



November 9th, 2017
Mr. Anil Prabhu, Manager, Fuels Evaluation Section
California Air Resources Board
1001 I Street
Sacramento, CA 95814

Sent via email: LCFSworkshop@arb.ca.gov

RE: October 16th, 2017 workshop regarding co-processing of low-carbon feedstocks in conventional petroleum refineries

Dear Mr. Prabhu,

We are happy to have the opportunity to comment on the proposed LCFS program for co-processing renewable biomass with crude petroleum oil. REG supports the LCFS policy and its inclusive approach to evaluating process technologies and renewable fuels. Furthermore, we believe CARB's forthcoming verification and enforcement regulation has the potential to strengthen the market and create further credibility for the policy as a whole. However, we are deeply concerned that a verification and enforcement paradigm that relies only on mass balancing is inadequate in assuring the delivery of reduced carbon intensity fuels to the citizens of California.

We are concerned that providing a designation of 'renewable' to products which are not required to demonstrate any actual renewable content will severely damage the reputation of the program and potentially open it to future legal challenges. We believe that co-processors, like dedicated renewable fuel production facilities, should be required to verify with certainty both the quantities of renewable fuel being claimed for LCFS and the actual carbon intensity of the qualifying fuel. A requirement to objectively determine both the volume and the carbon intensity of any credit-generating fuels is critical to the integrity and ultimate success of the program.

General Discussion of the Fate of Renewable Carbon in Co-Processing

Processing conditions and renewable feedstock properties will profoundly affect the ultimate fate of the renewable feedstock in a co-processing operation. This reality has been clearly illustrated by public comments from other stakeholders, is supported by all available information in the literature, and is represented in anecdotal accounts of previous efforts to co-process renewable and petroleum feedstocks. Including renewable feedstocks in a petroleum refinery could result in renewable content in the diesel and gasoline fractions. *However*, as noted by other stakeholders, renewable feedstocks will also end up in products that are not transportation fuels—namely, coke, asphalt, residual fuels, water, and non-condensable gases, including CO and CO₂.

Numerous cautionary comments about the unpredictable and profound effect of process conditions on renewable fuel yield have already been submitted by renewable fuel producers, consultants, and potential co-processors. For example, facilities which would hydrotreat lipids in conjunction with petroleum crude can experience substantial variations in yield, CO₂ production, and hydrogen consumption depending on hydrotreater catalyst selection and age, lipid feedstock type, and process condition choices. Feedstock impurity content, free fatty acid (FFA) content, and fatty acid profile will profoundly impact both the fate of the renewable feedstock and process carbon intensity. This is further compounded by variations in the extent of decarboxylation and cracking. It must be acknowledged that reaction selectivity (e.g., the extent of decarboxylation and cracking side reactions) will inevitably vary over the lifetime of each individual hydrotreater catalyst load.

Decarboxylation provides a very useful and straightforward illustration of the impact of reaction type on renewable feedstock fate and process carbon intensity. Simply put, decarboxylation can decrease hydrogen consumption significantly compared to full hydrotreating of a lipid feedstock. However, this hydrogen reduction is accomplished by reducing the fuel yield by as much as 8%. The magnitude of this yield loss is amplified when applied to renewable acids with carbon chains in the gasoline range. Decarboxylation means the carboxyl group of the fatty acid is removed as CO₂, providing no useful fate for one of the carbons in the renewable carbon chain. This tradeoff between yield and hydrogen consumption is documented in a recent set of comments by Life Cycle Associates and described and quantified more thoroughly below in Exhibit A.¹

CARB staff must ensure that this kind of tradeoff—in this case between yield and hydrogen consumption—is captured appropriately in the regulation so as to not unintentionally incentivize the conversion of energy-rich renewable lipids directly to non-useful products such as CO₂.

Companies which intend to co-process pyrolysis oil with petroleum oil in a Fluid Catalytic Cracking (FCC) unit, a dominant refining technology in the United States, will have even more difficulty predicting renewable feedstock fate and process carbon intensity. This was emphasized in the comments from Ensyn who stated, “Proprietary biocrude conditioning and injection methodologies are very significant contributors to effective biocrude co-processing.”²

Due to the unique nature of pyrolysis oils, which vary greatly depending on production technology and biomass feedstock properties, among other things, no temporary or standard pathway can consistently be applied. Renewable carbon fate and fuel product yields in the co-processing facility must be determined based on the exact combination of co-processing technology and pyrolysis oil. The literature demonstrates that pyrolysis oils are guaranteed to vary substantially based on biomass type,

¹ (Life Cycle Associates, 2017)

² (Ensyn, 2017, p. 3)

origin location, and production technique.³ These variations cannot be ignored, as they will significantly impact not only process carbon intensity but also the fate of the renewable feedstock. Allowing a compliance protocol based only on mass balancing is guaranteed to allow periodic, if not continual, deviation from the results generated during the relatively brief verification period.

Radiocarbon Assay to Verify Renewable Fuels from Co-Processing

Fortunately, a straightforward, cost-effective, and accurate verification strategy is already included in the LCFS co-processing proposal for any entity that chooses to co-process renewable feedstocks with petroleum oils. Instead of relying on highly uncertain predictions of renewable feedstock fate in a co-processing scheme, CARB can and should require that each co-processor test any finished products that are intended to generate LCFS credits for renewable content. Any process carbon intensity improvements for the refinery that result from the inclusion of renewable feedstock can then be applied to the verified renewable portion of the fuel(s). Consider, for example, the decarboxylation example mentioned above, assigning LCFS credits based on the verified renewable carbon content of a fuel product would obviate the need to accurately predict the extents of any reactions, whether side reactions or the desired conversion reactions. Rather than guess at what is happening to the renewable feedstock in the refinery, credits can be assigned simply, accurately, and—most important—verifiably to the renewable portion of any co-processed renewable fuels.

REG recommends that renewable carbon content be determined by radiocarbon assay using the accelerator mass spectrometer (AMS) test method option (Method B in ASTM D6866). This is a highly accurate, fast, and reasonably priced test that is suitable for this exact application, particularly considering that real-time test results are unnecessary under the rules of the LCFS.

Opponents of carbon dating have focused their comments on the accuracy and timeliness of Method C in ASTM D6866, but it is important to note that the ASTM test method actually includes two methods (Method B and Method C). Unfortunately, only a single precision statement was provided for the standard. Only the uncertainty estimates for Method C in D6866 have been discussed, which is $\pm 3\%$ absolute. However, in reality Method B has a relative standard deviation no worse than 5%, almost certainly better than 3%, and potentially much better even than 3% (as low as 0.2%)⁴. As an example of what this means, producers of a co-processed fuel stream with a nominal 3% renewable carbon content should be confident in their test results within an absolute standard deviation of less than 0.09%.

While it is true that instruments for the AMS method are currently less common than instruments for many traditional fuel tests, there are multiple labs that are able and willing to perform the test on

³ Bridgwater, A. V., D. Meier, and D. Radlein. "An overview of fast pyrolysis of biomass." *Organic geochemistry* 30.12 (1999): 1479-1493.

⁴ From a telephone survey of four test practitioners in the U.S. and from EN 16640 ("Determination of the bio-based carbon content using the radiocarbon method"), the analogous test method published by CEN, the European Committee for Standardization.

fuel samples. These include Beta Analytics and DirectAMS in the private sector and the Center for Advanced Isotopic Studies (CAIS) at the University of Georgia and the KCCAMS Facility at UC Irvine in the public sector. Furthermore, this test is simple and efficient. With an approximate turnaround of 2 - 5 business days and a cost of \$300 - \$500 per sample the requirements of this test are minor compared to the economic benefit provided from the LCFS program. This economic “burden” is trivial compared to other compliance testing costs. For example, biodiesel producers which are BQ-9000 certified currently experience testing costs that are far higher than those refineries would face on a per barrel basis. We estimate that on a per barrel basis BQ-9000 testing costs biodiesel producers between \$0.04 and \$0.14 per barrel. We estimate that ¹⁴C analysis conducted on two samples per week at \$500 dollars a test would cost approximately \$0.01 per barrel for a refinery producing 26,000 barrel per day of liquid transportation fuels. As noted in the posted NREL presentation, a co-processor with \$40/bbl WTI in a 2,000 MTPD refinery can expect to receive roughly \$45,000 a day in incentives.⁵ A single day’s incentives are more than enough to cover annual testing costs. Given the stakes associated with this proposed program, it is difficult to overstate the folly that would be involved in adopting the “trust, but no need to verify” compliance strategy being promoted by potential co-processors and their allies. CARB has never yet allowed that approach for dedicated renewable fuel providers, and the same objectivity should be applied to producers who wish to co-process. Requiring renewable carbon content testing for co-processors would be consistent with CARB’s historical position on testing requirements for biofuel producers at dedicated biorefineries.

Relying on a test which is this accurate and precise should abate the fear of stakeholders such as Kern who are already concerned with the 2% error imparted by each of their production flow meters.⁶ Testing for renewable carbon content will be substantially more accurate than the compounded error from the use of multiple flow meters such as those referred to by Kern. Furthermore, product testing will bring the additional benefit of confirming the actual renewable content of their fuels to consumers. Although test results are not produced instantaneously, CARB has the authority to allow producers to release their product for distribution before the results of ¹⁴C are certified. Since LCFS credits are generated 45 – 90 days after the end of a quarter, this should not adversely affect in any manner a producer wishing to co-process. The delay in credit generation is a well-established aspect of the program and should be familiar to all current participants in the LCFS. Dedicated biofuel production facilities have successfully worked with this protective feature of the LCFS for years, and in a co-processing scenario it provides ample time for producers to reassure themselves and any regulators about the renewable content of their products.

Finally, while the ASTM method has not yet had a champion willing to invest the amount of time needed to generate a method specific precision statement for Method B at ASTM, the same type of statistical methodology used by ASTM can be applied by any interested party who would like to have

⁵ (NREL, 2017)

⁶ (Kern Oil, 2017, p. 2)

more meaningful precision information for the method for regulatory use. The current lack of a precision statement, should not be an impediment to ensuring the integrity of the LCFS program of testing credit-generating co-processed fuels for renewable carbon content. Rather than give up on such a valuable method because there hasn't yet been a financial incentive for U.S. practitioners to conduct a meaningful precision study with ASTM, CARB should either fully explore options for bringing the published ASTM standard into the 21st century or should direct interested parties to different sources for more current information about the test, such as the European Union's version (EN 16640) or labs actually performing the test.

Frequency of renewable fuel verification by radiocarbon assay

REG recommends that CARB consider requiring ¹⁴C to be tested on any fuel products that will claim LCFS credits as a 'renewable' transportation fuel. We do not believe the agency needs to create a supplemental testing schedule, rather it can rely on existing rules in 13 CA ADC § 2296.⁷ The established fuel sulfur limit with its technically sound testing requirements has significantly *and verifiably* reduced sulfur compound emissions and improved California's air quality. As the LCFS matures, there is no need to "reinvent the wheel" for testing schedules. Rather, co-processing pathways can test for renewable content using ¹⁴C sampling on the same schedule to those fuel quality parameters already being regularly sampled under California rules.

If mass-balancing schemes are ultimately allowed as a compliance option for co-processors in spite of the risk to the integrity of the program, at the very least these must be bolstered by frequent verification of the expected renewable carbon content of any credit-generating co-processed fuel. The minimum meaningful frequency for such a monitoring program is weekly (i.e., at least one sample of each credit-generating fuel product should be tested for renewable content each week) and there should be additional random spot checks throughout the year of samples collected from the field. Anything less than this will leave the LCFS program open to significant nonconformance.

Since any party interested in verifying the actual renewable content of the ostensible renewable fuels in the market can do so easily, cheaply, and at any time, the credibility of the program would be at risk if no verification of renewable content is required for credit-generating co-processed fuels. Whether fuel consumer, fuel seller, journalist, activist, or academic, the list of parties who could be interested in confirming the actual performance of the co-processing option for renewable fuel production is long. Inclusion of a mass-balancing compliance scheme for ostensibly renewable fuels without a rigorous renewable content testing program would open the door to the opportunity for fraud and allow scandals which could ultimately harm the program. Fortunately, a valid and valuable option already exists for any co-processors who wish to utilize only a mass-balancing approach without verification testing: the Refinery Investment Credit Pilot Program (RICPP). Such fuel producers should be encourage

⁷[https://govt.westlaw.com/calregs/Document/ID99A8290D46911DE8879F88E8B0DAAAE?viewType=FullText&originContext=documenttoc&transitionType=CategoryPageItem&contextData=\(sc.Default\)](https://govt.westlaw.com/calregs/Document/ID99A8290D46911DE8879F88E8B0DAAAE?viewType=FullText&originContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default))

to participate in the Refinery Investment Credit Pilot Program, but they should not be allowed to generate credits in the renewable fuel program unless they agree to verify the renewable content of their credit-generating fuels on an ongoing basis.

Exhibit A: Discussion of lipid feedstock fate in a hydrotreating process

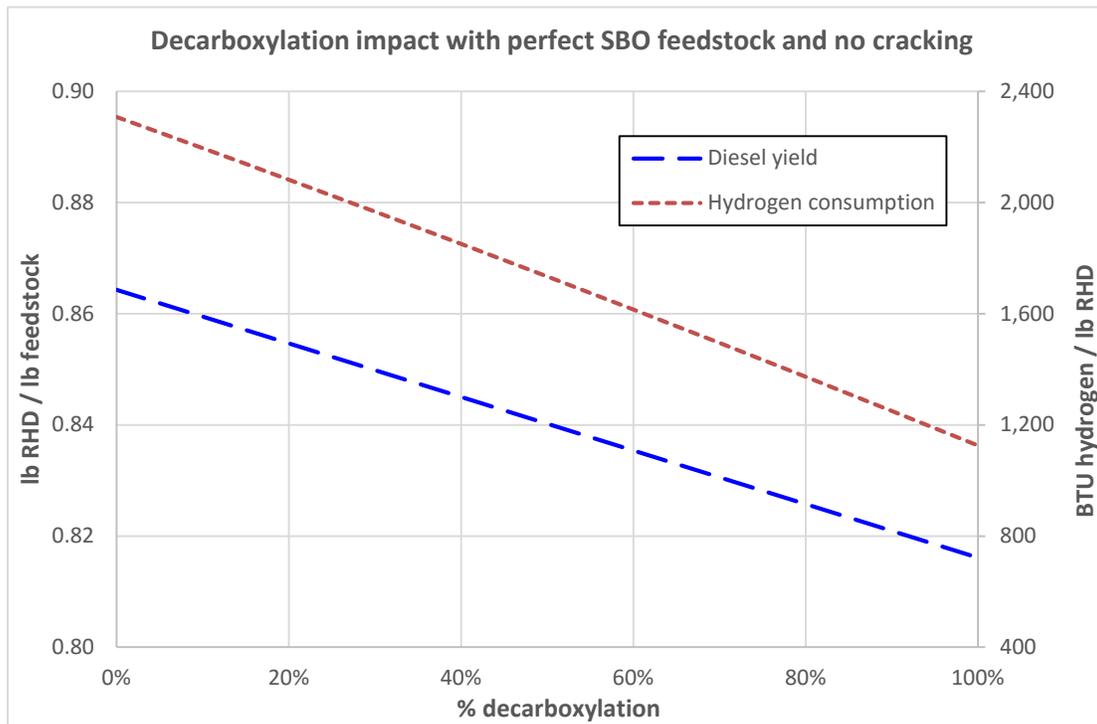
CARB staff should consider the inherent variability from co-processing crude oil with renewable biomass. Stakeholders, including Valero aptly described the variability in the fossil oil when describing the challenges that may result from baselining. We agree with them that there is significant variability, thus justifying the need for a baselining period sufficient to capture that statistical anomalies associated with a non-uniform feedstock. While we are not experts on the variability of crude oil, we can speak with expertise regarding the effects on hydrotreating yields resulting from the variations in renewable feedstock.

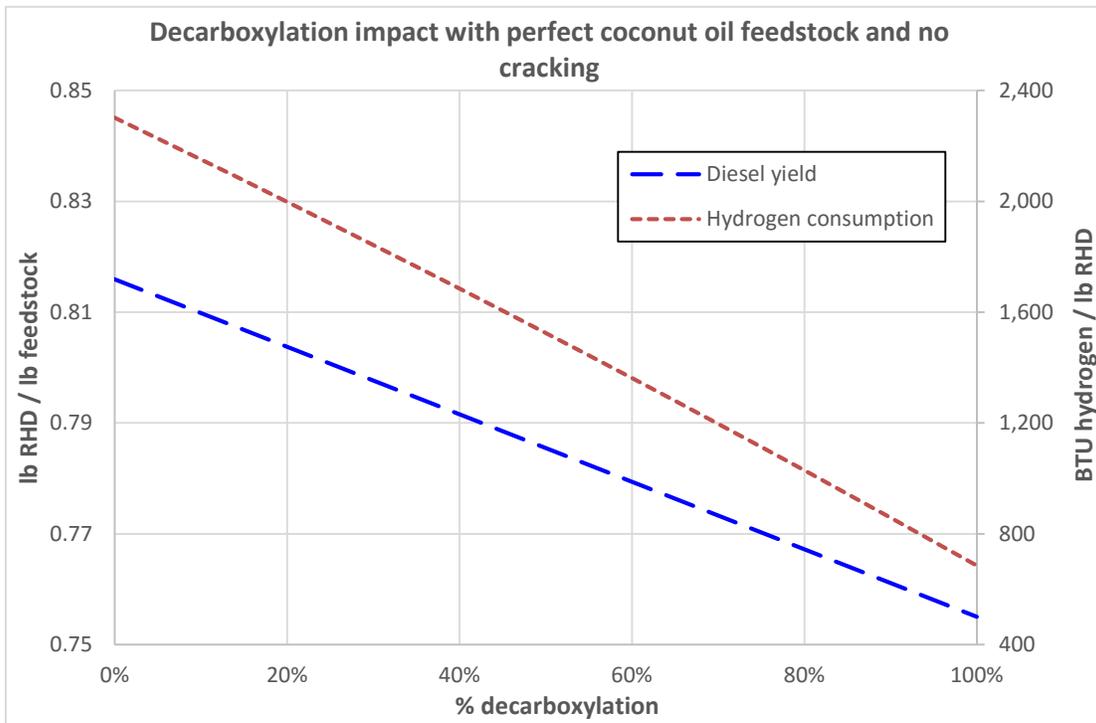
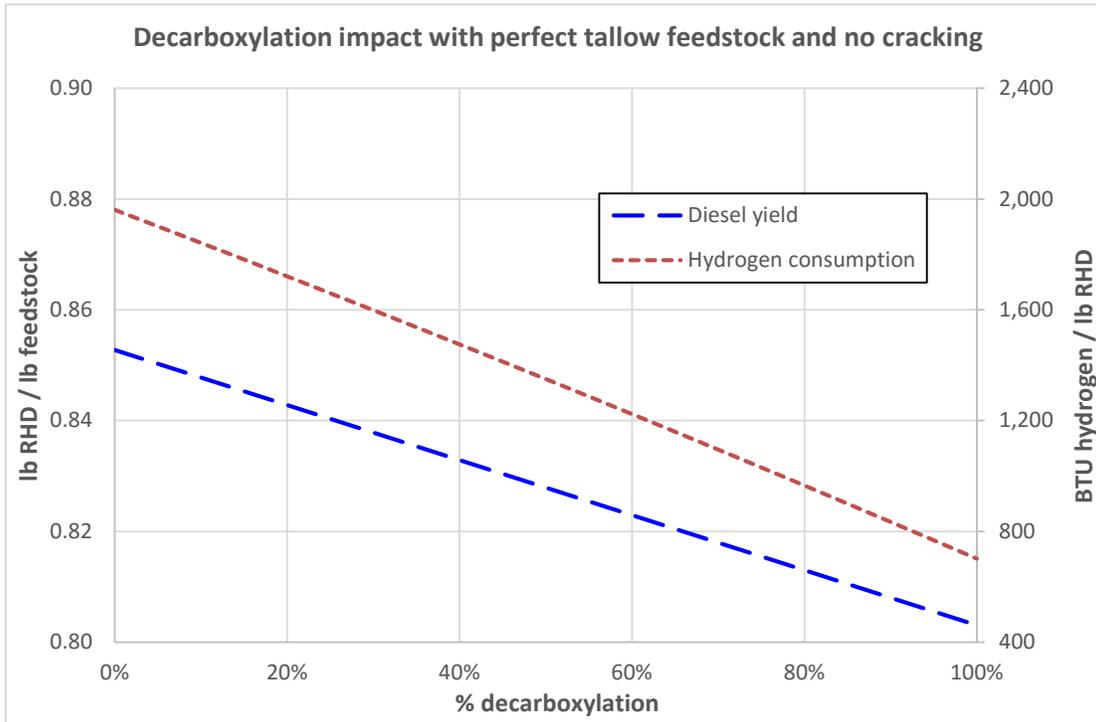
In our experience, several characteristics of the renewable feedstock can have a profound effect on the yield and on the products produced from co-processing. These are highly dependent upon the fatty acid profile, including the chain lengths and the level of saturation, as well as the FFA content, glycerin moiety content, and the unsaponifiable constituents and their respective concentrations. The variability inherent in these feedstocks is compounded by variability in hydrotreater processing condition, including temperatures and pressures inside the reactor, hydrogen feed level, catalyst type and age, and the ratio and, perhaps most important of all, characteristics of the petroleum oil in the mixture. These factors will contribute to the level of decarboxylation or decarbonylation of the renewable feedstock and the amount of cracking. While Life Cycle Associate's and Kern's assertion that the CO and CO₂ measured in the off gas should largely come from the renewable feedstock is true, knowledge of the amount of CO and CO₂ does not provide a meaningful estimate of the yield impact of the renewable feedstock on the various products leaving the refinery, whether fuel products or other. There are simply too many possibilities for where the renewable carbon can end up and too many ways for it to get there to draw any kind of conclusions from only one of the possible products of one possible reaction pathway.

As a representative example of the specific problems of the off-gas composition approach (and of unverified mass balancing in general), we have provided a few plots below depicting the dependence of yield and hydrogen consumption on the extent of the decarboxylation reaction (and only this single alternative reaction) in a hydrotreating reactor with various lipid feedstocks. Measuring CO₂ output provides no indication of the extent of other reactions that also occur in addition to the decarboxylation reaction—CO₂ output provides the analyst with only one piece of the puzzle. Since other reactions will inevitably occur as well (including full hydrotreating, which produces no CO₂ or CO) the only product testing that can actually determine the renewable volume content of the finished fuel products is renewable carbon content testing. As the plots below show, a molar decarboxylation range of 0 – 100% versus full hydrotreating is accompanied by a diesel yield variation of up to 8% when only these two

reactions are considered. The relative impact of decarboxylation on yield increases when other reactions such as cracking occur.

The other useful dependency the plots below depict is the impact of fatty acid profile on diesel product yield. Fats and oils vary greatly from source to source, and the carbon chain length distribution and extent of unsaturation in a feedstock will have a substantial impact on product yield as well as hydrogen consumption.





As a final cautionary note (and another example of why there is no such thing as a simple and meaningful indirect approach to estimating renewable carbon fate and predicting process carbon intensity impact), CARB staff must also carefully consider the effect of decarbonylation, an even less desirable fate for the carboxyl carbon. This is even less desirable from a carbon intensity perspective because it produces the same magnitude yield loss as decarboxylation but with greater hydrogen consumption because it also produces a water molecule along with the CO molecule. The decarbonylation reaction embodies, in a sense, the worst of both worlds.

Co-processing should be restricted to Tier 2 pathways

The intrinsic variability of renewable feedstock fate in co-processing applications outlined herein should provide ample evidence as to why each co-processing pathway will be unique. Accordingly, CARB should require a separate Tier 2 registration for each combination of feedstock and processing strategy. Furthermore, without ¹⁴C testing to verify renewable content, fuels produced from co-processing cannot and should not be categorized as ‘renewable’. To protect the integrity of the program co-processors who prefer to rely solely on a mass balancing compliance mechanism should be restricted to categorizing their fuel products as ‘lower carbon intensity petroleum fuels’ rather than ‘renewable fuels.’

We recognize the current regulatory scheme does allow for temporary fuel pathway codes for several types of dedicated renewable fuel facilities. This is currently appropriate considering that the production processes covered under these pathways to date are far simpler to model and far more uniform and consistent in feedstock properties, renewable fuel yields, and fuel product characteristics than any co-processing facility could realistically be. Thanks to the relative simplicity of the standalone renewable fuel processes and their clearly defined product streams, it is much easier for the agency to come up with generic carbon intensity estimates based on mass and energy flows of existing dedicated renewable fuel facilities. Ultimately, since these facilities lack the petroleum component, the potential to misrepresent the renewable content of fuels from dedicated renewable fuel facilities does not exist. Furthermore, staff can realistically estimate temporary CI scores based on the hundreds of datasets provided to them by pathway applicants.

On the other hand, it does not appear that a similarly robust dataset is available for co-processed fuels. In fact, the written and verbal comments from potential co-processors indicate that exactly the opposite is true. Petroleum refineries are much larger and more complex facilities that are designed to process a wide range of fossil feedstocks into a wide and highly flexible array of products. Before proceeding further, CARB should carefully and thoroughly evaluate the validity of the concept of a ‘standard’ process pathway given the inherent variability of processing options and feedstocks discussed herein.

Finally, due to the incredible difficulty of establishing any standard pathways which generally represent complex combinations of feedstock, processing strategy, and renewable content distribution

among the co-processed refinery products, CARB should not at this time, allow temporary pathway codes to be applied.

Conclusion

We are confident that every carbon intensity pathway and renewable fuel product for co-processing will be unique and thus will require close collaboration with the agency and technical experts to ensure the integrity of the LCFS. More specifically, we cannot envision any meaningful monitoring and compliance strategy that does not include renewable carbon content testing of any co-processed fuels intended to qualify for credits under the LCFS.

We thank you for the work that CARB staff have put into this proposal and the opportunity to provide written comments and we look forward to continuing the dialog on this important topic.

References

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