SHORT NON-REFEREED PAPER

SUGARCANE TRASH RECOVERY SYSTEMS FOR COGENERATION

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Abstract

The use of biomass, particularly sugarcane trash, as a sustainable and environmentally friendly source of renewable energy is gaining widespread attention. For sugarcane trash to be used as a viable energy source, it needs to be recovered from the field and transported to the mill economically. A costing model has been adopted and further developed with the objective of estimating the cost of trash collection and transport. The model was created in such way as to incorporate a number of different trash recovery routes which could be used. During the initial parts of this study, a number of different trash recovery routes which are applicable in South African conditions were identified. These routes include different methods of harvesting, trash separation infield or at the mill, method of trash collection, trash processing, and transportation of the trash. Processing to increase the bulk density of the trash prior to transport has been considered in this study as the low bulk density of the trash has been identified as a critical issue in other studies. By processing the trash, the energy density and bulk density of the trash are increased, which in turn improves the bulk density of the load and transport efficiency. Three trash densification processes were considered, these being torrefaction, pelleting and a combination of torrefaction and pelleting. Problems encountered when modelling these processes included estimating the capital cost requirements, as well as the maintenance and operating costs involved for each processing plant.

Keywords: sugarcane, trash, cogeneration, modelling, processing, cost, energy

Introduction

As fossil fuel reserves decline and their prices rise in response to growing demands for energy, renewable and environmentally friendly energy sources such as sugarcane trash are increasingly being considered as alternative sources of energy (Braunbeck *et al.*, 1999; Meyer *et al.*, 2012). However, for sugarcane trash to be seen as a viable energy source, the collection of this trash from the field and its delivery to a facility needs to be feasible (SRDC, 2011). As with other forms of biomass, a problem with sugarcane trash is the fact that it has a low bulk density which results in both high recovery and transport costs (Hassuani *et al.*, 2005). Routes therefore need to focus on improving both recovery and transport efficiency, which includes increasing the bulk density of the trash.

The aim of this paper is to summarise progress to date on a project which is estimating the cost (R/ton) of sugarcane trash recovery for different trash recovery systems which could potentially be applied in South Africa.

Identification of Recovery Routes

There are a number of trash recovery routes which can be used to get the sugarcane trash to the mill. The potential routes available are dependent on the method of harvesting. In South Africa, the majority of the sugar industry harvests burnt sugarcane by hand, with large areas under sugarcane not harvested mechanically. Thus, innovative trash recovery systems need to be developed to accommodate the manual harvesting of green sugarcane.

The following trash recovery routes are recommended by Smithers (2014): (i) manual whole stick harvesting with no infield separation of sugarcane and trash, (ii) manual whole stick harvesting and separation of sugarcane and trash in the field, with sugarcane stalks recovered using existing bundling, stacking or windrow systems and with the trash collected in a separate operation, (iii) manual whole stick harvesting and separation of sugarcane and trash in the field, with sugarcane stalks recovered using existing bundling, stacking or windrow systems and the trash collected and processed (e.g. torrefied and pelleted) prior to transport to the mill, (iv) mechanical chopper harvesting with sugarcane and trash separated infield, (v) mechanical chopper harvesting with partial separation of sugarcane and trash infield and, (vi) mechanical chopper harvesting with no infield separation of sugarcane and trash.

Where trash is left infield, the route will have to include a trash recovery method. This study includes current trash recovery methods used internationally, as well as potential methods which are still under development. Three infield trash recovery methods are included: the use of a baler, a forage harvester and a silage wagon. Although there have been previous trash recovery studies made of balers, forage harvesters and silage wagons have not yet been the subject of reported studies.

An additional procedure which could be included in a trash recovery route, is the processing of the trash. Trash processing involves increasing the bulk density and energy density, and thus improving the transport and thermal efficiency of the trash. The three processes included are torrefaction, pelleting and a combination of TOrrefaction followed by Pelleting (TOP). These processes can increase the energy density of the trash to 18, 17 and 22 GJ/m^3, respectively (Uslu *et al.*, 2008). Smithers (2014) indicates that dry sugarcane trash contains 2300 MJ/ton, which, when assuming a bulk density of 60 kg/m^3, relates to an energy density of 0.138 GJ/m^3. Therefore, processing increases the energy density of the trash by approximately a multiple of 100. Torrefaction is a pyrolysis process by which the trash is transformed into biochar. The torrefied biomass has a mass equivalent to 30% of its original mass but still holds approximately 90% of the original energy held in the biomass (Koppejan *et al.*, 2012). Pelleting involves compressing the biomass to create a more uniform and stable fuel (Erlich *et al.*, 2006).

Model Adoption and Development

A model is needed to estimate the cost of sugarcane trash collection, and to quantify the cost benefits of the effects that having a trash blanket will have on the soil. After a review of existing models the Economics of Trashing Decision Support Programme (Wynne and Van Antwerpen, 2004), developed by the South African Sugarcane Research Institute (SASRI), was selected as the model which would be adopted and adapted for this project. This model has been developed and refined by SASRI over a number of years and is well suited to local conditions. The spreadsheet model is comprised of 18 processes which are inter-related in order to estimate the total cost (R/ton) of harvesting burnt and green sugarcane. The model already included the processes of manually and mechanically harvesting green sugarcane, as well as the trash recovery process of baling.

For this model to take into account all possible trash recovery systems, it needed to be further developed. The following cost calculation elements were added to the model: forage harvester, silage wagon, torrefaction, pelleting, and TOP. By inter-relating the existing and new processes, the cost of trash recovery using any potential trash recovery system, or 'route', can be estimated.

The manual harvesting and chopper harvester elements not only take into account the harvesting process, but also the infield loading and transport, transhipment loading, and road transport of the sugarcane. The three trash recovery systems (baling, forage harvester, silage wagon) are similar in that they not only take into account the cost of trash recovery, but also the cost of loading and transport requirements for the collected trash. In these processes switches are used (yes or no) to determine whether a contractor is used during the harvesting/transport operations.

The input data for the processing of trash needed to be compiled. Inputs included capital cost, maintenance costs per year, operator wages, operating hours per day, electricity consumption and maximum life expectancy of the machines. The capital cost for processing plants in South Africa are difficult to establish as values in the literature were not in South African Rands, and direct conversion into the local currency would not give a realistic cost estimate. The managing director of a South African company that constructs pelleting plants was contacted, and the company's price listings were used (pers comm[1]). In order to find relative South African prices for torrefaction and TOP plants, the ratio between the capital cost for a pelleting plant and torrefaction and TOP plants was established, using literature derived international costs. These ratios were then used to convert the South African price for a pelleting plant, into an equivalent South African price for torrefaction and TOP plants. Depending on the intended throughput of the processing plant, the purchase prices will change accordingly. A regression was determined between capital cost and throughput rate using the above ratio-costing approach.

Model Validation and Verification

A sensitivity analysis was conducted on the 26 model inputs. Of these, ten were found to have a large effect on the model output. These included the area to be trashed, the season length, sugarcane yield per hectare, operating hours per day, fuel price, speed of infield transport, distance from field to mill, trash bulk density after being handled by recovery equipment, trash recovery efficiency of the recovery equipment for the selected route, and the trash mass per hectare. These parameters are mostly economies of scale related. Hence, great care needed to be taken to establish the most accurate estimates for these inputs.

A number of case studies are being investigated to validate the model. These include a mill area, growers who have collected, or are planning to collect trash, and collaboration with

[1] J Eksteen, Pietermaritzburg, 19 November 2013.

international experts in the field of trash collection. Once validated, the model will be applied to the case study sites to assess the costs of the various trash recovery routes and to identify the lowest cost routes.

Discussion

A number of trash recovery routes which are potentially applicable to conditions in South Africa have been identified. These routes include the method of harvesting, method of trash collection, and method of trash processing, if required. The user of the costing model is able to specify which trash recovery route is to be used. The model will then automatically estimate the costs relevant to the selected route and processes.

The modelling of the cost of sugarcane trash densification has not been shown in previous studies and thus proved to be challenging. Difficulties encountered included obtaining capital cost information for processing plants in South Africa, and obtaining the operator wages for a processing plant. These problems were dealt with by finding local businesses with experience in the processing industry, who were able to supply relevant data.

A sensitivity analysis conducted on the model has helped broaden the understanding of the model, and consequently, singled out the inputs which are important. As the model is yet to be validated, there are no results to be reported. The model validation will commence as soon as information is made available from the intended case studies. Once model validation is complete, the model will have outputs for each of these case studies, and these results will be reported.

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