DRAFT REPORT: VERSION 1

Urban Briquette Making Pilot

Scenarios for Briquette Value Chains (Part 3.2 of 5)

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1 Introduction

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 upto 0.45 $MtCO_2e$ by 2022[1]. 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 realize 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 briquettes producers, information from interviews with sector experts, secondary data on feedstock availability and quality and data from suppliers of raw materials for briquettes production. The first step seeks to answer the following questions discussed below.

i. 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[2]. 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[3] 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[4]. Using 10% as a target for the pilot of this would be a 100,000 tonnes for industrial or institutional use for the 5-year period proposed under the scenarios.

ii. Current supply of briquettes in the market

[1] 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

[2] Ministry of Energy. (2019). *Kenya Household Cooking Sector Study*

[3] Ibid

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

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-carbonized for industries and institutions. Small quantities of carbonized 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.

iii. 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 thus 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, readily available and affordable alternatives - charcoal.

On the other hand, the briquettes 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[5]. 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 and; (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 2 scenarios explore how an ideal value chain would look like by setting up a central production facility for briquettes.

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

2 Scenarios for Briquette Value chains

2.1 Scenario 1: Design and implementation of a national briquette production program

This scenario proposes the design and implementation of a national program mandated to promote the uptake of briquettes in Kenya. The program will work with already existing briquettes producers to aid them grow their businesses by addressing the various challenges in the sector. The program 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 program led by the World Bank Group. Since its inception in 2009, the program reports that over 42 million quality verified products have been sold since in Africa, Asia and Pacific region[6]. Another example of a similar approach is the Kenya Biogas Program, which employs a Marketing Hub model (BMH) for promotion of biogas. The model targets formally organized 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 program managed to install 19,000 units of biogas systems (2009-2013)[7].

This approach would concentrate its efforts to address the market needs of the target groups. The key components of the program would include; (i) recruiting the briquettes producers to the program; (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 and (iv) linking the producers to ready markets. Figure 1 below illustrates the different components of the program.

To be able to implement the activities of the program 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 program implementers will lobby for fiscal incentives for the imports of the briquette technologies and VAT exemption for briquette producers. The program will also coordinate activities under standard and testing with institutions such as KEBs and KIRDI. At the County level, the program can engage the Energy Centers for educating the public on the use of briquettes.

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

[7] Ministry of Energy. (2019). *Kenya Household Cooking Sector Study*

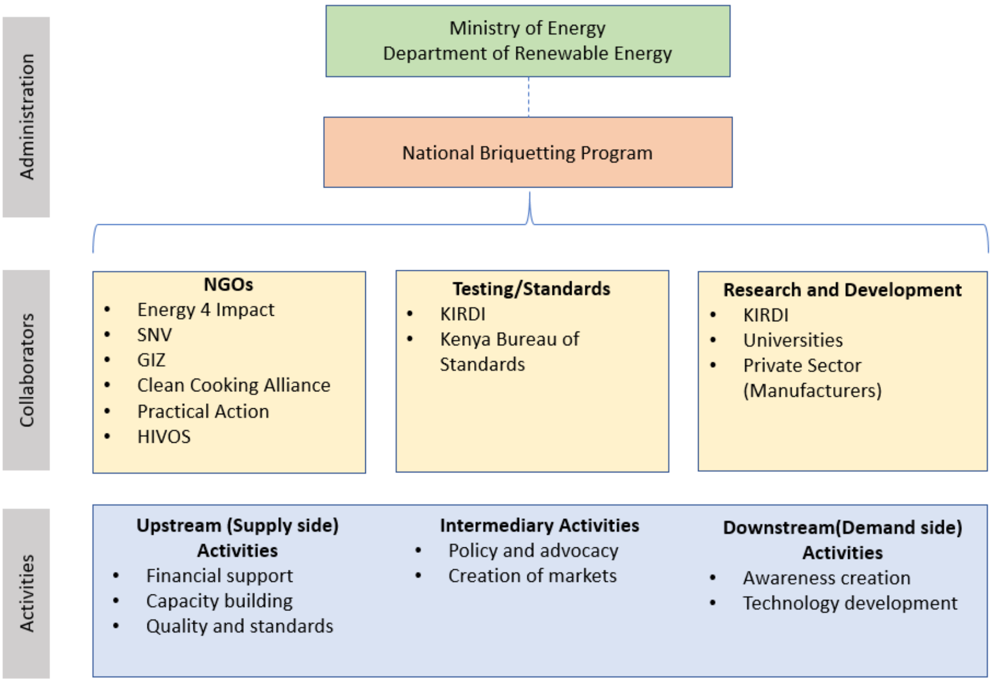

Figure 1: Summary of components of the program

2.1.1 Recruitment of briquettes producers

The program will cover producers of both carbonized and non-carbonized briquettes. It is advisable to recruit briquettes producers who have been in existence for at least 2 years and that demonstrate potential to scale. This is because they already have their business running with established clients, sources of raw materials and are aware of the existing challenges in the sector. The program will be complimenting their already established efforts. Newly formed businesses may not be resilient to the hurdles in the sector and some may be opportunistic producers who join the program with the hope of benefiting from donor money and quickly loose interest when faced by challenges. Participants to the program can be identified from organizations that have in the past implemented briquette programs 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 the information about the program or a national campaign through forums, advertisement (radio, television, websites, and social media platforms) will be launched to sensitize the producers about the program. 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).

2.1.2 Standards for briquette produced under the program

One of the key barriers to uptake of briquettes especially at the household level is the quality of briquettes produced. To this effect, the program will aim to address this challenge but ensuring that the producers recruited to the program produces 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 carbonized briquettes for household and commercial use — Specification*. The standard specifies requirements for sustainable production of charcoal and carbonized 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-carbonized briquettes from both wood and non-wood based feedstock. The producers will have to meet these standards to participate in this program. The program will facilitate producers to test their briquettes by subsidizing the cost of testing at the beginning of the program and gradually reduce the subsidy as more and more producers join the program. For the briquettes that do not meet the standard, information on the procedures to employ during the production process will be provided to help them achieve the specified standard.

2.1.3 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[8], the government can push institutions to start using briquettes towards providing 10% of their thermal requirements. The 10% share will be gradually 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 that only charcoal that is sustainably produced is available in the market. 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.

2.1.4 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 briquettes making equipment and maintenance, testing and labelling of the briquettes and purchasing of the 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 thus be advanced through varied forms such as Results Based Schemes (RBF). The program 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 program 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.

[8] This one of the proposed recommendations under the review of policy and regulatory report part 1 of 5

2.1.5 Facilitate accessing the right technologies

Another key challenge to be addressed by the program 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-carbonized 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[9]. Ultimately, the cost of importation is prohibitive making it difficult for emerging briquettes producers to be able 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 program that would like to import their briquetting machines can be provided with this incentive of tax exemption. For local production, the program will identify the local manufacturers with quality briquette making machines that can supply the machines to the briquette producers under the program and offer maintenance services for the machines.

2.1.6 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. Briquettes 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 program 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 Organizations (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 program objectives would be to; (i) create awareness of different briquettes types, (ii) highlight the benefits of briquettes relative to other fuels and, (iii) demonstrate how briquettes are best used and the right technologies (e.g. stoves) to use the briquettes.

Additionally, the program can use the Energy Centers 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 centers can also be demonstration points for the different briquette production technologies to the briquette producers.

2.1.7 Cost Estimation of the project

Table 1 below provides the cost estimation per component of the program with assumptions to the costing.

[9] 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 1: Estimation of the cost of the programme

#	Activity	Unit Cost (USD)	Quantities	Days	Total Cost (USD)	Comments
1.	Design of the program	1,000	3	30	90,000	- Hire a team of consultants to design the activities of the program, 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.	Program fund	50,000	35	1	1,750,000	- Loans capped at 5 million. Facilitation of testing and labelling of products - Program 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 _Techncial 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**	

2.1.8 *Risks and weaknesses of proposed Scenario*

i. Availability of funds

Successful implementation of the program is highly dependent on availability of funds to finance the various components of the program. The initial funding for the program 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 organization (SNV), The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH GIZ) etc.

ii. Time-frames

The design and implementation of the activities under the program 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 program is dependent on the level of commitment of these institutions to the program. Given it is a multi-stakeholder engagement; there is risks in delayed decision-making and actual progression of the project.

2.2 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-utilized[10]
ii. The cost of the feedstock is affordable compared to other types of feedstock. One manufacturer stated that since the waste is 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 baggase 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 carbonized briquettes for household use and non-carbonized briquettes for industrial and institutional use.

2.2.1 Carbonized briquettes for household use

The CPF would be ideally located in Kisumu County as most of the sugar mills are located in 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), Transmara (760,176 tonnes), Kibos (653,443 tonnes), Sukari (633,229 tonnes) and Butali (574,338 tonnes)[11]. 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.

[10] UNEP. (2019). *Sustainability of sugarcane bagasse briquettes and charcoal value chains in Kenya*
[11] Agriculture and Food Authority. (2019). Year Book of Sugar Statistics 2019.Nairobi; Kenya

i. 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 carbonization process (for carbonized 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 baggase 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[12]. 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.

ii. 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)[13] 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.

iii. 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.

iv. Briquetting process

The following activities will be carried out; (i) carbonization 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: carbonization 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.

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[12] Key Informant Interviews

[13] Costing and specification of the equipments Retrieved from WWW.Alibaba.Com

v. 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)[14]. 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.

vi. 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 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.

vii. 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.

viii. 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 2 below provides estimates for production of carbonized briquettes.

Table 2: Estimate of the setting up the CPF for carbonized briquettes and operation cost for the first year

#	Item	Quantity	Unit Cost (USD)	Total Cost (USD)	Assumptions
1.	Bagasse	34,000	6	204,000	- 70% loss during carbonization
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.	Carbonization furnace	8	15,000	120,000	- Capacity of the furnace 12 tonnes and takes 6-8 hours to carbonize.

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

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
	Total Cost			**2,192,200**	

2.2.2 Non-carbonized Briquettes for industrial use

An alternative pathway under this scenario is the production of non-carbonized 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 carbonized briquettes, production of non-carbonized briquettes does not require carbonizing 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 3: Estimate of the setting up the CPF for non-carbonized 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**	

2.2.3 Risks for the scenarios

i. *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[15]. 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[16]. 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

[15] As reported by the local newspaper

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

2.3 Scenario 3: Experimenting with new raw materials

The common raw materials used for briquette production include; macadamia nut shells, sawdust, charcoal dust, baggase, 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[17] and the plans by KenGen[18] 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 carbonized 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[19].

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 carbonized 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.

[17] 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.
[18] Brian Ngugi. (27 August 2020). KenGen, Nairobi Metropolitan Service (NMS) pen deal to tap power from garbage. *Business Daily*.
[19] 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.

i. 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[20]. 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 carbonized to increase the energy content and reduce the ash content. The waste must also be treated to kill the pathogens[21]. 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.

ii. Production process

The production process for carbonized 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.

iii. Cost of production

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

[20] 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

[21] 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 Program on Water, Land and Ecosystems (WLE), International Water Management Institute (IWMI).

2.3.1 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.

3 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 carbonized and carbonized briquettes.

i. *Carbonized briquettes vs non-carbonized briquettes*

The cost of large-scale production of carbonized briquettes is high compared to that of non-carbonized 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 carbonization 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 carbonized 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-carbonized 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. This would partly be solved by ensuring that 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. Therefore, consumer awareness needs to extend to the appropriate handling of briquettes during use and the appropriate stove for burning the briquettes[22].

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

[22] 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.

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 that can efficiently burn the baggase briquettes adopted. Table 4 below compares the two types of briquettes.

Table 4: Comparison of the types of briquettes

#	Type of briquettes	Target market	Strengths	Weakness
1	Carbonized 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-carbonized 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 carbonized 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.

ii. 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, scenario 2 and 3 the central production facilities' profit margins should be sufficient to run their daily operations after the first three years (assuming they breakeven by the third year) of being in business.

The strengths of scenario 1 is the fact that the program 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 program will be determined by the support accorded to the program 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 program will not result to realization of the set objectives. The producers under the program should also be able to out-last the period of the program.

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 5 below provides a summary of the three scenarios.

Table 5: Comparison of the proposed scenarios

#	Scenarios	Strengths	Weakness
1	Design and implementation of a national briquette production program	- Working with already existing briquette producers increases the chances of success - The program 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 program is tied to implementation of all the components described in the program 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

iii. 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.

3.1 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 carbonized 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 program.

ANNEX 1:RECOMMENDED TECHNOLOGIES FOR THE SCENARIOS

A	PRE-PROCESSING			
#	Technology/ Appliance	Description	Merits	Demerits
i	*SORTING*			
a)	Sorting equipment  Source: Link	- This is ideal for when small size raw materials of 2mm are required - Different models have different power rating and sieve sizes - Cost range is USD 1,050 – 3,350 - No professional training is required to run the machine	- Enclosed structure reduces noise and dust - The mesh can be easily replaced in case of damage - Simple operations	- Cost is high for informal briquette producers
ii	*SHREDDING*			
b)	Twin shaft agricultural waste shredder  Source: Link	- Used to reduce the particle to the desired size particles - Cost is determined by capacity and power rating USD 4,000-50,000 - No professional training is required to run the machine	- Low noise, less dust and high capacity - High efficiency	- High upfront cost for small –scale producers
iii	*MILLING*			

a)	Hammer mill  Source; Link	- 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, wood chips etc. - The cost is determined by size of particles desired and the power rating of the machine - The cost ranges from USD 900-1,500 - Capacity of 0.5-5 tonnes per hour	- Simple operations - Less noise pollution because of low vibrations - Low investment on energy consumption	- The electric hammer mill requires electricity to operate and this might not be available in some parts of the country

B	PYROLYSIS AND CARBONIZATION			
#	Technology/ Appliance	Description	Merits	Demerits
i	*PYROLYSIS*			
a)	Carbonization Furnace  Source: Link	- Used to carbonize the feedstock when producing carbonized briquettes - Capacity ranges from 3-12 tonnes/hour - Source of heat for the carbonization is wood or liquid gas - No technical expertise required to run the machine - USD 4,500-6,500	- Ideal for a large-scale production site - High carbonization ratio of 99% - Shorter carbonization time (6 hours from 24 hours	- High upfront cost compared the drum-oil carbonizer - Use of firewood as source of heat contributes to forest degradation

b)	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 - No professional training is required on how to use the machine - Cost is between USD 10-15	- Affordable to small-scale briquette producers	- Less quantities can be carbonized compared to the carbonization furnace - Firewood id the source of heat

C	*MIXING*			
#	Technology/ Appliance	Description	Merits	Demerits
a)	Electrical mixers (Wheel mixer)  Source: Link	- Has spindles that move from side to side to cause mixing of the raw materials - No professional training is required on how to use the machine - Cost USD 1,200-3,400	- The rolling wheel increases production efficiency with the raw material fully mixed. - Simple operation	- Cost may be high for small-scale briquette producers

D	*COMPACTION*			
#	Technology/ Appliance	Description	Merits	Demerits
i	*SCREW PRESSES*			
a)	Motorized screw press (fitted with a gear)  (Source; Kendubay Machinery)	- Locally fabricated motorized -screw machine. - Local fabricators include Kendubay Machinery, Kejofra Engineering and Benmah Product Company. - The gear fitted machine improves compatibility of the raw material compared to the one without a gear 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 tonnes per day when using charcoal dust as the raw material - Demonstration by the machine fabricator is sufficient to be able to use the machine - Cost USD 850-4,500	- Locally manufactured so readily available in the market - Spare parts can be sourced locally - Local expertise available to deal with breakdowns. - Affordable compared to imported machines	- Frequent breakdowns If poor fabricated - Informal producers so might be difficult to identify the fabricators
b)	Motorized screw press  Source: Link	- Imported - Capacity ranges from 1-6 tonnes per hour - Cost USD 2,500-5,000 - Demonstration or use of manuals is sufficient to use the machine	- Less breakdowns	- Importing process is long and small-scale producers may not be aware of the process - Local expertise may not have the expertise to repair the machine in case of a breakdown
ii	*PISTON PRESSES*			

a)	Hydraulic Briquette Pressing Machine 	- 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 - 500 Kgs per hour capacity is USD 70,000	- Available at different capacities - High efficiency - High quality i.e less breakdowns	- High upfront cost - Operational cost of electricity is high
b)	Extruder Briquetting Press 	- 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 - Costs 120,000 USD	- Available at different capacities - High efficiency High quality i.e less breakdowns	- High upfront cost - Operational cost of electricity is high

c)	Mechanical briquetting machines 	- 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 - The machine distributor provides training during installation - Cost ranges from USD 100,000 to 500,000.	- Available at different capacities - High efficiency - High quality i.e less breakdowns	- High upfront cost - Operational cost of electricity is high

E	*DRYING*			
#	Technology/ Appliance	Description	Merits	Demerits
a)	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 - Recommended for waste with high moisture content such as sludge - Cost is dependent on size of the greenhouse for example; 6M by 12 M - USD 1,500 and 24M by 12 M- USD 8000 - No training is required on how to use the greenhouse	- High efficiency for drying - Locally manufactured so readily available in the market - Local expertise to do the repairs - Relies on the sun so no cost of electricity	- Efficiency is reduced during cloudy days - More space is required for setting it up compared to the driers

b)	Driers e.g vertical driers  Source:Link	- 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 - Cost ranges based on power ratings (USD 10,000-100,000)	- High efficiency for large scale production of briquettes - Reduced floor space	- High upfront cost - High cost of operation compared to solar-drying (i.e cost of electricity)
c)	Open air drying (elevated) 	- This is done either using drying trays or racks. - The manufacturer can acquire the necessary materials (mesh and pools) from local stores and fabricate the rack. - No training required - The coffee roll, which is the main component of the sieve, is purchased per meter. I Meter- USD 3	- Affordable (both up-front and operation cost)	- Requires space to set up - Low efficiency compared to the driers

a	*Packaging of briquettes(where applicable)*			
#	**Technology/ Appliance**	**Description**	**Merits**	**Demerits**
a)	Packaging machines  Source: Link	- The machine weighs and pack the briquettes. The packing range include; 25kg to 50kg, 5kg-50kg,10kg, 10-20kg,25 to 50 kilos, 25 kgs. - Cost USD 6,666	- Saves time if you have large quantities of briquette - High accuracy compared to manual weighing and packing	- It is costly for small scale production - Operation cost such as electricity bill