Staff Summary
Method 2A Application for
Brazilian Sugarcane-based Ethanol Pathways

BP BIOCOMBUSTÍVEIS S.A. ETHANOL PRODUCTION FACILITY AT Central Itumbiara de Bioenergia e Alimentos S/A (Goias State, Brazil) (Pathway Codes: ETHS023 and ETHM008)

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Pathway Summary

BP Biocombustiveis S.A. (BP Biofuels) produces ethanol derived from sugarcane juice as well as by-product molasses at their Itumbiara integrated sugar and ethanol production facility (Itumbiara) in the State of Goias, Brazil. Sugarcane is harvested on company-owned and partnership farms, and then transported to the sugar mill and ethanol distillery. After the sugarcane has been crushed, the cane juice is filtered, treated, and decanted. Approximately one-third of the juice (36 percent) is sent directly to the ethanol distillery, with the remainder being sent to the sugar production process. A by-product of the sugar production process is molasses, which also becomes a feedstock for the ethanol production process. The by-product molasses is however, not exhausted of its sucrose content and may have a higher value than molasses commonly sold as a livestock supplement.

The life cycle of the BP Biofuels Itumbiara pathways begins with sugarcane cultivation and transport, followed by sugar and ethanol production. The agricultural and ethanol production phases of this pathway are identical to those described in the ARB's Brazilian sugarcane ethanol pathway.[1] The majority of the sugarcane harvested (approximately 86 percent) by BP Biofuels in the Itumbiara region is done by mechanical harvesters. The practice of harvesting manually, following pre-harvest burning, has largely been phased out by BP Biofuels at their owned or leased sugarcane farms.

The BP Biofuels Itumbiara facility also generates and utilizes process heat and electricity from bagasse combustion for all its industrial operations. Surplus electricity produced is exported to the local electrical grid. The major difference between the proposed BP Biofuels pathways and the Brazilian sugarcane-based ethanol pathway is the type of feedstock. The BP Biofuels Itumbiara facility utilizes a mixed feedstock of sugarcane juice and by-product molasses for the production of ethanol, whereas the Brazilian sugarcane ethanol pathway was based upon the use of pure sugarcane juice only for ethanol production. The Itumbiara integrated sugar and ethanol mill additionally uses a high-efficiency boiler, and implements energy efficiency measures that allow the mill to combust bagasse more efficiently thereby generating more excess power for export to the public grid.

[1] California Air Resources Board, 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, version 2.3, September 23, 2009. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_cane_etoh.pdf

Ethanol produced from fermentation of the sugarcane juice and molasses is transported by heavy-dutys truck from the mill in Itumbiara to the Uberlândia rail terminal at a distance of 90 miles from the facility. From the Uberlândia Terminal, the ethanol is transported to the eastern Port of Santos over a distance of 551 miles. At Santos**,** the anhydrous ethanol is loaded onto ocean-going tankers for shipment to California ports over an average distance of 8,758 miles. Ethanol transport and distribution modes in California from the ports are assumed to be 90 miles to a blending terminal by heavy-duty trucks, followed by and an additional 50-miles transport also by heavy-duty trucks for distribution to fuel-pumps.

Facility Location and Coordinates

The BP Biofuels Itumbiara sugar mill and ethanol production facility (Central Itumbiara de Bioenergia e Alimentos S/A) is located in the City of Itumbiara, State of Goias, Brazil. The geographic coordinates of the centroid of the ethanol distillery, shown in the satellite view below, are 18°30’56” S (latitude), and 49°21’40” W (longitude).

BP Biofuels – Central Itumbiara de Bioenergia e Alimentos
Sugar and Ethanol Production Facility at Itumbiara (Goias, Brazil)

Carbon Intensities of the BP Biofuels Itumbiara Pathways

ARB staff has assessed the inputs used by BP Biofuels to determine its well-to-wheels (WTW) pathway carbon intensities for the two pathways being proposed for certification. The sugarcane juice allocated to ethanol production directly mimics the Brazilian sugarcane-based ethanol pathway (reference pathway) closely. The remainder of the sugarcane juice allocated to sugar and molasses production varies from the reference pathway because it additionally involves sugar production. As sugar and molasses are products of the same agricultural, feedstock transport, and sugar production processes, the GHG emissions from these activities must be allocated between the two products. The allocation method chosen by BP Biofuels is the mass-based allocation methodology in which the total upstream and sugar production emissions are allocated on the basis of the ratio of the total reduced sugars (TRS) in the molasses entering the ethanol distillery to the total reduced sugars that enter the sugar production process for each ton of sugarcane that enters the factory gate. The sugarcane juice feedstock sent to ethanol production directly on the other hand inherits all of the upstream emissions related to the agricultural, farming, and transport processes.

Staff has determined that 15.59 grams of carbon dioxide-equivalent emissions per mega joule (gCO_2e/MJ) of fuel produced are attributed to sugarcane farming, agricultural chemicals, sugarcane transport, and sugarcane juice pre-treatment processes. These processes are upstream of ethanol production, and include an assessment of straw-burning emissions with a credit for mechanized harvesting. Correspondingly, based on the mass ratio of the TRS in by-product molasses per ton of sugarcane to the TRS in the post-crush sugarcane juice stream per ton of sugarcane, BP Biofuels has determined that 17.11 grams of carbon dioxide-equivalent emissions per mega joule (gCO_2e/MJ) of fuel produced are attributed to sugarcane farming, agricultural chemicals, sugarcane transport, sugarcane juice pre-treatment, sugar production, and to the production of the by-product molasses. When these upstream and sugar production emissions are combined with ethanol production, addition of denaturant, transport, and distribution emissions, the total well-to-tank (WTT) life cycle GHG emissions are estimated to be 23.61 gCO_2e/MJ fuel produced and 25.13 gCO_2e/MJ fuel produced for the BP Biofuels sugarcane juice-to-ethanol pathway and the by-product molasses-to-ethanol pathway, respectively. This WTT estimate does not include the credit for exports of surplus cogenerated electricity.

The BP Biofuels Itumbiara mill exports surplus cogenerated electricity to the public grid. Since the Itumbiara mill is an integrated refinery producing two products directly from sugarcane juice (sugar and ethanol), and a third product (ethanol) derived from a by-product (sugarcane molasses), the bagasse used for cogeneration must be allocated between the feedstocks used to produce sugar and ethanol from sugarcane juice, and must be further sub-allocated between finished sugar and by-product molasses. The applicable electricity cogeneration export credit for each pathway must be calculated based on this allocation. The reason is that, when the sugarcane juice is sent to ethanol production, the sugarcane bagasse that is generated after the cane crush is assumed to belong to the ethanol production pathway. When the sugarcane juice is sent to the sugar production process, the sugarcane bagasse that is generated after the cane crush is assumed to belong to the sugar mill. Since only the by-product of the sugar production process is fermented into ethanol, the credit is therefore assumed to be proportional to the fraction of fermentables (TRS) in by-product

molasses to the total amount of fermentables[2] (TRS) in the pure sugarcane juice, measured after the cane crush. In other words, the mass allocation methodology used to allocate upstream emissions is also used to determine the quantity of surplus cogenerated electricity exports that should be credited to the by-product molasses pathway. The resulting electricity cogeneration and surplus export credit, based on a displacement of Brazilian marginal electricity, is estimated to be11.67 gCO_2e/MJ of fuel produced for the sugarcane juice-to-ethanol pathway, and 20.75 gCO_2e/MJ of fuel produced for the sugarcane by-product molasses-to-ethanol pathway. When applied to the WTT carbon intensity (CI) of ethanol, this credit results in a net WTT CI of 11.94 gCO_2e/MJ for the sugarcane juice-to-ethanol pathway, and in a net WTT CI of 4.38 gCO_2e/MJ for the sugarcane by-product molasses-to-ethanol pathway. When life cycle emissions due to indirect land use change (ILUC) of 46 gCO_2e/MJ[1] are added to the WTT CI estimate, the final WTW CI for the BP Biofuels sugarcane juice-to-ethanol and sugarcane by-product molasses-to-ethanol pathways are estimated to be 57.94 gCO_2e/MJ and 50.38 gCO_2e/MJ of ethanol fuel produced, respectively. A summary of the disaggregated CI estimate for the BP Biofuels Itumbiara pathways is presented in Table 1.

A mass-based allocation factor was used to adjust the ILUC increment downward in the previous Indonesian and Central American sugarcane byproduct molasses-to-ethanol pathways. The full yield of ethanol from sugarcane juice per metric tonne of sugarcane was used in the denominator of this allocation factor to reflect the dynamics of the sugar and molasses markets in Indonesia and Central America. While sugar is a relatively high-valued export commodity in these regions, molasses was historically sold into local livestock feed markets (its value is too low to justify exports). The use of by-product molasses as an ethanol feedstock increases its value, but changes in the value of a by-product can only have a limited effect on the production of the primary product. Hence, the increase in the value of by-product molasses as an ethanol feedstock will have a limited effect on the amount of land brought into sugar cane cultivation. The demand for ethanol produced directly from sugar cane juice, on the other hand, directly drives the amount of land under sugar cane cultivation. When used as ethanol feedstocks, therefore, sugar cane juice and molasses will not have equal effects on the amount of land brought into sugar cane cultivation, and only a fraction of the ILUC could be apportioned to by-product molasses.

Staff however, re-evaluated the extent to which the Brazilian sugar, ethanol, and molasses markets are similar to the Indonesian and Central American markets. The result was a finding that the markets in which BP Biofuels operates bears little similarity to the corresponding Indonesian and Central American markets. The primary differences are (a) that molasses is produced exclusively as an ethanol feedstock for use within the integrated sugar and ethanol production complex (no outside market for molasses exists, and (b) that the feedstock molasses used in the Itumbiara mill is not “exhausted” molasses like that used in Indonesia and Central America. These differences indicate the molasses used in the Itumbiara mill can have a significant effect on the demand for cane juice and, by extension, the amount of land under sugar cane cultivation. There is no basis, therefore, for reducing the contribution of ILUC to the CI of the BP Biofuels Itumbiara sugarcane by-product molasses-to-ethanol pathway. Therefore, staff will require that the BP Biofuels pathways (and others like it in the future) include the full sugar cane ethanol land use change estimate of 46 gCO_2e/MJ.

[2] This ratio was found to be 0.35 for the sugarcane by-product molasses-to-ethanol pathway. For the sugarcane juice-to-ethanol pathway, the mass allocation ratio is assumed to be 1.0.

Table 1: Summary of Disaggregated WTW GHG Emissions for the BP Biofuels Itumbiara Pathways

Disaggregated Item	Value Reference	GHG Emissions Allocated to Cane Juice-to-Ethanol (g CO_2e/MJ)	GHG Emissions Allocated to Cane Molasses-to-Ethanol :
Well-to-Tank (WTT) Allocated GHG Emissions:		***Mass Allocation Factor: 1.00***	***Mass Allocation Factor: 0.35***
Sugarcane Farming	See Worksheet* "Cane Farming Inputs"	3.74	3.74
Agricultural Chemicals Use	See Worksheet* "Cane Farming Inputs"	8.64	8.64
Straw Burning Emissions	See Worksheet* "Straw Burning"	7.49	7.49
- Less Credit for Mechanized Harvesting	BP Biofuels Claimed Mechanization Level: 86%	(6.44)	(6.44)
Sugarcane Transport	See Worksheet* "T&D"	1.45	1.45
Cane Juice Pre-treatment	(Seabra et al, 2011)[3]	0.70	0.25
Sugar Production	See Worksheet* "Allocation"	-	1.97
Total Upstream GHG Emissions:		**15.59**	**17.11**
Ethanol Production	See Worksheet "EtOH Prod"	2.40	2.40
Ethanol Transport & Distribution	See Worksheet "T&D"	4.82	4.82
Addition of Denaturant	Indonesian Molasses Pathway	0.80	0.80
Well-to-Tank (WTT) GHG Emissions Estimate Before Electricity Export Credit:		***23.61***	***25.13***
Electricity Cogeneration and Surplus Export Credit	See Worksheet "Cogen Exp Cr"	(11.67)	(20.75)
Total Well-to-Tank (WTT) CI Estimate:		11.94	**4.38**
Land Use Changes	Brazilian Sugarcane Ethanol	46.00	46.00
Final Well-to-Wheel (WTW) CI Estimate:		**57.94**	**50.38**

* See Spreadsheet entitled “Final Disaggregation Analysis for BP-Biofuels ITB.xlsx”

The proposed Lookup Table entry for the BP Biofuels Itumbiara pathways is presented in Table 2 below:

[3] *Seabra et al. “Life cycle assessment of Brazilian sugarcane products: GHG emissions and energy use,” Seabra, J.E.A., Macedo, I.C., Chum, H.L., Faroni, C.E., and Sarto,C.A., Biofuels, Bioproducts, & Biorefining, 5:519-532, March 7, 2011.*

Table 2: Proposed Lookup Table Entry for Fuel/Feedstock

Fuel	Pathway Identifier	Pathway Description	Carbon Intensity Values (gCO_2e/MJ)		
			Direct Emissions	Land Use or Other Indirect Effects	Total
Ethanol	ETHS023	2A Application*: Brazilian sugarcane juice-based ethanol with average production processes, and credit for export of surplus cogenerated electricity, and mechanized harvesting.	11.94	46.00	57.94
Ethanol	ETHM008	2A Application*: Brazilian sugarcane by-product molasses-based ethanol with average production processes, and credit for export of surplus cogenerated electricity, and mechanized harvesting.	4.38	46.00	50.38

*Specific Conditions Apply

Applicable Operating Conditions

Operations at the BP Biofuels Itumbiara plant will be subject to the following conditions designed to ensure that the CI of the sugarcane juice-to-ethanol and sugarcane by-product molasses-to-ethanol pathways described in this Staff Summary will remain at or below the values appearing in Table 2 above. The conditions must be met for every gallon of ethanol sold by BP Biofuels in California. Exceptions are allowable only in the case of brief periods of planned maintenance or unpredictable, unavoidable, and uncontrollable force majeure events.

1. In order for BP Biofuels Itumbiara mill to sell ethanol in California using the fuel pathways described in this document, no less than 36 percent of the annual sugarcane juice crushed may be sent for direct ethanol production, with the remainder of the juice being allocated to BP Biofuels Itumbiara's sugar and by-product molasses production process. By-product molasses is the by-product of the sugar production process and has the approximate quality and ethanol yield of 85°Brix and 330 liters per metric tonne of molasses, respectively.

2. The mass allocation ratio, as determined from the mass flow rate of total reduced sugars (fermentables) in by-product molasses per ton of sugarcane being sent to the ethanol distillery to the mass-flow rate of the total reduced sugars in the pure post-crush sugarcane juice stream per ton of sugarcane, shall be determined as a rolling 12-month annual average, and shall not exceed 0.35.

3. The total volume of ethanol produced for export to California shall not exceed the volume calculated on the basis of the theoretical mass crush rate of 500 metric tonnes sugarcane per hour for sugar production, an ethanol yield of 7,489 gallons per hour, and the applicable operating conditions 1 and 2 above.

4. The CIs for ethanol produced by the BP Biofuels Itumbiara pathways is based on the allocation factors BP Biofuels applied to the pathways based upon the initial allocation

of cane juice-to-ethanol production, and cane juice-to-sugar production. Upstream emissions from sugarcane farming, agricultural chemical use, the estimated fraction of in-field straw burning, sugarcane transport, and sugar production are further allocated based upon the quality of by-product molasses derived from the sugar production process. This allocation factor is identified in the worksheet "Allocation."[4] If any of the input assumptions or parameters used to determine the allocation factors are changed, the CI estimate may no longer be valid. ARB must be notified of such changes as they occur, and their impacts on the ethanol fuel CI must be re-assessed if those changes are expected to be long-term changes or permanent.

5. The CI for ethanol produced by the BP Biofuels Itumbiara pathways includes a credit for electricity cogeneration and surplus exports. If the bagasse is used for any purpose other than cogeneration of electricity, or if additional bagasse is brought into the facility for cogeneration from outside the BP Biofuels Itumbiara mill, or if the boilers are de-rated, then the CI for the ethanol produced may no longer be valid and must be reassessed.

Staff Analysis and Recommendations

Staff has reviewed BP Biofuel's application for certification of Brazilian sugarcane juice and by-product molasses-based ethanol pathways for its Itumbiara mill located in the Goias State of Brazil and finds the following:

- Staff has replicated with reasonable accuracy, using a mass-based allocation methodology, the CA-GREETv1.8b GHG lifecycle emissions modeling spreadsheet, and other input process parameters furnished by BP Biofuels, the CI values being proposed for certification of Itumbiara pathways.

- Staff recognizes that the plant energy (process heat and electricity) consumption values reported for BP Biofuel's process reflect cogeneration activities from bagasse combustion with surplus electricity export to the public grid. In addition, the pathway well-to-tank GHG emissions analysis reflects applicable credits for the use of mechanized harvesting practices at the sugarcane farms.

- Staff agrees that the mass-based method used to allocate GHG emissions to the upstream sugarcane farming, transport, and sugar production processes is valid and representative for the sugarcane by-product molasses pathway being proposed for adoption.

- Staff proposes an interim approach to estimate the impact of ILUC emissions for this pathway based upon the ILUC estimate for ethanol derived from pure Brazilian sugarcane juice pathway. A revised interim or final value for ethanol derived from pure sugarcane juice or by-product molasses in Brazil may be proposed in the near term.

[4] See spreadsheet entitled "Final Disaggregation Analysis for BP-Biofuels ITB.xlsx" posted in "Supporting Information."

On the basis of these findings, ARB staff recommends that BP Biofuel's application for Method 2A LCFS pathways be approved with CIs of 57.94 gCO_2e/MJ and 50.38 gCO_2e/MJ of ethanol fuel produced from sugarcane juice and sugarcane by-product molasses at the Itumbiara mill, respectively.