INDONESIAN-MODIFIED GREET PATHWAY FOR THE PRODUCTION OF ETHANOL FROM SUGARCANE MOLASSES

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1. Pathway Summary

This lifecycle analysis calculates the carbon intensity (CI) of the production of ethanol from molasses in Indonesia. The production of raw sugar from sugarcane juice yields molasses as an unavoidable byproduct. Molasses is transported from the sugar refinery to an ethanol distillery where it is converted into anhydrous ethanol using a process that is essentially identical to the process used in Brazilian sugarcane ethanol plants. The finished product is shipped to California by ocean tanker. The carbon intensity (CI) of this pathway is 29.19 grams of CO_2-equivalent greenhouse gas emissions per mega joule of ethanol produced (gCO_2e/MJ).

Although the sugarcane cultivation, sugarcane transport, ethanol production, and finished fuel transport portions of this pathway are essentially identical to the corresponding steps in the Brazilian Sugarcane-to-ethanol Pathway,[1] the emissions associated with the production of the molasses feedstock must be disaggregated from the emissions associated with the production of raw sugar. The energy consumption and greenhouse gas (GHG) generation must be appropriately allocated between the molasses byproduct and sugar. The bulk of this pathway document, therefore, focuses on molasses production.

The Well-to-Tank (WTT) portion of this Life Cycle Analysis of the Indonesian molasses to ethanol pathway includes all steps from sugarcane farming to final finished anhydrous ethanol. The Tank-to-Wheels (TTW) portion includes actual combustion of the resulting fuel in a motor vehicle for motive power. Taken together, the WTT and the TTW analyses comprise a total Well-to-Wheel (WTW) analysis.

A version of the Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) [2] model developed by Argonne National Laboratory was used to calculate the energy use and greenhouse gas (GHG) emissions generated during the entire fuel life cycle, from sugarcane farming to producing ethanol to combusting ethanol in an internal combustion engine. Staff modified the original GREET model to create a California-specific version known as the CA-GREET model. [3] Changes were

[1] ARB (2009). Detailed California-Modified GREET Pathways for Brazilian Sugarcane Ethanol: Average Brazilian Ethanol, With Mechanized Harvesting and Electricity Co-product Credit, With Electricity Co-product Credit. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_cane_etoh.pdf

[2] Argonne National Laboratory (2008). The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model. http://greet.es.anl.gov/main

[3] ARB (2009) Lifecycle Analysis (CA-GREET): http://www.arb.ca.gov/fuels/lcfs/lcfs.htm

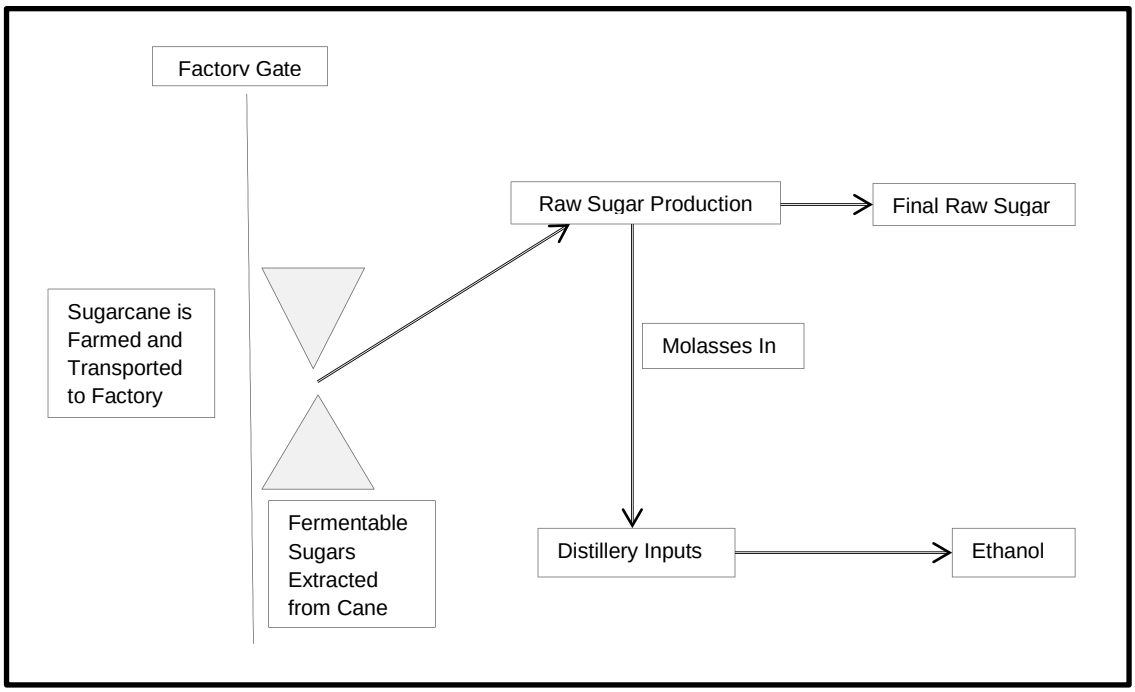
restricted mostly to adding California-specific input factors (emission factors, electrical energy generation mix, transportation distances, etc.); no substantial changes were made to the methodology inherent in the original GREET model on which this one is based. The results obtained from the California-modified GREET model (v1.8b, released December 2009) are reported in this document. Those results consist of the energy use and greenhouse gas (GHG) emissions from the production of ethanol using molasses which is an unavoidable by-product of the Indonesian sugar refining process. This pathway assumes that the ethanol produced is destined for use in motor vehicle fuels.

The calculation methodology and assumptions used to develop this molasses-to-ethanol pathway appear in a 2009 article by UC Berkeley researchers Anand Gopal and Daniel Kammen[4]

2. Process Control

Figure 1 describes the ILD's molasses-to-ethanol process for its plant in Indonesia. Sugarcane is pressed to extract the sugarcane juice. The juice is refined into raw sugar. The molasses byproduct is shipped to a distillery where it is fermented and distilled to produce ethanol.

Figure 1: Process Flow Diagram for the Production of Ethanol from Molasses



[4] Gopal Anand R and Daniel M Kammen. 16 October 2009. Molasses for ethanol: the economic and environmental impacts of a new pathway for the lifecycle greenhouse gas analysis of sugarcane ethanol. Environ. Res. Lett. 4 (2009) 044005 (5pp)

3. Allocation of GHG Emissions between Sugar and Molasses

The feedstock for the ethanol produced under this pathway is a byproduct of the Indonesian sugar industry. This byproduct—molasses—is sent to a distillery, where it is fermented and distilled into anhydrous ethanol. Molasses is a low-value byproduct that is used as a livestock feed supplement in Indonesia. This molasses cannot be upgraded to a food-grade product.[5]

Performing a life cycle analysis of the proposed molasses pathway requires that the total GHG emissions associated with the production of raw sugar be estimated. This includes the agricultural emissions from the cultivation of the sugarcane from which the raw sugar is produced. These emissions must then be allocated between the primary product—raw sugar—and the byproduct—molasses. The purpose of the allocation step is to subtract from the ethanol production totals the emissions that are associated only with the production of final raw sugar (which is not an ethanol feedstock). The agricultural and sugar production emissions that are allocated to the ethanol feedstock (molasses) are added to the emissions from the production and transport of ethanol. The result is the total life cycle emissions value for Indonesian ethanol made from molasses.

The market allocation methodology developed by the applicant allocates the total emissions from the sugar production process to the primary product (final raw sugar) and to the byproduct (molasses) based on the relative share of total sales revenues that accrue to each product for each ton of fermentable sugar (in cane juice) that enters the sugar production process. Standards in the ISO 14000 series, which establish guidelines for the conduct of life cycle analysis, state that the system expansion method should be used whenever possible to allocate emissions between main products, co-products, and byproducts. The use of this method would be both extremely difficult, and subject to significant distortion in the case of Indonesian molasses. A formal description of the applicant's market-based allocation method, as well as additional details on the rationale behind the use of this approach, appear in a peer-reviewed 2009 article published by UC Berkeley researchers Anand Gopal and Daniel Kammen (referenced in footnote 4). Although the system expansion method—when it can be feasibly implemented—is capable of producing emissions allocations that are more robust than the allocations that other methods produce, the market-based approach has a distinct advantage: it rewards producers for converting a waste or low-value product into a low-CI fuel, only so long as that product retains its low-value status. This is because the pathway CI will act as a check on the price of molasses: if producers seeking to capitalize on the low-CI of molasses-based ethanol create a surge in demand for the feedstock, its price will rise relative to price of sugar. As its price rises, its lifecycle CI will increase. This, of course would dampen the demand for molasses as an ethanol feedstock. System expansion-, mass-, and energy-based allocation methods are all insensitive to this price-CI feedback effect.

[5] The molasses that is sold for baking is actually raw sugar with a higher-than-normal mineral content.

Because sugar generates significantly more revenue than molasses, most of the emissions associated with sugar production are allocated to the sugar. The CI of sugar production, including the agricultural and feedstock transport stages, is 47.58 gCO_2e/MJ. Based on market price data going back six years, ILD calculates that 14.19 gCO_2e/MJ accrues to the molasses.

4. Carbon Intensity

Table 1 summarizes the energy used and GHGs emitted from each stage in the production of ethanol from molasses in Indonesia. In this analysis, the carbon intensity of sugarcane ethanol is calculated by considering all the incremental emissions that occur from farming through the production of ethanol. Land use change emissions are also included, as well as the emissions from adding a denaturant. The resulting carbon intensity of the Indonesian sugarcane-molasses-to-ethanol pathway is 29.19 gCO_2e/MJ.

Table 1: Summary of Well-To-Wheel Emissions for Sugarcane to Ethanol

	Pre- Allocation Energy and Emissions: Sugarcane-to-Ethanol				
	Energy Required (Btu/mmBtu Anhydrous Ethanol)	**Share of Total Energy %**	**GHG Emissions: Sugarcane to Ethanol (gCO_2e/MJ)**	**Share of Total Emissions (% of 47.57 gCO_2e/MJ in Prev. Column)**	**Allocated GHG Emissions: Molasses to Ethanol (gCO_2e/MJ)***
Well -to-Tank (WTT)					
Sugarcane Farming	62,978	2.50%	4.85	10.21%	1.72
Agricultural Chemicals Production	233,617	9.26%	26.37	55.42%	9.40
Straw Burning		0.00%	4.69	9.86%	1.66
Sugarcane Transport	25,344	1.00%	1.97	4.14%	0.70
Sugar Production			1.91	4.02%	0.68
Ethanol Production	1,137,475	45.08%	2.62	5.50%	2.62
Ethanol Transport & Distribution	63,815	2.53%	5.16	10.86%	5.16
Total WTT	**1,523,231**	**60.37%**	**47.57**	**100%**	**21.95**
Tank -to- Wheel (TTW)					
Carbon in Fuel	1,000,000	39.63%	N/A	N/A	N/A
Total TTW	**1,000,000**	**39.63%**	**0**	**N/A**	**N/A**
Total Well-to-Wheel (WTW)	**2,523,231**	**100%**	**47.57**	**N/A**	**21.95**
Land Use Change					6.44
Denaturant					0.80
Final WTW CI g/MJ					**29.19**

* The emissions allocations shown in this column are calculated as described in Section 3 of this report. Note that the values in the Sugarcane Farming, Agricultural Chemicals Production, Straw Burning, Sugarcane Transport, and Sugar Production rows are all allocated from the totals in the pre-allocation "GHG Emissions: Sugarcane to Ethanol" column. The values in the Ethanol Production and Ethanol Transport and Distribution rows, however are equal in the two columns (allocated versus pre-allocated GHG Emissions).