Raizen COPI Molasses-based Ethanol Application

Response to Comments

The comment numbers used in this document correspond to the comment numbers appearing on the Low Carbon Fuel Standard pathway application web page [http://www.arb.ca.gov/fuels/lcfs/2a2b/2a-2b-com.htm]

Comment: [Comments 2 and 7] The mass allocation factor of 0.34 used to adjust the sugar cane ethanol indirect land use change (ILUC) increment of 46 g CO_2e/MJ downward is incorrect. This factor reduces the size of numerator to account for the lower quantity of total reduced sugars (TRS) in the molasses, but it does not make the corresponding adjustment to the ethanol yield value in the denominator. Ethanol yield is proportional to the quantity of sugars entering the fermentation process. If the numerator is adjusted to reflect the proportion of TRS going to ethanol via molasses, the denominator should also be adjusted to reflect the known yield from that quantity of sugars. Leaving the yield unchanged indicates that 100 percent of the TRS from the cane crush is available for the production of ethanol from molasses, which is clearly not the case. Making the same TRS adjustment to both the numerator and the denominator results in an allocation factor of one, leaving the original ILUC value of 46 g CO_2e/MJ unchanged.

Response: 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 commenters maintain that the use of the molasses TRS in the numerator, and the full yield of ethanol derived from pure sugar cane juice[1] in the denominator is inconsistent. 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.

[1] This yield is estimated to be 24.04 gallons of ethanol per metric ton of sugarcane (CA-GREET, v.1.80b_December 2009. http://www.arb.ca.gov/fuels/lcfs/software.htm).

In response to the comments received on the Raizen COPI application, however, staff 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 Raizen COPI 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 Raizen COPI mill is not "exhausted" molasses like that used in Indonesia and Central America. These points are echoed in other responses appearing in this document. These differences indicate the molasses used in the Raizen COPI 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 carbon intensity (CI) of the Raizen COPI molasses pathway. In response to these comments, staff will require that the Raizen COPI pathway (and others like it in the future) include the full sugar cane ethanol land use change estimate of 46 g CO_2e/MJ.

Comment: [Comment 2] This pathway should include an operating condition to the effect that no cane juice can bypass sugar production and go directly to the distillery. [Comment 3] The flow diagram in the independent engineering review document shows both molasses and pure cane juice going to the distillery. Will Raizen COPI use the CI of 14.67 g CO_{2e}/MJ for just molasses-based ethanol?

Response: Staff concurs with this comment and has attached this operating condition to the Raizen COPI pathway. Staff notes that an amended process flow diagram was provided by Raizen Energia showing that the sugarcane juice at the Costa Pinto Mill is directed only to the sugar production process. The material balances reflect the diversion of by-product molasses to the distillery for ethanol production. Raizen Energia has reiterated that a revised third party document with the reengineered process would be provided to the USEPA for RFS2 purposes.

Comment: [Comments 3, 4, 6 and 8] The Raizen Costa Pinto (or Raizen "COPI") mill is four decades old and is doing nothing differently now than it was when it commenced production. Awarding it a CI of around 15 g CO_2e/MJ signals that investment in next-generation production technology is not necessary to earn a low CI under the LCFS. This CI will actually discourage investments in technologies which improve the efficiency of the sugarcane juice fermentation process, and technologies that produce ethanol from cellulosic feedstocks. The only real difference between this and the pure cane juice pathways now in effect is that this pathway offloads a large proportion of the GHG emissions associated with ethanol production to the sugar production process. The Raizen COPI

process for molasses-derived ethanol is hardly unique: an estimated 50.5 percent of all ethanol produced in the south-central region of Brazil is produced from molasses. Pure molasses is not used because the yeast strains used to convert sugars into ethanol prefer sucrose over the fructose and glucose proportions in the molasses. Fermentation efficiency is found to increase as additional sucrose is supplied to the process.

Response: Because staff will require the applicant to include the full Brazilian sugar cane ethanol ILUC value in its CI (see staff's response to Comments 2 and 7 above), Raizen COPI's molasses ethanol pathway will now have a CI of 46.43 g CO_2e/MJ. This increase recognizes the role of molasses as a feedstock rather than a low-valued by-product; it is not a reflection of the production technology in use at the Raizen COPI mill. Despite the allocation of some upstream emissions to the sugar production process, this change results in a CI for the COPI pathway that is comparable to that of sugarcane juice-derived ethanol.

Contrary to the commenters' assertion, the applicant has implemented a significant production technology improvement at the Costa Pinto mill, and that improvement has resulted in large co-product credit that, in turn, produces a CI reduction for the fuel being produced. Raizen COPI's high-efficiency boilers allow the mill to export more surplus cogenerated electricity to the grid, while still meeting the electrical and thermal energy needs of the mill itself.

Staff has no data indicating that yeast metabolize sucrose more efficiently than fructose or glucose. If the concentration of fermentable sugars is increased, the yields of ethanol will correspondingly increase. Staff however has no information indicating that the mix of fermentable sugars has any significant effect on the fermentation efficiency.

Raizen COPI has acknowledged the presence of sucrose sugars in their "not-exhausted" molasses (i.e., the molasses is not optimized to be a low value by-product).

Staff is aware that the Raizen COPI mill is not unique in its utilization of molasses as an ethanol feedstock. The Raizen COPI pathway (as revised to reflect these comments) will serve as precedent for future pathways of this type.

Comment: [Comments 3 and 10] Integrated Brazilian sugar and ethanol mills are quite different from the sugar mills in Central America and the Caribbean. In the latter case, the sugar mills and the ethanol distilleries are physically and geographically separated. The distilleries do in fact produce ethanol only from molasses. In the State of Sao Paulo, Brazil, sugar and ethanol production commonly occurs in a single integrated complex, and ethanol is produced from pure sugarcane juice as well as molasses feedstocks. In fact, sugar production in Brazil does not fully

"exhaust" the molasses of its highly polarized sugar (sucrose) content, as is done in Central America and the Caribbean. Molasses from integrated Brazilian operations like Raizen-COPI is never sold on the commodity market. It is produced only as an ethanol feedstock for use within the integrated sugar-ethanol complex. As such, it in no way resembles the original molasses pathway paradigm establish by Gopal and Kammen.[2] Under that paradigm, a single-purpose sugar-production facility sells low-valued, mostly exhausted molasses into the livestock feed market. That molasses is diverted into ethanol production. Using a version of the Gopal-Kammen paradigm based on a mass- rather than market-based allocation obligates the LCFS to artificially approve two pathways for what is in reality a single, undifferentiated ethanol product, produced from a single, undifferentiated sugar cane crop. The mass-based allocation approach endorsed by the applicant is not appropriate for an integrated production facility like Raizen-COPI because the molasses produced is not exhausted, and is used only as an ethanol feedstock.

Response: Staff generally concurs with these comments and has determined that Brazilian mills like Raizen COPI that use unexhausted molasses as a feedstock should not benefit from the reduced ILUC value associated with the Indonesian and Central American byproduct molasses-based ethanol pathways (see response to Comments 2 and 7, above). Staff notes, however, that the mass-based allocation used in the Raizen COPI molasses pathway does not produce a CI advantage over conventional sugarcane juice-based ethanol pathways. If it were not for the increased electricity cogeneration and surplus export credit associated with the Raizen COPI pathway (see the response to comments 3, 4, 6 and 8, above), Raizen's CI would be comparable to the sugarcane juice-based ethanol pathway CIs.

Comment: [Comment 7] Please clarify how the electricity cogeneration and surplus export credit was calculated.

Response: The co-product credit for electricity cogeneration and surplus export from Raizen COPI was determined using the same GHG emissions factors specified in ARB's Brazilian sugarcane juice-based ethanol pathway document[3] for displacement of Brazilian Marginal electricity (100 percent natural gas-based generation).

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[2] Gopal, A., and Kammen, D., 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 (5 pp).

[3] 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

The mass allocation factor utilized for estimating the TRS contribution from upstream processes to the ethanol production and distribution process was applied to the net surplus cogenerated electricity exported from the Raizen COPI mill. This resulted in a quantity of electricity (measured in kWh) being allocated to the Raizen COPI byproduct molasses-to-ethanol pathway. After accounting for the yield of ethanol produced from byproduct molasses, a final resultant metric of electricity exported per gallon of ethanol was produced. The GHG displacement factors for Brazilian Marginal electricity were then applied to this final metric after accounting for line transmission and distribution losses.

Staff depended upon material and energy balances provided by Raizen for the Costa Pinto mill to determine the theoretical surplus cogenerated electricity exports. This quantity was compared to actual exports from the mill for which invoices were provided.