SHORT NON-REFEREED PAPER

THE DEVELOPMENT AND APPLICATION OF AN ENERGY CALCULATOR FOR SUGARCANE PRODUCTION IN SOUTH AFRICA

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Abstract

The rising cost of energy and an increasing awareness of the negative environmental effects of Greenhouse Gas (GHG) emissions have led to a global effort to reduce fossil fuel Energy Use (EU). In this regard, the South African sugar industry is currently exploring measures to reduce EU and increase EU efficiencies of on-farm operations. To remain commercially and environmentally sustainable, measures need to be taken to reduce EU and increase EU efficiencies of on-farm operations. The purpose of this paper is to report on the development of an energy calculator for sugarcane production in South Africa. Case studies were used to test the functionality of the calculator. Results show that, in irrigated sugarcane production, the harvest and transport process, together with irrigation, account for between 70 and 80% of the total on-farm EU. For one of the case studies, an estimated 17% saving in the total on-farm EU was identified, and can be achieved if appropriate technology is adopted in irrigation practices. It is envisaged that the energy calculator will help farmers minimise on-farm EU and subsequently reduce input costs. It will also provide a valuable tool for researchers to benchmark and profile EU in sugarcane production in South Africa. Research focused on the sustainable production of sugar, from the agricultural to milling phase, is of high priority at present. The quantification of on-farm EU in sugarcane production will form a critical component of such research.

Keywords: sugarcane, fossil fuel, energy use, energy calculator, diesel, electricity

Introduction

Donovan *et al.* (1978) conducted research to quantify the fossil fuel Energy Use (EU) of sugarcane production in South Africa. Mill statistics and agricultural costing data from the South African Canegrowers' Association were used, together with the unit price of diesel and electricity, to calculate EU. In a Life Cycle Assessment (LCA) of the South African sugar industry, Mashoko *et al.* (2010) used consumption rates from literature sources and typical farming activities in the KwaZulu-Natal region to estimate the EU of sugarcane production.

To aid in the estimation of EU, calculator tools have been developed and used in many industries including agriculture. These calculators allow for the systematic examination of the energy intense processes and operations to highlight inefficiencies and potential cost saving opportunities, as well as the potential to improve quality and productivity (Baillie and Chen, 2011). A direct spin-off of the use of an EU calculator is the ability to estimate Greenhouse Gas (GHG) emissions linked to fossil fuel energy use.

The objective of this communication is to report on the development of an energy use calculator for sugarcane production in South Africa, and to demonstrate its effectiveness in assessing and comparing the direct EU and GHG emissions of two case studies in sugarcane production.

Materials and Methods

Energy calculator structure

The energy calculator apportions EU into the following six processes of sugarcane production:

(i) re-establishment,
(ii) ratoon management,
(iii) harvest and transport,
(iv) general tractor use,
(v) break cropping/green manuring, and
(vi) irrigation.

Although 'general tractor use' is not necessarily an agricultural process, it is included to account for the diesel consumption that cannot be defined by normal field operations. Examples of such tractor operations include water and seedcane carting, transporting labour, mowing of verges and farm maintenance.

EU is reported as energy consumed (L or kWh), as well as an Energy Use Intensity (EUI) (MJ/ha or MJ/t). EUI is a useful indicator of efficiency of converting energy into a useful product. This also allows for the comparison of farms and systems of unequal production area and yield potential. GHG emissions are reported as the mass of carbon dioxide equivalent gasses (CO_2e) emitted per hectare (kg/ha) or per ton of sugarcane harvested (kg/t).

There are three levels of assessment that can be conducted using the energy calculator. The choice of level depends on the detail of input data available. A Level 1 assessment uses financial accounts and farm records as a data source for calculations. Level 2 assessments require precise definition of all the operations that fall under the six sugarcane production processes. Theoretical and empirical equations are then used to estimate EU and GHG emissions. Lastly, a Level 3 assessment uses data collected from on-farm measurements of energy related parameters to identify opportunities to increase energy efficiencies.

Case studies

Level 1 and 2 assessments were conducted on two case studies in the industry. Results from the Level 1 assessments are not reported in this paper, as contracted operations make it difficult to account for and compare the total EU of both production systems. A Level 2 assessment, however, calculates EU for an entire production system regardless of the number of contracted operations.

The first case study took place on a commercial farm in Umfolozi supplying the Umfolozi Sugar Mill. Typical to this area, and operations that have a significant influence on total energy use are the supplementary irrigation practices and tramline system used for mill transport.

The second case study was conducted at the South African Sugar Research Institute (SASRI) farm in Pongola, where there is, on average, a 50% annual replant programme on predominantly small research plots. The farm is fully irrigated, and harvested cane is transported to the mill by road via a transloading zone. Instrumentation was installed on the research farm's electrical pumps, which allowed for an additional Level 3 assessment to be conducted on the irrigation system.

Results and Discussion

Table 1 summarises the EUI and GHG emissions for the two case studies from the Level 2 assessment. These are calculated per ton of sugarcane harvested during the period over which the assessment was conducted. Included in the results are the percentages of total EUI and GHG emissions made up by diesel and electricity consumption.

Table 1. Energy Use Intensity (EUI) and Greenhouse Gas (GHG) emissions of each case study for the Level 2 assessment.

Case study	Process	EUI (MJ/t)	GHG (CO_2e) emissions (kg/t)
1. Umfolozi	Re-establishment	1.7	0.1
	Ratoon management	7.6	0.5
	Harvest and transport	41.2	2.9
	General tractor use	14.7	1.0
	Break crop/green manuring	0.0	0.0
	Irrigation	34.0	9.6
	Total	**99.1**	**14.1**
	Diesel / Total	**65.7%**	**31.9%**
	Electricity / Total	**34.3%**	**68.1%**
2. Pongola	Re-establishment	6.6	0.5
	Ratoon management	2.6	0.2
	Harvest and transport	76.4	5.3
	General tractor use	43.1	3.0
	Break crop/green manuring	1.6	0.1
	Irrigation	133.2	37.5
	Total	**263.5**	**46.6**
	Diesel / Total	**49.4%**	**19.5%**
	Electricity / Total	**50.6%**	**80.5%**

The total EUI of a research farm production system is expected to, and does, exceed that of the commercial equivalent. This can be attributed to experimental field layouts, higher than normal replant programmes, and various additional field operations tailored for each experiment.

For both cases, the irrigation together with the harvest and transport processes have the highest EUI. The fully irrigated Pongola case study requires considerably more electrical energy than the supplementary case. So too is the road transport system of the Pongola case study more energy intense than the tramline system used in Umfolozi. The high 'general tractor use' EUI of the Pongola case study could be explained by the additional operations, such as the in-field weighing of harvested sugarcane, that are carried out at the research station.

Irrigation accounts for 68 and 81% of the total GHG emissions for Case Studies 1 (Umfolozi) and 2 (Pongola), respectively, even though they account for only 34 and 51% of the total EUI. This could be explained by the high CO_2e coefficient for coal powered electricity generation in South Africa. The CO_2e coefficient for electricity produced in South Africa is 1.015 kg/kWh (Letete *et al.*, 2009). This is almost double the 0.55 kg/kWh of Mauritius, where 60% of the electrical energy produced is generated in sugar mills using cogeneration processes (Soobadar *et al.*, 2010).

Results from the Level 3 assessment of the Pongola irrigation pump station showed 30% power dissipation through throttling valves. For the entire production system, a potential 17% saving in energy could be realised if the pump system matched the irrigation requirements. This can be achieved by replacing the existing pumps and motors with appropriately sized units, or by installing variable speed drives to control the motor speeds.

Conclusion

Research into EU and GHG emissions is justified by the lack of published literature, as well as the increasing concern over the cost of energy and environmental sustainability of sugarcane production. The available literature is predominantly international, and has a bias towards LCAs. Typically, LCAs of sugar production base the agricultural phase estimation of EU on mill level and industry level averages. An on-farm energy calculator is a tool that can assist in increasing the accuracy by which EU is estimated and can identify farming operations where energy could be used more efficiently.

The energy calculator was tested on two case studies. Both case studies showed that the calculator was practical and functional, and has the ability to identify energy intense operations and inefficiencies in EU. Irrigation and the harvest and transport processes were identified as major contributors to the total EU in the production systems. Irrigation specifically, accounted for the bulk of the total GHG emissions, and highlights the need to explore opportunities for 'cleaner' sources of electrical energy.

It is envisioned that the energy calculator could be used to establish mill area benchmarks and profiles for EU and GHG emissions in sugarcane production. In so doing, different production systems can be compared, as well as the effect that geographical and agro-hydrological characteristics have on EU. Such outcomes will form a critical component of current and future LCAs of sugar production.

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