Economic Potential For Residual Agro And Biomass Fuels In Ghana

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Study Coordinators
Aaron Sangmor Nyarkotey, Energy Advisor, SNV Netherlands Development Organisation (MGA Manager, GCIC Project)
Dramani Bukari, Energy Advisor, SNV Netherlands Development Organisation (Project Manager, GCIC Project)

Authors
Edem Cudjoe Bensah (lead), Julius Cudjoe Ahiekpor, Edward Antwi, Senior Lecturers – Centre for Renewable Energy and Energy Efficiency, Kumasi Technical University

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Acknowledgements
The authors are thankful to Aaron Sangmor Nyarkotey and Dramani Bukari for coordinating the study, providing logistical support, reviewing draft reports and providing comments and suggestions that have enriched the analysis. We are also indebted to field assistants – Bright Amponsem, Benjamin Boahen and Isaac Mensah– for the hard work exhibited during data gathering exercise across the regions. In addition, we are grateful to Mohammed Lukumanu and Raymond Kusorgbor of the Ghana Alliance for Clean Cooking (GHACCO), for meeting us to share their views on the sector. Further gratitude goes to briquette producers and sector stakeholders who found time to share their views, concerns and expectations with us. Details of persons consulted are provided in the Appendix.

Disclaimer
The opinions expressed in this report do not necessarily reflect those of SNV or GCIC.
November 2019

Executive Summary

The main biomass resources presently used for briquetting and pelleting in Ghana are wood waste, charcoal dust, coconut shells, and rice husks. Other biomass resources with prospects for use for briquettes and pellets include maize residues, palm kernel shell, cowpea shell, cashew nut shell, and cocoa pod husk.

In the survey, 63 wood waste production sites, 29 charcoal retailers and distributors, 28 paddy rice processing companies, 16 coconut retailers, 9 palm kernel processing sites and 7 maize/cowpea farms were visited. Four agro-processing companies were also surveyed. The estimated daily production of these residues are:

The total amount of residues from major crops and wood industry available for producing briquettes or pellets is about 1.5 million tons per year which can generate an annual revenue of USD 340 million.

Presently, there are over 25 producers of briquettes and pellets. Five are registered with Energy Commission as exporters of fuel. Products from two producers are also registered with Ghana Standards Authority. The Greater Accra Region hosts the largest number of producers. The production capacity of producers ranges from 3-3000 ton/month.

This study reveals that the briquette and pellet industry is highly profitable with payback time of between 1 to 3.5 years for a 1 ton per day set-up which requires an investment of about USD 900 thousand.

Nonetheless, scale up of the sector is faced with some barriers which include feedstock supply (not availability), market for products, competition with imported products, electricity supply stability, availability of suitable stoves, and limited access to funding for expansion.

Key stakeholders identified for the briquette and pellet market include Ministry of Energy (policy), Energy Commission (regulation), and Ghana Standards Authority (standards on fuels and stoves). Non-governmental actors include producers of briquettes and pellets, distributors and retailers of fuel, residues (raw material) suppliers, stove manufacturers and suppliers, and consumers of fuel. The rest include research, advocacy, funding organizations, and financial institutions.

It was found during the survey that there are few local manufacturers of briquette or pellet stoves whose products are sold in the market even though availability is restricted to few urban locations. The well-engineered stoves that are available in the market are imported and expensive relative to charcoal stoves. A household briquette stove costs over GHS 200 while institutional units cost over GHS 1000 or 2000 depending on size.

The high cost of the stoves coupled with unavailability of the fuel in market centres and low awareness are some of the reasons for the low adoption of briquette and pellet in Ghana.

It is therefore imperative for stakeholders to come together to support the development of well-engineered but affordable stoves that can be mass produced for the market. Without high quality and affordable stoves, the growth of the local market will be slow and national target will not be met.

Also, awareness creation campaigns should be prioritized. National actors such as Energy Commission, Environmental Protection Agency and Forestry Commission whose activities are supported through the work of producers of briquettes and pellets, should do more to support awareness creation.

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1. Introduction

1.1 Background

Briquettes and pellets are gaining ground and several businesses are making inroads in the sector in recent years in Ghana. The fuels are still not known to many would-be consumers in domestic, commercial and industrial circles. Uncarbonized briquettes are known to have been produced from sawdust from sawn mills at Akim Oda in the 1980s. Since then several briquette start-ups have emerged. In the area of pellets, the most successful case has been the establishment of Abellon Clean Energy Ghana Ltd., which produces up to 100 tonnes of pellets per day from sawdust supplied by wood workers at Sokoban wood village in Kumasi. Though some progress have been achieved, the penetration rate in the use of the fuels in the various sectors is extremely low.

Recently, there have been some initiatives to promote briquette and pellets production, utilisation and export, with funding from development partners. One such initiative involved development and training on production of briquettes from bamboo charcoal dust, coordinated by International Network for Bamboo and Rattan (IBAR) and funded by European Union. The Ghana Climate Innovation Centre (GCIC) is also assisting briquettes and pellets producers, where financial and business development support are provided to entrepreneurs in the business. The inclusion of briquetting and pelleting within the focal areas of GCIC interventions has resulted in an increase in the number of enterprises in the sector. Presently, GCIC provides financial, technical and business advisory support to six local companies. It is imperative to sustain such forms of assistance to players in the sector, with the aim of removing the barriers to the growth of the market.

This study carries out a techno-economic and feasibility assessment for the development of the market for briquette and pellet by identifying, quantifying and describing the different types of resource materials that can be processed into briquettes and pellets; evaluating the potential of building a sustainable market for briquettes and pellets; and assessing the willingness of users to adopt pellet or briquette-based cookstoves in Ghana. Field survey of promising residues was limited to sites in Ashanti, Greater Accra and Western Regions.

1.2 Why briquettes and pellets should be given premium attention

The development of a sustainable, market-based briquette and pellet industry will offer substantial benefits to the country as outlined in Figure 1.

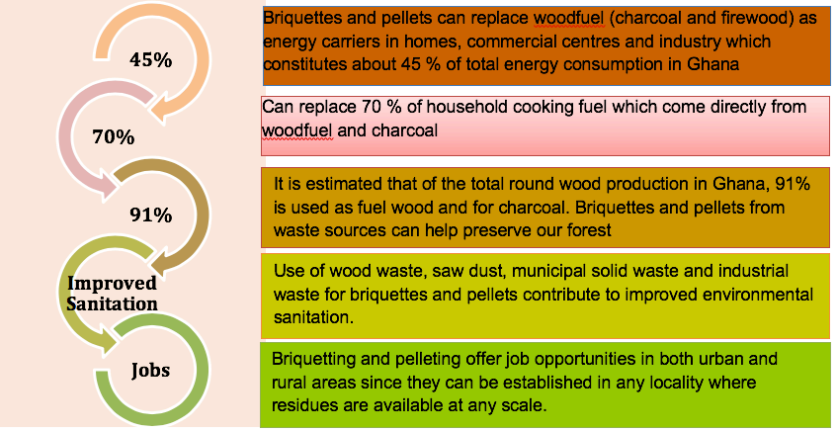


Figure 1 Benefits of briquettes and pellets to national economy

2. Policy, legal and regulatory environment

2.1 Institutional Set-up

The major actors in the briquettes and pellets subsector include policy makers, regulators and standards developers, research institutions, fuel producers, distributors and retailers, stove manufacturers and suppliers, feedstock/biomass suppliers, and end-users of the fuel (Figure 2). Others include research organisations and funding agencies.

2.1.1 Major Government Actors

The Ministry of Energy is responsible for providing policy guidelines on bioenergy as contained in various reports such as the National Energy Policy (currently under revision), Sustainable Energy for All Action Plan, Bioenergy Policy (draft), and Renewable Energy Masterplan (REMP). The Ministry supervises and coordinates the work of all sector institutions involved in bioenergy.

The Energy Commission is legally empowered to regulate the sector through the development of legislations and issuance of licenses and permits to players in the bioenergy sector. The Commission works closely with Ghana Standards Authority (GSA) to develop standards including those on fuels and improved cookstoves. Importation of briquettes/pellets as well as cookstoves are controlled by Custom Excise and Preventive Service (CEPS) and Ghana Standards Authority (GSA).

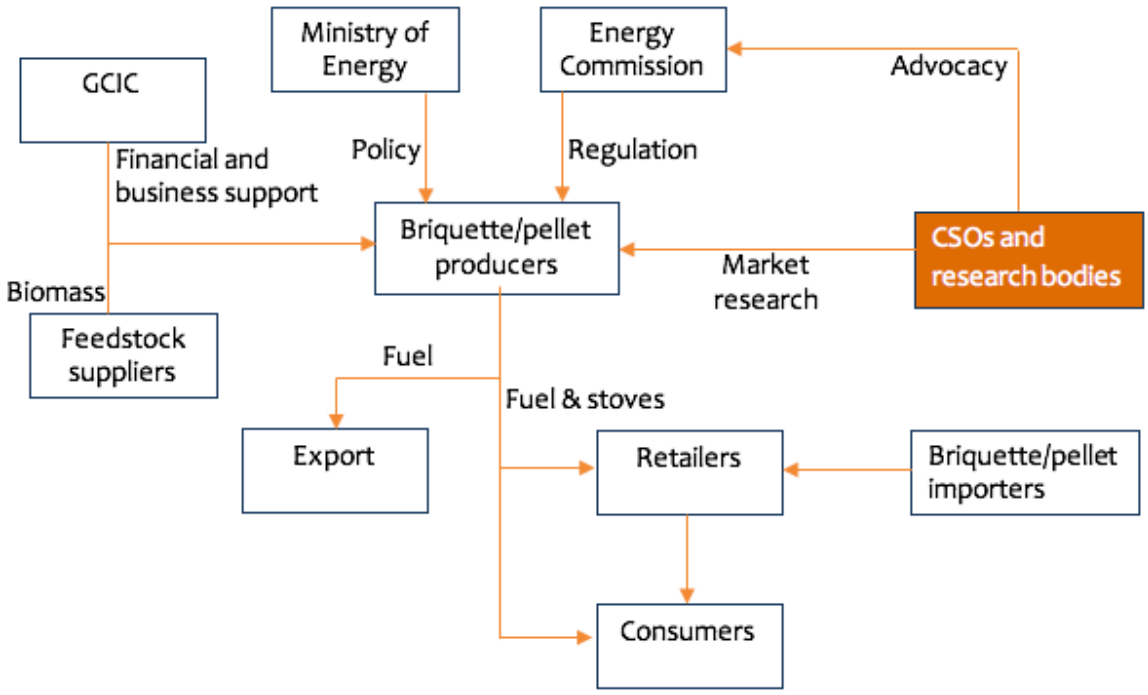


Figure 2 Key actors of the briquettes and pellets sector

2.1.2 Major non-government actors

Ghana Alliance for Clean Cooking (GHACCO)

The Ghana Alliance for Clean Cooking (GHACCO) is a non-profit association that advocates for creation of enabling environment for sustainable growth of the cookstove and fuel sector. GHACCO membership comprises non-governmental organisations (NGOs), community-based organisations (CBOs) cookstove and fuel producers, distributors and retailers, financial bodies, academic and research organisations, as well as partner agencies and development partners. The Alliance aims to promote the adoption and use of improved cookstoves and fuels by 4 million households by 2020.

Ghana Climate Innovation Centre

GCIC offers financing and capacity building services that address challenges to starting and growing business in the green economy, including solar energy, energy efficiency, waste management, climate smart agriculture and water management and purification. GCIC has been offering financial and capacity building services to start-ups in briquettes and pellets.

Development partners

Development partners that have been supporting bioenergy interventions including pellets and briquettes, are notably, Netherlands Development Organisation (SNV), Clean Cooking Alliance (CCA), German Agency for International Cooperation (GIZ), and European Union.

Development partners have provided various forms of assistance including technical, financial, and logistical.

Research and technology institutes

Notable research-based institutions include Technology Consultancy Centre and Brew-Hammond Energy Centre of KNUST, Institute of Industrial Research (IIR) of CSIR, Centre for RE and EE of Kumasi Technical University. NGOs such as Centre for Energy, Environment and Sustainable Development (CEESD) and Kumasi Institute of Technology and Environment (KITE).

2.2 Relevant policies and plans

The National Energy Policy of 2010 serves as the main guide for all energy related policies and for management of the energy resources in the country. Briquettes and pellets are not directly mentioned in the Policy but are indirectly captured under section 4.3 which emphasizes the use of improved methods of biomass conversion including waste-to-energy technologies.

Waste-to-energy interventions are also supported by the National Climate Change Policy (NCCP) of 2012 and the Strategic National Energy Plan of 2006. Briquettes and Pellets are not expressly mentioned in Ghana's intended nationally determined contributions (INDCs) 2015, nonetheless, they are implicitly captured within the cookstove sub-section where a target of 2 million ICs is planned by 2030.

Similarly, the Sustainable Energy for All Action Plan is silent on briquettes and pellets though it provides detailed strategies for mitigating the barriers to biomass cookstoves, including those fed with briquettes and pellets, through measures such as development of regulations, provision of incentives and funding mechanisms, improving quality control, creating awareness, and supporting research and technical capacity building.

2.3 Targets on briquettes and pellets

Under Renewable Energy Master Plan (REMP), targets for solid fuels such as pellets and briquettes are clearly spelt out, culminating in a minimum production capacity of 100,000 ton by 2030 (Figure 3).

The REMP does not however indicate whether the quantities produced are for exports or internal consumption.

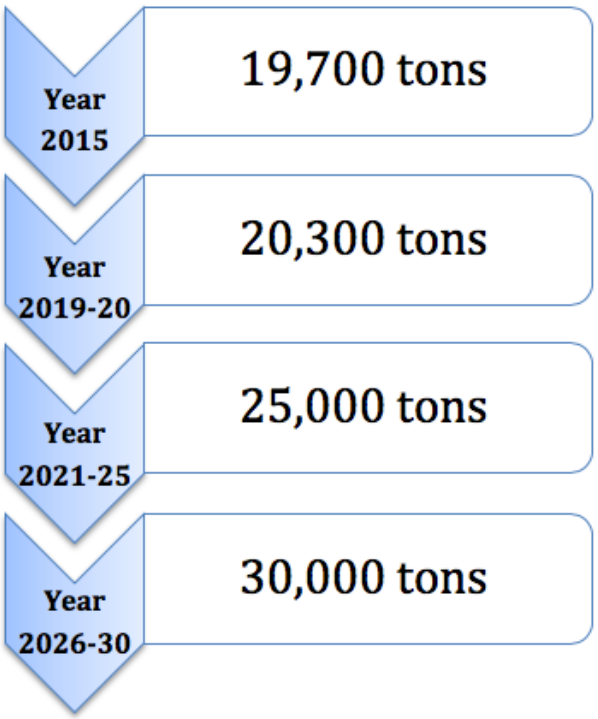


Figure 3 Targets for new briquette and pellet production capacities
Source: Ministry of Energy (2018)

2.4 Regulation

The production, marketing and sales of biobased fuels, including briquettes and pellets, are regulated by the Energy Commission. In section 8 of the Renewable Energy Act 2011 (Act 832), only licensed entities are permitted to undertake commercial activities (e.g. production, transportation, storage, distribution, importation and exportation) in the renewable energy industry. The Commission requires that all producers acquire license before embarking on construction of the production facility.

Exporters of briquettes and pellets are also required to obtain an export license from the Commission. A list of licensed exporters is shown in Appendix A. Presently, the Commission is finalizing the preparation of a regulation on woodfuel products, including all types of biofuels originating from woody and/or herbaceous biomass such as firewood, charcoal, bamboo, briquettes and pellets.

The regulation is expected to guide :

- Enforcement of sustainable harnessing and management of biomass used as fuel for domestic, commercial and industrial applications
- production of feedstock (woodlots/ plantations) for firewood and charcoal
- processing of firewood into secondary energy products under standard conditions;
- handling, packaging, transportation sales and marketing of woodfuel products.

The Energy Commission is in the process of completing a regulation to enforce minimum performance requirements on biomass cookstoves including briquettes and pellets stoves, in accordance to ISO standards on efficiency, emissions and safety.

The regulation will also enforce the labelling of cookstoves using standard labels prescribed by the Commission. It is imperative for local producers to team up with research institutes to improve on local designs to meet all requirements under the upcoming regulation.

All biomass cookstoves locally produced or imported shall be expected to meet the minimum performance requirement of 20% for thermal efficiency and a safety score of 70 measured in accordance with ISO 19867-1:2018(E), based on the draft regulation.

2.5 Standards

Presently, there are no standards on pellets and briquettes and producers are expected to meet ISO standards.

3. Resource materials for briquette and pellet production

3.1 Introduction

Ghana is 240,000 km2 big with water bodies and wetlands taking up to 6% of the land cover (Figure 4). While settlement takes up just about 2% of the total land cover. The remaining comprises agricultural land (33%), forest and (5%), savannah (40%), gallery and riparian forest (2%) and forest cover of about 5%.

3.1.1 Agricultural residues

Agriculture is by far the most dominant economic activity in Ghana. Until recently it was the leading contributor to the country's gross domestic product. Currently, agriculture remains the single largest employer accounting for nearly 80% of the population according to the Ghana Statistical Service (GSS). Food crops mainly cultivated in Ghana include cassava, yam, cocoyam, maize, millet, and sorghum plantain, rice.

Aside from food crops, Ghana is also a leading global producer of Cocoa beans (2nd in the world) and oil palm. These two crops remain the most dominant cash crop cultivated in Ghana even though other cash crops like cashew and coffee are also coming up. Other fruit crops such citrus, pineapples, and banana are also widely cultivated in addition to non-export oil-bearing crops like groundnut. As shown in figure 2 cassava is by far the leading crop produced in terms of tonnage with an annual production of about 18 million tons.

Due to the large interest in agriculture, residues are generated at the point of harvest and during processing. Some of residues include the stalk of the crops, leaves, husks, and shells. The types and quantities of residues generated differ among food crops; and whether the crop is perennial, in which case the fruits are harvested over a period exceeding three seasons, or annual, which are harvested once in their lifetime. Most of the food crops cultivated in Ghana except for fruits like citrus, papaya, and mango are annual crops. Cash crops such as cocoa, cashew, palm, and coffee are perennial. At the point of harvest, residues generated by annual crops include the trunk, leaves and stalk and straw. While perennial crops like cocoa and cashew generate pods and peduncle residues during harvest.

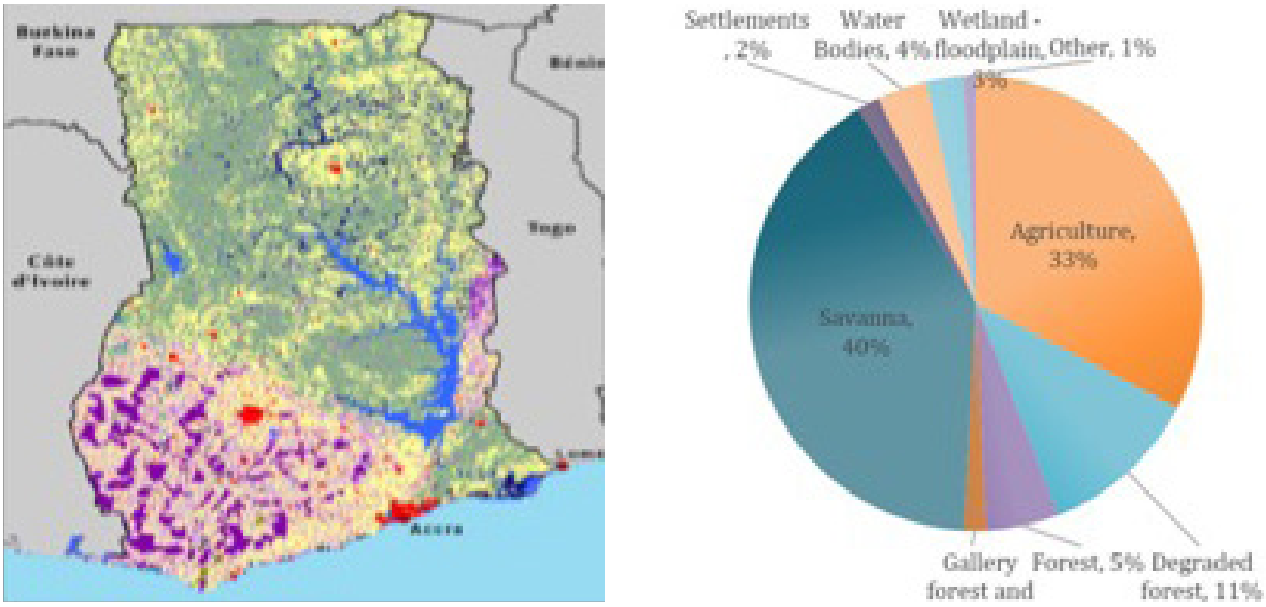


Figure 4 Land use in Ghana
Source: Adapted from www.eros.usgs.gov

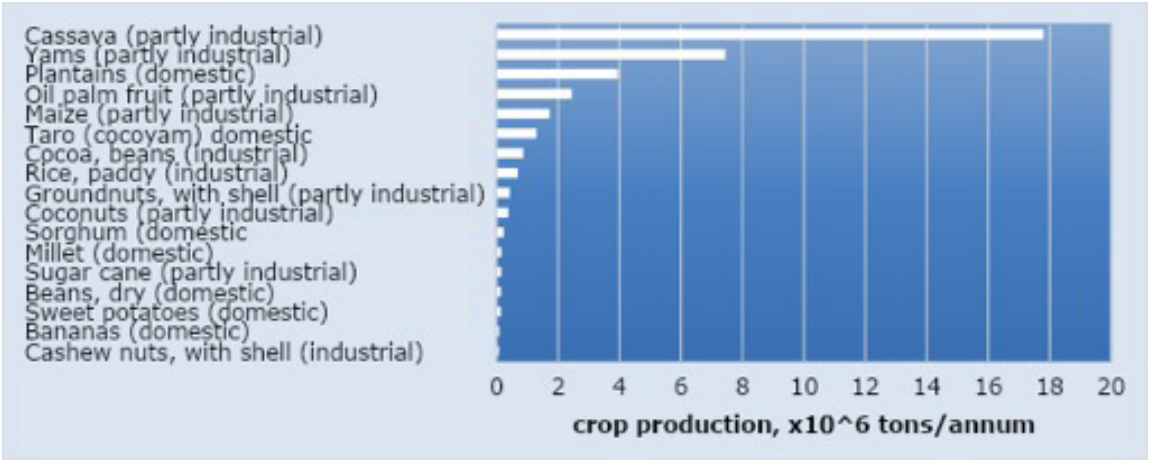


Figure 5 Crop production in million tonnes per annum

Table 1 presents the estimated theoretical potential of residues using 2016 crop production figures (Figure 4) from the Ministry of Food and Agriculture and residue to crop ratios reported in literature. Cassava peels have by far the largest potential of about 3.6 million tons of residues per annum. This notwithstanding, the residues are mainly dispersed over wide areas due to the absence of large-scale processing factories in Ghana. Also, the theoretical potential only represents the amount of residues generated; thus, the amount of residues available for exploitation is likely to be lower due to the importance of maintaining soil organic carbon content, by leaving some biomass from the annual crops on the fields to replenish the lost carbon. Other factors include lack of accessibility and competing uses of the residues.

A rule of thumb is to reduce the estimated theoretical potential by 50% to obtain the technical potential of the biomass. Residues generated during processing are however 100% accessible and may not be required to be returned to the field to replenish lost soil organic carbon content.

Table 1 Agricultural residue generation potential

Crop/ Product	Residues	Alternative uses	Calorific value MJ/kg	Est. Theoretical Potential X 10^6, t/a	Comment
Cassava	Peels Stalk	Animal feed Planting material	17	3.60 0.89	High potential but high moisture content. High concentration points include Techiman, Caltech ethanol plant at Hodze, and Ayensu starch factory
Palm fruits	Empty bunches Shells and filter cake	Fuel	18	0.33 0.13	High potential for both but competing uses exist as fuel in large and medium scale processing units. Small- and large-scale processing firms are found mainly in the Ashanti, Western and Eastern regions.
Rice	Straw Husk	Not utilized	17	0.77 0.12	High potential and centralized at milling sites in the country
Maize	Stalk Husk Cob	Not utilized	17	2.70 0.34 0.49	High potential but not centralized. The largest maize processing plant is in the Upper West region with a processing capacity of 30 tons/day
Cocoa beans	Pods Shells	Shells partly used as fuel; pods partly used for soap production	17	1.64 0.01	High potential of pods but with high moisture and potash content and not centralized. High concentration point in the forest belt of Ghana
Cashew nuts	Fruits Shells	Fruits (juice) Shell (fuel)	17	0.23 (wet) 0.01	High potential for the shells mainly in Prampram and Mim where large scale processing takes place but competing uses as fuel source exist. Sampa is the epicentre of cashew nut in Ghana
Yam	Straw	Animal feed	17	3.20	High potential but not centralized
Groundnuts	Shell Straw	Not utilized	17	0.18 1.00	Not centralized, large concentration point may be the northern region
Plantain	Trunk and leaves	Animal feed	17	1.80	High moisture and not centralized. Large concentration points may be in the forest belt and the coastal savannah

Highlights

- 2 million m3 of round wood extracted from the forest per anum
- 1 million m3 residues generated in total per annum
- 5000,000m^3 sawdust generated
- Remaining residues consist of barks, off cuts and shavings

Ghana used to be a leading producer and exporter of lumber; however, the dynamics have changed in recent times. Due to excessive over exploitation of Ghana's forest, production has slumped reflecting in the number of reduced logging firms operating now. It is reported that of the total round wood production in Ghana, 91% is used as fuel wood and for charcoal. The remaining (9%) is used as industrial round wood . However, the logging industry is still vibrant, employing about 120,000 people in Ghana .

Processed wood export has dwindled from about 400,000 m3/a in 2004 to about 262,000 m3/a in 2017. There are currently about 84 sawmills and 12 plywood producing companies in Ghana with majority of them in Kumasi and Takoradi.

Kumasi also doubles as having the largest cluster of artisanal wood workers in the wood village at Sokoban. Notwithstanding the reduction in export volumes, a substantial amount of waste is generated during the processing of lumber. It is estimated that 20-47% of the whole lumber is lost during processing. This includes the bark of the lumber, sawdust, offcuts and wood shavings.

A few large sawmills use the residues to fuel their boilers to generate process heat in the form of steam and or power. Apart from these direct uses of the wood residues, there are no known uses of the residues.

3.1.3 Industrial and municipal sectors

Municipal solid waste generation is about 0.47 kg/person/day in Ghana. The waste is mainly composed of organic materials of about 60%, and plastics making up most of the remaining component. Wooden pieces of waste constitute about 12% of the total waste generation in the country. The organic fraction contains 60 – 70% moisture, making it wet and unsuitable for direct thermal application. With a calorific value range of 14 MJ/kg on a dry basis, dry organic waste is a major source of fuel that could be pelleted or made into briquette. This notwithstanding, the high moisture content is a major inhibitory factor due to the heavy thermal load required to dry it to fuel grade biomass. Further, the practice of mixing all solid waste stream has the tendency to reduce the quality of the organic waste stream. Stones and other incombustible materials up to about 10% have been reported in the literature. However, given the sheer amount of solid waste generated 12,000 tons/day of which nearly 6,000 tons are organic makes it's a very attractive source of material for pellet and carbonized briquette.

3.2 Promising feedstock

Bamboo

Bamboo trees present a very good source of raw material for carbonized briquette. Bamboo biomass potential is about 115 t/ha. However, bamboo growth in Ghana is natural and thus difficult to estimate the actual biomass potential based on the acreage cultivated. This notwithstanding, bamboo biomass has a high energy content of about 19 MJ/kg and an ash content of about 4% of the total solids. Freshly cut bamboo trees have a low moisture content of just about 10% making it a very good fuel source.

A major drawback of bamboo's usage as a fuel source is the multiple uses bamboo can be put to. It is mainly used as a construction material in the construction industry of multi-story buildings in major cities like Accra, Kumasi, and Takoradi. Apart from this, it is also widely used in the carpentry industry in combination with rattan to make chairs and tables. And lastly, the phenomenon of bamboo bikes is catching up in Ghana even though the industry is nascent.

Palm tree trunk

75% moisture content
17 MJ/kg energy content (HHV)
3% Ash content

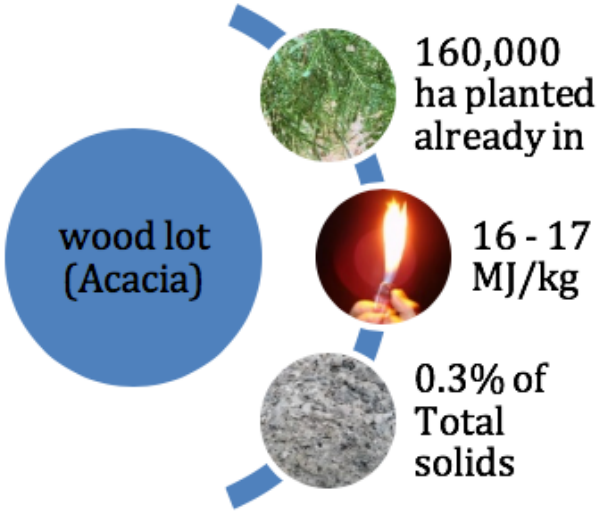
70% moisture content
16 MJ/kg energy content
3% Ash content

425,000 ha plantation
average life of plant 22 years
biomass yield is 90 ton/ha

The above-ground biomass potential of oil palm trees varies with the age of the palm trees. At 1.5 years old, the tree comprising the trunk (22%) and frond (78%) has a biomass potential of about 10.4 t/ha. However, this increases to about 90 t/ha when the tree is about 20 years old. This is primarily driven by an increase in the size of the trunk to about 56% of the total mass of the tree while the weight of the fronds reduces to about 44% Aside the biomass potential increasing, the yield per hectare drops with age after the initial maturity age. Between 15-20 years of the life of the tree, it is not economically viable to keep the tree. Thus, the trees are felled and replaced with new plantation.

Ghana has a palm plantation cover of about 435,000 ha. The trunk and the frond have a calorific value of about 17 and 16 MJ/kg respectively and ash content of approximately 3% of the total solids each. The main physical disadvantage is their moisture content which ranges 70 – 75% of the fresh biomass. Apart from taping the cellulose and glucose in the sap as palm wine, there is currently no known use for the trunk. Even then after tapping the sap, the trunk is allowed to decay naturally in the field. The fronds are also marginally used for basket weaving and broomsticks.

Woodlot



Woodlot is a dedicated forest purposely for the cultivation of energy shrubs and trees. In Ghana established woodlots comprise mainly plant acacia. As of 2015, 160,000 hectares of woodlot plantations had already been established by government agencies and some private companies. Woodlot has the capacity to generate renewable and sustainable firewood to produce briquette. The acacia tree when dried has a heating value of about 14 MJ/kg.

4. Technologies and Equipment

4.1 Introduction

According to the international ISO 17225 Standard, a briquette is a “densified biofuel made with or without additives, having a cubic, prismatic or cylindrical shape, with a minimum diameter of 25 mm, produced from woody biomass compression or crushed herb.” They are also defined as moulds of compressed biomass and can be made into a variety of shapes and sizes depending on the feedstock, the level of compactness and mould used and are usually no smaller than 2cm.

Pellets are smaller and denser, short roundish sticks of 6-12 mm diameter and are shaped by pressing dry biomass through a die with many holes.

4.2 Technologies

Briquettes and pellets are made through a process called densification, by applying pressure, heat and sometimes binding agent to loose biomass residues (forestry, agricultural or industrial raw material). The technology can be classified broadly into high pressure compaction, medium pressure compaction with a heating device and low-pressure compaction with a binder.

4.2.1 High and medium pressure compaction

There are two high pressure technologies: ram/piston press and screw press which
are both used for briquetting. In screw press and piston press technology, high pressure and heat is applied to bind the biomass. Binding material is not required in this process. Briquettes produced by a piston press are completely solid whiles screw press briquettes have a concentric hole which gives it better combustion characteristics due to a larger specific area.

4.2.2 Manual presses and low-pressure compaction

There are different types of manual presses used for briquetting biomass. They are specifically designed for the purpose or adapted from existing implements used for other purposes. Manual clay brick making presses are a good example. The main advantages of low-pressure briquetting are low capital costs, low operating costs and low levels of skill required to operate the technology.

Briquettes produced using this process have little mechanical strength and crumbles easily; thus, the use of a binder is unavoidable.

There are also reported cases of handmade briquettes in Eastern Kenya where no equipment is required. The biomass used are usually in the ground form such as sawdust, cow dung, and charcoal dust.

4.3 Type of binders

Binders for briquettes and pellets can be divided into three types: matrix type, film type, chemical type (Table 2).

Table 2 Major types of binders

Matrix Binders	Film Binders	Chemical Binders
Starch	Animal Glue	Ca(OH)2+CO2
Cement	Gum	Quick Lime+molasse
Palm Wax	Bentonite	MgO+MgCl2
Paraffin	Dextrin	Sodium
Clay	Molasses	Silicate+CaCl3
Kaolin	Water	Sodium Silicate+CO2
Asphalt	Sodium Silicate	HNO3
Polyvinyl Alcohol	Sucrose	Silica Gel
Methyl Cellulose	Ethanol	Resin

Matrix binders: These binders are normally used for extrusion and compression briquetting. Normally the void volume between the raw material will be around 2-10%, this type of binder fills completely the void spaces between the raw material, increase its plasticity and the particle bonding strength. It also has other functions such as dilution and lubrication, and reduce the internal friction of the raw material.

Film binders: Most of this type are liquid binder. The binder coats the particle of the raw material like a film. The film binder increases the strength of the briquette when the briquette is dried. It uses the surface tension to pull the material together.

Chemical binder: Increases the bond strength between the briquette particles through a chemical reaction between the binder and the material matrix.

4.4 Types of briquettes

Briquettes can be carbonised (charred) or non-carbonized. Carbonized briquettes are made from waste materials that have undergone carbonization (the conversion of organic substances into carbon in the absence of oxygen), as shown in Figure 6. Non-carbonized briquettes are produced from waste materials that are partially decomposed and then dried and can be made manually by hand, with presses, or with a mechanized mould or extruder (Table 3), and by mixing feedstock with water and binder.

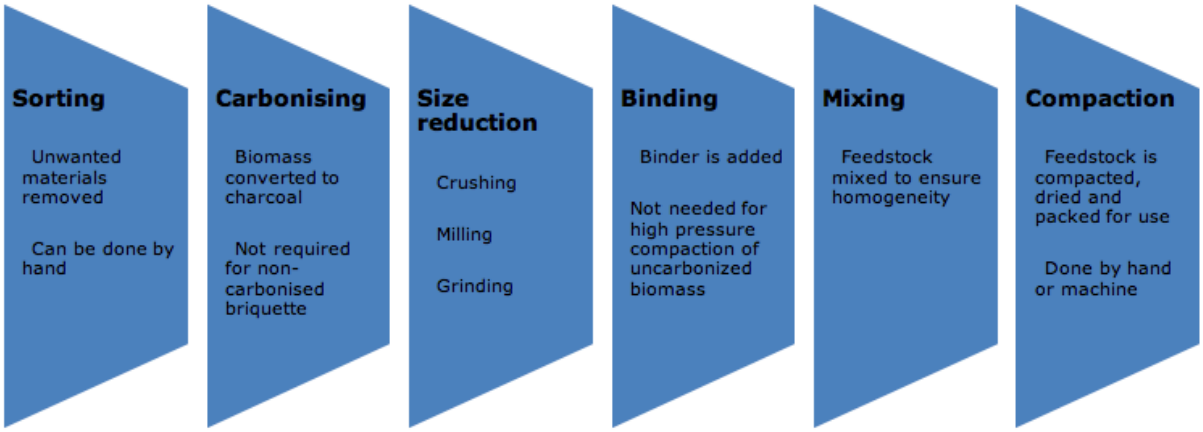
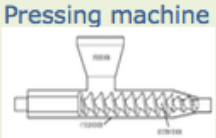


Figure 6 Process of producing Briquette
(Some stages not required for uncarbonized types)

Table 3 Equipment for briquetting

 Crusher	- Required for reducing the size of biomass - Not needed for charcoal dust and saw dust feedstock
 Kiln	- For carbonising biomass feedstock - Needed for producing carbonised briquette
 Mixer	- To mix the feedstock, binder, and water into a uniform composite before compaction
Pressing machine 	- Equipment for compacting the feedstock into briquette - Can be a screw press or a piston press

4.5 Production of Pellets

This is closely related to briquetting except that the product sizes are smaller (less than 12 mm). The pelletizer has a number of dies arranged as holes bored on a thick steel disk or ring and the material is forced into the dies by means of two or three rollers.

Pelletizers produce cylindrical briquettes between 5 mm and 12 mm in diameter and of variable length. They have good mechanical strength and combustion characteristics.

Equipment manufacturers and suppliers

There are no known manufacturers or suppliers of briquette and pellet making machines in Ghana presently. However, fabricators across the country can fabricate manually operated equipment on request for small and medium scale enterprises. For large-scale, automated production, the equipment must be imported.

There are several suppliers of briquette making machines globally. Few notable suppliers that have installed systems in Africa are profiled in Appendix B. C.F. Nielsen is the leading manufacturer of mechanical briquetting presses.

They supply briquetting solutions for production of industrial type briquettes for use in boilers and log type briquettes for fireplaces and ovens of private consumers.

4.6 Briquette and pellet stoves

There are several models of briquette and pellet stoves for various applications including household cooking, steam generation in industries, and residential space heating. These stoves have higher thermal efficiencies and are more environmentally friendly.

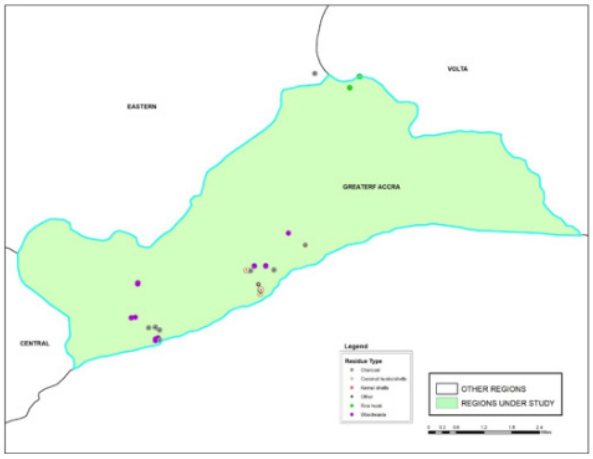
Household pellet stoves are usually smaller in size compared to firewood or charcoal stoves. However, they are more sophisticated and usually have the following components: hopper, auger system, fans, firebox, and safety features.

Several prototypes of briquette and pellet stoves (e.g. OPSD briquette stove) have been developed in Ghana but are yet to reach commercial production. However, some organisations such as ASA initiative and Institute for Sustainable Energy and Environmental Solutions (ISEES) have models that are sold on the market, though availability is restricted to few locations. Abellon, the leading producer of pellets, also supplies Indian made pellet stoves to end-users.

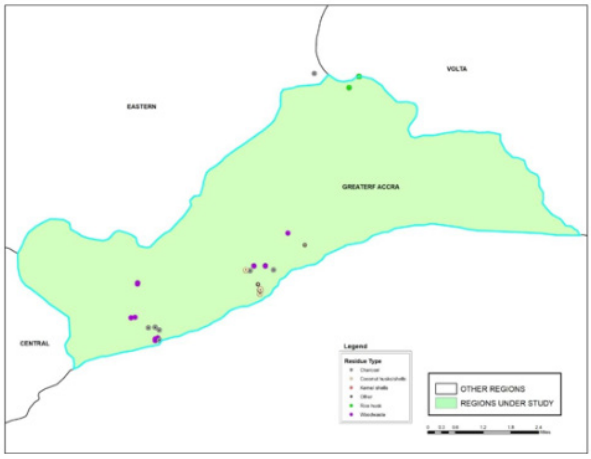
5. Mapping of residues

5.1 Background

The main raw materials used to produce briquettes and pellets in Ghana are saw dust and other wood waste, coconut shells/husks and charcoal dust. Others include rice husk and palm kernel shells. Survey of agro- and residual biomass was carried out in Ashanti, Greater Accra and Western regions, as shown below.



Ashanti Region



Greater Accra Region

Western Region

5.2 Wood waste

As shown in section 3, about 250,000 m3 of lumber is processed annually out of which 20-47% is generated as residues comprising barks, sawdust, offcuts and shavings. The wood processing industry is vibrant in Western and Ashanti regions. According to the website of Ghana Timber Millers Organisation (GTMO), its membership includes 100 timber processing companies. The Greater Accra Region also has an active sawmill industry. Wood waste is the most important raw material for briquettes and pellets in Ghana. It's readily available in appreciable quantities across the Regions surveyed, and in others as well.

The survey shows that considerable portions of wood residues generated are unused and thus available as raw materials for briquetting and pelleting (Figure 7). The most promising sites surveyed are outlined in Table 4.

Figure 7 Status of wood residues generated at surveyed sites

5.3 Rice husk and bran

120,000 Tonnes	33 Percent	Unused
Annual production potential	Sold by Farmers for animal feed	Burnt on farms

The rice industry is promising for the sustainable production of briquettes and pellets. Local rice production is increasing, and rice mills have become avenues for generation of rice husks. The annual potential of husks is about 120,000 tonnes.

The survey from the 28 husk and bran producing sites indicate about a third of bran is sold as animal feed while the husks are usually unused. Excess or non-used residues are burnt or disposed of on dumps. The surrounding towns around Asutsuare and Akuse generate larger volumes of husks and can be favourable area to locate a briquette factory. Further details are outlined in Table 5.

5.4 Coconut shell/husk

Coconut shells and husks are usually gathered free of charge from retailers of coconut who are found all over the cities and towns in the country. The residues are generated in small quantities, and locations generating residues in appreciable quantities are few. Nonetheless, coconut residues remain an important raw material for briquettes and pellets. Vendors of coconut usually dispose of the residues as waste, with most paying for disposal.

50% dump all charcoal dust generated
25% sell charcoal dust
A bag of dust is sold for GH¢10

The charcoal industry has been the lifeline of many in both rural and urban Ghana. Charcoal dust is generated in appreciable quantities in charcoal retail spots. Though existing uses exists, nearly half of surveyed sites dumped all dust. A quarter of retailers sell dust, averagely at a cost of GHS 10 per medium bag. Some of the spots (e.g. Ashaiman charcoal distribution centre) would be of interest in developing a viable briquette and pellet industry.

5.6 Kernel shells

Kernel shells are generated in small oil processing companies in many parts of southern Ghana. Some places also have clusters of small mills, generating shells in appreciable quantities. Kernel shells are sold to third parties for use in energy generation and can thus be used for briquettes and pellets even though the residues are sold.

5.7 Maize and cowpea residues

Ejura and surrounding communities are major maize and cowpea growing centres in Ashanti region and thus generates considerable quantities of residues – stovers, cobs, husks, etc. – during harvesting seasons. The survey indicates residues are available for conversion into briquettes and pellets. A lot of farms process maize within the farms.

A total of seven farms were visited, with a cumulative production of 2110 and 876 maxi bags per year of maize and cowpea, respectively. This is estimated to generate about 430 tonnes of maize residues (stalk, cobs, and husk) and 160 tonnes of cowpea residues (shell), per day.

5.8 Industrial residues

There are several large-scale agro- and wood-processing companies that generate large quantities of residues, with a considerable fraction unused and thus available for briquetting and pelleting. Few of such companies surveyed are shown in Table 5. Some industrial residues of interest surveyed include cocoa shells, shea nut residues and cashew shells. The cashew sub-sector is growing and there are processing companies in Tema. Residues are usually available in large quantities and in many cases not all residues are used in energy generation. Approximately, 14 tons/day of residues are produced by Olam Ghana (Kumasi), USIBRAS cashew (Ningo-Prampram) and Crocodile Machete Company (Tema).

It is imperative for producers to explore possibilities of depending on residues from industrial companies including those operating under the Ghana Free Zones Board.

Table 4 Highly promising sites for wood waste generation for briquettes and pellets

Site		Town	Waste type, waste quantity	Reasons site is promising	Comments
	Sokoban wood village	Sokoban	Sawdust; wood shavings; wood waste. More than 10,000 tons/day of waste generated	A wood village comprised of over 1000 sawmills and more than 10 timber factories.	Waste is available free of charge.
	Oforikrom wood site	Oforikrom	Sawdust; wood shavings	Cluster of sawmills; large quantities of wates are generated out of which half is burnt.	Waste is available free of charge.
	Kwadaso wood site	Kwadaso	Sawdust; wood shavings	Cluster of sawmills; large quantities of wates are generated out of which half is burnt.	Waste is available free of charge.
	Kokompe wood site	Kokompe	Sawdust; wood shavings	Cluster of sawmills, with large volumes of waste generated out of which about half is collected or disposed of by third parties.	Waste is available free of charge.
	Crocodile Matchet	Tema industrial area	Wood pieces and wood dust	20 tons of wood waste are produced every month.	Company is willing to give it out
	Ashaiman timber market	Ashaiman	Saw dust	Ashaiman timber market too is a cluster of wood processing shops and the supply of raw materials will always be readily available throughout the year	Some of them will be willing to give it for free.
	Accra Central, Kasoa and Ofankor sawmills	Accra	Sawdust; wood shavings; wood waste. Accra Central (~338 ton/day); Kasoa (~ 81 ton/day); and Ofankor (~ 25 ton/day)	These locations have many mills, with most members forming association; this makes it easier to obtain residues. About 50, 60 and 150 mills are members of the association at Ofankor, Accra Central and Kasoa, respectively.	Waste generated might be sold to prospective producers

Table 5 Other promising sites for non-wood residues

Site		Town	Waste type, waste quantity	Reasons site is promising	Comments
	Akwatia -line rice mills	Kumasi	Rice husk, about 560 bags of husk/week	Cluster of 28 rice mills	Association is willing to sell for bioenergy purposes at a fee.
	Rice mills	Akuse/ Asutsuare	Rice husk, about 822 bags/week	Cluster of 18 rice mills	Waste might be sold.
	Rice mills	Ejisu-Menhyia-Boankra-Nobewan-Konongo-road	Rice husk, about 440 bags/week	Total of nine rice mills along this route.	Waste might be sold.
	Ejura	Ejura	Maize cobs; husk; stover; cowpea shells; rice hulls and bran; charcoal dust	Ejura has a population of about 120,000 people out of which 80% are farmers, who cultivate maize, cowpea, rice and other crops. Large volumes of residues are generated in the farms.	Farmers are willing to sell residues to third parties. Ejura is a charcoal producing hub and has a lot of charcoal joints from where a lot of charcoal dust can be obtained.
	Usibras Cashew	Prampram	Cashew nut shells	2 tons of residues are generated daily; disposal of waste is one of the company's top challenges. Residues also occupy space, additional nuisance to the company.	The waste is available, and the company is willing to supply residues to third parties under formal agreement.
	Bekwai Zongo	Bekwai	Palm Kernel shells	This site is a cluster of palm kernel producers and the shell are available throughout the year.	The waste is available at a cost.
	Ashaiman High Tension	Ashaiman	Charcoal dust	Ashaiman high tension is the hub for charcoal market for both wholesalers and retailers. Charcoal dust is abundant and about 50% of the dust is unused.	Retailers are ready to sell dust at a negotiated price.

	Sites surveyed	Alternative uses	Calorific value MJ/kg	Est. Theoretical Potential X 10^6, t/a	Comment
Wood Waste	63	3,547	Residues usually available in uncontaminated state, and in dry form. However, some are found wet in the rainy season.	Residues are available for briquette producers all year round. 2 out of every 5 sites dispose of at least half of waste generated.	Mainly used as fuel and bedding material for livestock. Minor uses include substrate for growing mushroom and landfilling. Residues (fraction or full) from 2 out of every 3 sites are sold; this is higher in Greater Accra at 4 out of every 5 sites.
Kernel shells	9	6.0	Residues are homogeneous	Residues are generated usually from Jan to April. All residues produced are sold.	Shells are sold at GHS 20/medium bag or GHS 400-500/medium Kia truck. This approx. GHS 0.3-0.7/kg.
Rice husk	28	9.9	Residues found dry and uncontaminated	Residues are generated all year round in 85% of sites	Residues are mainly used as animal feed. Owners are used to selling residues. • A third of sites sell residues to third parties as fertilizer in burnt or unburnt forms • Burning is also a means to dispose of waste
Charcoal dust	29	2.8	Residues found dry and unmixed with other wastes	Residues generated all year round. All dust from half of sites visited are not used. Only 1 out of every 5 sites have 100% use for dust.	Sold at GHS 10/bag or about GHS 0.4/kg. A quarter of retailers sell charcoal dust. Uses include blacksmithing, earthing, filling, etc. Most retailers dispose of their dust in dumps.
Coconut residues	16	2.2	Available in uncontaminated forms. Residues are freely available among most retailers. Only one retailer supplied residues for charcoal production.	Average generation per retailer was estimated at 90 kg/d.	About 9 out of 10 retailers dispose of waste at a fee. Products from a coconut processing company were used for charcoal production.

6. Economic analysis of the sector

6.1 Briquette and pellet producers in Ghana

Briquette and pellet production is steadily growing and many entrepreneurs are becoming attracted to the industry. Appendix C lists producers profiled during the survey. Their capacities range from 3 – 3000 ton/month, with smaller producers relying mainly on manual production methods. The rest are semi-automated except Abellon whose operations are fully-automated.

With regards to consistency of operation, the main challenges affecting operations based on producers' perspectives include raw material supply, availability of ready market, occasional power outages, repair/maintenance of machinery, and heavy rainfall in the wet season especially in regions like Western and Ashanti. Thus, some producers operate below capacity, with some as low as 30%.

The availability of biomass to meet full operations of some producers is a major challenge. Companies that have sited their plants within waste production centres such as Sokoban wood village in Kumasi are supplied with adequate quantities of materials to meet production levels. That is however not the case for some medium-to-large scale producers who struggle to obtain adequate volumes to meet targets.

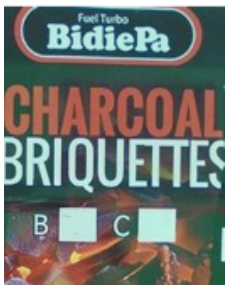
6.2 Market price of briquettes and pellets

The price of briquettes and pellets range from 0.9 – 12 GH¢ per kg, at an average price of 3.5 GH¢/kg and a standard deviation of 4.7. In contrast, the price of imported briquette sold in supermarkets range from GH¢ 5-10/kg.

6.3 Market for product

Finding a sustainable market for the products is one of the main challenges facing some producers. This situation is partly attributed to the low awareness among potential end-users, including households, commercial entities such as restaurants, schools and industries. From the Energy Commission, five producers are licensed to export products at a total quantity of 5460 tonnes per annum, while two producers have their products registered with Ghana Standards Authority.

Another challenge relates to importation of briquettes from countries such as South Africa which are sold in South African owned supermarkets at a cost of about 10 GH¢/kg. There is therefore a gradual growth in competition for market, and even biomass resources especially in Greater Accra where several producers are located.



6.4 Economics of briquette and pellet plants

a. Manual production of charcoal briquettes within charcoal retailing

Manual briquette production can easily be integrated into charcoal retailing. Charcoal retailers are found in large numbers in every village, town and city in the country, and they generate large quantities of charcoal dust, the bulk of which are unutilized as established by the survey. Similar to East Africa, retailers and women or youth groups can be trained on micro-scale briquette production from charcoal dust. This can be achieved using used cans for moulding briquettes or manually operated machines which can be acquired locally or imported. Free or cheap sources of binding include clay, cow dung, paper pulp and cassava starch. For such simple methods, the only operational cost is likely to come from the binding material and water for mixing. The economic analysis based on processing of 50 kg/day is given below.

Residue	Charcoal dust
Quantity of dust, kg/day	40
Binder (starch/clay/dung), kg/day	10
Cost of binder, GHS/kg	0.5
Operational (including utility) costs, GHS/kg of dust	0.2
Price of briquette, GHS/kg of briquette	1
Daily profit: revenue – operational costs, GHS/d	35
Monthly profit (25 days of work), GHS/month	875

Such manual charcoal briquette production systems can be adopted into charcoal retailing to boost the profits of retailers and to reduce waste. The briquette can be sold alongside charcoal, ensuring a sustainable means for using the dust.

b. Economic analysis of medium scale briquette production

The operation of briquetting or pelletisation plants is simple and does not require highly-skilled labour. Many vendors supply all tools and equipment required in a typical production assembly including milling machine, conveyors, dryers, carbonisers, pressers and packaging machines usually for production capacities of over 1 tonne per hour. The economic analysis is performed on a medium-size pellet plant, with a capacity of 1 tonne/h.

Chinese and Indian suppliers of equipment are significantly cheaper than European and American counterparts. The fixed capital investment (initial cost), based on quotations from Chinese suppliers, and taking into consideration Insurance and Freight, import duties and taxes, transport and installation costs, amounts to USD 172,741 (Appendix D). Annual operational cost (working capital) is estimated at USD 289,467.

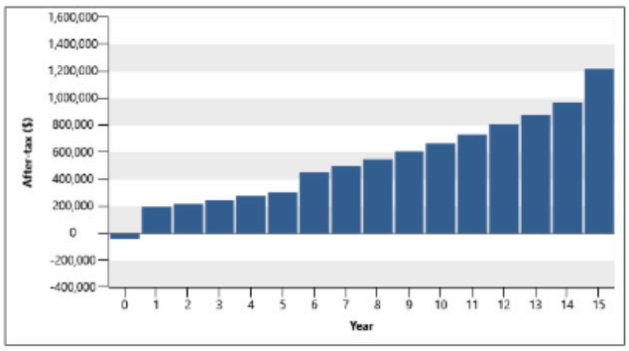
In the absence of carbon credits, the only revenue is the product. 1 tonne/h of saw dust is processed for a total of 12 h in a day. The plant operates for 24 days in a month for 12 months in a year. The quantity of pellet is estimated by assuming 5% material loss in the production chain. The selling price of pellet is taken to be 1300 GHS/tonne, which is consistent with those from existing producers.

Based on economic parameters given in Appendix D, the cash flows and economic viability are given below, indicating the attractiveness and economic viability of briquette and pellet production in Ghana. It should be noted that such gains are possible if entrepreneurs carefully site their plants in resource rich areas, where the residues are available free of charge or at low costs.

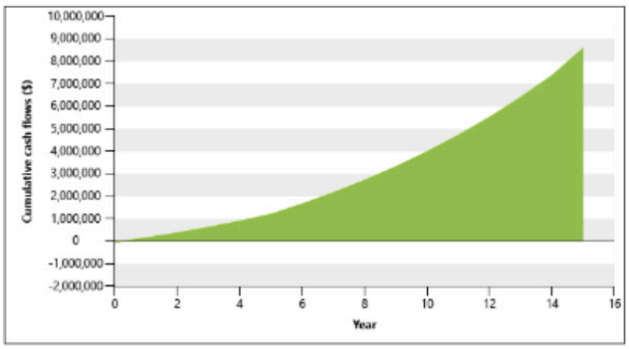
Financial viability		
Pre-tax IRR - equity	%	824%
Pre-tax IRR - assets	%	95.2%
After-tax IRR - equity	%	560%
After-tax IRR - assets	%	68.8%
Simple payback	yr	0.98
Equity payback	yr	0.18
Net Present Value (NPV)	$	3,488,807
Annual life cycle savings	$/yr	458,687
Benefit-Cost (B-C) ratio		98.9
Debt service coverage		3.6
GHG reduction cost	$/tCO$_2$	No reduction

Cash flow

Annual



Cumulative



6.5 Sensitivity analysis

The sensitivity study is performed by assuming a worse case scenario. Both fixed capital investment and working capital are increased by 20% while revenue from sale of pellets is reduced by equivalent fraction, with all other parameters kept constant. Under this adverse scenario, the project is still economically viable as observed below.

Financial viability		
Pre-tax IRR - equity	%	77.5%
Pre-tax IRR - assets	%	25.3%
After-tax IRR - equity	%	55.1%
After-tax IRR - assets	%	19.2%
Simple payback	yr	3.4
Equity payback	yr	5
Net Present Value (NPV)	$	922,516
Annual life cycle savings	$/yr	121,287
Benefit-Cost (B-C) ratio		22.6
Debt service coverage		1

6.6 Market size and investment requirements

As shown in Section 3, residues from forestry, agricultural, industrial and municipals sources are produced in large quantities that can potentially be converted to briquettes and pellets, with significant economic, social and environmental benefits. Table 7 summarises the investment requirement and economic potential of conversion of residues to briquettes and pellets. The availability of residues is conservatively taken as 30% of the theoretical potential to cater for alternative uses, losses as well as unavailability of some residues. The economic and market value is estimated based on the financial analysis of 1 ton/day plant.

6.7 End-users of briquettes and pellets

Presently, the major users of pellets as fuel for cooking are schools and restaurants. The end-users are usually supplied with pellet stoves by the producers. About GHS 2000-2500 are spent on fuel by most institutional end-users per month. Appendix E provides information on some consumers of pellets. Most users interview expressed satisfaction with the use of pellets, however, a few complained about difficulty in controlling the heat. Other useful attributes mentioned include convenience in usage, faster cooking, cleaner to use, less smoke and soot, and lower cost compared to firewood/charcoal. It was emphasised by a consumer that the positive attributes only work when the fuel is of high quality, and that low grad pellets become inconvenient to use. Another major concern is the quality of the cookstoves. It was obvious the locally-manufactured stoves require substantial technological improvements to meet standards on efficiency, emissions, usability and safety as observed by users.

Table 7 Economic potential of briquette and pellet investments

Residue	Availability, million ton/y	Capital expenditure (CAPEX), USD	Operational expenditure (OPEX), USD/y	Revenue, USD/y	Personnel income, million USD/y
Maize stalk, husk and cob	1.06	124	151	238	27
Rice straw/husk	0.27	31	38	60	7
Sawdust/wood waste	0.09	10	12	19	2
Other (groundnut, kernel, cocoa and cashew nut shells)	0.10	11.62	14.15	22.23	2.51
Total	1.51	177	216	339	38

6.8 Case studies of success stories in Ghana

Case study 1: Agricultural, Industrial & Commercial Products Limited Ltd. (AICPL)

AICPL is the largest briquette company in Ghana in terms of capacity. The factory was commissioned in September 2019 under the One-District-One-Factory (1D1F) initiative of government. Both carbonised and uncarbonized briquettes are produced from residues such as saw dust, rice husks, kernel shells, and bamboo. Most of the residues are from surrounding towns while others are obtained in Kumasi. The focus of the company is to produce and export high quality products. The company is presently test running and thus operates at half of its capacity of 100 ton/day.

As a new factory, there is the need to strengthen its raw material base while diversifying its market to include local industries such as Juaben Oil Mills where its products can be sold for energy generation at Juaben. AICPL can also benefit from the Juaben Oil Mill by making use of excess biomass generated by the mill.

Case study 2: Namco Processing

Namco produces carbonised briquette from coconut shells and charcoal dust. Located in the industrial city of Tema, the semi-automated plant has a capacity of 6 ton/day. A higher percent of biomass used is purchased within the region. Even though raw materials used are available, they are scattered and thus increases the operational cost of the company. The clients of the company include household, commercial entities, industries, while the export market is also a focus of the company. The product of the company is sold at GHS 12/kg. The major challenges facing the company relates to cost of gathering raw materials especially coconut husk, competition from imported products and the general high cost of local production.

In conclusion, the company should explore possibilities of using industrial residues within Tema and its environments, especially when some companies dispose of large quantities of residues.

Case study 3: Abellon CleanEnergy Ghana

Abellon is the first large-scale pellet production company in Ghana. The company is located at Sokoban Wood Village in Kumasi and has capacity to produce 100 tons of pellets per day using materials such as cocoa shells, maize waste, wood waste, sawdust and shea shells. Some residues are purchased while others are obtained free of charge. Pellets are produced for export and to serve local customers, mainly institutional, commercial and industrial entities, at a prices of GHS 1.3 per kg. The company also supplies well-engineered pellet stoves to its clients.

The major challenges facing the company include low numbers of customers willing to adopt the use of clean solid fuel, low awareness creation, no government support, and weak market.

6.9 Success Stories in Other Countries

There are several briquette initiatives in East Africa that have upscaled into commercial enterprises. Most of these were introduced by community-based organisations, NGOs and development partners to tackle income poverty alongside environmental conservation. A selection of these notable businesses and projects are presented here.

Case study 1: Kampala Jellitone Suppliers, Kampala, Uganda

Kampala Jellitone Suppliers (KJS) is a limited company located in the Natete suburb of Kampala. With a history in coffee roasting, KJS diversified into making briquettes primarily to fuel their own requirements but expanded into Uganda's first large-scale briquette producer now selling 2,400 tonnes per year. They produce non-carbonized briquette from agricultural waste. The company buys both milled and unmilled feedstock from farmers paying more for milled feedstock.

The company is financed by its founder and grants from the Danish International Development Agency (DANIDA), the United States African Development Foundation and the Ashden Awards. The initial grant from DANIDA helped to buy the first briquette machine, set up production and carry out research into briquetting technology but after that briquetting quickly became a self-sustaining part of the business. KJS have registered their venture as a CDM project in Uganda and with support from the Belgian Embassy are aiming to develop an appropriate methodology for carbon financing.

Case study 2: Chardust Ltd, Nairobi, Kenya

Founded in 1999 and based in Nairobi, Kenya, Chardust is an alternative energy company that manufactures and sells over 2,000 tonnes of carbonised briquettes per year made from recycled charcoal dust collected from charcoal vendors around Nairobi. They collect 8 tonnes of this waste per day before processing it into briquettes and distributing within the city limits. The company markets several different products targeted to different market segments. Their standard briquette is sold to urban (household and institutional) charcoal users. They also sell premium briquettes certified by the Kenya National Bureau of Standards, for the higher-end domestic barbeque market. Standard briquettes sell for US$0.14 per kg, while the premium briquettes sell for US$0.43 per kg (both wholesale prices). Chardust use roller press machines, imported from India as well as mechanical milling machines. While drying is done outdoors in the sun over 2 acres of land, they stock up to 100 tonnes of briquettes at a time to cover demand during the rainy periods when production drops due to slower outdoor drying. The company has experimented with a large down-draft pit kiln for carbonising agricultural waste, but it was found less economical than utilising charcoal waste.

Case study 3: East Africa Briquettes Company, Tanga, Tanzania

The East Africa Briquette Company has factories in Tanga, Northern Serengeti and Ngoronogoro in Tanzania. The briquettes are made with an Indian-made roller press fed by carbonised agricultural waste (Coconut husks, Cashew nut shells, maize stalks and cobs, and cotton crop waste). that is bought from people with a 'cash at the gate' policy, allowing them to develop a large network of people who provide a continuous supply of raw material. The company sells about 60 tonnes of its pillow shaped briquettes per month.

6.10 Mitigations strategies for removing barriers to adoption of briquettes and pellets

Though briquettes and pellets have been known for many years, their use in the homes and industry is low and awareness about them is also low. The availability and supply of these solid fuels as well as stoves are low, and entrepreneurs have not found success in marketing them. Moreover, the cost of producing the fuels is generally high due to high electricity tariffs while alternative fuels such as charcoal are relatively cheap. Cookstoves for briquettes are either expensive or unavailable, and most designs/models are imported. Table 8 provides a summary of the major challenges and possible actions required to mitigate or overcome them

Barrier	Observation	Mitigation strategies
High upfront cost	Many producers are operating below full capacity, some as low as 30%	• Producers should use cheaper and low-tech methods that are of high quality; • size of investments should be carefully scaled with respect to raw material availability.
Technology	Overall, investment and operational costs are higher for pellets, per ton basis. Only few producers produce pellets.	• Start-ups should consider briquettes due to lower upfront and operation costs, per ton basis
Inadequate availability of raw material	• Most biomass are not available at central points in large quantities. This increases cost of collection and transportation to site. • Medium- to large-scale plants face high risks of material shortage.	Siting of plants should be done carefully, taking into consideration the sustainability in supply of high-quality residues.
Consistency in supply of raw materials	Some residues such as rice husk and maize stover are seasonal.	Companies should source and use diverse residues, without compromising on quality of product.
Quality of raw material	• Rainy season presents immense challenges to producers in Western and other regions that receive high annual rainfall. • Drying to right moisture content is costly. • Raw material contaminated with dirt and other foreign materials	Companies should explore solar drying or use of residues that have lower moisture content. Residues should be collected as soon as they are generated to reduce levels of contamination.
High cost of raw material collection and supply	Some plants are poorly sited, far from the main sources of raw materials.	Prospective entrepreneurs should carry out a detailed raw material inventory before deciding on the scale of the plant.
Unavailability and/or high cost of domestic and institutional briquette or pellet stoves	• Imported stoves are costly; household stoves cost about GHS 250 while institutional units cost over GHS 1,000, with cost influenced by size. • Many attempts to promote pellet stoves in household have failed; the focus should always be institutional. • Ordinary cookstoves can be used on briquettes, mixed or unmixed with charcoal	Cheaper institutional stoves for pellets and briquettes should be readily available, accompanied with sustained awareness creation. Technical and financial assistance for manufacturing locally-made stoves are also needed.
Local stove models are not well-engineered and readily not available	Local stoves manufactured and supplied have not been evaluated against standards. A draft regulation on cookstoves is expected to be completed soon by the Energy Commission.	Well-engineered but low-cost models should be developed. Briquette producers should be encouraged to cooperate with technology centres to develop appropriate models for consumers of the fuels.

Table 8 Mitigation strategies for removing major barriers

Electricity tariffs	Some producers complain about frequent interruption of power; others complain about the high tariffs.	Project developers should practice energy conservation and efficiency in order to reduce costs. Existing companies should seek services of professionals for energy auditing of their production. Companies should explore possibility of solar drying to reduce costs, as employed by Chardust Ltd. of Kenya.
Lack of financial support for growth	• Expansion and scale-up has been a challenge due to absence of green credit lines and flexible financing opportunities. • Interest rates (25% or more) are high, making loans risky to take. • Some projects are grant-depended, and thus perform poorly without some form of grant support.	The Ministry of Energy and Energy Commission should work with Ministry of Finance to consider tax holidays for players in the sector. In addition, the Ministry of Energy should consider opening green credit lines with banks to support entrepreneurs in the sector.
Availability of charcoal briquettes low in the market	Imported charcoal briquettes are more visible in most supermarkets as opposed local producers.	Rigorous marketing and promotion; branding of local briquettes. Continuous supply of product.
High cost of transportation	The location of plants should be optimised to reduce transport costs on raw materials and products.	Entrepreneurs should locate their plants near the sources of raw material as much as possible.
Carbon financing	Unlike improved cookstove producers, briquette producers enjoy no carbon funding.	GCIC and other stakeholders should consider developing a programme of activity for the briquette and pellet sector in Ghana.

6. APPENDICES

Appendix A List of licensed exporters of briquettes and pellets

No	Name	**Annual Quota**	**Export** Destination	**Address/Contact**	Location
1	Namco Processing Enterprise	Asia and Europe	Asia and Europe	P.O. BOX CT4147, Cantonments, Accra +233 506710142 info@namco-gh.com	Community 2, Tema
2	BioGreen Ghana Limited	300 Tonne	Asia and Europe	P. O. Box NB 217, Nii Boiman, Abeka, Accra +233 240478215	Akramang in the Gomoa East District of the Central Region.
3	Zuriel Carbon Production	240 tonnes	Europe	P. O. Box 63 Nkawkaw +233 264186774 / +233 263750633 zurielcarbonproducts@gmail.com	Akoase in the Birim North District, Nkawkaw of the Eastern Region.
4	Agricultural, Industrial & Commercial Products Limited	1,120 Tonnes	Europe	P.O. Box 1791, Accra University Farms, Ajiringanor, Accra 0541735625 / 0275999537 / 0302979014 fsgrp@yahoo.com	Accra
5	Esereso Carbon Products Limited	800 tonnes	Europe	P.O.BOX 15469, Accra-North 0302928113 / 0243802765 / 0244354786 eseresocarbon@yahoo.com	Esereso

Source: Energy Commission
http://energycom.gov.gh/regnew

Appendix B Notable manufacturers of briquetting and pelleting machinery

Name and description	**Country of installation**	**Contact**
C.F Nielsen is a leading manufacturer of briquetting presses. They supply briquetting solutions all over the world.	Ghana[13] (Charcoal briquette) Kenya[14] (Pineapple waste briquette)	Tel: +4598337400 Email: sales@cfnielsen.com
GEMCO ENERGY Anyang GEMCO Energy Machinery Co., Ltd (a division of ABC Machinery) manufactures and supplies pellet mill, pellet plant and biomass briquette machine.	Ghana (Bamboo pellet machine)	Tel: 0086-372-5965148 Fax: 0086-372-5951936 Email: info@gemco-energy.com
Jay Khodiyar Founded in 1994 with a motto to serve environment, has been exporting briquette making machines to Africa since 2002.	Several	+91-76000 00018 info@jaykhodiyar.com
EP Machinery The company manufactures various briquetting machinery and supplies product to all parts of the world.	Several	Mobile: +86-13673361755, +86-13592528737 Email: sale@ep-machine.com

Appendix C List of producers of briquettes and pellets interviewed

Company name	Location	Residue used	Product	Capacity, ton/day	Target market
Agricultural, Industrial & Commercial Products Limited	Bonwire Bamang, Ashanti Region	Rice husk, saw dust, coconut shell, palm kernel shell, bamboo	Briquette (carbonised and uncarbonized)	100	Local Industry, export
Abellon	Sokoban, Ashanti	Saw dust	Pellet	100	Restaurants, schools, hotels, industry, export
JSK renewable energy ltd	Sokoban, Ashanti	Sawdust	Pellet	24	Household, restaurants, industry, export
Cookclean Ghana Ltd.	Bediakokrom, Ahafo Region	Saw dust	Briquette (uncarbonized)	13	Industry
Namco Processing	Community 2 Tema, Greater Accra	Coconut shell and husks, charcoal dust	Briquette (carbonized)	6	Households, restaurants, industry, export
Biogreen Ghana	Gomoa Akramah, Central	Coconut waste	Briquette (carbonized)	1	Restaurants, industry, export
Synergy Recycle and Waste Management Ltd.	Takoradi, Western Region	Coconut shells/husks	Pellet	0.3	Restaurants and institutions
OPSD	Adukro, Offinso, Ashanti	Cocoa shells, maize waste, wood waste, sawdust, shea shells	Briquette (carbonized)	0.1	Household
Green-Heat Technologies	Bortianor, Greater Accra	Coconut husks	Briquette (carbonized)	N/A	Commercial

Producers that were not interviewed are listed in the table below.

Name of company/ firm	Location			Contact		Product type	Residues used
	Region	District	City/ Town	Name	Email		
Global Bamboo Products Ltd.	Eastern	Atiwa East District	Anyinam	Gloria Asare Adu	info@globalbambooproducts.com	Briquette	Bamboo
Zaacoal	Greater Accra		Dodowa	Sulley A. Abubakar		Briquette	Coconut shells and husks
Gamma Energie	Greater Accra	La-Nkwantanan Madina municipal Assembly	Madina Estate	Emmanuel Asaam	info@gammaenergie.com	Briquette; Pellet	Cocoa pod husk, palm kernel shells, corn stalk, coconut shell & husk, wood waste (saw dust), charcoal dust
Wen-Neon Company Ltd.	Upper East	Builsa South District	Fumbisi	Grace Abachie	abachiegrace@gmail.com	Briquette	Rice husk
Nasag-Lach Company Limited	Volta	Central Tongu District	Adidome	Elizabeth Bayo	bayohelizabeth@gmail.com	Briquette	Rice husk
Asa Initiative	Central		Cape Coast	Veronica Akitti	Asainitiative@yahoo.com	Briquette	Charcoal dust
Relief International	Greater Accra						
Esereso Carbon Products Ltd	Ashanti		Esereso				
Jekora Ventures Ltd.					info@jekoraventures.com		
JSK Ren. Energy Limited						Pellet	
BioGreen Ghana Limited							
Zuriel Carbon Production					zurielcarbonproducts@gmail.com		
Ameasco Global Trading Enterprise							
Frekon Feeds Services							
All Wealth Ventures							

Appendix D Economic analysis of medium scale pellet plant

Cost of equipment and installation

Item	Size capacity	Quantity	Total cost (US$)
Hammer mill	55 kW; 1-2 t/h; screen size - 6 mm; accessories – Fan, Blower, Cyclone, Air Lock and Bag Dust Collector	1	18,800.0
Belt conveyor	8m max; 2.2 kW	1	2,720.0
Pellet machine (include dust separator and other accessories)	1-1.5 tonne/h; 90 kW	1	62,000.0
Bucket elevator	0.75 kW	1	6,200.0
Packing machine	1 kW	1	14,200.0
Screen shaker	0.5 kW	1	4,000.0
Subtotal (S1)			107,920.0
Shipping and transportation		20% S1	21,584.0
Subtotal (S2)			129,504.0
Tax/VAT		17.5% S2	22,663.2
Transportation of equipment to site			5,000.0
Total cost (EC)			157,167

Estimation of total capital investment

Item/activity	Details	Cost, USD	
Equipment cost (EC)		157167	
Installation cost	10% EC	15717	
Engineering and supervision	15% EC	23575	
Biomass storage and shed for plant	50% EC	78584	
Civil and electrical works	20% EC	31433	
Contingency	20% EC	31433	
Fixed capital investment		337909	
Estimation of working capital			**% contribution to WC**
Raw materials (saw dust, wood waste), USD/dry tonne	25	86400	21.0
Transportation of raw material, USD/tonne	10	34560	8.4
Transportation of finished product, USD/tonne	8	26266	6.4
Packaging, USD/tonne	10	34560	8.4
Land lease, USD/y		20000	4.9
Electricity, USD/tonne	34.2	38016	9.2
Repair and maintenance	10% FCI	33791	8.2
Administrative expenses	0.5% FCI	1690	0.4
Insurance	3% FCI	10137	2.5
Local taxes and permits	1% FCI	3379	0.8
Research and lab analysis	0.5% FCI	1690	0.4
Personnel, USD/tonne	25.3125	87480	21.2
Contingency	10% FCI	33791	8.2
Working capital		411759	100.0

Analysis
The clean energy software Retscreen Expert was used for economic and sensitivity analysis. The main parameters used for the analysis are given below.

Basis for economic analysis

Financial viability

Financial parameters

General		
Inflation rate	%	10%
Discount rate	%	10%
Project life	yr	15
Finance		
Incentives and grants	$	0
Debt ratio	%	90%
Debt	$	320,845
Equity	$	35,649
Debt interest rate	%	22%
Debt term	yr	5
Debt payments	$/yr	112,041
Income tax analysis		
Effective income tax rate	%	30%
Loss carryforward?		No
Depreciation method		Declining balance
Half-year rule - year 1		No
Depreciation tax basis	%	100%
Depreciation rate	%	5%

Appendix E Some end-users of briquettes and pellets

Name of organisation	Location	Fuel used
Joy Standard School	Ahinsan, Kumasi	Pellet
Joy Standard School	Feyiase, Bosomtwe district	Pellet
Nana Serwaa Nyarko Preparatory School	Adukrom, Offinso municipality	Carbonised briquette
Kumasi Catering Rest House Co. Ltd.	Kumasi	Pellet
St. John's School	Secondi	Pellet
Ghana Senior High Technical School	Takoradi	Pellet
HPW Fresh & Dry Ltd.	Adeiso	Uncarbonised Briquette

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