ESTIMATING COSTS OF HANDLING SUGARCANE TRASH FOR USE AS BOILER FUEL

By

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Abstract

THE COLOMBIAN sugar industry is compelled by legislation to eliminate all burning of sugarcane prior to harvest by January 2005. Consequently, various strategies are being investigated to reduce the adverse impact of green-cane harvesting on the overall sugar production system. With green-cane harvesting, the large amount of biomass left in the field in Colombia creates agronomical difficulties that necessitate chopping the trash before leaving it on the ground, or removing it. Cenicaña developed a special purpose attachment for a Claas-Jaguar 355 kW forage harvester which picks up the trash, chops it, and throws it directly into wagons that are hauled to the factory. Trials using trash for boiler combustion have been in progress since 1999. In order to have a smooth feed of biomass to the boilers, with the existing technology, it is necessary for the trash to be cut into pieces no bigger than 14 mm. These trials have been useful for technology refinement and possible projections. Monitoring of costs has been done, and a computer model (PARCA) has been developed, based on cost allocation techniques, logistics, push and pull techniques, and queuing theory. Cost structures and computer model results using coefficients obtained during the trials are presented. The updated trash cost delivered to the factory is between US$5.29/t and US$6.64/t.

Introduction

Briceño et al. (1999) presented pre-feasibility results of the use of sugarcane trash as an energy source. Two primary trash-handling systems were compared:
(i) baling the trash before delivery to the factory; and
(ii) cutting the residues into small pieces in the field before delivery.

Because of its operational simplicity and lower unit cost, the second system was favoured and further trials were conducted on this option. Of an average 120 tonnes cane per hectare, the available biomass left in the field after harvesting was estimated at 50%, or 60 t/ha. These figures are typical for Colombia but would not necessarily be true for other sugarcane producing areas. It has been found that boiler performance is not adversely affected when using up to 20% trash mixed with the bagasse, provided the total biomass moisture is below 54%.

The main objective of the trials was to determine the cost coefficients of the trash handling processes in order to complete the PARCA model and explore alternative system configurations.

Method and materials

Cost structures

In a scenario of strict environmental regulations imposed by legislation, where burning prior to and after harvesting is forbidden after January 2005, and with a portion of factory bagasse fuel being replaced by coal supplied by paper producers in exchange for bagasse, the costs and fuel properties of coal were considered the main reference input for a cost structure analysis.
The main piece of equipment used in the trials reported here was a 355 kW Claas-Jaguar forage harvester, fitted with a Cenicafé-designed and developed attachment for managing trash. Using this attachment, the trash is picked up, chopped, and thrown directly into wagons that are hauled to the factory where they are unloaded and the trash is fed to the boilers. Figure 1 shows the steps in trash handling from field to factory.

![Field and factory trash handling operations.](image)

Each task was quantified economically and its cost allocated using the Activity Based Costing (ABC) technique to obtain the Total Unit Cost. The separate elements used in the cost structure are given below.

**Target cost**

Target cost was related to the fuel (coal) to be replaced by trash, with the associated variables such as price, heat value and coal-burning boiler efficiency. This represented the target cost that would make the use of cane trash in the boilers an attractive economic proposition. Equation 1 was used to determine the target cost from windrowing the trash up to unloading it at the factory. In addition, the handling cost in the factory (storage, cleaning, conveying) is about US$1.00/t coal (Moreno, unpublished data).

\[
\text{Target cost (collection+transportation+unload) = } \frac{\text{Coal Cost (delivered to factory)}}{\text{HV coal} \times \eta_{cb}} / (\text{HV (trash + bagasse)} \times \eta_{bb})
\]

where

- \(\eta_{cb}\): coal boiler efficiency;
- \(\eta_{bb}\): bagasse boiler efficiency;
- \(HV\): Heat Value.

An approximate ratio of 3.47 tonnes of biomass to one tonne of coal was used to calculate the target cost of one tonne of trash entering the factory. Table 1 gives data used for this calculation.

**Table 1—Components used in Target Cost calculation.**

<table>
<thead>
<tr>
<th>Target Cost (trash collection and transport)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal price (US$/t)</td>
<td>19.48</td>
</tr>
<tr>
<td>Coal heat value</td>
<td>25 586 KJ/kg</td>
</tr>
<tr>
<td>Coal boiler efficiency</td>
<td>75%</td>
</tr>
<tr>
<td>Dry basis trash heat value</td>
<td>16 747 KJ/kg</td>
</tr>
<tr>
<td>Trash moisture</td>
<td>50%</td>
</tr>
<tr>
<td>Wet basis trash heat value</td>
<td>8 374 KJ/kg</td>
</tr>
<tr>
<td>Bagasse boiler efficiency</td>
<td>60%</td>
</tr>
<tr>
<td>Target Cost (US$/t) (50% moisture)</td>
<td>5.11</td>
</tr>
<tr>
<td>Target Cost (US$/t) (55% moisture)</td>
<td>4.40</td>
</tr>
</tbody>
</table>
Conversion factors

1 BTU/lb = 2.326 KJ/kg = 0.556 Kcal/kg
1 BTU = 1.055 J = 252 cal

Target Cost was strongly affected by trash moisture. When trash moisture was high, Target Cost was low, so it was necessary to reduce trash processing costs in the field to compensate for increases in moisture. Equation 2 calculates density as a function of trash moisture (Echeverri, 2002).

\[ \rho = 0.09135 + \frac{(%trash\ moisture/100) \times 0.09135}{(1 - (%trash\ moisture/100))} \]

where

\[ \rho : \text{trash density} \]
\[ %trash\ moisture : \text{moisture content of the trash} \]
\[ 0.09135: \text{constant obtained by mathematical regression} \]

Trash cost in the field

This cost is considered to range from an optimistic value of minus US$0.5/t (because of the benefits of taking a portion of the trash from the fields) to a pessimistic value of plus US$0.5/t (Briceño, 1999).

Windrowing trash

Two extreme values were considered based on cane producers’ experience: a minimum of US$19.48/ha and a maximum of US$30.30/ha (Villegas, 2002). This cost could be avoided if the hand cutters placed the trash in rows ready to be picked up.

Machinery unit cost (Posada and Orozco, 2000)

The cost of a brand new machine and its maintenance cost were assigned to a tonne of trash according to the machine’s output and estimated useful life of five years. Maintenance and repairs were estimated at 20% of the machine’s purchase price on a yearly basis.

Other related costs such as salaries, fuel, storage and taxes were assigned in proportion to machine output. Two scenarios were considered: 10% and 30% of supplementary (idle time/down time) costs. For the pilot factory, 10% was used.

Unloading cost

This is obtained from labour costs and unloading time required by the mixing rate and boiler requirements.

Transport cost

To arrive at a unit transport cost, it was assumed that brand new equipment and machinery were to be used. Fixed and operating costs were calculated and allocated as a function of machinery throughput. Wagons of various capacities were used in the trials, but the model was based on 22 m³ wagons, common in the area. Trials were conducted within a 10 km radius of the factory.

Trash storage cost

No storage cost was included because of the coordination of the transport and unloading systems.

Trash and bagasse mixing cost

A dedicated system for unloading, conveying and mixing is required for this technology. A cost ranging from US$0.4/t to US$0.6/t was considered, including operating and maintenance costs.

Trash cost margin

A ±15% margin for total unit cost versus target cost was considered to analyse economical feasibility.

1 The British Thermal Unit (Btu) is a precise measure of energy. It is the amount of energy required to raise the temperature of 1 pound of water 1 degree Fahrenheit when the water is near 39.2 degrees Fahrenheit.
Computer modelling

After trials, where a complete assortment of transport and unloading systems were used to feed the factory boilers, field and factory costs were obtained. The computer model PARCA was developed (Amú, 2003) using the ABC2 cost allocation technique, transportation logistics, agricultural machinery valuation methods, push and pull techniques, and queuing theory. Typical inputs from trials were:

- Results of machinery performance.
- Factory operation information.
- Machinery budgeting.
- Other technical information.

Table 2 presents typical trial and potential results using available technology. A total trash cost of US$6.64/t was obtained during the trial but this could decrease to US$5.29/t if operational conditions improve.

<table>
<thead>
<tr>
<th>Element</th>
<th>Unit costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Potential results</td>
</tr>
<tr>
<td></td>
<td>US$/t</td>
</tr>
<tr>
<td>Windrowing trash</td>
<td>0.49</td>
</tr>
<tr>
<td>Trash pick up and chopping</td>
<td>1.63</td>
</tr>
<tr>
<td>Transport</td>
<td>2.67</td>
</tr>
<tr>
<td>Unloading</td>
<td>0.10</td>
</tr>
<tr>
<td>Mixing and conveying</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5.29</strong></td>
</tr>
</tbody>
</table>

Conversion factors

1 BTU = 1.055 J
1 GJ = 10^6 J
1 MBTU = 10^6 BTU

Opportunities for reducing costs

The densification of whole trash by compaction in the field is an opportunity for reducing overall transport costs. A compaction system and an electrically driven heavy duty shredding machine at the factory are under design (Casanova and Otálora, 2003) using the results obtained by Astaiza (1998). The unit cost of handling trash for energy purposes will be reduced in the long term by spreading the initial investment cost over the lifespan of the equipment, and allocating a yearly proportion to trash handling.

Conclusions

- Care must be taken when calculating trash density, because it is directly related to moisture content. An apparent unit cost reduction in transport is obtained when handling trash with a high moisture content, although a higher cost per unit of transport energy (MBTU) is incurred.
- With current machine performance, it is more economical to windrow the trash to increase machine output. The cost of windrowing trash represents less than 10% of total costs.
- Approximately 82% of total unit costs are related to trash chopping and transport; therefore, more research and engineering development will have to be targeted at reducing this cost.

\(^2\) ABC is an alternative to the traditional way of accounting. ABC is a costing model that identifies the cost pools, or activity centres, in an organisation and assigns costs to products and services (cost drivers) based on the number of events or transactions involved in the process of providing a product or service.
• No additional soil compaction damage is expected because the tare mass of new wagons designed for trash handling will weigh less than 3.5 tonnes.

• Unloading time at the factory and associated costs are determined by the length of time taken to supply biomass to the boilers. The fraction of trash in the total biomass being burned in the boilers affects these costs. Thus far, a limit of 20% trash in the biomass has been determined to be the most economical.

• Unit cost calculations were obtained under the assumption of brand new equipment (machines, wagons, tractors). Continued operation of the system will lower the unit cost of trash handling, and this energy source should then become more economical.

• Based on current knowledge and technology, trash can be a viable option as fuel for boiler combustion if the content of ash is less than 10% on a wet basis, the moisture is less than 54%, and the transport distance from field to factory is less than 15 kilometres.

Acknowledgments
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REFERENCES


ESTIMACIÓN DES COUTS ASSOCIE A L'UTILISATION DE LA PAILLE DE CANNE COMME COMBUSTIBLE DANS LES CHAUDIÈRES
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MOTS CLES: Canne à Sucre, Récolte en Vert,
Manutention des Résidus de la Canne, Combustion des Chaudières.

Résumé
A PARTIR de janvier 2005, l’industrie sucrière colombienne sera tenue de par la législation de cesser tout brûlage de la canne avant la récolte. Par conséquent, diverses stratégies sont actuellement à l’étude afin de réduire les contraintes associées à la récolte en vert sur toute la filière de production. En Colombie, après la récolte en vert, une grande quantité de biomasse est laissée au champ, occasionnant des problèmes d’ordre agronomique - la paille devant être hachée avant d’être laissée au champ ou enlevée. Cenicana a conçu un accessoire spécial qui s’adapte à la récolteuse de fourrage Claas-Jaguar 355 kW, pour rassembler la paille, la hacher et l’envoyer directement dans les bennes avant de l’acheminer vers l’usine. Depuis 1999, l’utilisation de la paille de canne comme combustible dans les chaudières a fait l’objet de plusieurs essais. Afin d’assurer un approvisionnement régulier aux chaudières avec la technologie actuelle, il faut que la paille soit coupée en morceaux de 14 mm ou moins. Ces essais ont permis de peaufiner la technologie et de faire des extrapolations. Un suivi de l’évolution des coûts a été effectué et un modèle informatique (PARCA) a été développé suivant la technique d’affectation des coûts, la logistique, les techniques ‘push-pull’ et la théorie des files d’attente. Les structures de coûts et les résultats du modèle informatique utilisant les coefficients obtenus lors des essais, sont présentés. Le coût actuel de la paille fournie à l’usine se situe entre US$ 5,29/t et US$ 6,64/t.

ESTIMACIÓN DE COSTOS DE MANEJO DE RESIDUOS DE CAÑA DE AZÚCAR PARA USO COMO COMBUSTIBLE EN CALDERAS
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PALABRAS CLAVES: Caña de Azúcar, Cosecha en Verde,
Manejo de Residuos de Caña de Azúcar, Combustión en Calderas.

LA INDUSTRIA azucarera colombiana tiene el compromiso de eliminar las quemas de caña de azúcar antes de la cosecha en enero del 2005. Por lo tanto, varias estrategias se han investigado para minimizar el impacto de la cosecha de caña en verde durante el sistema de producción. Con la no quema gran cantidad de biomasa que queda en el campo crea problemas agronómicos que obligan a retirar el residuo. CENICAÑA desarrolló un cabezote especial con el propósito de alimentar una máquina Claas-Jaguar 355 kW picadora de forraje la cual permite picar el residuo y descargarlo en vagones que se transportan hasta la fábrica. La evaluación de combustión de residuo en calderas está en proceso desde 1999. La eficiencia de las calderas no se afecta cuando se mezcla un 20% de residuo con bagazo y la humedad es menor de 54%. Para obtener una buena alimentación de residuo para las calderas, con la tecnología existente, se requiere que el residuo se corte en un tamaño menor de 14 mm. Estos ensayos han sido útiles para el refinamiento de la tecnología y proyecciones. Para la obtención de costos se desarrolló un modelo computacional (PARCA) basado en técnicas de asignación de costos, logística, sistema push and pull y teoría de colas: La estructura de costos presentada y los resultados del modelo computacional fueron obtenidos usando datos de entrada observados durante las evaluaciones. El costo de residuo total desde la recolección hasta el descargue en la fábrica está entre US$ 5,29/t y US$ 6,64/t.