Situational Analysis for Producing Biomass Charcoal Briquettes in Zimbabwe

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Abstract

Charcoal briquettes made by compacting agricultural waste are one of the most environmentally friendly and cost effective ways of reducing a nation's dependence on non-renewable sources of energy. This cellulosic biomass waste fuel reduces deforestation by replacing use of wood as a solid fuel. Converting agricultural waste to briquettes controls methane generation from decomposing biomass by flaring it during the carbonization process. A situational analysis was conducted at different companies in Zimbabwe to assess the feasibility of producing charcoal briquettes from waste. Raw material assessment was carried out at Nyanga and Mutare Saw Mills for sawdust, Kwekwe Delta Chibuku for sorghum spent grains and Triangle and Hippo Valley sugarcane mills for baggase. Based on the findings, it was concluded that saw dust generated in Nyanga, Chimanimani and Mutare saw mills is the most abundant raw material which can be used to manufacture charcoal briquettes. The use of non-renewable fuels i.e. coal brings pollution problems which include the emission of greenhouse gases such as carbon dioxide (CO_2) and sulphur dioxide (SO_2). The situational analysis indicated it is feasible to adopt the charcoal briquetting technology if end users are ready to use the product and an appropriate technology like torrefaction is applied.

Keywords: Biomass, charcoal briquettes, agricultural waste, carbonization, situational analysis

1. Introduction

This review covers the situational analysis on the feasibility of setting up a charcoal briquetting plant in Zimbabwe using agricultural waste biomass. The review discusses the findings from industrial visits conducted across the country as well as technical researches into the techno-economic feasibility of the study.

So far, briquetting of biomass has been carried out on a commercial basis in the eastern region, especially in Mutare. It has however faced a number of problems, which are going to be discussed in this document. This review will cover a modification of the product to make charcoal briquettes which are cleaner, more energy efficient as well as having more uses compared to the biomass briquettes. Biomass that has been established to be available at a large scale and technically feasible for starting a charcoal briquette production plant using pine sawdust from Eastern Highlands, spent grains from Delta Beverages as well as charcoal dust from Chimanimani.

Currently, there is a strong worldwide interest in the development of environmentally friendly and profitable technologies that allow the exploitation of renewable energy sources. The availability of agricultural waste feedstock as an energy source presents renewable energy opportunities that could provide an alternative to the use of fossil fuels. The use of this biomass material has an additional importance from climate change because of biomass' potential to be CO_2 neutral.

2. Background to charcoal briquetting

Charcoal briquetting allows use of a wider range of raw materials since carbonisation has been recommended as the preliminary step to briquetting in most researchers. Choice of a binder then becomes a critical factor on the cost of the briquettes. Bonding with starch was proved to be more efficient compared with clay after comparing parameters such as ability to ignite easily without any danger, generation of less smoke, high calorific value, generation of less ash which reduce nuisance during cooking and strength for safe transportation and storage (Siemons, 2011; Zubaru, 2014).

Charcoal as well as briquettes has higher calorific value per unit weight than biomass which makes it more economical to transport over longer distances and allows storage in less space. It is also less liable to deterioration by insects and fungi which attack biomass which makes it ideal fuel for towns and cities (Malimbwi, 2000).

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3. Charcoal briquettes production through torrefaction

Briquette charcoal is a solid fuel from organic matter containing carbon, which has a high calorific value, and can be lit in a long time (Dermibas and Yazini, 2000; Dermibas and Dermibas, 2004). Bio charcoal is charcoal obtained by burning dry biomass without air (pyrolysis). Biomass is organic material derived from living things. Actual biomass can be used directly as a source of heat energy for fuel, but is less efficient because of the small density. Pyrolysis is the chemical decomposition process by using heating in the absence of oxygen. This process is called carbonization process for obtaining carbon or charcoal.

Generated in the pyrolysis process gases, such as CO, CO_2, CH_4, H_2, and light hydrocarbons. Type of gas produced varies depends on the raw materials. For example, coal pyrolysis produce gas such as CO, CO_2, NO, and SO. In large quantities, these gases pollute the environment and endanger human health directly and indirectly. Bio charcoal briquette has several advantages compared to regular (conventional) charcoal, among others:
The ignition of bio charcoal briquette does not produce smoke and odour, so it is practical for the bad economy society who live in cities with inadequate ventilation in their house there is no need to fan bio charcoal after it was on fire and to be ember (Grover and Mishra, 1996; Mwampamba et al., 2013).

3. Current charcoal briquetting situation in Zimbabwe

In Zimbabwe, carbonisation is being done using metal and brick kilns, which are a relatively old technology although if used with properly experienced personnel, it produces a desired product. In addition, Wattle Company, which is the main producer of the charcoal, is facing economic challenges and hence limited production versus the high demand of charcoal in Zimbabwe. Due to this demand gap, some industrial companies are importing charcoal from Zambia and Mozambique. Furthermore, the absence of a legal charcoal producing company is promoting illegal charcoal manufacturing activities

4. Raw material available in Zimbabwe

The raw material is always the beginning of each value chain for processed products. Zimbabwe is endowed with biomass-based waste and in this report we focus on sawdust, sorghum spent grains, bagasse among others.

4.1 Saw dust

Generally, saw dust (heaps shown in Figure 1) is produced in the eastern highlands part of Zimbabwe chiefly in Nyanga, Chimanimani and Mutare. Wattle Company's Nyanga Pine Sawmill which is the largest and conventional sawmill in Zimbabwe. Processing of pine trees to timber produces large quantities of sawdust, cuts chips and shavings and a small percentage is being utilised in boilers to produce steam used for drying timber mainly.

Figure 1: Heaps of sawdust being generated Wattle Company's Nyanga Pine mill.

The excess saw dust and logs are incinerated while the lops and tops are burned in the fields, but heaps of sawdust remain as a nuisance. The production capacity of the Nyanga Pine sawmill is 7000 tonnes/month and that of Mutarazi sawmill is 4000 tonnes where 10-14% is saw dust. Therefore Nyanga Pine sawmill assures provision of a minimum of 700 tonnes per month of sawdust and Mutarazi assures a minimum of 400 tonnes per month. Furthermore, due to limited disposal land and costs associated with its proper disposal, saw dust heaps continue to pile up. These heaps of sawdust faces fire hazards since it

spontaneously combusts during hot seasons and dust pollution. Local city council limits the dumping of sawdust into their dumpsites due to the issue of fire hazards.

4.2 Brewers spent grains

Delta Chibuku in Kwekwe produces sorghum spent grains (masese) as waste in the process of brewing beer. The brewing process produces 3 tonnes per day of spent grains. At the moment, there is no proper disposal of this waste which decays quickly after a small amount of the spent grains is sold to local farmers for use as animal feed. The spent grains are being sold at $20.00 per tonne but end up being disposed to landfills since farmers are failing to purchase all the available stocks. This type of agrobased waste is suitable for densification to make briquettes.

4.3 Sugarcane bagasse

Triangle Estate and Hippo Valley sugarcane mills produce bagasse, in the extraction of sugar juice. The bagasse is a good feedstock for densification to make briquettes however all the bagasse is used to fire the mill's boilers for steam generation used in the production of ethanol and generation of electricity. The company's livestock department also uses a certain amount of bagasse to produce animal feeds.

5. Briquetting technologies in Zimbabwe

Currently in Zimbabwe there is no commercial biomass briquetting plant. Jingura et. al. (2013) also highlighted the absence of operational briquetting schemes and failure of the briquetting schemes since it was not popular with the people. There is little of any systematic information about how briquetting plants have performed in practical operation. Mutare based companies namely Timber Products International (TPI) and Habourside Traders once produced biomass briquettes in 2003 and 2013 respectively. TPI highlighted that the briquetting business ceased since it was not profitable. TPI sold the briquettes to other industrial companies like Karina, Mutare Hospital and in retail supermarkets (i.e. OK, TM, Spar). However extensive marketing across Zimbabwe is needed to have a lucrative briquette selling business. Habourside Company used an Agico briquette maker which compressed sawdust to briquettes shown in Figure 2 at a rate of 400kg per hour but they have ceased to go commercial.

Figure 2: Harbourside Traders pile of Briquettes ready for market

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In the Mutare, Nyanga and the Eastern Highlands area, another impediment to the production of the sawdust briquettes is that the raw sawdust feedstock is being used as a fuel without any further processing which comes at a cost. It is therefore an issue of resistance to change to move away from the cost free use of the agricultural waste as compared to modifying this fuel efficiency by densifying the sawdust. However, briquettes production produces a fuel with high burning efficiency and its marketing will be profitable in areas outside the eastern. The success or failure of briquetting is very dependent upon the agricultural and fuel context in which it is applied so there is only a limited amount of information, which

can be obtained from technical appraisal or from the experience of briquetting plants (Purohit et al., 2006; Jingura et al., 2013). The experience of briquetting in Africa has, so far, been largely confined to a set of isolated projects in Kenya.
The fuels that are being mainly used in Zimbabwe including an assessment of the effectiveness of the use of the fuels. The efficiency was supported by the burners that are normally used for each indicated fuel. Because of the open nature of stoves used for solid fuels (wood and charcoal briquettes), their relative efficiencies are very low. Their everyday usage is mainly due to the low price of the respective burners.

6. Carbonisation (pyrolysis) technology in Zimbabwe

Currently carbonisation of wood into charcoal is being done in Chimanimani by Wattle Mimosa branch. They are using doomed beehive kilns, one made of brick (Figure 3) and the rest made of metal. They are promoting the use of metal kilns because of turnover. Brick kilns produce charcoal in 3 days whilst a metal kiln takes 1and half days, but brick kilns produce better charcoal, which is denser because it allowed less volatiles to escape, compared to metal kilns (Figure 4).

Figure 3: Brick kiln for carbonisation of timber waste at Wattle Company Mimosa.

Figure 4: Metal kiln for carbonisation at Wattle Company Mimosa.

They are currently using half dried wood because they claimed to improve charcoal quality compared to wet and dry wood. Also they are using wattle wood which is dense. They also removed bark to reduce the ash content of the charcoal. They also made sure they would load on a customised pallet to avoid moisture pick up by finished charcoal to preserve quality. However, they operate below capacity because of economic hardships. Furthermore, the waste charcoal is being burnt because there is no briquetting technology in use to bind the waste charcoal fines. Waste charcoal includes the fines and charcoal with high ash content. Currently, briquettes have a very high price because they are being imported. If the price is reduced to half, then it would have the same effectiveness as paraffin as well as LPG gas. Apparently, gas usage has gained much more popularity because it was advertised as the first solution to electricity power shortages, which was clean enough for domestic and urban use. Introduction of efficient stoves would make use of charcoal even cheaper. The energy being used most efficiently is electricity because of the dedicated stoves and appliances. But the problem that has been faced in Zimbabwe has been power shortages which led to load shedding. In addition, the rate at which the urban areas are expanding cannot be matched by electric power connections. That is why gas has been very successfully introduced into the Zimbabwean economy.

7. Charcoal briquettes adoption policy conditions

The policy environment for briquettes is quite different from that of wood charcoal and perhaps less complex. Briquettes are rarely produced directly from standing timber, which practically eliminates the involvement of ministries in charge of forest and natural resources. Instead, ministries overseeing briquettes are those in charge of energy and energy security, health, employment, business and revenue. However, there are no known state-sanctioned incentives to set up and run charcoal briquetting businesses in Zimbabwe. This has limited establishment and growth of the industry in the region. Inefficient, convoluted and unclear regulations for obtaining permits, paying taxes and running this type of business pose additional challenges to producers, especially those operating on a large scale and more likely to attract the interest of government inspectors and licensing authorities.

The absence of national standards to control the quality of briquettes (in terms of moisture content, fixed carbon, ash, volatiles and heating value) slows down market entry for briquettes to some extent. In some cases this has undermined the efforts of newer enterprises that have gone into operation following earlier enterprises' dissemination of low quality briquettes.

8. Charcoal briquettes adoption policy conditions

The first success was adopting a new technology, torrefaction process that makes charcoal briquettes from soft wood. Soft wood such as pine tree is deemed unsuitable for charcoal production since it produces a lower density and low calorific valued charcoal. Currently charcoal is made from hardwood. Wattle trees which produce a high calorific valued and denser charcoal in the market. Torrefaction densifies the biomass to make pine sawdust a viable option for charcoal briquettes. Torrefaction reduces environmental impact of emissions through recycling them to a burner for drying the biomass (Siemons et al., 2011; Sireesh et al., 2016). The problem included emissions from carbonisation process since by-products of charcoal production are pyroacids, primary acetic acid and methanol, tars, heavy oils and water, the majority of which would be emitted into the environment through the kiln exhaust. Other emissions that are also reused include methane, ethane, volatile organic compounds (VOCs) as well as particulate matter (PM). Although torrefaction technologies utilises VOCs and PM, other emissions into air would include carbon monoxide (CO) and carbon dioxide (CO_2) which would have to be minimised carbon imprint of the project. This is because level of these emissions depends mainly on the technology used for the production, the temperature developed during the pyrolysis as well as on the moisture content of the wood (Tumutegyereize et al., 2016).

Moreover, developing a product which is currently being imported is another success story, through upgrading a product that has faced challenges to take off. Making charcoal briquettes is expected to be more profitable through reduction of the current market price by production using local raw-material. It has

been established that a market for charcoal briquettes is available if the torrified material would be of the same quality as coal. Making of bio-coal would be an added advantage of this project over the previous briquettes which were biomass briquettes. Biomass briquettes face stiff competition even from firewood or just use of sawdust using proper stoves. It has been established that charcoal briquette have a better market as opposed to biomass briquettes. Urban houses are also becoming more open to usage of charcoal since it burns almost as smart as gas but would have an added advantage of heating the house. In areas like Harare, charcoal is being imported from Zambia for domestic use and is being sold in our local markets like Epworth where electrification is on the low side. Also industry would be more open to usage of bio-coal as opposed to biomass briquette because it looks and works almost as well as the traditional coal. Challenges would be getting a proper storage facility for the sawdust and its transportation since it is very flammable and dangerous. Challenges might emanate from fire hazards as well as Zimbabwean regulators like the Environmental Management Act (EMA).

Although agreements with sawmills are in their preliminary stages in terms of saw dust collection, nothing concrete has been agreed upon. The reason for failure is due to the fact that this project is currently in the preliminary stages which makes the project team unable to bind to any agreement although sawmills were more than eager to do so. Therefore, legal agreements need to be done on supply of the raw-material and its price before setting up a big plant. The other option includes setting up mobile charcoal briquetting plants since transportation of sawdust might have hazards and would make more locations with heaped sawdust accessible. Challenges are mainly on specifying product usage as well as environmental impact of the project. Therefore there might be need to educate end users on proper usage of the product. Challenges that might arise due to improper usage include carbon monoxide (CO), consistence and timing.

8. Conclusion

The domestic and industrial use of charcoal briquettes as a solid fuel Zimbabwe constitutes an important alternative that should be further developed as it allows for the economic revaluation of biomass waste and the mitigation of greenhouse gas emissions. Raw material for charcoal briquettes is locally available in abundance and technologies like torrefaction can be adopted for the manufacture of these briquettes. The chief raw material was found to be pine saw dust and baggase; however, other biomass feedstock includes sorghum spent grains from breweries across the country and charcoal fines from charcoal processing. The biomass briquetting technology presents positive results of higher bulk density, similar levels of calorific power, less moisture, and low levels of fixed carbon, chlorine and sulphur, promoting a healthier environment for the consumer and the environment. The energy content of biomass briquettes is considered sufficient for domestic and industrial use.

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References

Demirbąs A. and Demirbąs, A. S., Briquetting properties of biomass waste materials, *Energy Sources*, vol. 26, pp. 83–91, 2004. http://dx.doi.org/10.1080/00908310490251918

Demirbaş, A and Yazici, N., Upgraded fuel for domestic heating made from compacting biomass waste materials, *Energy Education Science and Technology*, vol. 5, pp. 73–84, 2000.

Grover, P. D. and Mishra, S. K., *Biomass briquetting: Technology and practices*; RWEDP Field Document no. 46. Food and Agricultural Organization of the United Nations, Bangkok, 1996.

Mwampamba, T. H., Owen, M. and Pigaht, M., Opportunities, challenges and way forward for the charcoal briquette industry in Sub-Saharan Africa, *Energy for Sustainable Development*, vol. 17, no. 2, pp. 158–170, 2013. https://doi.org/10.1016/j.esd.2012.10.006

Jingura, Muzondiwa, R. M., Musademba, D. and Kamusoko, R., A review of the state of biomass energy technologies in Zimbabwe, *Renewable and Sustainable Energy* Reviews, vol. 26, pp. 652–659, 2013. https://doi.org/10.1016/j.rser.2013.05.036

Purohit, P., Tripathi, A. K. and Kandpal, T. C., Energetics of coal substitution by briquettes of agricultural residues, *Energy*, vol. 31, pp. 1321–1331, 2006. https://doi.org/10.1016/j.energy.2005.06.004

Siemons, R. V., Ahmed, D. and Hood, H., *Cotton stalks charcoal agglomeration in the Sudan*. Boiling Point Newsletter, 198900, June 22, 2011.

Sireesh, G., Rao, C. J., Sreeramulu, D. and Madhavi, S. K., Evaluation of boiler efficiency of bio briquettes by indirect method, *International Journal of Mechanical Engineering and Technology*, vol. 7, no. 6, pp. 624–633, 2016.

Tumutegyereize, P., Mugenyi, R., Ketlogetswe, C. and. Gandure, J., A comparative performance analysis of carbonized briquettes and charcoal fuels in Kampala-urban, Uganda, *Energy for Sustainable Development*, vol. 31, pp. 91–96, 2016. https://doi.org/10.1016/j.esd.2016.01.001

Zubairu, A. and Gana, S. A., Production and characterization of briquette charcoal by carbonization of agro-waste, *Energy and Power*, vol. 4, no. 2, pp. 41-47, 2014. doi:10.5923/j.ep.20140402.03

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