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VIA ELECTRONIC MAIL

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California Air Resources Board
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RE: CARB Evaluation of Co-Processing in Petroleum Refineries Under the LCFS

Dear Mr. Wade:

Thank you for the opportunity to comment on the guidelines needed for co-processing renewable feedstocks in petroleum refineries. The National Biodiesel Board (NBB) understands that co-processing is potentially consistent with the goals of the Low Carbon Fuel Standard (LCFS), but disagrees with the Air Resources Board's (ARB) conclusion that support exists outside the refining community for mass balance and carbon balance methods of reconciliation.

Petroleum refining is significantly more complex than the transesterification process used in biodiesel production facilities. And we hope you agree that verification of quantifiable results will be critical for accurate validation of the carbon intensity and corresponding credit generation for fuels resulting from co-processing with conventional fossil fuels. The ARB should, therefore, require C14 dating to ensure that the volumes of renewable fuel generated through co-processing are properly quantified and should implement robust procedures for baseline sampling and analysis of greenhouse gas emissions to ensure the integrity of the program.

Since its inception, the LCFS was developed as a market-based program to lower the greenhouse gas emissions from petroleum-based transportation fuels like reformulated gasoline and diesel¹ as well as to "support the development of a diversity of cleaner fuels with other attendant co-benefits."² Biodiesel and Renewable Hydrocarbon Diesel producers currently supplying fuels into the California marketplace from stand-alone facilities have been vetted and approved through rigorous studies and modeling to ensure that their biofuels comport with the goals of the LCFS. In contrast, the mass balance and carbon balance methods proposed by the work group for co-processing at refineries would provide no verifiable quantification means to ensure that there will be any renewable content within finished fuel. And the workgroup has not proposed to require C14 analysis, which is the only method that could accurately assess the volumes of renewable fuel contained in fuel generated through co-processing.

¹ Low Carbon Fuel Standard, http://www.energy.ca.gov/low_carbon_fuel_standard/

² CARB Staff Report, Proposed Re-Adoption of the Low Carbon Fuel Standard, <https://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15isor.pdf>

Moreover, co-processing in existing refineries would not provide any of the indirect benefits that existing renewable fuels producers generate. Such benefits include capital investment in new infrastructure that brings fuel diversity and greater supply reliability, domestic energy security, and additional jobs in disadvantaged communities. For example, the biodiesel industry alone supports over 64,000 jobs across the U.S.

Given the limitations of co-processing at refineries and the difficulties with quantifying the renewable fuel content of co-processed fuel, the ARB must be proactive and thorough in ensuring that co-processing operations satisfy robust verification processes. Doing so is necessary to fulfill the workgroup's core objectives of establishing lifecycle carbon intensity for co-processed fuel as well as "establish[ing] guidelines for quantification of low carbon fuel volumes from co-processing," "evaluat[ing] greenhouse gas emissions of co-processing operations," and "develop[ing] monitoring and verification protocols for co-processed fuels."³ Failing to do so will undermine the integrity of the program, reduce the GHG emission benefits achieved under the LCFS, decrease the diversity and reliability of California's low carbon fuel supply, and reduce employment opportunities in California's disadvantaged communities.

I. Quantification of Low Carbon Fuel Volumes from Co-processing

A. Mass Balancing and Carbon Balancing

Neither the mass balancing method nor the carbon balancing method can provide an accurate assessment of the renewable content of co-processed fuel. In fact, each measurement, as part of both mass or carbon balancing methods would be significantly less precise than a direct measurement. As part of the discussion around this proposal, the ARB is seeking input "to ensure analyses requested as part of the application are representative and accurate." Any means for modeling, and the numerous data points that would be required, would lead to a sum of uncertainties greater than the value being proposed to measure. Each measurement will have its own uncertainty which, when used to create a balanced equation for determining a co-processed fuel pathway, will lead to values inconsistent with the outcomes. The desire to quantify that uncertainty by calculating a mean and standard deviation for each measurement can only be accomplished when examining identical samples and processes--none of which will be possible or capable when dealing with different refineries and different daily conditions.

Indeed, the U.S. Environmental Protection Agency (EPA) has found that a mass balancing approach is inadequate for verification of the renewable content of co-processed fuels. In late 2016, EPA proposed a rule entitled the "Renewables Enhancement and Growth Support" rule (commonly referred to as the "REGS Rule"), which would, among other updates to the RFS program, provides for potential pathways for co-processing of biointermediates.⁴ As part of that proposal, EPA observed that it was "concerned with the ability of the mass balance approach to accurately and precisely determine the number of RINs that can be generated for a co-processed partially renewable fuel." EPA explained that "the volume of biointermediate co-processed with petroleum at a refinery would likely be a small fraction of the refinery's throughput and would make it difficult to rely on a mass balance approach for RIN generation and may lead to the generation of RINs for the non-renewable portion of the co-processed fuel." EPA's concerns

³ Staff presentation on "Co-processing in Petroleum Refineries: 4th Work Group Meeting", https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/10162017_staffpresentation.pdf

⁴ 81 Fed. Reg. 80, 828, 80,836 (Nov. 16, 2016).

with mass balancing in the context of the RFS are equally applicable to the LCFS. Without the ability to accurately and precisely determine the renewable content for credit generation, no further calculations would be appropriate to determine reductions in greenhouse gas emissions and the carbon intensity of any finished fuels. And, as noted above, the LCFS is strictly designed to measure and trade reductions in real greenhouse gas emissions—not theoretical or potential greenhouse gas emissions.

B. C14 analysis

C14 analysis, as documented within the ASTM D6866 test method, is a standardized radiocarbon dating method used for various applications. It is a mature technology that has been in use for 60 years. D6866 is the “Standard Test Method for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples using Radiocarbon Analysis,” and is the predecessor to several other European and international test methods to determine biogenic carbon content. The method is capable of being performed on multiple sample matrices and any type sample phase. Method ASTM D7459 also provides a Standard Practice for Collection of Integrated Samples for the Speciation of Biomass (Biogenic) and Fossil-Derived Carbon Dioxide Emitted from Stationary Emissions Sources. These two methods can be used in conjunction to determine the actual gains of renewable carbon within liquid transportation fuels against that renewable carbon lost in processing. D6866 is currently published without any official precision and bias (repeatability and reproducibility), and while the overall uncertainty could be as high as +/-3% absolute, most studies and other international methods using this same technique are cited as having a relative standard deviation of just 0.2 to 5%. In such an instance where a batch of fuel resulting from co-processing that contains just 1% renewable content, the expected results of ASTM D6866 would be between 0.95 and 1.05%. This is considerably more precise and accurate as opposed to any balance equations utilizing previously purported baseline data.

In sharp contrast to the mass balance method, EPA found in its proposed REGS rule that ASTM D6866 method was a highly reliable means for verifying the renewable content of co-processed fuels.⁵ In particular, EPA found that Method B of ASTM D6866 would provide precise results. EPA therefore proposed that “only Method B of ASTM D6866 could be used to determine the renewable content of co-processed fuels” under EPA’s proposal related to the co-processing of biointermediates. Just as in EPA’s proposed REGS rule, ASTM D6866 is the best method for assessing the renewable volume of co-processed fuels under the LCFS. The ARB should develop rules consistent with EPA in this regard by implementing only the most accurate testing methods in order to ensure that co-processed fuels meet the greenhouse gas reduction and other goals of the LCFS.

Regulatory precedents for using C14 analysis can be found in 7 CFR 2902, USDA Guidelines for Designating Biobased Products for Federal Procurement; 40 CFR 98, US EPA Mandatory Greenhouse Gas Reporting; and AB32, GHG Reporting.

II. Baseline Sampling and Gas Analysis

Additionally, to ensure appropriate measurements and analysis can be performed to determine low carbon fuel volume from co-processing, sufficient data must first be obtained on the baseline operations. It has been suggested that 3 months of baseline sampling and gas analysis be provided to collect and measure data on feedstock inputs, product outputs (including gaseous

⁵ *Id.*

components) and energy/hydrogen use. NBB suggests that this time frame is not nearly long enough. Refinery operations operate in a fluid manner in order to manage market conditions and no two refineries are alike. Factors such as feedstock crude recipes, catalyst performance and effectiveness, seasonal demands, and energy prices all affect refinery operations and the proposed baseline sampling measurements. Other conditions such as planned maintenance, unexpected repairs and scheduled turnarounds will all impact energy use and baseline sampling.

A three-month requirement (or less) is not nearly enough time to statistically sample the baseline operations of any refinery and leaves the end result vulnerable to “cherry picking.” With each of the suggested parameters to measure volumetric/mass flows and elemental composition for each feedstock input and product output, there will be measurement uncertainties that will be compounded upon themselves for the various streams. Mass flowmeter technology, such as Coriolis meters, have their own bias when dealing with low flow rates, high viscosity fluids, and incompletely full lines. Mass flow meters such as these have published accuracies of +/- 1%^{A6}. Substitutions between volume and mass also require density determinations. Even the most accurate density measurements have uncertainties in reproducibility of just over 1%. Other elemental analyses to determine carbon balance are even less accurate. ASTM International test methods for Sulfur (ASTM D5453) and Nitrogen (ASTM D5762) are just a couple examples of test methods with uncertainties in reproducibility of over 10% of any reported results. When compounding all the variables and uncertainty between each of the necessary measurements, one could expect to see drastic fluctuations in the suggested daily measurements.

III. FCC units / Hydrotreating / Hydrocracking / Catalysts

The term co-processing covers a wide range of technologies and the NBB would like to suggest that the ARB consider each of the technologies separately as each likely has a different range of potential feedstocks that can be used, a different range of products that can be produced, and a different set of issues to consider in the GHG modelling. Renewable feedstocks can be handled in FCC units, hydrocrackers and/or hydrotreaters, and each of these has different operating conditions and catalysts.

Research organizations such as ASTM International as well as universities and even some refiners have published studies investigating co-processing. At the latest American Oil Chemists’ Society (AOCS) Latin America Congress, the University of the Republic of Uruguay presented findings looking at converting bio feedstocks into renewable fuels via refining hydrodeoxygenation with various catalysts. Even with their efforts to maximize a liquid transportation fuel in the lab study, they found significant cracking of the molecules into lower carbon fuels. The use of triglycerides as a feedstock would also lead to the loss of a significant portion of the renewable feedstock. Oxygen molecules comprise approximately 11% of triglycerides. These would certainly be lost in any processing techniques to create a hydrocarbon fuel. As the fatty acid chains separate from the glycerin backbone of the molecules, the glycerin molecule (3 carbon chain) would also be lost from any liquid fuels. This comprises approximately another 10% of any renewable inputs. In a recent ASTM International ballot detailing the specifications for aviation turbine fuels from co-processing, the research report⁷

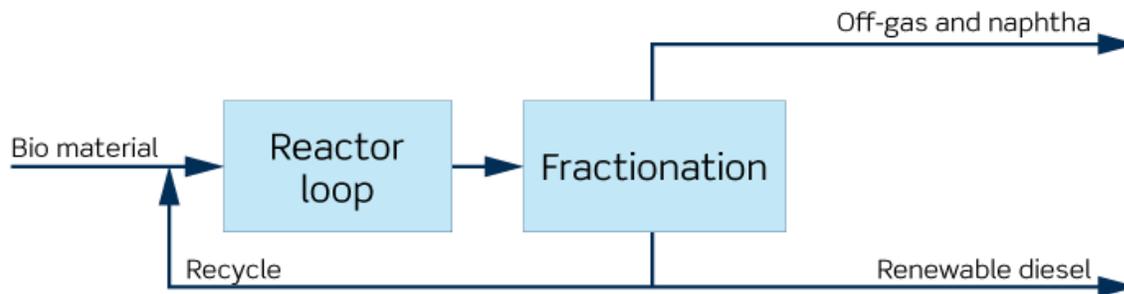
⁶ Attachment- Universal Flow Monitors Inc., General Instrument Specifications, MG nohi 09182007

⁷ ASTM International Committee D02 ballot 17-04 Item 28, WK53422 Research Report, with the appropriate permissions to cite within these comments. This document is not an ASTM standard; it is under consideration within an ASTM technical committee but has not received all approvals required to become an ASTM standard. You agree not to reproduce or circulate or quote, in whole or in part, this document outside of ASTM

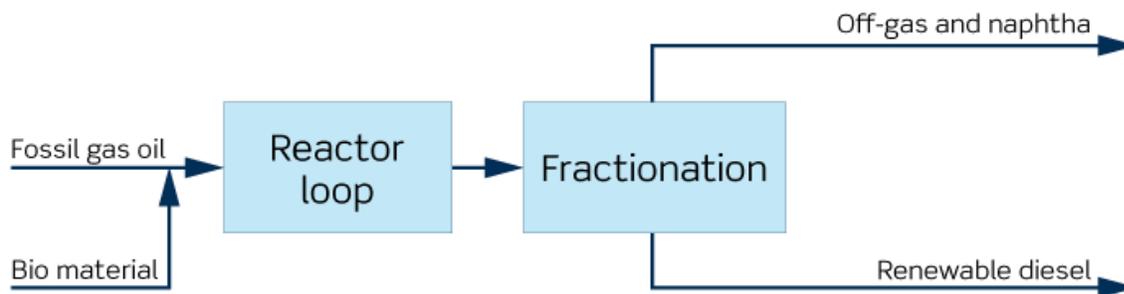
supplied by several refiners notes that conditions would be “sufficiently severe” to create fully saturated alkanes, along with water, carbon monoxide and carbon dioxide. These additional products would be in addition to the existing emissions resulting from petroleum processing and contrary to the goals of the LCFS to reduce greenhouse gas emissions. The refiners agree that “the exact composition of product depends upon the bio-oil and process conditions.” Further quoting from the research report, the refiners note that, “once formed, the paraffins are indistinguishable from similar molecules derived from crude oil unless analyzed for ¹⁴C Content. This attribute is a useful way to determine if bio-derived carbon has reached jet fuel fractions following co-processing”. Besides being “useful,” we believe that the C14 analysis performed in accordance with ASTM D6866 is imperative for allowing co-processing. The ARB should not place itself in the position of guesstimating carbon intensity values and volumes of renewable fuels produced.

A. Hydrotreating

Co-processing with petroleum diesel is a commercially available process⁸ and has been practiced at one refinery in Sweden since 2010. That refinery co-processes FAME and fossil diesel. The co-processing through a hydrotreater is very similar to a stand-alone renewable diesel process and Haldor Topsoe shows both configurations on its website as shown below.



Typical stand-alone HydroFlex™ configuration for processing of renewable feeds



Typical HydroFlex™ configuration for co-processing of renewable and fossil feeds

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⁸ Haldor Topsoe HydroFlex™. <https://www.topsoe.com/products/hydroflex™-technology>

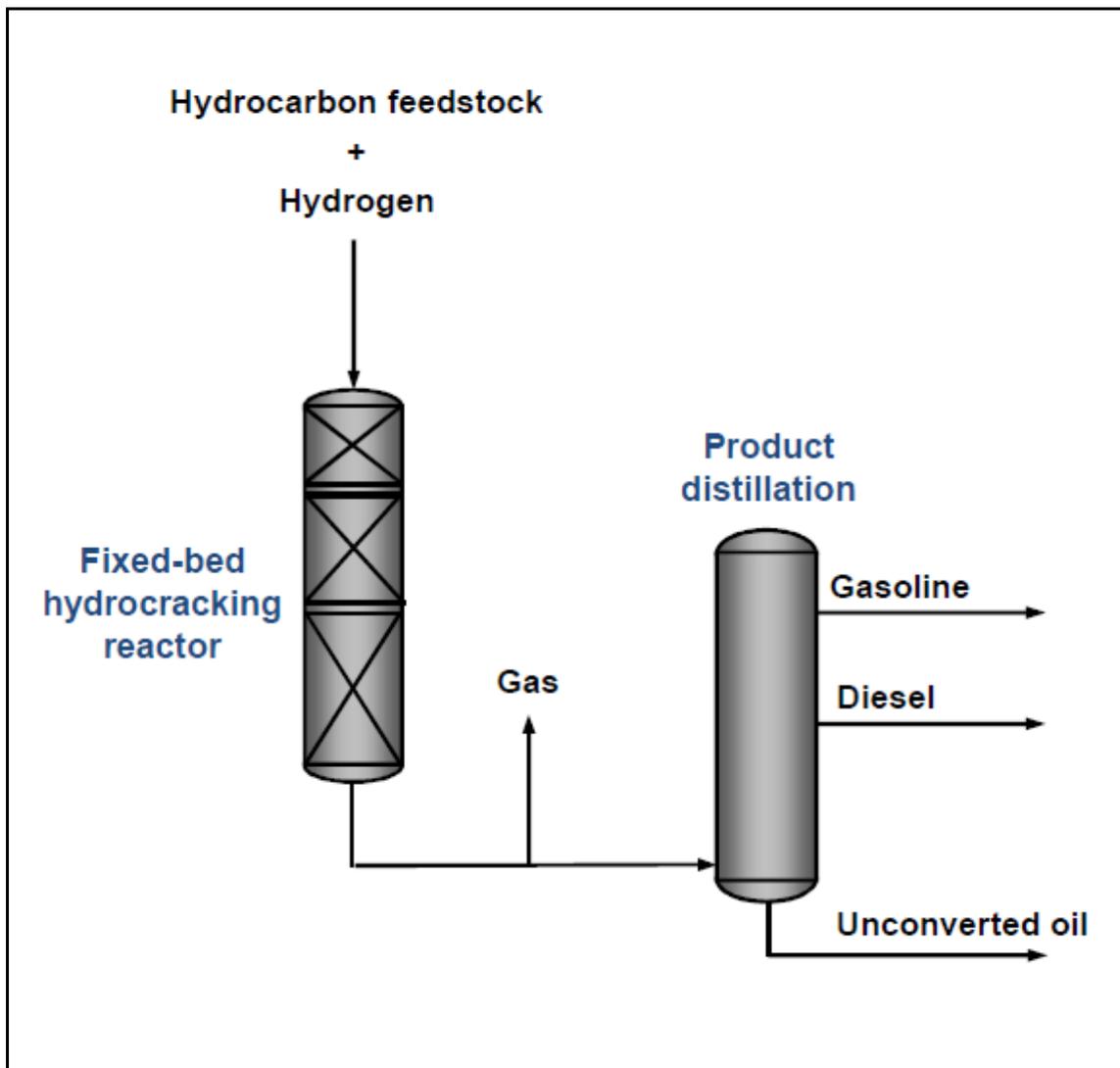
The bio-feedstock for hydrotreating is typically lipid-based. There has, however, been some work conducted on hydrotreating pyrolysis oils, but the hydrogen demand is much larger due to the higher oxygen content of the feed, resulting in operational issues. The carbon intensity (CI) data requirements for co-processing through the hydrotreater should be the same as they are for a standalone process and include hydrogen consumption, power and natural gas use, and any chemicals used for pre-treatment of the feedstock. The co-product composition and quantities should also be monitored and reported.

Since this co-processing configuration is relatively straightforward, three months of baseline data may be adequate to establish a baseline, though six months would be preferable. The baseline data should be equivalent to the information that is routinely captured at stand-alone plants, including samples (products and co-products) every 12 hours which are analyzed by GC and other means. An acceptable means other than the development of baseline data would be regular C14 analysis combined with the input mass flow data. The bio-component of co-processing through a hydrotreated is expected to be larger than it is through hydrocracking of FCC processing.

The CI modelling data for co-hydrotreating can also be compared to the information on stand-alone plants collected from Tier 1 and Tier applications.

B. Hydrocracking

There has been little discussion on the use of hydrocracking as a means of co-processing. A processing scheme is shown below.



This process also requires hydrogen to achieve the desired end products and thus may have a higher CI than product produced through an FCC unit, although it probably also means that there is more biogenic carbon that ends up in the products. It may be better suited to pyrolysis oils than to lipids. Hydrocracking capacity is less than FCC capacity in North America, so that may be one reason that less work has been done on this approach.

C. Processing Through an FCC

Most of the discussion in the ARB co-processing workshops has focused on co-processing through the FCC unit and with the use of pyrolysis oils as the bio feedstock. Unlike hydrotreating, there is very limited real-world experience with this concept and much of the available information contains some contradictions. Al-Sabawi et al (2012)⁹ published a review of the work done in this field. The conclusions from this review were as follows:

Although several studies have investigated the catalytic cracking of biomass-derived oils and their blends with conventional petroleum feedstocks, there are still important

⁹ *Fluid Catalytic Cracking of Biomass-Derived Oils and Their Blends with Petroleum Feedstocks: A Review.* Mustafa Al-Sabawi, Jinwen Chen, and Siau Ng *Energy & Fuels* 2012 26 (9), 5355-5372
DOI: 10.1021/ef3006417

knowledge gaps to be filled in this research area to achieve commercial application. These gaps include but are not limited to compatibilities of different bio-oils with conventional petroleum feedstocks, the effects of bio-oil species on competing FCC reaction mechanisms, and the heterogeneous kinetic modeling of the catalytic cracking of bio-oil/petroleum feedstock mixtures. All of these are directly related to the design and operation of commercial FCC units.

These conclusions call into question the baseline approach to determining the impact of co-processing on the FCC operation and the ability to isolate just the modelling data required to determine the CI of a co-process bio-oil, where not only the fossil component but also the biomass component may vary with time.

Processing bio-oil through a FCC unit can de-oxygenate the bio-oil without the addition of hydrogen. The oxygen is removed as CO or CO₂ rather than as H₂O as is the case with a hydrotreater. One should expect significantly lower liquid product yield as a result. The trade-off is lower hydrogen demand and thus better GHG performance but with a lower yield of biogenic carbon in the products.

This trade-off was reviewed by Venderbosch in his 2015 paper (A Critical View on Catalytic Pyrolysis of Biomass)¹⁰. While the paper did not focus on the processing of bio-oil through an FCC it did show that higher product yields would be obtained with hydrotreating to remove oxygen rather than through the decarboxylation process. The author notes that:

Evidence is given that in an initial stage of the catalytic process reactive components are converted to coke, gas, and water, and only to a limited extent to a liquid product. Catalysts are not yet good enough, and an appropriate combination of pyrolysis conditions, reactive products formed, and different reactions to take place to yield improved quality liquids may be practically impossible.

The NBB believes that the Carbon 14 methodology is the only appropriate method of determining the product yields for co-processing bio-oils in an FCC unit. The carbon balance approach ignores biogenic carbon that would be present in the coke and thus overestimates the product yield. The mass balance approach is complicated by the interactions between the fossil feedstock and the biogenic feedstock. Furthermore, carbon yields of 64 to 78% for bio-oil that are generated through these alternative approaches cannot be supported by the scientific understanding of upgrading pyrolysis oils.

IV. Performance Evaluation of the Finished Fuels - CRC Report No. AV-23-15

Another rationale for analyzing the actual finished fuels to determine the renewable content is to help ensure the adequacy of the existing test methods used to certify the quality of the product batches. The Coordinating Research Council (CRC) is a non-profit organization supported by the petroleum and automotive equipment industries. In one of its latest reports (AV-23-15¹¹), CRC evaluated the “Adequacy of Existing Test Methods for Aviation Jet Fuel and Additive

¹⁰ Venderbosch, R. H. (2015), A Critical View on Catalytic Pyrolysis of Biomass. ChemSusChem, 8: 1306–1316. doi: 10.1002/cssc.201500115

¹¹ CRC Report No. AV-23-15, Adequacy of Existing Test Methods for Aviation Jet Fuel and Additive Property Evaluation

Property Evaluation” particularly for synthesized hydrocarbons such as those created by co-processing. The industry often infers behaviors and the suitability of performance of a fuel from the analytical test results obtained. This study, while reviewing standards and test methods, found discrepancies in terminology and concerns with some of the commonly used standardized test methods. Within the review, dozens of test methods were identified as having concerns with possible impacts on the fuel composition or several having a high probability of being impacted by the composition of the material being tested.

V. Conclusion

NBB recommends that the ARB: (1) require C14 dating to ensure that the volumes of renewable fuel generated through co-processing are properly quantified; (2) establish protocols for thorough baseline sampling; and (3) create procedures for appropriate and adequate analysis of greenhouse gas emissions. Following this guidance would help ensure that any greenhouse emissions savings generated by co-processing are both real and verifiable. From our perspective this is an issue that speaks directly to the integrity of the LCFS program.

In simple terms we believe it is very important to the integrity of the LCFS program and GHG reduction goals to accurately measure the renewable carbon content and lifecycle carbon intensity of distillate fuel entering the California market from a petroleum refinery. We are concerned that assumptions based on mass balance may not accurately reflect the true carbon intensity of diesel fuel from a co-processing refinery. We are concerned with the unknown fraction of renewable feedstock that potentially contributes to other refinery output streams such as naphtha and propane. We are also concerned that renewable feedstock in a petroleum refinery could contribute to byproduct and waste streams that do not become valuable transportation fuel. While there may be economic advantages of a large-scale refinery, we question whether there could be significant yield loss in a large refinery optimized for petroleum relative to standalone biorefineries which are optimized for renewable feedstock. We are concerned that a mass balance approach could underestimate this yield loss of renewable product in a coprocessing refinery. Stand-alone biodiesel and renewable diesel facilities are often optimized for yield efficiency. We have observed specifically that biodiesel producers have optimized processing techniques in recent years to maximize the volume of renewable fuel produced relative to the volume of their feedstock inputs. This yield optimization comes at the expense of higher energy inputs. This tradeoff is reflected in the way that ARB currently assigns carbon intensity for biodiesel. The same rigor should be applied to coprocessing facilities.

Standalone biodiesel and renewable diesel facilities have made considerable investments to primarily produce renewable diesel substitutes. Diesel fuel is versatile and valuable for its ability to deliver energy density in a fuel that is compatible with the high torque compression ignition engines required for heavy duty transportation. The alternative for reducing carbon in diesel substitutes are relatively few compared to light duty applications. These factors combine to make LCFS credits and RINs in the distillate pool uniquely valuable. It would disrupt investment flows if coprocessing facilities received unwarranted LCFS credit in the distillate stream when their renewable product is actually flowing into gasoline, propane, or waste streams.

This also relates to our historical concern that the carbon intensity of diesel fuel and gasoline do not accurately reflect the emissions associated with refining byproducts such as petroleum coke and residual oils. These waste streams are burned for energy recovery, but they most likely would not be produced if they were not a waste stream of gasoline and diesel production. The emissions associated with burning these waste streams should also be accounted for in the carbon

intensity of diesel fuel. Under a coprocessing scenario, we are concerned that it may be possible for renewable product to further contribute to the carbon emissions from burning these waste streams that do not result in valuable transportation fuel.

We understand that the conventional petroleum industry has a large role to play in reducing the carbon intensity of fuel blends. We understand that financial rewards may be appropriate to incentivize innovation resulting in biomass displacing fossil fuels and resulting in lower carbon emissions. By providing financial rewards to a petroleum refinery, the potential is raised to increase that refinery's share of the market relative to other low carbon diesel alternatives. Even if this advantage is slight, it raises the question of indirect effects. Increasing total refinery emissions is a possibility. We expect ARB would prefer not to quantify the indirect emission resulting from these coprocessing scenarios, but we are reminded of the extensive length to which ARB has gone to penalize biofuels for indirect effects. At a minimum, ARB should assess the emissions from refinery byproducts and waste as part of the carbon intensity of petroleum fuels. This should also apply to co-processed refinery outputs.

Above all, ARB should approach the assessment of coprocessing pathways with all the scientific rigor available. The LCFS has proven to be an effective tool for removing barriers to change. The LCFS is appropriately making way for better fuels. Shortcuts that overestimate the GHG benefit of coprocessing will directly penalize the companies that have made significant investment in standalone facilities dedicated to processing renewable products. The renewable fuels industry welcomes partnerships with the technically capable and financially strong petroleum industry, because they have the power to reshape the transportation fuel market. That includes making low carbon fuels more widely available if they choose to do so. Financial incentives supported by scientific rigor are appropriate. However, those incentives should not levy relative penalties on the independent companies that have invested in dedicated renewable fuel facilities.

Sincerely,

A handwritten signature in black ink that reads "Don Scott". The signature is written in a cursive, flowing style with a large, sweeping underline.

Don Scott
Director of Sustainability
National Biodiesel Board