UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT
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PROMOTING COTTON BY-PRODUCTS
In Eastern and Southern Africa

Zambian Cotton and Cotton By-Products

Cotton Stalks and other Biomass Processing into Pellets and Briquettes

Investment Profile

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Investment Profile

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

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Summary

Cotton stalks and other agro-forestry waste provide good raw materials for producing cheaper, healthier and eco-friendly cooking and heating fuels, capable of replacing charcoal and firewood. Cotton stalks and other biomass also provide additional income and business opportunities for farmers and small and medium-sized enterprises (SMEs) intending to venture into modern cooking fuels market. Despite this huge energy and business potential, agro-forestry residues remain under-exploited in Zambia due to, among other reasons, their little-known techno-economic viability, limited product development and promotion. This investment profile summarises the techno-economic viability, potential social impacts and ecological soundness of cotton stalks and other biomass as feedstock for cooking/heating fuels. Laws, policies and other fundamentals affecting biomass processing investments in Zambia are also analysed.

Challenge: Increasing charcoal use risks depleting Zambia's forest lands, intensifying climate change effects, increasing cooking fuel prices beyond reach, and triggering a surge in air-pollution induced morbidity and related deaths (Bruce, Perez-Padilla, & Albalak, 2000). Only 17% of Zambian population has access to modern cooking fuels (electricity, gas and kerosene), leaving 84% rural households depending on firewood and 59% urban households depending on charcoal for cooking (Tembo, Mulenga, & Sitko, 2015). Limited options and access to clean cooking fuels and increasing fuel prices have triggered rampant deforestation leaving Zambia among the fastest deforesting countries. This is causing acute fuelwood shortages which may soon worsen if no substitutes to charcoal are found. Illegal charcoal trade out of Zambia into neighbouring countries, where more than 80% households rely on fuelwood for cooking, is also increasing (Gumbo, Moombe, Kandulu, & Kabwe, 2013).

Cotton stalks and other biomass: Zambia produces over 150,000 metric tonnes (MT) of cotton stalks (60% in Eastern 34% in Central and Southern provinces) annually, close to 200,000 MT soybean straws (40% in Central, 20% in Copperbelt and 15% in Eastern province); and close to 300,000 MT of maize stalks and cobs (with Central and Eastern accounting for 20% each and 15% in Southern province). Wheat and rice straws, pigeon pea stalks are also found in some farming areas. Apart from bagasse which currently is used in boiler heating and electricity generation, no other crop residues are processed into bioenergy. Instead they are lost to bush fires or burnt to clear the fields as per legal requirement. With such crop residue volumes, it is possible to have up to six months of a reasonable supply of soya straws (May-June), cotton stalks (July-August), maize husks and cobs (July-September), wheat straws (October-November). Pigeon pea stalks could also be incorporated to supplement raw material supply for another 1-2 months. Although these residues could be collected at almost zero cost, up to US$25 per MT maximum depending on available volumes and distance from the processing plant will be paid to motivate farmers to uproot and supply these crop residues as feedstock for pellets and briquettes production. Up to US$15 per MT has also been allotted for pre-processing handling (chipping and baling) and transportation.

Demand: Zambia consumes about 1,122,283 MT of charcoal annually. Consumption is concentrated in major cities and towns, with close to 767,000 (59%) of urban households accounting for 979,843 MT of total charcoal consumption, based on an average of 3.5 kilograms (kg) charcoal used daily per household. The remaining Zambian urban households (about 223,000) use charcoal in a mix with electricity or firewood. Each of these households uses a daily average of 1.75 kg of charcoal, for a total annual consumption of 142,441 MT of charcoal. About 84% of rural households also solely depend on firewood for cooking and other heating purposes (CSO, 2015).

Charcoal and firewood consumption by Zambian households is expected to skyrocket during the next decade, in line with projected population growth (2.8% annually), rapid urbanization (4% annually), and aggressive deforestation, which has continued unabated. High poverty levels and electricity tariff increases will further drive cooking energy prices even higher beyond the reach of many. Low-income households in urban and rural areas remain the most in need of clean cooking fuels and their growing demand could trigger severe cooking fuel shortages.

Market: The 59% urban households solely depending on charcoal for cooking and heating will be the prime market target for cotton stalk pellets. This category is searching for cheaper and better cooking fuels alternatives. The 38% urban households currently using a mix of charcoal and electricity for cooking will be the second target. This consumer category is already addicted to cleaner cooking fuels and will be easier to adopt the new cooking fuel - pellets. Schools, health institutions and hospitality industry will be the primary target market for the cotton stalk briquettes as a cheaper, healthier and, more eco-friendly cooking and heating fuel substitute to charcoal and firewood currently being used in their industrial boilers.

Required Investment: Just over US$ 111,000 capital investment is required to establish a pelleting plant with a capacity of 6.4 tonnes per day (TPD) or an 8 TPD briquetting plant. Of this amount up to US$17,000 is the cost

of land and buildings. A 6.4 TPD pelleting mill costs around US$ 45,000 ex-factory inclusive of all materials handling equipment, while an 8 TPD briquetting plant costs about US$ 40,000 ex-factory inclusive of all materials handling equipment. The difference in the total capital expenditure is for additional raw materials handling equipment and machinery required for hammering the raw materials to finer grade for pelleting.

***Viability and bankability**:* An 8 TPD briquetting mill with a 40% (US$ 41,475) equity and 60% (US$ 62,213) of debt financing structure and operating at 150 days per year, increasing to 300 days by year six, based on an eight-hour a day, is economically viable and bankable. Such a briquetting mill has a net present value (NPV) of US$ 65,477.48 after six years, an internal rate of return (IRR) of 24.6% against the weighted average cost of capital (WACC) of 8.3%, and a payback period (PBP) of 3.67 years. The proposed 8 TPD briquetting mill has also an interest cover ratio (ICR) of above 4.42, and a debt cover ratio (DSCR) of above 2 during its six-year loan period. A 6.4 TPD pelleting plant under similar financing and operational capacities is also viable as can be seen under Annex 1. A total on 134.4 and 168 tonnes of biomass will be required per month for a 6.4 TPD pelleting and 8 TPD briquetting respectively.

***Policy environment**:* Zambia has a range of supportive national policies for the planned investments in biomass processing into modern cooking and heating fuels. Key among the development policies is Zambia's Seventh National Development Plan (7NDP 2017-21), its second National Agricultural Policy (2NAP), National Industrial Policy, and the Youth Development Policy.

Zambia has also adequate legal corpus to facilitate and nurture planned investments in cotton stalks and biomass processing into cooking and heating fuel. Primary legal frameworks include: the Zambia Development Agency Act, which facilitates MSMEs development, investment promotion and trade; the Citizens economic Empowerment Act of 2006; the Business Regulatory Act of 2014; the Compulsory Standards Act of 2017; the National Technical Regulations Act of 2017; and the Patents Act of 2016. Current investment, contract, labour competition, environmental management, consumer protection and metrology laws are also adequate to support the planned investments in cotton stalks and other biomass processing into modern cooking and heating fuels in Zambia.

Major risks: Short raw materials supply window, unassured raw materials quality and quantity within feasible distance from the processing plant/mill, likely low market offtake, and competition from existing pellets and briquettes producers are the key challenges likely to affect the planned investments in cotton stalks and other biomass processing into cooking fuel pellets and briquettes. Measures have been proposed to help manage these potential risks.

The above potential risks notwithstanding, low-medium cost bioenergy processing technologies, coupled with widely available crop residues, including cotton stalks, represent an opportunity to transform Zambia's cooking fuels economy. SMEs interested in investing in agriculture and agro-processing ("agripreneurs") can now easily establish small-medium cooking fuel pellets and briquettes processing plants to provide cheaper, cleaner and more efficient substitute to firewood and charcoal. Increasing adoption of energy-saving cooking stoves by low-income and rural households is another key fundamental supporting cotton stalks and other biomass processing into bioenergy pellets and briquettes business.

1. Zambian Cotton Performance and Prospects

Zambia's cotton sector growth has generally declined due to a number of challenges. The sector's future growth prospects also risk a continued decline if key challenges are not addressed and industry opportunities remain under/unexploited. This notwithstanding, cotton remains the major smallholder cash crop and is key to Zambia's socio-economic growth. Currently, Zambian cotton is grown mainly for lint. Subsections below summarize the current cotton production, processing and marketing dynamics. Subsections also summarize key challenges affecting the sector, cotton value chain opportunities and sector prospects.

1.1 Socio-Economic Importance

Cotton offers farm income opportunities to over 200,000 smallholder farming families annually, indirectly supporting over 1.2 million rural people (Kabwe, 2017). Heavy smallholder farmers' involvement gives cotton a significant positive socio-economic effect on rural poverty alleviation. The cotton value chain employs over 1,000 permanent and approximately 10,000 seasonal workers. Cotton also generates over US$ 60 million in lint exports and accounts for 16% of Zambia's annual non-traditional exports (NTEs), valued at US$ 203.1 million in 2017. In 2016 cotton contributed about 0.3% to Zambia's gross domestic product (GDP). At its peak in 2012, cotton contributed up to 1.45% to national GDP, as shown in Table 1 below.

Table 1: Cotton Sector Contribution to National GDP

	2010	2011	2012	2013	2014	2015	2016
Total Zambia gross domestic product (GDP) (USD million)	19.1	21.2	21.4	21.8	20.2	21.1	19.5
Contribution of Cotton to Zambia's GDP per year (USD million)	47	118	309	80	67	54	65
Contribution of Cotton Sector to GDP (%)	0.25	0.56	1.45	0.37	0.33	0.25	0.33
Number of people employed in the cotton value chain (ginning companies)	About 1,000 permanent employees and 9,500 seasonal employees						

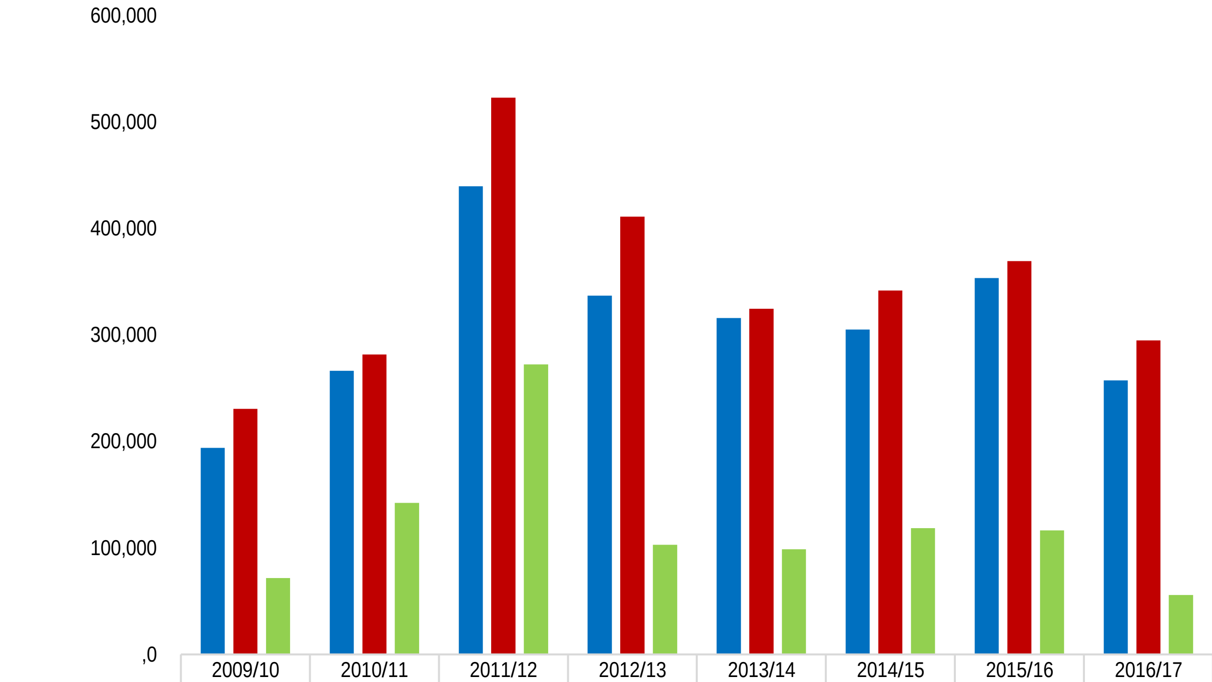
Source: Kwabe, 2017.

1.2 Cotton Production

Over the most recent decade, Zambia's seed cotton production averaged 122,000 MT annually. This translated into an average of 50,000 MT of lint and about 67,000 MT of cottonseed annually. Seed cotton output of 272,641 MT achieved in 2012 remain the highest ever recorded, while 55,000 MT recorded in 2017 is Zambia's lowest seed cotton output in last 10 years. Excessive rains severely affected seed cotton yields during the 2017 season, while better producer prices were behind the 2012 record crop.[1]

[1] Cotton Board of Zambia (*Pers. comm. Kwalombota Nyambe Senior Inspector)*

Figure 1: Cotton Farmers, Area Under Cultivation and Seed Cotton Output Estimates



	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16	2016/17
Number of farmers	193,894	266,222	439,641	336,790	315,824	305,193	353,529	257,427
Total HA s	230,648	281,689	522,779	411,054	324,690	341,702	369,355	294,808
Seed Cotton (MT)	71,755	142,292	272,201	102,938	98,723	118,564	116,557	55,925

Source: Central Statistical Office (CSO) Crop Estimates

On average, Zambia also produces over 150,000 MT of cotton stalks annually, which is left to waste and/or burnt as a diseases and pest control measure.

Over 90% of the national seed cotton crop is grown under outgrower schemes and is pre-financed by ginning companies.[2] The number of cotton farming households between 2010 and 2017 averaged 308,565 annually.[3] Correspondingly, the area under cotton production also increased to an annual average of 345,840 hectares (ha) over the same period.

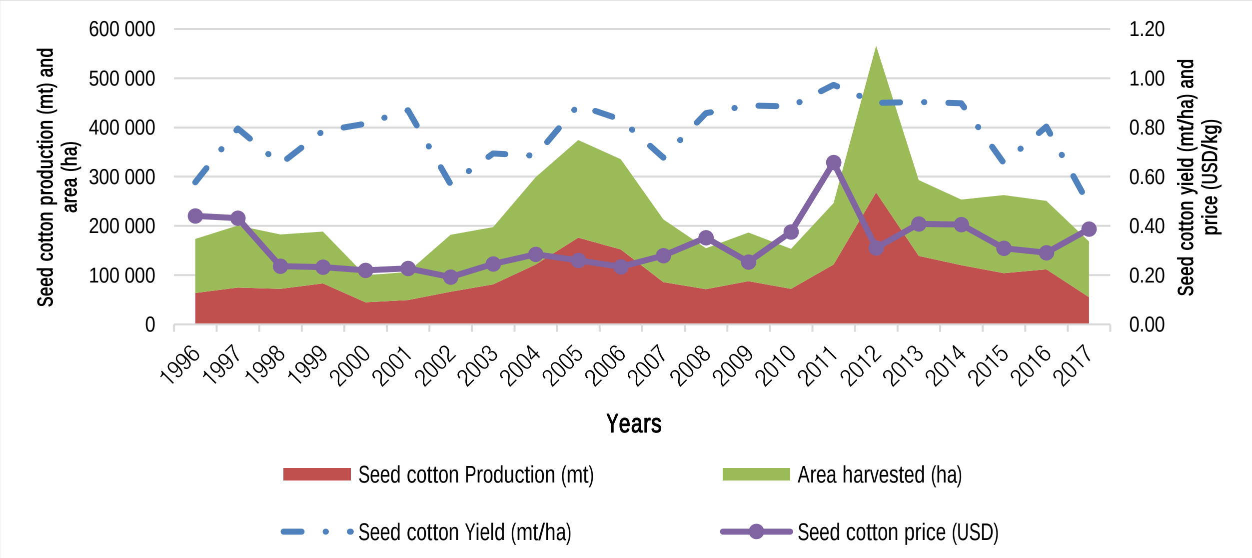
This, however, was not accompanied with productivity improvements as average seed cotton yields varied between 600 kg – 1,000 kg/ha during the last 10 years. Low and volatile international cotton lint prices; poor cotton production inputs quality; and poor agronomic skills and husbandry practices are among the major factors behind the declining seed cotton output nationally (*Kabwe, 2017*).

Unless drastic measures are taken, Zambia's cotton production may continue shrinking, especially if farmers' profit margins don't improve and investments aren't made in adding more value to cotton by-products like cotton stalks.

[2] Author's conversation with Kwalombota Nyambe Senior Inspector, Cotton Board of Zambia, October 2018

[3] Cotton Board of Zambia Estimates

Figure 2: Seed Cotton Hectarage, Production and Average Yields



Source: Central Statistics Office (CSO) – production indicators, Cotton Board of Zambia – prices (Kabwe, 2017)

1.3 Value Addition / Processing

Zambian cotton is currently grown mainly for lint and cottonseed oil/cake which constitute up to 41% and 55% respectively. Processing of other cotton by-products remains under developed and as a result Zambia is losing out on income and many value-added commodities from cotton by-products.

Total installed ginning capacity now stands between 350,000 and 400,000 MT by 10 main ginning companies. Ginning capacity utilization has remained low at 30-35% of their installed capacity due to declining seed cotton output. At 40% ginning out turn (GOT), this translates into an average of 46-50,000 MT of lint annually. Almost all lint produced (98%) or close to 47,800 MT is exported. As a result, Zambia imports nearly all of the textile and apparel products it consumes.

Of the total annual realisable cottonseed of 67,000 MT, close to 75% (50,250 MT) is processed into edible oil and cake, while 10% is retained for planting. Only 2 ginning companies (Parrogate Ginneries and China Africa Cotton) with a combined installed cottonseed crushing capacity of 17,000 tonnes a year, crush cottonseed for edible oil and cake. Two (2) other independent edible oil crushers exist, with Mt. Meru as the dominant player, using 67,500 MT line of its 362,000 MT annual installed oilseeds crushing capacity for cottonseed processing. The second company – Sakkar Oils has up to 11,000 MT cottonseed crushing capacity.

Zambia's once-thriving textiles and clothing industry has collapsed, opening up the country to imports, including of second-hand clothes. A thriving textile and clothing industry is needed to help Zambia industrialize and lengthen its cotton value chain. This will also help catalyse cottage handloom businesses, especially in rural areas, and help create wealth for cotton, textile and apparel value chain players.

1.4 Industry Challenges

Low production and productivity has been singled out as the main threat to Zambian cotton sector's future prospects (Kalinda & Bwalya, 2014). Seed cotton yields have remained unacceptably low at between 220-850 kg per hectare (kg/ha), against the 2,000 kg/ha yield potential of the seed varieties in circulation.[4] Yields have also remained low around 600kg/ha year on year. A litany of challenges, chief among them: reducing pre-financing due to increasing input loan defaults, limited local value addition, and increasing climate change effects have been identified as factors behind the declining productivity (Kalinda & Bwalya, 2014).

Poor seed cotton prices and reduced profit margins are forcing farmers to opt for alternative cash crops like soybeans (Kabwe, 2017). Inability by farmers to negotiate for pre-planting prices exacerbates volatility in seed

[4] Author's conversation with Kwalombota Nyambe Senior Inspector, Cotton Board of Zambia, October 2018

cotton prices (Chitah, 2016). This, together with a lack of transparency in how each buyer determines input prices has led to low profit margins for farmers. Side selling is also a problem, with buyers who haven't financed the crop offering slightly higher seed cotton prices to entice farmers into breaking their obligations to the contracted buyer. This leads, in turn, to input loan defaults and the inability of some ginning companies to invest into pre-financing the crop.

Poor inputs quality is another key challenge affecting cotton sector. There is growing industry consensus that planting seed under outgrower schemes has been over-recycled and comingled, and that generic crop protection chemicals are of less efficacy – thus undermining attainable seed cotton yields by farmers.

Near absence of cotton specialized extension services support is also behind the eroded cotton agronomic skills and husbandry practices especially among the younger generation farmers, who in most instances grow cotton out of lack of any other option. Most cotton farmers also face challenges in managing and controlling their pests and diseases and their fields are often overwhelmed by weeds.

Limited local value addition precludes farmers realising more income from their cotton crop, reducing their incentives to grow the crop and contributing to dwindling cotton production. Absence of a consensus seed cotton pricing formula in Zambia further prevents farmers from negotiating a more remunerative price for their crop, which incorporates revenues from by-products.

Increasing frequency of adverse weather conditions (floods and droughts) is also negatively affecting cotton output. 2017 is a good reference year when seed cotton production plummeted to 55,000 MT on account of excessive rains in most cotton growing areas. Prolonged dry spells especially at the begging of the rain season has continued affecting crop emergence and establishment.

1.5 Sector Opportunities

The Zambian cotton sector has a number of unexploited investment opportunities in productivity enhancements and improved value-added by-products.

Independent seed production and marketing is one such an investment opportunity. As of the time of writing, the national seed breeder, the Cotton Development Trust (CDT), relies on ginners to multiply and distribute planting seed. This arrangement places ginners in a conflict of interest, as they are the outgrower promoters distributing planting seed as part of the input packages they provide to farmers. For example, CDT has difficulty commercializing new, potentially more productive seed varieties, as they are more costly for ginners to produce. Moreover, ginners are not equipped to sort and track different varieties of ginned seed, making it difficult to track the performance of each variety. Farmers also complain that there is little planting seed available for purchase on the market – all seed comes through the ginners. Delinking seed production from commercial ginners would foster competition and potentially improve the development, dissemination and availability of better seed varieties.

Exploitation of current ICT advances for improved extension services delivery, agronomic skills trainings, good agricultural practices promotion, and digital financial services among cotton farmers is also a very promising investment opportunity. Investments in e-extension platforms could help improve and modernise cotton farmers' agronomic and business skills, exposure and use of modern agricultural technologies and best practices for improved productivity. Meanwhile, digital financial services could improve financial inclusion.

Increased processing of cotton by-products at the local level is another such an investment opportunity. These could include investments in small-scale cottonseed oil extraction, processing of cotton stalks into pellets and briquettes, and absorbent cotton from short-staple cotton and ginning waste, among others.

2. Proposed Investment

The proposed investment explores use of cotton stalks and other agro-forestry waste/biomass as feedstock for processing cooking and heating fuel pellets and briquettes.

A number of biomass pelleting, and briquetting plants have been established and being promoted in African countries such as Ethiopia, Kenya, Malawi, Uganda, Sudan and Zimbabwe (Bhattacharya, 2018) Some of these plants are using cotton stalks and other agro-forestry waste as a feedstock for processing biomass into alternative clean and cheaper cooking and heating fuel pellets and briquettes. This transformative cooking fuel feedstock and business opportunity, however, remains under-exploited in Zambia due to among other reasons, limited information on the techno-economic viability, and limited product development and promotion.

This profile proposes investments in small to medium sized pelleting plants (up to 6 TPD capacity) and a briquetting plant (up to 8 TPD capacity) depending on the desired end products, i.e. pellets for modern energy-saving cooking stoves or briquettes for industrial cookers and boilers.

2.1 Investment Rationale

The supply of modern and eco-friendly energy sources has not kept up with growing demand for cooking and heating fuels in Zambia. As a result, the majority of Zambian households consume fuelwood and demand continues to grow (Tembo, Mulenga, & Sitko, 2015). Meanwhile, demand growth has outpaced the supply of commercial fuelwood. Coupled with the insufficient supply of substitute cooking fuels, this has contributed to acute supply shortages and prices increases for cooking fuel.[5]

Increasing fuelwood use by majority Zambian households is fast becoming unsustainable and risks depleting Zambia's forest lands, intensifying climate change effects, raising cooking fuel prices beyond reach, and triggering a surge in morbidity and deaths related to household air pollution. It is against this background that Zambia plans to reduce the share of fuel wood to less than 40% by 2030[6] as part of its planned universal access to modern and clean energy, especially cooking fuels.

Proposed investments in cotton stalks and other biomass processing into solid bioenergy for cooking and heating fits perfectly well with Zambia's current development priorities seeking to promote value addition of most agricultural products; jobs and wealth creation especially among youths and women in rural areas; contribute towards Zambia's ongoing efforts of achieving universal access to modern cooking fuels by 2030; and its goal to achieve a productive and well conserved natural resource for sustainable development. The proposed investment in processing cotton stalks and other agro-forestry waste into pellets and briquettes is meant to sustainably provide affordable, cleaner and eco-friendly cooking and heating fuel options for urban and peri-urban households and SMEs, replacing firewood and charcoal.

The main agricultural and cotton producing areas of Central, Eastern and Southern Provinces of Zambia have been earmarked for the proposed investments in biomass pellet and briquette plants. The three earmarked provinces account for 91% of Zambia's total seed cotton, 53% total maize and 68% of total soybeans output. In addition, Southern Province accounts for over 90% of sugar cane output, while Central Province accounts for over 40% of national wheat output. Apart from an abundant availability of raw materials, these productive agricultural areas are also faced with widespread deforestation due to high fuelwood demand, continuing opening up of new farming lands, and increasing illegal charcoal trade and exports.

Proposed investments in biomass pelleting and briquetting is suited to small and medium enterprises (SMEs) looking to enter the market for affordable, cleaner and eco-friendly cooking and heating fuels. Cotton stalks and other crop residues represent an opportunity to transform the cooking and heating fuel segments. Impact investors, local SMEs and/or Agriprenuers can establish small-to-medium-scale pellet and briquette processing plants to provide cheaper, cleaner and more efficient substitutes to firewood and charcoal. This investment opportunity is also targeting small and medium-scale farmers, who stand to earn additional income as suppliers of agricultural residues to these plants. As such high cotton producing areas of Katete, Chipata and Mumbwa are among the most suited districts for this kind of investments,

Increasing adoption of energy-saving cooking stoves by low-income urban and rural households is another key fundamental supporting cotton stalks and other biomass processing into bioenergy pellets and briquettes business. The 59% urban households solely depending on charcoal for cooking and heating will be the prime market target for cotton stalks pellets. This category is searching for cheaper and better cooking fuels alternatives. Secondary target markets for pellets will be restaurants and the 38% urban households currently using a mix of charcoal and electricity for cooking. Schools, health institutions and industrial plants will be the primary target market for the cotton stalks briquettes as a cheaper, healthier and, more eco-friendly cooking and heating fuel substitute to the coal, furnace oil and charcoal they currently use in their boilers.

[5] Government of Zambia, 2008. National Energy Policy. Retrieved from: www.mewd.gov.zm/index.php/downloads/...policies/28-national-energy-policy-2008.

[6] Government of Zambia, 2006. Vision 2030. Retrieved from: https://www.iea.org/media/pams/zambia/ZambiaVision2030.pdf.

2.2 Pelleting and Briquetting Technologies

Densification technology will be used in processing cotton stalks and other agro-forestry residues into bioenergy pellets and briquettes. This technology will involve chipping of cotton stalks and other residues to less than 15mm loose biomass; compaction under pressure of chipped and loose cotton stalks and other agro-forestry residues to reduce its volume; and naturally agglomerating the compressed stalks/residues into briquettes, depending on market preference.

2.3 Required Inputs - Raw Materials

The planned biomass processing investments are designed to make use of cotton stalks as the primary raw materials for pellets and briquettes. Other agro-forestry raw materials targeted for this investment will include soybean and wheat straws, maize stover and cobs, bagasse, pigeon pea stocks and other selected forestry waste such as saw dust in Copperbelt Province. Availability of these earmarked agricultural and forestry waste/raw materials vary from area to area and by season.

2.3.1 Raw Material Characteristics

Calorific value (amount of heat generated by a unit of mass) and ash content (unburned fuel or mineral content and composition of fuel after oxidization) are some of the key characteristics considered when determining suitability of crop residues as feed stock for biomass energy for cooking and heating. Biomass briquettes and pellets, including from cotton stalks, are proposed as an alternative energy source to help reduce fuelwood consumption. Briquettes and pellets from cotton stalks offer consistent burning, less smoke, no unhealthy emissions and a competitive calorific value i.e. of 3,827 – 4,100 KCal/kg (Umeshi, Sarsavadiya, Vaja, & Mahadeo, 2015), against the average calorific value of about 4,900kCal/kg for most tropical tree species branches (Duraku, Ajime, Okoye, & Arinze, 2016).

Research has shown that cotton stalks pellets and briquettes are cleaner, non-polluting, and neutral in carbon dioxide (CO_2) emissions, as they burn steadily and completely, without producing smoke, leaving minimum residue of ash - always less than 4% - which can be used as a fertilizer for the garden too (Gravalos, et al., 2010). Calorific values and ash content for other earmarked crop residues (soybean, rice and wheat straws were reviewed and established).

Table 2: Ash Content and Calorific Values of Selected Crop Residues Earmarked as Feedstock for Pellets and Briquettes

Biomass Type	Ash Content (%)	Calorific Value (kCal/kg)
Cotton Stalks	3.0	4,100
Sugar Bagasse	1.8	4,380
Rice Straw	21.2	3,200
Wheat Straw	8.0	4,100
Soybean Straw	4.1	4,170

Source: (Jaykhodiyar, 2019)

2.3.2 Raw Materials Availability

To ensure adequate availability and/or raw materials supply, the proposed investment projects will have to use a mix of the following crop residues:

Soybeans straws available from May to August every year. Based on 1:1.5 residue to produce ratio (RPR), close to 200,000 MT of soybean straws are produced annually in Zambia, 40% of which is in Central Province, over 20% in Copperbelt Province and about 15% in Eastern Province. Most of the soybean straw is left as waste or lost to bush fires as it has low palatability to most livestock kept by smallholder farmers;

Cotton stalks available from July to September every year. At a 1:0.3 RPR Zambia produces over 150,000 MT of cotton stalks annually, over 60% of which is in Eastern Province and the rest in Central and Southern Provinces; and

Maize stalks and cobs available from June to October. At 1:0.65 RPR and 40% uptake rate, Zambia produces over 500,000 MT of stover of which Central and Eastern Provinces account for 20% each and Southern Province accounts for about 16% of total national maize stover output.

Wheat straws in rural areas of Central and Copperbelt Provinces, excess bagasse and pigeon pea stalks could also be incorporated to supplement the above major raw material supply in Central/Copperbelt, Southern and Eastern Provinces respectively.

2.3.3 Raw Material Cost

There is no fixed price for cotton stalks and other crop residues. A higher end cost of US$ 40 per MT of raw materials has been estimated based on the cost of labour to collect, chipping and transportation to the mill. At this raw materials cost, farmers will be able to receive up to US$ 25 per MT of crop residues depending on their distance to the processing plant, the balance of US$ 15 is to cover for all other pre-processing cost during raw materials storage, handling and other logistics, milling and additional drying costs. The price payable to farmers may reduce to 25-30% of the delivered cost of chipped stalks to the plant should the chipping, collection and delivery functions be assigned to a local agent, as is the case is in India.

The cost of the earmarked raw materials will also be affected by the farmers' willingness to sell their crop residues, such as maize stalks, and instead opt to keep it as folder for their livestock during the dry season. Maize cobs are also used as a direct cooking fuel and as result farmers may not easily sell their cobs after shelling their maize. The requirement to leave some crop residues as crop cover under the upcoming conservation farming systems is another factor likely to affect farmers' willingness to sell their soybean straws for pelleting and/or briquetting.

The Plant Pests and Diseases Act No. 13 of 1994 requires that all cotton stalks in Zambia are destroyed by burning by September to prevent the transmission of pests and diseases to the next year's crop. This regulation, coupled with minimal other applications for cotton stalks, means there is an abundant potential supply of this biomass for pellet and briquette plants. For cotton farmers, this represents an attractive opportunity to earn additional income from stalks that they would otherwise destroy.

2.3.4 Sourcing Logistics

Short collection window, long distances between raw material sources and the processing plant/mill, looseness and high-volume nature of most raw materials will be the major raw materials sourcing challenges likely to affect the planned bioenergy pellets and briquettes investment projects. To avert these foreseen challenges, the investment projects will have to:

- Let farmers uproot and heap their cotton stalks and other raw materials for sun-drying either in their fields or centralized local pre-processing bulking point;
- Incorporate mobile tractor-driven raw materials pre-processing, i.e. chippers/cutting units; and
- Have a reliable truck to mop and transport the raw materials to the processing facility.

Once chipped, raw materials will have to be transported to the processing facility. The processing facility will have to be strategically located to ensure raw materials are collected within a 50km radius around the processing facility.

2.4 Value Addition Processes

Depending on the end product either pelletization or briquetting will be the main processing activity at each of the planned investments. Briquettes are likely to be the most preferred replacement for charcoal and other industrial heating uses. The briquetting process will involve the following key processes:

2.4.1 Collection and Drying of Raw Material

Once uprooted, the stalks must be sun dried for at least a week to reduce the moisture content to between 8 – 12%. Farmers then aggregate sufficiently dried stalks in the fields, or at a bulking centre near the fields, for pre-processing.

2.4.2 Pre-Processing and Transportation of Raw Materials

Farmers or workers manually feed the stalks into a tractor driven chipper, which cuts them into pieces no longer than 10mm. The chipper's offtake will feed directly into a truck, where farmers or workers can manually compress the raw material.

Chippers can process between 10 and 16 MT of biomass per day, depending on aggregated volumes. The chipped raw material is then transported to the processing plant using tractors or trucks. Transportation costs will vary depending on distance to the processing plant and raw materials volume per load.

2.4.3 Briquetting


(Photo credit: UNCTAD)

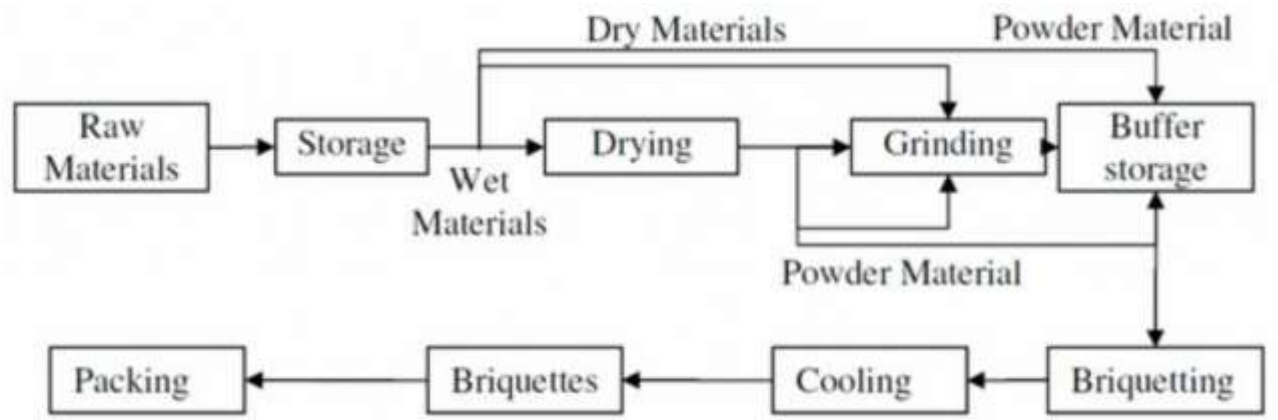
This process involves raw materials volume reduction by compaction under pressure into high density briquettes for industrial cooking and heating purposes. The briquetting process starts with the chipped raw materials being fed either manually or by pneumatic system into holding bins fixed over the briquetting press.

The material is then shovelled into the intake or moved by a screw conveyor from the holding bin into the press. Actual briquetting happens when the material is compressed by the ram through the taper bored die.

During compression, temperature rises causing the lignin to come out on the surface, binding the compressed raw materials naturally into the formed briquettes. In this way, briquettes typically do not require any additional binding agent. Formed briquettes are thereafter automatically pushed through the cooling line ending up at the packaging and storage point.

The above value addition processes are summarized by the flow chart depicted in Figure 3.

Figure 3: Briquetting Process Flowchart



Source: Bestbriquettes.com

Pelletization follows a similar process, with two differences. First, an additional step is required to mill the raw material to a finer grade using a hammer mill before feeding it into the pelleting plant. Pellets also require the addition of small quantities of a binding agent, which varies by biomass type. Production costs are therefore higher for pellets than for briquettes.

2.5 End Products and Services

Two major value-added end-products i.e. briquettes or pellets, will be produced, depending on the target market.

Pellets will be distributed and sold through township markets, targeting urban and peri-urban households who depend on charcoal for cooking and other heating purposes; through supermarket chains targeting households who use a mix of electricity and charcoal; and through agrodealers targeting peri-urban households and farmers using charcoal for both cooking and to heat their poultry houses.

Briquettes will be distributed and sold to institutions such as hospitals, boarding schools, lodges and restaurants, and other small industries (e.g. breweries) currently using coal, furnace oil or charcoal in their boilers used for cooking, agro-processing and heating purposes.

Strategic supply and market linkages will also be established with organizations promoting energy-saving stoves and modern cooking fuels, especially in the major towns of Eastern, Lusaka and Central Provinces, where consumers face shortages and high prices for fuelwood.

In the Copperbelt Province, where several saw mills are located, charcoal and pellets derived from sawdust will be the major competition to biomass pellets and briquettes. To survive this competition, the proposed biomass briquetting, and pelleting plants will have to be located in Eastern, Southern and Central Provinces, where it costs about US$ 50 per MT to transport pellets from Copperbelt.

To be competitive, biomass pellets and briquette plants need to sell their products at US$ 140 per tonne or less, representing a discount to charcoal of about US$ 20 per tonne, at the time of writing. This base price is meant to make pellets and briquettes more competitive than charcoal for the low-income urban households who depend on charcoal for cooking.

High calorific value, easy handling/attractive packaging and eco-friendliness of the pellets and briquettes from cotton stalks and other agro-forestry residues will be the other high selling points which will be used during product promotion. Pellets and briquettes will also be promoted together with modern energy-saving cook stoves currently being promoted and distributed by a number of local companies.

2.6 Market Analysis

The lack of access to modern cooking and heating fuels in Zambia has created a good business opportunity for biomass fuels. According to 2015 Living Conditions Monitoring Survey (LCMS), conducted by the Central Statistical Office, only 16% of Zambians had access to modern sources of cooking energy, such as electricity, gas and kerosene. As a result, 85% of rural households depend on firewood and 59% of urban households depend on charcoal for cooking and heating purposes.

Access to modern cooking fuels remains an acute challenge throughout Sub Saharan Africa (SSA), where more than 90% of households rely on firewood, charcoal and other waste for cooking.[7] This is one of the major factors fuelling illegal charcoal trade from Zambia into some neighbouring countries with depleted forest lands. Globally, about 2.8 billion people, or 38% of the world population, lack access to clean cooking fuels.[8]

2.6.1 Market Size – Demand

Globally, about 2.3 billion people, the majority of whom are in Sub Saharan Africa (SSA), will still have no access to clean cooking fuels by 2030.[9] Zambia also remains off-track to achieving universal access to clean cooking fuels by the year 2030. Access to electricity has remained low at 27% nationally, with 47% access in urban areas and only 3.3% access in rural areas. As a result, only 16% of Zambian households use electricity for cooking leaving, 51% of households dependent on firewood and 33% on charcoal. Over half (59%) of urban households use charcoal for cooking. A further 34% of urban households use a mix of charcoal and electricity. Close to 88% of rural household depend solely on firewood for cooking and heating, 10% use charcoal and only 2% use electricity (MOE, 2008)

Using the above energy use mix and current national, rural and urban household statistics it is estimated that total national charcoal usage/consumption is now about 1,122,284 MT annually.[10] Of this usage, close to 767,000 (59%) of urban households account for 979,843 MT based on an average of 3.5 kg charcoal use per day per

[7] International Energy Agency (IEA). World Energy Outlook 2017. Retrieved from: https://www.iea.org/weo2017/.

[8] *Ibid.*

[9] *Ibid.*

[10] Calculated using the Living Conditions and Monitoring Survey urban and rural household using charcoal estimates and the average 1.75 kg of charcoal per household per day estimate by the JCTR basic needs basket in Zambia

household. The rest of the Zambian households (about 223,000) who use charcoal in a mix with electricity or firewood account for 142,441.25 MT. This is based on an average of 1.75 kg charcoal use per day per household.

Demand for charcoal and firewood is expected to skyrocket during the next decade in line with projected population growth (2.8% annually), rapid urbanization (4% annually), and aggressive deforestation which has continued unabated. High poverty levels and electricity tariff increases will further drive cooking energy prices even higher beyond the reach of many. Low income urban and rural households will for a long time remain the most in need of clean cooking fuels and the likely trigger of the imminent cooking fuels crisis.

2.6.2 Target Customers

The 59% of urban households solely depending on charcoal for cooking and heating (Tembo, Mulenga, & Sitko, 2015) (MOE, 2008) will be the prime target market for cotton stalk-based pellets. These make up over 767,000 urban households who currently are the most in need and the hardest hit with rising cooking fuel prices. The low-income urban households without access to electricity are also increasingly exploring more affordable and cleaner/healthier cooking fuels. This is what has made this market segment as prime target for modern off-grid and low-cost energy serving cooking solutions.

The 34% of mostly urban households currently using a mix of charcoal and electricity for cooking will be the other targeted clientele base. These households are already addicted to cleaner cooking fuels but are exploring for more efficient and fairly priced cooking fuel options. This customer base is currently leading in exploring energy-saving cooking solutions. Schools, health institutions and hospitality industry will be the other market segment which will be targeted for the cotton stalks pellets and briquettes as a cheaper, healthier and, more eco-friendly cooking and heating fuel substitute to charcoal and firewood.

Small and medium scale breweries, agro-processing companies, schools, hotels and restaurants and hospitals will be the target market for the briquettes.

2.6.3 Export Market Prospects

Cooking fuels deficits are more acute in some of Zambia's neighbouring countries with depleted forest lands. This include Malawi, Tanzania and to some extent the desert parts of Namibia and Botswana. Increasing demand and reliance on charcoal for cooking is fuelling increased illegal charcoal exports into the above-mentioned countries. Replacement of illegal charcoal exports with formal biomass pellets and briquettes is thus one possible avenue Zambian investors could wish to explore and promote once the products are well established on the local market.

2.6.4 Market Trends

Currently charcoal costs about Zambian Kwacha - K2,300 (US$ 200) per MT retail price on average on the local market. Charcoal prices are higher when purchasing smaller volumes and slightly below average when buying per 90-100 kg bag. Charcoal prices also tend to increase during the peak demand periods, i.e. during winter months and in the rainy season. Power outages and electricity tariff adjustments are the other factors which drive up charcoal consumption and prices.

An increasing number of supermarket and some fuel stations/convenience shop outlets have started stocking and promoting imported charcoal briquettes in major towns at about US$ 347 per MT (i.e. K4/kg). At this price, only high-income households are buying these briquettes. About 3 local companies have also started promoting briquettes locally produced from sawdust. These are retailing at about K2,100 (US$ 183) per tonne.

2.6.5 Key Success Factors

Proposed biomass briquetting and pelleting plants stand to benefit from the following competitive factors:

- High transportation costs (US$ 50 per MT) of sawdust-based pellets out of the Copperbelt Province;
- Unreliable supply and an additional cost to dry sawdust of K200 (US$ 17.40) per tonne;
- Readily available agricultural waste, i.e. cotton stalks;
- Increasing low-medium cost bioenergy processing technologies; and
- The mountain challenges in accessing fairly priced cooking and heating fuels in most major agricultural areas.

Processing of cotton stalks and other major and crop residues are posed to transform Zambia's cooking fuels economy. SMEs and agripreneurs can now feasibly establish small to medium-scale plants to produce pellets for household cooking fuel or briquettes for industrial heating, representing a cheaper, cleaner and more efficient substitute for firewood and charcoal in areas experiencing rampant deforestation from agriculture and charcoal.

Ongoing promotion of energy-saving cooking stoves by development partners and private energy companies will also help improve the uptake of cotton stalks-based pellets and briquettes. As energy prices continue increasing, low-medium income households are also increasingly looking for cheaper, modern and energy-saving cooking solutions. With promotion and effective marketing, biomass processing into fairly priced high calorific and cleaner/eco-friendly cooking fuel is likely to have a reasonable offtake among the low-medium income customer base.

3. Business Case

Subsections below summarize the planned investment scope and size, economic viability, recommended financing structure, and the potential socio impact,

3.1 Investment Scope

Two (2) investment models have been proposed, i.e. a biomass pelleting plant and a biomass briquetting mill using cotton stalks, soybean straw, maize stover/cobs and other location specific agro-forestry waste suitable for the purpose. The two proposed models give prospecting investors options on the end-product (pellets or briquettes) depending on market demand dynamics in their intended local areas at the time of investing.

3.1.1. Technical Specifications and Output Capacity

A 6.4 MT per day (TPD) pelleting plant and an 8 TPD medium-sized briquetting mill have been chosen under this profile to help demonstrate the techno-economic viability of cotton stalks and other agro-forestry residues processing into bioenergy pellets or briquettes. The chosen pelleting plant and briquetting mill models use a wide range of raw materials including cotton stalks, residues from soybean, maize, wheat and sorghum, saw dust, bagasse and other wild grasses, forest twigs and other waste.

The proposed investments are earmarked for high seed cotton producing areas especially in Chipata and Katete in Eastern Province, and Mumbwa in Central Province. Table 3 summarizes the technical specifications of a 6.4 TPD pelleting plant and Table 4 outlines the technical specifications of an 8 TPD briquetting mill.

Table 3: Technical Specifications for a 6.4 TPD Pelleting Plant

TECHNICAL SPECIFICATIONS: 6.4 TPD PELLETING PLANT			
Product and Raw Materials		**Electricity/Power Requirements**	
Item/Description	**Specifications**	**Item/Description**	**Specifications**
Finished product	8-10 mm diameter, 60-150 mm in length cylindrical pellets	Required power connection	59 hp/45 kW
Production capacity	700-800 kg/hour depending on raw materials	Amp. load	50-60 Amp approximate
Raw material size & moisture content	Up to 10mm size raw materials of 8-12% moisture content	Power consumption	25-30 Unit / hour

Table 4: Technical Specifications for an 8 TPD Briquetting Plant

TECHNICAL SPECIFICATIONS: 8 TPD BRIQUETTING PLANT			
Product and Raw Materials		Electricity/Power Requirements	
Item/Description	Specifications	Item/Description	Specifications
Finished product	75 mm diameter, 50-350 mm in length cylindrical briquettes	Required power connection	59hp/45 kW
Production capacity	800-1,000 kg/hour depending on raw materials	Amp. load	59-73 Amp approximate
Raw material size & moisture content	Up to 10 mm size raw materials of 8-12% moisture content	Power consumption	Unit / hour

3.1.2. Support Infrastructure

The proposed pelleting and briquetting plants will require the following support infrastructure:

i) Up to 3,000 square meters (sqm) of land, i.e. 150 sqm space for the mill/plant, 500 sqm product storage, 50 sqm office space, and the remaining 2,300sqm space for raw materials bulking and future expansion area;

ii) A 3-phase electricity supply connection;

iii) A reliable water source; and

iv) Good access roads and telecommunication coverage.

3.1.3. Operations and Implementation

The proposed 8 TPD briquetting model will start with a single 8 hours shift operations for 150 days (from June/July to November/December) per year. Production is expected to increase by 16% annually until it hits 300 days of production per annum. The 300 days will be achieved by both introducing double production shifts during the harvesting period, when raw materials are abundantly available, and by building raw materials storage facilities for off-season processing.

3.2. Planned Investments

Planned investments are outlined in subsections below.

3.2.1. Capital Investments

Planned capital investments will include a complete pelleting plant or briquetting mill with raw materials handling equipment, a tractor, trailer, a tractor driven raw materials chippers and a hammer mill in case of the pelleting plant; and a light truck for product distribution to markets.

A 6.4 TPD pelleting mill costs around US$ 45,000 ex-factory inclusive of all materials handling equipment, while an 8 TPD briquetting plant costs about US$ 40,000 ex-factory inclusive of all materials handling equipment. Most pelleting plants and briquetting mills are modular and their TPD capacity can easily be increased by adding on more units. Smaller mobile pelleting plants of up to 3 TPD costing around US$ 27,000 and bigger briquetting mills are also available and/or could be tailor made. India and China are the leading manufacturers and suppliers of most pelleting and briquetting technologies currently on the market.

The pelleting or briquetting investment project will also require a half hectare (5,000 sqm) of land, to house the pelleting or briquetting equipment and buildings occupying a total area of 1,200 sqm, comprising the plant (150 sqm), storage (1,000 sqm) and offices (50s-qm). The remainder of the land is reserved for raw materials bulking and future expansion. The cost of the land and the structures to accommodate the plant is estimated to cost US$ 17,750. Table 5 shows the proposed land utilization and costs.

Table 5: Proposed Land Utilization for a Briquetting Mill or Pelleting Plant

Design Plan	
Space (SQM):	
Land Area	5,000.00
Plant and Buildings	1,200.00

Briquettes	Floor Coverage	Size (SQM)	Cost/SQM ($)	Cost ($)
Plant	12.50%	150.00	30	4,500.00
Storage	83.33%	1,000.00	10	10,000.00
Offices	4.17%	50.00	15	750.00
Land		5,000.00	0.5	2,500.00
TOTAL				17,750.00

Source: Author's calculations

Table 6 shows estimated total project development costs for an 8 TPD briquetting plant of US$ 113,688. This amount includes costs for the land and building, plant and equipment and assorted equipment such as tractor and trailer, light truck and a raw materials chipper. Project development fees are assumed to be 5% of all the other capital costs. The detailed project costs for a pelleting plant are attached as Annex 1.

Table 6: Total Briquetting Plant Establishment Costs

Capital Expenditure		
Capital Costs		
Land and Building	USD	17,750.00
Plant & Equipment	USD	40,000.00
Hammer Mill	USD	10,000.00
Tractor & Trailer	USD	18,000.00
Light Truck	USD	15,000.00
Chipper	USD	4,000.00
Brailing Machine	USD	4,000.00
Project Development Fees	USD	4,937.50
TOTAL	USD	113,687.50

Source: Author's calculations

3.2.2. Operational Costs

The main operational cost centres for a pelleting plant or a briquetting mill will include:

- Salaries and wages for up to 6-8 labourers, 2 skilled machine operators, a supervisor and 2 drivers. Salaries and wages will account for 6% of total operational costs;
- Electricity costs which at the estimated daily consumption rate of 25-30 units/hour will account for 7% of total operational costs;
- Repairs and maintenance which are estimated at 10% of total operational costs;
- Marketing and selling costs estimated at 20% of total operational costs;
- Packaging costs estimated at 1% of total operational costs;
- Raw materials costs have been estimated to account for 40% of total operational costs; and
- General expenses estimated at 20% of total operational costs.

Table 7 presents the proposed operational cost structure for the proposed pelleting or briquetting mill.

Table 7: Proposed Briquetting Plant Operational Cost Structure

Operational Expenditure	
Variable Costs (Percentage of total costs)	
Raw Materials	40%
Electricity	7%
Wages and Salaries	6%
Marketing & Selling costs	20%
Repairs and Maintenance	10%
Packaging	1%
General Expenses	16%
Profit margin (Margin after all operational expenses)	18%

Source: Author's calculations

With the above operational cost structure, the proposed briquetting model assumes a conservative profit margin of 18%. This profit margin means that 82% of the turnover is taken up by operational costs, which gives the model some flexibility in covering any unforeseen costs early in the project.

Table 8 provides the detailed operational costs for the proposed briquetting mill.

Table 8: Detailed Briquetting Plant Revenue and Operational Costs

Year	1	2	3	4	5	6
Revenue (USD)						
Sales	168,000.00	212,419.20	268,582.84	339,596.14	429,385.36	468,030.04
Other Income						
Total Revenues	**168,000.00**	**212,419.20**	**268,582.84**	**339,596.14**	**429,385.36**	**468,030.04**
Operating Costs						
Raw Materials	55,104.00	69,673.50	88,095.17	111,387.53	140,838.40	153,513.85
Electricity	9,643.20	12,192.86	15,416.65	19,492.82	24,646.72	26,864.92
Wages and Salaries	8,265.60	10,451.02	13,214.28	16,708.13	21,125.76	23,027.08
Marketing & Selling costs	27,552.00	34,836.75	44,047.59	55,693.77	70,419.20	76,756.93
Repairs and Maintenance	13,776.00	17,418.37	22,023.79	27,846.88	35,209.60	38,378.46
Packaging	1,377.60	1,741.84	2,202.38	2,784.69	3,520.96	3,837.85
General Expenses	22,041.60	27,869.40	35,238.07	44,555.01	56,335.36	61,405.54
Total Operating Expenses	**137,760.00**	**174,183.74**	**220,237.93**	**278,468.83**	**352,095.99**	**383,784.63**
Earnings Before Interest and tax (EBIT)	**30,240.00**	**38,235.46**	**48,344.91**	**61,127.30**	**77,289.36**	**84,245.41**
Debt Service:						
Interest	7,503.38	6,555.12	5,502.57	4,334.23	3,037.37	1,597.86
Principal	8,620.46	9,568.71	10,621.27	11,789.61	13,086.47	14,525.98
Total Debt Service	**16,123.84**	**16,123.84**	**16,123.84**	**16,123.84**	**16,123.84**	**16,123.84**
Cashflow Available to Equity (Surplus/Deficit)	**14,116.16**	**22,111.62**	**32,221.07**	**45,003.47**	**61,165.53**	**68,121.57**

Source: Author's calculations

3.3 Production and Revenue

The proposed 8 TPD is expected to start producing briquettes at 1,200 MT and will increase at an annual rate of 16%. The selling price has been set at US$ 140 per MT and is expected to increase by approximately 9% due to inflation-related changes. The 1,200 MT of briquettes will therefore be worth approximately US$ 168,000. Table 8 illustrates the expected sales revenue from briquettes, with a 16% annual increase in output until year 6.

The profiled pelleting plant on the other hand is expected to produce an initial quantity of is 960 MT of pellets during its first year, during which it is expected to operate for a maximum of five months. Initial pellets production volume is expected to increase at an annual rate of 16%. At US$ 140 per ton, year one pellets output will be valued at US$ 134,400 (see Annex 1).

3.4 Financing Structure and Terms

A blended financing of 40% (US$ 41,475) equity i.e. a combination of the grant funds and shareholder contribution, and 60% (US$ 62,213) of debt financing is being proposed for the planned briquetting plant investment. For evaluation purposes, the duration of the project was assumed to be six years. The debt was also assumed to run for this period.

It was further assumed that the cost of equity is 10%, while the cost of debt is 11%. This resulted in a weighted average cost of capital (WACC) of 8.3%. The WACC depicts what the project costs to develop. For calculation of net present value, the model assumed a required rate of return of 9%. The current interest rate on Zambia's Eurobonds was used as a guide for the required rate of return. Zambia's Eurobonds are currently hovering at interest rates of approximately 8.5% per annum. See Table 9 for the assumptions underlying these calculations.

Table 9: Proposed Investment Structure and Cost of Capital

Funding		
Equity portion		40%
Debt Portion		60%
Loan Tenure	Years	6
Equity	USD	45,475
Debt	USD	68,213
Project Cost	USD	113,688
Cost of equity (Re)		10%
Cost of Debt (Rd)		11%
Tax Rate		35%
Required Rate of return		9%
Weighted Average Cost of Capital (WACC)		8.3%

Source: Author's calculations

3.5. Investment Viability Assessment

Financial viability analysis of the proposed 8 TPD briquetting mill investment project was done using: i) net present value (NPV); ii) internal rate of return (IRR); and iii) the pay-back period (PBP). Viability of the proposed project was further assessed by calculating the interest cover ratio (ICR) and the debt service cover ratio (DSCR). Results of the above analyses are summarised in the subsections below.

3.5.1. Net Present Value

Net Present Value (NPV) was used to assess the added value to be generated by the proposed cotton stalks and other biomass briquetting investment project. NPV calculation was based on assumption of 9% as a required rate of return, i.e. based on Zambia's Eurobonds prevailing interest rates, which are hovering at approximately 8.5% per annum (Bloomberg, 2018)

Results show that, after repaying capital investments, operating costs and debt, the proposed biomass briquetting project has an NPV of US$ 65,478 after six years.

3.5.2. Internal Rate of Return

Internal rate of return (IRR) was another metric which was used to assess financial viability of the proposed cotton stalks and other biomass briquetting investment project. As a viability metric IRR measures the annual return that the project would be generating for the project investors/owners. Put differently, a measure of the maximum cost of the fundraising activity, in order to maintain project profitability.

The proposed cotton stalks and other biomass briquetting investment project has an IRR of 24.6%, a much higher figure than the 8.3% WACC. This means that the project's return is much higher than the cost of setting up the project and thus profitable to the investor.

3.5.3. Pay Back Period

Payback period (PBP) i.e. the time period required to recover the initial project investment costs, was another investment viability analysis tool which was used. Results of this analysis showed that the proposed cotton stalks and other biomass briquetting investment project has a PBP of 3.67 years, i.e. length of time that is required for the project to recover the initial investment.

3.5.4. Debt Servicing

Debt servicing analysis was also done to examine if the proposed project would be able to sustain the debt placed on it, using the interest cover ratio (ICR), i.e. capacity of the project is able to pay interest on the debt outstanding; and the debt service coverage ratio (DSCR) i.e. ability to pay both its principal and interest obligations from any debt obtained.

An interest cover ratio (ICR) greater than 1 means that the project is able to service its interest obligations. An ICR of 1.5 or lower is regarded as a risk. A DSCR above 1 means that the project is able to pay its debt obligations from its operating cash-flows, but most financiers require a minimum DSCR of 1.5.

Results of the above debt servicing analysis exercise show that the proposed briquetting mill has an interest cover ratio (ICR) of above 4.42 which means the project is able to comfortably meet its interest repayments during the period of the loan. The briquetting mill has also a DSCR above 2 in the entire period of the loan period. Table 10 summarises the debt servicing analysis results for the proposed project during the proposed six-year project and debt period.

Table 10: Interest Cover and Debt Servicing Ratios

Year	1	2	3	4	5	6
Interest Cover Ratio	4.42	6.40	9.63	15.46	27.90	57.81
Debt Service Cover Ratio	2.60	2.60	3.29	4.16	5.26	5.73

Source: Author's calculations

3.6 Socio and Development Impact

The proposed pelleting plant and briquetting mill investment projects were also evaluated for their alignment with national development priorities, jobs creation potential, benefits to local community players, and for their ecological soundness. Results of this appraisal exercise are summarized below.

3.6.1 Alignment to Development Priorities

Proposed investments in cotton stalks and other biomass processing into solid bioenergy for cooking and heating fits perfectly well with Zambia's current development priorities seeking to promote value addition of most agricultural products; jobs and wealth creation especially among youths and women in rural areas; and contribute towards Zambia's ongoing efforts of achieving universal access to modern cooking fuels by 2030.

3.6.2 Jobs Creation Potential

Production of cooking and heating energy from biomass creates a number of job opportunities starting with biomass suppliers in rural areas, transporters, briquetting plant workers, wholesalers and retailers. An 8 TPD briquetting mill is capable of creating the following jobs:

- Over 400 youths and women each supplying over 5 MT of cotton stalks and other agro-residues at US$ 25 per ton;
- Up to 6 biomass pre-processing jobs (tractor and biomass chipping and baling operators and loaders);
- Up to 10 unskilled, 2 skilled machine operators, and a supervisor in the biomass processing plant/mill;
- Up to 3 drivers for value-added products distribution/transportation to markets; and
- Many more. Indirect jobs in wholesaling and retailing of biomass pellets and briquettes.

3.6.3 Community Benefits and Transformation

Processing cotton stalks and other biomass into pellets and briquettes is a transformative venture capable of providing farmers and entrepreneurs an additional source of income. At 2,400 MT production per year, an 8 TPD briquetting mill is capable of contributing up to US$ 60,000 income to biomass producers. Once well-established cotton stalks processing will provide cotton farmers with additional income ranging from US$ 25 – 75 per hectare. This value addition of cotton by-product will ultimately help revitalize smallholder farmers' interest in growing cotton.

Cotton stalks and other biomass value addition investments will also contribute up to US$ 36,000 income to biomass pre-processors (chipping and transporter/distributors) to the processing mill. This will bring the potential income from biomass supplying and pre-processing close to US$ 100,000 for each 8 TPD cotton stalks briquetting plant.

Cotton stalks processing will be done and during after cotton harvesting when most labour from rural youths and women is idle. This is meant to make maximum use of cotton stalks and other agro-residues which currently are mostly destroyed.

Pellets and briquettes from cotton stalks and other agro-residues can also be produced and sold at up to US$ 20 per MT lower than charcoal, assuming a cost-effective supply of raw materials. Based on an average calorific value of 4,100 kCal/kg, 2,400 MT of cotton-based pellets would result in a savings of US$ 48,000, relative to charcoal.

By providing cheaper, cleaner and more efficient substitute to firewood and charcoal, cotton stalks value addition technologies are also capable of modernizing cooking dynamics in most rural communities. With time and enhanced product promotion, cooking pellets can lead to increased adoption of modern energy-saving cooking stoves by low-income and rural households in local communities hit with cooking fuel shortages.

3.6.4 Ecological Soundness

Recent studies (Tembo, Mulenga, & Sitko, 2015) indicated that Zambia is losing about 0.62% of its forests annually mainly due to wood extraction for charcoal and firewood, and agricultural land expansion. With 59.1% (over 767,000) urban households depending on charcoal and 85% of rural households using firewood for cooking and heating (CSO, 2015) Zambia is poised to continue losing its forest lands as population and urbanization continue rising.

Cotton stalks and other biomass pellets and briquettes provide cheaper, cleaner, more calorific, and eco-friendly cooking and heating fuels, which can replace use of charcoal and firewood. By providing smallholder farmers with additional income, value addition of cotton stalks and other biomass will help attenuate the risks they face related to low crop yields and provide them with a substitute for fuelwood and, thus, deforestation.

Cooking and heating pellets and briquettes made out of cotton stalks and other biomass have comparable calorific values: an average of 4,100 kcal/kg for biomass pellets and briquettes, compared to 3,500kcal/kg for firewood and double that for charcoal. Biomass fuels also emit less smoke, making them a more efficient and cleaner cooking fuel. Cotton stalks and other biomass pellets and briquettes are thus an ecologically sound alternative to charcoal and firewood.

4. Legal and Policy Environment

Zambia has a range of supportive national policies and an adequate legal corpus for the planned investments in biomass processing into modern cooking and heating fuels. Key among the development policies is Zambia's Seventh National Development Plan (SNDP 2017-21).

The SNDP 2017-21 sets out Zambia's envisioned development agenda anchored on creating a diversified and resilient Zambian economy for sustained growth and socio-economic transformation driven, among others, by agriculture, tourism, manufacturing and mining. The SNDP plans attaining these goals through value addition and industrialisation of agriculture and tourism, amongst other sectors with high growth, poverty reduction and job creation potential. The SNDP also seeks and aspires for private-sector driven economic development while Government continues playing its role of improving the policy and business environment. The SNDP further provides for key reforms in land administration and management, financial sector, business regulation, labour market, public service, ICT and trade facilitation.

Cotton stalks and other biomass processing into cleaner and more efficient cooking and heating fuel is in line with the SNDP 2017-21 goals and objectives. Through increased investments in value addition and industrialisation of cotton by-products, the proposed cotton stalks processing into pellets and briquettes is expected to spawn improvements and positive impacts on: i) employment creation especially for rural women and youths; and ii) wealth creation across all cooking energy value chain players.

The 2nd National Agriculture Policy (NAP) is another key national development policy which seeks to develop "an efficient, competitive and sustainable agricultural sector, which assures food and nutrition security, increased employment opportunities and incomes". Improved cotton stalks processing is also in line with the NAP prime objective increased employment opportunities and incomes.

The proposed cotton stalks processing investment projects also fits well with the National Industrial Policy 2018 (NIP), which seeks to transform Zambia "*from a producer and exporter of primary products into a net exporter of value-added goods utilizing local primary resources with increased citizens' participation*". Specifically, the NIP aims at increasing growth of the manufacturing sector from an average of 5% to 20% and its contribution to GDP from 8% to 15% by 2027. NIP implementation is expected to stimulate and encourage value addition activities on primary commodities as a means of increasing national export earnings and creating employment opportunities and ultimately transforming the Zambian economy into a diversified and competitive industrialized economy well integrated into the international trading system. Cotton is one of the eight manufacturing subsectors prioritized under the National Industrial Policy 2018.

The planned cotton stalks and other biomass value addition investment projects are also in line with Zambia's Youth Development Policy which seeks to promote the economic participation of Zambian youths in national development through employment creation and entrepreneurship development. Once formalized, cotton stalks and other biomass processing provides better avenues for poverty and vulnerability reduction, offers enhanced self-employment opportunities, promotes entrepreneurship, and remains as one of the few local based enterprises with better employment multiplier effects due to higher returns on investment.

Zambia has adequate legal corpus to facilitate and nurture planned investments in cotton stalks and biomass processing into cooking and heating fuel. Primary legal frameworks include the Zambia Development Agency Act which facilitate MSMEs development, investment promotion and trade; the Citizens economic Empowerment Act of 2006; the Business Regulatory Act of 2014; the Compulsory Standards Act of 2017; the National Technical Regulations Act of 2017; and the Patents Act of 2016. Current investment, contract, labour competition, environmental management, consumer protection and metrology laws are also adequate to support the planned investments in cotton stalks and other biomass processing into modern cooking and heating fuels in Zambia.

5. Risks and Mitigation

Success of the proposed biomass processing investments will hinge on cost-effective collection, pre-processing and delivery of raw materials to the pelleting/briquetting plant. Other key success factors will include the robust product development and promotion, and the competitiveness of the proposed pellets and briquettes. The matrix below summarizes major risks which will require to be mitigated if the proposed investments are to be viable and sustainable.

Risk	Description	Proposed Mitigation Measure(s)
Short supply of adequate, affordable raw materials	Poor cotton stalks volumes due to declining yields and competing uses for other agro-residues Small quantities of raw materials to collect from many farmers	Diversified raw materials to include: Soybean straws in May/June, Maize stover and cobs starting July/August, Cotton stalks August/September. Use of raw materials aggregators, Special price offers for raw materials supply
Raw materials transportation challenges	Bulk raw material volumes over a long distance to pelleting or briquetting plants	Use of mobile raw materials processing/chipping Customised pre-processed raw materials transportation and other logistics
Limited operation window	Raw materials are readily available only during harvesting season	Investment into affordable raw materials storage, and Investment into raw materials driers
Poor demand for pellets and briquettes	Poor adoption among housed and industrial pellets and briquettes users, and lack of offtake market for produced pellets and briquettes, Continued and increasing fuelwood use	Robust pellets promotion as alternative cooking energy among households Promotion of briquettes as heating energy alternative for industrial boiler users Strategic alliances with energy-saving technologies promoters and environmental conservationists
Competition from existing pellets and briquettes	Inability to compete with pellets and briquettes produced from sawdust and imports	Strategic locations: Closer to demand centres of Eastern, Southern and Central Provinces for low output transportation costs; Within high potential cotton, soybeans and maize production areas for effective raw materials collection/sourcing; Use of a market penetration pricing of US$ 40/MT, i.e. US$ 20/MT less than that of charcoal
Cost of financing	Unaffordable high cost of financing rendering the proposed investments into pelleting and briquetting plants economically unviable	Blended financing/investment structure of 40% equity and 60% debt financing Preference for impact and other low-cost debt financing sources, Up to six years project period.
Pelleting and briquetting technology challenges	Likelihood of option for cheaper and unproven pelleting and briquetting technologies which will fail to produce required products	Use of tested/proven pelleting and briquetting technologies from countries leading in biomass pellets and briquetting R&D and promotion; and Extensive technologies user trainings for maximised production efficiencies and product performance

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Annex 1: 6.4 TPD Pelleting Plant – Financial Model

A.1.1. Plant Size and cost

A 6.4 tonnes per day model was developed for the pellets. It was assumed that there would 300 days of production per annum. The total land required for this plant is 3,000 square metres. Of this, the plant and buildings will take up 650 square metres (Plant 100 Sqm, Storage 500 Sqm, and Offices 50 Sqm).

Table 11: Land Requirement for a 6.4 TPD Pelleting Plant

Design Plan	
Space (SQM):	
Land Area	3,000.00
Plant and Buildings	650.00

Pellets	Floor Coverage	Size (SQM)	Cost/SQM ($)	Cost ($)
Plant	15.38%	100.00	30	3,000.00
Storage	76.92%	500.00	10	5,000.00
Offices	7.69%	50.00	15	750.00
Land		3,000.00	0.5	1,500.00
TOTAL				**10,250.00**

Source: Author's calculations

The cost of the land and the structures to accommodate the plant is estimated to cost approximately US$ 10,250. The other capital expenses are estimated as below:

Table 12: Estimated Capital Expenses for a 6.4 TPD Pelleting Plant

Capital Expenditure		
Capital Costs		
Land and Building	USD	10,250.00
Plant & Equipment	USD	45,000.00
Hammer Mill	USD	10,000.00
Tractor & Trailer	USD	18,000.00
Light Truck	USD	15,000.00
Chipper	USD	4,000.00
Brailing Machine	USD	4,000.00
Project Development Fees	USD	4,812.50
TOTAL	USD	**111,062.50**

Source: Author's calculations

The total project development costs are estimated at US$ 111,062.50. This cost also includes costs for the land and building, plant and equipment, hammer mill and assorted equipment such as tractor and trailer, light truck, chipper and brailing machine. Project development fees are assumed to be 5 percent of all the other costs.

A.1.2. Volume/Revenues

It is assumed that the initial quantity of pellets produced is 960 metric tonnes per annum. It was further assumed that this production will increase at an annual rate of 16%.

Table 13: Pellets Production and Sales Volumes

Volume/Revenues		
Base Sales Value -Initial	Metric Tonnes	960
Sales Volume Growth Rate	% p.a	16%

Production capacity (TPD)	Days	Annual production	Price/MT ($)	Total Sales $
6.4	300	1,920	140	268,800

Revenue:		
Price/MT	USD	140

Source: Author's calculations

The selling price for the pellets has been set at US$ 140 per tonne. This is about US$ 20 less than a tonne of charcoal. The selling price is expected to increase by approximately 9 percent per annum due to inflation related changes.

A.1.3. Operational Expenses

The model assumed a conservative profit margin of 18%. This is deemed as conservative because the bulk of the raw materials will be obtained at almost zero cost. This profit margin means that 82% of the turnover is taken up by operational costs, see cost breakdown in table 10 below.

Table 14: Operational Cost Estimates for a 6.4 TPD Pelleting Plant

Operational Expenditure	
Variable Costs (Percentage of total costs)	
Raw Materials	40%
Electricity	7%
Wages and Salaries	6%
Marketing & Selling costs	20%
Repairs and Maintenance	10%
Packaging	1%
General Expenses	16%
Profit margin (Margin after all operational Expenses)	18%

Source: Author's calculations

A.1.4. Funding and Investment Appraisal

A.1.4.1 Funding

A blended investment structure of 40% equity and 60% debt financing was proposed as outlined in table 11 below.

Table 15: Proposed Investment Structure for a 6.4 TPD Pelleting Plant

Funding		
Equity portion		40%
Debt Portion		60%
Loan Tenure	Years	6
Equity	USD	44,425
Debt	USD	66,638
Project Cost	USD	**111,063**
Cost of equity (Re)		10%
Cost of Debt (Rd)		11%
Tax Rate		35%
Required Rate of return		9%
Weighted Average Cost of Capital (WACC)		8.3%

Source: Author's calculations

The model assumed that 40 percent of the project cost will be in the form of equity (US$ 44,425). This being a combination of the grant funds and shareholder contribution. The debt will make up 60% of the project cost (US$ 66,638). For evaluation purposes, the duration of the project was assumed to be six years. The debt was also assumed to run for this period. It was further assumed that the cost of equity is 10% while the cost of debt is 11%. This resulted in a weighted average cost of capital (WACC) of 8.3%. The WACC depicts what the project costs to develop.

For calculation of net present value, the model assumed a required rate of return of 9%. The interest rate currently prevailing on Zambia's Eurobonds is what was used as a guide for the required rate of return. Zambia's Eurobonds are currently hovering at interest rates of approximately 8.5% per annum.

A.1.4.2 Investment Appraisal

Given the various parameters. The project has a net present value (NPV) of US$ 10,181.78 after six years. The NPV is a tool used to calculate the current value of a future amount of money by compounding interest. This means that the project will generate over US$ 10,000 for the project owners. This is over and above the set up and running costs as well as the debt.

Table 16: Investment Viability Appraisal Ratios for a 6.4 TPD Pelleting Plant

Results		
Net Present Value (NPV)	USD	**10,181.78**
Internal Rate of Return (IRR)		**11.5%**
Payback Period	Years	**4.69**

Source: Author's calculations

The project has an internal rate of return (IRR) of 11.5%. The IRR estimates the profitability of the project. This metric shows the annual return that the project is generating for the project owners. The 11.5% it generates is much higher than the WACC. This means that the project's return is much higher than the cost of setting up the project.

The project has a payback period of 4.69 years. This is the length of time that is required for the project to recover the initial outlay.

A.1.4.3 Debt Servicing

From a financier's perspective, it is important to consider whether the project would be able to sustain debt that is placed on it. In order to do this, two measures are commonly used. The interest cover ratio (ICR) and the debt service coverage ratio (DSCR). The interest cover ratio is used to determine how easily the project is able to pay interest on the debt outstanding. It is obtained by dividing the project's Earnings Before interest and tax (EBIT) and the project's interest expense for the same period. An ICR greater than 1 means that the project is able to service its interest obligations. An ICR of 1.5 or lower is regarded as a risk. In the results obtained, the pelleting plant is able to comfortably meet its interest repayments during the period of the loan.

Table 17: Interest Cover and Debt Servicing Ratios for the Proposed 6.4 TPD Pelleting Plant

Year	1	2	3	4	5	6
Interest Cover Ratio	3.30	4.78	7.19	11.55	20.84	43.18
Debt Service Cover Ratio	1.54	1.94	2.46	3.10	3.93	4.28

Source: Author's calculations

The DSCR assesses the project's ability to pay both its principal and interest obligations from any debt obtained. It is calculated by dividing the EBIT by the project's total debt repayment (both interest and principal payments). A DSCR above 1 means that the project is able to pay its debt obligations from its operating cashflows. Most financiers require a minimum DSCR of 1.5. The pelleting plant's DSCR is above 1.5 in the entire period of the loan.

Table 18: Detailed Revenue and Operational Costs for the Proposed 6.4 TPD Pelleting Plant

Year	1	2	3	4	5	6
Revenue (USD)						
Sales	134,400.00	169,935.36	214,866.27	271,676.91	343,508.29	374,424.03
Other Income						
Total Revenues	**134,400.00**	**169,935.36**	**214,866.27**	**271,676.91**	**343,508.29**	**374,424.03**
Operating Costs						
Raw Materials	44,083.20	55,738.80	70,476.14	89,110.03	112,670.72	122,811.08
Electricity	7,714.56	9,754.29	12,333.32	15,594.25	19,717.38	21,491.94
Wages and Salaries	6,612.48	8,360.82	10,571.42	13,366.50	16,900.61	18,421.66
Marketing & Selling costs	22,041.60	27,869.40	35,238.07	44,555.01	56,335.36	61,405.54
Repairs and Maintenance	11,020.80	13,934.70	17,619.03	22,277.51	28,167.68	30,702.77
Packaging	1,102.08	1,393.47	1,761.90	2,227.75	2,816.77	3,070.28
General Expenses	17,633.28	22,295.52	28,190.45	35,644.01	45,068.29	49,124.43
Total	110,208.00	139,347.00	176,190.34	222,775.07	281,676.79	307,027.71
Earnings Before Interest and Tax (EBIT)	**24,192.00**	**30,588.36**	**38,675.93**	**48,901.84**	**61,831.49**	**67,396.33**
Debt Service:						
Interest	7,330.13	6,403.77	5,375.51	4,234.15	2,967.24	1,560.96
Principal	8,421.42	9,347.77	10,376.03	11,517.39	12,784.31	14,190.58
Total	**15,751.54**	**15,751.54**	**15,751.54**	**15,751.54**	**15,751.54**	**15,751.54**
Cashflow Available to Equity (Surplus/Deficit)	**8,440.46**	**14,836.82**	**22,924.39**	**33,150.30**	**46,079.95**	**51,644.78**

Source: Author's calculations

Annex 2: 8 TPD Briquetting Plant – Financial Model

A.2.1. Plant Size and cost

Model developed for production of 8 tonnes per day. It is assumed that there will be 300 days of production per annum. The total land required for this plant is 5,000 square metres. Of this total, the plant and buildings will take up 1,200 square metres (Plant 150 Sqm, Storage1,000 Sqm, and Offices 50 Sqm).

Table 19: Land Requirement for an 8 TPD Briquetting Plant

Design Plan	
Space (SQM):	
Land Area	5,000.00
Plant and Buildings	1,200.00

Briquettes	Floor Coverage	Size (SQM)	Cost/SQM ($)	Cost ($)
Plant	12.50%	150.00	30	4,500.00
Storage	83.33%	1,000.00	10	10,000.00
Offices	4.17%	50.00	15	750.00
Land		5,000.00	0.5	2,500.00
TOTAL				17,750.00

Source: Author's calculations

The land and the structures to accommodate the plant is estimated to cost approximately US$ 17,750.00. The other capital expenses are estimated as contained in table 20 below:

Table 20: Estimated Capital Expenses for an 8 TPD Briquetting Plant

Capital Expenditure		
Capital Costs		
Land and Building	USD	17,750.00
Plant & Equipment	USD	40,000.00
Hammer Mill	USD	10,000.00
Tractor & Trailer	USD	18,000.00
Light Truck	USD	15,000.00
Chipper	USD	4,000.00
Brailing Machine	USD	4,000.00
Project Development Fees	USD	4,937.50
TOTAL	USD	113,687.50

Source: Author's calculations

The total project development costs are estimated at US$ 113,687.50. This cost also includes costs for the land and building, plant and equipment, hammer mill and assorted equipment such as tractor and trailer, light truck, chipper and brailing machine. Project development fees are assumed to be 5 percent of all the other costs.

A.2.2. Volume/Revenues

It is assumed that the initial quantity of briquettes produced in 1,200 metric tonnes per annum. This production will increase at an annual rate of 16%.

Table 21: Briquettes Production and Sales Volumes

Volume/Revenues		
Base Sales Value -Initial	Metric Tonnes	1,200.00
Sales Volume Growth Rate	% p.a.	16%

Production capacity (TPD)	Days	Annual production	Price/MT ($)	Total Sales
8	300	2,400	140	336,000

Revenue:		
Price/MT	USD	140

Source: Author's calculations

The selling price for the briquettes has been set US$ 140 per tonne. This is about US$ 20 less than a tonne of charcoal. The selling price is expected to increase by approximately 9 percent due to inflation related changes.

A.2.3. Operational Expenses

The model assumed a conservative profit margin of 18%. This is deemed as conservative because the bulk of the raw materials will be obtained at almost zero cost. This profit margin means that 82% of the turnover is taken up by operational costs.

Table 22: Operational Cost Estimates for an 8 TPD Briquetting Plant

Operational Expenditure	
Variable Costs (Percentage of total costs)	
Raw Materials	40%
Electricity	7%
Wages and Salaries	6%
Marketing & Selling costs	20%
Repairs and Maintenance	10%
Packaging	1%
General Expenses	16%
Profit margin (Margin after all operational Expenses)	18%

Source: Author's calculations

The operational costs were broken down as per categories in the table above.

A.2.4. Funding and Investment Appraisal

A.2.4.1 Funding

Table 23: Proposed Investment Structure for an 8 TPD Briquetting Plant

Funding		
Equity portion		40%
Debt Portion		60%
Loan Tenure	Years	6
Equity	USD	45,475
Debt	USD	68,213
Project Cost	USD	113,688
Cost of equity (Re)		10%
Cost of Debt (Rd)		11%
Tax Rate		35%
Required Rate of return		9%
Weighted Average Cost of Capital (WACC)		8.3%

Source: Author's calculations

The model assumed that 40 percent of the project cost will be in the form of equity (US$ 45,475). This being a combination of the grant funds and shareholder contribution. The debt will make up 60% of the project cost (US$ 68,213). For evaluation purposes, the duration of the project was assumed to be six years. The debt was also assumed to run for this period. It was further assumed that the cost of equity is 10% while the cost of debt is 11%. This resulted in a weighted average cost of capital (WACC) of 8.3%. The WACC depicts what the project costs to develop.

For calculation of net present value (NPV), the model assumed a required rate of return of 9%. The interest rate currently prevailing on Zambia's Eurobonds is what was used as a guide for the required rate of return. Zambia's Eurobonds are currently hovering at interest rates of approximately 8.5% per annum.

A.2.4.2 Investment Appraisal

Given the various parameters. The project has a net present value of US$ 50,466.29 after six years. The NPV is a metric used to calculate the current value of a future amount of money by compounding interest. This means that the project will generate over US$ 50,000 for the project owners. This is over and above the set up and running costs as well as the debt.

Table 24: Investment Viability Appraisal Ratios for an 8 TPD Pelleting Plant

Results		
Net Present Value (NPV)	USD	50,466.29
Internal Rate of Return (IRR)		20.3%
Payback Period	Years	4.00

Source: Author's calculations

The project has an internal rate of return (IRR) of 20.3%. The IRR estimates the profitability of the project. This metric shows the annual return that the project is generating for the project owners. The 20.3% it generates is much higher than the WACC. This means that the project's return is much higher than the cost of setting up the project.

The project has a payback period of 4 years. This is the length of time that is required for the project to recover the initial outlay.

A.2.4.3 Debt Servicing

From a financier's perspective, it is important to consider whether the project would be able to sustain debt that is placed on it. In order to do this, two measures are commonly used. The interest cover ratio (ICR) and the debt service coverage ratio (DSCR). The interest cover ratio is used to determine how easily the project can pay interest on the debt outstanding. It is obtained by dividing the project's Earnings Before interest and tax (EBIT) and the project's interest expense for the same period. An ICR greater than 1 means that the project is able to service its interest obligations. An ICR of 1.5 or lower is regarded as a risk. In the results obtained, the briquetting plant is able to comfortably meet its interest repayments during the period of the loan.

Table 25: Interest Cover and Debt Servicing Ratios for the Proposed 8 TPD Briquetting Plant

Year	1	2	3	4	5	6
Interest Cover Ratio	4.03	5.83	8.79	14.10	25.45	52.72
Debt Service Cover Ratio	1.88	2.37	3.00	3.79	4.79	5.22

Source: Author's calculations

The DSCR assesses the project's ability to pay both its principal and interest obligations from any debt obtained. It is calculated by dividing the EBIT by the project's total debt repayment (both interest and principal payments). A DSCR above 1 means that the project is able to pay its debt obligations from its operating cashflows. Most financiers require a minimum DSCR of 1.5. The briquetting plant's DSCR is comfortably above 1.5 in the entire period of the loan.

Table 26: Detailed Revenue and Operational Costs for the Proposed 8 TPD Briquetting Plant

Year	1	2	3	4	5	6
Revenue (USD)						
Sales	168,000.00	212,419.20	268,582.84	339,596.14	429,385.36	468,030.04
Other Income						
Total Revenues	**168,000.00**	**212,419.20**	**268,582.84**	**339,596.14**	**429,385.36**	**468,030.04**
Operating Costs						
Raw Materials	55,104.00	69,673.50	88,095.17	111,387.53	140,838.40	153,513.85
Electricity	9,643.20	12,192.86	15,416.65	19,492.82	24,646.72	26,864.92
Wages and Salaries	8,265.60	10,451.02	13,214.28	16,708.13	21,125.76	23,027.08
Marketing & Selling costs	27,552.00	34,836.75	44,047.59	55,693.77	70,419.20	76,756.93
Repairs and Maintenance	13,776.00	17,418.37	22,023.79	27,846.88	35,209.60	38,378.46
Packaging	1,377.60	1,741.84	2,202.38	2,784.69	3,520.96	3,837.85
General Expenses	22,041.60	27,869.40	35,238.07	44,555.01	56,335.36	61,405.54
Total Operating Expenses	**137,760.00**	**174,183.74**	**220,237.93**	**278,468.83**	**352,095.99**	**383,784.63**
Earnings Before Interest and tax (EBIT)	**30,240.00**	**38,235.46**	**48,344.91**	**61,127.30**	**77,289.36**	**84,245.41**
Debt Service:						
Interest	7,503.38	6,555.12	5,502.57	4,334.23	3,037.37	1,597.86
Principal	8,620.46	9,568.71	10,621.27	11,789.61	13,086.47	14,525.98
Total Debt Service	**16,123.84**	**16,123.84**	**16,123.84**	**16,123.84**	**16,123.84**	**16,123.84**
Cashflow Available to Equity (Surplus/Deficit)	**14,116.16**	**22,111.62**	**32,221.07**	**45,003.47**	**61,165.53**	**68,121.57**

Source: Author's calculations

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