UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT
UNCTAD

PROMOTING COTTON BY-PRODUCTS

In Eastern and Southern Africa

Zimbabwe

Investment Profile

Biomass Briquettes and Pellets from Cotton Stalks

Submitted to:
Zimbabwe Investment Authority

28 January 2019

Project: 1617K - Funded by the United Nations Development Account - 2016-2019

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT
UNCTAD

VALUE ADDITION OF COTTON BY-PRODUCTS IN ZIMBABWE

Biomass Pellets and Briquettes Processing from Cotton Stalks Investment Profile for Zimbabwe Investment Authority

Agnes Chikukwa Hove (agnes@sequor.biz)

Photo Credit : http://www.bioenergy-machine.com/make-cotton-stalk-pellets-to-replace-fossil-fuel.html

Acknowledgments

UNCTAD commissioned this investment profile as part of United Nations Development Account Project 1617K: "Promoting cotton by-products in Eastern and Southern Africa (ESA)". The profile is intended as a tool for the Government of Zimbabwe to promote investments in the cotton by-products identified for development in the National Action Plan to develop by-products in Zimbabwe, validated by the Government on 31 January 2018.

For more information, please visit the project site at: www.unctad.org/commodities.

The investment profile was written by a national consultant, Ms. Agnes Chikukwa Hove, CEO of Sequor Consulting.

The work was supervised by Mr. Kris Terauds, Economic Affairs Officer, under the direction of Ms. Yanchun Zhang, Chief, Commodity Policy Implementation and Outreach Section (CPIOS), in UNCTAD's Commodities Branch.

While due care was taken in compiling and reviewing this report, any errors and omissions remain the author's responsibility.

Contacts

For further information on the Commodities Branch, please contact us at:

UNCTAD
Commodities Branch
Palais des Nations
8–14, Avenue de la Paix
1211 Geneva 10
Switzerland
Phone: +41 22 917 1648 / 6286
E-mail: commodities@unctad.org

UNCTAD/DITC/COM/NONE/2019/1

Table of content

List of Acronyms

ACTIF .... African Cotton and Textiles Industry Federation
ACVAZ .... Association of Cotton Value Adders of Zimbabwe
AGRITEX .... Department of Agricultural and Technical Extension
AMA .... Agricultural Marketing Authority
CGAZ.............. Cotton Ginners Association of Zimbabwe
CMB .... Cotton Marketing Board
COMESA. .... Common Market for Eastern and Southern Africa
COTTCO. .... Cotton Company of Zimbabwe
CTC .... Cotton Training Centre
CRI .... Cotton Research Institute (Zimbabwe)
ESA................. Eastern and Southern Africa
FAO................ Food and Agriculture Organization of the United Nations
FTA................. Free Trade Agreement
GDP................ Gross Domestic Product
GoZ .... Government of Zimbabwe
LPG .... Liquefied Petroleum Gas
SADC.............. Southern African Development Community
ZIA .... Zimbabwe Investment Authority

1. Executive Summary

Investment is fundamental to the growth of any economy, and Zimbabwe is no exception. Agriculture is the mainstay of Zimbabwe's economy, and investing in agricultural by-products enhances growth in the sector, making it more viable for farmers.

Investment in briquette and pellet production in Zimbabwe would achieve important and substantial environmental and socio-economic benefits. The collection and processing of cotton stalk waste in a briquette or pellet plant in Gokwe, Zimbabwe, would create jobs for rural workers, income for farmers and entrepreneurs and would indirectly support the local economy. The project will make cotton growing more viable through the creation of demand for value added products. The utilisation of cotton stalks collected from the fields would increase the value of the cotton plant and prevent the mandatory burning of the stalks thus reducing environmental damage

The strength of the project would lie in the continued availability of raw material feedstock, and the creation of a viable value chain, including end users of the briquettes and pellets.

There is an estimated availability of 120,000 MT per year of cotton waste suitable for briquetting or pelletisation in Gokwe. The market potential for a viable project has been estimated at 1,000 MT per month as a start. This would be for either a briquetting or pelleting plant, as the raw material quantity would not suffice for both at the onset.

Considering the growing availability of raw materials, assessed viability of the project and high market potential there are good long-term prospects to expand proposed production levels as and when the business increases and creates demand for additional raw material supply.

The profit and loss calculations show a healthy US$ 140,000 profit in the first year (FY1) of operations from a capital investment of US$ 200 000 and a 45% return on investment.

Purpose of document

This document presents an investment profile on biomass pellets and briquettes from cotton stalks.

The profile is a deliverable of the United Nations Development Account Project 1617K on "Promoting cotton by-products in Eastern and Southern Africa". UNCTAD is implementing the project in four African countries, including Zimbabwe, in partnership with United Nations Economic Commission for Africa (UNECA) and the Common Market for Eastern and Southern Africa (COMESA).

Overall, the project seeks to:

- Assess market and value addition opportunities for Biomass pellets and briquettes produced by cotton stalks;
- Facilitate evidence-based policies to catalyse and/or enhance the development of the biomass pellets and briquettes industry; and
- To attract investments in key unexploited value addition opportunities in cotton by-products with demonstrated high market potential.

The profile is intended as a tool for the Government of Zimbabwe to promote investments in the cotton by-products identified for development in the National Action Plan to develop by-products in Zimbabwe (UNCTAD, 2018a; 2018b), validated by the Government on 31 January 2018.

This research for this profile took place between October 2018 and November 2018. The research objectives were primarily achieved through primary and secondary data analysis, using the following research methods:

- Interviews
- Literature review
- Market research
- Financial projections

This Investment Profile document covers cotton production in Zimbabwe, it's history, challenges and opportunities which have culminated in the initiation of this project. It goes on to discuss biomass, particularly cotton stalks, its uses and how it is converted into pellets and briquettes for commercial use. The briquetting and pelletisation project is outlined with draft financials and required inputs. The document concludes with a profile of the Zimbabwean investment environment.

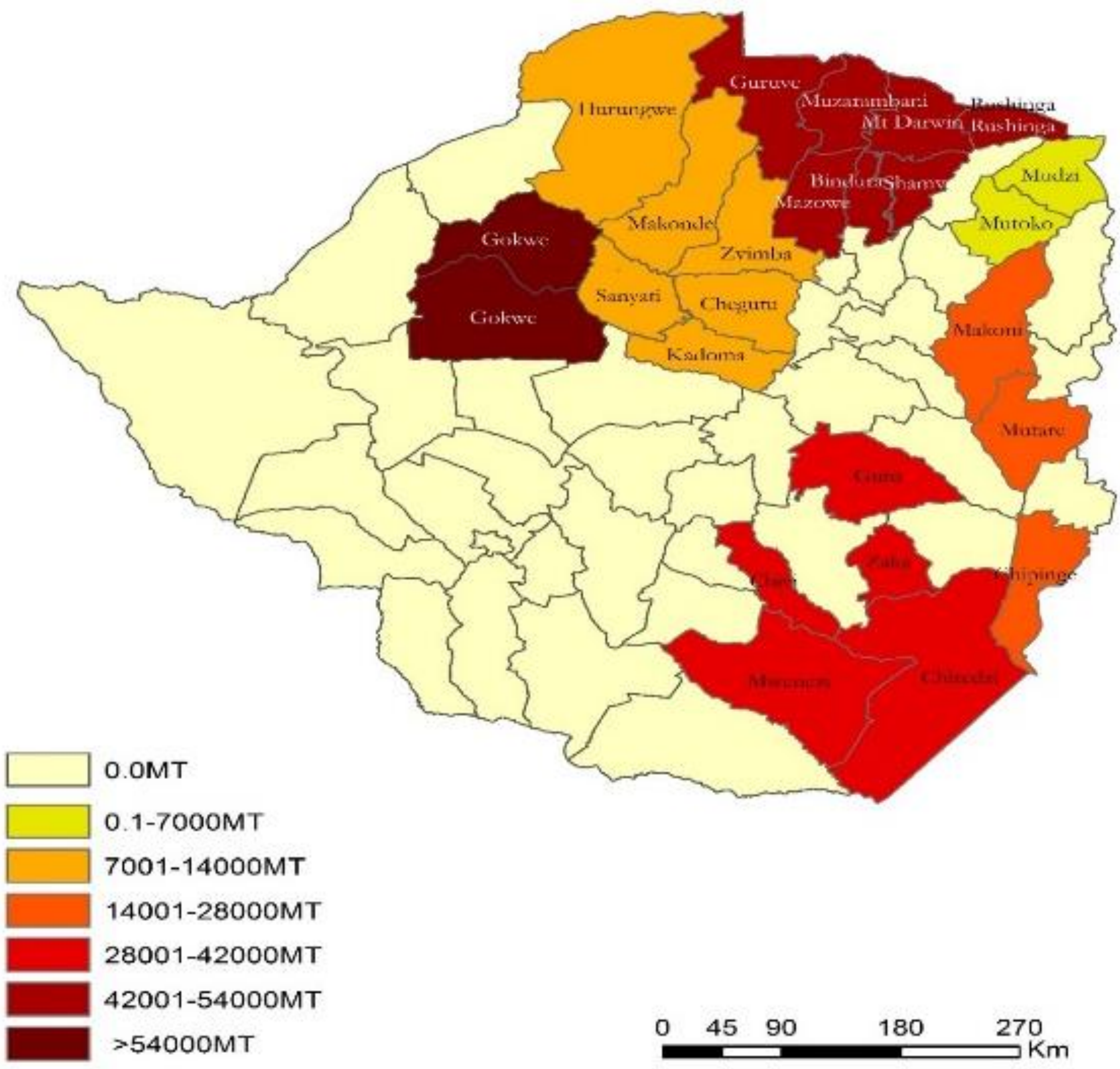
2. Cotton Industry Overview

2.1 Industry History and Trends

Cotton fibre is noted for its versatility, appearance, performance, comfort, and ability to provide numerous useful products. It continues to be an important crop for improving rural livelihoods in Zimbabwe, which creates thousands of jobs as it moves from field to fabric. Indeed, cotton is a major source of livelihood which can support up to 600,000 people, including farmers, farm workers, their families and industrial workers (Kabwe, *et al.* 2018), which contributes to income and employment creation while contributing to national foreign exchange earnings.

2.2 Cotton Production

Figure 1 Major cotton seed producing districts of Zimbabwe (Metric Tonnes, 2015-16 season)



Source: Kabwe, et al., 2018

Cotton is the second most important cash crop in Zimbabwe, after tobacco, and is grown by thousands of smallholder farmers on average plot sizes of about one hectare in the summer rainfall growing season, from November to April. Cotton is generally grown in four main regions of the country (see Figure 1) that are hot and receive rainfall of between 400 millimetres (mm) and 600 mm per annum, namely:

- Midlands province, covering areas in Gokwe South and Gokwe North.
- The northern part of the country, in parts of the Mashonaland Central province.
- Manicaland and Masvingo provinces, in the south-eastern part of the country.
- Binga in the Zambezi Valley of the Matabeleland North province.

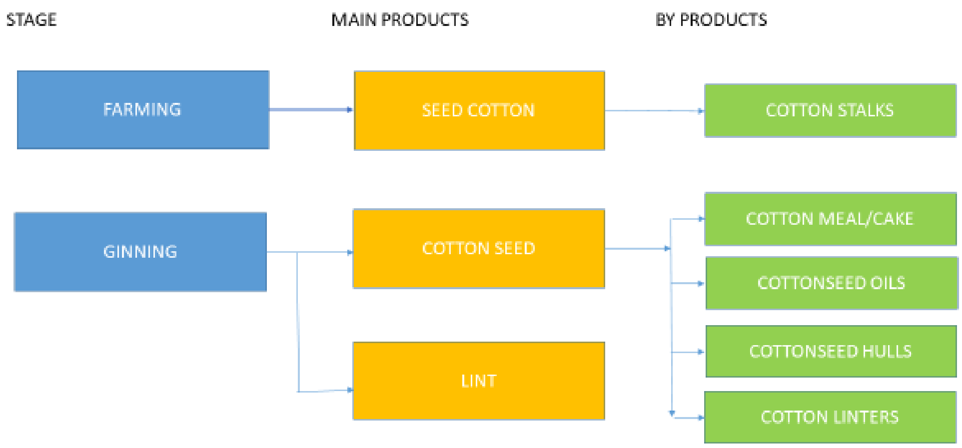
2.3 Summary of Subsector

The Government liberalised the marketing of cotton in 1994 and a relatively successful system of contract farming has continued since then. Contract farming is when registered cotton buyers provide farmers with inputs on credit for cotton production, in the form of seed, fertilisers and crop chemicals. The farmers enter into an 'inputs for harvest' contract with the registered cotton buying companies. There were six registered cotton-buying companies in the 2016/17 season in the sector (AMA, 2017).

2.4 Value Chain Functions and Participants

The cotton value chain develops through input support systems – encompassing local seed multiplication, importation and distribution of seed, fertilisers and chemicals – and seed cotton production. These basic functions are supported by research and varietal development, extension systems that nurture technical production skills, as well as credit and financial support to the sector. Secondary functions include primary marketing (i.e. farmer to ginnery), ginning, manufacturing (i.e. domestic use of lint), and lint exports.

Table 1: Cotton by-products value chain activity



Source: Buka G., 2016

Cotton also generates value in a number of non-agricultural industries, creating employment and economic activity. For example, cottonseed is utilised locally for edible oil and animal feed. Six major oil-pressing companies in Zimbabwe have a combined installed capacity of 530,000 MT for processing oilseeds. The Food and Agriculture Organization of the United Nations (FAO), in its Country Brief, estimates that Zimbabwe will produce about 125,000 tonnes of seed cotton in the 2016/17 season, representing 70,000 tonnes of cottonseed.

Cotton stalks can form part of the cotton value chain, as stalks have the potential to become another important by-product of the cotton crop.

2.5 Industry Driving Forces

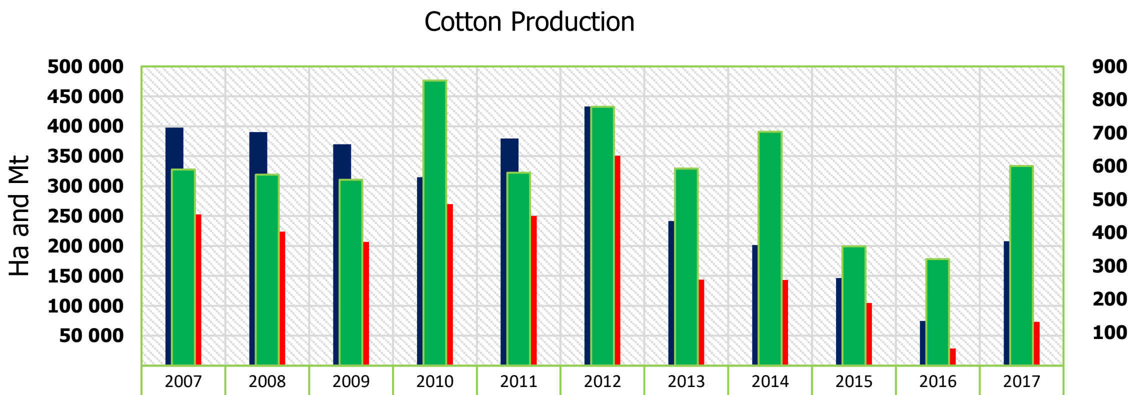
Contract farming, with seed cotton buying companies providing farmers with inputs on credit, has been a major pillar in the growth of the cotton subsector. This intervention has the potential to increase the number of farmers and possibly boost the income and productive capacity of smallholder farmers.

3. Performance, Structure and Prospects for the Cotton Sector

3.1 Cotton Production

Zimbabwe's cotton production reached a high of 350,000 MT of seed cotton, or 140,000 MT of cotton lint, in 2010, as shown in Figure 2, dropped in 2015 and is on an upward trend.

Figure 2: Cotton Hectarage, Production and Yields



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Area (Ha)	398 000	390 000	370 000	315 000	379 689	432 901	241 849	201 678	146 544	75 000	207 786
Production (Mt)	253 000	223 746	207 000	269 816	249 904	350 703	143 849	143 098	104 988	28 598	73 141
Yield (Kg/Ha)	590	574	559	857	580	778	593	703	359	320	600

Source: Cotton Hectares, Production and Yield Source, AMA, 2017

Average seed-cotton yields have declined from a high of 1,098 kilograms per hectare (kg/ha) in 2004, to a low of 519 kg/ha in 2016. Yields recovered to 600 kg/ha in 2017 (AMA, 2017).

3.2 Structure

The key role players in the Zimbabwean cotton industry are the growers, financiers and processors. The growers, who are mostly subsistence farmers are mostly funded through the contract farming model or they finance themselves from farm savings, as detailed in Table 2.

Table 2: Key Cotton Industry Role players

Crop	Grower	Financiers	Processors	Funding Model	Value Addition
Cotton	Subsistence farmers	Cotton Company of Zimbabwe	COTTCO	Contract farming	Lint
		Southern Cotton	Alliance Ginneries	Farm Savings	Cooking oil
		Alliance Ginneries	Grafax		Stock feed
		ETG Parrogate	Olam		Yarn
		China Africa	ETG Parrogate		
		Grafax	China Africa Cotton		

Source: AMA, 2017

3.3 Growth Prospects

As with the national economy, the cotton sector in Zimbabwe has gone through challenging and uncertain times recently which resulted in low productivity and high production costs. The sector is on an upward trajectory as shown in Figure 2. As farmers restart cotton production and increase hectarage under cultivation, investments in value added processing activities, such as the biomass briquetting and pelleting plants profiled in this document, will enhance growth prospects.

4. Cotton Industry Challenges

Although Zimbabwe's cotton industry plays a critical role in the economy, its production is threatened by consistently low productivity levels, high production costs and producer price negotiation impasses every season. The sector has faced many macroeconomic difficulties, which include inflation, distortion of the official exchange rate and shortages of key commodities such as fuel, as recently as in 2018.

Summary of challenges faced by the cotton sector 2017 season

The following challenges were faced in the 2016/ 17 season:

Table 3: Cotton Sector Challenges

Challenge	Description
Low yields:	Yields remained well below the seed varieties' potential of over 1,500 kg/ha
Rainfall:	Incessant rain during the season affected cotton production in some parts of the country.
Declining quality:	Late and non-payment of grade differential prices in the past undermined good agronomic practices, on-farm grading and overall crop quality.
Transportation:	Some farmers had transport challenges due to their isolation and long distances from markets. Some merchants failed to effectively service the farmers.
Rural infrastructure:	Absence of essential rural infrastructure such as properly maintained feeder roads increased the transaction costs for the rural farmers.
Competition from other crops:	Low average yields and good rainfall resulted in farmers migrating to other crops, such as maize and tobacco.

Source: AMA, 2017 Cotton end of year report, Vol VII

4.1 Opportunities for Investment in Value addition

Given that Zimbabwe exports over US$ 250 million of unprocessed cotton lint, there is an opportunity for investment in cotton processing plants. There is also an opportunity to invest in cotton by-products like cotton stalks in order to increase the overall value of the cotton plant and encourage more farmers to return to cotton farming.

4.2 Challenges into Opportunities: Investing in cotton by-products

Zimbabwe's cotton value chain starts with seed breeding and multiplication. The seed is distributed to farmers as part of the contract farming arrangement. Farmers plant the seed, to later harvest seed cotton, which they sell to their contracted buyer. Ginneries separate the seed cotton into its two components: lint and cottonseed.

Established value chains exist for both raw materials. Lint is the primary product of cotton and is transformed by the textile industry into yarn, textiles, garments and apparel, as well as into absorbent cotton wool. Meanwhile, cottonseed is a by-product that can be processed into four products, namely: edible oil, cottonseed cake, soap stock and cotton husks.

Stalks are a newly identified (in Zimbabwe) cotton by-product with commercial potential. The cotton stalks are currently unutilised in Zimbabwe, as farmers destroy them, either by burning them in the field or as wood fuel, to comply with pest management regulations {The Plant Pests and Diseases (Cotton) (Amendment) Regulations 1998}.

Cotton by-products can have a significant impact on the economic benefits of cotton as a crop enterprise. Challenges being faced by cotton growers have led to the generation of new innovative income generation ideas that are targeted at encouraging continued farming of cotton by creating value from the entire plant.

One of these creative ideas is cotton the production of biomass briquettes and pellets from cotton stalks. Briquettes can be used in industrial boilers and pellets in household stoves or restaurant cookers. Farmers could earn additional income by selling their cotton stalks to these briquetting and pelleting plants.

5. Introduction to Biomass Briquetting and Pelletisation

To make cotton farming more attractive and economically viable to farmers, alternatives must be considered. An innovative strategy for improving farm income that has been deployed in India is to compress chipped cotton stalks into briquettes or pellets that can be marketed as fuels to industrial and commercial users. In India, briquettes are used as a substitute for coal or fuel oil in industrial boilers and pellets as a substitute for liquefied petroleum gas (LPG) in boilers or cookers for restaurants and wood charcoal in household stoves.

Both biomass pellets and briquettes can be made from agriculture and forestry residues, wood processing scraps, as well as production and household wastes. Briquetting or pelletisation compresses chipped biomass into a renewable fuel. Pellets are small round rods, for example of 6-10 mm in diameter, whereas briquettes are much larger, for example of 90 mm in diameter. See figure 3 below for illustration.

Figure 3: Briquettes and Pellets

Photo Credit: https://cfnielsen.com/faq/briquettes-versus-pellets/

Briquettes are denser, they generate more heat when burned, thus briquetting machines are larger and more expensive. Meanwhile, pelleting machines generally have higher production costs – in addition to their smaller scale, they require a finer grade of raw material. Cotton stalks, for example, can be roughly chipped in the field, transported to a briquetting plant and processed directly. Raw material for a pelleting machine would require the additional step of hammering the chipped stalks into a finer size.

5.1 Environmental Benefits of Biomass Fuels

Traditional energy sources are characterised as exhaustible and some, like fossil fuels, have a substantial impact on the environment and have been identified as the main contributors to climate change. As a global solution, renewable energies play a vital role, since they are obtained from natural, regenerative sources that do not deplete; and they cause minimal to no environmental problems, such as climate change, radioactive waste, acid rain or air pollution (Hall *et al.*, 2000). The sources of renewable energy that have currently reached full commercial maturity include: solar, wind, rivers, geothermal energy, organic waste and energy stored in vegetation and forests (i.e. biomass) (Siemens, 2017).

There is a definite need in Zimbabwe and all Sub-Saharan Africa for environmentally friendly and affordable fuel. Deforestation has been highlighted as an issue of concern by numerous countries and institutions, and the consumption of charcoal and wood fuel is identified as one of the causes. As an alternative to charcoal, biomass briquette and pellet production relies on unused agricultural or industrial residues, and therefore does not contribute to deforestation. In addition, biomass briquettes and pellets are documented to release 60% less carbon dioxide, and 72% less carbon monoxide into the atmosphere when burning (Njenga *et al.*, 2014). The production of biomass briquettes and pellets therefore represents an opportunity to reduce pollution and deforestation associated with energy consumption.

5.2 History of Biomass Briquetting

Biomass briquettes are a substitute for coal and charcoal made from agricultural and forestry waste. Low-density biomass is converted into a high-density fuel with the help of a briquetting machine that uses no binders or chemicals, ensuring it is 100% natural.

Biomass briquetting represents a type of technology used for the conversion of biomass residues into a convenient and usable fuel. The technology is also known as densification or agglomeration. Five main types of densification equipment are available on the market: piston press densification, screw press densification, roll press densification, pelletising, low pressure or manual presses.

5.3 Full comparison of Briquettes vs Pellets

According to C.F. Nielsen, one of the world leading manufacturers of mechanical briquetting presses, briquettes boast the following main advantages over pellets:[1]

- **Lower investments costs** – are lower for a briquetting plant, not only the equipment, but also all other installations such as electrical installation, cooling, and size of buildings.
- **Lower operational costs** – power consumption is lower, especially as the raw material does not need to be downsized to the same extent. Spare part costs are lower and operations are simpler.
- **Simple technology** – a briquetting press can be operated by skilled labourers and does not require much training.
- **Moisture content** – a briquetting press can handle a higher range of moisture in raw material – from 6-18%.
- **Decentralized production** – briquettes can be located near where raw material is available, thus saving considerable logistical costs.
- **Lower transportation costs** – briquettes have a higher bulk density than pellets, meaning transportation by truck is less costly per unit of mass or volume.
- **Developing countries** – briquettes produced by a mechanical press can be made from many types of biomass, including agricultural waste, and can replace firewood and charcoal.

[1] C.F. Nielsen. The Art and Advantages of Briquetting. Retrieved from: https://cfnielsen.com/art-advantages-briquetting/.

Figure 4: Images of Briquettes and Pellets


BRIQUETTES


PELLETS

Photo Credit: https://www.indiamart.com/proddetail/biomass-briquettes-pellets-12820992855.html

Table 4: Raw Materials for Industrial Briquettes and Pellets

Preparation of raw material	Briquettes	Pellets
Requirement for max particle size	20x5x3 mm	2x2x2 mm
Requirement for moisture content	6-18%	10% +/-0,5%

Source: C.F. Nielsen. Retrieved from: www.cfnielsen.com.

Raw material preparation for briquette processing is more efficient than pelleting because the biomass does not necessarily have to be pre-processed or uniformly ground up through a hammer mill, which results in lower preparation costs. As shown in Table 5, operating costs for a briquetting plant are generally lower than for a pelleting plant.

Table 5: Operational Costs of Briquettes and Pellets

Operational costs	Briquettes*	Pellets**
Power consumption	35 kW per ton	90 kW per ton
Wear - spare and service parts - clean wood	2.3 US$ per ton	5.8 US$ per ton
Wear - spare and service parts - abrasive materials	5.8 US$ per ton	11.5 US$ per ton
Manpower	1 hour per 24-hour operation	24 hours per 24-hour operation

Source: C.F. Nielsen www.cfnielsen.com

*Note: * Data based on briquetting press with approx. 1,500 kg per hour*

*** Data based on general information. Specific data should be obtained from the pellet press manufacturer. (Source C.F. Nielsen www.cfnielsen.com).*

**** Currency converted from Euro to United States Dollars (US$) based on www.za.investing.com rate of exchange as at 10 January 2019.*

The diameter and length of briquettes versus pellets are as detailed in Table 6.

Table 6: Indicative specifications for briquettes and pellets

Specifications	Briquettes	Pellets
Diameter	40-120 mm	6-40 mm
Length	15-300 mm	10-20 mm
Max. obtainable bulk weight per m^3	650 kg	700 kg

Source C.F. Nielsen www.cfnielsen.com.

5.4 Briquetting of Agro-Residues

The briquetting of agro-residues is relatively new in developing countries. The briquetting technique was adapted for organic waste about 50 years ago in industrial countries, having been first developed to briquette low-grade coal, but interest waned in the 1960s. Interest in briquetting was only revived in the 1980s on any significant scale in most developing countries. This has meant that there is a lack of any systematic information about how briquetting plants have performed in practice (FAO, 1990). According to Cohen & Marega (2013), many briquetting operations in the informal sector in developing countries have tended to have a relatively short life span. The high-level view of the sector recently conducted by Mwampamba *et al.* (2013) summarises the challenges and opportunities in the sector, specifically in Sub-Saharan Africa, as shown in Table 7.

Table 7: Summary of factors affecting the briquette industry in Sub-Saharan Africa

Factors	Supporting Conditions	Opposing Conditions
Technological	• Numerous technological options available for all scales of production • Machines can deal with most types of biomass agro-residues (i.e. a single producer could handle multiple type of raw material)	• Machinery (and parts) must be imported (often from India or China) • A highly skilled technician needed to adjust machine settings to local conditions • May require design of stoves more appropriate for briquettes
Economic	• Voluntary carbon market or clean development mechanism: potential to earn carbon credits from avoided emissions • Cheap (in some cases free) biomass waste • Places value on waste and creation of new raw material • Diversification of energy portfolios	• Introduction and marketing of new product is expensive and benefits the competition • High capital costs for medium to large scale production • In some cases (especially agricultural waste), only seasonal supply of biomass agro-residues
Environmental and Health	• Use of waste that otherwise is unused, or disposed of in rivers, or burned, especially in urban areas • Briquettes could replace unsustainable charcoal and firewood production systems • Decrease air pollution indoors and outdoors	• Requires consistent supply of nearby biomass waste • Indoor pollution improvement advantage over wood charcoal not enough to convert wood consumers to briquettes

Source: Mwampamba et al. 2013

One of the problems with briquetting plants in Africa to date is that they are conceived of as “projects undertaken by development agencies rather than businesses and, as projects, they are extensively reviewed” (FAO, 1990), a condition that still applies in 2018.

Agricultural residues have, until recently, not aroused much interest as fuels in most African countries. There is however some evidence from countries where deforestation is a major problem that the considered introduction and use of residues is increasing.

5.5 Selection of Biomass Feedstocks for Briquetting

The potential biomass agro-residues that have generally been identified with the capacity to be economically dried and collected are: rice straw, rice husk, wheat stalks, coffee husk maize stalks, cotton stalks, and leaf wastes. Biomass feedstock is the foundation of the briquetting enterprise, but many businesses have failed by overestimating its availability (Hood, 2010).

There are many factors to consider before a biomass agro-residue qualifies for use as feedstock for briquetting. According to Azeus Machinery, a fabricator of biomass pelleting machinery, apart from its availability in large quantities, biomass feedstock should have the following characteristics:[2]

Low moisture content

Moisture content should be as low as possible, generally in the range of 10-15%. High moisture content will cause problems in grinding and excessive energy is required for drying.

Ash content and composition

Biomass residues normally have much lower ash content (except for rice husks, which comprise 20% ash) but their ashes have a higher percentage of alkaline minerals, especially potash. The ash content of different types of biomass is an indicator of slagging behaviour[3] of the biomass. Generally, the greater the ash content the greater the slagging behaviour. But this does not mean that biomass with lower ash content will not show any slagging behaviour. The temperature of operation, the mineral compositions of ash and their percentage combined, determine the slagging behaviour.

Flow characteristics

The material should be granular and uniform so that it can flow easily in bunkers and storage silos. Some of the appropriate agro-residues are:

I. **Rice husk:** Rice husk is an exceptional biomass. It has good flow ability,[4] normally available with 10% moisture and the ash contains fewer alkaline minerals, thereby it has a high ash sintering temperature.[5] It makes an excellent fuel although its calorific value is less than wood and other agro-residues.
II. **Groundnut shell:** Because of low ash (2-3%) and moisture content less than 10%, it is also an excellent material for briquetting.

[2] Azeus Machinery. Agricultural Waste Pellets Production. Retrieved from: https://www.biopelletmachine.com.
[3] Slag refers to the impurities that are oxidized during heating or burning. Source: Merriam-Webster, https://www.merriam-webster.com.
[4] In industrial operations, it is necessary to feed material from one processing operation to the next. Flow characteristics of different materials determine how efficiently they can be fed through processing operations, including minimizing production stoppages from blocked discharge outlets. Source: Ogden, C., 2009. Flow Mechanics of Switchgrass Bulk Solid in Hoppers under Gravity Discharge. College of Engineering, Purdue University. Retrieved from: https://engineering.purdue.edu/~biomass/Materials/Research-Profile_Cedric.pdf.
[5] Sintering is when the ash coalesces into a coherent mass by heating, without melting. Source: Merriam-Webster, https://www.merriam-webster.com.

III. **Cotton stalks:** This material is required to be chopped and then stored in dry form. It has a tendency to degrade during storage. Cotton stalks have a higher content of alkaline minerals and need to be used with caution.

IV. **Coffee husk:** An excellent material for briquetting which has low ash and available with 10% moisture content. The material is available in coffee growing areas.

We have thus established that Cotton stalks have the right characteristics for conversion into biomass briquettes.

Marketing of briquettes

The primary marketing problem for briquettes in Africa is lack of market information, including their price relative to coal and wood. Wood is used to cure tobacco. This poor competitiveness is likely due a combination of to the comparatively high capital cost of the briquetting plants and the low price of wood, which is sometimes also obtained for free. The persistent problem of lack of price competitiveness has obscured the issue of customer adoption of the product.

Briquettes of all types can find a market niche when they are produced regularly at prices not too far out of line with the competition. It is possible that the easiest area to exploit is in the substitution of wood in small boilers in hotels, institutions and small industry. Briquettes can also be produced on a large scale to generate energy for manufacturing plants, in boilers and in an electricity generation plant.

5.6 Available Agro-Residues in Sub-Saharan Africa

Agro-Residues are abundantly available in many Sub-Saharan Africa countries, but these are not utilised in a structured manner. Residues that are used by communities include rice husk, coffee husk, coir pith, jute sticks, bagasse, groundnut shells, mustard stalks and cotton stalks. Agro-Residues are mostly considered as waste and as such are mostly burned in the fields causing widespread air pollution.

Coal is a natural mineral mined in Zimbabwe which has many uses including use in boilers or for the generation of electricity. In India, briquettes are used as a substitute for coal in industrial boilers, thus it is important to establish the viability of this substitution in the Zimbabwean context.

Table 8: Comparison of coal and biomass characteristics

FUEL	DENSITY g/cm3	CALORIFIC VALUE kcal/ kg	ASH CONTENT %
Coal	1.30	3,800 – 5,300	20 - 40
Biomass briquettes from:			
Groundnut shell	1.05	4,750	2.0
Rice Husk	1.30	3,700	18.0
Sawdust	1.12	4,300	8.0
Cotton Stalk	2.33	4,400	3.0

Source: Singh, 1996

The list of appliances where the biomass briquettes can be used includes:

- **Stoves**: This has become a great option for replacement of wood in stoves as biomass briquettes produce less smoke and give better combustion.

- **Furnaces:** Furnaces require a large amount of fuel for igniting and generating energy. Briquetting helps in meeting the demand of fuel required in these furnaces as their power density is twice compared to coal.
- **Boilers:** Boilers also require coal or wood for burning and generating steam. The biomass briquette obtained through briquetting solves the problem of excessive use of coal.
- **Tobacco curing (Zimbabwe specific):** Commercial tobacco farmers use coal or firewood to cure their crop. Coal usually comes from Hwange Colliery and farmers face high transportation costs to tobacco growing districts. This presents an opportunity for the farmers to turn to biomass briquette use.

Advantages of biomass briquetting

Briquettes produced from briquetting of biomass are a fairly good substitute for coal, lignite and firewood. Biomass briquettes are also known as 'White Coal' because they don't pollute when burned, as well as numerous other advantages (Makwana, 2014). The advantages of biomass briquettes include:

- Provide additional income to farmers and create jobs.
- Biomass briquettes are a renewable energy source.
- Briquettes can be cheaper than non-renewable fuels, such as coal, oil or lignite.
- Substitute for firewood, thus reducing deforestation.
- Easy to handle, transport and store.
- Uniform in size and quality.
- Solves the problem of residual disposal of biomass, i.e. burning of cotton stalks in Zimbabwe.
- There is no sulphur in briquettes.
- There are low levels of ash produced and carried into the air when burning briquettes.
- Briquettes have a consistent quality, have high burning efficiency, and are ideally sized for complete combustion.

Disadvantages of biomass briquetting

- High investment cost of production and energy consumption.
- Undesirable combustion characteristics often observed e.g., poor ignitability, smoking, etc.
- Tendency of briquettes to loosen when exposed to water or even high humidity weather.

5.7 Adaptation of Briquettes

The potential for growth in briquetting has resulted in Indian and other manufacturers seeking more diversity of sources when it comes to the accessibility of raw materials employed for briquette manufacture.

Briquettes can minimise deforestation, create jobs in rural communities and raise awareness for alternative energy sources. Briquette production within the Zimbabwean context has:

Social impact: Contributes to social development through the creation of new jobs, community upliftment and the training of communities to use this new fuel source.

Environmental impact: The protection of the environment by reducing the use of charcoal and firewood.

Economic impact: Biomass briquettes are a fuel with better energy efficiency and often lower prices than traditional fuels.

In spite of obvious benefits and ready availability of raw materials, briquetting technology is yet to get a strong foothold in many developing countries because of the technical constraints involved and the lack of knowledge to adapt the use of current briquetting technologies to suit local conditions (Grover and Mishra 1996).

Overcoming the many operational problems associated with briquetting technologies, ensuring the quantity and quality of the raw material used are crucial factors in determining the commercial viability of briquettes as fuels for light industrial and cafeteria use.

The interest in using biomass residue briquettes for light industrial or heating purposes is on the increase in certain European countries, and it is envisaged that this will happen in Zimbabwe. Clean and dry residue briquettes are an ideal fuel for combustion in small-scale installations (Gravalos, l., 2016).

6. Feasibility of Making Cotton Stalk Briquettes and Pellets

Stalks are the main cotton by-product at farm level. The cotton stalk is treated as waste in Zimbabwe, as regulations require farmers to destroy them. The bulk of the stalk is burnt in the fields after the harvest of the cotton crop. Cotton production is therefore accompanied by the wastage of large volumes of stalks. However, new technologies continue to emerge and have been commercialised in other cotton producing countries to process cotton stalks into useful products, such as biomass briquettes or pellets.

Depending on the variety and the crop conditions, the cotton stalks are 0.8 to 1.5 meters long and their diameter above the ground varies from 1 to 2.5 cm (El Saeidy, 2004). The specific weight of the short chopped stalk is about 160 kg/m³. The calorific value of cotton stalks is equivalent to poor quality wood. Heating (calorific) value measures whether the material is suitable for burning a fire or as a thermal source of energy (El Saeidy, 2004).

Key to the development of a briquetting plant is the abundance or availability of cotton stalks as feed stock. In Zimbabwe, cotton production by farmers is steadily growing as is displayed earlier in the document in Figure 2, and as such a briquetting plant can potentially be a viable investment. Table 9 shows the incremental growth in cotton stalk supply as farmers grow more cotton.

Table 9: Selected indicators of cotton cultivation in Zimbabwe

	2015/16	2016/17
Cotton Farmers (number)	200,000	200,000
Cotton Cultivation Area (ha)	101,660	150,000
Cotton Stalk Chip (MT)	132,000	195,000
Seed Cotton Production @ 281 kg lint/ ha (MT)	71,500	125,000
Cotton Seed Production (MT)	28,800	70,000
Cotton Seed Oil (MT)	5,200	4,900

Source: Chigumira, 2017

Briquette Processes and Production

Briquette production plants are fully automated plants that use a number of processing steps to dry and compress agricultural residues, in this case cotton stalks, to be burnt for heat production (Seeger Engineering [SGE], 2015).

The Energy and Environment Partnership (2013) distinguishes between two main types of briquettes, namely; carbonised and uncarbonised – which are produced by two different processing techniques.

The first type of briquettes is carbonised, meaning they are made from biomass sources that have been processed through a process called partial pyrolysis,[6] this process drives off volatile

[6] The United Stated Department of Agriculture defines pyrolysis as: "the heating of an organic material, such as biomass, in the absence of oxygen. Because no oxygen is present the material does not combust but the chemical compounds (i.e. cellulose, hemicellulose and lignin) that make up that material thermally decompose into combustible gases and charcoal." Retrieved from: https://www.ars.usda.gov

compounds and moisture and leaves a higher concentration of carbon per unit. Hereafter, they are mixed with a binder, cast into appropriate shapes through pressing and finally dried.

Uncarbonised briquettes are processed directly from biomass sources through various casting and pressing processes, which is also known as solidification.

Cotton stalks are collected and dried in a solar biomass drier to reduce the moisture content to less than 15%. The size of the cotton stalk biomass is reduced by passing it through a shredding or chipping machine, where a uniform size of powdered biomass, e.g. 1/16 inch, is produced. A briquetting machine, for example with a high-pressure piston press, then compresses the chipped stalks into binder-less cylindrical briquettes.

The process of briquetting and palletisation is different, as is defined below.

6.1 Biomass Pelletisation

The stages of the biomass pelletisation process consists of pre-treatment of raw materials, pelletisation, and post-treatment. (Vyas D.K. *et al.*, 2015; Grover P.D. *et al.*, 1996; IFC, 2017). There are various steps in the pelletisation process, (Purohit P. *et al.*, 2016), the first of which is the preparation of the feedstock. This includes the selection of a feedstock suitable for this process and following the selection process, the feedstock must be filtered, stored, and covered for protection. Possible feedstock materials include sawdust, wood wastes, cotton stalks, agricultural and forestry residues. The filtration process is to remove stones, plastic waste, metal, etc which may have been mixed up in the feedstock. The feedstock is stored in to prevent contamination and moisture. The moisture content in fresh biomass can be quite high, and hence needs to be reduced to 10 to 15%. Drying increases the efficiency of biomass, while also reducing the amount of smoke it produces on combustion. However, the feedstock should not be over-dried, as a small amount of moisture helps in binding the biomass particles. The drying process is the most energy-intensive process and accounts for about 70% of the total energy used in the pelletisation process.

As a feedstock for pellet production, the use of residual biomass entails advantages such as low raw material costs, low production costs, reduction of waste to landfill and removal of undesirable residues that otherwise would be burnt or discarded, as is the current case for cotton stalks in Zimbabwe. In addition, in the case of residual biomass of industries, the resource is concentrated on the production site, which reduces transportation costs. On the other hand, the lack of a year-round consistent supply of biomass raw material is the main drawback for a pelleting operation.

Biomass from agriculture is available only after harvesting period, which lasts for only 2-3 months in a year. There is therefore a need to source, procure and then store a year’s worth of supply within this short period.

Transportation constitutes a significant portion of the production costs associated with a pelleting plant. The raw material must be shredded or chipped in the field, to increase its density for transportation. Due to high transportation costs, a supply radius wider than 50 kilometres (km), for example, can be uneconomical for a pelleting plant.

6.2 Biomass Briquetting

The briquette making process is similar to the pellet making process detailed above, except that the chipped or shredded biomass feedstock for briquetting need not be further hammered into a finer grade, as for pelletisation.

There are both low and high-pressure briquetting making technologies, some of which use a binder, while others do not. The binder is defined as a starchy glue that holds the biomass briquette together. One of the requirements of manual or low-pressure briquetting is a binder to keep the biomass briquette from falling apart. Binder-less briquetting is an option for those plants that use high compression machinery (Hood, 2010, p. 18).

According to Hood (2010, p. 16), the following three processes are required in briquette making:

A. Sieving – drying – preheating – densification – cooling – packing

B. Sieving – crushing – preheating – densification – cooling – packing

C. Drying – crushing – preheating – densification – cooling - packing

Most biomass briquette production plants start the process by drying the biomass in order to reduce the moisture content.

As stated earlier in this document, this profile will focus mostly on briquetting plants.

6.3 Properties of Cotton Stalks

Cotton stalks are the residues that are left unused in the cotton field with the estimated potential of an average dry matter yield of 3 MT/ha (Patil P.G., 2017). The dry matter yield can be as low as 1.3 MT/ha (Patil P.G., 2017). For the purposes of this profile, we are using Patil's dry matter yield calculations. Cotton stalks have good potential for use as biomass for energy production (Gemtos and Tsiricoglou, 1999). The general shape of cotton stalks ranges from columnar through pyramidal to rounded. The shape is determined by the length of the branches. The stems have a moderately thick, tough bark in which bast fibres are prominent. The outer layer of the bark is quite corky. It is a yellowish-brown colour on the older parts of the stems and greenish to reddish on the younger. The larger side of stems consists of a well-developed wood structure with prominent wood rays and water carrying vessels (Brown and Ware, 1958; Gad *et al.*, 1987).

The average fibre length of stems is about 1.1 mm. At room temperature cotton stalks contain 10-20% moisture. Their bulk density is about 450 kg/m^3. Stalks contain about 25% lignin, 37.9% cellulose, 20.4% hemi-cellulose, 4% extractives, and 4% ash (Fahmy *et al.*, 2000). The mean diameter of the stalks is about 10.3 mm and the mean height is about 126 cm (Tayel *et al.*, 1988).

El Bassam (1998) stated that dried cotton stems can be used as a fuel. The dried stems consist of a cellulose-rich material, which after pyrolysis and gasification could be a prime material for use in the industrial and energy sectors. Sumner *et al.*, (1984) reported that the cotton plant is known to have high-residue yields of cellulose biomass that make it well suited for use as a fuel providing energy. The energy value for cotton stalks was 21.3 megajoules per kilogram (MJ/kg), thus cotton plant residues were a better fuel than soybean or corn for a biomass furnace.

Cotton residues are a suitable fuel in areas where cotton is grown. Demian (1979) reported that one of the difficulties in cotton production is the need to clear the ground of old cotton stalks after the harvest in order to rid the field of the cotton diseases. The Zimbabwean Ministry of Agriculture obliged farmers to burn these stalks in the fields after the harvest operation in order to kill the pink bollworm, which is a harmful insect for cotton crops, and to prevent further infestation. The haphazard burning of huge amounts of cotton stalks generates pollution in the form of clouds of smoke covering the sky. This is an environmentally unfriendly practice which could potentially cause human health problems. Briquetting or pelleting the cotton stalks provides an ideal alternative solution.

A number of properties are commonly known to affect the success of briquetting and pelleting, including: heating value, moisture content of the material, density of the material.

High Heating Value

A high heating (calorific) value is essential for fuels burned as a thermal source of energy. The calorific energy in different organs (parts) of the cotton plant is different. The lowest calorific energy value in all plant organs was observed in the leaves, at 15.955 kilojoules per gram (KJ/g), however seeds contained the highest energy value, ranging from 22.750 to 23.078 KJ/g. The calorific values of dry cotton stalks varied from 15.861 to 15.100 KJ/g. See Table 10 below which shows the suitability of cotton stalks for briquetting plants.

Table 10: Residue evaluation

Residue	Moisture content (%)	Average Particle size (mm)	Calorific values KJ/g	Bulk density (kg/m³)	Porosity[7] (%)
Wheat straw	7.79	0.42	17.98	160.75	51.25
Corn stalk	6.40	0.49	15.40-18.25	127.32	18.51
Soybean stalk	7.30	0.43	21.81-23.01	242.34	68.03
Sugarcane stalk	8.15	0.55	-	110.86	77.58
Cotton stalk	7.45	0.38	15.100- 15.861	230.55	74.55

Source: Azeus Biomass Pellet Machine: www.biopelletmachine.com, Low Moisture Content of Cotton Stalk

Water is an agent that is used both as a binder and lubricant in briquetting and pelletising. Several investigations of different materials indicate that the strength and density of the briquette and pellet increase with increasing moisture until an optimal level is reached. The optimal moisture content for agricultural residues to be briquetted or pelletised ranges between 8-15%. Cotton stalk moisture content is in this range. The stalks are dried in the field, removing about 80% of their moisture in five days. That means the stalk moisture content reaches the recommended range in a time period of less than one week. This implies that cotton stalks should be briquetted of pelletised one week after the harvest operation is finished, without incurring any additional cost for drying.

High Bulk Density

Bulk density is the ratio between the weight of the briquettes and pellets and the amount of space they take up. It reflects the amount of solid material packed into the briquette or pellet and therefore has a relationship to the heat content of the fuel. Lower bulk density may result in lower conversion efficiency, as it gives rise to poor mixing characteristics and non-uniform temperature distribution, both of which may create unfavourable operating conditions in the thermochemical conversion systems. On the other hand, higher bulk density may result in lower transportation and storage costs and lower emissions during combustion. A good quality pellet will have a density of 650 kg/m³, a good quality briquette will range from 1100 kg/m³ to 1290 kg/m³.

Table 11: Indicative specifications of cotton stalk briquettes and pellets

Material	Moisture Content %	Ash Content %	Average Density kg/m3	Diameter mm	Calorific Value kcal/kg
Cotton stalk briquette	Under 20 Dry Base	6.68	500	50	3,700
Cotton stalk pellet	0.62	2.02	1,120	6	4,231

Source: Azeus Biomass Pellet Machine: www.biopelletmachine.com

[7] Porosity is the ratio of the volume of gaps in a material to the volume of its mass. Source: Merriam-Webster, https://www.merriam-webster.com.

6.4 Operating requirements

The production and operating requirements for commencing a biomass briquetting enterprise are detailed below. This includes an overview of required inputs for biomass briquetting. Key components include: access to raw materials or inputs, suitability of cotton stalks, operations site, equipment options, costs, suppliers, capacity and other relevant characteristics. The operations site requirements and estimated cost are also important.

6.5 Access to raw materials

During the 2016/ 17 season, the top three seed cotton producing districts were Gokwe North, Gokwe South and Mbire districts. As shown in Table 12, these districts (In italics) accounted for 58% of all cotton produced in Zimbabwe.

Table 12: Seed cotton production by Province and District, 2016/17

Province	District	Total seed cotton production (kg)	% of total
Midlands	***Gokwe South***	***14,765,818***	***20.19***
Midlands	***Gokwe North***	***18,019,994***	***24.64***
Midlands	Kwekwe	45,579	0.06
Matebeleland North	Binga	351,393	0.48
Mashonaland West	Kadoma	3,593,259	4.91
Mashonaland West	Chegutu	229,918	0.31
Mashonaland West	Hurungwe	674,772	0.92
Mashonaland West	Kariba	353,602	0.48
Mashonaland West	Makonde	958,588	1.31
Mashonaland Central	Rushinga	1,333,746	1.82
Mashonaland Central	Mt Darwin	2,326,298	3.18
Mashonaland Central	Bindura	576,872	0.79
Mashonaland Central	Mutoko	723,894	0.99
Mashonaland Central	***Mbire***	***10,238,929***	***14.00***
Mashonaland Central	Guruve	321,976	0.44
Masvingo	Chiredzi	6,560,780	8.97
Masvingo	Zaka	732,436	1.00
Masvingo	Bikita	1,152,353	1.58
Masvingo	Mwenezi	1,988,726	2.72
Masvingo	Chivi	1,001,310	1.37
Manicaland	Chipinge	6,675,473	9.13
Manicaland	Mutare/ Nyanga/ Buhera	515,515	0.70
	Grand Total	**73,141,231**	**100.00**

Source: AMA, 2018

The top two Districts were Gokwe South and Gokwe North, which combined account for approximately 45% of Zimbabwe's overall production of seed cotton. Gokwe South and North have the advantages of being in the same province, next to each other, making the two ideal for cotton stalk use as feedstock in briquetting plants.

Table 13: Preparation/Area under Cultivation

Year	Area (ha)	Cotton Stalk Chips (@1.3 MT chips/ha)
2015/ 16	150,000	195,000
2016/ 17	75,000	98,000
2017/ 18	200,000	260,000

Source: Calculations from Patil P.G. 2017

Zimbabwe's cotton farmers currently have 200,000 ha of land under cultivation, thus, based on calculations using the formula by Patil P.G. (2017) there is the potential to produce a total of 260,000 MT of cotton stalk briquettes or pellets in the 2017/ 18, of which 45% (117,000 MT) dried cotton stalks come from the same province (Gokwe).

6.6 Production and operating equipment for a biomass briquetting plant

The production and operating requirements for commencing a biomass briquetting enterprise are as listed below. This includes an overview of required inputs for biomass briquetting. Two feasibility studies (Hood, 2010, p. 18 and 77; Kalita, 2016, pp. 63 – 69) were conducted, detailing the required inputs for biomass briquette operations as summarised below.

Table 14: Inputs for Biomass Briquetting Plant

Inputs	Options
Raw material supply	Biomass - Agricultural residues- Cotton stalks
Weather-proof storage	Covered shelves or bins
Kiln for carbonizing biomass (optional)	CarbonZero kiln – small scale but efficient Kon-Tiki kiln – low-cost, fast acting, though not very efficient Adam-retort® – decent kiln, varying efficiency, also small scale
Hammer mill or grinder to reduce biomass particle size to 6 – 8 mm	Horizontal bed biochar reactor – high efficiency and capacity but requires high capital investment Clippers – cutting of biomass with similar sized particles Hammer mills – blunt hammers on a rotating drum, making particles of irregular size Combination type – combines both features of clippers and hammer mills
Drying compartment	Passive drying – relies on ambient temperatures and air flow Active drying – assisted flow of air
Intermediate storage bin - Raw material to be held in storage after leaving the dryer	Shelves or bins
Briquetting equipment	Piston press Screw press Roll press Pelletizing Low pressure/manual presses
Cooling racks - for cooling biomass briquettes prior to packaging	Shelves or bins

Inputs	Options
Ventilation hoods – smoke and fumes coming off the hot biomass briquettes need to be extracted to the outside of the operation site buildings.	Ventilation hoods

Source: Hood, 2010, p. 18 and 77; Kalita, 2016, pp. 63 – 69

6.7 Operations Site

Cotton Stalk biomass is mainly an agricultural by-product, which tends to be regional and seasonal. Biomass is voluminous, has low bulk density, and has high moisture content. If the biomass usage or processing plant is close to the source it becomes an economical source of fuel. Transporting it across large distances, produces logistical and environmental challenges and raises the cost.

Thus, the recommended site for the biomass briquette operations has been identified as the town of Gokwe, in Midlands Province as a strategy to minimise raw material transport. The selected site is removed from residential areas but close enough to Gokwe Centre to minimize transportation costs from farms.

Situated in the Midlands Province, Gokwe is well known for being the cotton capital of Zimbabwe. It is also known for being a rapidly developing and improving town in Zimbabwe. Gokwe attained town status in 2007, prior to that, Gokwe was called a growth point, a rural growth centre in other words. Gokwe town is situated in Gokwe South District. Gokwe cotton district encompasses a combination of both Gokwe North and South districts which have an estimated population of 24,000. Gokwe is known for its sunshine, generally available all year round, and it experiences an annual average temperature of 26°C. Cotton is the major agricultural income earner for most subsistence farmers in the Gokwe district. A briquetting plant will bring further socio-economic development to Gokwe through job creation and increased economic activity around the plant.

A briquetting plant should have enough land to dry and store biomass raw materials, as well as finished briquettes, possibly a minimum of one acre or urban land. It must have reliable access to both electricity and water. An old disused building is preferred to minimize costs, with renovations to the building and fencing to accommodate simple warehouse operations and storage.

Based on the above criteria, the author consulted a real estate agent in Gokwe in November 2018 to obtain an indicative land cost for a briquetting plant. The agent relayed that a suitable five-acre urban plot, one kilometre from Gokwe Centre, could be purchased for approximately US$ 70,000. No suitable rental properties were available at that time.

6.8 Potential Markets

Biomass briquettes can be used as a substitute for coal, wood and charcoal. Carbonised biomass briquettes are intended for industrial or institutional clients and may be used to replace charcoal or furnace oil. These briquettes may be used for large scale heating or commercial cooking operations. Biomass briquettes are intended for industrial consumers and replace wood or other raw biomass used in large scale boilers. Biomass briquettes can generate steam for electricity in an industrial boiler. They can be utilised in institutions, such as schools, hotels, or any large-scale kitchens (Siemens, 2017), and they can be used for tobacco curing.

A biomass briquette enterprise could potentially sell to the agricultural, industrial or institutional customer, which is made up of farms, schools, hotels, restaurants and businesses who use thermal applications for their cooking and/or processing needs. Cohen and Marega (2013) caution that industrial consumers require much higher volumes than most small-scale briquetting enterprises can produce.

A biomass briquette enterprise could potentially sell to industrial consumers; schools, hotels, restaurants and businesses, which make up a completely different market, and, according to Hood (2010, p.87) have a higher success rate in terms of consumer acceptance rate.

Tobacco farmers are another attractive target market, requiring fuel for their curing operations. Tobacco curing is seasonal and could therefore suit the seasonal availability of biomass feedstock for a briquetting operation.

6.9 Business Model

While a biomass briquette enterprise is theoretically a promising venture to consider, it will require investment, hard work, and continuous innovation to emerge as a profitable enterprise in a competitive market. Cotton stalk briquettes will be a new product to the Zimbabwean market, thus raising product awareness is critical to the success of the project. It is recommended to document any challenges or necessary deviations from the business model to help organisations considering similar ventures.

The business model begins with a value chain analysis outlining a product definition, description of the market, access to key inputs, production and operations strategy, outbound logistics, sales, marketing and after sales service. Each link in this value chain must be analysed with an emphasis on how value is created in each step.

It is also important to consider the cost breakdown for the various inputs into a briquetting plant to assess value for money of the briquettes (the finished product). The various cost components that need to be considered are:

- Feedstock or cotton stalks,
- Electricity,
- Cost of production and packaging the briquettes,
- Transport of briquettes to end user,
- Operations and maintenance costs,
- Cost of collection / Loading cost,
- Fuel cost and availability,
- Machinery cost.

6.10 Briquette Use

The briquettes are particularly recommended for:

Boilers: .... For steam generation

Food processing industries: ... Distilleries, bakeries, canteens, restaurants and drying etc.

Textile process houses: .... Dyeing, bleaching etc.

Agro-products: .... Tobacco curing, tea drying, oil milling etc.

Clay products: .... Brick kilns, tile making, pot firing etc.

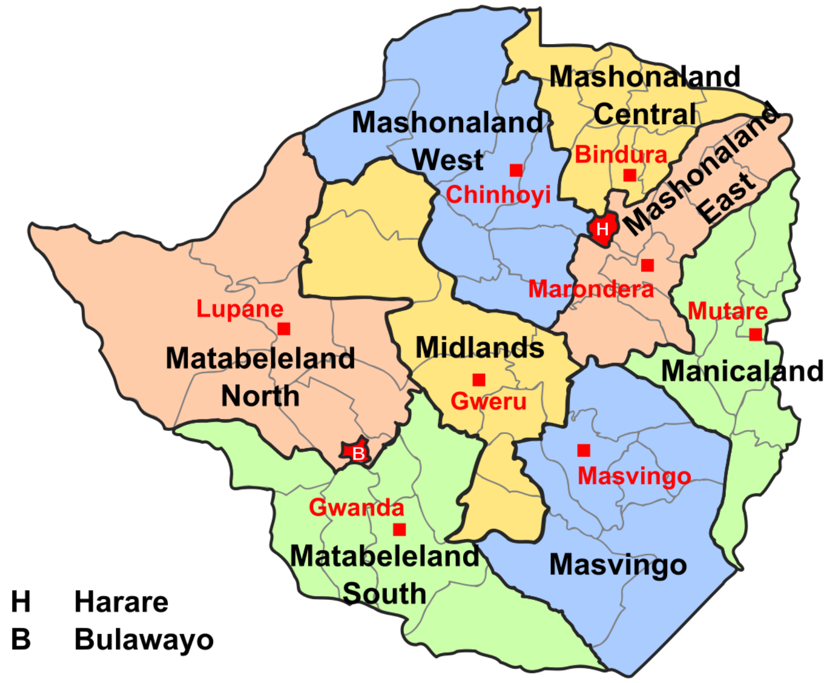
Domestic: .... Cooking and water heating

Gasification: .... Fuel for gasifiers

Charcoal: .... Suitable for making charcoal in kilns

Briquettes have strong market potential in Zimbabwe. The initial intention is to market the briquettes to tobacco farmers for tobacco curing. The majority of Zimbabwe's tobacco is grown in Mashonaland West province. Selling to tobacco farmers would be ideal as Midlands and Mashonaland West are neighbouring provinces as is shown in Figure 5 below.

Figure 5: Map of Zimbabwe Provinces



Source: Mangwanani, Public Domain, Retrieved from : https://commons.wikimedia.org/w/index.php?curid=5462589

7. Biomass Briquette Project

A biomass briquette project will involve the manufacture and sale of biomass briquettes. Biomass briquettes are an effective source of energy which is biodegradable and renewable. They can be a cost-effective substitute for coal, fuel oil, wood or charcoal, in selected industrial and commercial applications. On this basis, we propose that there is an attractive investment opportunity to establish a biomass briquetting plan in Gokwe Centre.

The project plant will market its briquettes to industrial and commercial users with boilers, as well as tobacco drying operations.

7.1 Project Objectives

This project aims to achieve the following objectives:

- Create a viable local market for biomass from cotton stalks by encouraging increased biomass utilisation.
- Develop a briquetting and pelletisation plant to process the biomass into Briquettes and Pellets.
- Develop a market for biomass briquettes and pellets through awareness raising and consumer education.
- Create employment for the local community in the plant and value chain.
- Develop a viable briquette and pellet value chain in Zimbabwe- collectors, transporters, processors, and end users.

Financial Overview

Financial projections detailed in this document include start-up cost estimates, year 1 – year 3 (2019- 2021) cash flow projections, and a pro forma income statement. The start-up budget, cash flow projections and income statements were created from a template created by the author. Prices were obtained from the Zimbabwean market for products which were locally available.

7.2 Capital and Operating Expenditures

The start-up budget for the briquetting plant is estimated at US$ 200,000, comprising capital and operations expenditures of US$ 100,000 each. The capital expenditure includes the registration costs, equipment purchase, a mortgage deposit, two years of mortgage payments, and site construction costs. The start-up budget includes the cost of both a pickup truck and trailer, which are necessary for both collecting the raw biomass cotton stalks and delivering the finished biomass briquettes to customers.

The initial deposit for the land on which the plant is located (including two years of mortgage payments) forms part of the capital cost. Another component of the cost is the plant set up, equipment and the process of briquetting itself. The first component of the operational costs is the price of buying cotton stalks from the source. For the farmer, this is an opportunity for waste disposal, so there is little cost added at this stage. Transport, both from cotton fields to the briquette plant and from there to the end user, adds a significant amount to the briquette cost. Storage of the cotton stalks and packaging of the briquettes also add to the cost structure. Detailed start-up costs are as on Table 16. (The list of requirements for the plant are as per table 15 above.)

Table 15: Detailed start-up costs for Briquette Plant

Cost item	Cost estimate (US$)
Kiln	2,500
Briquetting machine	23,600
Grinder	900
Drying racks for biomass briquettes	380
Drying racks for cotton stalks	380
Plastic crates	75
Electrical cords	38
Cleaning supplies	38
Promotional materials	56
Safety equipment	150
One-year mortgage deposit plus 24-month payments	27,600
Infrastructure adaptations to operations site, adaptation of machines to local conditions	6,800
Truck and Trailer (3 tonne)	11,000
Additional Equipment costs (computers, etc)	16,000
Operational and Labour training	5,000
TOTAL	**94,517**

Source: Siemens, J., 2017 (Converted from Canadian Dollars to US Dollars. Rate of Exchange- I CAD to 0.7527 US$. Canadian Dollars to United States Dollars rate as at 30/11/2018)

Assumptions:

1. All costs/ prices are in United States Dollars (US$).
2. Pricing for plant and equipment sourced from B2B (Business to Business) briquette plant suppliers online and compared with various briquette marketplace websites.
3. Other prices are Zimbabwe market related.
4. Training includes bringing in an expert to train local personnel.

7.3 Income and Expenditure

The income and expenditure projections are for the first three years of operations. For Year 1, Table 17 shows the expenditure structure for the first six months of operations, these numbers would be consistent over three years. It is assumed that the monthly production peak of 20 MT/ day, and 600 MT/ month will be consistent. The anticipated production of 200 MT of briquettes will be packaged in 10,000 x 20 kg bags of briquettes per month (200 MT). Revenue estimates assume the sale of 8,000 x 20 kg bags of briquettes per month (160 MT). We have estimated the market entry price of a 20 kg briquette bag will be sold at US$ 10 each, aligned to the current Zimbabwean price of charcoal. (Zimbabwe classifieds, Zimcart www.zimcart.com as at 17 December 2018).

It is assumed a 12-year loan of US$ 200,000 with 7% interest will be accessed from a financial institution, the facility also allows for 24 months of interest only repayments to allow the business the opportunity to stabilise. Other options for raising start-up capital, could be a combination of debt and equity funding, thus selling a portion of the business to another potential investor or investing institution.

The capital equipment depreciation is calculated at five years.

Table 16: Monthly expenditure for 6 months

Production Supply costs		Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Cotton stalks purchase and collection (including transport)	@ 600 MT/ month	37,950	37,950	37,950	37,950	37,950	37,950
Bags	@ 10 kg bags x US$ 2.00 per bag	6,000	6,000	6,000	6,000	6,000	6,000
Cost of Production		43,950	43,950	43,950	43,950	43,950	43,950
Utilities costs	Electricity @ US$ 400/ month water @ US$ 100/ m	500	500	500	500	500	500
Admin Costs- phone, internet	@ 100 pm	100	100	100	100	100	100
Labour Costs 6 shifts/ day 1 manager	@ US$ 400 pm and US$ 1,000	3,400	3 400	3 400	3 400	3 400	3 400
Total Cost	**Operational costs**	**47,950**	**47,950**	**47,950**	**47,950**	**47,950**	**47,950**

Source: Author

Assumptions:

1. All costs are in United States Dollars (US$).
2. Raw material quantity allocation is as per Patil P.G. 2017 @ 1.3 MT per ha. Gokwe has the capacity to produce 117,000 MT (refer table 13 above) of cotton stalks, of which the briquetting plant would consume an estimated 10,000 MT.
3. The above calculations are based on a briquetting plant whose capacity is 20 MT/ day, or 600 MT/ month (Source: Patil P.G. 2017, CIRCOT)
4. The above calculations assume paying farmers an average price for chipped stalks of US$ 43.25 per MT and an average logistics cost to deliver the feedstock to the plant of US$ 23 per MT (Source: Patil P.G. 2017, CIRCOT).
5. Not included in the table (but included in the financial model) is an estimated monthly allocation of US$ 20,000 for awareness raising, marketing, sample distribution and skilled consultants. We have also catered for recruitment costs, and sundries.

7.4 Financial Projections

According to the pro forma income statement (Table 18 below), at the end of Year 1, a net profit after interest of over US$ 143,249 will be obtained. Year 2 ends with a net profit of nearly US$ 200,000, Year 3 profit is US$ 264,184. The operating profit margin, based on 20 MT/ day is slightly over 44%. An additional US$ 10,000/ month of expenses has been allocated to the cost of initial marketing, distribution of samples to potential customers and overall community education on biomass briquettes. Another US$ 10,000/ month in expenses has been allocated to management and consultants.

Table 17: Model 1: 3-Year Financial Projections

	US$	US$	US$
Profit and Loss Summary	**Year 1**	**Year 2**	**Year 3**
Revenue	960,000	1,056,000	1,161,600
Costs	-534,600	-561,330	-589,397
Gross Margin	**425,400**	**494,670**	**572,204**
Total Expenses	-268,500	-281,925	-296,021
Net Profit before Interest	**156,900**	**212,745**	**276,182**
Interest	-13,651	-12,853	-11,998
Net Profit After Interest	**143,249**	**199,892**	**264,184**
	US$	US$	US$
Cash Flow Summary	**Year 1**	**Year 2**	**Year 3**
Opening Balance	**0**	**122,349**	**310,696**
Loan Repay and interest	200,000	0	0
Capex	-150,000	0	0
Cash In	800,000	1,040,000	1,144,000
Costs	-445,500	-556,875	-584,719
Depreciation	0	0	0
Expenses	-268,500	-281,925	-296,021
Interest	-13,651	-12,853	-26,318
Closing Balance	**122,349**	**310,696**	**547,638**

Source: Author

Assumptions:

1. Based on a 20 MT/day capacity plant (600 MT/ month).
2. Capital loan amount is US$ 200,000.
3. Production of 10,000 x 20 kg bags of briquettes per month (200 MT).
4. Sales of 8,000 x 20 kg bags of Briquettes per month (160 MT).
5. 20 kg Briquette Bags sold at US$ 10 each- aligned to the current Zimbabwean price of charcoal. (Zimbabwe classifieds, Zimcart www.zimcart.com as at 17 December 2018).
6. Interest is at 7% for a 12-year loan with 24-months of interest only payments
7. Staffing caters for recruitment of two high level experts to kick start the project.
8. Also included are company registration and other statutory costs.

The low cost of raw materials into a briquetting plant allows the project to be viable. Revenue for Year 1 is projected at US$ 960,000, Year 2 is projected at US$ 1,056,000 and Year 3 US$ 1,161,600. Contingencies have been allowed for fuel cost, which is a key component of the ongoing project cost.

7.5 Investment requirements

Investment requirement would include an initial capital investment of US$ 200,000. The challenge is not simply in raising funds, but creating a market for the briquettes in the area. Investment has been allocated into education programmes that raise awareness on the multiple benefits of briquetting cotton stalk biomass.

The implementation team and project leadership team are also key to project success. It is important to engage a subject matter expert to assist in the initial stages of project implementation and plant set-up. The team also needs to include an entrepreneurial business manager, who will maintain the financial stability of the project, ensure cost structures are adhered to and that an effective marketing strategy is implemented.

7.6 Economic and Financial Viability

According to Table 18, at the end of year 1, the cash-flow projection shows a cash balance of US$ 122,349. This is based on a production volume of 600 MT/month. However, over US$ 200,000 in start-up funding needs to be raised, of which about US$ 100,000 is set aside for capital expenditure. Positive year-end cash balances continue through year 2 at US$ 310 696 and nearly doubles in year 3 at US$ 547,638. With respect to the repayment of the loan, the cash flow projection assumes that only interest payments will be made in Years 1 and 2, with principal repayment commencing in year 3.

The pro forma income statement shows similar results with a net income of US$ 143,249 in year 1, US$ 199,892 in year 2 and of US$ 264,184 in year 3. The gross profit is slightly above 44%. The pro forma income statement demonstrates that increased raw materials and scaling-up production would provide a significantly higher operating profit margin, accompanied by a higher margin of safety, lower risks, and substantially greater net income.

The financial forecasts include a salary of approximately 6 shifts per day @ 400 per month for 6 general workers and 1 team leader/ manager @ 1,000 for 21 working days a month. The Briquetting plant's capacity is 20 MT/ day or 600 MT/ month.

Comparative Cost of Biomass Energy Alternatives

One of the largest inhibitors to the successful scale-up of many biomass briquetting companies involves competing with the low cost of firewood and charcoal. Firewood can be obtained for free in rural Zimbabwe and forested areas of the city. Though firewood is frequently for sale, costs vary depending on location. However, it is almost always cheaper than charcoal. The biomass briquettes have been benchmarked with the Zimbabwean retail cost of charcoal (as at 17 December 2018), both are priced at US$ 10 per 20 kg bag.

With effective promotion and community education, a briquetting plant can add value to Gokwe town as a viable enterprise. It can generate an eco-system of employees, suppliers, transporters and its own unique value chain.

7.7 Technical Considerations

Briquette quality is key to the success of the project is the biomass briquette quality. The material should have a lower heating value (LHV) or net calorific value (NCV) of at least 15 MJ/kg to generate enough heat for cooking or for curing tobacco. A minimum table of standards should be developed as part of the project quality management and used to test biomass briquette quality initially on a weekly basis (Siemens, 2017).

Many tried and tested models have been implemented in other African countries and internationally for manufacturing briquettes, which should be used to guide operations. Some models use grinders and others do not. While grinders are not essential, their use with cotton stalk biomass, which is bulky and sometimes awkward, will greatly reduce labour costs and improve the efficiency of the briquetting machine. The briquetting machine itself should have a motor of at least 22.5 kW and a capacity of 250 kg per hour. Screw extruder machines capable of producing up to 375 kg/hour using a 7.5 HP engine, which is sufficient for biomass briquetting start-up. India is known to have a wide range of biomass briquetting equipment models on the market, and an in-depth study will facilitate the selection of the most relevant equipment to suit Zimbabwean requirements (Siemens, 2017).

Briquette Plant Compliance

Several regulations apply to the start-up of an enterprise. The new business needs to go through several stages of registration and approval. In addition, before the business can commence production of biomass briquettes, several environmental assessments including an Environmental Impact Assessment (EIA), and site inspection, must be conducted. The Standards Association of Zimbabwe (SAZ) also needs to be engaged for standardisation of quality and documentation of specifications. Following that, a standardisation certification is needed, and finished product must be branded with standardisation stickers. At least two months should be allowed for regulatory requirements to be addressed.

7.8 Risk Identification

These are the potential risks to a briquetting project.

Supply Side Issues

Due to unavailability of cotton stalks and other agro-residues outside of the harvesting seasons, the briquette plant must either invest in stockpiling raw material or operate for only six months per year.

Technology Issues

The machines used for this purpose have high wear-and-tear costs and parts need to be replaced frequently.[8]

Market Related Issues

Fluctuations in raw material prices are a possible risk. Once farmers realise that the raw materials have a commercial value, they may raise raw material prices to uneconomic levels. It is important for briquette plants to maintain surplus space to store enough quantities of raw material to make them relatively immune to price fluctuations.

Infrastructural Problems

The briquette plant is to be located in a rural town (Gokwe) where the cotton is grown and stalks are abundant, but power supply is unreliable. The power supply availability could affect operations.

7.9 Critical Success Factors

In order to ensure overall project success there are certain traits that will ensure sustained project success.

[8] Jain, P., Khater, A.K., 2011. Limitations of 24/7 Operation of a Capacity Briquette Plant For Binderless Fibrous Biomass. Biomass Magazine, 1 November. Retrieved from: http://biomassmagazine.com.

There are numerous briquette equipment suppliers in India and China. Wear and tear on the equipment is high. Thus, in order to ensure the longevity to the project, the investors need good quality sturdy machines. This is it important to research the network of briquette equipment suppliers to identify those with good quality machines for use in this project.

The vision is to gradually increase plant capacity as feedstock increases and as demand for the briquettes increases. The investor must therefore select a plant model of the initial plant which is scalable, with the potential to double or triple the initial capacity of 20 MT/day, should demand and raw material availability warrant.

Transportation is a key price component, so the plant needs to be strategically located, in close proximity to the feedstock source and be accessible to a major client.

8. Investing in Zimbabwe

Zimbabwe has a young and vibrant entrepreneurial sector which emerged out of the political and economic challenges that the country has been through in the last 20 years. There are an estimated three million small and medium enterprises (SMEs) in the country whose activities are primarily in the agricultural sector, as well as in trade, manufacturing and services. SMEs tend to remain small due to their limited access to capital and credit.

Zimbabwe has numerous business organisations to support investors, these include Zimbabwe National Chamber of Commerce (ZNCC) and the Confederation of Zimbabwe Industries (CZI).

Zimbabwe's financial services sector has transformed dramatically over the last decade. The domination of traditional banks has been challenged by faster and frictionless mobile money platforms like Ecocash. The current Zimbabwean cash crisis is propelling these services forward.

Zimbabwe is a peaceful country with ideal climate, low crime levels and a conducive social and political atmosphere. Zimbabwe also boasts a solid educational system for investors who have children, with international schools available.

8.1 General Data

Table 18: Zimbabwe Profile

Total Area	390,757 square kilometres
Land	386,670 square kilometres
Water	4,087 square kilometres
Border Countries	Botswana (West), Mozambique (East), South Africa (South), Zambia (North)
Capital City	Harare
Official Language	English
Climate	Tropical low temperatures from April to July. It is warm to hot From August to October. The rainy season begins in November and ends in March.
Population	+/- 15 million (2016)
Annual Population Growth	1.1%
Literacy Level	90%
Major Economic Sectors	Agriculture, (18.5% of GDP – backbone of the country), Mining (4% of GDP, over 60 minerals, largely untapped), Manufacturing (15.5% of GDP, diverse), Tourism (6% of GDP) [2016 statistics]
Financial Sector	Well established and sophisticated
Infrastructure and Energy	Good road, rail and air transport network, modern communications systems, hydro & thermal power
Access to markets	Membership in regional groupings such as: Southern African Development Community (SADC), COMESA, African, Caribbean, and Pacific Group of States (ACP), European Union Generalised scheme of preferences (GSP), World Trade Organization (WTO)

Source: ZIMSTAT and Reserve Bank of Zimbabwe through Zimbabwe Investment Authority (ZIA)

Zimbabwe is centrally and strategically located in Southern Africa. Although landlocked, it enjoys easy access to neighbouring countries. Zimbabwe shares borders with South Africa, Botswana, Mozambique, and Zambia. Zimbabwe's population was estimated at 16 million in 2016. The population is highly educated with 90% literacy rate. English is Zimbabwe's official language and most Zimbabweans are conversant in English.

Through bilateral, regional and multilateral arrangements the country enjoys preferential market access to the regional and international community. (ZIA, 2018)

One of the largest waterfalls in the world is located in Zimbabwe, Victoria Falls, on the border of Zimbabwe and Zambia. Lake Kariba, one of the largest man-made lakes in the world, is also located in Zimbabwe. Zimbabwe is endowed with abundant wildlife, and all the Big Five animals can be found here.

According to the Zimbabwe Investment Authority (ZIA, 2018), the country offers the following unique selling points to potential investors:

- It is centrally and strategically located within the Southern African Development Community (SADC) region which provides a regional gateway (North-South Corridor) and access to major regional markets of SADC.
- SADC member states include Angola, Botswana, Comoros, Democratic Republic of the Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, the United Republic of Tanzania, Zambia and Zimbabwe.
- A strong human capital base – with the highest literacy rate in Africa of 90,7% (the African Economist, 2015)
- The use of multicurrency systems which eliminates exchange rate risk.
- Fully liberalised current account which facilitates ease of doing business.
- Dividends are freely remittable.
- Natural resource endowment with over 55 exploitable important mineral resources.
- Country's strength in resource endowment, education and well developed mining industry which made it to win the bid to host the Pan African Minerals University of Science and Technology.
- Pro-market policies that government is implementing such as Ease of Doing Business reform initiatives.
- Existence of Investment Promotion and Protection Agreements (Bilateral and Multilateral).
- Voted World Best Climate (tied with Malta) (International Living Magazine, 2011).
- Voted World Best Tourism Destination (European Council on Tourism and Trade, 2014).

Politics: Zimbabwe is a democratic country with an Independent judiciary. Parliamentary elections are held every 5 years.

Labour force: The majority of the Zimbabwean labour force is highly educated and has attained at least four years of secondary education. Wages are very competitive in comparison with the rest of the world, and due to a high unemployment rate, skilled, semiskilled and unskilled labour is readily available. The majority of the labour force is English speaking.

Infrastructure: Good quality road and rail network link all major cities and neighbouring countries, and there are three international airports, In Harare, Bulawayo and Victoria Falls. There is adequate provision of electrical power (hydro and thermal), a number of solar projects coming on-stream, postal and telecommunication services, which are continually being upgraded. Mobile telecommunications network access is available in most parts of the country, as is internet connectivity.

8.2 The Economy

The Zimbabwean economy is essentially agricultural-based but has strong mining and manufacturing sectors. The main industries include:

Agriculture: Largest outputs of produce include tobacco, cotton, maize, wheat, sugar, oilseeds, coffee, timber, horticulture, beef and dairy. Main exports include tobacco, horticulture, tea and coffee.

Manufacturing: The manufacturing sector of the economy is diverse. Main products include food products, beverages, tobacco, textiles and clothing, paper, furniture, wood, chemicals and metals.

Mining: Zimbabwe has extensive mineral resources. Most minerals are exported. The major minerals extracted include gold, nickel, coal, chrome, iron ore, platinum, diamonds, granite and precious stones.

Tourism: This is a rapidly growing sector of the economy, providing a large proportion of the country's foreign exchange earnings. The major tourist centres include Victoria Falls, Hwange National Park, Kariba, Gonarezhou National Park, Great Zimbabwe, and the Eastern Highlands.

Financial Services: This sector of the economy is well established and sophisticated. Exports are encouraged in all areas of the economy and a number of tax incentives are available to promote exports.

8.3 Investor Protection and Security

Zimbabwe's constitution protects its investors, guaranteeing the right to private property and prohibiting its expropriation without adequate compensation.

Zimbabwe is a signatory to the following treaties:

- Multilateral Investment Guarantee Agency (MIGA)
- Overseas Private Investment Corporation (OPIC)
- International Convention on Settlement of Investment Disputes
- New York Convention on the enforcement of Foreign Arbitral Awards
- United Nations Convention on International Trade Law.

Zimbabwe has also signed Bilateral Investment promotion and International Protection Agreements with: United Kingdom of Great Britain and Northern Ireland, China, Iran, Germany, Denmark, Mozambique, Sweden, Malaysia, India, Netherlands, Indonesia, Portugal, Jamaica, Switzerland, Italy, and Egypt (ZIA, 2018).

8.4 Procedure for investing in Zimbabwe

Zimbabwe's political landscape has seemingly changed from the better following the resignation of President Robert Mugabe in November 2017. The indigenisation policy of 51% local ownership for companies has been scrapped for all sectors except diamond and platinum mining. Zimbabwe Investment Authority (ZIA) is the country's investment promotion body, established to promote and facilitate both foreign and local investment.

To establish a business in Zimbabwe, company registration is required, followed by ZIA investment licensing, operational, residence and work permits for foreign investors. The process is detailed in table 20 below.

Table 19: Procedure for investing in Zimbabwe

STEP		No OF DAYS TO PROCESS
1.	Registration of Company: Fill in MOU and Articles of Association with Registrar of Companies, CR6 & CR14 Form	14 days
2.	Issuance of Investment license by ZIA	5 days
3.1	Zimbabwe Revenue Authority: Registration for PAYE, income tax, VAT, customs duty	5 days
3.1	Zimbabwe Revenue Authority: Immigrants rebate	1 day
4.1	Immigration Control Department: Investor Residence Permits	14 days
4.2	Immigration Control Department: Temporary Employment permits	4-6 weeks
5.1	Environmental Management Authority: Environmental Impact Assessment (EIA) Licence	30 days
6.1	Environmental Management Authority: Prospectus submission EIA Report	60 days

Source: Zimbabwe Investment Authority publication – One Stop Shop

While the Zimbabwe Investment Authority will in the initial phase direct the Investor on how to go about establishing themselves as a business in Zimbabwe, line Ministries however will play the role of guiding the investor. In most cases, the Ministry of Industry and Commerce will take on the responsibility of assisting the investor in setting up their business in Zimbabwe.

Taxation in Zimbabwe in made to Zimbabwe Revenue Authority (ZIMRA) and the rates are as detailed in Table 22 below. The tax rates below are as at 1st November 2018.

Table 20: Breakdown of the tax structure in Zimbabwe

Zimbabwe Taxes	Last	Previous
Personal Income Tax Rate	51.50	45.00
Corporate Tax Rate	25.75	25.75
Sales Tax Rate	15.00	15.00

Source: Zimbabwe Investment Authority

Zimbabwe is an attractive investment destination. The Zimbabwean government has shortened the time it takes to register a company in Zimbabwe thereby making it easier to invest in Zimbabwe. Support is available to investors through the Zimbabwe Investment Authority to make the process as smooth as possible.

9. Macro-Economic Environment in Zimbabwe

Zimbabwe declared herself "Open for Business" as has been highlighted by the new president, His Excellency President Emmerson D Mnangagwa. This renewed call for investors has been backed up by several reforms being promulgated, which make it easier to attract investors into Zimbabwe.

Zimbabwe uses a basket of multi-currencies for its trade and investment transactions. The multi-currency system was introduced in 2009. These currencies include the United States Dollar (US$), Great Britain Pound (GBP), South African Rand (ZAR), Botswana Pula (BWP), the Euro, Japanese Yen (JPY), Australian Dollar (AUD), Chinese Yuan (CNY) and the Indian Rupee (INR).

Authorised Dealers (banks) can open accounts for both individuals and corporates, in any of the nine (9) currencies in the multicurrency basket. Any of the currencies in the multicurrency basket can be used for settlement of both local and international transactions. Furthermore, Authorised Dealers can receive export proceeds on behalf of account holders in any of the currencies in the multicurrency basket (GoZ, 2018a).

Economic indicators

Table 21: Real GDP at Market prices (US$ millions)

Year	Real GDP- US $ millions
2013	13,572.80
2014	13,861.50
2015	14,095.71
2016	14,182.50
2017	14,551.44

Source: Economic Research Division, Reserve Bank of Zimbabwe

Agriculture is the lifeblood of Zimbabwe's economy. Tobacco, cotton, maize and sugarcane, among others provide a livelihood for 70% of the country's predominantly rural dwelling population. According to the Reserve Bank of Zimbabwe, the economy is expected to grow by 4.5% in 2018, spurred by a 10.7% growth in agriculture. (Source: Economic Research Division, Reserve Bank of Zimbabwe, 2018)

Government put measures in place to address the trade deficit, which is continuously part of the Industrial Development Policy. In this plan, the Government focused on identified strategic sectors to provide the impetus necessary for the rest of industry to grow. Overall Vision and Mission to overturn the balance of trade deficit is to transform Zimbabwe from being a producer of primary goods into being a producer of processed value-added goods for both the domestic and local market.

The government working with the private sector has embarked on a drive to develop exports across the board with focus on value addition clusters that include the Cotton to Clothing cluster as one of the main pillars of this programme. Government has also undertaken steps to improve the 'Ease of Doing Business in Zimbabwe' which is a drive at ensuring that new investors, especially foreign investors, face minimal hurdles when setting up operations in Zimbabwe (ZIA, 2018).

9.1 Transitional Stabilisation Programme (TSP) Reforms Agenda

Zimbabwe's latest economic blueprint is entitled The Transitional Stabilisation Programme (TSP), and it was launched by the Minister of Finance in 2018 (GoZ, 2018b). The Transitional Stabilisation Programme (TSP) outlines policies, strategies and projects that guide Zimbabwe's social and economic development interventions up to December 2020. The reforms are intended to run from October 2018 to December 2020. The vision of the Government led programme is "**Towards a Prosperous and Empowered Upper Middle Income Society by 2030**". Investment themes in the TSP that are relevant to investment in Zimbabwe include (among others):

- Ease of Doing Business

The Transitional Stabilisation Programme will implement measures to the Ease of Doing Business Reforms, with the objective of improving the country's competitiveness in terms of the business and investment environment. This includes enforcing contracts, which currently is time consuming and difficult for the average business entity.

The Transitional Stabilisation Programme will also put in place the necessary legislative and administrative reforms to consolidate and harmonise the various scattered legislative pieces into an omnibus investment Act. The Act will also create the Zimbabwe Investment and Development Authority and equip it to be a one-stop investment authority.

- Resuscitating Industry and Industry Development

The Transitional Stabilisation Programme will prioritise increased investment in the manufacturing sector, with an emphasis on value addition and beneficiation of agriculture produce and minerals, to increase job creation and export earnings.

Zimbabwe's three (3) main entry points for foreign investment are; the Zimbabwe Investment Authority (ZIA), Zimbabwe Stock Exchange (ZSE) and the Reserve Bank of Zimbabwe (RBZ).

9.2 Preferential Regional Market Access

Investors in Zimbabwe have access to the country's large preferential market access.

Investors have preferential access, duty-free quota-free, to a market of 450 million people, as Zimbabwe is a member of the COMESA and member to the COMESA Free Trade Agreement (FTA). With this access to COMESA's 16 Member States participating to the FTA investors will have direct access to the market with the highest rate of return on investment in the world (COMESA Regional Investment Agency).

Zimbabwe provides investors a further access to the SADC Trade Protocol market, composed of 15 countries representing together a market of another 142 million people to whom they can export duty free.

Investors will further have access to the European Union Market through Zimbabwe Interim Economic Partnership Agreement concluded with the European Union, representing another market of 510 million people (80% of the goods produced in Zimbabwe investors have duty free quota free access to the European Union market).

9.3 Economic Infrastructure

According to the 2017 Inter-Censal Demographic Survey, conducted by the Zimbabwe National Statistics Agency (ZimStat, 2017), Zimbabwe's population is estimated at 13.6 million, of which 8 million, or 60% are economically active. While the country's minimum wages are among the highest on the continent -US$ 200 per month in the textile sector and US$ 180 per month in the Clothing Sector - the quality of labour offsets this cost. The highly skilled labour force reduces the cost of engagement and training over the immediate and short term. Furthermore, the government along with other stakeholders currently lobby the worker's Trade Unions to re-assess wages.

Table 22: Labour description and cost

Skilled labour

Labour cost US$180 – US$400/month - Skilled labour includes people capable of exercising considerable independent judgment, e.g. factory supervisors.

Semi-skilled labour

Labour cost US$180 – US$300/month - Semi-skilled labour includes workers who perform defined routine tasks where emphasis is on performing assigned tasks while expectation on judgment and skill are lower that the skilled workers.

Unskilled labour

Labour cost US$180 – US$250/month - Unskilled labour includes workers who perform simple duties such as helpers and support the skilled and semi-skilled workers. Use of Job training graduates them to semi-skilled workers.

Despite its turbulent recent legacy, Zimbabwe remains the second most diversified economy in the sub-Saharan region, after South Africa. Tourism is thriving, and there is definitive potential in retail as it slowly migrates from the informal sector. The Industrial Index of the Zimbabwe Stock Exchange (ZSE) has a market capitalisation of US$ 9 billion, and corporate governance, accounting and reporting standards are on par with the best in the region. Since President Mnangagwa's inauguration in 2018, the ZSE industrial index has narrowed in pricing differential between Harare and London listings (the Old Mutual Implied Rate), which is a positive reflection of boosted confidence and the anticipation of fresh foreign capital inflows.

9.4 Cotton to Clothing Strategy 2014- 2019

The government of Zimbabwe recognises the cotton industry and its value chain as a pillar in the revival of the economy and has worked with its private sector as well as regional and international donors to draft the Cotton to Clothing Strategy. The European Union, COMESA and the International Trade Centre (ITC) funded this strategy, which is the result of extensive consultation and input of stakeholders in the value chain.

The Strategy was launched in October 2014 and it provides all the key and ambitious attributes that are required to revive the Zimbabwe Cotton to Clothing Value Chain. The strategy aims to deliver by 2019:

- Increase the number of smallholder farmers growing cotton from 200,000 to 250,000;
- Increase yields by 71%, to 1,200 kg/ha;
- Increase seed cotton production to 450,000 MT/year, up from the current 30,000 tons;
- Attain ginning capacity utilisation of 69.55%, up from 20% in 2017;
- Process 25% of cotton fibre domestically, up from the current 3-5%;
- Export 90,000 MT of lint, up from the current 12,000 MT;

- Increase exports of textiles and garments by 390%, to US$ 110 million;
- Create more than 40,000 new jobs in the textile and clothing sectors;
- Achieve 100% of companies complying with international standards related to working conditions, quality management and sustainability.

The increase in yields and number of cotton farmers, will also result in an increase in an increase in cotton stalk agro-residues, which will enhance the viability of this project.

10. Investment Threats and Risks

Foreign investment is welcome in Zimbabwe, especially where it creates employment, leads to the introduction of technology and skills transfer (ZIA, 2018) As with any economy, there are threats and risks for potential investment.

10.1 Investment Risks

These are a few of the main threats and risks to consider when entering the Zimbabwean market.

Threats for investment include the liquidity crunch being faced in Zimbabwe. There was little hard currency in circulation at the time of writing, in early 2019, and this can pose a risk to foreign investors. Investors may ask questions on the reliability of the process of repatriation of funds. It is important to point out that these factors may pose the biggest obstacles to foreign direct investment. Table 23 below summarises key investment risks and their recommended mitigation.

Table 23: A description of the main risks and recommendations for mitigating these risks

Main risks	Mitigation of risks	Recommendations
Corruption	Stay away from corruption by avoiding middle man as well as short cuts. Follow due process of the laws.	Be professional, ethical and transparent. Report all cases to the police or relevant authorities.
Liquidity crunch	Use of plastic money and mobile money transfer services.	Mobile money through partnering with Ecocash, Telecash, and One Money is the way to go. Innovation with technology driven payments should be prioritised. Rolling out of point of sale machines from the start will be an advantage.
Ease of doing business	Dealing with the Zimbabwe Investment Authority (ZIA), ZimTrade and Zimbabwe's Ministry of Industry and Commerce will enlighten investors on the investment environment.	Follow all due diligence procedures. There are government to government bilateral agreements between Zimbabwe and numerous countries that ring-fence investors and their private property.

Source: Author

While there are threats, real and perceived, it is important to note that there are numerous strengths and opportunities. The country remains one of the most attractive investment destinations in Southern Africa because of its human capital. Zimbabwe boasts of a highly educated labour force. The country also has favourable policies on repatriation of funds and flexible labour policies. The current use of a basket of currencies can be used as an advantage when investors buy cheaper goods from outside countries with weaker currencies. The renewable energy and manufacturing sectors are "ripe" for risk takers as there are numerous shortages, assuring investors of a ready market.

11. References

1. Agricultural Marketing Authority (AMA), 2017. *Zimbabwe 2017 Cotton End of Year Report, Volume VII*. Government of Zimbabwe, Harare.
2. Azeus Machinery, 2016. *Make Cotton Stalk into Fuel Pellets*. Retrieved from: www.azeus.com.
3. Brown, H. and Ware, J., 1958. Cotton. Mc Graw-Hill Book Company, New York. pp. 99-105.
4. Buka G., 2016. *Cotton and its By-Products Sector in Zimbabwe*. Background paper for project "Promoting cotton by-products in Eastern and Southern Africa". UNCTAD, New York and Geneva. Retrieved from: https://unctad.org/en/PublicationsLibrary/sucmisc2017d3_en.pdf.
5. Chigumira G., 2017. *Analysis of Cotton By-Products Survey in Zimbabwe*. UNCTAD, New York and Geneva. Retrieved from: https://unctad.org/en/PublicationsLibrary/sucmisc2017d11_en.pdf.
6. Cohen Y. and Marega A., 2013. *Assessment of the Briquette Market in Kenya*. Report for Swedish International Development Cooperation Agency (SIDA), Stockholm. Retrieved from: https://www.energy4impact.org/file/1712/download?token=T4J_JRTl.
7. Demian, T. F., 1979. *Design measures for cotton stalk clearing machines*. Agricultural mechanization in Asia, Winter 1979. pp. 55-58.
8. El Saeidy E., 2004. *Renewable Energy in Agriculture in Egypt: Technological Fundamentals of Briquetting Cotton Stalks as a Biofuel*. Doctoral thesis. Humboldt University, Berlin. Retrieved from: https://www.researchgate.net/publication/279826536_Technological_fundamentals_of_briquetting_cotton_stalks_as_a_biofuel.
9. El Bassam, N., 1998. *Energy plant species*. James & James Ltd, London, UK.
10. Energy and Environment Partnership (EEP), 2013. *Analysing Briquette Markets in Tanzania, Kenya and Uganda*. Retrieved from: https://eepafrica.org/briquette-study/.
11. Fahmy, Y., Zimbardi, F., Viola, E., Ricci, E., Cardinale, M., and Elzanati, E., 2000. *Steam explosion pretreatment of cotton stalks*. Conference paper. 1st World Conference for Energy and Industry, 5-9 June 2000, Sevilla, Spain.
12. FAO, 2018. *Country Brief – Zimbabwe*. Retrieved from: http://www.fao.org/giews/countrybrief/country.jsp?code=ZWE, accessed November 10, 2018.
13. FAO, 1990. *Briquetting in Africa, Chapter 13: Briquetting Report*. Retrieved from: http://www.fao.org/docrep/t0275e/T0275E06.htm
14. FAO, 1995. Proceedings of the international workshop on Biomass Briquetting, New Delhi, India, 3-6 April. Retrieved from: http://www.fao.org/docrep/006/AD582E/ad582e00.pdf.
15. Gad, A., Omar, M., Kasem, A. and Karim, U. 1987. *The Morphology of the crops and grasses. The Modern Publications*, Alexandria, Egypt.
16. Gemtos, T. A. and Tsiricoglou, Th., 1999. *Harvesting of cotton residues for energy production*. Biomass and Bioenergy, 16, pp. 51-59.

17. Government of Zimbabwe, 2018a. *Investment Guidelines and Opportunities in Zimbabwe*. Retrieved from: https://www.investzim.com.
18. Government of Zimbabwe, 2018b. *Zimbabwe Transitional Stabilisation Programme*. Retrieved from: http://www.zimtreasury.gov.zw/index.php/treasury-updates?download=139:abridged-transitional-programme.
19. Gravalos I., 2016. *An Experimental Determination of Gross Calorific Value of Different Agroforestry Species and Bio-Based Industry Residues*. Natural Resources, 7(1), pp. 57-68.
20. Grover P.D. and Mishra S.K., 1996. *Biomass Briquetting: Technology and Practices*. FAO, Rome. Retrieved from: http://www.fao.org/docrep/006/ad579e/ad579e00.pdf.
21. Hall D., House J. and Scrase I., 2000. *Chapter 1: Overview of biomass energy*. In Rosillo-Calle F., Bajay S. and Rothman H. (Eds.), *Industrial Uses of Biomass Energy: The example of Brazil,* pp. 1-26. Taylor & Francis, London.
22. Hood, A., 2010. *Biomass briquetting in Sudan: A feasibility study*. USAID, Washington, D.C. Retrieved from: http://pdf.usaid.gov/pdf_docs/PBAAA440.pdf.
23. IFC, 2017. *Converting Biomass to Energy, A Guide for Developers and Investors 2017*. Retrieved from: https://www.ifc.org/wps/wcm/connect/7a1813bc-b6e8-4139-a7fc-cee8c5c61f64/BioMass_report_06+2017.pdf?MOD=AJPERES.
24. Kabwe S., Mutambara J., Mujeyi K., Blackmore E., Vorley B. and Weng X., 2018. *Contract farming and informality: drivers and governance responses in Zambia and Zimbabwe*. International Institute for Environment and Development, London. Retrieved from: https://www.cifor.org/library/6929/.
25. Kalita, S., 2016. *Investigation of small scale power generation and biomass briquette production from biomass, involving cases from Bolivia*. Masters dissertation. Aalto University, Helsinki, Finland. Retrieved from: https://aaltodoc.aalto.fi/bitstream/handle/123456789/23919/master_Kalita_Saurav_2016.pdf?sequence=2.
26. Makwana D., 2014. *Biomass Briquettes – Substitute to Fossil Fuels*. Blog entry, 18 April. 2 Green Energy, Santa Ynez, California, USA. Retrieved from: http://www.2greenenergy.com/2014/04/18/biomass-briquettes-fossil-fuels/.
27. Mwampamba, T., Owen, M., Pigaht, M., 2013. *Opportunities, challenges and way forward for the charcoal briquette industry inSub-Saharan Africa*. Energy for Sustainable Development, 17(2), pp. 158-170.
28. Njenga, M., Karanja, N., Karlsson, H., Jamnadass, R., Liyama, M., Kithinji, J., & Sundberg, C., 2014. *Additional cooking fuel supply and reduced global warming potential from recycling charcoal dust into charcoal biomass briquette in Kenya*. Journal of Cleaner Production, 81, pp. 81-88.
29. Patil, P. G., 2017. *Priority Cotton By-Products activities for Development*. Workshop Presentation, Promoting Cotton By-Products in Zimbabwe, Harare, Zimbabwe, 27-28 September. UNCTAD, New York and Geneva. Retrieved from: https://unctad.org/meetings/en/Presentation/1617K_Zimbabwe_PG_Patil_27092017.pdf.
30. Purohit P. and Chaturved V., 2016. Te*chno-economic Assessment of Biomass Pellets for Power Generation in India*. Working paper. Council on Energy, Environment and Water, New Delhi, India. Retrieved from: http://pure.iiasa.ac.at/id/eprint/13896/1/CEEW%20-

%20Working%20Paper%20-%20Techno-economic%20assesment%20of%20bio-pellets%20-%2025Oct16.pdf.

31. Seeger Engineering, 2015. *Energy and Environmental Technology-Focus on our Future*. Retrieved from: http://www.seeger-engineering.eu/en/59-seag.
32. Siemens, J., 2017. *Exploring the feasibility of a Biomass Briquette Enterprise in Nairobi*. Masters dissertation. University of Victoria, Canada. Retrieved from https://dspace.library.uvic.ca/bitstream/handle/1828/9044/Siemens_Joelle_MPA_2017.pdf?sequence=1&isAllowed=y.
33. Singh, N.P., 1996. *Agriwaste programme in India: an overview*. Proceedings of the International Conference on Biomass Energy Systems, 26-27 February, New Delhi, India, pp. 65-72.
34. Sumner, H. R., Hellwig, R. E. and Monroe, G. E., 1984. *Harvesting cotton plant residue for fuel*. Transactions of the American Society of Agricultural Engineers, 27(20), p. 968.
35. Tayel, S., Wahby, M., and Khairy, M., 1988. *Cotton picking as affected by its physical and mechanical properties*. Misr Journal of Agricultural Engineering, 5(4), pp. 419-432.
36. UNCTAD, 2018a. *Zimbabwe National Action Plan to promote cotton by-products*. Policy document from the project "Promoting cotton by-products in Eastern and Southern Africa". Retrieved from: https://unctad.org/en/PublicationsLibrary/ditccomnone2018d3_en.pdf.
37. UNCTAD, 2018b. *Zimbabwe Policy Recommendations to promote cotton by-products*. Policy document from the project "Promoting cotton by-products in Eastern and Southern Africa". Retrieved from: https://unctad.org/en/PublicationsLibrary/ditccomnone2018d2_en.pdf.
38. Vyas D.K., Sayyad F.G., Khardiwar M.S. and Kumar S., 2015. *Suitability of cotton stalks for briquetting and pelleting*. Current World Environment, 10(1), pp. 263-269.
39. ZEPARU, 2014. *Zimbabwe's Cotton to Clothing Value Chain Study*. ZEPARU Occasional Research Paper No.1/2014. Harare, Zimbabwe.
40. Zimbabwe Investment Authority (ZIAac), 2018. *The Zimbabwe Investment Guide*. Retrieved from: https://www.investzim.com.
41. Zimbabwe National Statistics Agency (ZimStat), 2017. I*nter-Censal Demographic Survey 2017*. Retrieved from: https://zimbabwe.unfpa.org.