DRAFT REPORT: VERSION 1

Urban Briquette Making Pilot

Baseline Report on The Existing Briquettes Value Chain (Part 3.1 of 5)

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1 Introduction

Briquettes are increasingly considered as an alternative to charcoal and fuelwood. The term "briquette" is a composite term used to identify a wide range of biomass-based cooking fuels that vary in terms of processing, raw materials, shape, size, energy density and price. There are several ways of classifying briquettes but the most common distinguishes those that have undergone pyrolysis and those that have not. Carbonized briquettes have undergone pyrolysis, after which they are mixed with a binding agent and then compacted. Non-carbonized briquettes are processed using different methods but mainly by casting and pressing processes also known as compaction or solidification. Even with years of experience and demonstrated technical potential and appropriateness, perennial barriers still hinder the uptake of briquettes as a mainstream cooking and heating solution within households. Key among these are the relative high cost of the fuel, constrained feedstock supply, disjointed or non-existent supply and distribution networks, and competition from alternative sources of cooking fuels.

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 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.

2 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[1]. A 20-year projection indicated a 16% increase in supply and an 18% increase in demand by the year 2032 signifying an increasing deficit[2]. Firewood demand on the other hand stood at 18,702,748m^3 against a potential supply of 13,654,022m^3 in 2013[3]. 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 1below.

[1] 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.

[2] Ibid

[3] Ibid

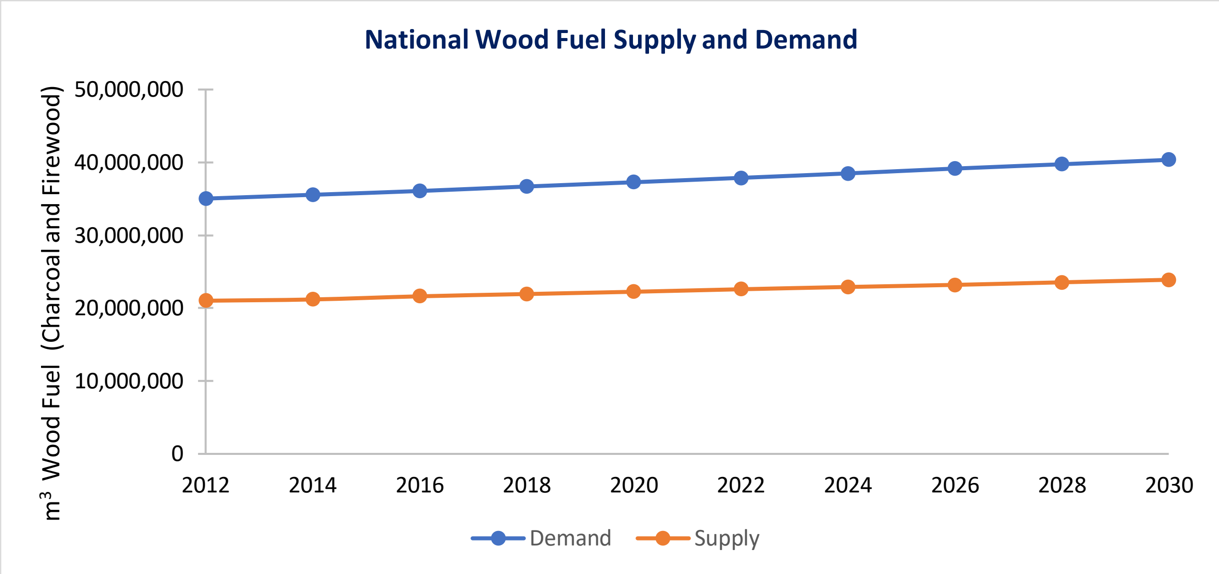

Figure 1: National Projected Supply and Demand of Wood Charcoal and Firewood

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[4]. 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[5], 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[6]. However, the increase in charcoal consumption between 2004 and 2013 was higher than the urbanization rate for the same period[7]. Unless a fundamental shift is realized, 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.

2.1 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

[4] Iiyama, M., et.al., (2014) *Achieving sustainable charcoal in Kenya: Harnessing the opportunities for cross-sectoral integration*. Technical Brief. Nairobi, Kenya.
[5] KNBS (2019). *Kenya population and housing census results, Kenya National Bureau of Statistics*. Ministry of Planning, Kenya
[6] Data from World Bank Data
[7] Iiyama, M., et.al., (2014) *Achieving sustainable charcoal in Kenya: Harnessing the opportunities for cross-sectoral integration*. Technical Brief. Nairobi, Kenya.

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.

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 2)[8]. The mean annual national charcoal consumption among households that use charcoal was estimated at 395.2 kilograms per household per year[9] 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[10]. 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%[11].

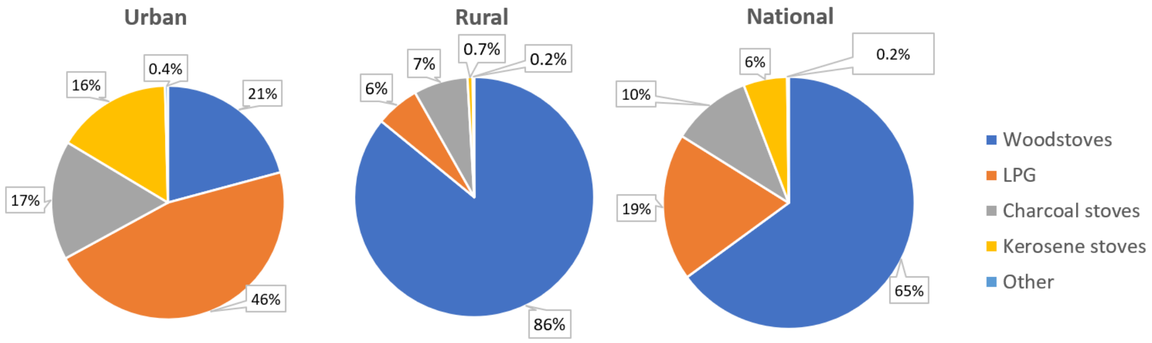

Figure 2: Household level primary cooking fuels – urban, rural and national (Data from MoE, 2019)

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[12].

2.2 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[13] 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.

[8] Ministry of Energy (2019). *Kenya Household Cooking Sector Study*
[9] ibid
[10] ibid
[11] ibid
[12] ibid
[13] Climate and Energy Advisory Ltd (2018). *Study on Use of Biomass Cookstoves and Fuels in Institutions in Kenya* (unpublished)

Table 1 provides a summary of the cooking fuels mix in Kenya's institutions.

Table 1: 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-carbonized 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[14]. 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[15].

2.3 Industrial use of charcoal / Firewood

<u>Tea Industries</u>

The tea sector is a high consumer of firewood with estimations that production of 1kg of tea consumes around 1.9kgs of firewood[16]. Kenya, the third largest tea exporting country with exports valued at USD 1.17 billion in 2016[17], has an annual production of around 415.68 million kilograms[18] of tea produced by 113 tea factories[19]. 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

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

[15] 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

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

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

[18] Xinhua (2019). *Kenya's tea production expected to drop 12% in 2019. http://www.xinhuanet.com/english/africa/2019-02/12/c_137815978.htm*

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

remaining 1 % is from fuel oil[20]. 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[21]. Table 2 shows firewood consumption volumes by tea factories for the period 2014 – 2018[22].

Table 2: 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[23] 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 3 is a summary of the numbers.

Table 3: 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[24].

3 Assessment of the existing briquettes production chain

[20] ibid
[21] ibid
[22] ibid
[23] Republic of Kenya (2002). *Study on Kenya's Energy Demand, Supply and Policy Strategy for Households, Small Scale Industries and Service Establishments*
[24] BAT Kenya (n.d.). *Environmental Sustainability.* http://www.batkenya.com/group/sites.

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[25].

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[26] however, the supply chain for the briquette making processes in Kenya may be loosely categorized into three key classes as summarized in Figure 3: 1) Upstream activities, 2) Midstream activities and 3) Downstream activities. These are discussed in the sections that follow.

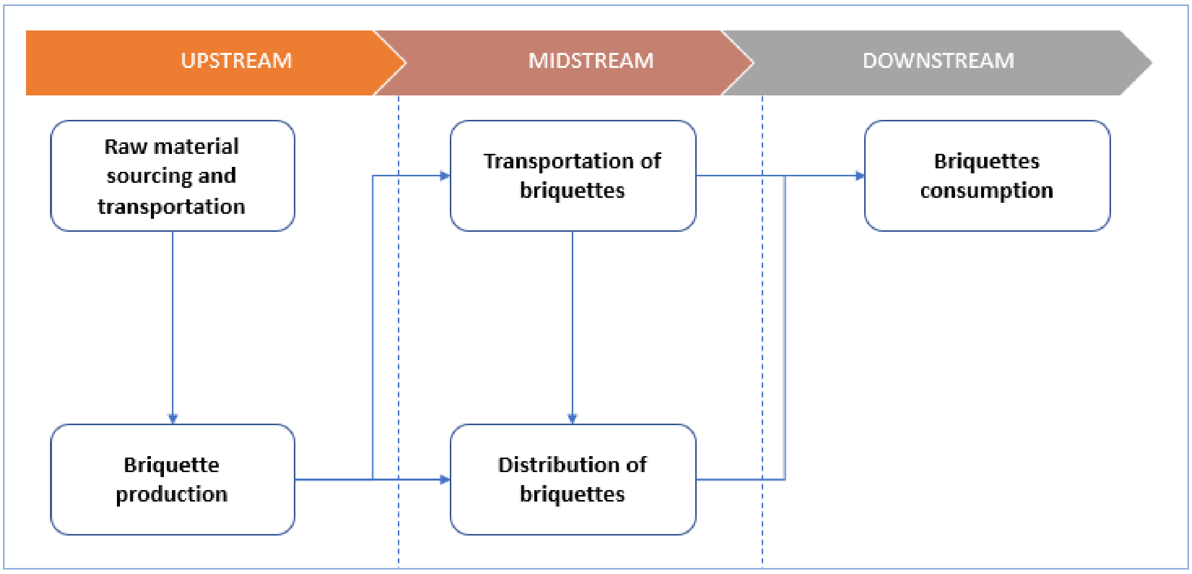

Figure 3: Summary of the supply chain of the briquette making processes

3.1 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[27].

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[25] 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 Program on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

[26] 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 Program on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

[27] KII's with briquette producers

3.1.1 Sourcing of Raw Materials

3.1.1.1 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[28]. 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[29]. 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 carbonized (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[30].

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.

I. *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[31]. As a result, there exists numerous quantities of agricultural residues that can be utilized 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[32].

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[28] 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 Program on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

[29] 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

[30] 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 Program on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

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

[32] OECD. *Glossary of Statistical Terms*. https://stats.oecd.org/glossary/detail.asp?ID=77

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 4[33].

Table 4: 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)

[33] 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)[34].

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[35]. 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[36,37] . Mombasa generates between 602 to 2,000 t/day, of which, only 50 % is collected[38] and Kisumu generates between 395 to 1,000 t/day of which, only 20 %[39] is collected (Table 5). Once collected, the waste is disposed at designated sites, Dandora, Kachoka and Mwakirunge for Nairobi, Kisumu and Mombasa respectively.

Table 5: 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[40]	2,400	1440	500	300	875	525
NAMA 2017[41]	3,030	1818	395	237	602	361.2
MoEF 2019[42]	2,400	1440	1000	600	2000	1200
NCC, 2010[43]	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%[44]. 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 6). However, there are various competing uses of organic waste such as feeds for

[34] 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.
[35] 0.7 Mtons of charcoal are consumed in urban areas (MoE,2019). 10-15 % is converted to charcoal dust
[36] Muok Ben (2020). Wte Project in Kenya. Multiple Solid Waste Energy Conversion in Developing Countries, 208 – 209.
[37] Ali A.A. (2009). *Characterisation, management and improvement strategies for household waste in Nairobi* (Doctoral dissertation). University of Nairobi, Nairobi, Kenya.
[38] Oyake-Ombis L. (2017). Awareness of Environmentally Sound Solid Waste Management by Communities and Municipalities in Kenya.
[39] Munala G., & Moirongo B. O. (2011). The Need for an Integrated Solid Waste Management in Kisumu, Kenya. *JAGST, 13* (1)
[40] ibid
[41] UNDP (2017). *Nationally Appropriate Mitigation Action on a Circular Economy Solid Waste Management Approach for Urban Areas in Kenya.*
[42] National Sustainable Waste Management Policy 2019 (Revised Draft)
[43] Integrated Solid Waste Management Plan for Nairobi 2010
[44] Ali A.A. (2009). *Characterization, management and improvement strategies for household waste in Nairobi* (Doctoral dissertation). University of Nairobi, Nairobi, Kenya.

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.

Municipal waste in the form of faecal sludge is another biomass resource. Sewerage plants are available in 32 urban centres across 21 counties[45]. 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.

II. ***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[46]. 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[47]. 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 unutilized[48]. 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

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

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

[47] 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.

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

and heat)[49]. 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[50]. Approximately 65% of the rice straws are sold to farmers for livestock feeds while the remainder is utilized 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[51]. 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[52]. 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.

Table 6: 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

[49] 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.

[50] ibid

[51] 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.

[52] 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

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[53]. 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[54]. 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 utilized, 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[55].

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.

3.1.2 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,[56] 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

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

[54] 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/

[55] 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

[56] ibid

whereas the volatile and ash content leads to lower charcoal yield[57]. 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 7.

Table 7: Physical and Chemical Characteristics of Selected Biomass Residues Available in Kenya

Feedstock	Properties						
	Fixed Carbon (%)	Volatile Matter (%)	Ash Content (%)	Moisture Content (%)	Bulk Density (Kg/m^3)	Calorific Value (MJ/kg)	Sources
Sugarcane	13.6	82.1	4.3	50.0	N/A	N/A	Lopez (2016)[58]
Cassava	30.0	59.0	4.9	7.2	N/A	N/A	Adebisi (2017)[59]
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)[60]
Cotton	5.0	81.8	7.1	6.9	NA	19.0	Muhammad et al (2015)[61]
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)[62]
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)
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)

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[57] 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

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

[59] 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

[60] 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.

[61] 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

[62] 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.

In their study to characterise the most optimal quality for feedstock, Asamoah (2016), deduced the following qualities (Table 8).

Table 8: 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 carbonization process[63] or the proportion of carbon available for char combustion after volatile matter is removed from the biomass [64]. 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-carbonized 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 carbonized 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[65]. 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 8.

Ash is the non-combustible component of the biomass; the higher the ash content the lower its calorific values[66]. 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[67]. 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

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[63] 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 Program on Water, Land and Ecosystems (WLE).51p. (Resource Recovery and Reuse Series 7). doi: 10.5337/2017.200

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

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

[66] ibid

[67] ibid

23.5%) as raw material pointed to corrosion of briquetting machinery as a major disadvantage[68]. As for burning devices, residual ash, if not removed after burning will affect the flow of clean air[69] and the slagging inhibits the combustion process by supporting overheating of the burning device.
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[70]. 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[71]. 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[72].

According to studies,[73] the average value of moisture content for Municipal Solid Waste (MSW) in Nairobi is 68.9%, the average bulk density is 289 kg/m^3. 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.

3.1.3 Cost of feedstocks

The price of fuel is one of the key determinants on its rate of adoption at the consumer level[74]. 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

[68] Survey with briquette producers
[69] ibid
[70] ibid
[71] 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
[72] 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.
[73] 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.
[74] Ministry of Energy (2019). *Kenya Household Sector study.*

thus a desirable raw material for briquetting[75]. 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[76]. 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 9). 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 (carbonized and non-carbonized) were interviewed

There is no standard price for the feedstocks as reported by various briquette producers hence giving a wide price range as shown in Table 9. 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 9: Approximate prices per kg for selected biomass residue feedstocks in Kenya[77]

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

3.1.4 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 4. 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

[75] 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*

[76] Key Informant Interview with Makomboki Tea Factory

[77] Survey with briquette producers

producers sourced sawdust over a range of 0 km – 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 0 – 300km but one producer traverses 400 km to source bagasse.

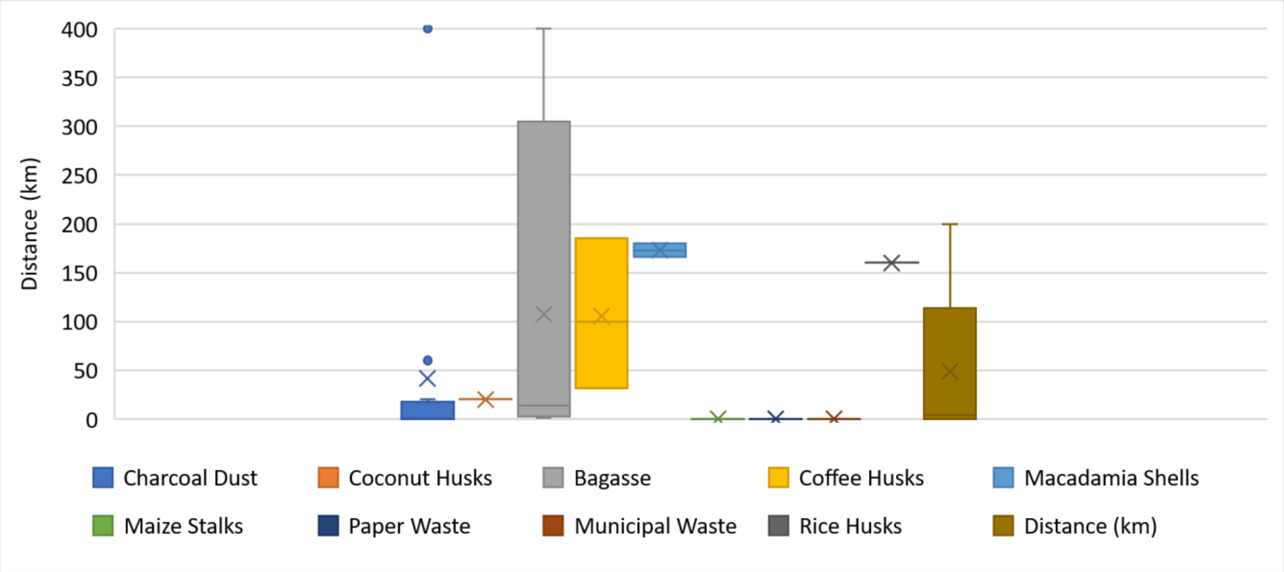

Figure 4: Distances from point of sale of feedstock to briquette production sites

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 4. 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 10: 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

3.1.5 Production of briquettes

The general briquette making process includes the i) collection and preparation of raw biomass ii) carbonization 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[78]. The preparation of raw biomass covers the sorting, separation, collection, transportation and resizing of materials. After resizing, non-carbonized briquettes are compacted using a high-pressure machine that melts the lignin material to act as a binder. For carbonized briquettes, the feedstocks are first thermally combusted in the absence of oxygen through a process called pyrolysis[79] 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[80]. 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 11).

Table 11: Production capacity for 2019[81]

#	Production Range (tonnes/2019)	Type of businesses	Type of briquettes	Main end-users
1	1,000-2,500	Limited Companies (4 companies)	Non-carbonized	- Factories - Public institutions - Small enterprises e.g. Kiosks
2	200-700	Limited Companies (3 companies)	Non-carbonized Carbonized	- Factories - Public Institutions

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

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

[80] Survey results

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

				- Households
3	5-100	CBOs (2 CBOs) Sole Proprietors (3 producers) Limited Companies (1 company)	Carbonized Non-carbonized Semi-carbonized	- 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 5 below the level of awareness among the businesses. Although the graph shows that more women are not aware of the existence of the standards, it can be explained by the high proportion of women (11/20) interviewed for this study.

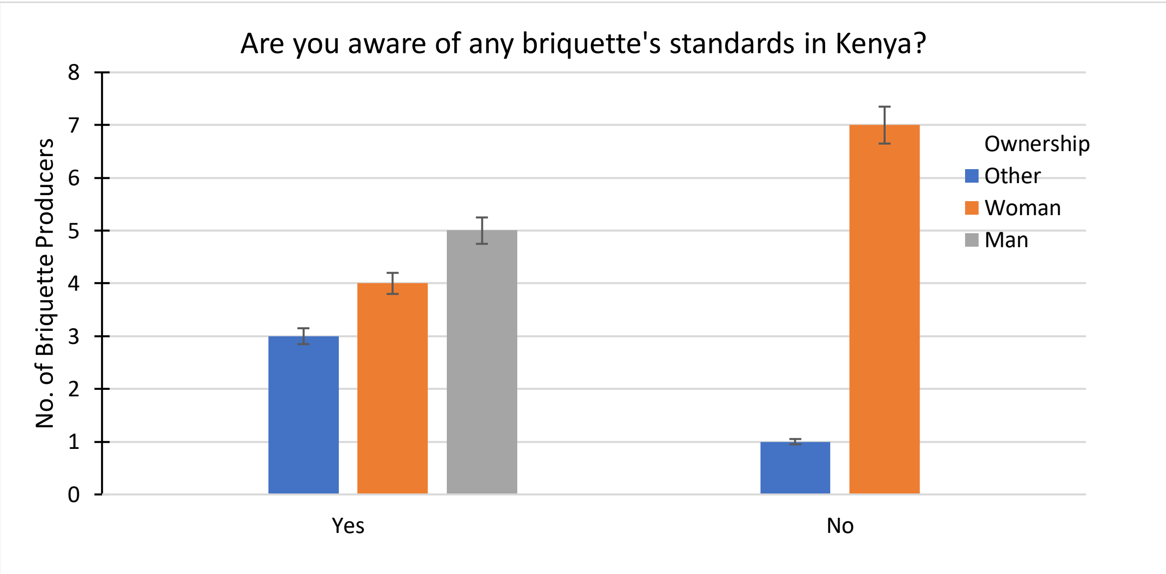

Figure 5: Number of briquettes producers aware of briquette standards in Kenya disaggregated by gender ownership of the businesses

Only 60% of the businesses (12) were aware of the briquette standards which are currently under development in Kenya (Figure 5). 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.

3.2 Midstream Activities

3.2.1 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-carbonized) 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 2 kg, 5kg and 10 kg 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; Carbonized briquettes were priced at KES 25 – 30 per 2 kg bag while the non-carbonized 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 per Kg (for both household[82] and industrial[83, 84]applications). The average cost of firewood is KES 25 for firewood per Kg[85]; fuelwood for industry is approximately KES 1500 – 1800 / m^3 or approximately KES 3 - 5 per Kg[86] , supported by a CCAK study on the use of biomass cookstoves and fuels in institutions which reported KES 3 – 5 per Kg for firewood[87].

3.2.2 Distribution channels of briquettes

As earlier stated, the value chains will vary depending on briquettes production scale, type of briquettes produced (carbonized vs. non-carbonized), 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 (carbonized and non-carbonized) 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

[82] MOE 2019. *Kenya Household Cooking Sector Study: Assessment of the Supply and Demand of Cooking Solutions at the Household Level.*
[83] MOE 2019. *Kenya Household Cooking Sector Study: Assessment of the Supply and Demand of Cooking Solutions at the Household Level.*
[84] *CCAK 2018. Study on Use of Biomass Cookstoves and Fuels in Institutions in Kenya.*
[85] MOE 2019. *Kenya Household Cooking Sector Study: Assessment of the Supply and Demand of Cooking Solutions at the Household Level.*
[86] EED Advisory 2018. Kenya Biomass Availability Assessment (unpublished)
[87] CCAK 2018. Study on Use of Biomass Cookstoves and Fuels in Institutions in Kenya.

to the consumers through door to door sales through hired agents or community members. Only 3 producers, (15%) utilized 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.

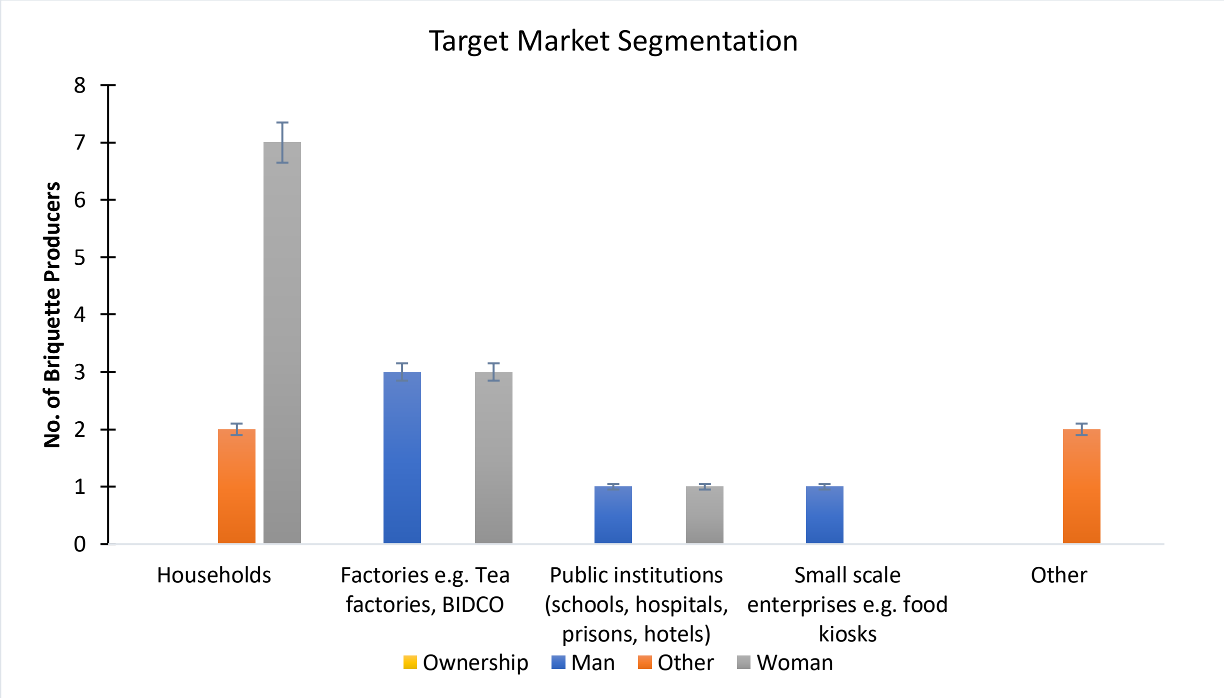

Figure 6: Target Market Segmentation disaggregated by the briquette producers' gender. Other represents businesses owned by groups such as Community Based Organizations, CBO.

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.

3.3 Downstream Activities

The main end users are identified according to the type of briquettes purchased. The large-scale producers supply non-carbonized 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 carbonized and non-carbonized 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 7). 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

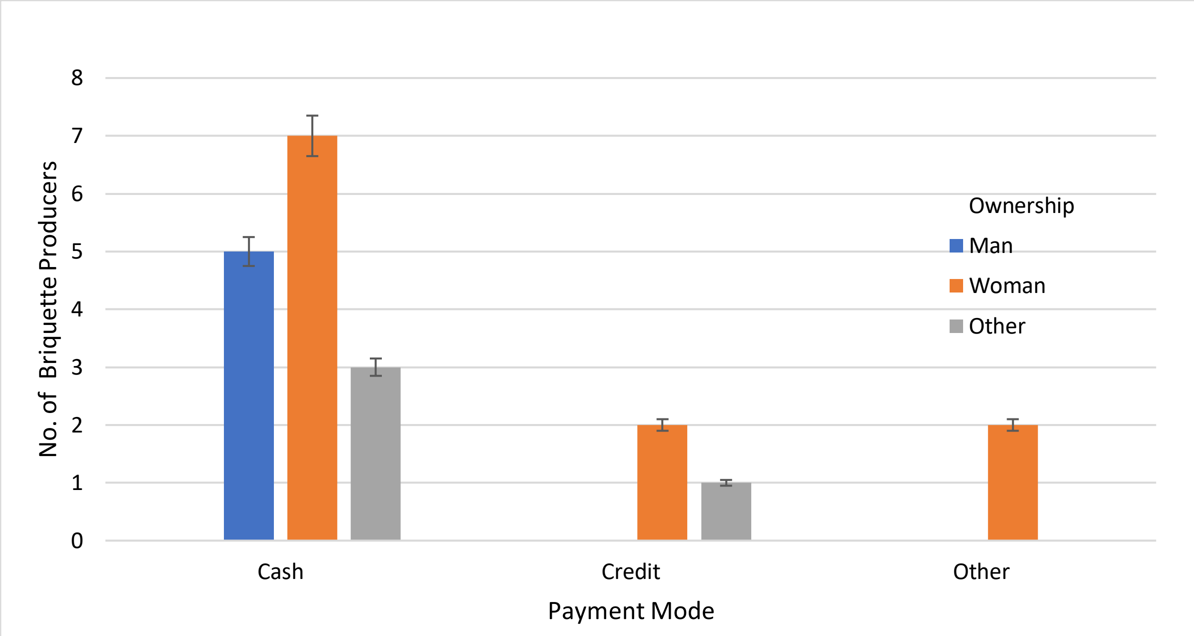

Figure 7: Main mode of payment offered to consumers by briquette producers disaggregated according to gender ownership

3.4 Conclusion

The supply of traditional solid wood is not commensurate to the demand. As at 2012, the Ministry of Environment reported a deficit in sustainable supply of 55% wood charcoal and 27% firewood which is bridged through unsustainable sources. The viability of alternative biomass fuels such as briquettes to replace traditional solid biomass fuels will depend on several factors, key of which, sustainability of the supply chain. This study aims to assess the essential elements of the briquette supply chain including upstream activities (sourcing of raw materials and production process), mid-stream activities (transportation of briquettes and distribution channels) and downstream activities (briquettes consumption) in order to give an overview of material availability, quality, standardization and market price estimation, transport cost estimations for raw materials and briquettes.

Due to the ubiquitous nature of biomass waste feedstocks, various sources from the agricultural, forestry and waste sectors were identified. Suitable feedstocks in the agricultural sector include biomass residue from field and processing activities for crops including maize, sugarcane bagasse, coffee, sisal, inter alia. However, a true assessment of existing availability of the biomass resource for briquetting requires a review of the existing quantities of supply, the centrality of feedstock production, competing needs, quality and cost of the feedstock. Most viable feedstocks were assessed through a funnel-like approach using the aforementioned elements which were identified as feedstocks identified as: rice (74,533t/yr), sisal, and sugarcane (1,252.824t/yr); municipal waste, sludge and market organic waste. Although charcoal dust and sawdust are high quality feedstocks their supply is often affected by perpetual national bans instituted on the charcoal and milling industries. Transportation from the source to point of production varied according to feedstock whereas charcoal dust was easily accessible with average distances of less than 50 km, one producer reported occasionally (3 times annually) sourcing the fines from as far 400 km to supplement their supply. Most production sites were located closer to the target market rather than the feedstock. Midstream activities included packaging and transportation of briquettes. The packaging sizes ranged from 1 kg to over 25 kg. The later was mostly utilized by industrial and factory consumers. Producers distributing through supermarkets were required to seek certification from the Kenya Bureau of Standards. The Standards also stipulated the packaging sizes for these sellers. The cost of the of the briquettes was dependent on the type of briquette. The average cost of the carbonized briquettes ranged from KES 25 - 30 per kg. Non-carbonized briquettes mostly utilized by industries and mid-scale entities was priced at KES 10 – 15 kg. The consumer profiles for briquettes include households, factories, public institutions, small-scale businesses / kiosks and factories. Although majority of the producers reported purchasing feedstock on a credit basis, there was a variation in their supply dynamics to consumers. That is, they offered credit terms, more so, for institutions and factories. Briquettes provide a favourable alternative to traditional biomass both in terms of quantities and quality for both carbonized and non-carbonized briquettes.

ANNEXES

ANNEX 1: Non-exhaustive list of biomass residue suppliers in Kenya

No.	Company	Waste
1	South Nyanza Sugar Company	Baggase
2	Transmara Sugar Company	Baggase
3	Nzoia Sugar Company	Baggase
4	West Kenya Sugar Company	Baggase
5	Kibos Sugar and Allied Industries Limited.	Baggase
6	Butali Sugar Mills.	Baggase
7	Sukari Industries Limited.	Baggase
8	Kisii Sugar Factory.	Baggase
9	Sony Sugar	Baggase
10	Kwale International Sugar Company	Baggase
11	Navida Natural Foods	Coconut Shells
12	Malindi Industries	Coconut Shells
13	Kofinaf	Coffee Husks
14	Kenya Planters Cooperative Union (KPCU)	Coffee Husks
15	Thika Coffee Millers	Coffee Husks
16	Central Kenya Coffee Mill	Coffee Husks
17	Kenya Nut Company	Macadamia Nuts
18	Kakuzi	Macadamia Nuts
19	Equatorial Nuts	Macadamia Nuts
20	Wondernut International	Macadamia Nuts
21	Mwea Rice Mills	Rice Husks
22	Ahero Irrigation Scheme	Rice Husks
23	Lake Basin Development Company	Rice Husks
24	Nice rice millers	Rice Husks
25	Kisima Farm	Sawdust
26	Raiply	Sawdust
27	Timsales	Sawdust
28	Comply	Sawdust
29	Independent Sawmillers	Sawdust
30	Furniture workshops along Ngong' road	Sawdust
31	Timberyards (Kawagware)	Sawdust
32	REA Vipingo	Sisal Bole
33	Teita Sisal Estate	Sisal Bole
34	Lomolo Sisal Estate	Sisal Bole
35	Mogotio Plantation	Sisal Bole
36	Parklands	Charcoal dust
37	South C and Kawagware	Charcoal dust
38	Kariakor market	Charcoal dust
39	Kisumu City Municipal	Organic waste
40	Nairobi City Council	Organic waste
41	Kawagware Market	Organic waste
42	Delmonte (K) Limited	Pineapple waste
43	Kakuzi	Pineapple waste
44	Ndemo farms	Pineapple waste