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Can Bio-ethanol Play a Role in Sustainable Development?

A Life Cycle Assessment from Mauritius

Abstract

This CEEPA study from Mauritius looks at the production of bio-ethanol from the country's sugarcane crop. It asks whether this could offer an economically and environmentally sustainable way to reduce the country's reliance on fossil fuels and so lessen greenhouse gas emissions. To do this, it assesses the complete production pathway of bio-ethanol in terms of its energy use, carbon emissions and potential costs.

The study is the work of a team from the University of Mauritius. The study finds that overall the production of one litre of bio-ethanol from sugar cane is responsible for the production of 41.91g of CO_2. In comparison, one litre of gasoline emits 2,321.7g of CO_2. It concludes that, when carbon emissions and associated social costs are taken into account, ethanol could be environmentally more cost-effective than gasoline.

Sugarcane cultivation in Mauritius.

A summary of CEEPA Discussion Paper No. 53: 'Bio-Ethanol For Sustainable Development: The Case Of Sugar Cane In Mauritius' by Riad Sultan, Abdel Khoodaruth, Verena Tandrayen-Ragoobur, Department of Economics and Statistics, University of Mauritius, Reduit, Mauritius

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Report Summary

Bio-ethanol is produced through the fermentation of agricultural products such as sugarcane, molasses, corn, wheat and sugar beet. As a vehicle fuel, bio-ethanol can either be used in a pure form or blended with gasoline, typically 5–20 percent by volume. In its blended form it can be used in existing vehicles with no engine modifications or it can be used in its pure form in vehicles with modified engines. Bio-ethanol is being promoted world-wide as a potential solution to the transport sector's over-reliance on fossil fuels and as a way of reducing greenhouse gas emissions.

The use of bio-ethanol is of particular interest in Mauritius because the country has a massive economic stake in bio-ethanol production from sugar cane. In 2003, sugarcane was cultivated on 85 percent of the arable land in Mauritius. However, in recent years sugarcane production has come under significant pressure following changes in EU sugar prices and national sugar quotas. In response to this economic challenge, the Mauritian Government has devised a multi-annual adaptation strategy in the form of a ten-year (2006–15) Action Plan. The objective of this plan is to ensure the commercial viability and sustainability of the sugar sector. One of the key elements of this plan is an increase in the contribution of sugarcane production to national energy production. This will involve the production of 30 million litres of ethanol from the molasses produced by two of the country's four remaining sugar factories. This ethanol will be used to fuel new power plants and will also be used as vehicle fuel.

Is bio-ethanol sustainable?

Despite the ambitious plans being laid for the use of bio-ethanol in Mauritius there has been a lot of international debate about whether bio-ethanol actually represents an economically viable and environmentally sustainable fuel. It is clear that bio-ethanol will only lower fossil fuel use and reduce carbon emissions if its entire production system can offer both a net energy gain and net carbon savings. What's more, if biofuel offers only a small improvement in the net energy balance, but a huge increase in costs in relation to alternative options, then it is unlikely to offer a cost-effective means of achieving the goal of a low carbon economy. The key aim of this study was therefore to assess the true environmental and economic impact of bio-ethanol if manufactured along the lines set out in the Mauritian Government's plans.

To do this, the researchers used a Life Cycle Analysis to assess all the key steps of the production process that converts sugarcane to bio-ethanol. This was done to see how much energy was used, how much CO_2 was produced and what costs were incurred. Any carbon emitted during the combustion of biofuels was not taken into account, as it was assumed that this carbon had been captured as CO_2 from the atmosphere by photosynthesis during plant growth. A sensitivity analysis was also undertaken to see how production inputs and technologies affected energy use and CO_2 production.

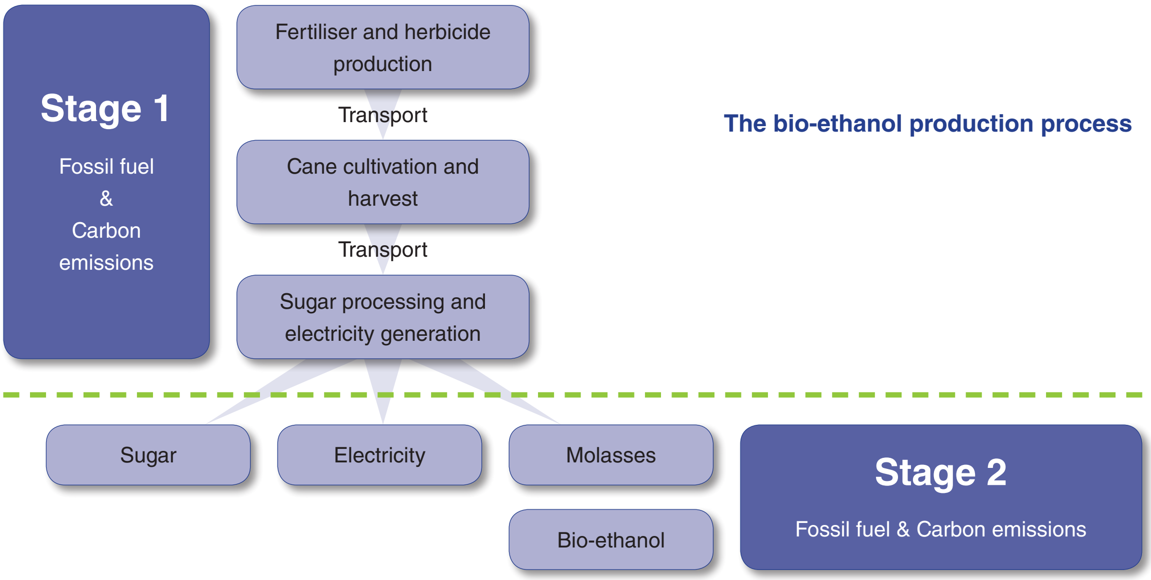
> **"When carbon emissions and their associated social costs are taken into account, bio-ethanol is more cost-effective than gasoline."**

Assessing the bio-ethanol production process

The production of bio-ethanol from sugarcane involves two main stages. Stage One is feedstock production, which involves the cultivation of the sugarcane crop and the production of molasses. Stage Two is the conversion of molasses to ethanol. This is carried out in distillery plants that are integrated with a sugar mill.

The main elements of Stage One that were assessed were the production of inputs for sugar cane farming, the transportation of agricultural inputs to the sugar cane fields, the irrigation of the fields, the transportation of sugar cane to factories and sugar milling. The assessment of Stage Two involved a review of the energy and emissions of the plants where the conversion of molasses took place.

The assessment of each of these steps involved a significant number of detailed calculations. For example, to calculate the amount of energy used in the transportation of fertilizer and herbicide from harbors to the sugar cane fields, the researchers took into consideration the average distance traveled, the amount of chemicals that were transported per trip and the carrying capacity of the trucks used. This allowed a calculation of fuel use, transport costs and pollutant emissions.



The bio-ethanol production process

Taking renewable energy and co-products into account

The study assessed both renewable and non-renewable energy inputs. For example, when sugar cane arrives at the sugar mill, it is crushed to extract juice and the water content of the juice is removed through a heating and evaporation process. Bagasse is the main energy source for sugar mills. Bagasse is a by-product of sugar cane crushing and sugar manufacturing. Since bagasse is derived from biomass, the carbon released is eventually absorbed through photosynthesis in sugar cane. This was taken into account in the study's calculations.

One of the key aspects of the Mauritian molasses-based ethanol production process is that it produces multiple other products. For this reason it was important for the researchers to take into account the energy consumption and carbon emissions associated with these co-products. An economic-based value method was used to do this. This method distributes energy and CO_2 emissions according to the economic value of co-products.

The information used in the assessment came from the government's Digest of Agricultural Statistics and its Digest of Energy Statistics. These information sources gave detailed accounts of all key inputs. For example, they revealed that in Mauritius the amounts of Nitrogen, Phosphorous and Potassium used in one hectare of sugar cultivation are 138kg, 50kg and 175kg respectively. Such information was vital to the study as the fertilizer and herbicide used in the cultivation phase of bio-ethanol production uses a lot of energy and is responsible for the production of significant quantities of CO_2. Indeed, the manufacture of fertilizer and herbicide is responsible for the largest share (63.6 percent) of the energy used in the bio-ethanol production process.

How bio-ethanol performs in comparison with gasoline

The study finds that, overall, the production of one litre of bio-ethanol from sugar cane is responsible for the production of 41.91g of CO2. In comparison, one litre of gasoline emits 2,321.7g of CO_2. When these emissions are broken down, it is clear that the transportation of sugar cane to the factory is responsible for the largest share of the carbon emissions caused by the production of bio-ethanol – 62.2 percent of the emissions are caused during the transportation phase.

In terms of energy, the study finds that bio-ethanol contains significantly more energy than is used in its production. The net renewable energy balance of the production process stands at 18.92MJ (energy balance is defined as the difference between the energy content of ethanol and the energy used in its production). It is also clear that the use of bagasse in the sugar milling process helps improve the performance of the bio-ethanol production process. It contributes 17.8 percent of the energy used – energy which can be subtracted from the overall total because it is renewable.

Despite bio-ethanol's positive energy balance, it produces less energy than gasoline. Conventional gasoline has an energy content of 32.4MJ per litre. The amount of gasoline that one litre of bio-ethanol would replace would only produce 1,509.2g of CO_2 emissions. The net carbon emission avoided by using one litre of bio-ethanol is therefore estimated at 1,467.29 g of CO_2 (1,509.2g–41.91g).

Social costs mean that bio-ethanol is cost effective

In terms of costs the study finds that it costs the economy Rs1.06 to produce one MJ of ethanol. Therefore, ethanol production is not cost-effective when compared to the cost incurred for gasoline (which stands at Rs0.68 per MJ). Based on this finding, it appears that it is more cost effective to import gasoline than to produce ethanol, even though ethanol has a net positive energy balance. Indeed, the study finds that, to be cost effective compared to gasoline, the cost of producing one litre of ethanol should be Rs12.87 – this is unlikely since the cost of feedstock itself is Rs12.

However, the study finds that this situation changes when social costs are taken into account. The IPCC defines the social cost of carbon as the value of the climate change impacts from one tonne of carbon emitted as CO_2, aggregated over time and discounted back to the present day. Researchers calculate that the minimum value for this is around 5 Euro per tonne of CO_2. This means that one tonne of CO_2 will cost society Rs41.9. Since one litre of gasoline emits 2.32 tonnes of CO_2, the external cost of one litre of gasoline is Rs486.04. When private costs are also taken into account, one MJ of gasoline has a cost of Rs15.09.

Overall, this means that when carbon emissions and their associated social costs are taken into account, bio-ethanol is socially and environmentally more cost-effective than gasoline.

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