking that requires special attention since the structure will be housing machinery/ equipment and human activities. The plan should have a budget and timeline when all construction activities are to be completed. The facility needs to be environmentally sound (orientation towards natural light, sound proof the machine room to avoid noise pollution, waste collection and management unit in place etc.), accessible and safe to use. The key to its successful completion relies on engaging an experienced factories designer and construction team. It is also important for the producer acquaint him/ herself with the design plan for purposes of managing the budget and ensuring the construction remains as per the design plan. Poor design plans and budgetary planning can lead to high construction costs, delays, re-scheduling of issues, and costly changes to the design plan. The recommended building material is steel metal and iron sheets designed for construction of factories to withstand machinery/equipment vibrations. It should adhere to all the standard factory regulations and health and safety guidelines. These guidelines are public and are easily accessible.

2.2 Raw materials for briquette production

2.2.1 Sourcing of the raw materials

Identification of suitable feedstock is a key step in production of briquettes. The choice of a particular feedstock is driven by various factors including: (i) proximity to a source, (ii) quantities available (iii) cost considerations and (iv) quality. The selected feedstock should meet the following characteristics:

i. Available throughout the year to ensure that production is not interrupted;

ii. Low cost (transport cost and actual cost of the raw material. A cost KES 0-3 per Kg is ideal;

iii. Low moisture content to reduce the cost of transporting bulky raw materials and drying;

iv. Quality in terms of calorific value, ash content and volatile matter.

For production of carbonised briquettes, purchasing already carbonised materials is ideal as carbonisation of the raw material leads to 50-80 % loss of raw material, which is not economical for feedstock that has an attached cost and is available in limited quantities. Where the quantity of quality briquettes materials is lacking, there is a possibility of blending low quality with high quality raw materials to realise the expected quality.

Collection and processing of centrally located feedstock is preferred although if the quantities from one supplier are not enough to meet the production capacity then you can source from several points. In that case, plan the logistics, which may be tedious and costly. Table 50 below shows possible sources of raw materials that are commonly used in briquettes production in Kenya.

276 Charcoal Briquette Machinery. (nd) Retrieved from https://www.charcoalbriquettemachine.com/news/biomass-briquette-plant-design.html

Table 50: Potential sources of raw materials

#	Type of waste	Possible sources of the waste	Region
1.	Bagasse	South Nyanza Sugar Company, Transmara Sugar Company, Nzoia Sugar Company, West Kenya Sugar Company, Kibos Sugar and Allied Industries Limited, Butali Sugar Mills, Sukari Industries Limited, Kisii Sugar Factory, Sony Sugar	Western Kenya
		Kwale International Sugar Company	Coastal Region
2.	Sawdust	Along Naivasha-Nakuru highway	Central Kenya & Rift Valley
		Timber yards	Urban and Peri-urban areas
		Furniture workshops	Urban and Peri-urban areas
3.	Charcoal dust	Charcoal wholesalers and vendors in urban areas	Urban and Peri-urban areas
4.	Coffee husks	Kofinaf	Central Kenya
		Central Kenya Coffee Mill	Central Kenya
		Thika Coffee Mill	Central Kenya
5.	Macadamia waste	Equatorial Nuts	Central Kenya

2.2.2 Pre-processing of the raw materials

The preparation of raw materials includes drying, sorting and separation, shredding, grinding, pulverizing and milling. This is determined by the condition of the feedstock.

i) Drying

This step is aimed at expelling moisture for the wet raw materials. The recommended moisture content is between 6% - 16%[277]. This is important to allow complete compacting of the raw materials and to ensure the briquettes do not disintegrate soon after extrusion from the briquetting machines. Common drying methods include; solar drying (greenhouse and open air-drying) and use of driers. The scale of production and cost of each method are key factors to consider when deciding which type of drying technique to settle for. The merits, demerits and cost of each method are discussed below to determine the most suitable method to employ for your business.

277 Nikolaisen, L.S., and Jensen, P.D. (2013). Biomass feedstocks: categorisation and preparation for combustion and gasification. Biomass Combustion Science, Technology and Engineering (pp. 36 -57). Woodhead Publishing Series in Energy. https://doi.org/10.1533/9780857097439.1.36

Table 51: Drying options

Drying of raw materials	
Technology/ Appliance	**Description**
Drier for drying feedstock  *Source: Acacia Innovations*	Feed the raw material into the drier and run the machine by connecting to power. Once the producer purchases the drier, the manufacturing company installs the drier and trains the employees on how to operate the machine. **Merits** • Ideal for large-scale production of briquettes • High efficiency can dry 15-20 tonnes of raw materials in 1-2 hours (37KW rating) • Reduced floor space compared to open-air drying where the raw material is spread out in field **Demerits** • Not available locally • High upfront cost • Operation cost i.e., electricity bills **Cost**: Cost ranges based on output (USD 10,000-100,000)
Solar drying-greenhouse  *Source: Nawasscoal*	Channel the raw material into the greenhouse. Leave for 1-3 days. Ideal for drying waste with high moisture content such as sludge. Various greenhouse installers in Kenya e.g., PEGWA Enterprises and Amiran **Merits** • Available locally • No electricity cost • High efficiency for waste with high moisture (1- 3 days for waste with 98% moisture content e.g., sludge) **Demerits** • Efficiency is reduced during cloudy days • More space is required for setting it up compared to the driers **Cost**; Cost is dependent on size of the greenhouse for example; 6M by 12 M - USD 1,500 and 24M by 12 M- USD 8000
Solar-drying (Open-air)  *Source: Kofinaf Coffee Mill*	The feedstock is spread out on an open field to dry. In case it rains, it's covered with a polythene paper or tent-like material. **Merits** • Available locally • No cost of setting up **Demerits** • Efficiency is reduced during cloudy days • More space is required to spread out the waste **Cost**: No cost of setting up but may require to hire labour to spread the raw material out

Some materials have low moisture content and hence require no drying e.g. macadamia nuts and charcoal dust. In other instances, the supplier can dry the feedstock at source. The only limitation with this is the increased cost per kilogram of feedstock. For example, sawdust that is dried goes for KES 5-8 per Kg compared to wet sawdust that goes for KES 3 per Kg.

ii) Sorting of raw materials

Sorting or waste separation is required under the following circumstances;

i. The feedstock has high levels of foreign materials and other impurities that may interfere with the briquetting process

ii. The feedstock has large particles that require milling in order to achieve uniform particle size for briquetting

If the scale of production is small and the feedstock does not have high levels of foreign matter, handpicking would suffice to separate the waste. However, use of sieves and sorting machines is recommended for large-scale production because of its increased efficiency. Table 52 below provides details of a sorting option.

Table 52: Details of the sorting machine

Sorting of raw materials	
Technology/ Appliance	**Description**
Sorting machine  *Source: Alibaba.Com*	This is ideal when small size raw materials of 2mm are required. The raw material is fed to the machine from the top then the machine is rotated side to side. The small particles are sieved out and large particles are retained at the top of the sieve. **Merits** • Enclosed structure reduces noise and dust • The mesh can be easily replaced in case of damage • Simple operations • No professional training is required to run the machine **Demerits** • Cost is high for informal briquette producers **Cost:** Cost range is USD 1,050 – 3,350
Sorting sieves  *Source:Local briquette producers*	These are fabricated by mounting a coffee mesh roll on a rack. The roll is purchased from local stores. This is ideal for when small size raw materials of 2mm are required. Large particles are sorted and then crushed. **Merits** • The raw materials to fabricate the equipment can be sourced locally • Less costly compared to imported sorting machines in relation to upfront and operation cost (no electricity cost) • Ideal for small-scale production • No professional training is required to operate the machine **Demerits** • Operated manually and therefore less efficient compared to automatic machines. **Cost:** The coffee roll, which is the main component of the sieve, is purchased per meter. One Meter- USD 3

Hand-picking  *Source: www.Pixabay.com*	This type of sorting is done manually. No cost of machine and technical skill required. This is used mainly to remove foreign materials from the waste. **Merits** • No cost of setting up • Ideal for small-scale production • No professional training is required to sort by hand picking **Demerits** • Low efficiency compared to an electric machine **Cost**: The only cost associated with this method is cost on labour

iii) Milling and Shredding

Raw materials with a hard outer shell such as the macadamia nuts require crushing or milling to facilitate proper compaction. Milling is also done to ensure even particle sizes of the raw materials. Uneven sizes of the materials will result in mal-formed briquettes. Paper waste, wheat straws and sugarcane bagasse may require shredding depending on the desired particle size. Below is the equipment that a briquette producer can employ to execute these two tasks.

Table 53: Details of the sorting and shredding machine

Milling of the raw materials	
Technology/ Appliance	**Description**
Hammer Mill  *Source: Alibaba.Com*	This is used for crushing or milling raw materials to achieve the desired particle sizes and to reduce the size of the hard-raw materials such as macadamia nuts, wood chips etc. The raw material is fed into the machine through the feeding inlet and the equipment is run by connecting the machine to electricity. **Merits** • Simple to operate • Less noise pollution because of low vibrations • Low investment on energy consumption **Demerits** • Requires electricity to run. The producer has to be connected to electricity. **Cost** • Dependent on the output • The cost ranges from USD 900-1,500

Twin shaft agricultural waste shredder  *Source: Alibaba.Com*	Used to reduce waste to the desired size particles. The raw material is fed into the machine through the feeding inlet and the equipment is run by connecting the machine to electricity. **Merits** • Low noise, less dust and high capacity • High efficiency • No professional training is required to run the machine **Demerits** • Requires electricity to run. The producer has to be connected to electricity. **Cost** • Cost is determined by capacity and power rating USD 4,000-50,000

iv) Carbonisation of the raw material (for carbonised briquettes)

Carbonisation or pyrolysis of the biomass feedstock, which is the conversion of raw materials into carbon in the absence of air, is only done in the production of carbonised briquettes. The aim of the process is to increase the energy content of the raw material. Not all raw materials have to go through this process as some like charcoal dust are already carbonised. Before carbonisation, ensure that raw material is dried. If not, some of the material will have to burn to produce the energy for drying feedstock before carbonisation begins resulting to high loss of raw materials[278].

High temperatures are a requirement for pyrolysis, but because most of the biomass is both a fuel and the material that is being carbonised, there is need to maintain a balance between producing heat and releasing carbon material. For example, at 270°C[279] most of the agricultural waste remains unburned (sawdust is 250°C) and can be converted to carbonised briquettes[280].

Table 54: Summary of the carbonisation options

Carbonizing of the raw materials (for carbonised briquettes)	
Technology/ Appliance	**Description**
Drum kiln Carbonizer  *Source: Hubpages Link*	Load the raw material into the drum and close the lid. Place the drum on a three stone open fire and leave for material to carbonize. It takes 4 hours to carbonize the material. **Merits** • Affordable to small-scale briquette producers • Locally available • No professional training is required on how to use the technology **Demerits** • Low capacity (50Kgs) for large-scale producers • Uses firewood as source of heat **Cost** • Recycled oil drum can be bought from local jua Kali markets • Cost is between USD 10-15

278 Wondwossen Bogale. (2009). Preparation of Charcoal Using Agricultural Waste. file:///C:/Users/TBC/Downloads/56314-Article%20Text-95679-1-10-20100708.pdf

279 Ibid

280 KII with the briquette manufacturers

Carbonisation Furnace  *Source: Alibaba.com*	Load the raw material into the drum and close the lid. Introduce an external source of heat (firewood or gas) leave for material to carbonize. Depending on capacity can carbonize 3-12 tonnes per hour. Merits • Ideal for a large-scale production site • High carbonisation ratio of 99% • Shorter carbonisation time (6 hours from 24 hours) Demerits • High upfront cost compared to the drum carbonizer • Use of firewood as source of heat contributes to forest degradation Cost Cost • Cost is determined by the capacity (tonnes that can be carbonised) of the furnace USD 4,500-6,500

2.3 Briquette production

i) Mixing

This step only applies to the production of carbonised briquettes. A binding agent is added to the raw materials in the presence of water to enhance bonding and to attain stable briquettes. A good binder has the following characteristics;

- Effective in holding the briquette together
- Produces low ash content after burning
- Burns without smoke

Examples include gum Arabica, fine clay, cassava flour, wheat flour, molasses, soaked wastepaper and red soil. Poor quality binders such as clay, red-soil and waste papers that produce smoky briquettes should be avoided. Binders made from molasses and gum Arabica are preferred because of their strong gelling characteristics and form quality briquettes due to low ash content. Options for mixing include manual mixing where a producer uses a drum and stirs the different components or the use of an electric mixer, which is automatic once, connected to power and more effective compared to the manual mixing.

Table 55: Details of the raw material mixer

Mixer (for carbonised briquettes)	
Technology/ Appliance	**Description**
Electrical mixers (Wheel mixer)  *Source: Alibaba.com*	Load the raw material, water and the binder into the mixer. The mixer has spindles that move from side to side to enhance the mixing of the raw materials **Merits** • No professional training required on how to use the machine • The rolling wheel increases production efficiency with the raw materials fully mixed. • Simple operation **Demerits** • Cost may be high for small-scale briquette producers • Operational cost is higher due to use of electricity compared to manual mixing **Cost** • Cost is determined by the output capacity (tones that can be mixed) and ranges from USD 1,200-3,400

Rotating Mixer  *Source Nawasscoal*	Raw materials are added to the rotating drum from the upper end, heat is introduced in the low side, which forms the countercurrent contacting allowing the materials to mix to form the briquettes. Varying production capacity that can go up to 1,000 Kgs a day **Merits** • Available from local fabricators e.g., Jaffidian Enterprise Limited. • Less expensive compared to the electric mixer **Demerits** • Efficiency is reduced as mixing is done manually **Cost** • Cost is determined by the capacity of the mixer. A capacity of 1,000 Kgs per day goes for USD 2,500
Manual Mixing  *Source: Practical Action*	Used for small-scale production. The raw material is mixed with the binder using hands or using a spade to stir the mixture in a container. **Merits** • Low or no initial cost as you may use hands for mixing the feedstock and the binder • Low running cost as there is no electricity bills to run the machines or maintenance costs for associated with the use of mixing equipment • Ideal for small-scale production **Demerits** • Low efficiency as mixing is done manually • Mixing may be uneven compared to electric mixers

ii) Compacting

Compacting is key to dispel entrapped air, which is the main cause of loose briquettes. Loose briquettes tend to disintegrate easily. The consideration to be made when deciding on the type of compacting machine to purchase is the type of briquettes to be produced. Non-carbonised briquettes require machines that can attain high temperature and pressure. On the other hand, carbonised briquettes use machines that are of low-medium pressure and temperature to avoid combustion of the carbonised materials.

These machines are available locally and through importation, (a list of local fabricators and importers of briquette machines is provided at the annex). Imported machines are from either Europe, India or China. Although the machines from Europe are expensive compared to the rest of the machines in the market, they have several advantages including: high quality, high efficiency, less breakdowns and they can be automated reducing the number of employees required in a production site. The cost of the machine is mainly dependent on their production capacity per hour and quality. The merits and demerits of the different compacting technologies are discussed below to guide the producer in selecting the most suitable technology for compacting.

Table 56: Types of compacting machines (medium-pressure machines)

Medium-pressure compacting machines (for carbonised briquettes)	
Technology/ Appliance	**Description**
Motorized screw press (fitted with a gear)  *Source: Kendubay Machinery*	The machine is fitted with a gear to improve compatibility of the raw material. Demonstration by the machine fabricator is sufficient to be able to use the machine. Local fabricators include Kendubay Machinery, Kejofra Engineering and Benmah Product Company. **Merits** • Locally manufactured and readily available in the market • Spare parts can be sourced locally • Local expertise available to deal with breakdowns. • Affordable compared to imported machines **Demerits** • Frequent breakdowns if poorly fabricated • Informal produced hence difficult to identify the fabricators **Cost** • Cost USD 850-4,500 depending on the power rating.
Motorized Screw Press  *Source: Kencoco Limited*	Imported machine. Use of the briquette manual is sufficient to operate the machine. **Merits** • Less breakdowns **Demerits** • Importing process is long and small-scale producers may not be aware of the process • Expertise to repair the machines may not be available locally in case of a breakdown. **Cost** • Cost USD 2,500-5,000

Table 57: High pressure compacting machines

High pressure machines	
Technology/ Appliance	**Description**
Extruder Briquetting Press  *Source: C.F. Neilsen*	Manufactured and distributed in Kenya by C.F. Neilsen. Production Capacity of 500 Kgs per hour. Used to produce household briquettes. The machine distributor provides training during installation on how to use the machine. **Merits** • Available at different capacities • High efficiency • High quality i.e., less breakdowns **Demerits** • High upfront cost • Operational cost of electricity is high compared to locally fabricated machines **Cost** • Cost USD 2,500-5,000

Hydraulic Briquette Pressing Machine  *Source: C.F. Neilsen*	Manufactured and distributed in Kenya by C.F. Neilsen. Production capacity of 30kg to 1,500 Kgs per hour. The machine distributor provides training on how to use the machine during installation. The machine is electric and therefore the producer must be connected to the grid **Merits** • Available at different capacities • High efficiency • High quality i.e., less breakdowns **Demerits** • High upfront cost • Operational cost of electricity is high **Cost** • 500 Kgs per hour capacity is USD 70,000

iii) Drying briquettes

This applies to carbonised briquettes. Several drying options exists that a producer can select from. The main ones are solar drying and use of driers. Solar drying can be done by placing the briquettes on drying racks, on laying them gently on the ground or through racks placed in a greenhouse. The drying racks can be built to allow stacking of several trays thus saving on floor space or can be made using simple material e.g., wire mesh. Advanced drying methods include the use of driers (e.g., flash driers) which is highly efficient taking up to 1-2 hours to dry briquettes compared to solar drying which can take between 1-3 days.

Table 58: Types of drying options

Drying techniques	
Technology/ Appliance	**Description**
Solar drying-(greenhouse)  *Source: Nawasscoal Limited*	Place the briquettes on drying racks inside a greenhouse. There are various greenhouse installers in Kenya e.g., PEGWA Enterprises and Amiran. **Merits** • High efficiency compared to open air drying • Low operational costs such as electricity bills **Demerits** • Costly compared to open air drying **Cost** • Cost is dependent on size of the greenhouse for example; 6M by 12 M - USD 1,500 and 24M by 12 M- USD 8000
Open Air Drying of Briquettes  *Source: Eversafe Ltd*	Place the briquettes on drying racks in an open field. **Merits** • Low upfront cost compared to use of greenhouses • Low operational costs since electricity is not used. **Demerits** • Dependent on weather conditions and producers have to have a shed during the rainy seasons **Cost** • The coffee mesh roll, which is the main component of the sieve, is purchased per meter. I Meter- USD 3 in hardware shops.

Table 59: Advanced drying methods

Drying techniques	
Technology/ Appliance	**Description**
Driers- e.g., vertical driers  Source: Maxton Engineering	The briquettes are conveyed to the top of the dryer by belt conveyor and evenly distributed on the across section by a distributing device. As the cone rotates, the water vapor is evaporated from the briquettes. **Merits** • High efficiency for large-scale production of briquettes • Reduced floor space • Not dependent on weather conditions **Demerits** • High upfront cost • High cost of operation compared to solar-drying (i.e., cost of electricity) • Must be imported **Cost** • Cost ranges based on power ratings (USD 10,000-100,000)

How to purchase the machines

Most of the machines used in the different briquetting processes are imported but others are locally fabricated. Annex 2 provides contacts to local machine fabricators and distributors of imported machines.

In case the briquette producer would wish to import the briquettes directly from the manufacturers, the section below provides guidelines on how that can be achieved.

Guidelines on how to import briquette-making machines

The first step is to identify the type of machine to be purchased from an established platform like Alibaba. Since this is heavy machinery, sea freight is ideal and is cheaper compared to airfreight but much slower. It can take up to 45 days or more depending on the port of departure. There are several means of payment including; (i)PayPal, (ii) Online payments using a card (if buying off an online platform and (iii)Wire transfer (for huge amounts of 2500 USD and above bank wire transfers are feasible while for anything under USD 2500 PayPal or card are more cost effective)

Once the merchandise has left the port of departure, a tracking number is issued through the contact email address provided to help with tracking the shipment. On arrival, package goes through the custom for clearing. This can be done through clearing and forwarding companies at a fee.

In addition to the cost of the machine, the following costs are incurred at the port of entry;

1. VAT (14% currently but usually 16% of Cost Insurance and Freight value (CIF)
2. Customs duty (0-35% of CIF) depending on the tariff used for the item. Different items have different HS codes and different countries charge different amount. (EAC external tariff has information on Harmonized System codes and corresponding duty rates)
3. Import Declaration Fee from 3.5% of CIF value
4. Railway Development Levy (2% of CIF)
5. Kenya Bureau of Standards
6. Agency fees (depends on the clearing agent)

For large value items where value is 500,000 KES or above there is need to do an inspection at source. After inspection, you are issued with a certificate of conformity (COC) and there after you can ship. Failure to inspect at source attracts a 25% penalty by KEBS

Maintenance of the Machines

A series of activities are performed towards the preservation and restoration of mechanical machines, or equipment/tool to make it sound for efficient and effective work performance. Maintenance may involve regular routine cleaning (dusting and wiping), checks, servicing, repair, and replacement of worn out or non-functioning parts of the machines.

The machine can be manual (simple), or mechanical (complex) within a manufacturing enterprise. The purpose for maintenance of machines, equipment and tools in briquette production is to prevent damages to the machines, enhance their performance, and also ensuring that they remain conditionally fit at all times. Maintenance falls into three categories:

Routine Maintenance – This is an activity done on a regular basis while the machine, equipment, or tool is in service. It involves from cleaning by dusting or wiping, and checking for any defects and fixing them, checking oils and greasing.

Diagnostic Testing – This is done to ascertain the condition of a machine, equipment or tool due to failure to perform, deterioration, suspicion or fault.

Maintenance Testing – This is an activity performed to a machine, equipment, or tool to assess its condition in an off-motional state.

The maintenance activities must be well recorded and the records kept for references. Machines are like motional automobiles whenever they are serviced; a tag is hanged or recorded somewhere to provide maintenance information when needed. Steps to take for quality maintenance of a machine include:

Note

1. Servicing machines must be done by only qualified and authorized personnel

2. Electrical power to mechanical machines and equipment/tool must be disconnected before servicing or cleaning begins.

3. Electric machines should have a voltage stabilizer to ensure that a constant voltage is delivered to the machine even during power surges.

4. In regions with unreliable power or off grid areas, diesel generators can be utilised. However, this would increase the carbon footprint of the business as emissions from diesel are higher compared to electricity[281]

5. Always read the machines' instructions Manual for guidance on servicing

6. Let authorized and qualified personnel operate machinery and equipment/tools to minimize faults and accidents.

Measures to reduce carbon foot printing at production level

Various carbon footprint reduction approaches can be employed at the different stages of briquette production. The first avenue to reduce carbon emission is in the selection of the type of raw material to be used for briquette production. For example, charcoal dust is sourced from charcoal that may be unsustainably produced which may be contributing to carbon emissions. Although it is difficult for the producer to ascertain whether the charcoal was sustainably produced, the government can regulate the charcoal production sector to ensure that the charcoal in the market is sustainably produced.

The second approach in reducing the carbon footprint in the production of briquettes is in choosing the type of machines to be utilised under the various stages of the production process. Out-dated technologies have low efficiency and thus high consumption of electricity, which results to greenhouse emissions. Briquette producers can also ensure technologies that have low emissions and environmentally friendly are employed under the various production processes. For instance, for milling of the raw materials, a hammer mill that is powered by electricity has low emissions compared to one that runs on diesel. In drying of the raw materials and briquettes, use of solar drying (greenhouses) is more environmentally friendly due to low emissions compared to the as use of driers which require electricity for operation. Carbonisation of the raw materials should be done using cleaner sources of heat as opposed of firewood that is unstainable harvested from natural forests. The producers can identify private farms that grow the trees sustainably to be their sources of firewood.

Measures of reducing carbon emissions in the daily operation of the production site should be implemented. These measures include; use of Light-emitting diode (LED) which has reduced energy consumption and an extended lifespan compared to fluorescent lighting fixtures thus reducing the carbon emissions. Other practices that can be implemented at the production level include, switching off machines that are not in use, switching off light bulb during the day and relying on natural light, frequent servicing of the machines, and continuous monitoring of energy use in the business to identify areas to reduce energy consumption.

281 More than 80% of electricity in Kenya is from clean sources (hydro, geothermal and wind)

Finally, the producers can explore ways to reduce carbon emission in the transportation of the raw materials to the production site and the briquettes to the end-users. The production site can either be close to the source of the raw materials or to the end-users. This will reduce the distances to be covered, which will aid in mitigating carbon emission from the use of fossil-based fuels. Bulk delivery of briquettes and purchase of raw materials is recommended to reduce the number of trips that have to be made in a day.

iv) Testing and quality assurance of briquettes

Briquette producers must ensure that the briquettes meet the minimum quality standards that fulfil the customer's expectations. The quality of briquettes is defined in terms of the following parameters; smoke emissions, moisture content, density, calorific value and ash content. Other characteristics to consider include performance, reliability, safety and appearance for convenience reasons.

The Kenya Bureau of standards adopted the ISO standards on solid biofuels Part 1-7 in 2015 to provide additional guidelines covering the non-carbonised briquettes from both wood and non-wood-based feedstocks and standards for briquette and the standards on carbonised briquettes are being finalized. However, currently the KEBS uses the South Africa briquettes standards for carbonised briquettes and the ones under development have borrowed heavily from South African ones. In Kenya, we have two main testing centres that briquette producers can have their briquettes tested. These are; University of Nairobi and Kenya Industrial Research and Development Institute (KIRDI). Kenya Bureau of Standards tests products to ensure that they meet the minimum requirement for use. If the briquettes meet the stipulated criteria then a permit of sale is provided to the producer and a mark of standardization provided for the label of the briquette package. This mark is very important to win consumer confidence and if you want to sell through supermarkets then the standardization mark is a mandatory requirement. Below are steps to follow to acquire the KEBs label of quality;

- The producer initiates the process with KEBs
- Make payment (KES 5,000 for SMEs)
- The product is tested
- If the briquettes meet the specified criteria, a permit is provided within 2-3 months
- If the briquettes do not meet the requirements feedback is provided to the producer and the process starts again
- KEBs schedules for annual surveillance visits to ensure that the briquettes still adhere to the standards

v) Packaging

The type of end-users determines the type of packaging to be employed by the producers. Large-scale briquettes users (non-carbonised) such as industries and institution require no defined packaging as the fuel is loaded to either the pick-ups or the Lorries and are measured in tonnes. Briquettes for end users are mainly packed in 2 kg, 5kg and 10 kg bags (brown bags). The briquettes are weighed (using a weighing scale) and packed manually for small-scale producers. The producer can compare the cost of buying and operating a packaging machine versus hiring employees to pack the briquettes manually.

Table 60: Types of packaging

Type of Package	Description
Household Briquettes   *Source: Kencoco Limited and Nawasscoal*	• This package is for household briquettes • The packages can range from 2-25 Kgs • The KEBs mark of quality is affixed/written to the package to build the conumer confidence
Institution/Indusrial Briquettes  *Source: Acacia Innovations*	• This package is for large-scale briquettes end-users such as institutions • The packages can range from 25-50 Kgs • The KEBs mark of quality is affixed/drawn to the package to build the conumer confidence

vi) Storage

Dried briquettes should be stored in a warehouse at room temperature of 20°C within the production site waiting for sales and distribution. The size of the storage house is dependent on the scale of production. The storage must be free of water and insects such as termites. The briquettes can also be protected from moisture by wrapping them with a polythene bag, putting them off the floor and away from leaking roofs or pipes.

2.4 Briquette marketing and distribution channels

Marketing

Marketing is a very important component of any business. Without good marketing strategy, it is difficult for your product to be known and get the right traction. Therefore, dependent on the size of the business, the target market, size of the business and the marketing budget will determine the approach and the technique to be used. There are two main approaches to marketing that can be adopted.

Above the line marketing (ATL) campaign- This type of marketing is broad and not targeted to a specific audience. The main aim of this approach is to create brand awareness and customer good will. Examples include advertisements on television, radios and billboards. Since this approach is costly, it can be used at the start of business. After people are aware of the briquettes and consumer loyalty has been built, the producers can resort to other forms of marketing that are more affordable.

Below the line, marketing (BTL) campaign- This type of marketing is targeted to a given audience and it is direct. It includes the following:

One on one meetings –This is ideal for end-users such as industries and institutions. The producer can arrange for face-to-face meetings with the administration of these institutions and introduce their products and businesses. Products for trial can also be provided.

Door to door campaigns- This approach is for household briquettes. The producer can identify his/her target area and hire personnel who can provide brochures about the business to the potential end-users. The brochures can have information about the products and benefits that the household would accrue from usig the briquettes. Door to door, approach is ideal for marketing briquettes in densely populated areas such urban and peri-urban areas. To reach a wider audience, especially in rural areas and in low-income areas such as Kibera, Community-Based Organisations (CBOs) such as women groups and youth groups can be used as avenues for awareness creation.

Roadshows- This approach can be employed for large-scale producers of household briquettes. The roadshows can hold demonstration on how to use the briquettes e.g., quick ways of lighting the briquettes, what type of stoves burn briquettes well, which type of foods can be cooked with briquettes etc. To reach a wider audience, the roadshows are recommended for urban areas where the population is concentrated per unit square.

Distribution

1. Direct distribution - this is directly from the producer to consumer
2. Indirect distribution - through intermediaries such as supermarkets, general retails outlets,

Concerning distribution of the briquettes, various approaches can be employed. Direct distribution applies to households close to the briquette business and is commonly used for institutional and industrial consumers through contracts arrangement. Indirect distribution uses intermediaries to reach out to consumers such as supermarkets, general retail outlets, mobile distribution trucks, digital platforms and commission agents. In urban areas, supermarkets (for briquettes to be sold through supermarket, they must have a Kenya Bureau of Standard mark), mini-shops are common and evenly distributed compared to rural areas allowing briquette distribution to reach a wider market. Households are also concentrated per unit area in urban and peri-urban areas making door-to-door sales or a mobile distribution truck ideal for reaching the end-users. The businesses can try out the different approaches and evaluate over a specified period, which is the most effective in terms of sales and cost.

2.5 Environmental and social-economic benefits of production and Uptake of briquettes

It is estimated that 2Mton of charcoal are consumed annually at the household level282. Most of the Charcoal in Kenya is unsustainably produced which contributes to forest degradation. Industries such as tea factories and institutions (schools, prisons, hospital etc.) form a category of large-scale consumers of wood fuel. For instance, in 2018, the tea factories in operation consumed around 904,000 tons of firewood283. Other industries with significant consumption of firewood and charcoal include brick making, tobacco processing, milk processing, fishing and fish smoking, bakeries and restaurants and kiosks. Consumption of firewood and charcoal at a rate that does not allow for regeneration of forests results to land cover change and impacts on an important global carbon sink (forests). Sustainable production and large-scale uptake of briquette will contribute to curbing deforestation and forest degradation and contribute to climate change mitigation by having more trees to absorb carbon.

Briquette production is viewed as one of the pathways that can be used for waste management resulting to cleaner environments and healthy societies. Increase in population especially in urban areas has resulted in the increase in the quantities of waste generated. This is especially the case in countries where waste collection and management systems are not fully developed. Consequently, open dumpsites are common in these cities and they form breeding grounds for disease causing pests and parasites such as rats that pose a significant risk to public health. Utilization of this waste for briquette production will aid in addressing the health concerns and environmental issues associated with waste generation.

Development and growth of the briquette sector will also contribute to creation of jobs. Different job opportunities exist across the briquette production value chain including; raw material suppliers, brokers of both raw materials and briquettes, workers in the briquette production sites, distribution points and salesmen. This is viewed as an opportunity to grow the household income contributing to better lives. Quality briquettes also increases the cooking options at the household level.

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282 Ministry of Energy (2019). Kenya Household Cooking Sector Study

283 UNEP (2019). Sustainability of sugarcane bagasse briquettes and charcoal value chains in Kenya

3 Identification of viable business models

The aim of this chapter is to enable a briquette business start-up to evaluate their business model and guide already existing briquette businesses to resources that can help improve their business models. The business model addresses the technical aspects of the briquettes production chain from a business lens. The aim is to build sustainable, scalable and economically viable businesses that will be able to compete in the competitive market. This can be realised using two proven approaches on business model development namely: The Lean Canvas Model (designed for start-ups) and Business Model Canvas (designed for already existing businesses).

3.1 Lean Canvas business model

The Lean Canvas Model (LCM) is designed for start-ups. Before embarking on a briquette production, a producer needs to determine if there exists a business opportunity, the risks and the uncertainties involved in the business. The tool focuses on the problems-solutions approach. It has 9 core components as discussed below.

Problem

Define the problem that you want to solve for your customer segment. Without a problem to solve then the product has no market. The producer can conduct market intelligence studies or through literature, review to identify some of the prevailing challenges in the general fuel sector and whether the briquettes have an upper hand of addressing the challenge. Some of the key issue identified in the fuel sector include cost, high carbon emission from fossil fuels, emerging investment trend among others and in briquetting sector; the challenges include poor quality briquettes for households, lack of developed supply chains and inconsistent availability of the product in the market among others. A business idea can be based on how to address these problems by researching on possible ways to tackle these barriers.

Solution

The next step after identifying the problem is to formulate possible solutions to the problem. The issue on poor quality can be addressed by using the briquettes standards, which are currently in use, understanding what people, are using as an alternate and working on your briquettes to be comparable and or better. To be able to achieve these standards the producer can identify the suitable briquetting machines and raw materials (as discussed in chapter 2 of this manual). Training is also important on how to produce suitable briquettes. This can be obtained from briquette technology experts or being part of the United Briquette Producer Association.

Unique Value Proposition

This step explains what value you are adding to your customers. Why would a customer buy your product and not the already existing solutions in the market or from other existing businesses? How will the briquettes compare with existing solutions such as charcoal in terms of cost, quality and availability? How do the briquettes produced compare with briquettes from other producers? If the briquettes you aim to produce will not add value to the end-users, uptake and continued use will be low and sustainability of the business may not be Realised.

Unfair Advantage

This is hard to develop but very important when looking for investors and partners. The question to answer is what is unique to your briquettes and cannot be easily replicated by other briquette producers or other alternative solutions in the market? The aim of that gives you a competing edge over the other competing solutions in the market.

Customer Segment

This step answers who your target market is. Households, poultry farmers, and space heating in hotels, institutions and small eateries on the roadside (kiosks) consume carbonised briquettes. Non-carbonised briquettes are for institutions and thermal intense industries. Depending on the market intelligence, you have gathered you can decide on which type of end-users to target. Key information to gather is where demand is high among the different groups of end-users.

Key Metrics

Identify the key metrics that you will track as indicators for the success of your business. Quantities sold monthly can be used as a measure of business expansion. If you are selling the briquettes to large-scale users, you can track the repeat customers and the new ones that are added over time.

Channels

Identify how the products will reach the end-users. These will be determined by the location of the end-users and cost associated with the various distribution channels. Direct sales from the producers reduces the cost associated with transporting the briquettes to the consumers but also is limited to the consumers near the production site. Introducing distribution points along the supply chain for household's briquettes introduces a mark-up on the cost of the briquettes, which turn out to be more costly than if bought at the producer's site. The briquette producers can compare the merits and demerits of each possible distribution channel and decide on the most effective distribution channel to employ. Another key component under this is to determine how to create awareness of the products to the consumers. Possible options of creating consumer awareness campaigns include road shows, advertising, and one on one engagement with potential consumers (e.g., schools and industries) demonstrations and providing trial briquettes to the target market.

Cost structure

Estimate the cost associated with setting up the business and daily operations. Cost of fixed assets such as machinery, premises, acquiring permits and variable costs such as cost of feedstock, cost of labour etc. The estimates of the cost of machinery are provided in chapter 2. This is useful in determining how long it will take the business to break even and to calculate the profit margins.

Revenue streams

Determine the pricing of briquettes. This is informed by the cost of production. The producer must ensure that the price of briquettes reflects the cost of production but at the same time ensure that the briquettes are competitive compared to the price of the alternative solutions. If the cost is higher than the cost of alternative solutions e.g., charcoal then the value add of the briquettes must be higher than what charcoal has to offer. This will be important in convincing the customers why the cost is higher than charcoal by explaining the advantages of briquettes to charcoal.

The table below provides an example of a filled-out template for a carbonised briquette start-up business. The cost of component is not calculated as it would be highly determined by the scale of production per producers but the main items to be calculated have been outlined.

Table 61: An example of a filled out LCMP template

PROBLEM	SOLUTION	UNIQUE VALUE PROPOSITION	UNFAIR ADVANTAGE	CUSTOMER SEGMENTS
List your top 1-3 • Sub-standard briquettes • Low supply of briquettes (quantities and consistency) • Lack of consumers awareness	Outline a possible solution for each problem • Use stipulate procedures/standards to produce quality briquettes that meet consumer specifications. This will be influenced by suitable raw materials and technologies • Ensure that production of briquettes is consistent by having sufficient raw materials and the suitable briquetting machines • Create consumer awareness campaigns (road shows, demonstrations and providing trial briquettes to the target market)	Single clear, competing message that states why you are different and worth paying attention • Provide quality briquettes (smokeless, low ash content, high calorific value etc.)	Something that cannot easily be bought copied Large energy out-put over a period time. Thus, ideal for cooking foods that take long to cook, space heating and cooking of large quantities of food as experienced in hotels or institutions	List your target customers and users • Households • Poultry farmers • Space heating for hotels • Small eateries such as Kiosks • Institutions
EXISTING ALTERNATIVES		**HIGH-LEVEL CONCEPT**	**CHANNELS**	
List how these problems are solved today • Use of alternative cooking solutions e.g., charcoal		List your X for Y analogy e.g., YouTube-Flicker for videos	List your path to customers (unbound or outbound) • Direct sales-from the production site (consumer going to the producer) and consumer delivering to the consumer at a cost • Business to Business	
	KEY METRICS			
	List the key numbers that tell you how your business is doing • Quantities sold • Repeat consumers • New consumer			

COST STRUCTURE	REVENUE STREAMS
List your fixed and variable costs Fixed cost • Cost of machinery (this will be guided by discussions in chapter 2) • Cost of premises Protective clothes • Business permit • Cost of testing of briquettes Variable costs • Cost of labour • Cost of feedstock • Renewal of business permit	List your streams of revenue • Sale of briquettes

3.2 Business Model Canvas

The Business Model Canvas (BMC) is designed for already existing businesses with the aim of visualizing and testing your business model to identify areas of improvement. The LCBM discussed above was developed from the BMC. All the components of LCMB discussed above apply to the BCM. However, BCM has 3 additional components that are not covered under LCBM. These components are discussed below.

Key partners

The existing briquette production businesses have to answer these three questions;

1. Who are your most important partners?
2. Which key resources do you acquire from partners? And;
3. Which key activities do your partners perform?

Key partners in the briquette sector could range from financing institutions (EEP Africa, KawiSafi, Acumen etc.), briquette programme implementers (Practical Action, Energy for impact, Netherlands Development Organisation etc.), the United Briquette Production Association (UBPA). The financing organisation would provide financing to viable business models through grants or loans that the business can use to expand the work. Organisations that have implemented briquette programmes in the past or have on-going programmes would provide information on lessons learnt, direct the briquette producers to useful actors in the sector such as briquetting machines fabricators and importers and inform them of programmes that are on the pipeline that could potentially benefit the briquette businesses. Being part of an association with other briquette producers such as UBPA is useful in activities such as capacity building and you get access to current information on the prevailing trends in the sector.

Key activities

What are the activities you perform every day to create & deliver your value proposition?

- Sourcing of raw materials
- Production of quality briquettes
- Marketing of the briquettes

Customer relationships

What relationship does each customer segment expect you to establish and maintain, for example, dedicated personal assistance, self-service, automated service etc.

Annex 2: KII Guide for Potential suppliers of briquetting materials

A. SUPPLIER IDENTIFICATION		
1.	Name of the company (if in an informal location state source of the feedstock e.g. Kawangware market)	
2.	State the location of the main office (Town):	
3.	Respondent Name:	
B. Feedstock resource ASSESSMENT		
1.	What are the types of biomass residue produced on your site?	A. Bagasse B. Coconut husk/shell C. Coffee husk D. Cotton stalk E. Macadamia nutshell F. Maize cob/stalk G. Pineapple pulp H. Rice husk/straw I. Sawdust J. Flower stalk K. Wheat straw L. Sisal boles/waste M. Cassava stalks N. Cashew nutshell O. Millet stalks P. Other
2.	Please estimate the monthly production for each of the biomass residue identified above (Q 1)	see table below

Month	Tonnes
January	
Feb	
March	
April	
May	
June	
July	
Aug	
Sept	
Oct	
Nov	
Dec	

C. BIOMASS SALE ASSESSMENT		
3.	How do you dispose/utilize MOST of the biomass waste generated?	A. Use it B. Sell it C. Dispose through a company/individual (at no cost) D. Left on growing Sites E. Burn it
4.	If you use it, how do you use it and the estimated proportions of use?	(see table below)
5.	If you dispose through a company at no cost, which companies/ individuals do the disposal? If yes C for Q C1	
6.	Who are the buyers (ALL) of the biomass residue and estimated amounts in tonnes per day during the peak and low season?	(see table below)
7.	What is the average price of the residue in KES per unit tonne?	
8.	What is the frequency of collection of the biomass waste for the peak season?	A. Daily B. Once a week C. Twice a week D. Once a fortnight E. Once a month F. Other/specify
9.	What is the frequency of collection of the biomass waste for the low season?	A. Daily B. Once a week C. Twice a week D. Once a fortnight E. Once a month F. Other/specify

Question 4:

Use	Percentage (%)
Composting	
Animal Feed	
Burning	
Energy Production	
Mulching	
Others, specify	

Question 6:

Company	Amounts at peak season(tonnes)	Amounts low season (tonnes)
Briquette manufacturers		
Other energy generating companies (waste-energy)		
Thermal intensive industries e.g., tea factories		
Animal feed producers		
Cottage industries (e.g., food kiosk)		
Other, specify		

Annex 3: Briquette Manufacturers' Questionnaire

A. Enterprise Identification		
1.	State the location of the main office (Town)	
2.	Business Name:	
3.	Respondent Name:	
4.	Position of respondent in the company	
5.	Respondent Phone Num.	
6.	Date of interview	|__|__| / |__|__| / |__|__| dd/mm/yy
7.	In what year did this business start operating?	
8.	Is the business registered with the national/county government?	A. Yes B. No
9.	In what year was the business registered?	
10.	How many permanent, full-time individuals does this establishment employ? Please include all employees and managers. (Permanent, full-time employees are defined as all paid employees that are contracted for a term of one or more fiscal years and/or have a guaranteed renewal of their employment contract and that work a full shift)	
11.	How many of the permanent full-time workers in this enterprise are female?	
12.	What roles do the female workers play in the enterprise?	A. Managerial role B. Operational roles C. Sales and marketing D. Other, specify
13.	How many temporary employees does this establishment employ? (Temporary workers are all paid short-term, i.e., for less than a year, employees with no guarantee of renewal of contract employment and work full-time)	
14.	How many temporary workers employed in this enterprise are female?	
15.	What roles do the female workers play in the enterprise?	A. Managerial role B. Operational roles C. Sales and marketing D. Other, specify

B. PRODUCTION PROCESS		
16.	What feedstocks do you use in the production process?	A. Bagasse B. Charcoal dust C. Coconut husk/shell D. Coffee husk E. Cotton stalk F. Flower stalk G. Macadamia nut shell H. Maize cob/stalk I. Organic waste J. Other K. Paper waste L. Pineapple pulp M. Rice husk/straw N. Sawdust O. Wheat straw
17.	Please state the primary source of your feedstock	A. Registered companies (specify name) B. Individuals C. Abandoned waste e.g., in dumpsites D. Other (Specify)
18.	Please state the source (geographic location/nearest town) of your feedstock	
19.	What is the price per kg/tonne of feedstock? (KES)	
20.	What is the annual average kgs/tonnes of feedstock that is purchased?	
21.	How far is the source of the feedstock to the production site? (Kms)	
22.	How do you transport the feedstock from the source to your production site?	A. Hire a vehicle B. Collect it from a walking distance C. Hire youth to pick it from a walking distance D. Use of a boda- boda E. Other (Specify)
23.	How much does it cost to transport the feedstock per trip?	
24.	What are the other uses (competing uses) for the feedstock?	
25.	Is there any pre-processing done on the feedstock before use?	A. Yes B. No

26.	Provide more details on the pre-processing of the feedstock	
27.	What type of briquettes are produced by the company?	A. Carbonised briquettes B. Non-carbonised briquettes 28
28.	Why do you not carbonize the briquettes?	A. Costly B. Lack of the knowhow C. Not aware of the benefits D. Other (Specify)
29.	What technology/technologies is used in the briquette production?	A. Handmade B. Manual machines C. Locally fabricated electric machines D. Imported machines E. Others, specify
30.	How did you acquire the technology?	A. Donation from an NGO, development institutions B. Donation from friends /family etc C. Own savings D. Loan from bank/finance institution E. Loan from family/friends F. Other (Specify)
31.	What was the cost of the technology?	
32.	What are the chemical properties of the briquette at manufacturing?	A. Moisture content, B. Ash content, C. Energy content D. Other
33.	What is the average production volume per day/ month? year?	
C. DISTRIBUTION CHANNELS AND MARKETING STRATEGY		
34.	Which is your target market? (geographic)	A. Urban B. Rural C. Both
35.	Who are your main customers?	A. Distributors e.g supermarkets B. Households C. Factories e.g., Tea factories, BIDCO D. Public institutions (schools, hospitals, prisons, hotels) E. Small-scale enterprises e.g., food kiosks F. Other, please specify

36.	Please select all the top three distribution channels for the briquettes you manufacture (point of sale)	A. Supermarkets/market stalls B. Direct sales C. Door to door through agents or community members D. Microfinance institutions E. Community Based Organisations F. Other (specify)
37.	Please map out the possible channels through which the briquettes reach the consumers.	
38.	How do you reach your target market? (Main channel)	A. TV adverts B. Radio adverts C. Word of mouth D. E-marketing E. Print media F. Social media G. None H. Other (specify)
39.	How do you transport the briquettes to the selling point?	A. Hire a vehicle B. Walking distance to the selling point C. Hire youth to deliver to the selling point D. Use of boda-boda E. Other (Specify)
40.	Estimate the radius where your customers are located	
41.	How much does it cost to transport the briquettes to the selling point?	
42.	Which of the above distribution channel works best for your business?	
43.	How much briquettes do you approximately sell per week	
44.	Is there a recommended retail price for the briquettes? If. Yes, please indicate value	A. Yes B. No
45.	How does the cost of briquette compare with the cost of wood and charcoal in your area of operation?	
D. FINANCING OF BUSINESS		
46.	Please provide the initial cost of setting up this business?	
47.	What is the mode of payment by your customers?	A. Cash B. Credit C. Both D. Other, please specify

48.	For how many months do you offer the credit?	
49.	How do you pay for your supplies?	A. Cash B. Credit C. Both D. Other, please specify
50.	If on credit, what is the repayment plan?	
51.	Have you ever received a loan/grant? If Yes, please indicate the organisation	A. Yes B. No
52.	Which institution provided the loan or the grant?	
53.	How much was the loan or the grant?	
54.	Did you experience any difficulties in applying for the loan? If yes provide more details	
E. CHALLENGES AND OPPORTUNITIES		
55.	Please state the three main challenges to growing your operations.	
56.	Please state the three main recommendations you would make to help in growing your operations and in improving the briquette sector	
57.	Please state any additional comments	

Annex 4: List of Briquette Manufacturers' Interviewed

#	Name of Business	Location	Name of Respondent	Gender
1.	Imarisha Kenya	Nyeri	David Nderitu	Male
2.	Mwaki Mutheu	Kitui	Patrick Vaati	Male
3.	Kiangure Springs environment initiative	Tetu-Wamagana-Nyeri-Gathuthi	Joram Mathenge	Male
4.	Biomass Energy East Africa Limited	Kisumu	Rose Maiyo	Female
5.	Loyce Auma	Nairobi	Loyce Auma	Female
6.	African Solutions	Kisii Town	Elias	Female
7.	Eco charge	Nakuru	Mary Nyambura	Female
8.	Nerea Akinyi	Kisumu Ndogo Nairobi, Kibera	Nereah Akinyi	Female
9.	Kings Biofuels	Kenol-Thika	Francis Akamu	Male
10.	Wood Heat Energy Limited	Fly- over along the Nakuru highway	Isaiah Maobe	Male
11.	Janet Adhiambo	Kibra	Janet Adhiambo	Female
12.	Eversafe briquette Limited	Mai Mahiu Naivasha	Lydia Waithera	Female
13.	Titus Kinoti	Njiru Nairobi	Titus Kinoti	Male
14.	Kencoco	Kikambala Kilifi	Said Twahir	Male
15.	Sanivation	Naivasha	Dickson Ochieng	Male
16.	Roda Auma	Kibira	Rodha Auma	Female
17.	Nyalore Impact	Homa Bay Town	Dorothy Otieno	Female
18.	Bioafriqenergy Limited	Machakos	Doreen Achieng	Female
19.	White coal industries ltd	Kisumu Kibos road	Anonymous	Anonymous
20.	Acacia Innovations	Bungoma	Elana Laichena	Female
21.	Eco-charcoal Limited	Coastal Kenya	Béatrice Despioch	Female

Annex 5: List of Briquette Machine Fabricators and Distributors Interviewed

#	Name of company	Type of Business	Name of respondent	Contacts	Gender
1.	Kejofra Engineering	Local Fabricators	Martin Maina	0741 077384	Male
2.	Benmah Product Company	Local Fabricators	Benson Mahogo	0722 237869	Male
3.	Kendubay Machinery Service	Local Fabricators	Mr. Victor	0798 990468	Male
4.	Camco Machinery	Importer/distributor	Mr. Osiemo	0714 255499	Male
5.	CF Neilsen	Manufacturer/ distributor	Thomas Nyabera	020 4440293	Male

Annex 6: List of Organizations Interviewed

#	Organization
1	Ministry of Energy
2	Kenya Bureau of Standards (KEBs)
3	Kenya Bureau of Standards (KEBs)
4	Energy and Petroleum Regulatory Authority (EPRA)
5	Clean Cooking Association of Kenya (CCAK)
6	Energy 4 Impact
7	The Clean Cooking Association
8	The Charcoal Project
9	Eco-charcoal Limited
10	Practical Action
11	SNV Netherlands Development Organization
12	World Bank, Lighting Africa Global
13	Kenya Off Grid Solar Access Project