Comments of Growth Energy on the Air Resources Board Staff Presentations at a Public Consultation Meeting on Regulations for Commercialization of Alternative Diesel Fuels

These comments respond to the CARB staff's request for comments on the staff's presentations at the November 21, 2014 public consultation meeting on the proposed adoption of regulations to govern commercialization of alternative diesel fuels, including as part of compliance strategies for the California Low Carbon Fuel Standard ("LCFS") regulation.

1. Methodology for Assessing Impact of Biodiesel Use on NOx Emissions

As Growth Energy has commented previously, CARB staff's approach to assessing the NOx emission impacts of biodiesel and biodiesel blends in heavy-duty diesel engines is flawed.[1] The staff's approach does not adequately protect the environment, in part because it ignores the fact that the existing emissions test data indicate that there are statistically significant increases in emissions of oxides of nitrogen (NOx) at biodiesel blend levels below B5, the lowest level at which CARB staff has chosen to perform testing. As fully explained in an expert report prepared for Growth Energy by Mr. Robert Crawford of Rincon-Ranch Consulting,[2] any sound statistical analysis of the available data indicates that statistically significant increases in NOx emissions occur at biodiesel blend levels below B5.

In light of the recent release of biodiesel emissions data by CARB staff, Mr. Crawford has updated his work to include all of that data. The results of this updated analysis were summarized by Jim Lyons of Sierra Research during a presentation made at the October 20, 2014 ADF workshop, and detailed documentation regarding the updated analysis was provided to CARB staff

[1] See Attachments A – D.

[2] See Crawford, R., "NOx Emission Impact of Soy- and Animal-based Biodiesel Fuels: A Re-Analysis," December 10, 2013.

by Mr. Lyons via email on October 24, 2014,[3] along with a request that it be posted on agency's ADF website.

As CARB staff has been advised, inclusion of the newly released biodiesel emission test data does not alter Mr. Crawford's previous findings. Likewise, the CARB staff's decision to characterize biodiesels as "low saturation" or "high saturation," instead of "soy" or "animal" based," does nothing to alter Mr. Crawford's findings or protect against increases in NOx emissions resulting from biodiesel use in California. CARB staff has not posted Mr. Crawford's updated analysis on the agency's ADF webpage; has never discussed or explained why it has not adopted Mr. Crawford's approach; and did not discuss Mr. Crawford's revised analysis in any way during the November 21, 2014 workshop. CARB staff appears determined to avoid full public review of the available data, in violation of its environmental protection regulations and the statutes that apply to this rulemaking, including the California Environmental Quality Act ("CEQA") and the Global Warming Solutions Act of 2006 ("AB 32").

2. Proposed Biodiesel Control Levels

For what it treats as low saturation biodiesel blends, CARB staff is proposing a control level of B5 from April 1 to October 31 of each year and a control level of B10 throughout California during the rest of the year. What this means, based on the proposed regulatory language[4] released by CARB staff, is that during the summer, mitigation of increased NOx emissions is not required until low saturation biodiesel blend levels exceed B5 (e.g., B6)—despite the fact that ***CARB staff acknowledges that statistically significant impacts occur at the B5***

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3 Although these were already provided to CARB staff, materials related to Mr. Crawford's most recent analysis are attached to these comments.

4 Proposed Section 2293.6(a)(2).

level.[5] Given this, there can be no dispute that the staff proposal will result in increases in NOx emissions in California. Such an outcome, however, is not permitted under CEQA and AB 32.

During the winter the control level for low saturation biodiesel blends increases from B5 to B10, meaning that NOx mitigation is not required until the biodiesel blend level reaches B11. As a result, CARB staff is allowing unmitigated increases in NOx emissions in California to as much as double during the winter. Further, Growth Energy is not aware of, nor has CARB staff identified, any other NOx control measure affecting stationary, area, or mobile sources that is allowed to be relaxed during the winter months anywhere in California. Such an inconsistency cannot be squared with CARB's CEQA obligations or the requirements of AB 32, which include the avoidance of controls that would have the effect of increasing regulated emissions (such as NOx) or hampering compliance with state and federal ambient air quality regulations.

For high saturation biodiesel blends, CARB staff is proposing a year-round control level of B10, meaning that NOx mitigation is not required until the B11 level. Again, this is above the B10 level at which even CARB staff has determined that statistically significant increases in NOx emissions will occur; therefore, it will allow unmitigated increases in NOx emissions to occur throughout California.

Growth Energy again urges CARB staff to revise its proposal to ensure that it is protective of California air quality by requiring mitigation of potential NOx emission increases from all levels of biodiesel blends, the need for which is indicated by Mr. Crawford's work. CARB cannot risk increases in NOx emissions by failing to require year-round NOx mitigation for low saturation

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5 This was acknowledged by CARB staff at the October 20th workshop. See *http://www.arb.ca.gov/fuels/diesel/altdiesel/20141017_ADF_statistical_analysis.pdf* and *http://www.arb.ca.gov/fuels/diesel/altdiesel/20141017_ADF_discussion_paper.pdf*

biodiesel blends beginning at the B5 level, and for high saturation biodiesel blends beginning at the B10 level.

3. New Technology Diesel Engines and the Sunset and Exemption Provisions

CARB staff claims, currently without empirical support or any other explanation, that the use of biodiesel blends in so-called "new technology diesel engines" (NTDEs) will not result in increased NOx emissions regardless of the type of biodiesel used or the blend level up to at least B20. Based on that claim, CARB staff is proposing to eliminate the requirements for mitigation of biodiesel-related NOx emission increases when the population of vehicles equipped with NTDEs in the California truck fleet reaches a certain level and for biodiesel blends used by centrally fueled truck fleets that are composed of at least 90% of vehicles equipped with NTDEs. The available studies in the peer-reviewed literature, which have been previously identified by Growth Energy for CARB staff,[6] contradict the staff's claim. The proposed exemptions for fleets of vehicles comprised mainly of vehicles equipped with NTDEs and the sunset provisions are therefore not permitted under the governing statutes because they would permit an unmitigated risk of increased NOx emissions, and adverse impacts on air quality.

4. Definitions of CARB Diesel and Blend Level

At present, CARB staff is proposing to define "CARB diesel" to which biodiesel will be allowed to be blended under the ADF regulation as follows:[7]

> *...a light or middle distillate fuel that may be comingled with up to five (5) volume percent biodiesel and meets the definition and requirements for "diesel fuel" or "California nonvehicular diesel fuel" as specified in 13 CCR 2281, et seq. "CARB diesel" may include: renewable diesel; gas-to-liquid fuels; Fischer-Tropsch diesel; CARB diesel blended with additives specifically formulated to reduce emissions of one or more criteria or toxic air contaminants relative to reference CARB diesel;*

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6 See Attachment D

7 Proposed Section 2293.2(a)(9)

and CARB diesel specifically formulated to reduce emissions of one or more criteria or toxic air contaminants relative to reference CARB diesel.

The "blend level" of a biodiesel blend or blend of another ADF would be defined[8] as follows:

...the ratio of an ADF to the CARB diesel it is blended with, expressed as a percent by volume. The blend level may also be expressed as "AXX," where "A" represents the particular ADF and "XX" represents the percent by volume that ADF is present in the blend with CARB diesel (e.g., a 20 percent by volume biodiesel/CARB diesel blend is denoted as "B20").

Because "CARB diesel" can contain up to 5% biodiesel and the control levels proposed by CARB staff above which NOx mitigation is required are defined in terms of "blend levels," the actual biodiesel content of a biodiesel blend under the staff proposal could be as much as 5% greater than the "blend level" used to determine if NOx mitigation is required. Thus, for example, under the staff proposal NOx mitigation of a summer blend of "low saturation" biodiesel blend would not be required even though it contains 10% biodiesel and the unmitigated NOx emissions would be as much as twice those assumed by CARB staff.

There are at least two ways by which CARB staff could easily address this issue. The first would be to require biodiesel blenders to test the CARB diesel fuels they use in order to determine the biodiesel content and type of biodiesel present in a given CARB diesel before blending occurs. The second would be to require that biodiesel blenders use only CARB diesel fuels that have been certified as containing no biodiesel. In any case, CARB staff must modify its proposal to ensure that the actual biodiesel content of blends is accurately known and that appropriate NOx mitigation requirements are imposed. Failure by CARB staff to require accurate measurement and reporting of the biodiesel content of biodiesel blends will lead to unmitigated increases in NOx emissions

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8 Proposed Section 2293.2(a)(4)

along with other potential issues, including violations of pump labeling and vehicle manufacturer warranty requirements.

5. Phase-In Requirements and Program Review

Under the current staff proposal, although the ADF regulation would become effective on January 1, 2016, ***mitigation of increased NOx emissions from the use of biodiesel blends would not be required until 2018.***[9] In addition, CARB staff is proposing to perform a "review" of efficacy of the NOx mitigation requirements of the biodiesel provisions of the ADF regulation by December 31, 2019.[10] As in other respects, the CARB staff proposal fails to adequately protect against adverse air quality impacts and violates the statutes governing this rulemaking. To comply with CEQA and AB 32, the Board must mandate in the ADF rulemaking that mitigation of NOx increases commences as soon as the amended LCFS regulation becomes effective. CARB staff has not explained and cannot explain why California air quality should be exposed for an additional two years to adverse effects from the impacts of increased NOx emissions owing to biodiesel use (which CARB staff itself has estimated to be currently 1.3 tons per day statewide,[11] even after incorrectly assuming that there is no NOx increase from use of biodiesel in NTDEs).

Similarly, with respect to the program review, instead of acting to ensure that there are no adverse air quality impacts associated with biodiesel use by proposing mitigation requirements for all biodiesel blends of B1 and above, CARB staff is proposing to wait three years after the implementation of the ADF regulation before making an effort to "determine the efficacy" of the proposed NOx mitigation provisions. As pointed out numerous times in these and previous

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[9] Proposed Section 2293.6(a)(1)

[10] Proposed Section 2293.6(a)(6)(A)

[11] See *http://www.arb.ca.gov/fuels/diesel/altdiesel/20141017_ADF_discussion_paper.pdf*

Growth Energy comments on the proposed ADF,[12] the currently proposed NOx mitigation provisions are inadequate and will result in increases in NOx emissions and associated adverse impacts on air quality in California. There is no legal basis for waiting until the end of 2019 for CARB staff to make that determination.

6. Authority Granted to the Executive Officer

Under the staff proposal, the Executive Officer, rather than the Board, would be authorized to make findings regarding the potential adverse environmental impacts of potential alternative diesel fuels other than biodiesel.[13] Under CEQA and the Board's implementing regulations, the duty to consider and assess, and to mitigate, potential adverse environmental impacts lies with the Board, not the Executive Officer. In the current rulemaking regarding biodiesel blends, CARB staff is establishing the precedent for the Board, rather than the Executive Officer, to make decisions regarding adverse environment impacts, and the same process must be followed for any future alternative diesel fuel.

7. Unfair Competitive Advantages

At present, producers and blenders of biodiesel used in California are allowed to profit from the sale of that fuel under the Low Carbon Fuel Standard (LCFS) regulation through the generation of LCFS credits, despite the fact that use of that fuel results in unmitigated increases in NOx emissions and adverse air quality impacts. Under the proposed ADF regulation, producers and blenders of other alternative diesel fuels would similarly be allowed to profit via the LCFS regulation during Stages 1, 2, and 3a, despite the fact that their products lead to adverse environmental impacts. Such an approach is unexplained and anticompetitive—CARB staff

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[12] See Attachments A – D.

[13] See for example, proposed Sections 2293.5(b)(3), 2293.5(b)(6) 2293.5(c) and 2293.5(d).

should ensure that no ADF for which adverse environmental impacts have been established can generate LCFS credits ***before the producers of that ADF are required to mitigate those impacts***. For example, if CARB adopts the staff proposal that mitigation of biodiesel NOx impacts is not required until January 1, 2018, then no biodiesel sold in California before that time should be allowed to generate LCFS credits. If this issue is not addressed by CARB staff, producers and blenders of low carbon intensity fuels, such as ethanol, for which mitigation measures must be implemented will be disadvantaged, and producers and blenders of fuels such as biodiesel that are not required to mitigate adverse environmental impacts will be undeservedly rewarded.

Respectfully submitted,

GROWTH ENERGY

ATTACHMENT A

growth energy™
America's Ethanol Supporters

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PHONE 202.545.4000 FAX 202.545.4001
GrowthEnergy.org

December 12, 2013

By Electronic Mail

Clerk of the Board
California Air Resources Board
1001 I Street, 23rd Floor
Sacramento, California 95812

Re: Proposed Regulation to Govern Commercialization of New Alternative Diesel Fuels (2103 Cal. Reg. Notice Register 1646 (October 25, 2013)

Dear Madam:

Growth Energy, an association of the nation's leading ethanol manufacturers and other companies who serve the nation's need for alternative fuels, is submitting to you the enclosed materials in response to the October 15, 2013, notice of proposed regulatory action to establish rules to govern the commercialization of new alternative diesel fuels.

Growth Energy is a strong supporter of biodiesel fuels, which continue to play an important part in our nation's efforts to achieve energy independence with renewable sources and to address environmental concerns. While we applaud the effort to incentivize greater use of all renewable fuels, including biodiesel, we have several significant concerns about the CARB staff's current regulatory proposal and the regulatory process.

Growth Energy believes that significant but feasible changes must be made to the CARB staff's proposed regulations, because the staff's current proposal does not include all reasonable and feasible methods of mitigating potential increases in emissions of oxides of nitrogen ("NOx"), among other reasons. The required changes to the staff's proposal are explained in the enclosed comment and will facilitate the lawful commercialization and use of biodiesel in California in a manner that fully protects the environment. In addition, the CARB staff has not yet publicly released all the test data and analysis on which it is basing its proposal. The decision to postpone the public hearing until March 2014 affords time for the staff to make full disclosure of all the data and analysis.

Please contact me or David Bearden, our General Counsel, at 605-965-2375 if you have any questions concerning this submission.

Sincerely,

Tom Buis

Tom Buis
CEO, Growth Energy

STATE OF CALIFORNIA

AIR RESOURCES BOARD

PROPOSED REGULATION TO GOVERN THE COMMERCIALIZATION
OF NEW ALTERNATIVE DIESEL FUELS

GROWTH ENERGY'S RESPONSE
TO THE NOTICE OF PUBLIC HEARING DATED OCTOBER 15, 2013
2013 CAL. REG. NOTICE REG. 1646 (OCTOBER 25, 2013)

DECEMBER 12, 2013

Executive Summary

These Comments by Growth Energy on the proposed regulation to govern the commercialization of alternative diesel fuels address two main issues: (1) the duty of the Air Resources Board to mitigate potential increases in exhaust emissions of oxides of nitrogen ("NOx") from engines operated on biodiesel fuels, and (2) the analytical and procedural obligations for this rulemaking under the governing statutes.

Growth Energy strongly supports the use of biodiesel to achieve the Nation's environmental and energy independence objectives. As with other elements of California's effort to participate in those national strategies, however, the proposed alternative diesel fuel regulation must avoid having unintended negative environmental consequences, and must be considered carefully and in a manner that permits full and effective public participation. The flaws in the current regulatory proposal for alternative diesel fuels can be readily addressed through feasible mitigation measures, which would put biodiesel in parity with other alternative fuels for which the Board has for many years required risk mitigation through regulation.

As explained in these Comments, a detailed review of the Air Resources Board staff's analysis of the impacts of biodiesel use on NOx emissions, and a reanalysis of the data used by the staff made available to the public, shows that statistically significant increases in NOx emissions must be expected from the use of biodiesel blends of less than ten percent including blends of five percent and lower amounts of biodiesel. Applying the Board's normal precautionary principles, and consistent with the obligations of the California Environmental Quality Act and the Global Warming Solutions Act, the staff's proposed "Significance Level" of ten percent for biodiesel blends should instead be reduced to zero, because the use of biodiesel at any level can be expected to result in increased NOx emissions if not mitigated using reasonable and feasible measures.

These Comments also show that the potential increases in NOx emissions caused by biodiesel use under the proposed regulation are far larger than the NOx levels considered significant enough to require costly mitigation or control measures in the State's two "extreme" areas for ozone nonattainment -- the South Coast Air Basin and the San Joaquin Valley Air Pollution Control District. It would counterproductive, and not consistent with the governing statutes, for the Board to commit itself to measures that will result in NOx emissions increases in order to implement the low-carbon fuel standard under the Global Warming Solutions Act, especially when those increases greatly exceed the levels for which the State's air quality districts currently require mitigation or control of those emissions when they come from other sources.

These Comments also urge the Board to ensure that all comments and data received by the staff in connection with this rulemaking effort, or relied upon in formulating the proposed regulation, be placed in the public rulemaking file, and that sufficient time be allowed to review those materials before the Board considers regulatory action. If the Board directs the staff to address these important issues of public access and transparency -- which are governed by the Administrative Procedure Act -- this regulatory item can be completed in a timely manner.

Table of Contents

Page

Comments of Growth Energy on the Proposed Regulation To Govern the Commercialization of New Alternative Diesel Fuels

Growth Energy respectfully submits these comments on the California Air Resources Board's proposed regulation to govern the commercialization of new alternative diesel fuels (the "proposed ADF regulation"). As explained below, Growth Energy believes that the Board should direct the staff to make revisions in the proposed ADF regulation and cannot adopt the proposed ADF regulation in its current form. The proposed ADF regulation does not require the use of feasible measures that are necessary to mitigate adequately the potential adverse environmental impacts of increased use of biodiesel blends in California.

I. INTRODUCTION AND OVERVIEW

CARB's obligation to examine the impacts of widespread biodiesel usage, and to address potential adverse environmental impacts, have recently been clarified by the California Court of Appeal in *POET LLC, et al. v. California Air Resources Board*, (2013) 218 Cal. App. 4th 681. In that litigation, ARB claimed that it intended to "ensure" that there would be "no" increase in regulated pollutants from Diesel-powered engines in California as a result of the LCFS regulation, and in particular that there would be no increase in exhaust emissions of oxides of nitrogen ("NOx") resulting from the use of biodiesel fuel. 218 Cal. App. 4th at 732.

The CARB staff's proposed approach to the task of NOx mitigation in the proposed ADF regulation falls far short of the claimed metric: whatever the benefits of the proposed ADF regulation for other purposes, the staff's approach will not ***ensure*** that the implementation of the LCFS regulation can cause ***no*** increase in NOx emissions. These comments briefly outline, and the accompanying materials fully explain, the unnecessary environmental risks to the State's efforts to control NOx emissions that the proposed ADF regulation fails to address.[1] Those risks are not based on unqualified speculation, or merely the opinion of Growth Energy; the risks can be demonstrated from the emissions data that the CARB staff has placed in the docket, when those data are evaluated using simple but appropriate statistical tools and methods.[2] Moreover, the increases in NOx emissions, which the CARB staff's data establish, are significant by any contemporary measure: the increases in NOx emissions that the increased use of biodiesel will cause as a result of the LCFS regulation are many times larger than the NOx increases that CARB and regional air quality authorities require to be mitigated. (*See* pp. 18-19 below.)

Addressing the problem of increased NOx emissions is a feasible task, as the Staff Report that accompanies the proposed ADF regulation concedes. Once the risk is established, and the methods of mitigation are determined to be feasible, CARB's task is clear: under the California Environmental Quality Act ("CEQA"), it must require mitigation before it can proceed with regulation.[3]

In this instance, mitigation may impose direct costs on the firms that choose to use biodiesel to comply with the LCFS regulation, and indirect costs on the operators of Diesel engines, but CARB decided nearly five years ago that the benefits of the LCFS regulation overall were worth the costs. In that respect, biodiesel should be treated no differently than the

[1] In addition to the materials cited below in notes 2 and 4, Growth Energy is also attaching to these comments for inclusion in the rulemaking file -- and for analysis and response by the Board -- its earlier comments on the CARB staff's ADF regulatory proposal, submitted on September 16, 2013. Those comments, and likely many other comments from other parties, were not placed in the rulemaking file when CARB issued its 45-day notice. *See* pp. 13-14 below (requirements of the California Administrative Procedure Act).

[2] *See* R. Crawford, "NOx Emissions Impact of Soy- and Animal-Based Biodiesel Fuels: A Re-Analysis" (Dec. 2013) (hereinafter "Crawford Report"), attached to these Comments as Exhibit A.

[3] *See POET*, 218 Cal. App. 4th at 731-742.

alternative fuels that the LCFS regulation requires for gasoline, which are ethanol, natural gas and electricity.

Instead of requiring the Diesel sector to bear its fair share of the costs of the LCFS regulation through proper environmental mitigation, however, the CARB staff's proposed approach deploys what the Staff Report calls an "Effective Blend Level" concept to exempt biodiesel fuel from any meaningful mitigation requirement.[4] Rather than following the precautionary principles that have constantly guided CARB rulemaking -- which in other contexts sometimes have inclined the Board to require extreme regulatory stringency based on scant evidence of actual harm -- in this one instance, the CARB staff appears intent on risking air quality rather than requiring feasible, if costly to some, mitigation measures. The CARB Staff Report suggests in one place that this deviation from the Board's longstanding regulatory strategy may be necessary to protect the growth of the biodiesel "market."[5] But the CARB staff cites no evidence to support its speculation that the biodiesel "market" is at risk, and there is no evidence of such a risk in the public rulemaking file. Even if such a private market risk existed, however, neither the California Global Warming Solutions Act nor the California Government Code allow CARB to consider factors extrinsic to the statutes in meeting the clean-air goals established by law.[6] The California statutes protect California citizens and air quality, not market entrepreneurs and arbitragers. It is not the proper purpose of any California regulation to

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[4] *See* Declaration of James M. Lyons (hereinafter "Lyons Decl."), attached to these Comments as Exhibit B.

[5] *See* Staff Report at 63 (rejecting "immediate" mitigation because "this option has the potential to disrupt or even collapse the burgeoning ADF market by unnecessarily placing overly restrictive requirements that are not warranted by emissions testing"). Tellingly, that portion of the Staff Report has no citations to support the claim.

[6] In its current proposal, the CARB staff is engrafting onto the Global Warming Solutions Act a provision allowing it to avoid mitigation of environmental harm, in order to encourage particular industries or based on general economic preferences. CARB cannot proceed in that fashion. *Cf. Clean Air Constituency v. CARB*, (1974) 11 Cal.3d 801 (CARB lacks authority to establish criteria to govern its actions that are not found in its enabling statutes).

pick "winners" and "losers:" all fuels, including all alternative fuels, must have their environmental risks properly assessed, and when feasible mitigated in full.

The balance of these Comments is divided into two parts. The first part, in Section II below, summarizes the technical analyses contained in the accompanying report of Robert Crawford, a statistician with expertise in evaluation of emissions data, and in the Declaration of James M. Lyons, an expert in automotive air pollution who evaluates the "Effective Blend Level" concept as a method of addressing the risks of increased NOx emissions. Section II also summarizes the relevant portions of the Staff Report dealing with the available mitigation methods and their feasibility. The second part, in Section III below, explains the Board's legal obligations to mitigate the risks of increased NOx emissions presented by biodiesel fuel usage.

II. ENVIRONMENTAL ASSESSMENT OF THE PROPOSED REGULATION

Were the matter ever in any doubt, the Court of Appeal's *POET* decision, which the California Supreme Court has recently declined to review, makes it clear that the Board must take seriously the issue of NOx emissions increases from the increased use of biodiesel in order to comply with the LCFS regulation. CARB has recognized, first in the LCFS regulatory process and more recently in court, that the LCFS regulation will increase the use of biodiesel. The CARB staff now claims in the current ADF rulemaking, however, that emissions testing proves that the use of biodiesel blends containing less than 10 percent biodiesel will not increase NOx emissions. That claim is demonstrably wrong, as Mr. Crawford establishes in his analysis of the available emissions data. (*See* Exhibit A and Section A below.) Because the data do not support the CARB staff's claims that operation of engines on blends below 10 percent biodiesel will not increase NOx emissions, and in fact show the opposite, CARB has a duty to mitigate. The CARB staff's environmental analysis is also unsound in other respects as well, as demonstrated in Mr. Lyons' Declaration. (*See* Exhibit B and Section B below.)

A. Impact of the Proposed Regulation on Exhaust Emissions of Oxides of Nitrogen

Mr. Crawford's report carefully reviews each of the six studies cited in the CARB staff's literature review on biodiesel NOx emissions, as well as CARB's biodiesel characterization study ("Durbin 2011") and the data available from that study. It is important to note at the outset that not all the data from the CARB study has been made available to the public. CARB should publish all of the testing presented in Durbin 2011[7] and any future testing that it sponsors in a complete format that allows for reanalysis, and an opportunity to evaluate those materials prior to the deadline for submission of public comments or CARB's hearing on the approval of the proposed ADF regulation.

Putting aside the CARB staff's failure to make a complete disclosure of the data reflected in Durbin 2011, it is clear that the data from Durbin and the other six studies do not support the CARB staff's conclusion and, indeed, the data refute the staff's conclusion in some instances. These are the salient points from Mr. Crawford's analysis:

- There is ***no evidence*** supporting the staff conclusion that NOx emissions do not increase until the B10 level is reached. Instead, there is consistent and strong evidence that biodiesel increases NOx emissions in proportion to the biodiesel blending percent.

- There is ***clear and statistically significant evidence*** that biodiesel increases NOx emissions at the B5 level in at least some engines for both soy- and animal-based biodiesels.

None of the six studies in the literature measured the NOx emissions impact from biodiesel at blending levels below B10. Only two studies tested a fuel at the B10 level. All

[7] The data should be published in a useable format, and should include (a) the measured emission values for each individual test replication; or (b) averages across all test replications, along with the number of replications and the standard error of the individual tests. The first format (individual test replications) is preferable because that would permit a full examination of the data including effects such as test cell drift over time.

other testing was at the B20 level or higher. Because none tested a B5 (or similar) fuel, the studies do not constitute substantial evidence that NOx emissions are not increased at B5 or other blending levels below B10. Those six studies therefore provide no data or evidence supporting the validity of the staff's claim that biodiesel below B10 does not increase NOx emissions. To the contrary, all of the studies are consistent with the contention that biodiesel increases NOx emissions in proportion to the blending percent. Indeed, two of those six studies present evidence and data that the NOx impact from biodiesel is a continuous effect that is present even at very low blending levels and will increase at higher levels in proportion to the blending percentage.

With regard to the CARB biodiesel characterization report, Mr. Crawford has uncovered the fact that for the three engines for which the CARB staff has published the emission values measured in engine dynamometer testing, all of the data demonstrate that biodiesel fuels significantly increase NOx emissions for both soy- and animal-based fuels by amounts that are proportional to the blending percent. That is true for on-road and off-road engines and for a range of test cycles. When B5 fuels were tested for those engines, NOx emissions were observed to increase. NOx emission increases are smaller at B5 than at higher blending levels and the observed increases for two engines were not statistically significant by themselves based on the pair-wise t-test employed in Durbin 2011. However, the testing for one of the engines (the 2007 MBE4000) showed statistically significant NOx emission increases at the B5 level for both soy- and animal-based blends. The data are sufficient to disprove the staff's contention that biodiesel blends at the B5 level will not increase NOx emissions.

In sum, based on examination of all of the studies cited by CARB as the basis for its proposal to exempt biodiesels below B10 from mitigation, it is clear that the available research points to a very substantial risk, if not a certainty, that both soy- and animal-based biodiesel blends will increase NOx emissions in proportion to their biodiesel content, including at the B5 level. Based on data in the CARB Biodiesel Characterization Report, soy-based biodiesels will increase NOx emissions by about 1% at B5 and 2% at B10, while animal-based biodiesels will increase NOx emissions by about one-half as much: 0.45% at B5 and 0.9% at B10. All of the available research shows that the NOx increases are real and implementation of mitigation measures will be required to prevent increases in NOx emissions due to biodiesel use at blending levels below B10. The available research likewise demonstrates that, to the extent CARB is identifying B10 as a "threshold of significance" under CEQA, (1) the utilization of this threshold is unsupported by the evidence in the record. For the same reasons, and for the reasons discussed in Section III.B below, the utilization of B10 as a "threshold" is contrary to the Legislature's mandate that the regulations should "not interfere with ... efforts to achieve and maintain federal and state ambient air quality standards." Cal Health & Safety Code § 38562(b)(4).

B. The "Effective Blend Level" Concept

Mr. Lyons' Declaration builds on the analysis performed by Mr. Crawford and demonstrates that the CARB staff's "effective blend level" concept will operate to exempt biodiesel from any meaningful mitigation, even if biodiesel is causing real-world increases in NOx exhaust emissions from Diesel engines operated in California. Mr. Lyons demonstrates, in particular, that "despite the forecast nine-fold increase in biodiesel use in California from 50 million to 450 million gallons from 2013 to 2023 ... the forecast Effective Blend Level of biodiesel decreases to less than zero over virtually all of the period in question." (Lyons Decl. ¶ 14.)

If the fractional coefficients being applied in the "effective blend level" equation (*see* Lyons Decl. ¶¶ 11-12) are incorrect to any significant extent, the environment will not be protected. The CARB staff has apparently selected those coefficients without allowing for the possibility of errors that could understate NOx impacts -- a clear violation of CARB's precautionary norms. The adverse effects will be severe if there is error in the coefficients, because the CARB staff itself recites evidence that the biodiesel market will be concentrated in low-blend biodiesel. (*See* Lyons Decl. ¶¶ 15, 17.) Growth Energy is aware of no other regulatory concept in any CARB program in which mitigation measures required by CEQA depend on a formula that could err as easily as the "effective blend level" equation could.

The mischief in the "effective blend level" coefficients lies in their complexity and the risk of quantitative error. A much simpler but equally fatal analytical flaw, which also violates both sound regulatory policy and the requirements of CEQA, is the failure of the effective blend level calculation to ensure that any NOx increases that require mitigation will be addressed by the use of a mitigation measure in the ***same*** relevant location, and at the ***same*** time, as the NOx increases are occurring. If NOx mitigation does not occur in the same area and at the same time as biodiesel use that increases NOx emissions, the environmental harm presented by those increased NOx emissions will go unmitigated; the adverse impacts of NOx increases are defined by their location, and their severity is greatest at the time when the emissions occur.

As Mr. Lyons points out, the "effective blend level" concept does not fully protect, for example, Los Angeles residents, if NOx increases experienced in the summertime in Los Angeles can be offset by the biodiesel "market" in whole or part by practices that mitigate those emissions in a different season and in another place. (*See* Lyons Decl. ¶¶ 19-20.) The regulation, as proposed by the CARB staff, does nothing even to incentivize, much less require, the biodiesel "market" to deliver mitigation at the time and place it is needed. That may be a result of the CARB staff's conclusion that, as they have written the mitigation rule, it is unlikely that mitigation will ever be required; if so, that simply underscores the weakness of the mitigation rule itself (*see*, *e.g.*, Lyons Decl. ¶¶ 8-10, 15-18). CEQA and its implementing guidelines must be read to require mitigation where and when the adverse effect would otherwise occur. By not accounting for that requirement, the "effective blend level" concept violates CEQA.

Mr. Lyons' Declaration identifies other flaws in the staff proposal that must be addressed. As his Declaration establishes, the data on which CARB relies for its assumption that "new-technology" diesel engines will have lower NOx emissions when operated on biodiesel is inadequate to support the weight it is given by the CARB staff (*see* Lyons Decl. ¶¶ 21-23); that data cannot be treated as substantial evidence to support a regulation that posits lower emissions from such engines. Each of the issues raised in Mr. Lyons' Declaration must be addressed by the Board.

C. Available Mitigation Measures

Mitigation of the risks of NOx increases from biodiesel usage is entirely feasible. The proposed ADF regulation can easily be modified to ensure that the use of biodiesel will not result in increased NOx emissions by setting the "Significance Level" for biodiesel blends at zero -- which is the level that the available data require -- so that mitigation would occur whenever and wherever it should. In addition, CARB must eliminate the use of annual statewide averages for determining the "effective blend levels" and instead use actual blend levels at the batch level. These two changes would require that mitigation be applied to all biodiesel blends in light of the actual amount of biodiesel present in each specific blend.

Appendix 1 to proposed Section 2293.5(c) specifies the three mitigation measures that CARB staff has identified for mitigation of increases in NOx emissions due to biodiesel use. They include (i) addition of di-tert-butyl peroxide to biodiesel blends at a level that varies with the amount of biodiesel in the blend and (ii) blending of low-NOx diesel fuel along with biodiesel into biodiesel blends. Under the staff's proposal, parties responsible for mitigation of increased NOx emissions from biodiesel can choose either of those approaches. They all could be easily applied to any blend containing ten percent or less biodiesel, as well as blends of more than ten percent, if appropriately modified to ensure that there would be no increase in NOx emissions associated with the use of biodiesel. The Staff Report and the rulemaking file contain no significant evidence that such approaches could not be applied at the batch level.

In addition to conceding the feasibility of the three identified mitigation measures by including them in the proposed ADF regulation, the Staff Report also provides cost estimates for the application of each measure.[8] Absorption of those estimated costs by entities or individuals choosing to use biodiesel is in no way inconsistent with the types of costs that have been imposed by CARB on other California businesses and residents in other regulatory programs. Indeed, the Global Warming Solutions Act gives CARB no choice but to require the regulated parties and their downstream customers to absorb those costs: the Legislature has specifically directed that CARB is to "ensure" that "activities undertaken pursuant to the regulations" adopted to implement the Act -- including the use of biodiesel to comply with the LCFS regulation -- "do not interfere with ... efforts to achieve and maintain federal and state ambient air quality standards." Cal. Health & Safety Code § 38562(b)(4).

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[8] Those costs are $0.25 per gallon of biodiesel blended for di-tert-butyl peroxide, $1.20 per gallon of biodiesel blended for low-NOx diesel and a one-time expense of between $100,000 and $200,000 for the certification of a biodiesel blend that could then be sold in California in any volume. *See* Staff Report at 59 and *id.* App. C.

In addition to being technically feasible, consistent with costs required by other CARB regulations, the mitigation measures outlined in the Staff Report can be implemented. In some instances, regulated parties would simply have to ensure that steps have been taken to ensure their final blends meet the fuel property specifications associated with the certified blend. Mitigation using di-tert-butyl peroxide or low NOx diesel requires only knowing the amount of biodiesel in the blend and ensuring that the entity performing the blending also be responsible for adding di-tert-butyl peroxide or low NOx diesel to the blend.

The Staff Report claims that "[i]t would be impractical to determine the individual blend level for each gallon of biodiesel blend being sold across the State." The Staff Report continues: "To do so would require the retailers and marketers of biodiesel blends (i.e., the diesel dispensing facilities) to continuously test and determine the biodiesel blend level for each of the approximately 3 billion gallons of on-road diesel fuel sold in California each year."[9] The Staff Report offers no support for that claim, however, and it is contradicted by the overall regulatory experience under the LCFS regulation as well as the data necessary to actually to employ the Effective Blend concept. The LCFS regulation already requires producers of biodiesel sold in California or other entities to which the fuel is transferred to report the volumes of biodiesel to CARB via the Low Carbon Fuel Standard Reporting Tool ("LRT") in order to receive greenhouse gas emission reduction credits. (*See* 17 C.C.R. § 95484(b)(B)(2).) Moreover, in order to employ the Effective Blend concept, data regarding the amount of biodiesel used in blends of five percent or less, as well as the type and volumes of biodiesel used in blends of more than five percent, would be required. Presumably, this data will also be derived from the LRT. The LRT is currently treated by CARB as an accurate source of data regarding biodiesel use in

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[9] Staff Report at 23.

California.[10] The CARB staff regularly publishes quarterly summaries of greenhouse gas credits generated from biodiesel and other fuels under the LCFS.[11]

Given that biodiesel producers must report both their production volumes and production pathways (*e.g.*, soy-based, animal-based, or other) to CARB via the LRT in order to generate greenhouse gas credits under the LCFS regulation, the implementation of NOx mitigation measures involving use of di-tert-butyl peroxide or low NOx diesel under the ADF regulation would be simple and straightforward. All that CARB would have to do is to require entities earning greenhouse gas credits under the LCFS for non-certified biodiesel blends to also report to CARB via the LRT how, when, and where mitigation of the NOx emissions associated with the use of that biodiesel via di-tert-butyl peroxide or low NOx diesel was achieved. Recordkeeping requirements analogous to those that already apply to data reported via the LRT would also apply to mitigation of biodiesel NOx impacts.

By following that approach, CARB staff can both ensure that there are no NOx increases associated with the use of biodiesel in California while simultaneously avoiding any need to involve retailers and marketers of biodiesel in the "impractical" activity described in the Staff Report unless those same retailers and marketers of biodiesel were earning greenhouse gas reduction credits from biodiesel under the LCFS. If the CARB Executive Officer or the staff disagrees with Growth Energy on this point, it is incumbent upon them to explain why and for the Board to give the public an opportunity to respond before CARB weighs the evidence and arguments, because this is an issue involving available and practical mitigation measures under CEQA.

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[10] *See, e.g.*, Staff Report at 30.

[11] The most recent summary for the second quarter of 2013 is available at http://www.arb.ca.gov/fuels/lcfs/20130930_q2datasummary.pdf.

III. THE BOARD'S LEGAL OBLIGATIONS

The Court of Appeal clarified in *POET* that CARB is subject, among other provisions, to sections 15004 and 15352 of the CEQA Guidelines. The Court of Appeal also gave clear instructions about the need to comply with the rulemaking-file requirements of the Administrative Procedure Act. Perhaps most importantly, the Court of Appeal made plain the Board's duty to mitigate, in particular with respect to the subject of NOx exhaust emissions from engines operated on biodiesel. This final section of Growth Energy's comments summarizes the steps that CARB must take to meet its obligations under the governing statutes as clarified by the Court in *POET*, with primary emphasis on the duty to mitigate under CEQA.

A. Procedural and Structural Rulemaking Requirements

CARB must recognize that *any* communications it has received of a factual nature, or data that it has acquired in connection with regulatory action, are not exempt from the requirement to disclose those communications in the public rulemaking file under Gov't Code § 11347.3 (absent a valid and complete demonstration of privilege). *See POET*, 218 Cal. App. 4th at 741-754. At present, the rulemaking file for the ADF proposal cannot possibly be claimed to include all material required for the rulemaking file: Growth Energy knows this, because its own comments of September 16, 2013 (*see* Exhibit C) have not been placed in that file. As noted above, CARB has apparently not made full disclosure of all data relevant to the Durbin emissions study. (*See* p. 5 above.) Likewise, the Staff Report claims that the proposed ADF regulation "is based upon feedback from nearly every corner of the regulated industry as well as other impacted organizations and individuals that are impacted by actions concerning or that regulate the fuels industry."[12] The rulemaking file, when last checked in the week of

[12] Staff Report at 3-4.

December 2, 2013, did not contain any written comments reflecting that "feedback;" those materials should have been in the rulemaking file no later than October 15, 2013, when the public hearing on the proposed ADF regulation was announced. *See* Cal. Gov't Code § 11347.3(a), (b)(6), (7).

Accordingly, one of the first steps that CARB must take in the current proceeding is to ensure compliance with section 11347.3 of the Government Code, and re-issue a notice of proposed rulemaking to allow 45 days of comment prior to a public hearing at which it would take action on a proposed ADF regulation. If CARB takes this action quickly, there will be no delay in program objections, including reconsideration of the LCFS standards during 2014.

It is also clear from *POET* that, as CEQA and the guidelines direct, there are other reasons why CARB cannot take action with respect to the proposed ADF regulation. *See POET*, 218 Cal. App. 4th at 717-731. If CARB is the decision-maker with respect to the proposed ADF regulation, it must evaluate the environmental issues presented by the staff proposal for itself, and complete the environmental review process required under CEQA and CARB regulations, *before* the Board commits CARB to the proposed ADF regulation. Likewise, the opportunity to participate in the environmental analysis must be adequate -- which in this instance, it is not, in part because not all the relevant data has been publicly released. A comment deadline scarcely 45 days after the staff analysis has been released, when all relevant data have not been provided, will not permit an adequate environmental assessment.

To comply with the procedural requirements of CEQA as confirmed in *POET*, CARB should direct the staff to complete the environmental review process (including full disclosure of the basis for its proposal); prepare a complete rulemaking file; respond to public comment; and publish a Final Statement of Reasons, before considering the proposed ADF regulation on its merits at a subsequent hearing. At that hearing, interested parties should be allowed all the time required to present and to respond to legitimate technical, empirically-based analysis of the environmental issues presented by the proposed ADF regulation. CARB can neither approve the proposed ADF regulation with the record in its current status and at the type of hearing planned for this week, nor defer the environmental assessment to a point after it has committed itself to the proposed regulation, nor delegate any of its CEQA responsibilities identified by the Court of Appeal in *POET*.

B. The Duty to Analyze Potential Impacts and Mitigate Significant Impacts

The importance of NOx emissions control for California air quality is well known and is illustrated, for example, by a June 2012 CARB Report entitled "Vision for Clean Air: A Framework for Air Quality and Climate Planning," prepared in conjunction with the South Coast Air Quality Management District and the San Joaquin Valley Unified Air Pollution Control District.[13] That report addressed potential control strategies that will be required to bring the only two areas of the country designated as being in extreme nonattainment of the National Ambient Air Quality Standard ("NAAQS") for ozone[14] into attainment. In working to identify potential control strategies, these three agencies chose to focus on ways to reduce NOx emissions (and not hydrocarbon emissions) because "NOx is the most critical pollutant for reducing regional ozone and fine particulate matter."[15] The report also identifies diesel-powered heavy-duty vehicles as the largest source of NOx emissions in California, and classifies diesel-powered

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[13] *See* CARB, Vision for Clean Air: A Framework for Air Quality and Climate Planning (June 27, 2012) (available at http://www.arb.ca.gov/planning/vision/docs/vision_for_clean_air_public_review_draft.pdf).

[14] *See* http://www.epa.gov/airquality/ozonepollution/designations/2008standards/final/region9f.htm.

[15] *See* Vision for Clean Air at 10.

construction, mining and agricultural equipment as other significant sources of NOx emissions in California.

As indicated above, CEQA requires that mitigation measures must be implemented locally and must be contemporaneous with the emissions events of concern; the type of statewide mitigation concept contained in the Staff Report, unbounded to relevant time intervals, does not comply with CEQA. It is therefore relevant to consider, by way of example, the heavy-duty diesel vehicle NOx emissions inventory for the South Coast and San Joaquin Valley areas during calendar years 2015 and 2020. On-road heavy-duty diesel emission estimates were developed using CARB's latest emission factor modeling software EMFAC2011.[16] The model estimates regional emissions, in tons/day, by vehicle class and model year. Emission estimates were computed for both older vehicles as well as vehicles using what CARB would consider to be NTDEs -- which in this case were assumed to be 2010 and later model-year vehicles. Emissions from off-road construction equipment were estimated using CARB's 2011 In-Use Inventory model.[17] Emissions from agricultural equipment were developed using CARB's OFFROAD2007 model because CARB's regulatory in-use inventory model is still under development for this sector.[18] For construction and agricultural equipment, NTDE vehicles were assumed to be those with engines certified to Tier 4 emission standards. It was assumed Tier 4 engines are used in 2013-and-later model year engines rated at or below 50 HP, 2014-and-later model year engines between 51 and 750 HP, and to 2015-and-later model years for engines

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[16] For more information on EMFAC2011 and to download modeling materials, *see* http://www.arb.ca.gov/msei/modeling.htm.

[17] For more information on CARB's off-road model, *see* http://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles.

[18] Information about OFFROAD2007 and the pending in-use agricultural sector model can also be found at http://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles.

above 750 HP. The resulting inventories are presented in Tables 1 and 2 for calendar years 2015 and 2020, respectively.

Table 1

2015 Heavy-Duty NOx Emission Inventories for the South Coast and San Joaquin Valley Air Basins (tons per day)

Air Basin	On-Road		Construction		Agricultural		Total
	Older	NTDE	Older	NTDE	Older	NTDE	
South Coast	117.27	14.91	24.04	0.42	3.92	0.26	160.82
San Joaquin	83.07	15.44	11.85	0.21	26.73	1.86	139.16

Table 2

2020 Heavy-Duty NOx Emission Inventories for the South Coast and San Joaquin Valley Air Basins (tons per day)

Air Basin	On-Road		Construction		Agricultural		Total
	Older	NTDE	Older	NTDE	Older	NTDE	
South Coast	66.53	28.44	20.0	1.8	2.2	0.5	119.47
San Joaquin	32.13	30.33	11.5	1.0	15.0	3.8	93.76

Tables 1 and 2 show that vehicles with NTDEs account for only about 10% of NOx emissions in 2015 and between 25% and 40% of NOx emissions in 2020. Therefore, even if the CARB staff's assertion that biodiesel does not increase emissions from NTDEs were correct, the majority of NOx emissions would still be coming from older engines where, it has been clearly demonstrated, NOx emissions increase with the use of higher biodiesel blends. Applying the estimated NOx increases developed from the available emissions data analyzed by CARB staff (*see* Lyons Decl. ¶ 9, Table 1), and assuming more realistically and conservatively (as CEQA requires) that NTDEs will be affected by biodiesel in the same way as other engines, the overall increases in NOx emissions caused by biodiesel use will be (i) between 0.7 and 1.6 tons per day in 2015 and between 0.5 and 1.2 tons per day in 2020 in the South Coast, and (ii) between 0.6 and 1.4 tons per day in 2015 and between 0.4 and 0.9 tons per day in 2020 in the San Joaquin Valley.

One way to put the magnitude of these potential increases in NOx emissions into context is to compare them with the air quality significance thresholds applied by the South Coast Air Quality Management District[19] and the San Joaquin Valley Air Pollution Control District[20] when evaluating the potential emission impacts of proposed projects in their jurisdictions. In the San Joaquin Valley Air Pollution Control District, the threshold is 10 tons per year while in the South Coast basin, the threshold is 0.0275 tons per day which equals 10 tons per year if daily emissions occurring over the course of the year are equal. The potential 2015 emission increases from the use of five percent biodiesel blends in the South Coast and the San Joaquin Valley are ***25 to 60 times higher*** than the 10-ton-per-year threshold. Even with reductions in diesel NOx emissions by 2020, the potential NOx increases due to biodiesel remains ***15 to 40 times higher*** than the 10-ton-per-year threshold. Potential increases of NOx emissions on such a scale require mitigation at the time and in the place where they will occur. *See POET*, 218 Cal. App. 4th at 740 (under CEQA, "ARB must adopt mitigation measures that minimize the adverse impact" of a potential increase in NOx emissions). Moreover, despite the fact that increases of NOx emissions resulting from the proposed ADF regulation would significantly exceed thresholds adopted by the South Coast Air Quality Management District and the San Joaquin Valley Air Pollution Control District, the ISOR fails to analyze whether the proposed ADF regulation has the potential to conflict with, or obstruct, applicable air quality plans.

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[19] *See* http://www.aqmd.gov/ceqa/handbook/signthres.pdf.

[20] *See* http://www.valleyair.org/transportation/CEQA%20Rules/GAMAQI%20Jan%202002%20Rev.pdf.

There is no question that an increase in biodiesel usage will occur as a result of the LCFS regulation, a measure adopted under the Global Warming Solutions Act. *See POET*, 218 Cal. App. 4th at 700-01. Consequently, under not only CEQA, but also the Global Warming Solutions Act, CARB cannot permit emissions increases from biodiesel of such a magnitude when both the South Coast Air Quality Management District's 2012 Air Quality Management Plan[21] and the San Joaquin Valley's 2013 One Hour Ozone Plan[22] contain control measures intended to reduce NOx emissions by amounts of about the same magnitude as the potential emission increases resulting from biodiesel use at the five percent level. *See* Cal Health & Safety Code § 38562(b)(4) (greenhouse gas control measures such as the LCFS regulation are not to "interfere with … efforts to achieve and maintain federal and state ambient air quality standards.").

IV. CONCLUSION

For the reasons explained above and in the reports and analyses accompanying these Comments, CARB cannot lawfully approve the proposed ADF regulation at this week's public hearing. CARB cannot commit itself now to the proposed ADF regulation and adjourn the important task of environmental assessment to a post hoc process. The available emissions data do not support, and indeed refute, the CARB staff's claim that low-level biodiesel blends are benign. Mitigation is required, and is required at the time and in the places where the NOx emissions increases can be expected to occur. If CARB directs the staff to make straightforward changes in the proposed ADF regulation in a timely manner that will require feasible mitigation

[21] *See* South Coast Air Quality Management District, 2012 Air Quality Management Plan, 2012 AQMP CARB/EPA/SIP Submittal (Dec. 2012) (available at http://www.aqmd.gov/aqmp/2012aqmp/Final/index.html).

[22] *See* http://www.valleyair.org/Air_Quality_Plans/Ozone-OneHourPlan-2013.htm.

measures, there will be no jeopardy to any program objective of the Global Warming Solutions Act or any other CARB project.

Respectfully submitted,

GROWTH ENERGY

EXHIBIT A

NOx Emissions Impact of Soy- and Animal-based Biodiesel Fuels: A Re-Analysis

December 10, 2013

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NOX EMISSIONS IMPACT OF SOY- AND ANIMAL-BASED BIODIESEL FUELS: A RE-ANALYSIS

prepared for:

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NOX IMPACT OF SOY- AND ANIMAL-BASED BIODIESEL FUELS: A RE-ANALYSIS

Table of Contents

Page

List of Tables

List of Figures

1. EXECUTIVE SUMMARY

1.1 Background on the Proposed Rule

The California Air Resources Board (CARB) has proposed regulations on the commercialization of alternative diesel fuel (ADF) that were to be heard at the December 2013 meeting of the Board. The proposed regulations seek to "… create a streamlined legal framework that protects California's residents and environment while allowing innovative ADFs to enter the commercial market as efficiently is possible."[1] In this context ADF refers to biodiesel fuel blends. Biodiesel fuels are generally recognized to have the potential to decrease emissions of several pollutants, including hydrocarbons (HC), carbon monoxide (CO), and particulate matter (PM), but are also recognized to have the potential to increase oxides of nitrogen (NOx) unless mitigated in some way. NOx emissions are an important precursor to smog and have historically been subject to stringent emission standards and mitigation programs to prevent growth in emissions over time. A crucial issue with respect to biodiesel is how to "… safeguard against potential increases in oxides of nitrogen (NOx) emissions."[2]

The proposed regulations are presented in the Staff Report: Initial Statement of Reasons (ISOR) for the Proposed Regulation on the Commercialization of New Alternative Diesel Fuels[3] (referenced as ISOR). Chapter 5 of the document describes the proposed regulations, which exempt diesel blends with less than 10 percent biodiesel (B10) from requirements to mitigate NOx emissions:

> There are two distinct blend levels relative to biodiesel that have been identified as important for this analysis. Based on our analysis to date, we have found that diesel blends with less than 10 percent biodiesel by volume (<B10) have no significant increase in any of the pollutants of concern and therefore will be regulated at Stage 3B (Commercial Sales not Subject to Mitigation). However, we have found that biodiesel blends of 10 percent and above (≥B10) have potentially significant increases in NOx emissions, in the absence of any mitigating factors, and therefore those higher blend levels will be regulated under Stage 3A (Commercial Sales Subject to Mitigation).[4]

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[1] "Notice of Public Hearing to Consider Proposed Regulation on the Commercialization of New Alternative Diesel Fuels." California Air Resources Board, p. 3. http://www.arb.ca.gov/regact/2013/adf2013/adf2013notice.pdf.

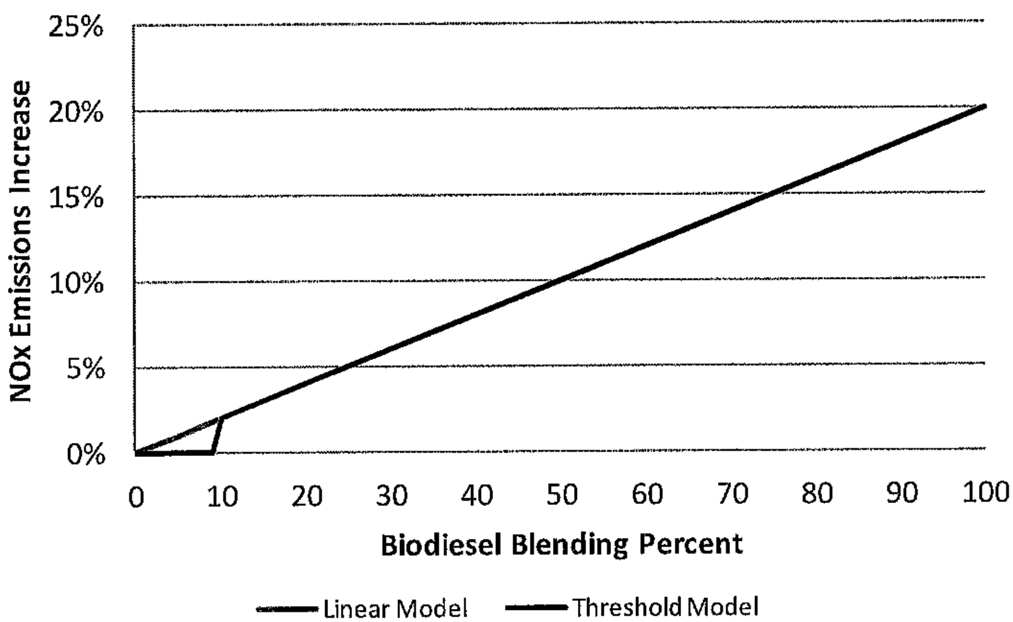
[2] Ibid. p. 3.

[3] "Proposed Regulation on the Commercialization of New Alternative Diesel Fuels. Staff Report: Initial Statement of Reason." California Air Resources Board, Stationary Source Division, Alternative Fuels Branch. October 23, 2013. http://www.arb.ca.gov/regact/2013/adf2013/adf2013isor.pdf.

[4] Ibid, p. 22.

Existing research on the NOx emission effects of biodiesel has consistently been conducted under the hypothesis that the emission effect will be linearly proportional to the blending percent of neat biodiesel (B100) with the base diesel fuel. The Linear Model that has been accepted by researchers is shown as the blue line in Figure 1-1. The Staff position cited above is that biodiesel fuels do not increase NOx emissions until the fuel blend reaches 10% biodiesel. This so-called Staff Threshold Model departs from the Linear Model that underlies past and current biodiesel research by claiming that NOx emissions do not increase until the biodiesel content reaches 10 percent.

Figure 1-1
Linear and Staff Threshold Models for Biodiesel NOx Impacts



The Staff Threshold model is justified by the statement: "Based on our analysis to date, we have found that diesel blends with less than 10 percent biodiesel by volume (<B10) have no significant increase in any of the pollutants of concern." Other portions of the ISOR state that Staff will track "... the effective blend level on an annual statewide average basis until the effective blend level reaches 9.5 percent. At that point, the biodiesel producers, importers, blenders, and other suppliers are put on notice that the effective blend-level trigger of 9.5 percent is approaching and mitigation measures will be required once the trigger is reached."[5] Until such time, NOx emission increases from biodiesel blends below B10 will not require mitigation.

Section 6 of the ISOR presents a Technology Assessment that includes a literature search the Staff conducted to obtain past studies on the NOx impact of biodiesel in heavy-duty

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[5] Ibid, p. 24.

engines using California diesel (or other high-cetane diesel) as a base fuel. Section 6.d presents the results of the literature search with additional technical information provided in Appendix B. The past studies include the Biodiesel Characterization and NOx Mitigation Study[6] sponsored by CARB (referenced as Durbin 2011).

The results of the Staff literature search are summarized in Table 1-1, which has been reproduced from Table 6.1 of the ISOR. For B5 and B20, the data represent averages for a mix of soy- and animal-based biodiesels, which tend to have different impacts on NOx emissions (animal-based biodiesels increase NOx to a lesser extent). For B10, the data represent an average for soy-based biodiesels only. Staff uses the +0.3% average NOx increase at B5 in comparison to the 1.3% standard deviation to conclude:

> Overall, the testing indicates different NOx impacts at different biodiesel percentages. Staff analysis shows there is a wide statistical variance in NOx emissions at biodiesel levels of B5, providing no demonstrable NOx emissions impact at this level and below. At biodiesel levels of B10 and above, multiple studies demonstrate statistically significant NOx increases, without additional mitigation.[7]

Table 1-1
Results of Literature Search Analysis

Biodiesel Blend Level	NOx Difference	Standard Deviation
B5	0.3%	1.3%
B10[a]	2.7%	0.2%
B20	3.2%	2.3%

Source: Table 6.1 of Durbin 2011
Notes:
[a] Represents data using biodiesel from soy feedstocks.

The Staff conclusion is erroneous because it relies upon an apples-to-oranges comparison among the blending levels. Each of the B5, B10, and B20 levels include data from a different mix of studies, involving different fuels (soy- and/or animal-based), different test engines, and different test cycles. The B5 values come solely from the CARB Biodiesel Characterization study, while the B10 values come solely from other studies. The B20 values are a mix of data from the CARB and other studies. The results seen in the table above are the product of the uncontrolled aggregation of different studies that produces incomparable estimates of the NOx emission impact at the three blending levels.

[6] "CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California: Biodiesel Characterization and NOx Mitigation Study." Prepared by Thomas D. Durbin, J. Wayne Miller and others. Prepared for Robert Okamoto and Alexander Mitchell, California Air Resources Board. October 2011.
[7] ISOR, p. 32.

As will be demonstrated in this report, the Staff conclusion drawn from the data in Table 1-1 is not supported by past or current biodiesel research, including the recent testing program sponsored by CARB. In fact, past and current studies indicate that biodiesel blends at any level will increase NOx emissions in proportion to the blending percent unless specifically mitigated by additives or other measures.

1.2 Summary and Conclusions

The following sections of this report examine the studies cited by CARB one-by-one. As evidenced from this review, it is clear that the data do not support the Staff conclusion and, indeed, the data refute the Staff conclusion in some instances. Specifically:

- There is no evidence supporting the Staff conclusion that NOx emissions do not increase until the B10 level is reached. Instead, there is consistent and strong evidence that biodiesel increases NOx emissions in proportion to the biodiesel blending percent.

- There is clear and statistically significant evidence that biodiesel increases NOx emissions at the B5 level in at least some engines for both soy- and animal-based biodiesels.

Considering each of the six past studies obtained from the technical literature and their data on high-cetane biodiesels comparable to California fuels, we find the following:

1. None of the six studies measured the NOx emissions impact from biodiesel at blending levels below B10. Only two studies tested a fuel at the B10 level. All other testing was at the B20 level or higher. Because none tested a B5 (or similar) fuel, none of them can provide direct evidence that NOx emissions are not increased at B5 or other blending levels below B10.

2. These studies provide no data or evidence supporting the validity of the Staff's Threshold Model that biodiesel below B10 does not increase NOx emissions. In fact, all of the studies are consistent with the contention that biodiesel increases NOx emissions in proportion to the blending percent.

3. Two of the studies present evidence and arguments that the NOx impact from biodiesel is a continuous effect that is present even at very low blending levels and will increase at higher levels in proportion to the blending percentage.

Considering the CARB Biodiesel Characterization report, we find that:

4. For the three engines where CARB has published the emission values measured in engine dynamometer testing, all of the data demonstrate that biodiesel fuels significantly increase NOx emissions for both soy- and animal-based fuels by amounts that are proportional to the blending percent. This is true for on-road and off-road engines and for a range of test cycles.

5. Where B5 fuels were tested for these engines, NOx emissions were observed to increase. NOx emission increases are smaller at B5 than at higher blending levels and the observed increases for two engines were not statistically significant by themselves based on the pair-wise t-test employed in Durbin 2011.[8] However, the testing for one of the engines (the 2007 MBE4000) showed statistically significant NOx emission increases at the B5 level for both soy- and animal-based blends.

By itself, the latter result is sufficient to disprove the Staff's contention that biodiesel blends at the B5 level will not increase NOx emissions.

Based on examination of all of the studies cited by CARB as the basis for its proposal to exempt biodiesels below B10 from mitigation, it is clear that the available research points to the expectation that both soy- and animal-based biodiesel blends will increase NOx emissions in proportion to their biodiesel content, including at the B5 level. CARB's own test data demonstrate that B5 will significantly increase NOx emissions in at least some engines.

Based on data in the CARB Biodiesel Characterization report, soy-based biodiesels will increase NOx emissions by about 1% at B5 (and 2% at B10), while animal-based biodiesels will increase NOx emissions by about one-half as much: 0.45% at B5 (and 0.9% at B10). All of the available research says that the NOx increases are real and implementation of mitigation measures will be required to prevent increases in NOx emissions due to biodiesel use at blending levels below B10.

Finally, we note that CARB has not published fully the biodiesel testing data that it relied on in support of the Proposed Rule and thereby has failed to adequately serve the interest of full public disclosure in this matter. The CARB-sponsored testing reported in Durbin 2011 is the sole source of B5 testing cited by CARB as support for the Proposed Rule. Durbin 2011 publishes only portions of the measured emissions data in a form that permits re-analysis; it does not publish any of the B5 data in such a form. It has not been possible to obtain the remaining data through a personal request to Durbin or an official public records request to CARB and, to the best of our knowledge, the data are not otherwise available online or through another source.

CARB should publish all of the testing presented in Durbin 2011 and any future testing that it sponsors in a complete format that allows for re-analysis. Such a format would be (a) the measured emission values for each individual test replication; or (b) averages across all test replications, along with the number of replications and the standard error of the individual tests. The first format (individual test replications) is preferable because that would permit a full examination of the data including effects such as test cell drift over time. Such publication is necessary to assure that full public disclosure is achieved and that future proposed rules are fully and adequately informed by the data.

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[8] As discussed in Section 3.3, the pair-wise t-test is not the preferred method for demonstrating statistical significance.

1.3 Review of 2013 CARB B5 Emission Testing

In December 2013, after the release of the ISOR and in response to an earlier Public Records Act request, CARB released a copy of new CARB-sponsored emission testing conducted by Durbin and others at the University of California CE-CERT[9]. The purpose of the study was "... to evaluate different B5 blends as potential emissions equivalent biodiesel fuel formulations for California."[10] Three B5 blends derived from soy, waste vegetable oil (WVO), and animal biodiesel stocks were tested on one 2006 Cummins ISM 370 engine using the hot-start EPA heavy-duty engine dynamometer cycle. A preliminary round of testing was conducted for all three fuels followed by emissions-equivalent certification testing per 13 CCR 2282(g) for two of the fuels. As noted by Durbin: "[t]he emissions equivalent diesel certification procedure is robust in that it requires at least twenty replicate tests on the reference and candidate fuels, providing the ability to differentiate small differences in emissions."[11]

Soy and WVO B5 Biodiesel

The B5-soy and B5-WVO fuels were blended from biodiesel stocks that were generally similar to the soy-based stock used in the earlier CARB Biodiesel Characterization Study (Durbin 2011) with respect to API gravity and cetane number. In the preliminary testing, the two fuels "...showed 1.2-1.3% statistically significant [NOx emissions] increases with the B5-soy and B5-WVO biodiesel blends compared to the CARB reference fuel."[12] The B5-WVO fuel caused the smaller NOx increase (1.2%) and was selected for the certification phase of the testing. There, it "... showed a statistically significant 1.0% increase in NOx compared to the CARB reference fuel"[13] and failed the emissions-equivalent certification due to NOx emissions.

Animal B5 Biodiesel

The B5-animal derived fuel was blended from an animal tallow derived biodiesel that was substantially different from the animal based biodiesel used in the earlier Durbin study, and was higher in both API gravity and cetane number. The blending response for cetane number was also surprising, in that blending 5 percent by volume of a B100 stock (cetane number 61.1) with 95% of CARB ULSD (cetane number 53.1) produced a B5 fuel blend with cetane number 61.

In preliminary testing, the B5-animal fuel showed a small NOx increase which was not statistically significant, causing it to be judged the best candidate for emissions-equivalent certification. In the certification testing, it "...showed a statistically

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[9] "CARBB5 Biodiesel Preliminary and Certification Testing." Prepared by Thomas D. Durbin, G. Karavalakis and others. Prepared for Alexander Mitchell, California Air Resources Board. July 2013. This study is not referenced in the ISOR, nor was it included in the rule making file when the hearing notice for the ADF regulation was published in October 2013.

[10] Ibid, p. vi.

[11] Ibid, p. viii.

[12] Ibid, p. 8.

[13] Ibid, p. 9.

significant 0.5% reduction in NOx compared to the CARB reference fuel"[13] and passed the emissions-equivalent certification. The NOx emission reduction for this fuel blend appears to be real for this engine, but given the differences between the blendstock and the animal based biodiesel blendstock used in the earlier Durbin study it is unclear that it is representative for animal-based biodiesels in general..

Summary

The conclusions drawn in the preceding section are not changed by the consideration of these new emission testing results. For plant-based biodiesels (soy- and WVO-based), the new testing provides additional and statistically significant evidence that B5 blends will increase NOx emissions at the B5 level. The result of decreased NOx for the B5 animal-based blend stands out from the general trend of research results reviewed in this report. However:

- The same result – reduced NOx emissions for some fuels and engines – has sometimes been observed in past research, as evidenced by the emissions data considered by CARB staff in ISOR Figure B.3 (reproduced in Figure 2.1 below). As shown, some animal-based B5 and B20 fuels reduced NOx emissions while others increased NOx emissions with the overall conclusion being that NOx emissions increase in direct proportion to biodiesel content of the blends and that there is no emissions threshold.

- Increasing cetane is known to generally reduce NOx emissions and has already been proposed by CARB as a mitigation strategy for increased NOx emissions from biodiesel[14]. The unusual cetane number response in the blending and the high cetane number of the B5-animal fuel may account for the results presented in the recently released study.

Considering the broad range of plant- and animal-based biodiesel stocks that will be used in biodiesel fuels, we conclude that the available research (including the recently released CARB test results) indicates that unrestricted biodiesel use at the B5 level will cause real increases in NOx emissions and that countermeasures may be required to prevent increases in NOx emissions due to biodiesel use at blending levels below B10.

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[14] For example, see Durbin 2011 Section 7.0 for a discussion of NOx mitigation results through blending of cetane improvers and other measures.

2. CARB LITERATURE REVIEW

The Staff ISOR explains that the Appendix B Technology Assessment is the basis for CARB's conclusion that biodiesels below B10 have no significant impact on NOx emissions. The assessment is based on data from seven studies (identified in Table 2-1) that tested high-cetane diesel fuels. The first study (Durbin 2011) is the Biodiesel Characterization Study that was conducted for CARB, while the others were obtained through a literature search.

Table 2-1
List of Studies from High-Cetane Literature Search

Primary Author	Title	Published	Year
Durbin	Biodiesel Mitigation Study	Final Report Prepared for Robert Okamoto, M.S. and Alexander Mitchell, CARB	2011
Clark	Transient Emissions Comparisons of Alternative Compression Ignition Fuel	SAE 1999-01-1117	1999
Eckerle	Effects of Methyl Ester Biodiesel Blends on NOx Emissions	SAE 2008-01-0078	2008
McCormick	Fuel Additive and Blending Approaches to Reducing NOx Emissions from Biodiesel	SAE 2002-01-1658	2002
McCormick	Regulated Emissions from Biodiesel Tested in Heavy-Duty Engines Meeting 2004 Emissions	SAE 2005-01-2200	2005
Nuszkowski	Evaluation of the NOx emissions from heavy duty diesel engines with the addition of cetane improvers	Proc. I Mech E Vol. 223 Part D: J. Automobile Engineering, 223, 1049-1060	2009
Thompson	Neat fuel influence on biodiesel blend emissions	Int J Engine Res Vol. 11, 61-77.	2010

Source: Table B.2 of Durbin 2011

Figure 2-1 reproduces two exhibits from Appendix B that show increasing trends for NOx emissions with the biodiesel blending level. Based on the slopes of the trend lines,

Figure 2-1
NOx Emission Increases Observed in Biodiesel Research Cited in Staff ISOR

Figure B.2: NOx Impact of Soy Biodiesel Blended in High Cetane Base Fuel

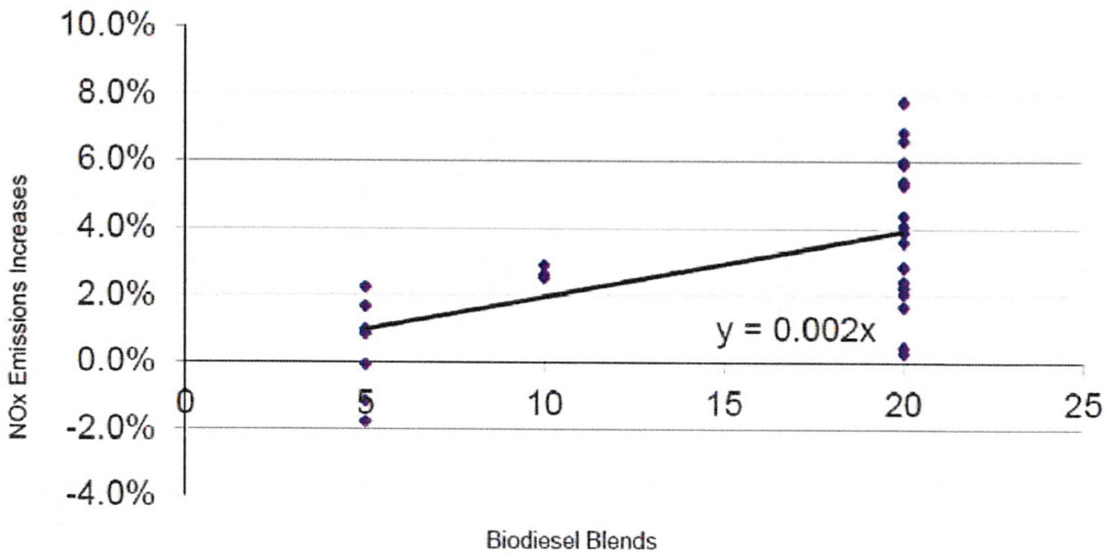
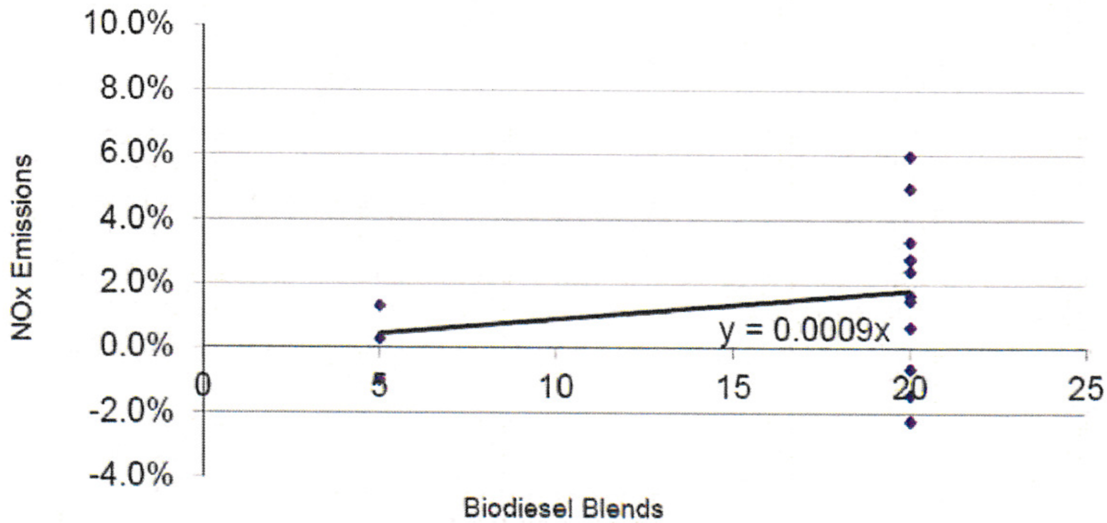


Figure B.3: NOx Impact of Animal Biodiesel Blended in High Cetane Base Fuel



Source: Figures B.2 and B.3 of Appendix B: Technology Assessment

soy-based biodiesels are shown to increase NOx emissions by approximately 1% at B5, 2% at B10, and 4% at B20. Animal-based biodiesels are shown to increase NOx emissions by about one-half as much: 0.45% at B5, 0.9% at B10, and 1.8% at B20. Although there is substantial scatter in the results, these data do not appear to support the Staff Threshold Model that biodiesel does not increase NOx emissions at B5 but does so at B10.

We will examine the Durbin 2011 study at some length in Section 3. In this section, we look at each of the other studies cited by the Staff to find out what the studies say about NOx emissions impacts at and below B10.

2.1 Review of Literature Cited in the ISOR

The Staff literature search sought and selected testing that used fuels with cetane levels comparable to California diesel fuels; the Staff does not, however, list those fuels or provide the data that support the tables and figures in Appendix B of the ISOR. Therefore, we have necessarily made our own selection of high-cetane fuels in the course of reviewing the studies. The key testing and findings of each study are summarized below, with a specific focus on what they tell us about NOx emission impacts at B10 and below.

2.1.1 Clark 1999

This study tested a variety of fuels on a 1994 7.3L Navistar T444E engine. Of the high-cetane base fuels, one base fuel (Diesel A, off-road LSD) was blended and tested at levels of B20, B50, and B100. NOx emissions were significantly increased for all of the blends. The other base fuel (CA Diesel) was tested only as a base fuel. Its NOx emissions were 12% below that of Diesel A, making it is unclear whether Diesel A is representative of fuels in CA. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

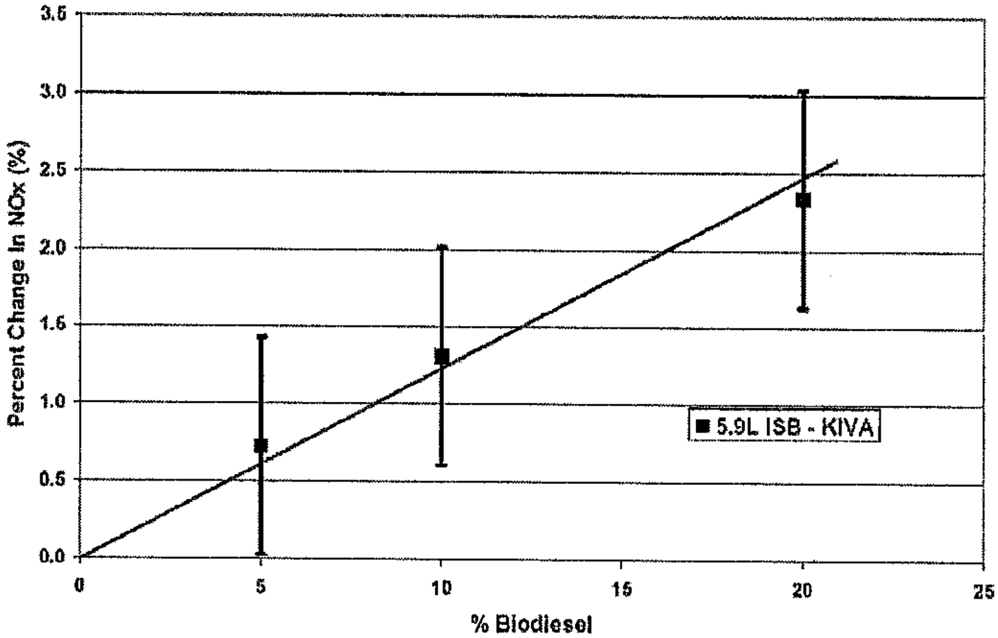
2.1.2 Eckerle 2008

This study tested low and mid/high-cetane base fuels alone and blended with soy-based biodiesel at the B20 level. The Cummins single-cylinder test engine facility was used in a configuration representative of modern diesel technology, including cooled EGR. Testing was conducted under a variety of engine speed and load conditions. FTP cycle emissions were then calculated from the speed/load data points. The test results show that B20 blends increase NOx emissions compared to both low- and high-cetane base fuels. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

The study notes that two other studies "show that NOx emissions increase nearly linearly with the increase in the percentage of biodiesel added to diesel fuel." Eckerle's Figure 21 (reproduced below as Figure 2-2) indicates a NOx emissions increase at B5, which is the basis for the statement in the abstract that "Results also show that for biodiesel blends containing less than 20% biodiesel, the NOx impact over the FTP cycle is proportional to

the blend percentage of biodiesel." The authors clearly believe that biodiesel fuels have NOx emission impacts proportional to the blending percent at all levels including B5.

Figure 2-2
Impact of Biodiesel Blends on Percent NOx Change for the 5.9L ISB Engine Operation Over the FTP Cycle



Source: Figure 21 of Eckerle 2008

2.1.3 McCormick 2002

This study tested low- and mid-cetane base fuels alone and blended with soy- and animal-based biodiesel at the B20 level. The testing was conducted on a 1991 DDC Series 60 engine using the hot-start U.S. heavy-duty FTP. NOx emission increases were observed for both fuels at the B20 level. Mitigation of NOx impacts was investigated by blending a Fisher-Tropsch fuel, a 10% aromatics fuel and fuel additives. This study conducted no testing of the NOx emissions impact from commercial biodiesels at the B10 level or below.

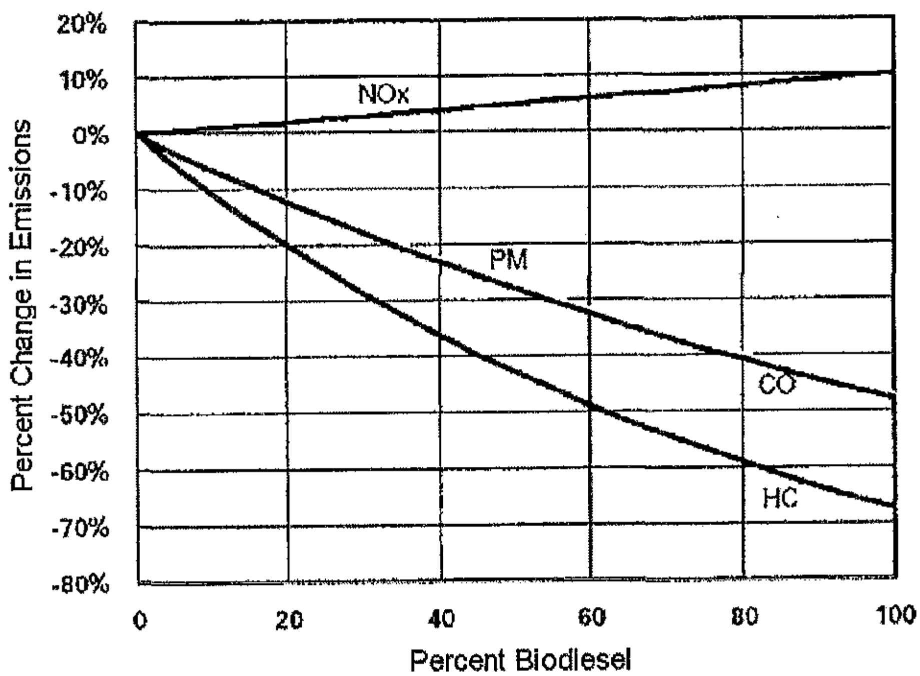
This study also tested a Fisher-Tropsch (FT) base fuel blended at the B1, B20, and B80 levels. Although the very high cetane number (≥75) takes it out of the range of commercial diesel fuels, it is interesting to note that the study measured higher NOx emissions at the B1 level than it did on the FT base fuel and substantially higher NOx emissions at the B20 and B80 levels. While the B1 increase was not statistically significant given the uncertainties in the emission measurements (averages of three test runs), it is clear that increased NOx emissions have been observed at very low blending levels.

2.1.4 McCormick 2005

This study tested blends of soy- and animal-based biodiesels with a high-cetane ULSD base fuel at B10 levels and higher. Two engines were tested – a 2002 Cummins ISB and a 2003 DDC Series 60, both with cooled EGR. The hot-start U.S. heavy-duty FTP test cycle was used. The majority of testing was at the B20 level with additional testing at the B50 and B100 levels. One soy-based fuel was tested at B10. The study showed NOx emission increases at B10, B20, and higher levels. The study also investigated mitigation of NOx increases. This study conducted no testing of the NOx emissions impact from biodiesels below the B10 level.

The authors present a figure (reproduced as Figure 2-3) in their introduction that shows their summary of biodiesel emission impacts based on an EPA review of heavy-duty engine testing. It shows NOx emissions increasing linearly with the biodiesel blend percentage.

Figure 2-3
Trend in HC, CO, NOx and PM Emissions with Biodiesel Percent



Source: McCormick 2005

2.1.5 Nuszkowski 2009

This study tested five different diesel engines: one 1991 DDC Series 60, two 1992 DDC Series 60, one 1999 Cummins ISM, and one 2004 Cummins ISM. Only the 2004 Cummins ISM was equipped with EGR. All testing was done using the hot-start U.S. heavy-duty FTP test cycle. The testing was designed to test emissions from fuels with and without cetane-improving additives. Although a total of five engines were tested, the base diesel and B20 fuels were tested on only two engines (one Cummins and one DDC Series 60) because there was a limited supply of fuel available. NOx emissions increased on the B20 fuel for both engines. A third engine (Cummins) was tested on B20 and B20 blended with cetane improvers to examine mitigation of NOx emissions. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

2.1.6 Thompson 2010

This study examined the emissions impacts of soy-based biodiesel at the B10 and B20 levels relative to low-cetane (42), mid-cetane (49), and high-cetane (63) base fuels using one 1992 DDC Series 60 engine. The emissions results were measured on the hot-start U.S. heavy-duty FTP cycle. The study found that NOx emissions were unchanged (observed differences were not statistically significant) at B10 and B20 levels for the low- and mid-cetane fuels. NOx emissions increased significantly at B10 and B20 levels for the high-cetane fuels. This study conducted no testing of the NOx emissions impact from biodiesels at levels below B10.

2.2 Conclusions Based on Studies Obtained in Literature Search

From the foregoing summary of the studies cited by Staff, we reach the conclusions given below.

1. None of the six studies measured the NOx emissions impact from commercial-grade biodiesel at blending levels below B10, and only two studies tested a fuel at the B10 level. All other testing was at the B20 level or higher. Because none tested a B5 (or similar) fuel, none is capable of providing direct evidence regarding NOx emissions at B5 or other blending levels below B10.

2. These studies provide no data or evidence supporting the validity of Staff's Threshold Model that biodiesel below B10 does not increase NOx emissions. In fact, all of the studies are consistent with the contention that biodiesel increases NOx emissions in proportion to the blending percent.

3. Two of the studies present evidence and arguments that the NOx impact from biodiesel is a continuous effect that is present even at very low blending levels and will increase at higher levels in proportion to the blending percentage. One study tested a Fischer-Tropsch biodiesel blend at B1 and observed NOx emissions to increase (but not by a statistically significant amount).

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3. CARB BIODIESEL CHARACTERIZATION STUDY

3.1 Background

CARB sponsored a comprehensive study of biodiesel and other alternative diesel blends in order "… to better characterize the emissions impacts of renewable fuels under a variety of conditions."[15] The study was designed to test eight different heavy- duty engines or vehicles, including both highway and off-road engines using engine or chassis dynamometer testing. Five different test cycles were used: the Urban Dynamometer Driving Schedule (UDDS), the Federal Test Procedure (FTP), and 40 mph and 50 mph CARB heavy-heavy-duty diesel truck (HHDDT) cruise cycles, and the ISO 8178 (8 mode) cycle. Table 3-1 (reproduced from Table ES-1 of Durbin 2011) documents the scope of the test program. Because the Staff relied only on engine dynamometer testing in its Technology Assessment, only the data for the first four engines (shaded) are considered here.

Table 3-1
A Breakdown of the Test Engines for the Different Categories of Testing

2006 Cummins ISM[a]	Heavy-duty on-highway	Engine dynamometer	
2007 MBE4000	Heavy-duty on-highway	Engine dynamometer	
1998, 2.2 liter, Kubota V2203-DIB	Off-road	Engine dynamometer	
2009 John Deere 4.5 L	Off-road	Engine dynamometer	
2000 Caterpillar C-15	Heavy-duty on-highway	Chassis dynamometer	Freightliner chassis
2006 Cummins ISM	Heavy-duty on-highway	Chassis dynamometer	International chassis
2007 BME4000	Heavy-duty on-highway	Chassis dynamometer	Freightliner chassis
2010 Cummins ISX15	Heavy-duty on-highway	Chassis dynamometer	Kenworth chassis

Source: Table ES-1 of Durbin 2011, page xxvi
Notes:
[a] Data for the first four engines (shaded) are considered in this report.

[15] Durbin 2011, p. xxiv.

The original goal of this report was to subject all of the NOx emission testing in Durbin 2011 to a fresh re-analysis. However, it was discovered that Durbin 2011 did not report all of the data that were obtained during the program and are discussed in the report. The chassis dynamometer testing was conducted at the CARB Los Angeles facility. Emission results for the chassis dynamometer testing are presented in tabular and graphical form, but the report does not contain the actual emissions test data. For the engine dynamometer testing, some of the measured emission values are not reported even though the emission results are reported in tabulated or graphical form. Requests for the missing data were directed to Durbin in a personal request and to CARB through an official records request. No information has been provided in response and we have not been able to obtain the missing data from online or other sources.

For this report, we have worked with the data in the forms that are provided in Durbin 2011 as being the best-available record of the results of the CARB study. Because Staff used only data obtained in engine dynamometer testing, the analysis presented in this report has done the same. Nevertheless, the results of the chassis dynamometer testing are generally supportive of the results and conclusions presented here. Durbin 2011 notes:

> "... The NOx emissions showed a consistent trend of increasing emissions with increasing biodiesel blend level. These differences were statistically significant or marginally significant for nearly all of the test sequences for the B50 and B100 fuels, and for a subset of the tests on the B20 blends."[16]

Durbin notes that emissions variability was greater in the chassis dynamometer testing, which leads to the sometimes lower levels of statistical significance. There was also a noticeable drift over time in NOx emissions that complicated the results for one engine.

3.2 Data and Methodology

Table 3-2 compiles descriptive information on the engine dynamometer testing performed in Durbin 2011. The experimental matrix involves four engines, two types of biodiesel fuels (soy- and animal-based), and up to four test cycles per engine. However, the matrix is not completely filled with all fuels tested on all engines on all applicable test cycles. The most complete testing is for the ULSD base fuel and B20, B50, and B100 blends. There is less testing for the B5 blend, and B5 is tested using only a subset of cycles. For this reason, we first examine the testing for ULSD, B20, B50, and B100 fuels to determine the overall impact of biodiesels on NOx emissions. We then examine the more limited testing for B5 to determine the extent to which it impacts NOx emissions.

This examination is limited by the form in which emissions test information is reported in Durbin 2011. A complete statistical analysis can be conducted only for the two on-road engines for which Appendices G and H of Durbin 2011 provide measured emissions, and for a portion of the testing of the Kubota off-road engine for which Appendix I provides

[16] Durbin 2011, p. 126.

Table 3-2
Experimental Matrix for Heavy-Duty Engine Dynamometer Testing Reported in Durbin 2011

Engine	Biodiesel Type	Fuels Tested	Test Cycles	Notes
On-Road Engines				
2006 Cummins ISM	Soy	ULSD, B20, B50, B100, B5	UDDS, FTP, 40 mph, 50 mph	B5 tested on 40 mph and 50 mph cruise cycles
	Animal	ULSD, B20, B50, B100, B5	UDDS, FTP, 50 mph	B5 tested only on FTP.
2007 MBE4000	Soy	ULSD, B20, B50, B100, B5	UDDS, FTP, 50 mph	B5 tested only on FTP.
	Animal	ULSD, B20, B50, B100, B5		B5 tested only on FTP.
Off-Road Engines				
1998 Kubota V2203-DIB	Soy	ULSD, B20, B50, B100, B5	ISO 8178 (8 Mode)	none
	Animal	Not tested		
2009 John Deere	Soy	ULSD, B20, B50, B100	ISO 8178 (8 Mode)	B5 not tested
	Animal	ULSD, B20, B5		none

measured emissions. The data needed to support a full re-analysis consist of measured emissions on each fuel in gm/hp-hr terms, which are stated in Durbin 2011 as averages across all test replications along with the number of replications and the standard error of the individual tests. With this information, the dependence of NOx emissions on biodiesel blending percent can be determined as accurately as if the individual test values had been reported and the appropriate statistical tests for the significance of results can be performed.

Regression analysis is used as the primary method of analysis. For each engine and test cycle, the emission averages for each fuel are regressed against the biodiesel blending percent to determine a straight line. The regression weights each data point in inverse proportion to the square of its standard error to account for differences in the number and reliability of emission measurements that make up each average. The resulting regression line will pass through the mean value estimated from the data (i.e., the average NOx emission level at the average blending percent), while the emission averages for each fuel may scatter above and below the regression line due to uncertainties in their measurement. The slope of the line estimates the dependence of NOx emissions on the blending percentage.

Where the data points closely follow a straight line and the slope is determined to be statistically significant, one can conclude that blending biodiesel with a base fuel will increase NOx emissions in proportion to the blending percent. The regression line can then be used to estimate the predicted emissions increase for a given blending percent. The predicted emissions increase is the value one would expect on average over many measurements and is comparable to the average emissions increase one would expect in a fleet of vehicles.

The same level of analysis is not possible for the testing on B5 fuel, which is reported as a simple average for the on-road engines and is not reported at all for the off-road engines. For the B5 fuel, Durbin 2011 presents emission test results in a tabulated form where the percentage change in NOx emissions has been computed compared to ULSD base fuel. This form supports the presentation of results graphically, but it does not permit a proper statistical analysis to be performed. Specifically, the computation of percentage emission changes will perturb the error distribution of the data, by mixing the uncertainty in measured emissions on the base fuel with the uncertainties in measured emissions on each biodiesel blend, and it can introduce bias as a result of the mixing. Further statistical analysis of the computed percent values should be avoided because of these problems. Therefore, a more limited trend analysis of the NOx emissions data for B5 and the John Deere engine is conducted.

3.3 2006 Cummins Engine (Engine Dynamometer Testing)

Table 3-3 shows the NOx emission results for the 2006 model-year Cummins heavy-duty diesel engine based on a re-analysis of the data for this report. As indicated by highlighting in the table, the relationship between increasing biodiesel content and increased NOx emissions for soy-based biodiesel is statistically significant at >95% confidence level[17] in all cases. For the animal-based biodiesel, the relationship is statistically significant at the 92% confidence level for the UDDS cycle, the 94% confidence level for the 50 mph cruise, and the >99% confidence level for the FTP cycle.

For the soy-based fuels, the R^2 statistics show that the emissions effect of biodiesel is almost perfectly linear with increasing biodiesel content over the range B20, B50, and B100. Although not as high for the animal-based fuels (because the emissions effect is smaller and measurement errors are relatively larger in comparison to the trend), the R^2 statistics nevertheless establish a linear increase in NOx emissions with increasing biodiesel content over the same range. The linearity of the response with blending percent is well supported by the many NOx emissions graphs contained in Durbin 2011.

The table also gives the estimated NOx emission increases for B5 and B10 as predicted by the regression lines. For soy-based fuels, the values are 1% for B5 (range 0.8% to 1.3% depending on the cycle) and 2% for B10 (range 1.6% to 2.6% depending on cycle).

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[17] A result is said to be statistically significant at the 95% confidence level when the p value is reported as $p \leq 0.05$. At the $p \leq 0.01$ level, a result is said to be statistically significant at the 99% confidence level, and so forth.

Table 3-3 Re-Analysis for 2006 Cummins Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B20, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	Pct Change	Pct Change
Soy-based							
	UDDS	0.997	5.896	0.0100 [a]	0.001	0.8%	1.7%
	FTP	0.995	2.024	0.0052	0.003	1.3%	2.6%
	40 mph	1.000	2.030	0.0037	<0.0001	0.9%	1.8%
	50 mph	0.969	1.733	0.0028	0.016	0.8%	1.6%
Animal-based							
	UDDS	0.847	5.911	0.0021 [b]	0.080	0.2%	0.4%
	FTP	0.981	2.067	0.0031	0.001	0.7%	1.4%
	50 mph	0.887	1.768	0.0011	0.058	0.3%	0.6%

Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.
[b] Orange highlight indicates result is statistically significant at the 90% confidence level or better.

For animal-based fuels, the values are approximately one-half as large: 0.4% for B5 (range 0.2% to 0.7%) and 0.8% for B10 (range 0.4% to 1.4%). These predicted increases are statistically significant to the same degree as the slope of the regression line from which they are estimated. That is, the NOx increases predicted by the regression line for soy-based fuels are statistically significant at the 95% confidence level (or better) on all cycles and the predicted NOx increases for animal-based fuels are statistically significant at the 90% confidence level (or better) on all cycles and at the >99% confidence level for the FTP.

Because the limited data on B5 were not used to develop the regression lines for each cycle, and no test data on B10 are available, use of the lines to make predictions for B5 and B10 depends on their linearity over the range between ULSD and B20. Based on the R^2 statistics and the graphs in Durbin 2011, the slopes observed between ULSD and B20 are the same as the slopes observed between B20 and B100 for each of the test cycles. We believe that the linearity of the response with blending percent for values over the range ULSD to B100 would be accepted by the large majority of researchers in the field, as would the use of regression analysis to make predictions for B5 and B10.

The Durbin 2011 report takes a different approach for determining the statistical significance of NOx emission increases for each fuel. For each fuel tested, it computes a percentage change in emissions for NOx (and other pollutants) relative to the ULSD base fuel. It then determines the statistical significance of each observed change using a conventional t-test for the difference of two mean values (2-tailed, 2 sample equal

variance t-test). The t-test is conducted on the measured emission values before the percentage emission change is computed.

The t-test would be the appropriate approach for determining statistical significance if only two fuels were tested. However, it is a simplistic approach when three or more fuels are tested because it is applied on a pair-wise basis (B5 vs. ULSD, B20 vs. ULSD, etc.) and does not make use of all of the data that is available. It will have less power than the regression approach to detect emission changes that are real. This limitation is in one direction, however, in that the test is too weak when 3 or more data points are available, but a finding of statistical significance is valid when it occurs. As long as the linear hypothesis is valid, the regression approach should be the preferred method for analysis and for the determination of whether biodiesel blending significantly increases NOx emissions.

Because emission changes will be smallest for B5 (because of the low blending volume), the pair-wise t-test is most likely to fail to find statistical significance at the B5 level. In cases where the pair-wise t-test for B5 says that the emission change vs. ULSD is not statistically significant – but slope of the regression line is statistically significant – the proper conclusion is that additional B5 testing (to improve the precision of the emission averages) would likely lead to the detection of a statistically significant B5 emissions change using the t-test. In this case, the failure to find statistical significance using the t-test is not evidence that B5 does not increase NOx emissions.

For this engine, soy-based B5 was tested on the 40 mph and 50 mph cruise cycles and animal-based B5 was tested on the FTP. To examine this matter further, Table 3-4 reproduces NOx emission results reported in Tables ES-2 and ES-3 of Durbin 2011. Soy-based B5 was shown to increase NOx emissions on the 40 mph cruise cycle, but not on the 50 mph cruise cycle. Animal-based B5 was shown to increase NOx emissions on the FTP. Durbin 2011 noted (p. xxxii) that "[t]he 50 mph cruise results were obscured, however, by changes in the engine operation and control strategy that occurred over a segment of this cycle." Therefore, we discount the 50 mph cruise results and do not consider them further. Neither of the remaining B5 NOx emission increases (for the 40 mph Cruise and FTP cycles) were found to be statistically significant using the t-test, although the 40 mph cruise result for soy-based fuels comes close to being marginally significant (it would be statistically significant at an 86.5% level). The NOx emission increases at higher blending levels were found have high statistical significance (>99% confidence level).

This format, used throughout Durbin 2011 to report emission test data and to show the effect of biodiesel on emissions, is subject to an important statistical caveat. The percent changes are computed by dividing the biodiesel emission values by the emissions measured for the ULSD base fuel. Therefore, measurement errors in the ULSD measurement are blended with the measurement errors for each of the biodiesel fuels. The blending of errors in each computed percent change can bias the apparent trend of emissions with increasing biodiesel content. As will be shown in Section 3.3.2, we can see this problem in the animal-based B5 test data for this engine.

Table 3-4 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2006 Cummins Engine (Engine Dynamometer Testing)						
	Soy-based Biodiesel				Animal-based Biodiesel	
	40 mph Cruise		50 mph Cruise		FTP	
	NOx % Diff	p value	NOx % Diff	p value	NOx % Diff	p value
B5	1.7%	0.135	-1.1%	0.588	0.3%	0.298
B20	3.9% [a]	0.000	0.5%	0.800	1.5%	0.000
B50	9.1%	0.000	6.3%	0.001	6.4%	0.000
B100	20.9%	0.000	18.3%	0.000	14.1%	0.000

Source: Table ES-2 and ES-3 of Durbin 2011, p. xxviii
Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on the pair-wise t-test.

3.3.1 NOx Impact of Soy-based Biodiesel at the B5 Level

Figures 3-1a and 3-1b display the trend of NOx emissions with blending percent for the soy-based biodiesel on the 40 mph cruise cycle. Figure 3-1a plots the percentage increases as reported by Durbin 2011 in contrast to two different analytical models for the relationship:

- The Linear Model shown by the blue line; and
- The Staff Threshold model (black line), in which the NOx emission change is zero through B9 and then increases abruptly to join the linear model.

In Figure 3-1a, the linear model is an Excel trendline for the computed percent changes. While the data violate a key assumption for the proper use of regression analysis, this approach is the only way to establish a trendline given the form in which Durbin 2011 tabulates the data and presents the results of its testing.

Figure 3-1b plots the actual measured emission values in g/bhp-hr terms in contrast to the same two analytical models. Here, the linear model line is determined through a proper use of regression analysis, in which each emission average in g/bhp-hr terms is weighted inversely by the square of its standard error, using the data for ULSD, B20, B50 and B100 (i.e., excluding the B5 data point). In the case of this engine and biodiesel fuel, both forms of assessment show generally the same trend for NOx emissions as a function of blending percent. Although the NOx emission increases for B5 may fail the t-test for significance, emissions are increased at B5 and the B5 data point is fully consistent with the Linear Model. The Threshold model is clearly a less-satisfactory representation of the test data.

Figure 3-1a
Durbin 2011 Assessment: 40 mph Cruise Cycle NOx Emissions Increases
for Soy-Biodiesel Blends (2006 Cummins Engine)

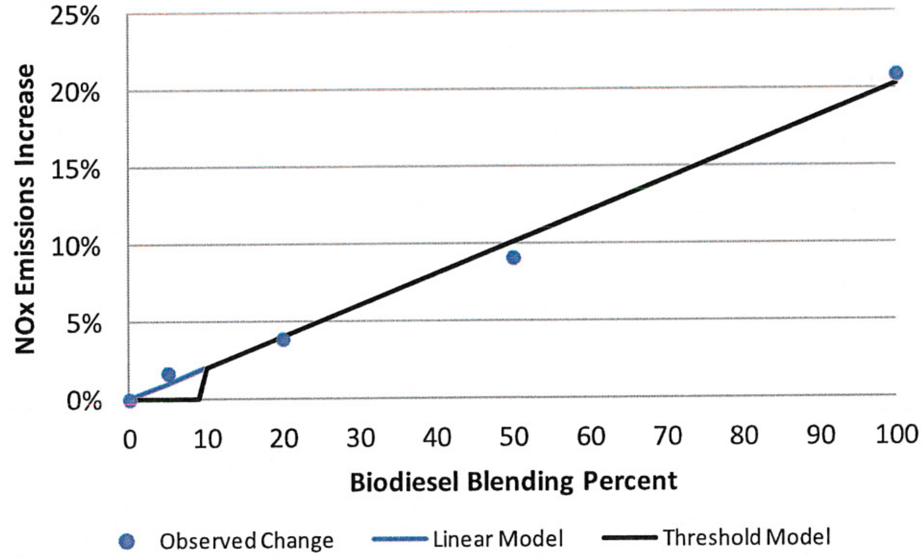
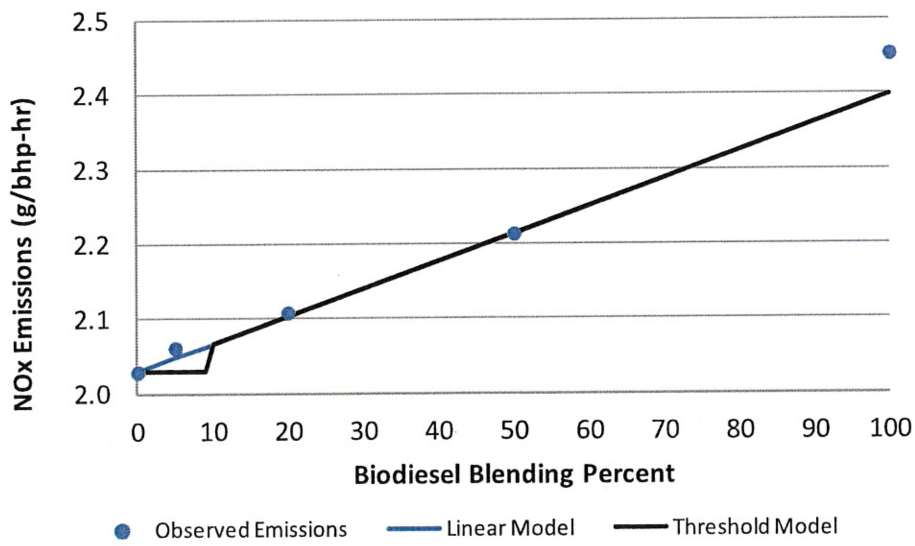


Figure 3-1b
Re-assessment of 40 mph Cruise Cycle NOx Emissions Increases
for Soy-Biodiesel Blends (2006 Cummins Engine)



Note that the slope of the trendline (Figure 3-1a) is greater than the slope of the regression line (Figure 3-1b). In the latter figure, the B100 data point stands above the regression line, which passes below it. The regression line (but not the trendline) is fit in

a manner that accounts for the uncertainties in each data point, so that the line will pass closer to points that have smaller uncertainties and farther from points that have greater uncertainties. For these data, the B100 data point has the largest uncertainty (±0.026 g/bhp-hr) followed by the B20 data point (±0.025 g/bhp-hr). The other three data points (ULSD, B5, and B50) have uncertainties less than ±0.001 g/bhp-hr. The B20 data point happens to fall on the line, but the B100 data point is found to diverge above. Because the regression analysis can account for the relative uncertainties of the data points, it provides a more accurate and reliable assessment of the impact on NOx emissions.

3.3.2 NOx Impact of Animal-based Biodiesel at the B5 level

Figures 3-2a and 3-2b display the trend of NOx emissions with blending percent for the animal-based biodiesel on the FTP test cycle as reported by Durbin 2011 and as re-assessed in this report using regression analysis, respectively. As Figure 3-2a shows, the NOx percent change values reported by Durbin 2011 appear to follow the Staff Threshold model in that NOx emissions are not materially increased at B5, but are increased significantly at B20 and above. As a result, the blue trendline in the figure (fit from the B20, B50 and B100 data points) has a negative intercept.

Figure 3-2b paints a very different picture from the data. Here, the ULSD and B5 data points stand above the weighted regression line (blue) developed from the data for ULSD, B20, B50 and B100. In the data used to fit the regression line, the ULSD data point has the largest uncertainty (±0.013 g/bhp-hr) while the other three data points (B20, B50, and B100) have uncertainties of ±0.002 g/bhp-hr (one case) and ±0.001 g/bhp-hr (two cases). Considering all of the data, the B5 data point has the second highest uncertainty (±0.007 g/bhp-hr). The regression line closely follows a linear model with a high R^2 (0.981) considering the weighted errors, while the ULSD and B5 points lie above it.

Because the ULSD data point is subject to more uncertainty and appears to be biased high compared to the regression line, the NOx percent changes computed by Durbin 2011 are themselves biased. The trendline result in Figure 3-2a that appeared to be supportive of the Staff Threshold model now appears to be the result of biases in the ULSD and B5 emission averages.

Two important conclusions can be drawn from the foregoing:

1. Accurate and reliable conclusions regarding the impact of B5 on NOx emissions cannot be drawn from the computed percent changes that are reported in Durbin 2011. Nor can accurate and reliable conclusions be drawn from visual inspection of graphs that present such data. Weighted regression analysis of the measured emission values (g/bhp-hr terms) must be performed so that the uncertainties in emissions measurements can be fully accounted for.

2. When a weighted regression analysis is performed using the testing for this engine, there is no evidence that supports the conclusion that B5 blends will not increase NOx emissions. In fact, the data are consistent with the conclusion that biodiesel increases NOx emissions in proportion to the blending percent.

Figure 3-2a
Durbin 2011 Assessment: FTP NOx Emissions Increases for Animal-based Biodiesel Blends (2006 Cummins Engine)

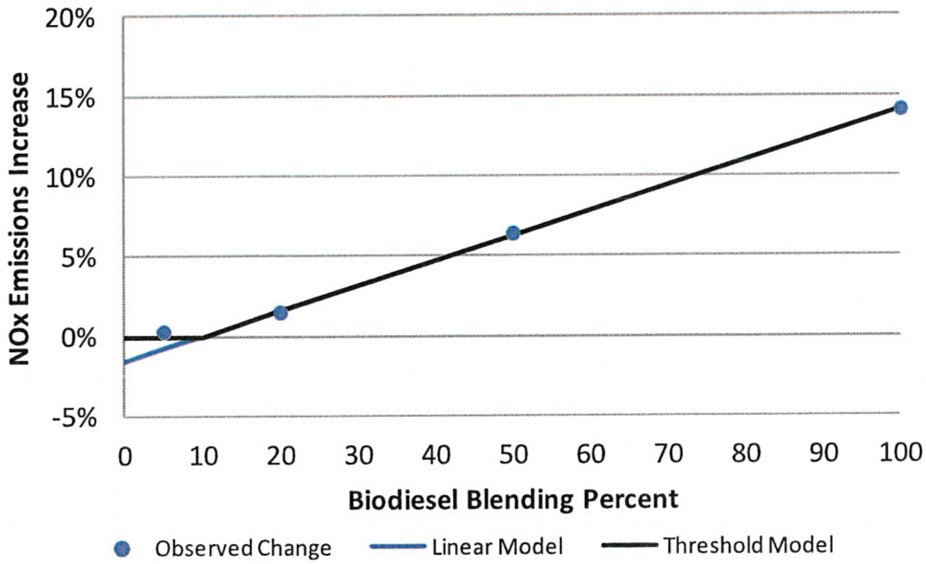
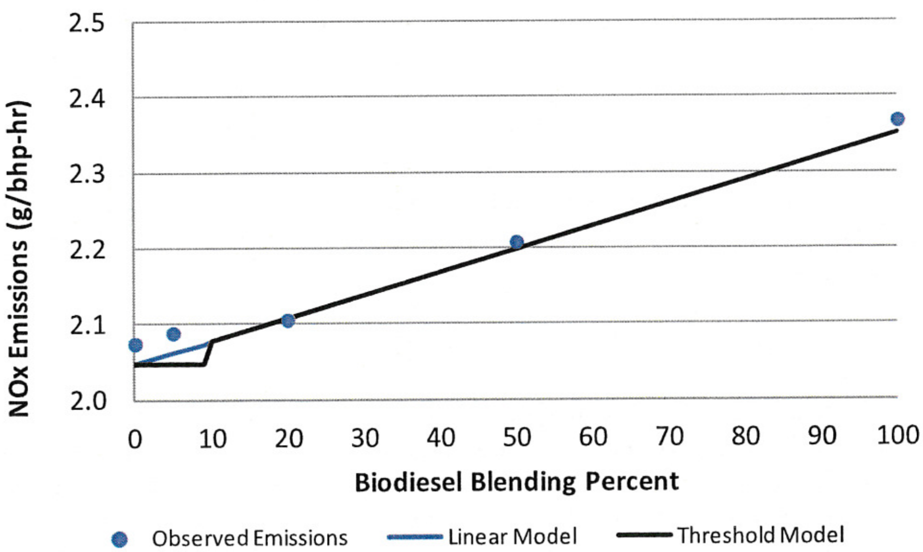


Figure 3-2b
Re-assessment of FTP NOx Emissions Increases for Animal-based Biodiesel Blends (2006 Cummins Engine)



3.4 2007 MBE4000 Engine (Engine Dynamometer Testing)

To analyze the data for the 2007 MBE4000 engine, it has proved necessary to remove two data points, one for the soy-based B20 fuel on the 50 mpg cruise cycle and one for the animal-based B50 fuel on the FTP test cycle:

- Appendix H reports the 50 mph cruise emission average for soy-based B20 to be 0.014 ± 0.020 g/bhp-hr. This value is implausible and wholly inconsistent with the NOx emission change of +6.9% reported in Table ES-4 of Durbin 2011, which would imply a NOx emission average of 1.21*1.069 = 1.30 g/bhp-hr.

- Appendix H reports the FTP emission average for the animal-based B50 fuel to be 2.592 ± 0.028 g/bhp-hr, which stands well above the other test data on animal-based biodiesel. This value is also inconsistent with the NOx emission change of +12.1% reported in Table ES-4 of Durbin 2011, which would imply a NOx emission average of 1.29*1.121 = 1.45 g/bhp-hr.

We believe these reported values are affected by typographical errors and have deleted them from the dataset used here.

With these corrections, Table 3-5 shows the results of the NOx emissions analysis for the 2007 model-year MBE4000 heavy-duty diesel engine. As indicated by highlighting in the table, the relationship between increasing biodiesel content and increased NOx emissions is statistically significant at >99% confidence level in two cases for soy-based biodiesel (the UDDS and FTP cycles) and at the 90% confidence level in one case (the 50 mph cycle). For the animal-based biodiesel, the relationship is statistically significant at the 96% confidence level for the UDDS cycle, the 98% confidence level for the FTP cycle, and >99% confidence level for the 50 mph cycle.

Durbin 2011 again notes a problem with the 50 mph cruise test results, saying (p. xxxii) that "[the NOx] trend was obscured, however, by the differences in engine operation that were observed for the 50 mph cruise cycle." Therefore, we will focus the discussion on the UDDS and FTP results.

For the soy-based fuels, the R^2 statistics show that the emissions effect of biodiesel is almost perfectly linear with increasing biodiesel content over the range from ULSD to B20, B50, and B100 for all cycles (including the 50 mph cruise). That is, the NOx emissions increase between ULSD and B20 shares the same slope as the NOx emissions increase between B20 and B100. For the animal-based biodiesel, the R^2 statistics also establish a linear increase in NOx emissions with increasing biodiesel content over the same range. The linearity of the response with blending percent is also well supported by the many NOx emissions graphs contained in Durbin 2011.

Table 3-5 Re-Analysis for 2007 MBE4000 Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B20, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	Pct Change	Pct Change
Soy-based							
	UDDS	0.989	2.319	0.0090 [a]	0.005	4.6%	9.1%
	FTP	0.998	1.268	0.0049	0.006	2.5%	5.0%
	50 mph	0.979	1.198	0.0054 [b]	0.092	2.7%	5.5%
Animal-based							
	UDDS	0.913	2.441	0.0036	0.044	2.0%	4.0%
	FTP	0.999	1.288	0.0038	0.020	2.5%	5.0%
	50 mph	0.994	1.205	0.0049	0.003	2.5%	5.0%

Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.
[b] Orange highlight indicates result is statistically significant at the 90% confidence level or better.

The table also gives the estimated NOx emission increases for B5 and B10 as predicted by the regression lines. For soy-based fuels, the values are ~3.5% for B5 (range 2.5% to 4.6% depending on the cycle) and ~7.5% for B10 (range 5.0% to 9.1% depending on cycle). For animal-based fuels, the values are approximately two-thirds as large: ~2.3% for B5 (range 2.0% to 2.5%) and ~4.5% for B10 (range 4.0% to 5.0%). The predicted increases are statistically significant to the same degree as the slope of the regression line from which they are estimated. That is, the predicted NOx increases are statistically significant at the >99% confidence level for soy-based fuels on the UDDS and FTP cycles and at the >95% confidence level for animal-based fuels on all cycles. The predicted NOx increase is statistically significant at the 90% confidence level for soy-based fuels on the 50 mph cruise cycle.

For this engine, soy- and animal-based B5 were tested on the FTP. Table 3-6 reproduces the NOx emission results reported in Tables ES-4 and ES-5 of Durbin 2011. While there are caveats on use of the pair-wise t-test, the FTP test data for this engine show NOx emissions at the B5 level for both soy- and animal-based fuels that are statistically significant at the 99% confidence level (or better) in this case. That is, the test data for this engine as reported by Durbin 2011 refute the Staff Threshold Model that biodiesel blends below B10 do not increase NOx emissions.

Table 3-6 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2007 MBE4000 Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel FTP		Animal-Based Biodiesel FTP	
	NOx % Diff	p value	NOx % Diff	p value
B5	0.9% [a]	0.007	1.3%	0.000
B20	5.9%	0.000	5%	0.000
B50	15.3%	0.000	12.1	0.000
B100	38.1%	0.000	29%	0.000

Source: Table ES-4/5 of Durbin 2011, p. xxix
Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test.

Figures 3-3a and 3-3b below compare the FTP data for this engine to the regression line representing the linear model (blue) and the Staff Threshold model (black) for both soy- and animal-based biodiesel. In both cases, the regression line was developed using the data for ULSD, B20, B50, and B100 (i.e., excluding the B5 data point). For both soy- and animal-based biodiesels, the data point for B5 falls on the established line, while the Staff Threshold model is inconsistent with the data. For this engine, it is clear that soy- and animal-based biodiesels increase NOx emissions at all blending levels.

Figure 3-3a
Re-assessment of FTP Cycle NOx Emissions Increases for Soy-based Biodiesel Blends (2007 MBE4000 Engine)

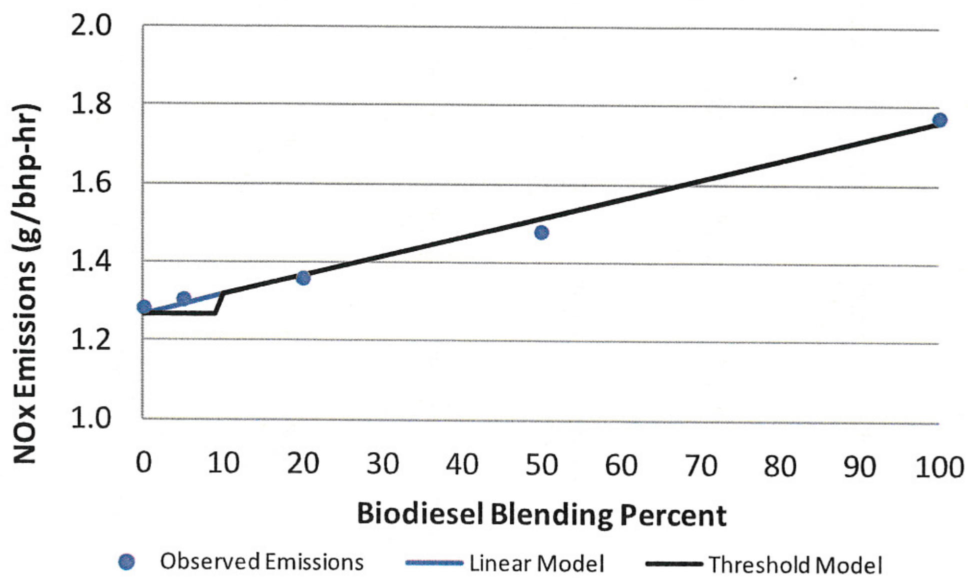
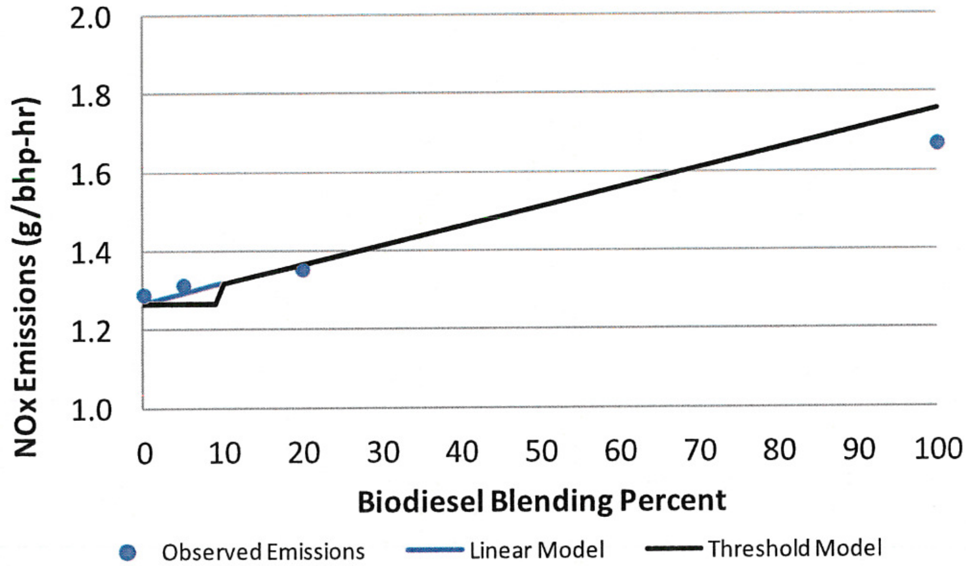


Figure 3-3b
Re-assessment of FTP Cycle NOx Emissions Increases for Animal-based Biodiesel Blends (2007 MBE4000 Engine)



3.5 1998 Kubota TRU Engine (Engine Dynamometer Testing)

The 1998 Kubota V2203-DIB off-road engine was tested on the base fuel (ULSD) and soy-based biodiesel at four blending levels (B5, B20, B50, B100) in two different series using the ISO 8178 (8-mode) test cycle. Appendix I reports the measured emissions data only for the first series (ULSD, B50, B100). Using this subset of data, Table 3-7 summarizes the results of the re-analysis for this engine.

As for the other engines, the results of the analysis demonstrate the following:

- The high R^2 statistic shows that the emissions effect of biodiesel is almost perfectly linear over the range B50 and B100. That is, the slope from ULSD to B50 is the same as the slope from B50 to B100. The slope of the regression line is statistically significant at the 99% confidence level.

- NOx emissions are estimated to increase by 1.0% at the B5 level and by 2.1% at the B10 level. These estimated NOx emission increases are statistically significant to the same high degree as the regression slope on which they are based.

Table 3-7 Re-Analysis for 1998 Kubota V2203-DIB Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	Pct Change	Pct Change
Soy-based	ISO 8178	0.999	12.19	0.0256 [a]	0.01	1.0%	2.1%

Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.

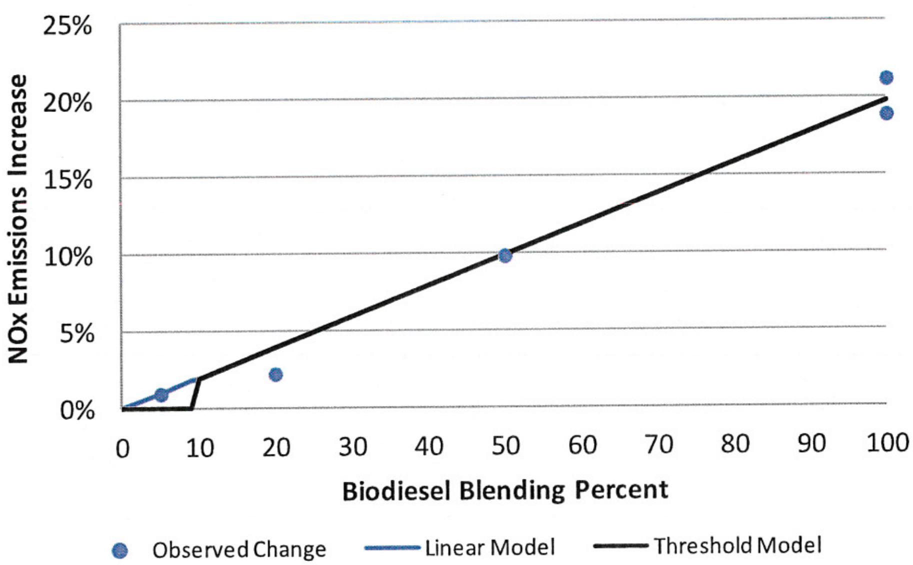
The second test series involved ULSD, B5, B20, and B100 fuels. Measured emissions data are not given in Appendix I, so we must work with the calculated percent changes in NOx emissions tabulated in Durbin 2011. Table 3-8 reproduces the NOx emission results reported in Table ES-8 of Durbin 2011 for the two test series. For the second test series, biodiesel at the B5 level increased NOx emissions, but the result fails the pair-wise t-test for statistical significance. The NOx emission increase at the B20 level was statistically significant at the 90% confidence level, and the increase at the B100 level was statistically significant at the >99% confidence level. The significance determinations use the pair-wise t-test, which is subject to caveats, but this is the only method available to gauge significance because re-analysis of the computed percentage changes is not possible.

Table 3-8 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 1998 Kubota TRU Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel Series 1 ISO 8178		Soy-Based Biodiesel Series 2 ISO 8178	
	NOx % Diff	p value	NOx % Diff	p value
B5	Not tested		0.97%	0.412
B20	Not tested		2.25% [a]	0.086
B50	7.63% [b]	0.000	Not tested	
B100	13.76%	0.000	18.89%	0.000

Source: Table ES-8 of Durbin 2011, p. xxxviii
Notes:
[a] Orange highlight indicates result is statistically significant at the 90% confidence level or better based on pair-wise t-test.
[b] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test

Figure 3-4 displays the trend of NOx emissions with blending percent for the first and second test series combined. As the figure shows, the available data points scatter around the trendline determined from the emission change percentages (not from regression analysis). The B20 data point falls below the trend line while the two B100 data points bracket the trend line. It is not possible to explain the divergence of the B20 data point

Figure 3-4
Durbin 2011 Assessment: ISO 8178 Cycle NOx Emissions Increases for Soy-based Biodiesel Blends (1998 Kubota Engine, Test Series 1 and 2 Combined)



because the emissions data for the second test series are not published in Durbin 2011. The B5 data point clearly supports the Linear Model and is inconsistent with the Staff Threshold Model.

3.6 2009 John Deere Off-Road Engine (Engine Dynamometer Testing)

The only information on the 2009 John Deere off-road engine comes from the tabulation of calculated percentage emission changes. Table 3-9 reproduces these data from Table ES-7 of Durbin 2011. For the soy-based biodiesel, NOx emissions are significantly increased at the B20 and higher blend levels. The increase for B20 is statistically significant at the 90% confidence level and the increases for B50 and B100 are statistically significant at the >99% confidence level based on the pair-wise t-test. A soy-based B5 fuel was not tested.

Table 3-9 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2009 John Deere Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel ISO 8178		Animal-Based Biodiesel ISO 8178	
	NOx % Diff	p value	NOx % Diff	p value
B5	Not tested		-3.82	0.318
B20	2.82% [a]	0.021	-2.20	0.528
B50	7.63%	0.000	Not tested	
B100	13.76%	0.000	4.57	0.000

Source: Table ES-7 of Durbin 2011, p. xxxviii
Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test.

For animal-based biodiesel, the testing shows the unusual result that B5 and B20 appear to decrease NOx emissions, while B100 increases NOx. The B5 and B20 decreases are not statistically significant, while the B100 increase is statistically significant at the >99% confidence level. Durbin 2011 concludes:

> The animal-based biodiesel also did not show as great a tendency to increase NOx emissions compared to the soy-based biodiesel for the John Deere engine, with only the B100 animal-based biodiesel showing statistically significant increases in NOx emissions.[18]

Durbin 2011 does not discuss these results further and does not note any problems in the testing, making further interpretation of the results difficult. Figure 8-1 of Durbin 2011 presents the NOx results for this engine with error bars. First, we note that the figure appears to suggest that NOx emissions were increased on the B20 fuel in contradiction to the table above. Second, it is clear that the error bars are large enough that no difference in NOx emissions can be detected among ULSD, B5, and B20 fuels. Overall, this result could be consistent with the Staff Threshold Model through B5, but the failure to detect a NOx emission increase at B20 is not. Without further information, it is not possible to determine whether the result seen here is a unique response of the John Deere engine to animal-based biodiesel or is the result of a statistical fluctuation or an artifact in the emissions data.

3.7 Conclusions

The Biodiesel Characterization report prepared by Durbin et al. for CARB is an important source of information on the NOx emissions impact of biodiesel fuels in heavy-duty engines. It is the sole source of information on the NOx impact of B5 blends cited in the ISOR. When the engine dynamometer test data are examined for

[18] Durbin 2011, p. xx.

the three engines for which emissions test data have been published, we find clear evidence that biodiesel increases NOx emissions in proportion to the blending percent. Where B5 fuels were tested for these engines, NOx emissions are found to increase above ULSD for both soy- and animal-based blends in all three engines and by statistically significant amounts in one engine.

Specifically, a re-analysis of the NOx emissions test data demonstrates the following:

1. For the 2006 Cummins engine, biodiesel fuels are found to significantly increase NOx emissions for both soy- and animal-based blends by amounts that are proportional to the blending percent. This result indicates that biodiesels will increase NOx emissions at blending levels below B10. When B5 fuels were tested, NOx emissions were observed to increase but by amounts that fail to reach statistical significance according to the pair-wise test.[19] Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

2. For the 2007 MBD4000 engine, biodiesel fuels are found to significantly increase NOx emissions for both soy- and animal-based blends by amounts that are proportional to the blending percent. This result indicates that biodiesels will increase NOx emissions at blending levels below B10. When B5 fuels were tested, NOx emissions were observed to increase and by amounts that are found to be statistically significant using the pair-wise t-test.[13] <u>This result alone is sufficient to disprove the Staff Threshold Model</u>. Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

3. For the 1998 Kubota TRU (off-road) engine, soy-based biodiesel fuels are found to significantly increase NOx missions. Animal-based biodiesel was not tested. When a soy-based B5 fuel was tested, NOx emissions were observed to increase but by amounts that fail to reach statistical significance according to the pair-wise test.[13] Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

The measured emissions test data for the other off-road engine (2009 John Deere) are not contained in the Durbin 2011 report and CARB has not made them publicly available. Thus, a re-analysis was not possible. Based on the tables and figures in Durbin 2011, soy-based biodiesel fuels were shown to significantly increase NOx emissions at B20 levels and higher, but B5 was not tested. Testing of animal-based blends shows no change in NOx emissions at B5 and B20 levels, but B100 is shown to significantly increase NOx emissions. Durbin 2011 discusses this result only briefly, and it is unclear what conclusions can be drawn from it.

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[19] As discussed in Section 3.3, the pair-wise t-test is not the preferred method for demonstrating statistical significance.

APPENDIX A

RESUME OF ROBERT W. CRAWFORD

Education

1978 Doctoral Candidate, ScM. Physics, Brown University, Providence, Rhode Island
1976 B.A. Physics, Pomona College, Claremont, California

Professional Experience

1998-Present Independent Consultant

Individual consulting practice emphasizing the statistical analysis of environment and energy data with an emphasis on how data and statistics are properly used to make scientific inferences. Mr. Crawford provides support on statistical, data analysis, and modeling problems related to ambient air quality data and emissions from mobile and stationary sources.

Ambient Air Quality and Mobile Source Emissions – Mr. Crawford has worked with Sierra Research on elevated ambient CO and PM concentrations in Fairbanks AK and Phoenix AZ, including the effect of meteorological conditions on ambient concentrations, the relationship of concentrations to source inventories, and the use of non-parametric techniques to infer source location from wind speed and direction data. Ongoing work is employing Principal Components Analysis to elucidate the relationship between meteorology and $PM_{2.5}$ concentrations in Fairbanks. In the past year, this work led to creation of the AQ Alert System, a tool used by air quality staff to track $PM_{2.5}$ monitor concentrations during the day and to prepare AQ alerts over the next 3 days based on the meteorological forecast.

In past work for Sierra, he has also conducted studies of fuel effects on motor vehicle emissions for Sierra. For CRC, he determined the relationship between gasoline volatility and oxygen content on tailpipe emissions of late model vehicles at FTP and cold-ambient temperatures. For SEMPRA, he determined the relationship between CNG formulation and tailpipe emissions of criteria pollutants and a range of air toxics. Other work has included the design of vehicle surveillance surveys and determination of sample sizes, development of screening techniques similar to discriminant functions to improve the efficiency of vehicle recruitment, the analysis of vehicle failure rates measured in inspection & maintenance programs, and the statistical evaluation of data collected on freeway speeds using automated sensors.

Stationary Source Emissions – Over the past 5 years, Mr. Crawford has worked with AEMS, LLC on EPA's MACT and CISWI rulemakings for Portland Cement plants, in which significant issues related to data quality, data reliability, and emissions variability are evident. Key issues include the need to properly account for uncertainty and emissions variability in setting emission standards. He also supported AEMS in the

current EPA rulemaking on reporting of greenhouse gas emissions from semiconductor facilities, where the proper characterization of emission control device performance was a key issue. He is currently supporting AEMS in a regulatory process to re-determine emission standards for an industrial facility where the new standard will be enforced by continuous emissions monitoring (CEMS). At issue is how to set the standard in such a way that there will be no more than a small, defined risk that 30-day emission averages will exceed the limitations while emissions remain well-controlled .

Advanced Combustion Research – In recent work for Oak Ridge National Laboratory, Mr. Crawford conducted a series of statistical studies on the fuel consumption and emissions performance of Homogenous Charge Compression Ignition (HCCI) engines. One of these studies was for CRC, in which fuel chemistry impacts were examined in gasoline HCCI. In HCCI, the fuel is atomized and fully-mixed with the intake air charge outside the cylinder, inducted during the intake stroke, and then compressed to the point of spontaneous combustion. The timing of combustion is controlled by heating of the intake air. If R&D work can demonstrate a sufficient understanding of how fuel properties influence engine performance, the HCCI combustion strategy potentially offers the fuel economy benefit of a diesel engine with inherently lower emissions.

1979-1997 Energy and Environmental Analysis, Inc., Arlington, VA. Director & Partner (from 1989).

Primary work areas: Studies of U.S. energy industries for private and institutional clients emphasizing statistical analysis, business planning and computer modeling/forecasting. Responsible for the EEA practice area that provided strategic planning and forecasting services to major energy companies. Primary topical areas included: U.S. energy market analysis and strategic planning; gas utility operations; and natural gas supply planning.

U.S. Energy Market Analysis

During 1995-1997, Mr. Crawford directed EEA's program to provide comprehensive energy supply and demand forecasting for the Gas Research Institute (GRI) in its annual Baseline Projection of U.S. Energy Supply and Demand. Services included: development of U.S. energy supply, demand, and price forecasts; sector-specific analyses covering energy end-use (residential, commercial, industrial, transportation), electricity supply, and natural gas supply and transportation; and the preparation of a range of publications on the forecasts and energy sector trends.

From 1989 through 1997, he directed the use of EEA's Energy Overview Model in strategic planning and long-term market analysis for a client base of major energy producers, pipelines, and distributors in both the United States and Canada. The Energy Overview Model was used under his direction as the primary analytical basis for the 1992 National Petroleum Council study The Potential for Natural Gas in the United States. Mr. Crawford also provided analysis for clients on a wide range of other energy market issues, including negotiations related to an LNG import project intended to serve U.S. East Coast markets. This work assessed the utilization and economic value of seasonal

gas deliverability in order to develop LNG pricing formulas and evaluate the project's viability.

Other topical areas of work during his period of employment with EEA include:

Gas Load Analysis and Utility Operations – Principal investigator in a multi-year research program for the Gas Research Institute (GRI) that examined seasonal gas loads, utility operations, and the implications for transmission and storage system reliability and capacity planning.

Gas Transmission and Storage – Principal investigator for a study of industry plans for expansion of underground gas storage capacity in the post-Order 636 environment, including additions of depleted-reservoir and salt-formation storage, an engineering analysis of capital and operating costs for the projects, and unbundled rates for new storage services.

Natural Gas Supply Planning – Mr. Crawford was EEA's senior manager and lead analyst on gas supply planning issues for both pipeline and distribution companies, which included technical and analytic support in development and justification of gas supply strategies; and identification of optimal seasonal supply portfolios for Integrated Resource Planning proceedings.

Transportation Systems Research

Mr. Crawford also had extensive experience in motor vehicle fuel economy and emissions while at EEA. He participated for five years in a DOE research program on fuel economy, with emphasis on the evaluation of differences between laboratory and on-road fuel economy. His work included analysis of vehicle use databases to understand how driving patterns and ambient (environmental) conditions influence actual on-road fuel economy. He also developed a software system to link vehicle certification data systems to vehicle inspection and testing programs and participated in a range of studies on vehicle technology, fuel economy, and emissions for DOE, EPA, and other governmental agencies.

SELECTED PUBLICATIONS (emissions and motor vehicle-related topics)

Statistical Assessment of $PM_{2.5}$ and Meteorology in Fairbanks, Alaska: 2013 Update. Crawford and Dulla. Prepared for the Alaska Department of Environmental Conservation. (forthcoming).

Statistical Assessment of $PM_{2.5}$ and Meteorology in Fairbanks, Alaska. Crawford and Dulla. Prepared for the Alaska Department of Environmental Conservation. March 2012.

Principal Component Analysis: Inventory Insights and Speciated $PM_{2.5}$ Estimates. Crawford. Presentation at Air Quality Symposium 2011, Fairbanks and North Star Borough, Fairbanks, AK. January 2011.

Influence of Meteorology on $PM_{2.5}$ Concentrations in Fairbanks Alaska: Winter 2008-2009. Crawford. Presentation at Air Quality Symposium 2009, Fairbanks and North Star Borough, Fairbanks, AK. July 2009.

Analysis of the Effect of Fuel Chemistry and Properties on HCCI Engine Operation: A Re-Analysis Using a PCA Representation of Fuels. Bunting and Crawford. 2009. Draft Report (CRC Project AFVL13C)

The Chemistry, Properties, and HCCI Combustion Behavior of Refinery Streams Derived from Canadian Oil Sands Crude. Bunting, Fairbridge, Mitchell, Crawford, et al. 2008. (SAE 08FFL 28)

The Relationships of Diesel Fuel Properties, Chemistry, and HCCI Engine Performance as Determined by Principal Components Analysis. Bunting and Crawford. 2007. (SAE 07FFL 64).

Review and Critique of Data and Methodologies used in EPA Proposed Utility Mercury MACT Rulemaking, prepared by AEMS and RWCrawford Energy Systems for the National Mining Association. April 2004.

PCR+ in Diesel Fuels and Emissions Research. McAdams, Crawford, Hadder. March 2002. ORNL/TM-2002/16.

A Vector Approach to Regression Analysis and its Application to Heavy-duty Diesel Emissions. McAdams, Crawford, Hadder. November 2000. ORNL/TM-2000/5.

A Vector Approach to Regression Analysis and its Application to Heavy-duty Diesel Emissions. McAdams, Crawford, Hadder. June 2000. (SAE 2000-01-1961).

Reconciliation of Differences in the Results of Published Shortfall Analyses of 1981 Model Year Cars. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70045. October 1985

Short Test Results on 1980-1981 Passenger Cars from the Arizona Inspection and Maintenance Program. Darlington, Crawford, Sashihara. August 1984.

Seasonal and Regional MPG as Influenced by Environmental Conditions and Travel Patterns. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70045. March 1983.

Comparison of EPA and On-Road Fuel Economy – Analysis Approaches, Trends, and Impacts. McNutt, Dulla, Crawford, McAdams, Morse. June 1982. (SAE 820788)

Regionalization of In-Use Fuel Economy Effects. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70032. April 1982.

1985 Light-Duty Truck Fuel Economy. Duleep, Kuhn, Crawford. October 1980. (SAE 801387)

PROFESSIONAL AFFILIATIONS

Member, Society of Automotive Engineers.

HONORS AND AWARDS

2006 Barry D. McNutt Award for Excellence in Automotive Policy Analysis. Society of Automotive Engineers.

US Patent 7018524 (McAdams, Crawford, Hadder, McNutt). Reformulated diesel fuels for automotive diesel engines which meet the requirements of ASTM 975-02 and provide significantly reduced emissions of nitrogen oxides (NO_x) and particulate matter (PM) relative to commercially available diesel fuels.

US Patent 7096123 (McAdams, Crawford, Hadder, McNutt). A method for mathematically identifying at least one diesel fuel suitable for combustion in an automotive diesel engine with significantly reduced emissions and producible from known petroleum blend stocks using known refining processes, including the use of cetane additives (ignition improvers) and oxygenated compounds.

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EXHIBIT B

BEFORE THE
CALIFORNIA AIR RESOURCES BOARD

In re:	)
	)
Proposed Regulation on the Commercialization of Alternative Diesel Fuels (Public Hearing Scheduled for March 20, 2014)	)
	)

Declaration of James M. Lyons

I, James M. Lyons, declare and state as follows:

1. I am an engineer with training and expertise in motor vehicle fuels, automotive emissions control, and automotive air pollution. I am a Senior Partner of Sierra Research, Inc. ("Sierra"), an environmental consulting firm located at 1801 J Street, Sacramento, California. Sierra specializes in research and regulatory matters pertaining to air pollution control, and does work for both governmental and private sector clients. I have been employed at Sierra Research since 1991. I received a B.S. degree in Chemistry from the University of California, Irvine, and a M.S. Degree in Chemical Engineering from the University of California, Los Angeles. Before joining Sierra in 1991, I was employed by the State of California in the Mobile Source Division of the California Air Resources Board ("CARB").

I. Introduction, Qualifications, and Materials Considered

2. I have prepared this Declaration and the analysis it contains for Growth Energy. I hold the opinions expressed in this Declaration with a reasonable degree of engineering and scientific certainty. I plan to request an opportunity to testify before CARB at the public hearing scheduled for this matter, so that I may answer any questions concerning my opinions and the analysis and sources on which I have based those opinions. I also request that CARB review and

respond to each part of the analysis and opinions presented in this Declaration before deciding what action to take on the CARB staff's proposed alternative diesel fuel ("ADF") regulation.

3. During my career, I have worked on many projects related to the following areas: (1) the assessment of emissions from on- and non-road mobile sources, including ships and locomotives; (2) analyses of the unintended consequences of regulatory actions; and (3) the feasibility of compliance with air quality regulations. I have also studied how the use of biodiesel fuels can influence exhaust emissions of oxides of nitrogen ("NOx") when used in vehicles and engines operated in California, and I have prepared and filed declarations regarding that issue in *POET LLC et al. v. California Air Resources Board*, an action in which I was a co-petitioner.

4. I have testified as an expert under state and federal court rules in cases involving CARB regulations for gasoline, Stage II vapor recovery systems and their design, combustion chamber system design, and issues related to emissions from heavy-duty vehicles and engines. While at Sierra I have acted as a consultant on automobile air pollution control matters for CARB and other governmental organizations. I am a member of the American Chemical Society and the Society of Automotive Engineers and have co-authored nine peer-reviewed monographs concerned with automotive emissions, including greenhouse gases and their control. In addition, over the course of my career, I have conducted peer-reviews of numerous papers related to a wide variety of issues associated with pollutant emissions and air quality. My résumé is attached as Attachment A.

5. I have reviewed a report being filed along with this Declaration by Growth Energy that has been prepared by Mr. Robert Crawford of Rincon Ranch Consulting, entitled *NOx Emissions Impact of Soy- and Animal-based Biodiesel Fuels: A Re-Analysis* (December

2013). I have also studied the CARB Initial Statement of Reasons ("ISOR" or "Staff Report") released to support the proposed ADF regulation, and the studies cited in the ISOR that are pertinent to Mr. Crawford's analysis. The additional materials I have considered to prepare this Declaration are identified as references.

6. Mr. Crawford's report examines the empirical basis for the CARB staff's claims that the use of biodiesel in California is unlikely to warrant environmental mitigation, and that the use of biodiesel blends below the ten percent blend level (B10) in California pursuant to the proposed ADF regulation will not result in increases in NOx emissions.

7. Mr. Crawford's report applies generally accepted methods of data analysis and demonstrates expertise in the subject-matter of the report; Mr. Crawford is an expert in the field in which he opines in his report; and his report is the type of analysis on which experts in the field of automotive emissions control rely.

II. Analysis and Opinions

A. Increases in NOx Emissions from Biodiesel Blends Below B10

8. As explained in detail in Mr. Crawford's report, a proper statistical analysis of the available emissions data relied upon by CARB staff in developing the proposed ADF regulation demonstrates that statistically significant increases in NOx emissions will result from biodiesel blends that contain less than ten percent biodiesel, including at the five percent level (B5) and below. In addition, Mr. Crawford's report demonstrates that NOx emissions increase in direct proportion of the amount of biodiesel in a blend and there is not, as CARB staff claims, a "threshold" below which biodiesel use in a blend will not increase NOx emissions. Given this, as I explain below in more detail, CARB staff should be proposing a Significance Level of zero, rather than ten percent, for biodiesel. Given the issues identified with the CARB staff analysis of

biodiesel impacts on NOx emissions by Mr. Crawford, CARB has no credible scientific basis upon which to adopt the ADF regulation as proposed with the biodiesel Significance Level set at ten percent.

9. CARB staff presents, in Figures B.2 and B.3 of the ISOR, regressions of all the available emissions data considered by CARB staff in developing the proposed ADF regulation. Based on Mr. Crawford's findings, the slopes of these regression lines can be used to calculate the increases in NOx emissions expected from the use of soy- and animal-based biodiesel as a function of biodiesel content in the blend. The values calculated for soy- and animal-based biodiesel at selected blends levels over the range from one percent to twenty percent are shown in Table 1.

Table 1
Expected Increases In NOx Emissions from Biodiesel Use Based on Available Emissions Data Considered by CARB Staff

Biodiesel Blend Level %	Percentage Increase in NOx Emissions	
	Soy-Based	Animal-Based
1	0.2	0.09
2	0.4	0.18
3	0.6	0.27
4	0.8	0.36
5	1	0.45
10	2	0.90
20	4	1.80

10. As shown in Table 1, the magnitude of the NOx increase for animal-based biodiesel is approximately half that observed for soy-based biodiesel. As also shown in Table 1, the emissions data considered by CARB show that increases in NOx emissions between about one and two percent occur at the proposed B10 significance threshold.

B. The "Effective Blend Level" Concept Provides No Assurance Against Increases in NOx Emissions Due to Biodiesel Use

11. The proposed ADF regulation relies on a concept called the "Effective Blend Level" (EB) for biodiesel to determine when mitigation would be required. The formula proposed by CARB staff for calculating the Effective Blend Level for biodiesel is found in proposed Section 2293.6(a) and is reproduced below.

$$EB = 100 \times \left[\frac{NBV - 0.5LN - 0.73RD - VM - 0.55AB}{TCV}\right]$$

As specified in Section 2293.6(a), the above formula is to be used to compute an annual average statewide value for the Effective Blend Level relative to the total volume of fuel used in compression ignition engines excluding alternative fuels such as natural gas and liquefied petroleum gas ("TCV") in the state during that year.

12. The calculation begins with establishing the net volume of biodiesel of all types used in California *excluding biodiesel used in blends of five percent or less* (NBV) — a step that has no scientific basis, as demonstrated by Mr. Crawford's analysis, and that, on its own, completely invalidates the use of the EB metric for the intended purpose. The NBV value is then further reduced by subtracting 50% of the volume of low NOx Diesel (LN) used statewide and 73% of the volume of renewable Diesel used statewide. The remainder is then further reduced by subtracting the volume of biodiesel of all types used in blends where steps have been taken to voluntarily mitigate NOx increases (VM) and then again by subtracting 55% of the volume of animal-based biodiesel (AB) to account for the smaller magnitude of the NOx emission increases observed with that fuel.[1] The final value is then divided by TCV (i.e., the total volume of fuel

1 Those voluntary mitigation measures are assumed to have been taken before the so-called "Significance Level" is reached and mitigation would be required under the staff's proposal. *See* ¶ 13.

used in compression ignition engines excluding alternative fuels such as natural gas and liquefied petroleum gas in the state during that year) and multiplied by 100 to yield the Effective Blend Level on a percentage basis.

13. As specified in proposed Section 2293.5(c)(4), mitigation of NOx increases associated with biodiesel would be required only when the value of EB reaches 9.5 percent, which is 95% of the 10% Significance Level proposed for biodiesel.

14. There are a number of specific problems with the concept and calculation of the predicted Effective Blend Level that create the potential for significant increases in NOx emissions to result from the use of biodiesel in California; these are explained in detail below and should be addressed by CARB. As an initial matter, however, the overall problem with the EB concept will allow massive increases in the amount of biodiesel used in California without requiring any mitigation of the associated increase in NOx emissions. This can be seen readily by comparing CARB staff's projections of biodiesel use in California (Figure 6.2 of the ISOR) with CARB staff's projections regarding the Effective Blend Level for biodiesel (Figure 6.5 of the ISOR). Those two figures are reproduced below in Figure 1. As can been seen, despite the forecast nine-fold increase in annual biodiesel use in California from 50 million to 450 million gallons from 2013 to 2023 shown in Figure 6.2 of the ISOR, the forecast Effective Blend Level of biodiesel **decreases** to less than zero over virtually all of the period in question — meaning that, under the CARB staff's proposal, no mitigation of the increase in NOx emissions in California from biodiesel use will ever occur. CARB needs to confront and eliminate the EB concept from the staff's proposal, in light of this very simple demonstration of why the EB concept will not protect the environment against increases in NOx emissions.

Figure 1. CARB Biodiesel Forecasts

Figure 6.2: Statewide Biodiesel Volume

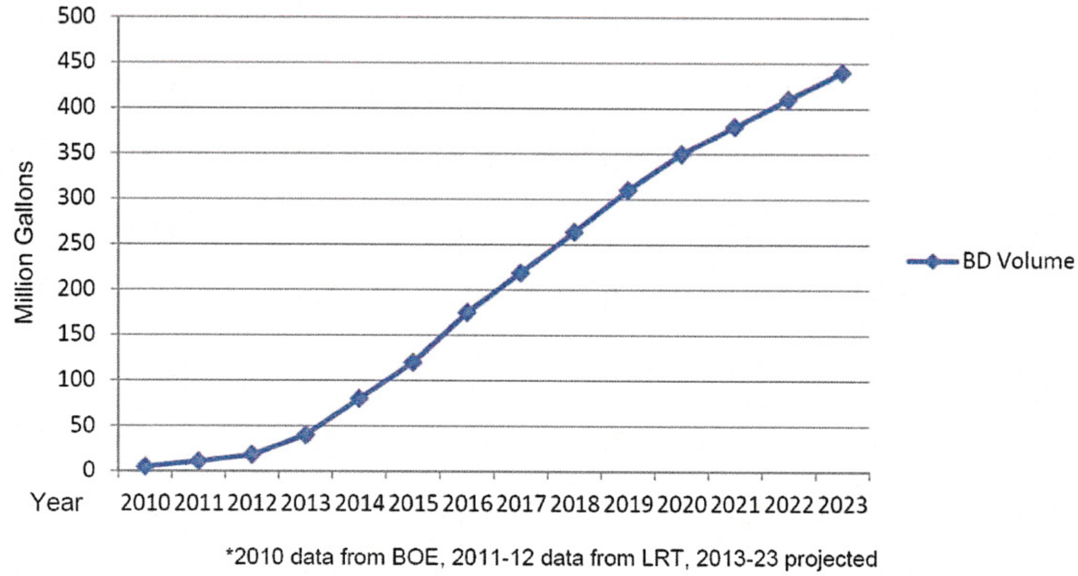
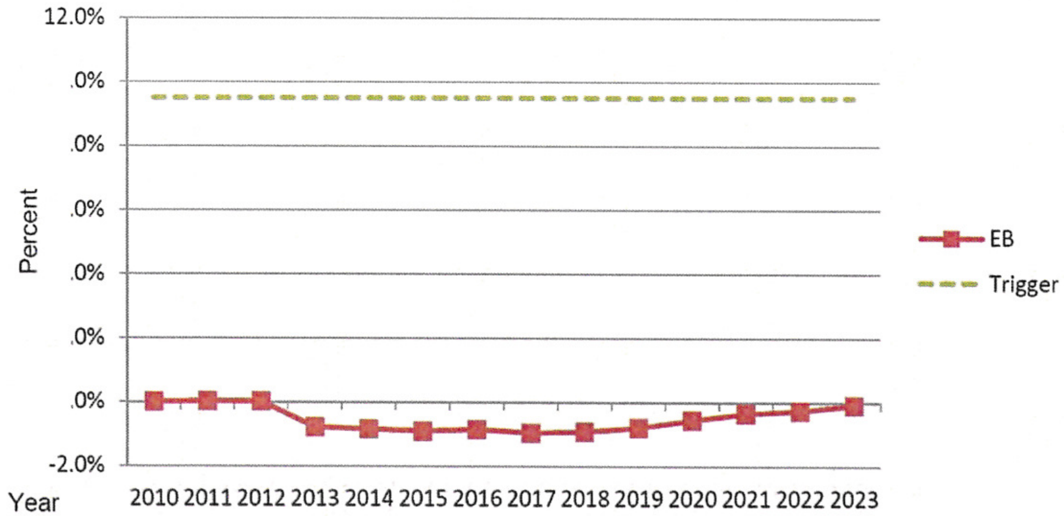


Figure 6.5: Effective Biodiesel Blend Level Forecast



Source: CARB Initial Statement of Reasons. Note that Figure 6.5 is reproduced directly from the ISOR, which is missing some increments on the y-axis.

15. Next, CARB needs to modify the proposed ADF regulation in order to address CARB staff's faulty assumption that biodiesel blends of up to five percent will have no impact on NOx emissions. With respect to five percent blends, CARB staff states on page ES-3 of the Staff

Report that "biodiesel used in blends at B9 or below, including the B5 (B0 to B5) in predominant use today, does not increase NOx." The Staff Report also attempts to justify the exclusion of five percent blends from the EB calculation by arbitrarily excluding these blends from the ADF regulation. That assertion is undercut by the Staff Report's frank and correct admission on page 51 that "[g]iven the significant price premium for higher biodiesel blends such as B20 or B100, it is highly unlikely that operators of heavy-duty, legacy diesel fleets would opt to use the more expensive, higher biodiesel blends when comparable, lower cost conventional CARB diesel or B5 blends are readily available."

16. As noted above, Mr. Crawford's analysis demonstrates that statistically significant increases in NOx emissions will occur from the use of five percent biodiesel blends and, as Table 1 shows, the available emissions data relied upon by CARB staff indicate that at the five percent blend level, biodiesel use is expected to increase NOx emission by between about 0.5 and one percent. There is no doubt that unmitigated NOx emission increases of this magnitude have the potential to create significant adverse environmental impacts in areas of California with severe air quality problems.

17. It is also important for CARB to understand the import of the staff's prediction that biodiesel blends of five percent or less will be the primary means by which biodiesel will be used in California. As the Staff Report states on page 30:

> Staff has communicated with many of the stations that sell biodiesel as well as the major terminal operators in the state, and has found that the vast majority of the biodiesel currently being sold in California and expected to be sold in the future is sold as blends of B5 or less.

The fact that most biodiesel used in California will be sold as blends of five percent biodiesel or less, coupled with the fact that – as Mr. Crawford has explained – the available data show statistically significant increases in NOx emissions from such blends, means that biodiesel use in

California under the proposed ADF regulation will result in unmitigated increases in NOx emissions. Again, the critical nature of the CARB staff's invalid assumption about the NOx impacts of blends at or below five percent simply cannot be ignored by CARB.

18. Even if it were correct that blends of B5 and less have no impact on NOx emissions, the EB calculation double-counts for the supposedly benign effect of those blends, and therefore makes mitigation even more unlikely. This can be illustrated by noting that CARB staff estimates that 450 million gallons per year of biodiesel will be used in California in 2023. (See Figure 6.2 of the Staff Report.) A recent California Energy Commission forecast[2] for total Diesel use in California in 2023 is about 4 billion gallons. On that basis, and without discounting for low NOx, renewable Diesel, or voluntary mitigation, the actual Effective Blend Level would be 11.25 percent and mitigation would be required for at least some biodiesel blends under the proposed ADF. Under CARB staff's approach, however, if a substantial portion of that biodiesel — for example, 50 percent — is five percent or lower blends, the Effective Blend Level drops to 5.6 percent and no mitigation of any kind is required for any biodiesel blends. That result is clearly incorrect, and the EB calculation must be modified to include, rather than exclude, B5 blends.

19. Another fundamental problem with the proposed EB calculation is that it is based on annual statewide average fuel use. NOx emissions have local and immediate impacts on air quality, with the questions of when and where they occur in the state being of critical importance with respect to the significance of those impacts. It follows directly that mitigation of NOx increases associated with biodiesel use must occur in the same area at the same time if air quality

[2] See *http://www.energy.ca.gov/2011publications/CEC-600-2011-007/CEC-600-2011-007-SD.pdf*.

impacts are to be avoided. However, the EB completely fails to provide this assurance because CARB staff has either (1) ignored that reductions in NOx emissions from mitigation must take place at the same time and in the same area as NOx increases from biodiesel use, or (2) without support from anything in the rulemaking file, assumed that mitigation will occur in the same area and at the same time as the increases in NOx emissions.

20. To illustrate the problems the EB creates for mitigation, consider, for example, that under the proposed ADF regulation, increases in NOx emissions could occur from trucks operating on biodiesel in Los Angeles during August and exacerbate already high ambient ozone levels in that area. In turn, this increase in NOx emissions could be "mitigated" by reductions in NOx emissions from trucks operating on renewable diesel in the San Francisco area during December, when high ozone levels are not a problem. In this example, the EB concept would allow residents of Los Angeles to suffer adverse environmental impacts while the residents of San Francisco would realize no environmental benefit. Clearly the approach to mitigation designed into the EB concept by CARB staff makes no sense.

C. CARB Staff's Assumption that Biodiesel Use Will not Increase Emissions from New Technology Diesel Engines Is Not Adequately Supported

21. In the Staff Report, CARB staff makes frequent statements regarding the impact of biodiesel on NOx emissions from "new technology diesel engines" (or "NTDEs"). For example, on page ES-3 of the ISOR, the staff states categorically that "use of biodiesel in 2010-compliant engines and other so-called 'New Technology Diesel Engines' does not increase NOx, regardless of the biodiesel blend level." Only one reference, Lammert et al.,[3] is provided in the staff report

[3] Lammert, M., McCormick, R., Sindler, P. and Williams, A., "Effect of B20 and Low Aromatic Diesel on Transit Bus NOx Emissions Over Driving Cycles with a Range of Kinetic Intensity," *SAE Int. J. Fuels Lubr.* 5(3):2012,

(Continued...)

to support this and other, analogous, statements by CARB staff. As CARB staff acknowledges, this single study involved chassis dynamometer testing of only two urban buses with NTDEs, with both engines being the same model produced by the same manufacturer. The extrapolation of that limited testing to the entire population of heavy-duty Diesel vehicles with NTDEs used in different applications and with different engine designs produced by a number of different manufacturers is simply not credible or reliable.

22. In addition, the CARB staff fails to acknowledge the following statement made by the authors of the Lammert study about the measurement of NOx emissions: "For much of the cycle[,] NOx would be at or near the detection limit of the laboratory equipment which resulted in a 95 percent confidence interval that was high relative to the value of the cycle emissions." That effect, which can be clearly seen in Figures 10 and 11 of the Lammert study, renders the claim that there was no statistically significant increase in NOx emissions observed from the use of biodiesel in NTDEs an artifact attributable to the lack of sensitivity of the NOx measurement instrumentation used in the study.

23. In sum, the CARB staff's unequivocal statements regarding the impact of biodiesel on NOx emissions from all vehicles with NTDEs is simply not reasonable based on data from (1) a single study that (2) that tested only two urban buses equipped with the same engine and (3) used instrumentation that was, at best, barely able to measure NOx emissions from the test vehicles in general, and clearly was not sensitive enough to reliably detect changes in NOx emissions due to use of different fuels. Nothing else in the rulemaking file supports the CARB staff's claim that there will not be increased NOx emissions from the use of biodiesel in NTDEs.

I declare under penalty of perjury under the laws of California that the foregoing is true and correct to the best of my knowledge and belief.

Executed this __12th__ day of December 2013 at Sacramento, California.

James M. Lyons

ATTACHMENT A

ATTACHMENT A

sierra
research

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Résumé

James Michael Lyons

Education

1985, M.S., Chemical Engineering, University of California, Los Angeles

1983, B.S., Cum Laude, Chemistry, University of California, Irvine

Professional Experience

4/91 to present — Senior Engineer/Partner/Senior Partner
Sierra Research

Primary responsibilities include oversight and execution of complex analyses of the emission benefits, costs, and cost-effectiveness of mobile source air pollution control measures. Mr. Lyons has developed particular expertise with respect to the assessment of control measures involving fuel reformulation, fuel additives, and alternative fuels, as well as accelerated vehicle/engine retirement programs, the deployment of advanced emission control systems for on- and non-road gasoline- and Diesel-powered engines, on-vehicle evaporative and refueling emission control systems, and Stage I and Stage II service station vapor recovery systems. Additional duties include assessments of the activities of federal, state, and local regulatory agencies with respect to motor vehicle emissions and reports to clients regarding those activities. Mr. Lyons has extensive litigation experience related to air quality regulations, product liability, and intellectual property issues.

7/89 to 4/91 — Senior Air Pollution Specialist
California Air Resources Board

Supervised a staff of four professionals responsible for identifying and controlling emissions of toxic air contaminants from mobile sources and determining the effects of compositional changes to gasoline and diesel fuel on emissions of regulated and unregulated pollutants. Other responsibilities included development of new test procedures and emission standards for evaporative and running loss emissions of hydrocarbons from vehicles; overseeing the development of the state plan to control toxic emissions from motor vehicles; and reducing emissions of CFCs from motor vehicles.

4/89 to 7/89 — Air Pollution Research Specialist, California Air Resources Board

Responsibilities included identification of motor vehicle research needs; writing requests for proposals; preparation of technical papers and reports; as well as monitoring and overseeing research programs.

9/85 to 4/89 — Associate Engineer/Engineer, California Air Resources Board

Duties included analysis of vehicle emissions data for trends and determining the effectiveness of various types of emissions control systems for both regulated and toxic emissions; determining the impact of gasoline and diesel powered vehicles on ambient levels of toxic air contaminants; participation in the development of regulations for "gray market" vehicles; and preparation of technical papers and reports.

Professional Affiliations

American Chemical Society
Society of Automotive Engineers

Selected Publications (Author or Co-Author)

"Review of CARB Staff Analysis of 'Illustrative' Low Carbon Fuel Standard (LCFS) Compliance Scenarios," Sierra Research Report No. SR2012-02-01, prepared for the Western States Petroleum Association, February 20, 2012.

"Review of CARB On-Road Heavy-Duty Diesel Emissions Inventory," Sierra Research Report No. SR2010-11-01, prepared for The Ad Hoc Working Group, November 2010.

"Identification and Review of State/Federal Legislative and Regulatory Changes Required for the Introduction of New Transportation Fuels," Sierra Research Report No. SR2010-08-01, prepared for the American Petroleum Institute, August 2010.

"Technical Review of EPA Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis for Non-GHG Pollutants," Sierra Research Report No. SR2010-05-01, prepared for the American Petroleum Institute, May 2010.

"Effects of Gas Composition on Emissions from Heavy-Duty Natural Gas Engines," Sierra Research Report No. SR2010-02-01, prepared for the Southern California Gas Company, February 2010.

"Effects of Gas Composition on Emissions from a Light-Duty Natural Gas Vehicle," Sierra Research Report No. SR2009-11-01, prepared for the Southern California Gas Company, November 2009.

"Technical Review of 2009 EPA Draft Regulatory Impact Analysis for Non-GHG Pollutants Due to Changes to the Renewable Fuel Standard," Sierra Research Report No. SR2009-09-01, prepared for the American Petroleum Institute, September 2009.

"Effects of Vapor Pressure, Oxygen Content, and Temperature on CO Exhaust Emissions," Sierra Research Report No. 2009-05-03, prepared for the Coordinating Research Council, May 2009.

"Technical Review of 2007 EPA Regulatory Impact Analysis Methodology for the Renewable Fuels Standard," Sierra Research Report No. 2008-09-02, prepared for the American Petroleum Institute, September 2008.

"Impacts of MMT Use in Unleaded Gasoline on Engines, Emission Control Systems, and Emissions," Sierra Research Report No. 2008-08-01, prepared for McMillan Binch Mendelsohn LLP, Canadian Vehicle Manufacturers' Association, and Association of International Automobile Manufacturers of Canada, August 2008.

"Attachment to Comments Regarding the NHTSA Proposal for Average Fuel Economy Standards Passenger Cars and Light Trucks Model Years 2011-2015, Docket No. NHTSA-2008-0089," Sierra Research Report No. SR2008-06-01, prepared for the Alliance of Automobile Manufacturers, June 2008.

"Evaluation of California Greenhouse Gas Standards and Federal Energy Independence and Security Act – Part 1: Impacts on New Vehicle Fuel Economy," SAE Paper No. 2008-01-1852, Society of Automotive Engineers, 2008.

"Basic Analysis of the Cost and Long-Term Impact of the Energy Independence and Security Act Fuel Economy Standards," Sierra Research Report No. SR 2008-04-01, April 2008.

"The Benefits of Reducing Fuel Consumption and Greenhouse Gas Emissions from Light-Duty Vehicles," SAE Paper No. 2008-01-0684, Society of Automotive Engineers, 2008.

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"Summary of Federal and California Subsidies for Alternative Fuels," Sierra Research Report No. SR2007-04-02, prepared for the Western States Petroleum Association, April 2007.

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EXHIBIT C

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September 16, 2013

By Electronic Mail

Alexander Mitchell
Floyd Vergara
California Air Resources Board
Stationary Source Division
1001 I Street
Sacramento, California 95812

Re: Comments Regarding CARB's Alternative Diesel Fuels Rulemaking

Dear Sirs:

Growth Energy, an organization of ethanol producers and supporters, has a number of concerns with the Alternative Diesel Fuels (ADF) Regulations currently under development by the staff of the California Air Resources Board (CARB) which were the subject of a September 5th workshop held in Sacramento. These concerns, which are described in detail below, focus on the treatment of biodiesel and biodiesel blends currently being proposed by CARB staff. Overall, the provisions of the proposed ADF regulations would allow for the widespread use of biodiesel and biodiesel blends in California without adequately mitigating the resulting increases in emissions of oxides of nitrogen (NOx). The treatment being proposed by CARB staff for biodiesel and biodiesel blends is unacceptable in that it will result in adverse air quality impacts and violates several of the "underlying principles" in the February 15, 2013, CARB White Paper concerning its conceptual approach to the regulation of alternative diesel fuels, including:[1]

1. Protection of public health;
2. Preservation or improvement of air quality; and
3. Reliance on the best scientific knowledge available.

Given the above, Growth Energy urges CARB staff to revise the proposed ADF regulations to eliminate the potential for biodiesel use in California to result in increased emissions, degraded air quality and adverse impacts on public health.

[1] See page 3 of CARB's White Paper "Discussion of Conceptual Approach to Regulation of Alternative Diesel Fuels", February 15, 2013 which is available at http://www.arb.ca.gov/fuels/diesel/altdiesel/20130212ADFRegConcept.pdf

1. The Proposed ADF Regulation Incorrectly Ignores Increases in NOx Emissions Associated with Use of Biodiesel Blends

As currently drafted, the proposed ADF regulation fails to require any mitigation for increases in NOx emissions associated with the use of biodiesel until total biodiesel usage in the state amounts to at least 10% of all fuel used in diesel engines in California on an annual basis.[2] While the potential for increased NOx emissions due to this arbitrarily established "significance level" for biodiesel use is discussed in Section 2 below, its basic premise appears to be an assumption that there are no NOx emissions associated with the use of biodiesel blends at or below the B10 level. In support of the inaccurate assumption that there is some threshold level below which biodiesel use will not increase emissions, CARB cites its White Paper, which states:[1]

> *Furthermore, for purposes of this rulemaking B5 blends will be considered a legal California diesel fuel with no emissions mitigation required.*

This arbitrary threshold is not supported by any data or analysis, and we are unaware of any published analysis of emissions test data that supports the assumptions that there are no increases in NOx emissions at either the B5 or up to the B10 levels.

In contrast, a preliminary analysis of data from CARB's most recently funded biodiesel testing program[3] demonstrates that NOx emissions would increase significantly at the B5 and B10 levels in at least some engines and for some biodiesel types. Here, the term "significant" means both that the NOx increase is statistically significant and that it is large enough to be of concern. Although the fact that CARB has not made all of the emissions data from this testing program publically available makes analysis difficult, results of a preliminary analysis are shown in Table 1 below for a 2006 model-year Cummins heavy-duty diesel engine. As shown, the relationship between increasing biodiesel content and increased NOx emissions is statistically significant at the 95% confidence level in all cases for soy-based biodiesel and at the 90% confidence level or better for animal-based biodiesel.

Further, the R^2 statistics for soy-based fuels show that the emissions effect of biodiesel is almost perfectly linear with increasing biodiesel content. Although not as high because the emissions effect is smaller and measurement errors are relatively larger in comparison to the trend, the R^2 statistics for the animal-based fuels also clearly establish a linear increase in NOx emissions with increasing biodiesel content. Because the slope or the regression equations are statistically significant in all cases and the R^2 statistics are high, there is no evidence in the data for the Cummins engine of the "threshold effect" that CARB staff claims which purports that biodiesel content has to reach the B5 or B10 level before NOx emissions begin to increase.

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[2] See slide 18 of the staff presentation for the September 5th workshop which is available at http://www.arb.ca.gov/fuels/diesel/altdiesel/20130905ADFWorkshopPresentation.pdf

[3] Available at http://www.arb.ca.gov/fuels/diesel/altdiesel/20111013_CARB%20Final%20Biodiesel%20Report.pdf

PRELIMINARY ANALYSIS SUBJECT TO REVISON

Table 1. 2006 Cummins Engine (Dynamometer Testing)

Model: NOx = A + B · BioPct

(Note: Dataset does not yet include the data on B5.)

Bright yellow highlight indicates result is statistically significant at 95% confidence level or better.
Light yellow highlight indicates result is statistically significant at the 90% confidence level or better.

Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	% Change	Pct Change
Soy-based							
	UDDS	0.997	5.896	0.0100	0.001	0.8%	1.7%
	FTP	0.995	2.024	0.0052	0.003	1.3%	2.6%
	40 mph	1.000	2.030	0.0037	<0.0001	0.9%	1.8%
	50 mph	0.969	1.733	0.0028	0.016	0.8%	1.6%
Animal-based							
	UDDS	0.847	5.911	0.0021	0.080	0.2%	0.4%
	FTP	0.981	2.067	0.0031	0.001	0.7%	1.4%
	50 mph	0.887	1.768	0.0011	0.058	0.3%	0.6%

Turning to the importance of the magnitude of the NOx increases, the South Coast Air Quality Management District (SCAQMD) Final 2012 Air Quality Management Plan estimates 2014 NOx emissions from on-road and non-road diesel vehicles to be approximately 190 tons per day.[4] This means that the approximately 1% increase in NOx emissions due to B5 blends translates to an increase of about 2 tons per day in NOx emissions in the South Coast Air Basin alone, while an approximately 2% increase at B10 equals 4 tons per day within that basin. Continuing to B20 the impact would be 8 tons per day. That these are significant increases is clearly evidenced by the fact that both CARB and SCAQMD have adopted numerous emission control measures targeting NOx that have achieved reductions that are similar to or smaller than these values.

Instead of acknowledging emissions testing data CARB itself generated that show increases in NOx emissions associated with B5 and B10 blends, CARB staff instead claims that more research is necessary before it can consider mitigation of B5 impacts: [5]

> *Staff is currently contracting with the University of California at Riverside to develop data to determine whether there are significant adverse air-related impacts from the use of B5 blends sufficient to warrant mitigation in the future.*

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[4] See Figure 3-9 available at http://www.aqmd.gov/aqmp/2012aqmp/Final-February2013/MainDoc.pdf

[5] See page 4 of CARB's White Paper "Discussion of Conceptual Approach to Regulation of Alternative Diesel Fuels", February 15, 2013 which is available at http://www.arb.ca.gov/fuels/diesel/altdiesel/20130212ADFRegConcept.pdf

This represents an impermissible deferral of analysis and mitigation of significant impacts under CEQA. Moreover, as participants in the process that lead to the adoption of CARB's Low Carbon Fuel Standard (LCFS) regulation in 2009 where CARB adopted indirect land use change (ILUC) values based on preliminary and unsubstantiated modeling results claiming a need to rely on the best available science, Growth Energy finds CARB staff's current position that ignores actual data showing NOx increases from low level biodiesel blends to be unsupported.

2. The Proposed "Significance Threshold" for Biodiesel would Allow Significant Increases in NOx Emissions to Occur in the South Coast and San Joaquin Valley Air Basins Exacerbating Existing Air Quality Problems

In addition to CARB staff's failure to analyze low-level biodiesel blends, the "significance threshold" proposed by CARB staff for biodiesel use in California would allow significant increases in NOx emissions due to biodiesel use to occur in the South Coast and San Joaquin Valley air basins that experience the worst air quality problems in the state.

According to CARB staff's presentation for the September workshop,[6] staff is proposing to evaluate the significance of NOx increases due to biodiesel use on a statewide rather than a regional basis. Given the proposed use of a statewide average biodiesel level and the B10 significance threshold, the potential exists for significant quantities of B20 or even higher levels of biodiesel blends to be used without mitigation in areas of the state with significant air quality problems, such as the South Coast and/or San Joaquin Valley air basins. At this point, even CARB staff acknowledges that use of B20 blends results in significant NOx increases and as noted above based on CARB's own test data B20 use in the South Coast Air Basin could increase NOx emissions by as much as 8 tons per day in 2014.

Given the severe air quality problems that exist in the South Coast and San Joaquin Valley air basins, CARB must modify the proposed ADF regulation so that it guarantees that increased NOx emissions related to biodiesel use would not occur in these areas. The reduction of NOx emissions is important, particularly in light of CARB's "Vision for Clean Air,"[7] which demands the elimination of NOx emissions from diesel engines in both air basins as a perquisite for achieving the state's air quality goals.

3. The Proposed Transfer of Credit for Reductions in NOx Emissions Generated by Low NOx Diesel Producers to Offset Increases in NOx Emissions Generated by Biodiesel Producers is Not Equitable

[6] See slide 18 of the staff presentation for the September 5th workshop which is available at http://www.arb.ca.gov/fuels/diesel/altdiesel/20130905ADFWorkshopPresentation.pdf

[7] See http://www.arb.ca.gov/planning/vision/docs/vision_for_clean_air_public_review_draft.pdf

According to CARB staff's presentation at the September workshop,[8] staff is proposing to directly offset increases in NOx emissions resulting from the use of biodiesel with reductions in emissions due to the use of "low NOx" diesel fuels, which are defined by specific properties as shown in the staff presentation for the September 5th workshop.[9] To date, however, we are unaware of any information or explanation from CARB staff as to why producers of low NOx diesel fuels should be forced by CARB regulations to surrender credit for the NOx emission reductions their fuels achieve in order to benefit the producers of biodiesel fuels which increase NOx emissions.

Given that the production of low NOx diesel fuel is not currently mandated by any existing CARB regulation, the resulting emission benefits should be considered "surplus," and could presumably be used to generate Mobile Source Emission Reduction Credits under CARB regulations.[10] Further, the use of such fuels by fleets or distribution of such fuels by fuel providers could potentially be considered to be projects that qualify for incentive funding under the Carl Moyer Program.[11]

Instead of forcing producers of low NOx diesel fuels to transfer the credit for the NOx reductions attributable to their products without compensation to producers of biodiesel fuels that increase NOx emissions, CARB should establish a market mechanism to incentivize the production of low NOx fuels and to disincentivize the production of NOx-increasing biodiesel fuels. The most logical approach to accomplish this would seem to be providing NOx reduction credits to producers of low NOx fuels under the LCFS regulation while assigning NOx emission debits to producers of biodiesel and then requiring the latter to purchase and surrender credits sufficient to offset the increases in NOx emissions associated with their products.

4. The Proposed Treatment of Biodiesel and Biodiesel Blends Used in "New Technology Diesel Engines" (NTDEs) is Not Equitable With CARB's Treatment of Other Fuels

In addition to defects with the proposed ADF regulations described above, we are unaware of any published analysis or supporting data that the use of biodiesel at any concentration in NTDE's would not result in increased NOx emissions. The rationale for this treatment appears to be an assumption that the advanced emission control systems found on NTDEs eliminate any impact of fuel composition on emissions of NOx and potentially other pollutants.

Our primary concern with this proposal is that CARB staff has not provided any supporting data or analysis. In addition, if NTDEs are truly insensitive to fuel composition impacts, CARB should make changes similar to those proposed by biodiesel for other fuels. More specifically, if CARB staff's assumption that NTDE emissions are not sensitive to fuel composition is in fact correct, it follows that there is no longer any need to use CARB diesel fuel in NTDEs instead of less expensive federal diesel fuels which could be substituted without any adverse emission impacts.

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[8] See slide 19 of the staff presentation for the September 5th workshop which is available at http://www.arb.ca.gov/fuels/diesel/altdiesel/20130905ADFWorkshopPresentation.pdf

[9] See slide 24 of the staff presentation for the September 5th workshop which is available at http://www.arb.ca.gov/fuels/diesel/altdiesel/20130905ADFWorkshopPresentation.pdf

[10] See http://www.arb.ca.gov/msprog/mserc/mserc.htm

[11] See http://www.arb.ca.gov/msprog/moyer/moyer.htm

Clearly, CARB could develop a "significance threshold" for the sale of federal diesel fuel in California similar to that proposed for biodiesel which would achieve this objective while providing the benefit of reduced diesel costs without adverse air quality impacts. Growth Energy therefore encourages CARB staff to revise the ADF to avoid these impacts.

Sincerely,

David Bearden

David Bearden
General Counsel

OTHER EXHIBITS

Public Review Draft
June 27, 2012

Vision for Clean Air: A Framework for Air Quality and Climate Planning

This document has been prepared by the staffs of the California Air Resources Board, the South Coast Air Quality Management District and the San Joaquin Valley Unified Air Pollution Control District. Publication does not signify that the contents reflect the views and policies of the Air Resources Board, the South Coast Air Quality Management District or the San Joaquin Valley Unified Air Pollution Control District. This document will be presented as an informational item at a noticed public meeting scheduled for June 28, 2012.

Table of Contents

Executive Summary

As California plans for the future, transformational technologies, cleaner energy, and greater efficiency are expected to provide the foundation for meeting air quality standards and climate goals. California's success in reducing smog has largely relied on technology and fuel advances, and as health-based air quality standards are tightened, the introduction of cleaner technologies must keep pace. More broadly, a transition to zero- and near-zero emission technologies is necessary to meet 2023 and 2032 air quality standards and 2050 climate goals. Many of the same technologies will address both air quality and climate needs. As such, strategies developed for air quality and climate change planning should be coordinated to make the most efficient use of limited resources and the time needed to develop cleaner technologies.

Vision for Clean Air: A Framework for Air Quality and Climate Planning takes a coordinated look at strategies to meet California's multiple air quality and climate goals well into the future. Its quantitative demonstration of the needed technology and energy transformation provides a foundation for future integrated air quality and climate program development. *Vision for Clean Air* focuses on mobile sources and associated energy production. Similar analyses will be necessary for industrial and other emission sources to develop a complete foundation for integrated planning.

Recognizing that the severity of California's air quality problems varies by region, *Vision for Clean Air* examines what is needed to attain air quality standards by the federal deadlines in the areas with the worst air quality -- the South Coast Air Basin and the San Joaquin Valley Air Basin. However, the technologies and strategies identified will pay clean air dividends for all air districts, helping them achieve or maintain federal air quality standards and reduce local air toxics exposure.

Ozone and Climate Planning Horizons

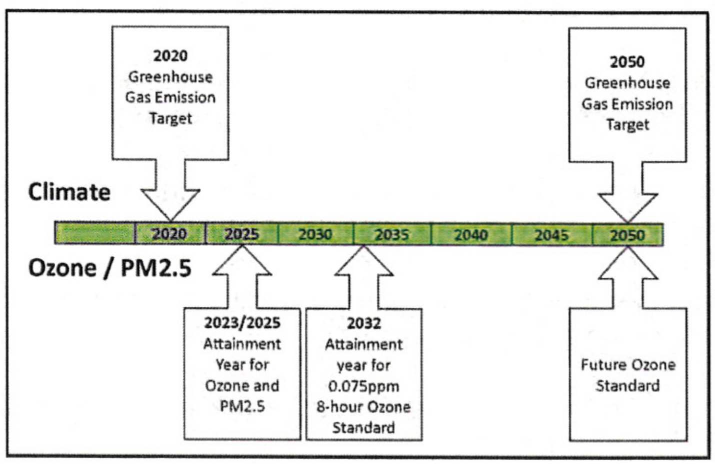

Figure 1

Achieving the 2020 greenhouse gas emission target established by the Global Warming Solutions Act of 2006 (AB 32) is a statewide goal. For the long term, California has set for itself the 2050 goal of greenhouse gas emissions of 80 percent less than 1990 levels overall, and specifically 80 percent less than 1990 levels for the transportation sector.[1] In 2013, the

[1] Governor Brown Executive Order B-16-2012

AB 32 Scoping Plan will be updated to address post-2020 greenhouse gas emissions.

In 2009, the Air Resources Board (ARB), the South Coast Air Quality Management District (SCAQMD) and the San Joaquin Valley Air Pollution Control District (SJVAPCD) developed a partnership with the U.S. Environmental Protection Agency (U.S. EPA) to promote technology advancements needed to meet air quality standards by federal deadlines. In *Vision for Clean Air,* ARB and the South Coast and San Joaquin Valley air districts examine how those technologies can meet both air quality and climate goals over time.

California's deadlines for meeting federal air quality standards extend past 2020, and U.S. EPA recently announced that the deadline for the updated ozone standard will be 2032.[2] Since scientific studies continue to document health impacts of air pollution at progressively lower levels, air quality standards are periodically revised, becoming more stringent over time. Broad deployment of zero- and near-zero emission technologies in the South Coast and San Joaquin Valley air basins will be needed in the 2023 to 2032 timeframe to attain current national health-based air quality standards as required by federal law.

For greenhouse gases, California's 2050 climate goal provides an ambitious long-term target. Many strategies developed to meet the shorter-term air quality standards — notably use of cleaner energy sources — will have benefits toward the longer-term climate goal. Pursuing cleaner energy sources is also the focus of the State's energy policies, providing the opportunity for economic, as well as environmental benefits. Coordinated planning with identified milestones will support the transition to zero-and near-zero emission technologies needed to meet these goals.

To explore the scope of technology advancements needed to meet air quality and climate goals, several key questions are posed:

- What technologies, fuels, and other strategies are needed to meet local air quality and greenhouse gas goals? Are they the same?
- What are the implications of federal air quality deadlines coming 20 to 30 years before the 2050 greenhouse gas goal?
- How can the strategies to meet local air quality targets and greenhouse gas goals best complement each other?
- What are the energy infrastructure demands of coordinated air quality and greenhouse gas strategies?

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[2] *Vision for Clean Air* uses 2035 as the target date for the updated ozone standard. After the analytical effort for *Vision for Clean Air* began, U.S. EPA formally set the attainment deadline at 2032.

- How do California's air quality and climate policies need to adapt as emissions move from the vehicle itself to predominantly upstream sources such as electricity and hydrogen or equivalent generation facilities?

Quantitative scenarios were developed for key transportation-related sectors to gain insight into the key questions above. The sectors that are the focus of this report are by far the largest contributors to greenhouse gas emissions and regional air pollution in California. Greenhouse gas emission reduction goals are statewide and the scenarios use a lifecycle emissions analysis approach. The analysis of smog-forming pollutants is regional, reflecting the need to meet air quality standards on that basis. The localized impacts of toxic diesel particulate matter are recognized, and play an important role when evaluating the passenger and freight transport systems. Reducing emissions in these mobile source sectors is key to attaining air quality and climate goals, but does not represent all of the emission reductions needed for individual regions to demonstrate attainment of federal air quality standards. Comprehensive attainment strategies containing both mobile and stationary source measures will be developed as individual regions develop new air quality plans.

The scenarios illustrate the nature of the technology transformation needed to meet the multiple program milestones through 2050. The scenarios highlight the interplay between reducing smog-forming pollutants and greenhouse gases. The scenario results demonstrate the importance of considering the multi-pollutant impacts of policy choices. Planning efforts, public investment, and rulemaking decisions by State, federal, and local agencies will play an important role in the outcome. In making these decisions, agencies will need to consider factors including technical feasibility and cost, downstream and upstream emission reduction potential, energy production capacity and infrastructure, and the necessary pace of transformation needed to meet air quality and climate goals.

In designing the scenarios, it was necessary to make general assumptions about future growth, the pace of introduction of various technologies, and other factors. It is recognized that the scenarios contained herein are not the only pathways to meet air quality and climate goals. Thus, the scenarios are not refined analyses that would be directly used for program development, but will provide input into future planning efforts by air quality agencies. Similarly, economic and environmental analyses are steps that need to be done in future plans.

An update to the AB 32 Scoping Plan is due in 2013. State Implementation Plans (SIPs) to meet the federal particulate matter air quality standards in the South Coast and the San Joaquin Valley are due later this year and major ozone SIPs for the recently updated federal ozone standard will be due in 2015. More detailed analyses will begin to emerge as part of these efforts.

Achieving California's Air Quality and Climate Goals

The federal Clean Air Act requires states to identify the reductions of smog-forming emissions necessary to meet each federal air quality standard. Also under the federal planning process, states must identify the actions needed to bring emissions down to the attainment levels by the required deadlines. These two parts of a state's SIP comprise the attainment demonstration. Federal rules set out detailed procedures, technical requirements, and public processes for the development of attainment demonstrations. As mentioned earlier, the scenarios in *Vision for Clean Air* are not intended to be attainment demonstrations within the meaning of the Clean Air Act, but they do serve to illustrate the scale of technology change needed to meet the federal standards in 2023 and beyond. The federal Clean Air Act specifically recognizes the need for advanced technologies in attainment demonstrations for extreme ozone nonattainment areas. The South Coast and San Joaquin Valley air basins are the only two extreme ozone areas in the nation.

> ***Meeting Federal Ozone Standards***
>
> **For the South Coast Air Basin, it is estimated that oxides of nitrogen, one of the key ingredients in ozone and fine particulate formation, must be reduced by around 80 percent from 2010 levels by 2023, and almost 90 percent by 2032. Similar levels of emissions reductions are likely needed in the San Joaquin Valley by 2032.**

The federally approved SIPs for these two regions rely on a mix of currently available technologies and the development of advanced technologies in order to attain the ozone air quality standard by 2023. Reaching the longer-term 2032 ozone air quality standard and the 2050 climate goal requires even greater transformation. This includes, for example, nearly complete transformation of passenger vehicles to zero-emission technologies, approximately 80 percent of the truck fleet to zero-or near-zero technology, and nearly all locomotives operating in the South Coast air basin to be using some form of zero-emission technology.

> ***Meeting Climate Change Goals***
>
> **To meet the goal of reducing California's greenhouse gas emissions to 1990 levels by 2050, emissions must be reduced by 85 percent from today's levels.**

The Global Warming Solutions Act of 2006 set the 2020 greenhouse gas emissions reduction goal into law. It directed ARB to develop early actions to reduce greenhouse gases while also preparing a Scoping Plan to identify how best to reach the 2020 limit. The State's goal to further reduce greenhouse gases by 2050 was first established when Governor Schwarzenegger signed Executive Order S-3-05 in 2005. In March 2012, Governor Brown issued Executive Order B-16-2012 setting a California target for reductions of greenhouse gas emissions from the transportation sector of 80 percent less than 1990 levels by 2050 and calling for the establishment of benchmarks for the penetration of zero-emission vehicles and infrastructure for 2015, 2020, and 2025.

Coordinated Air Quality and Climate Planning

The *Vision for Clean Air* scenarios illustrate seven key concepts that together provide a foundation for coordinated solutions to California's air quality and climate goals.

- **Technology Transformation:** Transformation to advanced, zero-and near-zero emission technologies, renewable clean fuels, and greater efficiency that can achieve both federal air quality standards and climate goals.
- **Early Action:** Acceleration of the pace of transformation to meet federal air quality standard deadlines, with early actions to develop and deploy zero- and near-zero technologies also needed to meet climate goals.
- **Cleaner Combustion:** Advanced technology NOx emissions standards for on- and off-road heavy-duty engines beyond the cleanest available today to meet federal air quality standards in a timely manner.
- **Multiple Strategies:** A combination of strategies — technology, energy, and efficiency — applied to each sector.
- **Federal Action:** Federal actions, in addition to actions by state and local agencies and governments, to help clean-up sources that travel nationally and internationally such as trucks, ships, locomotives and aircraft.
- **Efficiency Gains:** Greater system and operational efficiencies to mitigate the impacts of growth, especially in high-growth freight transport sectors and vehicle efficiency gains to reduce fuel usage and mitigate the cost of new technologies.
- **Energy Transformation:** Transformation of the upstream energy sector and its greenhouse gas and smog forming emissions concurrent with the transformation to advanced technologies downstream.

Development of coordinated solutions to California's air quality and climate goals will require the efforts of multiple agencies at all levels of government. The solutions span all sectors, rely on the development of multiple technologies, and require the coordinated deployment of technologies and energy infrastructure. ARB has the role of setting technology-forcing standards for mobile sources that have been the distinguishing feature of the State's air quality progress and climate leadership. Action by the federal government, for trucks, locomotives, aircraft, and ships, is also critical. Finally, transformation of the energy sector will require multiple agencies, including the California Energy Commission, the Public Utilities Commission, ARB, and local air districts, to share a common vision.

The SCAQMD, SJVAPCD, and other local air districts play a key role through actions to accelerate the use of new, cleaner mobile technologies at the regional level to improve air quality and meet federal air quality standards. While *Vision for Clean Air* focuses on the mobile sectors and the energy system to power them, attainment of the federal air quality standards will also require similar transformation of traditional stationary sources covered through SIP planning. Air districts will need to continue their actions to reduce emissions from these sources in order to meet federal requirements. Metropolitan planning organizations, port authorities, and local governments will also play important roles in the overall pollution control strategies.

Private sector activities will be key to developing the technology, building the engines, and implementing the necessary transformation. Engine and vehicle manufacturers will need to continue the development and marketing of advanced technologies. Energy industries will need to supply the renewable fuels and energy, including the necessary infrastructure. In the freight transport industries, increased efficiencies that support growth while mitigating environmental impacts will be essential. Both public and private investment will be needed to enable the technology transformation necessary to achieve California's air quality and climate goals.

Vision for Clean Air lays the foundation for an integrated approach to develop and deploy the cleanest emissions control technologies. For many of the sectors discussed, zero- and near-zero emission technologies have been developed or anticipated to be developed over the next few years. *Vision for Clean Air* provides a timeline for coordinated development and accelerated deployment of the types of technologies expected to be needed in each of the sectors.

Vision for Clean Air is being released as a draft document for discussion at a public meeting in June 2012 and at public workshops in August. The document sets the stage for subsequent planning efforts through scenarios designed to illustrate the scope of change needed to meet federal air quality standards and California's climate goals. The scenarios presented are not intended to identify a specific course of action to meet each air quality and climate goal. Nor are the scenarios a prediction of the actual mix of vehicle technologies, fuels, and clean energy sources expected to emerge in the long term. Public and private investment, regulatory decisions, and consumer preferences will all affect the success of specific strategies and options to meet these ambitious goals.

An Approach for Integrating Air Quality and Climate Planning

The federally approved 2007 State Implementation Plans for the South Coast Air Basin and the San Joaquin Valley Air Basin call for broad use of advanced technologies, clean energy, and greater efficiencies to provide the foundation for meeting federal air quality standards. The 2008 Scoping Plan, required by California's Global Warming Solutions Act of 2006, similarly called for a statewide transition to clean energy and advanced technologies and outlined actions toward that end. To understand the interplay among strategies to meet air quality and climate goals, and to develop common and effective solutions to both, basic questions need to be answered. These include:

Crosscutting Issues

Figure 2

- What technologies, fuels, and other strategies are needed to meet local air quality and greenhouse gas goals? Are they the same?
- What are the implications of federal air quality deadlines coming 20 to 30 years before the 2050 greenhouse gas goal?
- Is the pace of needed transformation the same? How can the strategies to meet air quality targets and greenhouse gas goals best complement each other?
- What are the energy infrastructure demands of coordinated air quality and greenhouse gas strategies?
- How do California's air quality and climate policies need to adapt as emissions move from the vehicle itself to predominantly upstream sources such as electricity and hydrogen generation facilities?

To begin to answer these questions and lay a foundation for future coordinated planning for criteria pollutants regulated through air quality standards (i.e., criteria pollutants), toxic pollutants such as diesel particulate matter, and greenhouse gases, *Vision for Clean Air* uses quantitative scenarios. These scenarios examine the nature of the technology and fuel transformation needed to meet the multiple air quality and greenhouse gas milestones between now and 2050.

Vision Scenarios

Under the Clean Air Act, traditional air quality planning typically focuses on the emissions reductions expected in a single future year from regulations adopted in the immediate three to five years. *Vision for Clean Air* takes a broader approach and uses scenarios to illustrate the change needed in multiple milestone years to meet future emissions targets. This effort is not a plan, but rather, it provides valuable insight for future planning efforts that will include a stakeholder input process. This long-term approach is more common in greenhouse gas analyses. The advantage of long-term planning is that it reveals the scope of advanced technologies needed, how quickly the technologies need to come on line, and the key decision points for technology development and deployment along the way.

A scenario is a combination of technology, energy, and efficiency assumptions that change over time. Scenarios represent a projection of what could be possible — a -what if" story that provides context for decision-making. Scenarios are intended to inform decision-making but are not predictions of what the future will be. So rather than being a list of State Implementation Plan or SIP-ready control measures, the scenarios provide a view of a mix of technologies that could be successful in helping California meet its multi-pollutant goals. Further, the scenarios do not represent a policy choice that favors certain technologies and fuels over others. This scenario planning effort does not identify winners or losers on a specific path to meet air quality and climate goals. Rather, it demonstrates a combination of technologies and fuels that yield the scale of needed transformation. Any other mix of technologies and fuels achieving equivalent or better regional criteria pollutant and life cycle greenhouse gas reductions can be considered part of the scenario.

A Scenario is a "What If" Set of Assumptions about Technologies, Fuels and Efficiencies

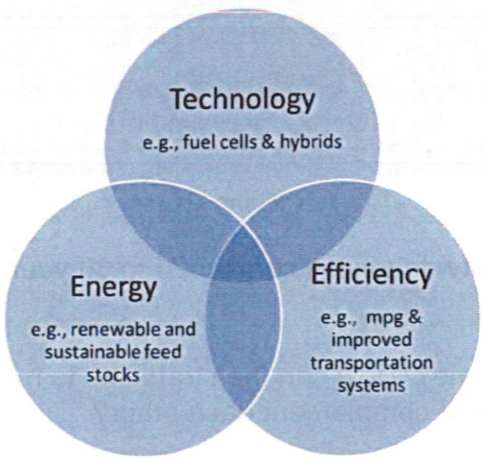


Figure 3

Scenarios were developed through an iterative process of assuming varying levels of technology sales penetration, fuel supply, and efficiency changes. These are ambitious assumptions going beyond the existing programs, and could be expected to require further actions, such as innovation, investment, incentives, and regulations to achieve. However, the scenarios do not include actions such as further incentive funding to accelerate penetration of advanced technologies and clean fuels to meet federal

Scenarios for Mobile Sectors

Scenarios have been developed for passenger cars; freight transport, including trucks, ships, locomotives, cargo handling equipment, and harbor craft; planes, and off-road equipment. The scenarios also include the refineries and power plants needed to produce the fuels and electricity to power the engines in these devices. Together, this covers approximately 45 percent of the State's greenhouse gas emissions and approximately 85 percent of its NOx emissions. The remainder of the greenhouse gas emissions are from non-transportation related sources such as industrial, power generation, commercial, residential and agricultural uses.

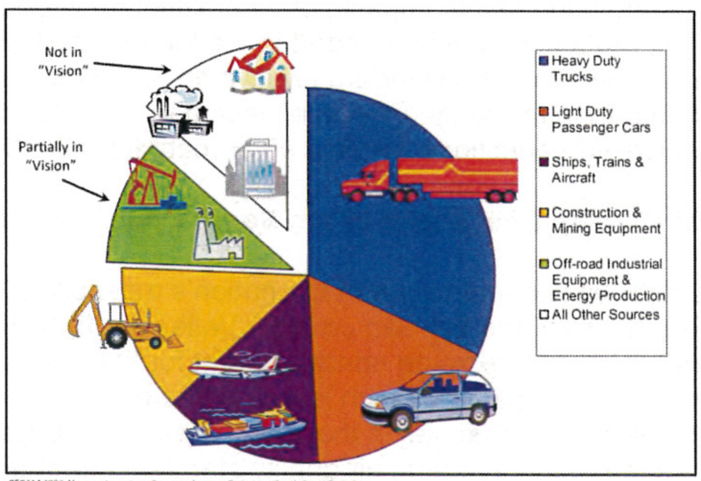
air quality deadlines. For example, expedited turnover of vehicles, as has been achieved with incentives programs implemented by State and local jurisdictions, is not assumed in the scenarios. All of the scenarios include as the starting point all technology and fuel regulations in place today, including passenger vehicle standards, truck and engine standards, the low carbon fuel standard, and the 33 percent renewable electricity requirement.

Most of the technologies and energy sources relied on in the scenarios exist in some form today; some technologies are already on the market, while others are still maturing through demonstration programs and limited test markets.[3] As a result, *Vision for Clean Air* focuses on the development and deployment of emerging technologies not the invention of undefined future technologies. The available technologies that provide fewer smog-forming and greenhouse gas emissions are fuel cells, electric hybrids with a large portion operating in an —all lectric range", and electric vehicles, a combination of which is assumed to be the future norm over time. Similarly, alternative fuels such as hydrogen and clean biofuels such as cellulosic ethanol and biomethane and other renewable energy sources are assumed to play an important role in the energy sectors. Additional operational efficiencies to reduce vehicle miles traveled and overall energy demand are also assumed to occur.

Vision Targets

Targets are characterized as the percent reduction needed from today's emission levels in order to meet the federal air quality standards for ozone and the State's long-term goal to reduce greenhouse gas emissions to 80 percent below 1990 levels by 2050. New federal air quality standards for particulate matter are also expected in the near future. Legally-binding emission targets to attain federal air quality standards are established through the air quality planning process set out in State and federal law. The attainment targets for the 0.080 ppm ozone standard, with a 2023 attainment date, are set in the State's federally approved ozone plans. Planning for the 0.075 ppm federal standard is just beginning, but the attainment target is 2032 for the

Relationship of Vision Inventory to SIP Inventory
2010 NOx SIP Sources as Portion of Total Inventory



CEPAM 2009 Almanac Inventory, Summer Average Emissions, South Coast Emissions

Figure 4

[3] The single exception is the carbon capture sequestration process that will be necessary if fossil fuels are to remain in the energy mix of the future. This process has been demonstrated in limited cases, but long-term data has yet to be developed.

extreme ozone areas of the South Coast Air Basin and San Joaquin Valley. The targets used here are estimates of what the attainment targets could be past 2023 based on current air quality information. *Vision for Clean Air* focuses on oxides of nitrogen (NOx) emissions as NOx is the most critical pollutant for reducing regional ozone and fine particulate matter.

The SIP air quality targets and the 2050 greenhouse gas goal apply to the total emissions from all sources. In developing future SIPs and climate plans, the full spectrum of emissions sources must be considered. *Vision for Clean Air* focuses on mobile sectors and assumes the same percent reduction must be achieved by each. Future planning efforts will need to look at the tradeoffs among strategies for specific source categories that achieve relatively more or fewer reductions in light of technological, economic, and other factors. The following are the air quality goals used in the scenario development process:

- Achieve the 0.08 ppm 8-hour federal ozone standard by 2023 by reducing NOx emissions by 80 percent from 2010 levels.
- Achieve the 0.075 ppm 8-hour federal ozone standard by 2032 by reducing NOx emissions by 90 percent from 2010 levels.
- Reduce greenhouse gas emissions by 80 percent below 1990 levels by 2050. This is equivalent to 85 percent from today's levels.

This document does not evaluate emission reductions needed to attain a potential new ozone standard (i.e., 0.06 - 0.07 ppm 8-hr standard). As scientific studies are documenting health impacts of air pollution at very low levels, it is expected that further NOx reductions will be needed in the long-term. U.S. EPA is expected to consider adopting an ozone standard lower than 0.075 ppm in 2013. Achieving a future ozone standard in the range EPA is expected to consider could require additional NOx emissions reductions, totaling 95 percent from 2010 levels.

Air Quality Challenges in the South Coast and San Joaquin Valley

California is home to two of the nation's most pressing air quality challenges. The South Coast and the San Joaquin Valley are the only two areas in the country designated as extreme nonattainment for the federal ozone standard. These same two areas also experience high levels of fine particulate matter. Because of the severity of the air quality changes in these two areas, they determine the transformational change needed to meet federal air quality standards throughout the State. Still, while they face a similar air quality challenge, they are different in terms of the nature of their emission sources.

South Coast Air Basin

The 2007 SIP for the federal ozone standard contains commitments for emission reductions from mobile sources that rely on advancement of technologies, as authorized under Section 182(e)(5) of the federal Clean Air Act. These measures, which have come to be known as the —Blak Box," account for a substantial portion of the NOx emission reductions needed to attain the federal ozone standards — over 200 tons/day. Attaining these standards will require reductions in emissions of nitrogen oxides (NOx) well beyond reductions resulting from current rules, programs, and commercially-available technologies.

Mobile sources emit over 80 percent of regional NOx and therefore must be the largest part of the solution. For the South Coast, the top NOx emission sources projected in 2023 are shown in Figure 5. On-road truck categories are projected to comprise the single largest contributor to regional NOx in 2023. Other equipment involved in goods movement, such as marine vessels, locomotives and aircraft, are also substantial NOx sources.

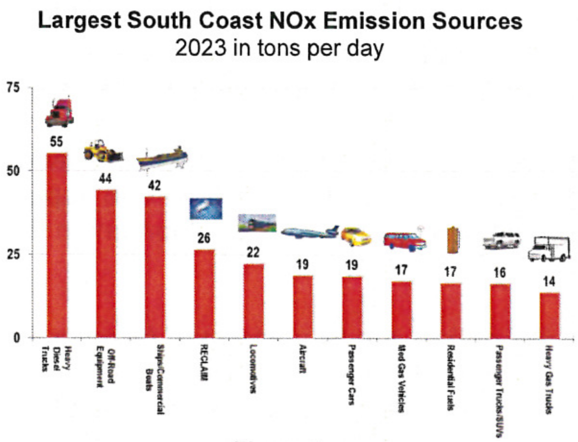


Figure 5

Preliminary projections indicate that the region must reduce regional NOx emissions by about two-thirds by 2023 beyond the benefits of adopted rules and programs, and three quarters by 2032, to attain the national ozone standards as required by federal law.

Since most of the significant sources are already controlled by over 90 percent, attainment of the ozone standards in the South Coast Air Basin will require broad deployment of zero- and near-zero emission technologies in the 2023 to 2032 timeframe. On-land transportation sources such as trucks, locomotives, and cargo handling equipment have technological potential to achieve zero- and near-zero emission levels. Current and potential technologies include hybrid-electric, battery-electric, and hydrogen fuel cell on-road vehicle technologies. Other technologies and fuels may also serve regional

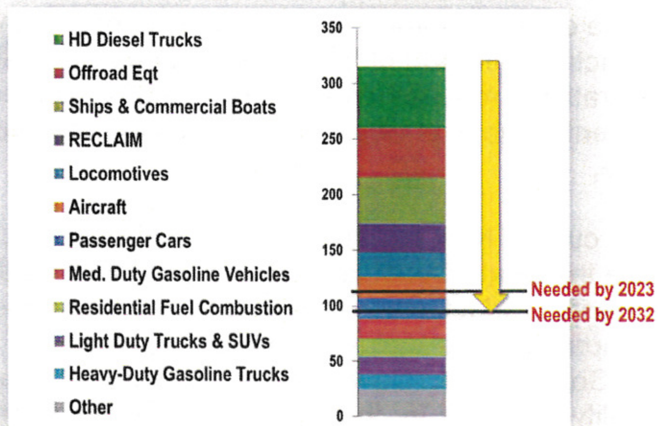


Figure 6

needs, e.g. natural gas-electric hybrids or alternative fuels coupled with advanced aftertreatment technologies. Air quality regulatory agencies have historically set policies and requirements that are performance based and allow any technologies that will achieve needed emission reductions on time.

While there has been much progress in developing and deploying transportation technologies with zero- and near-zero emissions (particularly for light-duty vehicles and passenger transit), additional technology development, demonstration, and commercialization will be required prior to broad deployment in freight and other applications.

San Joaquin Valley Air Basin

Diesel trucks are also the single largest source of NOx emissions in the San Joaquin Valley. However, truck traffic in the Valley is dominated by interstate trucks and other through traffic traveling on the major north-south corridors of Interstate 5 and State Route 99. In contrast, a significant amount of South Coast truck traffic is associated with freight transport from the ports and inland. As a result, the age and activity of the trucks in the two regions differ, suggesting that there may be different options and constraints in terms of technology transformation for trucks that operate in the Valley.

Passenger vehicles are the second largest source of NOx emissions in the San Joaquin Valley. The Valley may present different challenges in terms of infrastructure to support advanced technology passenger vehicles given the nature of urban development in the region.

With the most productive agricultural region in the nation, the San Joaquin Valley is also home to the unique emissions sources of the agricultural industry. While mobile agricultural equipment emissions are significant, a separate scenario was not developed for these sources. Efforts are underway now to clean up mobile agricultural equipment to the cleanest currently available conventional technology. Emission reductions from those efforts are important for reducing ozone levels and measures to achieve these reductions are part of the region's ozone SIP. Given the challenges posed by the operational requirements of this type of equipment and the importance of continuing the current cleanup efforts, consideration of potential future technologies is not included here.

The current NOx targets are set in the approved ozone SIP for the San Joaquin Valley. Like the South Coast, the San Joaquin Valley SIP includes longer-term (—BlackBox") emission reductions due by 2023. Because emissions in the South Coast are so large compared to the Valley, the absolute magnitude of the reductions needed is less than in the South Coast. Nevertheless, the scale of needed transformation is similar. Air quality modeling for the San Joaquin Valley to determine what emission reductions are needed to attain the 0.075 ppm ozone standard in 2032 will be done for the SIP due in 2015. Given the stringent level of the standard, it is expected that on a percentage basis the San Joaquin Valley and South Coast will need a similar magnitude of new reductions.

Vision Tool

A spreadsheet-based tool developed from the Argonne National Laboratory Vision 2011 Model was used to evaluate the scenarios. The Argonne model was intended to be used to evaluate transportation energy policy questions in the context of greenhouse gas emissions. The *Vision for Clean Air* effort started with the Argonne model and was heavily modified and expanded, such that the tool used for *Vision for Clean Air* is fundamentally a different model.

The basic steps outlined in Figure 7 forecast penetration of vehicle technology and fuels into passenger car and truck fleets based on vehicle stock turnover rates, the rates at which new vehicles and technologies enter the fleet and old vehicles leave. The Argonne model is limited in that it only models greenhouse gases and only for passenger vehicles and trucks based on national fleet characteristics. The tool used for *Vision for Clean Air* adds forecasting capability for smog-forming pollutants (NOx and reactive organic gases) and diesel particles. It is also a California-specific model using new vehicle sales, vehicle miles traveled, vehicle survival rates, and emission rates from ARB's mobile source emissions model, EMFAC. Finally, non-road mobile sources, off-road equipment, locomotives, ships, harbor craft, and cargo handling equipment are included based on ARB's existing emissions inventory models for these sources.

Vision for Clean Air Modeling Structure

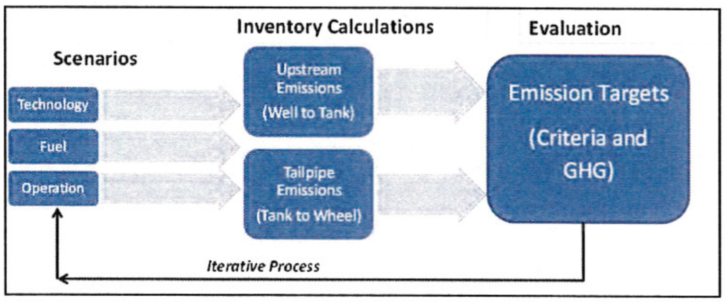


Figure 7

Fuel and electricity demand are estimated by type based on the fleet technology mix, vehicle miles traveled, and engine efficiencies. Emissions from energy production activities are then calculated using assumptions about fuel feedstock, carbon intensity, and NOx emission rates. Carbon emissions are calculated with a global lifecycle from energy production to end use. Smog-forming emissions use a modified life-cycle approach where upstream, fuel pathway emissions are included only if they are within the region studied in the scenario. For simplicity, it was assumed that one half of the NOx emissions from mobile source-related energy production occur within the region in which the energy is used.

This modified lifecycle approach for analyzing smog-forming emissions associated with mobile-source energy production differs from typical air quality planning. In SIPs, mobile and stationary source emissions (including refineries and power plants) are calculated and reported separately. The advantage to linking upstream and

EPA United States Environmental Protection Agency

http://www.epa.gov/airquality/ozonepollution/designations/2008standards/final/region9f.htm

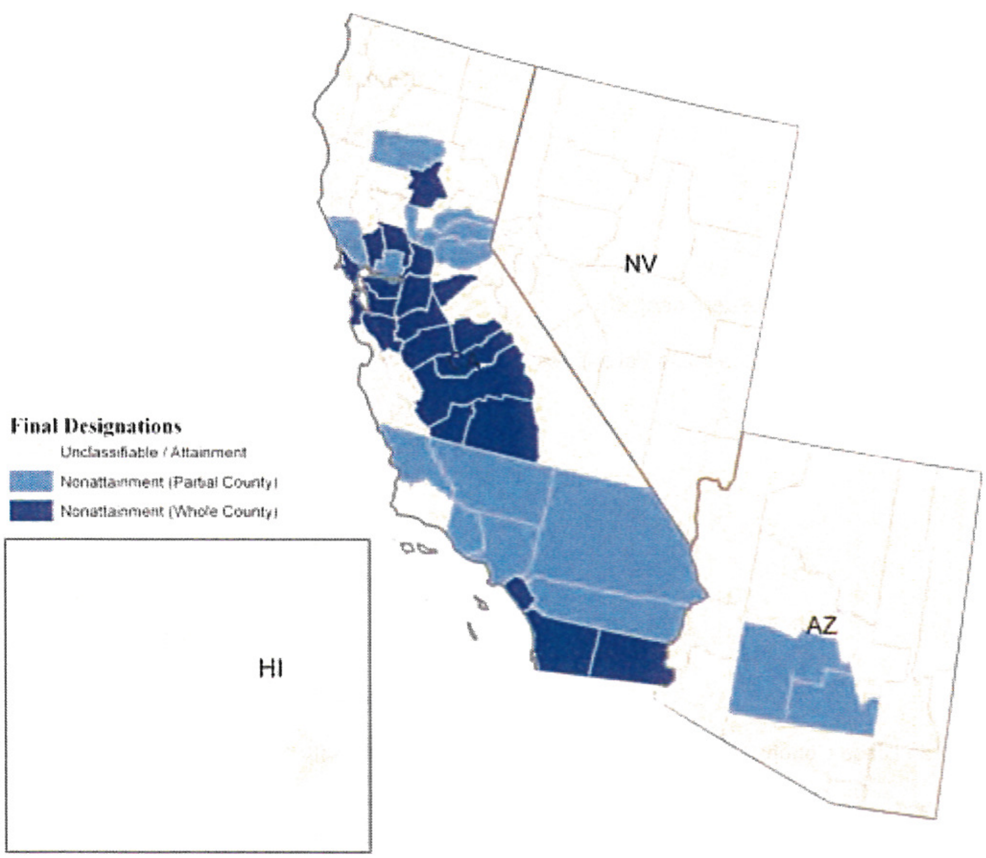
Area Designations for 2008 Ground-level Ozone Standards

2008 Ground-level Ozone Standards — Region 9 Final Designations, April 2012

EPA is implementing the 2008 ozone standards as required by the Clean Air Act. Meeting these standards will provide important public and environmental health benefits. EPA has worked closely with states and tribes to identify areas in the country that meet the standards and those that need to take steps to reduce ozone pollution.

EPAs final designations are based on air quality monitoring data, recommendations submitted by the states and tribes, and other technical information. EPA will work closely with states and tribes to implement the standards using a common sense approach that improves air quality, maximizes flexibilities and minimizes burden on state and local governments.

Map of Final Designations - EPA Region 9



This table identifies area designations for EPAs region 9 states. In some cases EPA designated partial counties. These are identified by a (P). If a county is not listed below, EPA has designated it as unclassifiable/attainment.

EPA Areas for Designations for the 2008 Ozone Standards

State	Area Name	Counties	Area Classification
American Samoa	Entire territory is unclassifiable/attainment		
Arizona	Phoenix-Mesa, AZ	Maricopa (p)	Marginal
		Pinal (p)	
	Rest of state is unclassifiable/attainment		
California	Calaveras County, CA	Calaveras	Marginal
	Chico (Butte County), CA	Butte	Marginal
	Imperial County, CA	Imperial	Marginal
	Kern County (Eastern Kern), CA	Kern (p)	Marginal
	Los Angeles-San Bernardino Counties (West Mojave Desert), CA	Los Angeles (p)	Severe
		San Bernardino (p)	
	Los Angeles-South Coast Air Basin, CA	Los Angeles (p)	Extreme
		Orange	
		Riverside (p)	
		San Bernardino (p)	
	Mariposa County, CA	Mariposa	Marginal
	Nevada County (Western part), CA	Nevada (p)	Marginal
	Riverside County (Coachella Valley), CA	Riverside (p)	Severe
	Sacramento Metro, CA	El Dorado (p)	Severe
		Placer (p)	
		Sacramento	
		Solano (p)	
		Sutter (p)	
		Yolo	
	San Diego County, CA	San Diego	Marginal
	San Francisco Bay Area, CA	Alameda	Marginal
		Contra Costa	
		Marin	
		Napa	
		San Francisco	
		San Mateo	

State	Area Name	Counties	Area Classification
		Santa Clara	
		Solano (p)	
		Sonoma (p)	
	San Joaquin Valley, CA	Fresno	Extreme
		Kern (p)	
		Kings	
		Madera	
		Merced	
		San Joaquin	
		Stanislaus	
		Tulare	
	San Luis Obispo (Eastern San Luis Obispo), CA	San Luis Obispo (p)	Marginal
	Tuscan Buttes, CA	Tehama (p)	Marginal
	Ventura County, CA	Ventura (p)	Serious
	Morongo Areas of Indian Country (Morongo Band of Mission Indians)	Areas of Indian Country	Serious
	Pechanga Areas of Indian Country (Pechanga Band of Luiseno Mission Indians of the Pechanga Reservation)	Areas of Indian Country	Moderate
	Rest of state is unclassifiable/attainment		
Guam	Entire territory is unclassifiable/attainment		
Hawaii	Entire state is unclassifiable/attainment		
Nevada	Entire state is unclassifiable/attainment		
Northern Mariana Islands	Entire territory is unclassifiable/attainment		

< Back to US map

Tribal information is available on the Tribal Designations page.

Recommendations from Region 9 States and EPA Responses

Last updated on Friday, February 01, 2013

AQMD
South Coast
Air Quality Management District
21865 Copley Drive, Diamond Bar, CA 91765-4182
(909) 396-2000 ≠ www.aqmd.gov

SCAQMD Air Quality Significance Thresholds

Mass Daily Thresholds [a]		
Pollutant	**Construction [b]**	**Operation [c]**
NOx	100 lbs/day	55 lbs/day
VOC	75 lbs/day	55 lbs/day
PM10	150 lbs/day	150 lbs/day
PM2.5	55 lbs/day	55 lbs/day
SOx	150 lbs/day	150 lbs/day
CO	550 lbs/day	550 lbs/day
Lead	3 lbs/day	3 lbs/day

Toxic Air Contaminants (TACs), Odor, and GHG Thresholds	
TACs (including carcinogens and non-carcinogens)	Maximum Incremental Cancer Risk ≥ 10 in 1 million Cancer Burden > 0.5 excess cancer cases (in areas ≥ 1 in 1 million) Chronic & Acute Hazard Index ≥ 1.0 (project increment)
Odor	Project creates an odor nuisance pursuant to SCAQMD Rule 402
GHG	10,000 MT/yr CO2eq for industrial facilities

Ambient Air Quality Standards for Criteria Pollutants [d]	
NO2 1-hour average annual arithmetic mean	SCAQMD is in attainment; project is significant if it causes or contributes to an exceedance of the following attainment standards: 0.18 ppm (state) 0.03 ppm (state) and 0.0534 ppm (federal)
PM10 24-hour average annual average	10.4 $\pi g/m^3$ (construction)[e] & 2.5 $\pi g/m^3$ (operation) 1.0 $\pi g/m^3$
PM2.5 24-hour average	10.4 $\pi g/m^3$ (construction)[e] & 2.5 $\pi g/m^3$ (operation)
SO2 1-hour average 24-hour average	0.25 ppm (state) & 0.075 ppm (federal – 99th percentile) 0.04 ppm (state)
Sulfate 24-hour average	25 $\pi g/m^3$ (state)
CO 1-hour average 8-hour average	SCAQMD is in attainment; project is significant if it causes or contributes to an exceedance of the following attainment standards: 20 ppm (state) and 35 ppm (federal) 9.0 ppm (state/federal)
Lead 30-day Average Rolling 3-month average Quarterly average	1.5 $\pi g/m^3$ (state) 0.15 $\pi g/m^3$ (federal) 1.5 $\pi g/m^3$ (federal)

[a] Source: SCAQMD CEQA Handbook (SCAQMD, 1993)

[b] Construction thresholds apply to both the South Coast Air Basin and Coachella Valley (Salton Sea and Mojave Desert Air Basins).

[c] For Coachella Valley, the mass daily thresholds for operation are the same as the construction thresholds.

[d] Ambient air quality thresholds for criteria pollutants based on SCAQMD Rule 1303, Table A-2 unless otherwise stated.

[e] Ambient air quality threshold based on SCAQMD Rule 403.

KEY: lbs/day = pounds per day ppm = parts per million $\pi g/m^3$ = microgram per cubic meter ≥ = greater than or equal to
MT/yr CO2eq = metric tons per year of CO2 equivalents > = greater than

GUIDE FOR ASSESSING AND MITIGATING AIR QUALITY IMPACTS

Prepared by
the Mobile Source/CEQA Section
of the Planning Division
of the San Joaquin Valley Air Pollution Control District
1990 E. Gettysburg Avenue
Fresno, CA 93726

January 10, 2002 revision
Adopted August 20, 1998

This document is an advisory document, that provides Lead Agencies, consultants, and project applicants with uniform procedures for addressing air quality in environmental documents. Copies and updates are available from the SJVAPCD Planning Division at (559) 230-5800. Questions on content should be addressed to either the Mobile Source/ CEQA Section at (559) 230-5800 or the SJVAPCD CEQA representative at the regional office that covers the county in which the project is located.

ACKNOWLEDGEMENTS

The principal authors of this document were:

- Dave Mitchell – Supervisor, Mobile Source / CEQA Section
- Joe O'Bannon – (former) Air Quality Planner, Southern Region
- Joan Merchen – Senior Air Quality Planner, Central Region

Significant contributions were also made by:

- Phil Jay – District Counsel
- Tracy Bettencourt – (former) Environmental Planner, Northern Region
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GUIDE FOR ASSESSING AND MITIGATING AIR QUALITY IMPACTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Demolition Asbestos Impacts. Project construction sometimes requires the demolition of existing buildings at the project site. Buildings often include materials containing asbestos. Airborne asbestos fibers pose a serious health threat if adequate control techniques are not carried out when the material is disturbed. The demolition, renovation, or removal of asbestos-containing materials is subject to the limitations of the National Emissions Standards for Hazardous Air Pollutants (NESHAP) regulations as listed in the Code of Federal Regulations[34] requiring notification and inspection. Most demolitions and many renovations are subject to an asbestos inspection prior to start of activity. The SJVAPCD's Compliance Division in the appropriate region should be consulted prior to commencing any demolition or renovation of any building to determine inspection and compliance requirements. Strict compliance with existing asbestos regulations will normally prevent asbestos from being considered a significant adverse impact.

4.3.2 Thresholds of Significance for Impacts from Project Operations

The term "project operations" refers to the full range of activities that can or may generate pollutant emissions when the development is functioning in its intended use. For projects such as office parks, shopping centers, residential subdivisions, and other indirect sources, motor vehicles traveling to and from the projects represent the primary source of air pollutant emissions. For industrial projects and some commercial projects, equipment operation and manufacturing processes can be of greatest concern from an emissions standpoint. Significance thresholds discussed below address the impacts of these emission sources on local and regional air quality. Thresholds are also provided for other potential impacts related to project operations, such as odors and toxic air contaminants.

(Lead Agencies may refer to Section 5, for guidance on calculating emissions and determining whether significance thresholds for project operations may be exceeded, and thus whether more detailed air quality analysis may be needed.)

Ozone Precursor Emissions Threshold. Ozone precursor emissions from project operations should be compared to the thresholds provided in Table 4-1. Projects that emit ozone precursor air pollutants in excess of the levels in Table 4-1 will be considered to have a significant air quality impact.

Both direct and indirect emissions should be included when determining whether the project exceeds these thresholds. The following total emissions thresholds for air quality have been established by the SJVAPCD for project operations. Projects in the SJVAB with operation-related emissions that exceed these emission thresholds will be considered to have significant air quality impacts.

[34] 40CFR Part 61, Subpart M

Table 4-1
Ozone Precursor Emissions Thresholds
For Project Operations

Pollutant	Tons/yr.
ROG	10
NOx	10

Local Carbon Monoxide Concentrations Threshold. Estimated CO concentrations, as determined by an appropriate model, exceeding the California Ambient Air Quality Standard (CAAQS) of 9 parts per million (ppm) averaged over 8 hours and 20 ppm for 1 hour will be considered a significant impact.

Odor Impacts Threshold. While offensive odors rarely cause any physical harm, they can be very unpleasant, leading to considerable distress among the public and often generating citizen complaints to local governments and the SJVAPCD. Any project with the potential to frequently expose members of the public to objectionable odors will be deemed to have a significant impact. Odor impacts on residential areas and other sensitive receptors, such as hospitals, day-care centers, schools, etc., warrant the closest scrutiny, but consideration should also be given to other land uses where people may congregate, such as recreational facilities, worksites, and commercial areas. Analysis of potential odor impacts should be conducted for the following two situations:

- **Generators** – projects that would potentially generate odorous emissions proposed to locate near existing sensitive receptors or other land uses where people may congregate, *and*

- **Receivers** – residential or other sensitive receptor projects or other projects built for the intent of attracting people locating near existing odor sources.

The SJVAPCD has determined some common types of facilities that have been known to produce odors in the SJV. These are presented in Table 4-2 along with a reasonable distance from the source where the degree of odors could possibly be significant.

A Lead Agency should use Table 4-2 to determine whether the proposed project, either as a generator or a receiver, would result in sensitive receptors being within the distances indicated in Table 4-2. In addition, recognizing that this list of facilities is not meant to be all-inclusive, the Lead Agency should evaluate facilities not included in the table or projects separated by greater distances than indicated in Table 4-2 if warranted by local conditions or special circumstances. If the proposed project would result in sensitive receptors being located closer than the screening level distances indicated in Table 4-2, a more detailed analysis, as described in Section 5, should be conducted.

ATTACHMENT B

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VIA EMAIL

February 18, 2014

Jim Aguila, Manager
Substance Evaluation Section
Stationary Source Division
California Air Resources Board
1001 I Street
Sacramento, CA 95812

Dear Mr. Aguila:

This letter transmits comments regarding the workshop held on February 13, 2014, concerning the Alternative Diesel Fuels (ADF) regulations proposed by the staff on October 15, 2013. The scope of the comments presented here was constrained by the fact that there were only five calendar days and only two business days provided between the date of the workshop and the February 18th deadline for comments announced by CARB staff at the workshop.

As explained below, the modified ADF regulations discussed at the workshop would allow for the widespread use of biodiesel and biodiesel blends in California without adequately mitigating the resulting increases in emissions of oxides of nitrogen (NOx). The workshop proceedings also confirm concerns expressed during the 45-day comment period for the ADF regulations last year that CARB is not providing adequate and prompt public access to relevant documents and information that are in the agency's possession.

Sincerely,

Jim Lyons
Senior Partner

Attachments

ADF Regulation Comments

Submitted by James M. Lyons, Sierra Research
February 18, 2014

1. CARB Has Not Published the Comments from the South Coast Air Quality Management District That Underlie Staff's Proposed Modifications for Extreme Ozone Non-Attainment Areas.

In the January 31, 2014 workshop notice,[1] CARB states:

> *During the 45-day public review process, staff received comments and proposed alternatives to the noticed regulation that staff would like to more fully consider and evaluate. Staff will be preparing modifications to the original proposal and make the modifications available for public review during a supplemental 15-day public comment period.*

Furthermore, CARB staff notes on slide 8 of the workshop presentation[2] with respect to "45-day rulemaking comments" that:

> *SCAQMD comment requested additional protections for extreme ozone non-attainment areas (South Coast Air Basin, Jan Joaquin Valley).*

However, the relevant comment document from the South Coast Air Quality Management District ("SCAQMD") does not appear as part of the comments submitted during the 45-day comment period posted on the CARB website as shown in the screen shot taken on February 17, 2014, and presented as Figure 1 below. In addition, since there was no public hearing on the proposed regulations held on December 12 or 13, 2013, no comment document could have been provided in that venue.

Because the SCAQMD comments have not been made available to the public, it is impossible for any stakeholder to understand or comment on either the scope of the SCAQMD request or the responsiveness of the modifications proposed by CARB staff at the workshop. CARB staff should make all documents and correspondence related to the SCAQMD comments publicly available and include them in the rulemaking file.

---

[1] *http://www.arb.ca.gov/fuels/diesel/altdiesel/ADFmtgnotice_021314.pdf*

[2] *http://www.arb.ca.gov/fuels/diesel/altdiesel/021314_PublicMeetingPres.pdf*

Figure 1
Screen Shot From CARB Website on February 17, 2014


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Air Resources Board

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Monday, February 17, 2014

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- Reducing Air Pollution
  - ARB Board Meetings

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- Background
- Biographies
- Board Meeting Dates for 2011
- Public Participation Opportunities
  - How to Send and View Board Item Comments
    - Send Us Your Comments
- Rulemaking Activity
- Webcast Calendar
- Workshops / Meetings
  - Future Meetings
  - Past Meetings

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BELOW IS THE COMMENT LOG FOR ALTERNATIVE DIESEL FUELS 2013 (ADF2013).

#	Received From	Subject	Comment Period	Date/Time Added to Database	Attachments or Additional Form Letters
1	Gault, Roger, Truck and Engine Manufacturers Assoc.	Alternative Diesel Fuel Proposed Regulation	45 Day	2013-12-10 15:09:48	Attachment
2	Johnson, Norman,	Bosch Comments: Proposed Regulation of the Commercialization of New Alternative Diesel Fue	45 Day	2013-12-11 14:31:01	Attachment
3	Grey, Gina, WSPA	WSPA Comments on Proposed New Alternative Diesel Regulation	45 Day	2013-12-11 17:22:59	Attachment
4	Syz, Brittany,	Comments to Proposed Reg on Commercialization of New ADF	45 Day	2013-12-12 10:23:39	Attachment
5	This comment was posted then deleted because it was unrelated to the Board item or it was a duplicate.				
6	Guarraci, Brian, POET	Comments on ADF2013	45 Day	2013-12-12 13:52:45	Attachment
7	Buis, Tom, Growth Energy	Comments on ADF2013	45 Day	2013-12-12 15:13:35	Attachment

Comments posted to adf2013 that were presented during the Hearing:

There are no comments posted to adf2013 that were presented during the Board Hearing.

We expect that any written comments received during the Board Hearing will be posted within one week of the Board Hearing.

2. CARB Staff Has Failed to Include Results from On-Going CARB-Sponsored Research Regarding the Impacts of Biodiesel on NOx Emissions in the Rulemaking Process.

During last week's workshop, a representative of the SCAQMD commented that increases in NOx emissions due to biodiesel use at levels as low as five percent biodiesel ("B5") remained a concern to his agency based on emission test results from an ongoing CARB-sponsored study being conducted by the University of California, Riverside ("UCR"). The SCAQMD representative stated that the UCR data showed statistically significant increases in NOx emissions for some types of B5 blends compared to conventional diesel fuel. CARB staff's response to this comment was that the study was still "on-going" and that no conclusions can be drawn from the emission testing until the study is completed. In response to questioning, CARB staff indicated that the contract for the project expires in July 2014 and suggested that all work related to the study would be complete by that date. As stakeholders have previously commented, CARB staff must include all available emission data regarding biodiesel impacts on emissions of NOx and other pollutants in the file for this rulemaking.

It should be noted that, even if some members of the CARB staff consider the UCR work to be incomplete, other members of the CARB staff evidently consider the UCR data to be complete enough to warrant use in public meetings. Direct evidence supporting the assertion made by the SCAQMD representative at the workshop is provided by a presentation made by Georgios Karavalakis of UCR on April 10, 2013, at the 23rd Coordinating Research Council (CRC) Real World Emission Workshop, which lists among the coauthors two CARB staff members and acknowledges funding from CARB contract No. 10-417. A copy of this presentation and documentation demonstrating that it was presented at the April 2013 workshop is attached to these comments.

In the section of the presentation labelled "CARB HD Engine Study Results," data are presented from preliminary emissions testing of B5 blends of both soy and waste vegetable oil ("WVO") based biodiesels using procedures similar to those set forth in Appendix A of the Initial Statement of Reasons ("ISOR") for the proposed ADF regulations. Based on these data, the authors conclude in the presentation that "NOx emissions showed slight but statistically significant, increase for B5-WVO and B5-soy blends." The authors conclude with respect to "certification testing" that "NOx emissions showed a statistically significant increase for B5-WVO" and that "The B5-WVO failed the statistical certification test, based on NOx emissions."

This presentation raises a number of issues that CARB staff must address. First, the presentation provides evidence that directly contradicts the assertion made by CARB staff in the ISOR that there is no evidence of increased NOx emissions at biodiesel levels below B10—an assertion that is the foundation for the CARB environmental impact analysis presented in the ISOR. Second, these data directly support Robert Crawford's conclusions[3] that biodiesel use at levels below B10 will result in increased NOx emissions. Mr. Crawford's work was included by Growth Energy in its comments submitted to CARB staff during the 45-day comment period. Third, given that these data were available at least as early as April 2013, CARB staff should explain why they were not included in the staff's analysis of NOx impacts published in the ISOR nor in the rulemaking file for the ADF regulation.

Again, CARB staff must include in the rulemaking file for this proceeding all emission test data currently available from this B5 testing program and any other biodiesel testing programs that the agency is sponsoring or otherwise participating in. This is particularly important here as the test data being excluded do not support the staff's assumption in the ISOR that there is no increase in NOx emissions until biodiesel blends reach the B10 level.

3. **The Proposed Modifications to the ADF Regulation Affecting Extreme Ozone Non-Attainment Areas Will Not Prevent Significant Increases in NOx Emissions from Biodiesel Use.**

As presented by CARB staff at last week's workshop, the modifications to the proposed ADF regulation that would impose different requirements for extreme ozone non-attainment areas would be limited to the following:

[3] Crawford, R., "NOx emission Impact of Soy- and Animal-based Biodiesel fuels: A Re-Analysis", December 10, 2013.

1. Establishment of "effective blend" (EB) requirements for biodiesel producers and importers;

2. Requirements for biodiesel producers and importers to submit compliance plans demonstrating how NOx emission increases will be mitigated once their EB level reaches five percent; and

3. Implementation of NOx mitigation measures once their EB level reaches seven and a half percent.

Presumably CARB staff has proposed these changes because they recognize that the originally proposed ADF regulation could lead to unacceptable increases in NOx emissions in the South Coast and San Joaquin Valley Air Basins. Nevertheless, the changes do nothing to ensure that increased NOx emissions due to biodiesel use will not actually occur.

The basic problem with the staff's proposed modifications is their continued reliance on the flawed effective blend (or EB) concept which, as pointed out in comments provided during the 45-day comment period, virtually ensures that the use of biodiesel in California will result in unmitigated increases in NOx emissions. As stakeholders indicated during the 45-day comment period, the only way to ensure that there are no increases in NOx emissions is for CARB staff to abandon the EB concept and to impose appropriate mitigation requirements based on the **actual** biodiesel content of all biodiesel blends. Furthermore, by appropriately mitigating the increases in the NOx emissions associated with biodiesel use, areas like the South Coast and San Joaquin Valley Air Basins will also realize the benefits of any NOx reductions associated with the use of "Low NOx diesel."

4. **The Proposed ADF Regulation Should Be Modified to Require Determination and Reporting of the Biodiesel Content of All Biodiesel Blends Prior to Their Sale to Ultimate Consumers.**

During last week's workshop, it became clear that the proposed ADF regulation will not ensure that the biodiesel content of blends sold in California will be accurately known or reported to CARB. As indicated by workshop participants, at present CARB has no requirement for determining the biodiesel content of diesel fuels being imported or distributed in the state that contain biodiesel up to the B5 level. Given this, a party interested in blending 5% biodiesel into a "diesel" fuel may be unaware of the fact that the "diesel" fuel could already contain up to 5% biodiesel and that the resulting blend would therefore be B10, not B5. Similarly, a party interested in blending 20% biodiesel into a "diesel" could in fact produce a B25 blend, instead of the intended B20 blend. Obviously, both circumstances have substantial ramifications with respect to potential NOx increases associated with the use of biodiesel in California.

Given the above, CARB must modify as necessary its existing diesel fuel regulations as well as the proposed ADF regulations to ensure that the biodiesel content of all blends of biodiesel and diesel sold in California is accurately known and reported to both CARB as well as the Division of Measurement Standards. This could easily be accomplished by requiring that all "diesel" fuels used in biodiesel blends be tested before blending for Fatty Acid Methyl Ester (FAME) content using appropriate test procedures such as the EN14103:2011 procedure already referenced in the proposed ADF Regulations or the ASTM D7371 procedure. Alternatively, CARB could require testing of final blends for FAME content. Again, failure by CARB to require accurate measurement and reporting of the biodiesel content of biodiesel-diesel blends will lead to unmitigated increases in NOx emissions along with other potential issues, including violations of pump labeling and vehicle manufacturer warranty requirements.

5. CARB Staff Must Publish an Analysis of All Alternatives to the Proposed ADF Regulation Raised During the 45-Day Comment Period.

The "Analysis of Alternatives" presented on pages 62 and 63 of the ISOR states:

> *Specifically for biodiesel, we considered two alternatives to the proposal: business as usual (i.e., no proposed regulation), and requiring implementation of the mitigation measures for all biodiesel blends above B10 immediately without the proposed phase in process.*

CARB staff must perform an expanded analysis of alternatives that includes not only the modifications to the original proposal discussed at the workshop but also all alternatives recommended during the 45-day comment period. No such analysis was presented at last week's workshop. Clearly CARB staff should perform this analysis and consider the results, including public comment, before formally proposing modifications to the ADF regulation.

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BIODIESEL AND RENEWABLE DIESEL CHARACTERIZATION AND TESTING IN MODERN LD DIESEL PASSENGER CARS AND TRUCKS AND HD ENGINES

Georgios Karavalakis[1], Maryam Hajbabaei[1], Daniel Short[1], Diep Vu[1], Robert L. Russell[1], Tom Durbin[1], Akua Asa-Awuku[1], Kent C. Johnson[1], Alexander Mitchell[2], and Jim Guthrie[2]

[1]University of California, Riverside
Bourns College of Engineering
Center for Environmental Research and Technology (CE-CERT)
[2]California Air Resources Board, 1001 "I" Street, P.O. Box 2815, Sacramento, CA 95812

www.cert.ucr.edu

Introduction

- **Potential Sources of Biodiesel**
  - Vegetable oils
    - Edible oils: Soybean oil, rapeseed oil, palm oil, etc.
    - Inedible oils: Jatropha, Camelina, Karanja, etc.
  - Animal Fats
  - Waste Cooking Oils
  - ‘Alternative’ Oils
    - Algae
- **Benefits**
  - Reduce petroleum dependence
  - Reduce overall life cycle CO_2 emissions
  - Potential improvements in “smog” emissions

Alternative Fuels Legislation

Federal

- Energy Policy Act
  - Renewable Fuels Standard
  - Biofuels Research and Development

California

- Low Carbon Fuel Standard (LCFS)
  - Reduce 10% carbon intensity of California's transport fuels by 2020.
- AB 32 – Global Warming Solutions Act
- Bioenergy Action Plan
- AB 1007 – Alternative Fuels Plan
- AB 118 – Alternative and Renewable Fuel and Vehicle Technology Program

Concerns about using Biodiesel from Emissions Perspective

- Concern about NOx emissions increases with biodiesel
  - Lack of information with vehicles/engines fitted with DPF, SCR, and LNT controls
- A general trend towards higher aldehyde emissions (i.e., formaldehyde, acetaldehyde, acrolein, etc.)
- Biodiesel origin and quality may adversely affect the formation of light molecular-weight PAH emissions
- Characterization of biodiesel exhaust from SCR-fitted vehicles is still incomplete; potential formation of nitrogen-containing compounds (nitro-PAHs)
- Concern about nanoparticle number emission increases with biodiesel

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Objectives of the AVFL – 17b Study

- Evaluation of fuel type and quality on exhaust emissions of modern technology light-duty diesel vehicles.
- Assessment of the impact of modern technology aftertreatment control devices on the emissions formation from biodiesel and renewable diesel fueled vehicles.
- Emphasis on gaseous toxic emissions, ammonia, and ultrafine particles.
- Chemical characterization of PM emissions; Concern about EC/OC fractions, PAH, and nitro-PAH compounds some of which are carcinogenic and mutagenic to humans.
- Evaluation of emissions during DPF regeneration events on different fuels; physicochemical characterization of PM.

Test Fuels and Vehicles for the AVFL – 17b Study

- A total of seven fuels will be used in the study
  - A Federal ULSD and a CARB ULSD, which will serve as baseline fuels
  - Three biodiesels obtained from soy, waste cooking oil, and animal fat
  - A renewable diesel (Hydrogenated Vegetable Oil - HVO)
  - All biodiesels and HVO will be blended with Federal diesel at 20% by volume. CARB diesel will be blended with WCO.
- Currently, we tested a total of 3 vehicles with plans to test 5 additional vehicles.

#	Aftertreatment	MY	Displacement	Configuration
Veh #1	DOC+DPF+SCR	2012	3.0L	V6
Veh #2	DOC+DPF+SCR	2012	6.6L	V8
Veh #3	DOC+DPF+SCR	2012	2.0L	4 cylinders
Veh #4	DOC+DPF+LNT	2012 or 2013	6.7L	6 cylinders
Veh #5	DOC+DPF+SCR	2012/13	6.7L	V8
Veh #6	DOC+DPF+SCR	2012/13	3.0L	V6
Veh #7	DOC+DPF+LNT	2012/13	2.0L	4 cylinders
Veh #8	TBD	2012 or 2013	TBD	TBD

Testing Protocol

- Emissions and fuel economy tests will be performed on the Federal Test Procedure (FTP) driving cycle.
  - Each vehicle/fuel combination will be tested at least twice.
  - A third test will be performed if the differences in FTP regulated emissions exceed a predefined limit: THC 33%, NO_x 29%, CO 70%, provided the absolute difference in the measurements is greater than 5 mg/mi.
- For the oil conditioning protocol, the vehicle will be conditioned on the oil for a period approximately equivalent to two US06 cycles, followed by an LA4 and a US06 cycle sequence repeated twice. This protocol provides more robust preconditioning, especially for improving the repeatability of the nucleation mode particles under hot start/running conditions.

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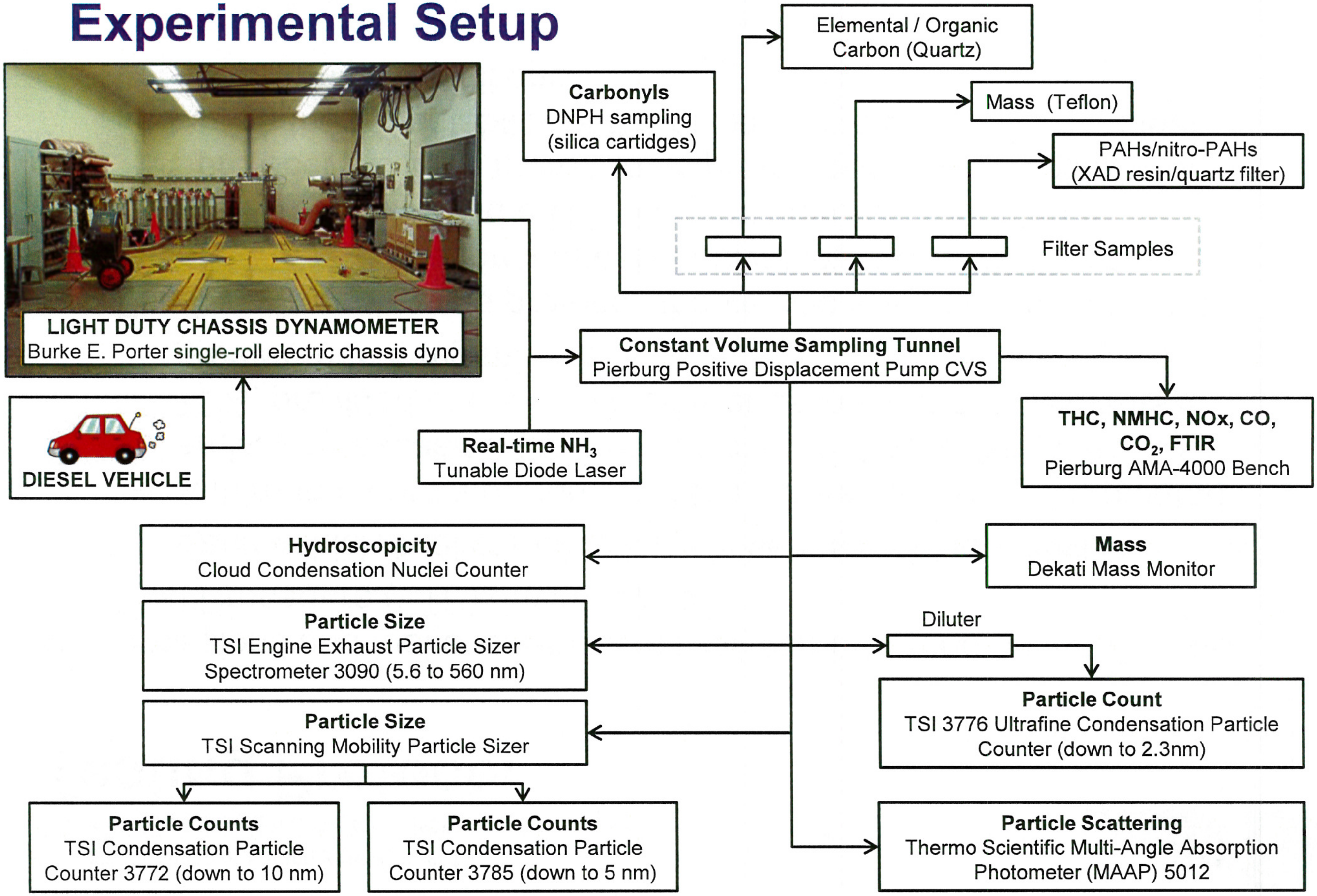
Experimental Setup

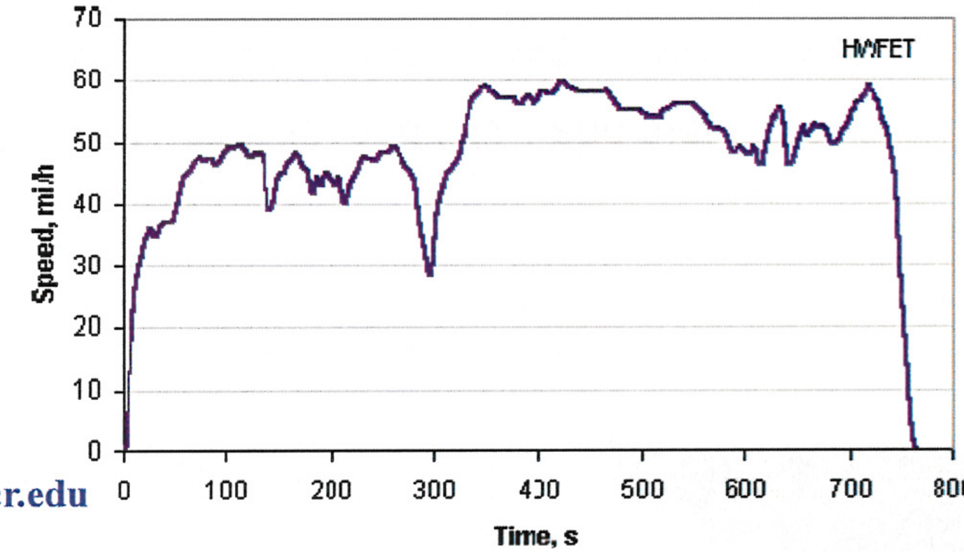


Regeneration Testing Protocol

- A total of two fuels were tested during regeneration testing: Federal ULSD and Fed/SME-20.
- The regeneration testing protocol included driving the vehicle on-road on a route designed to simulate the LA4 portion of the FTP cycle in terms of typical speeds as well as number of stops, for approximately 170 miles (20 LA4s) to build up soot in the DPF.
- Testing was conducted over a double EPA Highway Fuel Economy Cycle (HWFET).

Baseline HWFET (emissions collection) → Baseline Regen → 20 LA4s (on-road) → Regen #1 → 20 LA4s (on-road) → Regen #2

- Regulated emissions, PM mass, particle number emissions and particle size distributions, carbonyls, PAHs/nitro-PAHs, EC/OC, and NH_3 emissions will be measured during a regeneration event for each vehicle/fuel combination.



Current Status

- Measurements are being made for:
  - Regulated emissions (NOx, PM, THC, CO, CH_4, NMHC, and CO_2) and fuel economy
  - Aldehydes and ketones
  - Real-time ammonia
  - EC/OC fractions
  - Particle number emissions
  - PAHs and nitro-PAHs
- Additional measurements are being made for:
  - Particle size distributions
  - Black carbon
  - Particles solubility
  - Hydroscopicity

Additional Work

- Comprehensive statistical analysis based on a complete data set
- QA/QC

- Future Work:
  - Further study on the emissions from low-environmental impact feedstock biodiesels, such as algae-based fuels
  - A more complete assessment on the emissions performance of high concentration renewable diesel (HVO) blends in modern technology diesel vehicles.
  - More information is needed on the physical, chemical, and biological characterization of particulate emissions during regeneration events from light- and heavy-duty vehicles operated on alternative fuels.

Acknowledgements

- This project is totally funded by the Coordinating Research Council (CRC) under contract No. CRC AVFL – 17b.
- Mr. Kurt Bumiller and Mr. Mark Villela of the University of California, Riverside for their contributions in conducting the emissions testing for this program.
- Thanks for the technical guidance from the CRC AVFL- committee and the AVFL-17b technical panel led by Dr. Mani Natarajan of Marathon Petroleum Company.
- Thanks to Mercedes Benz and Volkswagen for providing the vehicles.
- The Panel Members are: Brent Bailey (CRC), Mani Natarajan (Marathon Petroleum Company), Bill Cannella (Chevron), Dominic DiCicco (Ford), King Eng (Shell), Garry Gunter (Phillips 66), Scott Jorgensen (GM), David Lax (API), Shailesh Lopes (GM), Jenny Sigelko (Volkswagen), Marie Valentine (Toyota), William Woebkenberg (Daimler), Krystal Wrigley (Exxon Mobil)

CARB HD Engine Study Results

Objectives of the HD Engine Study

- Evaluation and development of NO_x neutral biodiesel formulations
- Certification of one or more biodiesel blends under CARB Alternative Diesel Fuel Formulation Certification Procedure

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Test Fuels

- B5-animal, B5-WVO and B5-soy
- CARB Reference fuel

(title 13, CFR, section 2282(g)(3) fuel specification with nominally 10% aromatic content)

Test Matrix

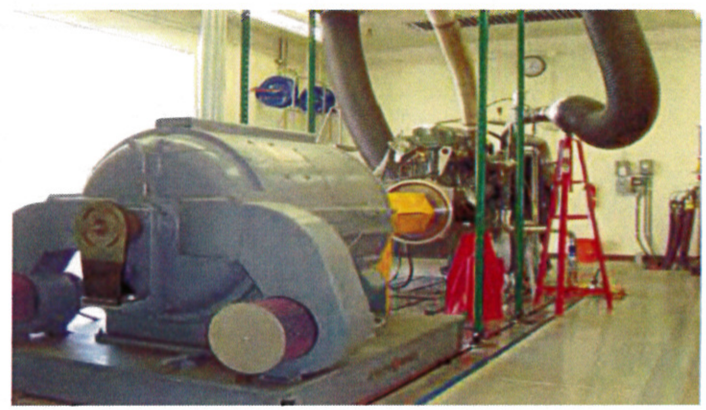
- Preliminary/scoping testing with B5-animal, B5-WVO and B5-soy
- Full Certification Test with B5-animal and B5-WVO

Testing Details

- 2006 Cummins ISM 370 : In-line, 6 Cylinder, Turbocharged, with EGR
- Federal Testing Procedure (FTP)
- THC, NMHC, CO, NO_x, CO_2, PM, Soluble Organic Fraction (SOF)

Test Sequence

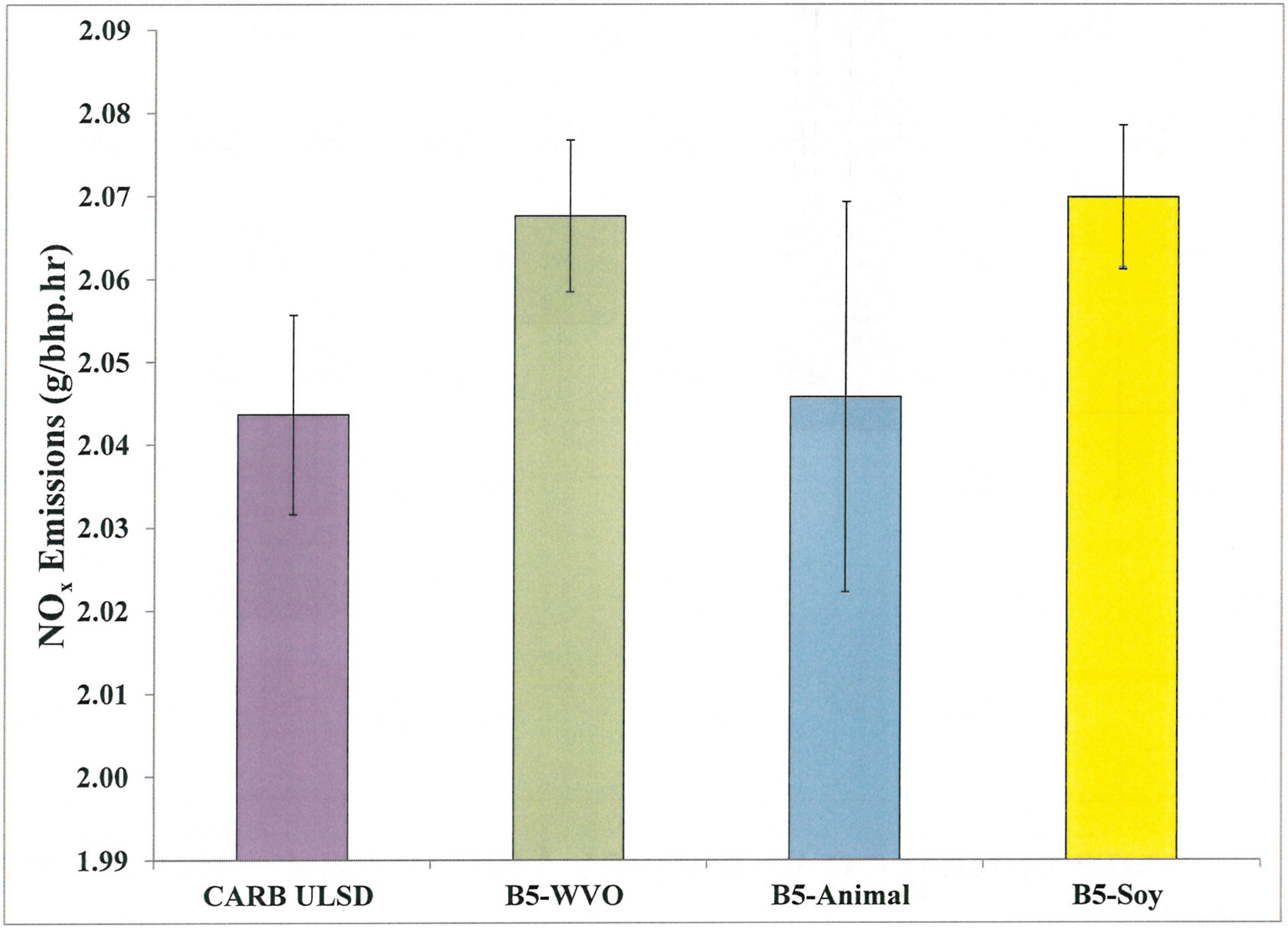
Day	Fuel Test Sequence
1	RC CR RC CR
2	RC CR RC CR
3	RC CR RC CR
4	RC CR RC CR
5	RC CR RC CR



Fuel Properties

Property	Test Method	Units	CARB	B100-Animal	B100-WVO	B100-Soy	B5-Animal	B5-WVO
Heating value	ASTM D240	BTU/lb	19689	17133	17076	17140	19661	19649
API Gravity@60°F	ASTM D4052			30.20	28.40	28.43	38.5	38.2
Specific Gravity @60°F	ASTM D4052		0.839	0.8750	0.8851	0.8848	0.8326	0.8339
Carbon	ASTM D5291	wt%	85.80	76.19	76.67	77.10	85.78	85.85
Hydrogen	ASTM D5291	wt%	13.61	12.28	11.98	11.85	13.8	13.82
Carbon Unit per Energy		Carbon lbs./BTU	4.36×10^{-5}	4.45×10^{-5}	4.49×10^{-5}	4.50×10^{-5}	4.36×10^{-5}	4.37×10^{-5}
Sulfur		ppm	4.7	6.5	11.1	1.1	4.5	5.3
Cetane number			53.1	61.1	54.6	49.2	61	52.2

NO_x Emissions – Preliminary Testing of B5 Certification



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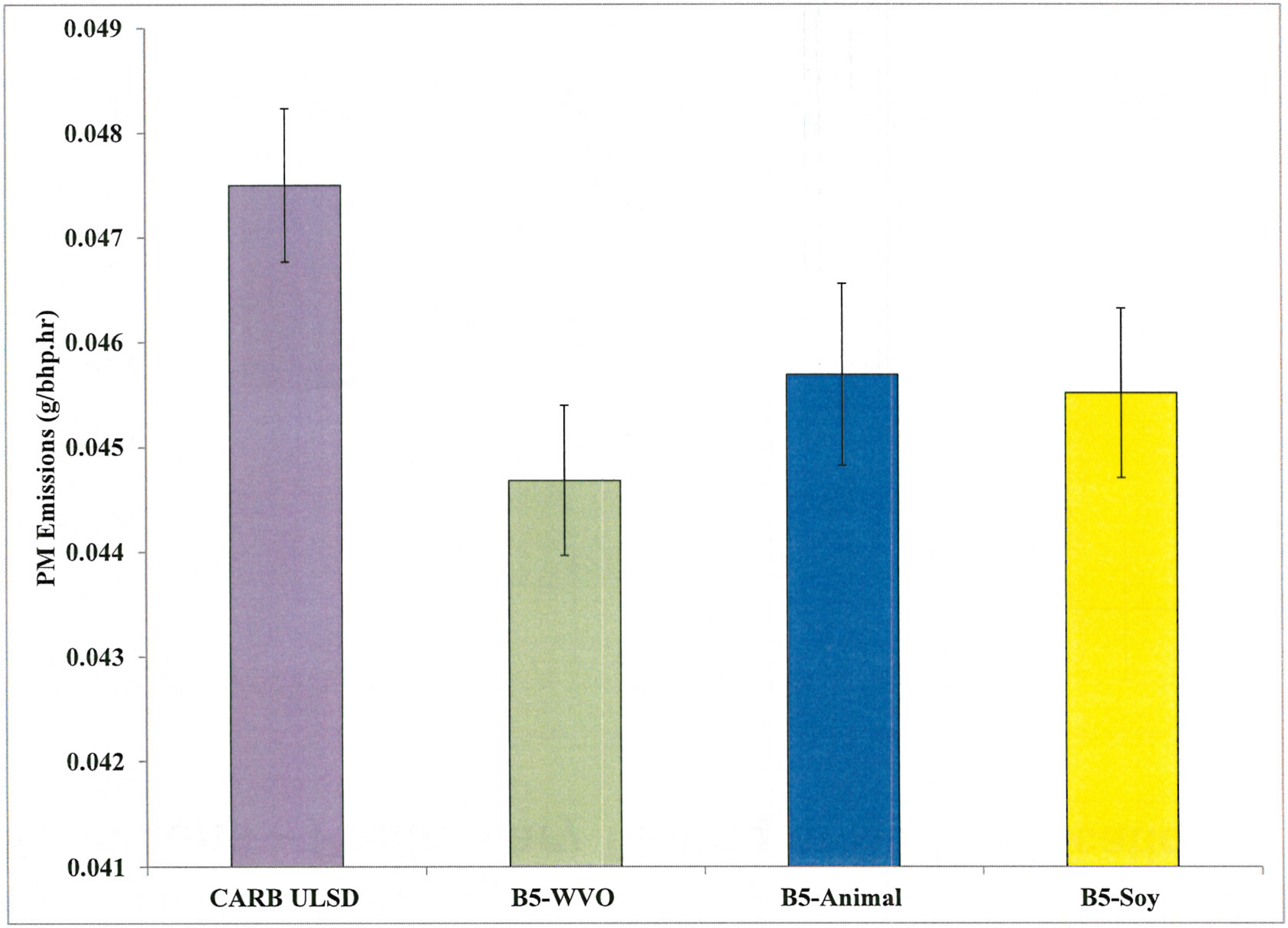
PM Emissions – Preliminary Testing of B5 Certification



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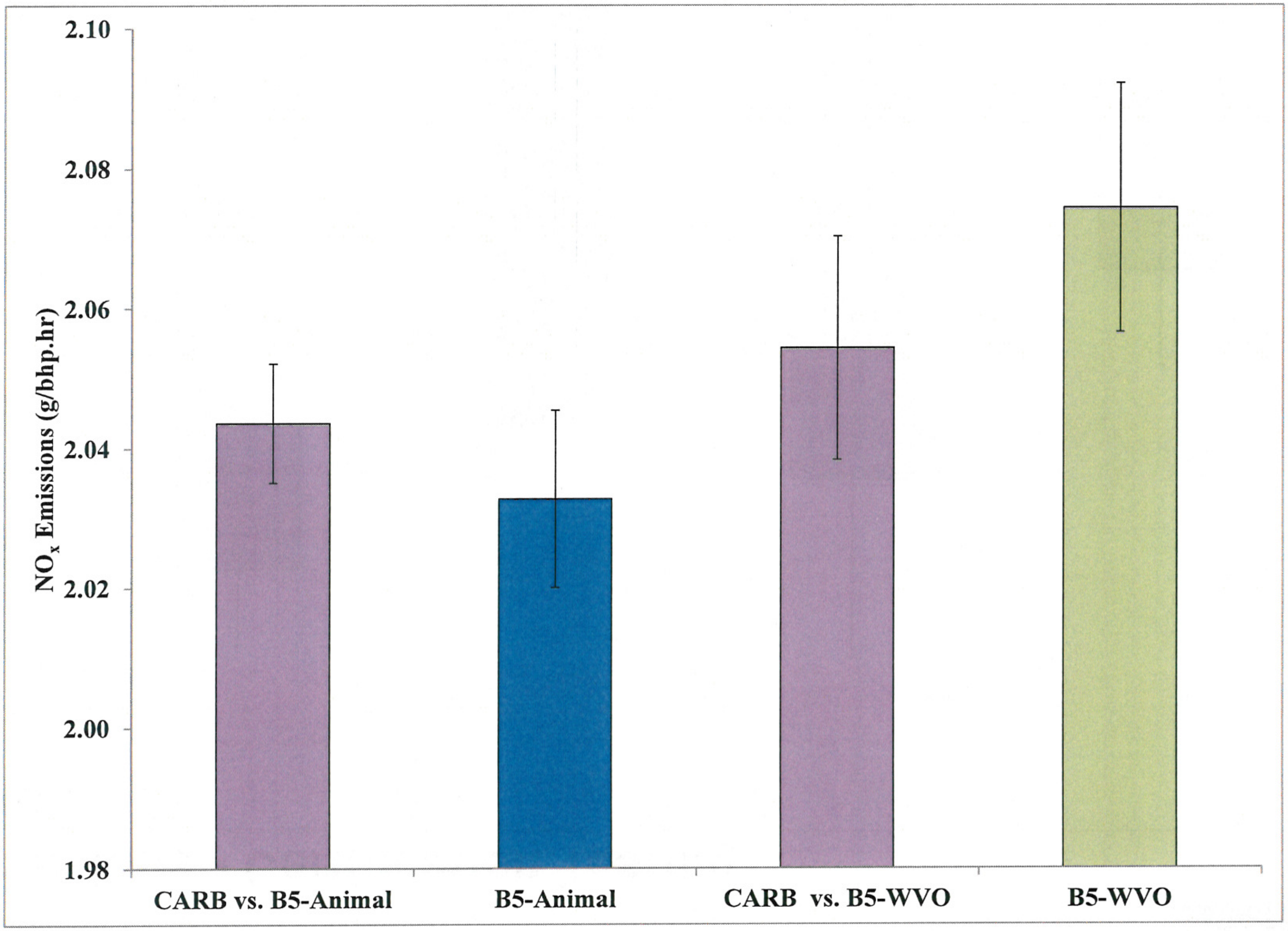
NO_x Emissions- Certification Testing



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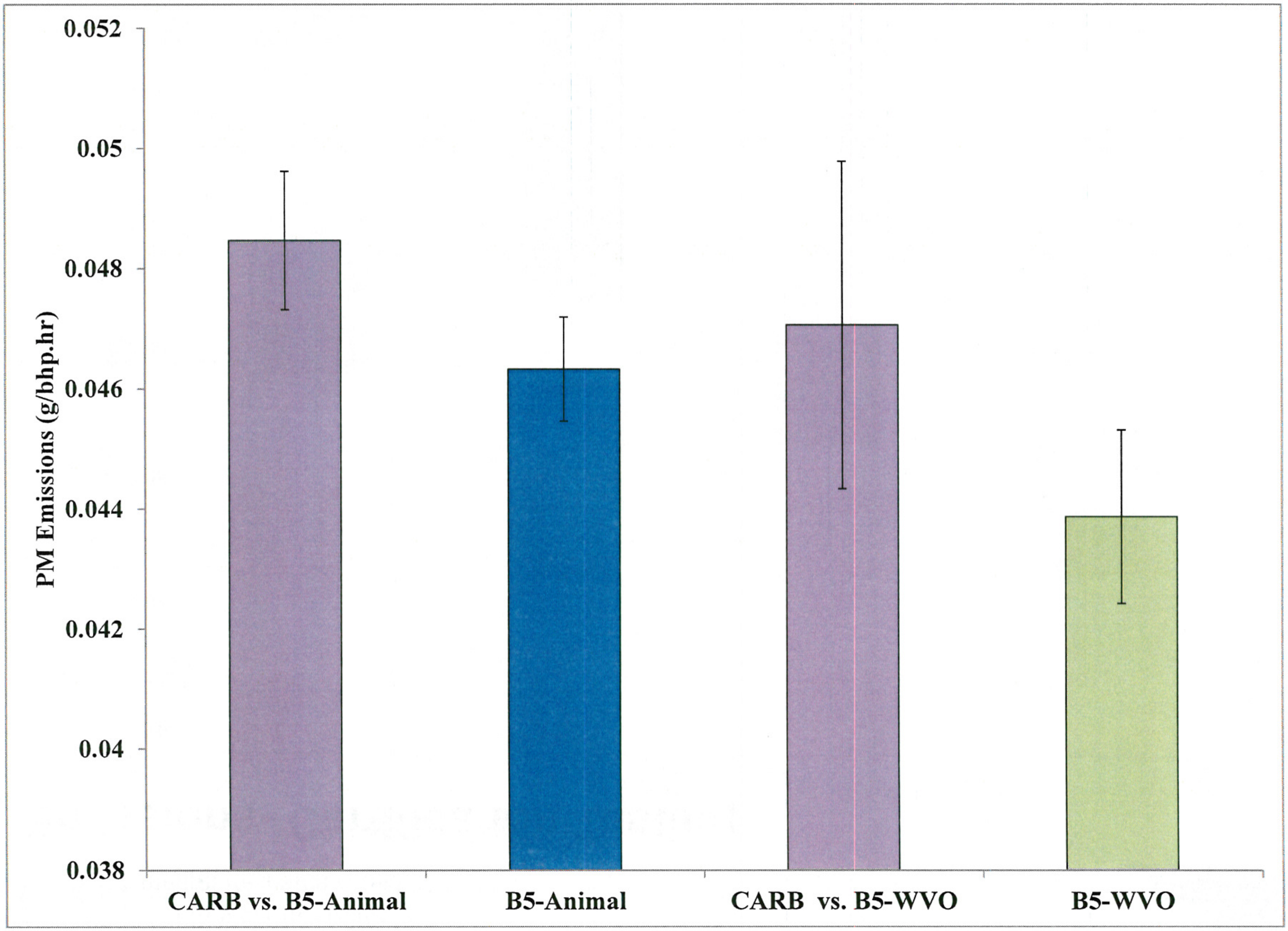
PM Emissions - Certification Testing



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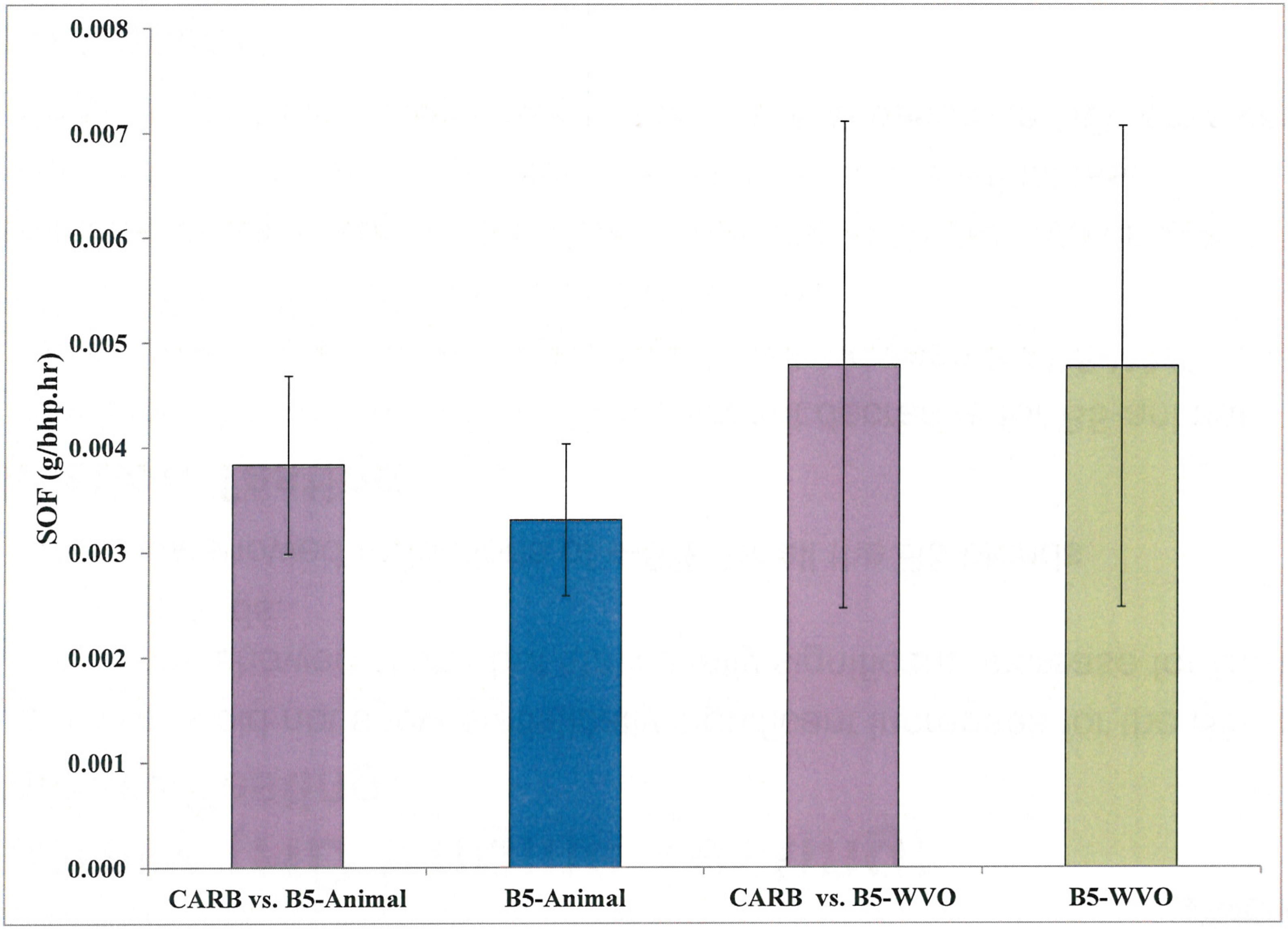
SOF Analysis- Certification Testing



Summary (HD Engine Testing)

Preliminary Testing

- NO_x emissions did not show statistically significant increases for the B5-animal.
- NO_x emissions showed slight, but statistically significant, increase for B5-WVO and B5-soy blends.
- PM emissions showed reductions of 4-6% for all the B5 blends.

Certification Testing

- NO_x emissions showed a statistically significant decrease for B5-animal.
- NO_x emissions showed a statistically significant increase for B5-WVO.
- PM showed reductions for both tested B5 blends.
- B5-animal showed a reduction in SOF compared to CARB reference fuel.
- The B5-animal successfully passed the certification statistical test.
- The B5-WVO failed the statistical certification test, based on NO_x emissions.

Additional work

- Further testing on B20 blends with additives has been conducted and is being analyzed.
- A more comprehensive study of the impacts of B5 on NO_x emissions in CARB diesel is planned in the near future.

Acknowledgements

- Funding from the California Air Resources Board (CARB) under contract No. 10-417.
- University of California Transportation Center (UCTC) Dissertation Grant
- Mr. Edward O'Neil, Mr. Donald Pacocha, Mr. Joe Valdez, and Mr. William Le Fevre of the University of California, Riverside for their contributions in conducting the emissions testing for this program.

AGENDA

23rd CRC REAL WORLD EMISSIONS WORKSHOP

Workshop Organizers

Mani Natarajan, Co-Chairman, Marathon Petroleum Company
Dominic DiCicco, Co-Chairman, Ford Motor Company
Alberto Ayala, California Air Resources Board
Brent Bailey, Coordinating Research Council
Megan Beardsley, U.S. Environmental Protection Agency OTAQ
Kevin Black, Federal Highway Administration
Rob R. Graze, Jr., Caterpillar, Inc. Technical Center
Philip Heirigs, Chevron Global Downstream
Jorn Dinh Herner, California Air Resources Board
Henry Hogo, South Coast Air Quality Management District
John Koupal, Eastern Research Group
Tom Long, U.S. Environmental Protection Agency NRMRL
Chris Tennant, Coordinating Research Council
Matthew Thornton, National Renewable Energy Laboratory

Hyatt Regency Mission Bay, San Diego, California
April 7-10, 2013

23rd CRC Real World Emissions Workshop

Schedule of Events

Sunday, April 7, 2013

4:30 PM	- 6:00 PM	Registration and Poster Setup
6:00 PM	- 7:00 PM	Welcome Reception

Monday, April 8, 2013

7:30 AM	- 8:30 AM	Registration and Continental Breakfast
8:30 AM	- 8:40 AM	Welcome from the Chairs
8:40 AM	**- 10:15 AM**	**Session 1: Emission Rates and Inventory**
10:15 AM	- 10:55 AM	Poster Session and Demonstrations
10:55 AM	**- 12:00 PM**	**Session 2: Emissions Control Measures and Emerging Technologies**
12:00 PM	- 1:30 PM	Lunch
1:30 PM	**- 2:15 PM**	**Session 2 continued**
2:15 PM	**- 2:50 PM**	**Session 3: I/M and In-Field Measurement Method Development**
2:50 PM	- 3:20 PM	Poster and Demonstration Viewing
3:20 PM	**- 4:35 PM**	**Session 3 continued**
4:35 PM		End of Day
6:00 PM	- 9:30 PM	Evening Cruise of San Diego Harbor

Tuesday, April 9, 2013

7:30 AM	- 8:00 AM	Registration and Continental Breakfast
8:00 AM	- 8:50 AM	Keynote Speaker
8:50 AM	**- 9:40 AM**	**Session 4: Emission Trends and Modeling**
9:40 AM	- 10:20 AM	Poster and Demonstration Viewing
10:20 AM	**- 11:05 AM**	**Session 4 continued**
11:05 AM	**- 12:10 PM**	**Session 5: Laboratory Measurement Method Development**
12:10 PM	- 1:40 PM	Lunch
1:40 PM	**- 2:55 PM**	**Session 5 continued**
2:55 PM	- 3:25 PM	Poster and Demonstration Viewing
3:25 PM	**- 5:15 PM**	**Session 6: Particulate Matter Characterization**
5:15 PM		End of Day
5:30 PM	- 6:30 PM	Poster Exhibition and Reception

Wednesday, April 10, 2013

7:30 AM	- 8:00 AM	Registration and Continental Breakfast
8:00 AM	**- 10:05 AM**	**Session 7: Off-Road**
10:05 AM	- 10:35 AM	Poster and Demonstration Viewing
10:35 AM	**- 12:10 PM**	**Session 8: Fuel Effects: Spark Ignition**
12:10 PM	- 1:40 PM	Lunch
1:40 PM	**- 3:05 PM**	**Session 9: Fuel Effects: Compression Ignition**
3:05 PM	- 3:25 PM	Open Discussion
3:25 PM		End of Workshop

Welcome Sunday, April 07, 2013

4:30-6:00 pm	**Registration in Bayview Ballroom Foyer and Poster Setup in Mission Ballroom**
6:00-7:00 pm	**Welcome Reception in the Cabanas**

DAY ONE Monday, April 08, 2013

All sessions take place in Bayview Ballroom unless otherwise noted.

7:30 AM	**Registration in Bayview Ballroom Foyer** Continental Breakfast in Mission Ballroom
8:30 AM	Welcome from the Chairs: Mani Natarajan, Marathon Petroleum Co., and Dominic DiCicco, Ford Motor Co.

SESSION 1: Emission Rates and Inventory

8:40 AM	*Introduction by Session Leaders Henry Hogo, South Coast Air Quality Management District, and John Koupal, Eastern Research Group*		
■ 8:45 AM	Black Carbon and Primary Organic Aerosol Emissions From On-Road Gasoline and Diesel Vehicles	Robert Harley	University of California Berkeley
■ 9:00 AM	Trends in Heavy-Duty Truck Emissions in the South Coast Air Basin	Gary Bishop	University of Denver
■ 9:15 AM	Cold Temperature Measurement of Particulate and Gaseous Emissions from Tier 2 MSAT Vehicles	David Hawkins	U.S. Environmental Protection Agency
■ 9:30 AM	Characterization of Drayage Activities at the Port of Houston	Carl Fulper	U.S. Environmental Protection Agency
■ 9:45 AM	Integrated Emissions from 938 Heavy-Duty Vehicles under Realistic Driving Conditions in Vancouver Canada	Don Stedman	University of Denver
10:00 AM	General Discussion of Session 1		

10:15 AM Poster Session and Demonstrations in Mission Ballroom *(see Pages 10-12 for Listings)*

SESSION 2: Emissions Control Measures and Emerging Technologies

10:55 AM	*Introduction by Session Leader Jorn Herner, California Air Resources Board*		
■ 11:00 AM	Phase 2 of the Advanced Collaborative Emissions Study (ACES): Highlights of Project Finding	Imad Khalek	Southwest Research Institute
■ 11:15 AM	Summary of Heavy-Duty Diesel Vehicle Selective Catalytic Reduction (SCR) Performance: Lessons to Date	John Collins	California Air Resources Board
■ 11:30 AM	The Air Quality Impacts of Trains in London Paddington Station	Uven Chong	University of Cambridge
■ 11:45 AM	Investigation on the Effect of Injection System Parameters on Emission Characteristics During Low Temperature Combustion Using Response Surface Methodology	Mario Velardi	West Virginia University

12:00 PM Lunch in Red Marlin Restaurant

■	1:30 PM	Quantification of Perturbation Effects on an Alternative Ignition System	Greg Yoder	West Virginia University
■	1:45 PM	Bivento.org - An Online Platform to Manage Real Traffic Emissions	Francisco Gala	Bivento-Technet
	2:00 PM	General Discussion of Session 2		

SESSION 3: I/M and In-Field Measurement Method Development

	2:15 PM	*Introduction by Session Leader Phil Heirigs, Chevron Global Downstream*		
■	2:20 PM	Assessing the Prevalence and Emissions Impact of High Emitters in California	Sherrie Sala-Moore	California Air Resources Board
■	2:35 PM	Results of Field Study of On-Board Diagnostic (OBD) Evaporative Codes	Carl Fulper	U.S. Environmental Protection Agency
	2:50 PM	**Poster and Demonstration Viewing in Mission Ballroom** *(see Pages 10-12 for Listings)*		
■	3:20 PM	Characterizing Emissions Reduction Performance and Test Methods of In-Use Diesel Retrofit Technologies from the National Clean Diesel Campaign	Britney McCoy	U.S. Environmental Protection Agency
■	3:35 PM	Synchronization of Portable Emissions Measurements Systems Data	Chris Frey	North Carolina State University
■	3:50 PM	Establishment of the PEMS-M Instrumentation Specifications for the In-Service Conformity of HDE in Europe	Athanasios Mamakos	Southwest Research Institute
■	4:05 PM	Evaluation, Quantification, and Performance of Accurate In-Use Fuel Economy Measurements	Kent Johnson	University of California, Riverside (CE-CERT)
	4:20 PM	General Discussion of Session 3		
	4:35 PM	**END OF DAY**		
	6:00 PM	Evening cruise of San Diego Harbor - meet in front of hotel lobby to board coaches. LAST BUS LEAVES AT 6:10 PM		

DAY TWO Tuesday, April 09, 2013

	7:30 AM	**Registration in Bayview Ballroom Foyer**		
		Continental Breakfast in Mission Ballroom		
	8:00 AM	KEYNOTE SPEAKER		

SESSION 4: Emission Trends and Modeling

	8:50 AM	*Introduction by Session Leader Megan Beardsley, U.S. Environmental Protection Agency*		
■	8:55 AM	Improving the Accuracy of Modeling Compressed Natural Gas Transit Buses in MOVES	Andrew Eilbert	U.S. Environmental Protection Agency
■	9:10 AM	Projecting 2025 California Light-Duty Vehicle Fleet Emissions -- MOVES, EMFAC, and Suggested Updates	Robert Sawyer	University of California, Berkeley
■	9:25 AM	Current Analysis and Potential Updates to the EMFAC Model in California	Sam Pournazeri	California Air Resources Board
	9:40 AM	Poster and Demonstration Viewing in Mission Ballroom *(see Pages 10-12 for Listings)*		
■	10:20 AM	Updated Emissions Estimates for Pleasure Craft and Recreational Vehicles in California	David Chou	California Air Resources Board
■	10:35 AM	Development of a Simplified Version of MOVES and Incorporation into a Traffic Simulation Model	Chris Frey	North Carolina State University
■	10:50 AM	General Discussion of Session 4		

SESSION 5: Laboratory Measurement Method Development

	11:05 AM	*Introduction by Session Leaders Kevin Black, Federal Highway Administration, and Matt Thornton, NREL*		
■	11:10 AM	Low PM Mass Assessment and Analysis E-99	Kent Johnson	University of California, Riverside (CE-CERT)
■	11:25 AM	An Analysis of Sub 1 mg/mi PM Mass from Light-Duty Vehicles	Jim Watson	California Air Resources Board
■	11:40 AM	A New Laboratory Method for Very Low Particular Mass Emissions Measurement	Jonathan Bushkuhl	AVL North America
■	11:55 AM	Particle Generator for Engine Exhaust Simulation	Imad Khalek	Southwest Research Institute
	12:10 PM	Lunch in Red Marlin Restaurant		
■	1:40 PM	Optimization of the Pegasor Particle Sensor for Automotive Exhaust Measurements	Leonidas Ntziachristos	Aristotle University
■	1:55 PM	Toward the Inclusion of FT-IR in the Certification of Engine Emissions for Both Standard and Alcohol-Based Fuel Blends	Richard Frazee	AVL North America
■	2:10 PM	Real-time Measurements of Metallic Ash Emissions from Engines	David Kittelson	University of Minnesota
■	2:25 PM	Impact of Modern Diesel Engine and Aftertreatment Technology on Test Repeatability and Emissions Prediction	Nigel Clark	West Virginia University CAFEE
	2:40 PM	General Discussion of Session 5		

2:55 PM **Poster and Demonstration Viewing in Mission Ballroom** *(see Pages 10-12 for Listings)*

SESSION 6: Particulate Matter Characterization

3:25 PM	*Introduction by Session Leader Rob Graze, Caterpillar, Inc.*		
3:30 PM	Real-time DPF Filtration Efficiencies and Particle Number Emissions from Modern Diesel and Dual-Fueled HD Engines	Marc Besch	West Virginia University
3:45 PM	Morphology and Nanostructures of Particulates from an Engine-Simulating Particle Generator	Heeje Seong	Argonne National Laboratory
4:00 PM	Study of Variability in Particulate Mass Measurement and Comparison with Particle Number Count Measurement Method	Pragalath Thiruvengadam	West Virginia University
4:15 PM	Quantifying Particulate Matter Emissions from Gasoline and Diesel Vehicles: Gas Particle Portioning and Sampling Artifacts	Albert Presto	Carnegie Mellon University
4:30 PM	Physiochemical and Toxicological Properties of Size Segregated PM Emissions from a 2010 Compliant Heavy-Duty Diesel Truck - Is Diesel PM Still Diesel PM?	Jorn Herner	California Air Resources Board
4:45 PM	Investigation of Particle Size Distributions in a Exhaust Plume Emitted by Heavy-Duty Diesel Trucks at Cruise and Idling Operations	Presented by Mario Velardi for Daniele Littera	West Virginia University
5:00 PM	General Discussion of Session 6		

5:15 PM **END OF DAY**

5:30 PM **Poster Exhibition and Reception in the Mission Ballroom** (5:30-6:30 pm)

DAY THREE Wednesday, April 10, 2013

	7:30 AM	**Registration in Bayview Ballroom Foyer** Continental Breakfast in Mission Ballroom		

SESSION 7: Off-Road

	8:00 AM	*Introduction by Session Leader Alberto Ayala, California Air Resources Board*		
■	8:05 AM	Load Factors, Emission Factors, Duty Cycles, and Activity of Diesel Nonroad Vehicles	Tim DeFries	Eastern Research Group
■	8:20 AM	Emission Factors from In-Use Non-Road Construction Equipment Using 1065 Compliant PEMS	Tanfeng (Sam) Cao	University of California, Riverside (CE-CERT)
■	8:35 AM	Remote Sensing Measurements of In-Use Locomotive NOx Emissions	Matthew Breuer	University of Puget Sound
■	8:50 AM	Projected Growth for Ocean-Going Vessels	Louis Browning	ICF International
■	9:05 AM	Evaluation of Hybrid Retrofit System for a Tugboat	Nicholas Gysel	University of California, Riverside (CE-CERT)
■	9:20 AM	In-Use Measurement of Passenger Diesel Locomotive Emissions for Biodiesel and Petroleum Diesel Fuels	Christopher Frey	North Carolina State University
■	9:35 AM	Particulate Matter and Other Criteria Pollutants Reduced by Algae Fuels in Marine Vessels	Yusuf Khan	University of California, Riverside (CE-CERT)
	9:50 AM	General Discussion of Session 7		

10:05 AM Poster and Demonstration Viewing in Mission Ballroom *(see Pages 10-12 for Listings)*

SESSION 8: Fuel Effects: Spark Ignition

	10:35 AM	*Introduction by Session Leader Tom Long, U.S. Environmental Protection Agency*		
■	10:40 AM	Characterization of Particular Matter Emissions from Light-Duty Vehicles Technologies Using Physical, Chemical and Cellular Assays	Satya Sardar	California Air Resources Board
■	10:55 AM	Effects of Five Gasoline Properties on Exhaust Emissions from Light-Duty Tier 2 Vehicles	Aron Butler	U.S. Environmental Protection Agency
■	11:10 AM	Effects of Fuel Sulfur Level on Emissions from Tier 2 Vehicles in the In-Use Fleet	Aron Butler	U.S. Environmental Protection Agency
■	11:25 AM	Criteria Emissions, Toxic Pollutants, and Particle Number Emissions from Gasoline PFI and GDI Vehicles Operated on Ethanol and Isobutanol Blends	Daniel Short	University of California, Riverside (CE-CERT)
■	11:40 AM	A Comprehensive Evaluation of PM, NOx, Ammonia, and Greenhouse Gas Emissions from Current Model Year Heavy-Duty Vehicles	Arvind Thiruvengadam	West Virginia University
	11:55 AM	General Discussion of Session 8		

12:10 PM Lunch in Red Marlin Restaurant

SESSION 9: Fuel Effects: Compression Ignition

1:40 PM	*Introduction by Session Leader Mani Natarajan, Marathon Petroleum Company*		
■ 1:45 PM	Biodiesel and Renewable Diesel Characterization and Testing in Modern LD Diesel Passenger Cars and Trucks and HD Engines	Georgios Karavalakis	University of California, Riverside (CE-CERT)
■ 2:05 PM	Emissions, Fuel Economy and Duty Cycle Testing and Analysis of Hybrid Electric Trucks Operating in the California Fleet	Matthew Thornton	National Renewable Energy Laboratory
■ 2:20 PM	Hybrid and Electric Bus Emissions and Energy Test Program in South America	Sebastian Tolvett	Sistemas Sustentables
2:35 PM	General Discussion of Session 9		

2:50 PM **Open discussion - Mani Natarajan and Dominic DiCicco, Chairmen**

3:26 PM **END OF Workshop**

Poster Exhibits

Emission Rates and Inventory

Measurement of Regulated and Greenhouse Gas Emissions from In-Use Vehicle Activity during a Cross-Continental Trip	Hemanth Kappanna [presented by Pragalath Thirvengadam]	West Virginia University
On-Board Measurement of Reduced-Nitrogen Emissions from Vehicles during Real-World Driving	John Moss	Oak Crest Institute of Science
Technology Significantly Lowers Emissions from Yard Tractors over Past 10 Years	Poornima Dixit	University of California, Riverside (CE-CERT)
Benchmarking Vehicle Fleet Performance: Real World Monitoring as an Everyday Activity	Stephen Hanley	University of Leeds Institute for Transport Studies
Emissions of Air Toxic Species from Light-Duty Vehicles with Gasoline Direct Injection (GDI) and Port Fuel Injection (PFI) Engines	Oliver Chang	California Air Resources Board
Idling Emissions from Recent Model Year Heavy-Duty Diesel Vehicles	Doh-Won Lee (presented by Josias Zietsman)	Texas A&M Transportation Institute
Contribution of Cold Starts to Real-World Total Trip Emissions for Light-Duty Gasoline Vehicles	Chris Frey	North Carolina State University

Emission Control Measures and Emerging Technologies

Exhaust Emissions Reductions Using a Seawater Scrubber on a Container Ship	Andrew Burnette	Infowedge
In-Use NOx Emissions from 2010 or Newer Heavy-Duty Diesel Engines Equipped with OEM Aftertreatment Devices	Chandan Misra [presented by John Collins]	California Air Resources Board
Update on Pase 2 of the Advanced Collaborative Emissions Study (ACES Phase 2)	Chris Tennant	Coordinating Research Council

I/M and In-Field Measurement Methods

Results of the TEDDIE Project and Future Developments Concerning Emissions Testing in Europe EmissionCheck 2020	Hans Juergen Maeurer	DEKRA Automobil GmBH Germany
Operational Challenges Faced During Vehicle Emissions Testing in Hong Kong	Kwok-Lam Ng	Hong Kong Environmental Protection Department
Evidence of Flipper Vehicles in Arizona Random Sample Triplicate IM147 Data	Tom Wenzel	Lawrence Berkeley National Laboratory
Ultrafine Particle Measurements and Evaluation of the Mobile Source Contribution in New York City	Robert Anderson	TSI, Inc.

Comparison of a Portable FTIR with SEMTECH-DS under Real-World Urban Driving Conditions	Eddie Lo	Hong Kong Environmental Protection Department
Relative Amounts of Gases in Exhaust Plumes by Laser Remote Sensing	Stewart Hager	HEAT, LLC
Off-Cycle Light-Duty Diesel Vehicle Emissions Measurement with PEMS: Project Description and Preliminary Data	Marc Besch	West Virginia University

Emission Trends and Modeling

Methodology to Predict Real World Aerodynamic Drag Losses Due to On-Road Cross-Wind Effects	Nigel Clark	West Virginia University

Laboratory Measurement Methods Development

An Analysis of Light-Duty Vehicle PM Data Generated in CARB HSL Cell 2 and Cell 3	Mang Zhang	California Air Resources Board
Time-Resolved FTIR Measurements of Non-Methane Organic Gases (NMOG) in Vehicle Exhaust Gas	Christine Gierczak	Ford Motor Company
Pulse Height Monitor to Improve Data Reliability of Condensation Particle Counter for Engine Emission Applications	Tim Johnson	TSI, Inc.
Measurement of Dioxin Formation in Heavy-Duty Diesel Engines	Robert Fanick	Southwest Research Institute
~~Variability of PM Mass Measurement for Two Sub 1 Mg/Mi Vehicles~~ (withdrawn)	~~Satya Sardar~~	~~California Air Resources Board~~
Onsite Checks on Particle Number Equipment	Manfred Linke	AVL List GmbH

Particulate Matter Characterization

Determination of Suspended Exhaust PM Mass for Light-Duty Vehicles	Heejung Jung	University of California Riverside (CE-CERT)
Insight Into Detailed Properties of Nano-Particles from Various Engine Combustion Sources	Kyeong Lee	Argonne National Laboratory

Off-Road

Real-World In-Use Tailpipe Emissions Measurements of Over the Snow Vehicles at Yellowstone National Park	Christopher Frey	North Carolina State University
Hybrid Off-Road Equipment Evaluation: Part 1 - Duty Cycle Development	Tangfeng (Sam) Cao	University of California Riverside (CE-CERT)

Techniques for the Convenient Off-Road Monitoring an dEnforcement of Heavy-Duty Vehicle Exhaust Emissions	Peter McClintock	Applied Analysis
Characterization of Real-World Emissions from Heavy Haulers in Canadian Oil Sands Mining	Xiaoliang Wang	Desert Research Institute

Fuel Effects: Compression Ignition

Effect of Biodiesel Feedstock on Regulated Emissions, Gaseous Toxics, and Ultrafine Particles from Two Trucks Fitted With and Without Aftertreatment Controls	Nicholas Gysel	University of California Riverside (CE-CERT)

Fuel Effects: Spark Ignition

Impact of Natural Gas Fuel Composition on Criteria and Toxic Emissions from Transit Buses	Maryam Hajbabaei	University of California Riverside (CE-CERT)

Demonstrations

TSI Engine Emissions Solutions	Tim Johnson Bob Anderson	TSI, Inc.
Photoacoustic Measurement of Black Carbon Emissions	Gavin McMeeking	Droplet Measurement Technologies
Particle Mass and Particle Number Measurement for Automotive Engine and Aircraft Turbine Applications	Siegfried Roeck	AVL
RDE Real Driving Emissions Measurement with AVL PEMS Equipment*	Siegfried Roeck	AVL
Sensors, Inc.	Robert Wilson	Sensors, Inc.
Dekati and Pegasor Instruments for PM Sampling, Conditioning, and Analysis	Tyler Beck	Particle Instruments
Real-World Emissions Testing Based on FTIR Technology	Ron Tandy	A&D Technology

*This demonstration is located in the parking lot outside the ballroom.

■ Mani Natarajan, Co-Chairman, Marathon Petroleum Company

Mani Natarajan is currently working at Marathon Petroleum Company as a Fuels Technology Advisor. He is leading a CRC project on biodiesel and renewable diesel characterization in modern LD diesel passenger cars and trucks. He is currently the co-chairman of the CRC Real World Emissions and Emissions Modeling Group. He is a member of the CRC Emissions Committee, CRC AVFL Committee, CRC Atmospheric Impacts Committee and API Vehicle Emissions Group. Over the past 23 years, he has been very active in CRC and API projects, conducting fuels/emissions-related research. He has a B.S and M.S. in Chemistry and a M.S. and Ph.D. in Chemical Engineering. He was an Associate Professor at the College of Engineering, The University of Toledo. Previously, as Manager of Research at Surface Combustion, he led projects in advanced combustion, renewable energy and heat treatment. He was a consultant for Pratt & Whitney in the super alloy manufacturing development of the Integrally Bladed Rotors (IBR) for jet engines. He is a member of SAE, AIChE and ACS.

■ Dominic DiCicco, Co-Chairman, Ford Motor Company

Dominic DiCicco was recently appointed to the position of Environmental Policy Manager in the Sustainability and Vehicle Environmental Matters Division at Ford Motor Company. His new role involves supporting the execution of Ford Motor Company's strategic product plans as well as topics of mutual interest on improving fuel quality and regulations, requiring interaction with the US Environmental Protection Agency (US EPA), California Air Resources Board (CARB) and other government entities around the world. Mr. DiCicco is the co-chairman of the CRC Real World Emissions and Emissions Modeling Group and serves as a member on both the CRC Emissions Committee and CRC AVFL Committee. He is a Ford representative on the Fuels Working Group of United States Council for Automotive Research (USCAR), the Alliance of Automobiles and other industry-related efforts. Recent and past major projects have included key roles in working towards the successful reduction in sulfur content in fuels, elimination of manganese across the Canadian marketplace and more recently in the evaluation of mid-level ethanol blends (such as E15 and E20). His career with Ford Motor Company is nearly 20 years young, more than half this time supporting fuels after starting at the Ford Research Laboratory in the Chemical Engineering Department researching exhaust emission catalytic systems. Mr. DiCicco holds a M.S. and B.S. in Chemical Engineering and a B.A. in Chemistry, all from Wayne State University.

Session Leaders

■ Alberto Ayala, California Air Resources Board

Alberto Ayala was appointed as Deputy Executive Officer of the California Air Resources Board at the end of 2012. In this capacity, Alberto is responsible for the Board's ambient monitoring and laboratories and mobile source control and operations programs. Alberto became a member of CARB's research staff in 2000 and has since held various management assignments in programs such as Carl Moyer Incentives, AB 32 early actions, mobile refrigerant rules, diesel retrofits, and car, truck, and bus emissions research. Most recently he served as Chief of the Monitoring and Laboratory Division. Alberto oversees the full range of policy, regulatory, and research efforts of over 400 professionals focused on achieving CARB's goals for clean, zero-emission, and low-carbon transportation; state-of-the-art monitoring for air and climate pollution; and a widely recognized motor vehicle emissions and fuels testing program. He contributed to the first car GHG emissions regulation in 2004 and is now directing one of CARB's most important efforts, the advanced clean cars program.

Prior to CARB, Alberto was a member of the engineering faculty at West Virginia University, where he now holds an adjunct appointment, and was an ordnance system design engineer for Teledyne Ryan Aeronautical. He holds B.S., M.S., and Ph.D. degrees in Mechanical Engineering from the University of California, Davis. His internships were with GE, the California Energy Commission, and the Atmospheric Boundary Layer Wind Tunnel Laboratory at UC Davis. He has published extensively, been a speaker nationally and internationally, and lectured as a Visiting Professor in California and abroad.

■ Megan Beardsley, US Environmental Protection Agency OTAQ

Megan Beardsley is an environmental scientist in the Air Quality & Modeling Center within the Assessment and Standards Division of EPA's Office of Transportation and Air Quality. Her group is responsible for the development of mobile source models, including MOVES and NONROAD, and supporting EPA programs and policies through emissions and activity research, policy analysis, emissions inventory development and air quality modeling support. Megan has worked for EPA since 1992. She has an interdisciplinary B.S. from Stanford University and an M.S. in Resource Policy from the University of Michigan.

■ Kevin Black, Federal Highway Administration

Kevin Black is a Highway Engineer working as an Air Quality Analyst on air quality issues for the Federal Highway Administration's Resource Center in Baltimore. He has a B.A. in Geography from George Mason University, a B.S. in Civil Engineering from Virginia Tech and an M.S. in Civil Engineering from George Mason University. He has worked in several offices within FHWA, including the Office of Research, the Office of Engineering, the Office of Natural and Human Environment, and currently the Resource Center. His present position is responsible for analyzing the environmental impacts of air pollutants in support of FHWA air quality policy.

■ R. Rob Graze, Jr., Caterpillar, Inc. Technical Center

Rob Graze is degreed in Physics with additional study in Mechanical Engineering. His Research Background includes work in the areas of tribology, lube system and bearing design, diesel and large SI engine combustion development , particulate and gaseous emissions measurement, and partial flow dilution system design and refinement.

■ Philip Heirigs, Chevron Global Downstream

Phil Heirigs, a native of California, holds a B.S. in Engineering and a M.S. in Chemical Engineering from the University of California, Los Angeles, and is a licensed Professional Engineer in the state. His professional career began with a short stint in the nuclear power industry, which was followed by nearly seven years with the California Air Resources Board. Mr. Heirigs then spent 15 years at Sierra Research, a Sacramento-based consulting firm. In June 2007, Mr. Heirigs joined Chevron, where his key responsibilities have included the analysis of issues related to the life cycle assessment of transportation fuels, vehicle fuel economy, advanced vehicle technologies and costs, transportation fuel demand, the impact of fuel specification changes on vehicle emissions, and vehicle emissions modeling.

■ Jorn Dinh Herner, California Air Resources Board

Jorn Herner has worked for the last eight years at the California Air Resources Board. In his current position as Chief of the Research Planning and Emission Mitigation Branch in the Research Division, he oversees the division's extramural research program, the implementation of measures to reduce greenhouse gases, and the vehicle emissions research program. His main research interests are the effect of new emission control technologies and fuels and the relative toxicity of emissions from various combustion sources. Jorn has a B.A. and M.S. from the University of California, Berkeley, and earned his Ph.D. in Civil and Environmental Engineering from the University of California, Davis.

■ Henry Hogo, South Coast Air Quality Management District

Henry Hogo is the Assistant Deputy Executive Officer for the Mobile Source Division in the Office of Science and Technology Advancement at the South Coast Air Quality Management District (SCAQMD). Mr. Hogo received a Bachelor of Science degree in chemistry from the University of California, Berkeley, and has been working in the air pollution field for over 35 years. As Assistant Deputy Executive Officer in the Mobile Source Division, Mr. Hogo is responsible for the implementation of the District's Clean Fleet Vehicle Rules, development of mobile source strategies for the SCAQMD's air quality management plans, analysis of mobile source emissions impacts on air quality, and providing input on state and federal mobile source regulations.

■ John Koupal, Eastern Research Group

John Koupal is a Principal Engineer with Eastern Research Group, Inc. (ERG) with over twenty years of experience in mobile source emission research, policy, modeling and inventory development in the U.S. and abroad. Prior to joining ERG, Mr. Koupal served many roles within the U.S. EPA's Office of Transportation and Air Quality, including directing the group responsible for mobile source modeling and emission inventory development, providing technical and analytical support for several EPA rules, and leading the development of the MOVES model. Mr. Koupal worked for Nissan from 1995-1997 on emissions certification and regulatory issues. Mr. Koupal was named to the Advisory Committee on the National Mobile Source Emission Inventory of China in 2010, and the Board of Advisors for UC Riverside?s Center for Environmental Research and Technology (CE-CERT) in 2012. Mr. Koupal graduated from the University of Michigan with a Bachelor's Degree in Industrial and Operations Engineering in 1989.

■ Tom Long, US Environmental Protection Agency NRMRL

Tom Long received his M.S. in Engineering from West Virginia University, where he worked with Nigel Clark on the design of the first heavy-duty mobile dynamometer. Later, he served as the West Coast Coordinator for West Virginia's Center for Alternative Fuels, Engines, and Emissions (CAFEE). After working as a contractor to the U.S. EPA in RTP, North Carolina, Tom was hired by the government to coordinate the dynamometer facility operated by the EPA's Office of Research and Development. His area of research includes the measurement of mobile source emissions using both stationary and chassis dynamometer, PEMS, and near road stationary sites. He is particularly interested in fuel and temperature effects on the quantity and characteristics of mobile source emissions.

■ Matthew Thornton, National Renewable Energy Laboratory

Matt Thornton is a principal research engineer at the National Renewable Energy Laboratory. He received his Ph.D. from Georgia Institute of Technology. He is involved in testing and analysis research programs that assess the fuel economy and performance impacts of advanced fuels and powertrains for light- and heavy-duty vehicles, and is currently the acting director for NREL's Center for Transportation Technologies and Systems.

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ATTACHMENT C

Comments of Growth Energy on the Air Resources Board Staff Presentations at a Public Consultation Meeting on Regulations for Commercialization of Alternative Diesel Fuels

These comments respond to the CARB staff's request for comments on the staff's presentations at the April 17, 2014 public consultation meeting on the proposed adoption of regulations to govern commercialization of alternative diesel fuels, including as part of compliance strategies for the California low-carbon fuel standard ("LCFS") regulation.

1. CARB-Sponsored and Related Emissions Testing and Research

During the April 17th meeting, CARB staff indicated that the agency had an "ongoing" study of the emission impacts of B5 and B10 blends underway and that data from that study would be released to the public and incorporated into the rulemaking process. Incorporation of this data into the rulemaking process is essential in order to comply with the Global Warming Solutions Act of 2006 and other statutes that apply to CARB's implementation of the 2006 Act.[1] CARB must provide not only a full report on that study, but also all data that it has obtained in connection with the study and related materials. Nearly four weeks have passed since the April 17th public meeting and, to Growth Energy's knowledge, the CARB staff has not met its commitments.[2] Growth Energy and other stakeholders will need sufficient time to review the data and related materials in order to participate effectively in the ADF and LCFS rulemakings. Also during the course of the workshop, CARB staff indicated that two other agency-sponsored studies of biodiesel blends had been conducted but not yet released to the public. Again, all

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1 *See, e.g.*, Cal. Health & Safety Code § 38562(e) ("The state board shall rely upon the best available … scientific information … when adopting regulations required by this section."); *see also id.* § 38563(b)(4) (regulations to implement the 2006 Act must not "interfere with[] efforts to achieve and maintain federal and state ambient air quality standards."). The California Environmental Quality Act's requirements likewise cannot be met unless CARB considers all relevant data on the potential of biodiesel usage to increase NOx emissions.

2 Much of the data from this study and related materials may also be responsive to a Public Records Act request that Growth Energy has filed with CARB, but no data and very few related materials have been released to date.

reports as well as underlying data and other relevant materials must be made publicly available. All these materials, from each study, must be placed in a public rulemaking file without further delay, pursuant to subsections 6 and 7 of section 11347.3(a) of the Government Code.

2. Methodology to Establish a Significance Threshold and Related Issues

To date, CARB staff has indicated that it has attempted to identify a significance threshold for biodiesel blends by comparing emissions results when engines are tested on nominally specific biodiesel blends, and when the same engines are tested in similar ways on fuel containing no diesel. The defect in such a method is that it does not permit assessment of emissions when engines are operated on biodiesel blends other than those tested, including, for example, biodiesel blends below B5. The appropriate method to determine the significance threshold is contained in an analysis prepared for Growth Energy by Mr. Robert Crawford and placed in the rulemaking file last year.[3] After evaluating the linearity and statistical significance of the relationship between NOx emissions and biodiesel content, Mr. Crawford demonstrates that use of biodiesel even at levels below B5 will result in increased NOx emissions. CARB should adopt Mr. Crawford's approach to establishing the significance threshold for biodiesel, or explain in full any reasons for not doing so.

Despite the fact that CARB staff has correctly chosen to propose mitigation of biodiesel NOx impacts on a per-gallon basis in extreme ozone non-attainment areas, this issue is important because the use of the current methodology for establishing the significance level will not prevent significant increases in NOx emissions in these areas.

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3 Crawford, R., "NOx Emission Impact of Soy- and Animal-based Biodiesel Fuels: A Re-Analysis," December 10, 2013.

3. Protection of the Environment on a Statewide Basis

Based on the presentation at the recent public consultation meeting, CARB staff continues to propose the highly flawed "effective blend" approach for determining the point at which mitigation of biodiesel NOx impacts would be required under the proposed ADF regulation. Instead, CARB staff should also require the per-gallon mitigation concept proposed for extreme ozone nonattainment areas and the appropriate significance threshold to be used in all other areas of the state.

4. Minimum Requirements to Determine and Report Blend Levels

The CARB staff's presentation at the recent meeting did not clarify how the proposed ADF regulation will ensure that the biodiesel content of blends sold in California will be accurately known to fuel purchasers or reported to CARB. At present, CARB appears to have no requirement for determining the biodiesel content of diesel fuels being imported or distributed in the state that contain biodiesel up to the B5 level. Given this, a party interested in blending 5% biodiesel into a "diesel" fuel may be unaware of the fact that the "diesel" fuel could already contain up to 5% biodiesel and that the resulting blend would therefore be B10, not B5. Similarly, a party interested in blending 20% biodiesel into a "diesel" could in fact produce a B25 blend, instead of the intended B20 blend. Obviously, both circumstances have substantial ramifications with respect to potential NOx increases associated with the use of biodiesel in California.

Given the above, CARB must modify as necessary its existing diesel fuel regulations as well as the proposed ADF regulations to ensure that the biodiesel content of all blends of biodiesel and diesel sold in California is accurately known and reported to both CARB as well as the Division of Measurement Standards. This could easily be accomplished by requiring that all "diesel" fuels used in biodiesel blends be tested before blending for Fatty Acid Methyl Ester ("FAME") content using appropriate test procedures such as the EN14103:2011 procedure already referenced in the proposed ADF regulations or the ASTM D7371 procedure. Alternatively, CARB could require testing of final blends for FAME content. Again, failure by CARB to require accurate measurement and reporting of the biodiesel content of biodiesel-diesel blends will lead to unmitigated increases in NOx emissions along with other potential issues, including violations of pump labeling and vehicle manufacturer warranty requirements.

Respectfully submitted,

GROWTH ENERGY

NOx Emissions Impact of Soy- and Animal-based Biodiesel Fuels: A Re-Analysis

December 10, 2013

Prepared for:

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Prepared by:

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NOX EMISSIONS IMPACT OF SOY- AND ANIMAL-BASED BIODIESEL FUELS: A RE-ANALYSIS

prepared for:

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December 10, 2013

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NOX IMPACT OF SOY- AND ANIMAL-BASED BIODIESEL FUELS: A RE-ANALYSIS

Table of Contents

Page

List of Tables

List of Figures

1. EXECUTIVE SUMMARY

1.1 Background on the Proposed Rule

The California Air Resources Board (CARB) has proposed regulations on the commercialization of alternative diesel fuel (ADF) that were to be heard at the December 2013 meeting of the Board. The proposed regulations seek to "… create a streamlined legal framework that protects California's residents and environment while allowing innovative ADFs to enter the commercial market as efficiently is possible."[1] In this context ADF refers to biodiesel fuel blends. Biodiesel fuels are generally recognized to have the potential to decrease emissions of several pollutants, including hydrocarbons (HC), carbon monoxide (CO), and particulate matter (PM), but are also recognized to have the potential to increase oxides of nitrogen (NOx) unless mitigated in some way. NOx emissions are an important precursor to smog and have historically been subject to stringent emission standards and mitigation programs to prevent growth in emissions over time. A crucial issue with respect to biodiesel is how to "… safeguard against potential increases in oxides of nitrogen (NOx) emissions."[2]

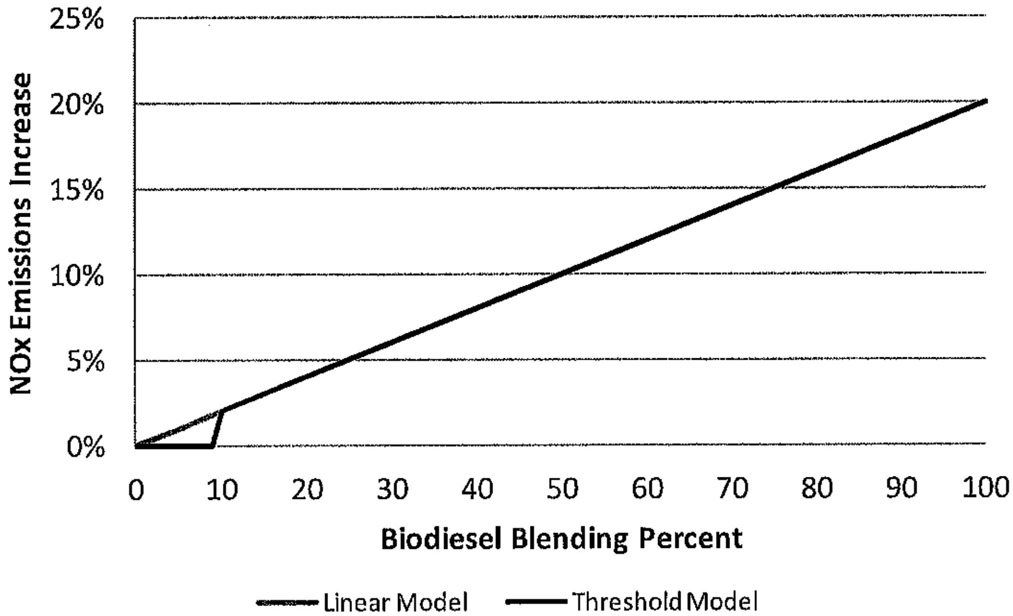
The proposed regulations are presented in the Staff Report: Initial Statement of Reasons (ISOR) for the Proposed Regulation on the Commercialization of New Alternative Diesel Fuels[3] (referenced as ISOR). Chapter 5 of the document describes the proposed regulations, which exempt diesel blends with less than 10 percent biodiesel (B10) from requirements to mitigate NOx emissions:

> There are two distinct blend levels relative to biodiesel that have been identified as important for this analysis. Based on our analysis to date, we have found that diesel blends with less than 10 percent biodiesel by volume (<B10) have no significant increase in any of the pollutants of concern and therefore will be regulated at Stage 3B (Commercial Sales not Subject to Mitigation). However, we have found that biodiesel blends of 10 percent and above (≥B10) have potentially significant increases in NOx emissions, in the absence of any mitigating factors, and therefore those higher blend levels will be regulated under Stage 3A (Commercial Sales Subject to Mitigation).[4]

[1] "Notice of Public Hearing to Consider Proposed Regulation on the Commercialization of New Alternative Diesel Fuels." California Air Resources Board, p. 3. http://www.arb.ca.gov/regact/2013/adf2013/adf2013notice.pdf.
[2] Ibid. p. 3.
[3] "Proposed Regulation on the Commercialization of New Alternative Diesel Fuels. Staff Report: Initial Statement of Reason." California Air Resources Board, Stationary Source Division, Alternative Fuels Branch. October 23, 2013. http://www.arb.ca.gov/regact/2013/adf2013/adf2013isor.pdf.
[4] Ibid, p. 22.

Existing research on the NOx emission effects of biodiesel has consistently been conducted under the hypothesis that the emission effect will be linearly proportional to the blending percent of neat biodiesel (B100) with the base diesel fuel. The Linear Model that has been accepted by researchers is shown as the blue line in Figure 1-1. The Staff position cited above is that biodiesel fuels do not increase NOx emissions until the fuel blend reaches 10% biodiesel. This so-called Staff Threshold Model departs from the Linear Model that underlies past and current biodiesel research by claiming that NOx emissions do not increase until the biodiesel content reaches 10 percent.

Figure 1-1
Linear and Staff Threshold Models for Biodiesel NOx Impacts



The Staff Threshold model is justified by the statement: "Based on our analysis to date, we have found that diesel blends with less than 10 percent biodiesel by volume (<B10) have no significant increase in any of the pollutants of concern." Other portions of the ISOR state that Staff will track "... the effective blend level on an annual statewide average basis until the effective blend level reaches 9.5 percent. At that point, the biodiesel producers, importers, blenders, and other suppliers are put on notice that the effective blend-level trigger of 9.5 percent is approaching and mitigation measures will be required once the trigger is reached."[5] Until such time, NOx emission increases from biodiesel blends below B10 will not require mitigation.

Section 6 of the ISOR presents a Technology Assessment that includes a literature search the Staff conducted to obtain past studies on the NOx impact of biodiesel in heavy-duty

[5] Ibid, p. 24.

engines using California diesel (or other high-cetane diesel) as a base fuel. Section 6.d presents the results of the literature search with additional technical information provided in Appendix B. The past studies include the Biodiesel Characterization and NOx Mitigation Study[6] sponsored by CARB (referenced as Durbin 2011).

The results of the Staff literature search are summarized in Table 1-1, which has been reproduced from Table 6.1 of the ISOR. For B5 and B20, the data represent averages for a mix of soy- and animal-based biodiesels, which tend to have different impacts on NOx emissions (animal-based biodiesels increase NOx to a lesser extent). For B10, the data represent an average for soy-based biodiesels only. Staff uses the +0.3% average NOx increase at B5 in comparison to the 1.3% standard deviation to conclude:

> Overall, the testing indicates different NOx impacts at different biodiesel percentages. Staff analysis shows there is a wide statistical variance in NOx emissions at biodiesel levels of B5, providing no demonstrable NOx emissions impact at this level and below. At biodiesel levels of B10 and above, multiple studies demonstrate statistically significant NOx increases, without additional mitigation.[7]

Table 1-1
Results of Literature Search Analysis

Biodiesel Blend Level	NOx Difference	Standard Deviation
B5	0.3%	1.3%
B10[a]	2.7%	0.2%
B20	3.2%	2.3%

Source: Table 6.1 of Durbin 2011
Notes:
[a] Represents data using biodiesel from soy feedstocks.

<u>The Staff conclusion is erroneous because it relies upon an apples-to-oranges comparison among the blending levels</u>. Each of the B5, B10, and B20 levels include data from a different mix of studies, involving different fuels (soy- and/or animal-based), different test engines, and different test cycles. The B5 values come solely from the CARB Biodiesel Characterization study, while the B10 values come solely from other studies. The B20 values are a mix of data from the CARB and other studies. The results seen in the table above are the product of the uncontrolled aggregation of different studies that produces incomparable estimates of the NOx emission impact at the three blending levels.

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[6] "CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California: Biodiesel Characterization and NOx Mitigation Study." Prepared by Thomas D. Durbin, J. Wayne Miller and others. Prepared for Robert Okamoto and Alexander Mitchell, California Air Resources Board. October 2011.

[7] ISOR, p. 32.

As will be demonstrated in this report, the Staff conclusion drawn from the data in Table 1-1 is not supported by past or current biodiesel research, including the recent testing program sponsored by CARB. In fact, past and current studies indicate that biodiesel blends at any level will increase NOx emissions in proportion to the blending percent unless specifically mitigated by additives or other measures.

1.2 Summary and Conclusions

The following sections of this report examine the studies cited by CARB one-by-one. As evidenced from this review, it is clear that the data do not support the Staff conclusion and, indeed, the data refute the Staff conclusion in some instances. Specifically:

- There is no evidence supporting the Staff conclusion that NOx emissions do not increase until the B10 level is reached. Instead, there is consistent and strong evidence that biodiesel increases NOx emissions in proportion to the biodiesel blending percent.

- There is clear and statistically significant evidence that biodiesel increases NOx emissions at the B5 level in at least some engines for both soy- and animal-based biodiesels.

Considering each of the six past studies obtained from the technical literature and their data on high-cetane biodiesels comparable to California fuels, we find the following:

1. None of the six studies measured the NOx emissions impact from biodiesel at blending levels below B10. Only two studies tested a fuel at the B10 level. All other testing was at the B20 level or higher. Because none tested a B5 (or similar) fuel, none of them can provide direct evidence that NOx emissions are not increased at B5 or other blending levels below B10.

2. These studies provide no data or evidence supporting the validity of the Staff's Threshold Model that biodiesel below B10 does not increase NOx emissions. In fact, all of the studies are consistent with the contention that biodiesel increases NOx emissions in proportion to the blending percent.

3. Two of the studies present evidence and arguments that the NOx impact from biodiesel is a continuous effect that is present even at very low blending levels and will increase at higher levels in proportion to the blending percentage.

Considering the CARB Biodiesel Characterization report, we find that:

4. For the three engines where CARB has published the emission values measured in engine dynamometer testing, all of the data demonstrate that biodiesel fuels significantly increase NOx emissions for both soy- and animal-based fuels by amounts that are proportional to the blending percent. This is true for on-road and off-road engines and for a range of test cycles.

5. Where B5 fuels were tested for these engines, NOx emissions were observed to increase. NOx emission increases are smaller at B5 than at higher blending levels and the observed increases for two engines were not statistically significant by themselves based on the pair-wise t-test employed in Durbin 2011.[8] However, the testing for one of the engines (the 2007 MBE4000) showed statistically significant NOx emission increases at the B5 level for both soy- and animal-based blends.

By itself, the latter result is sufficient to disprove the Staff's contention that biodiesel blends at the B5 level will not increase NOx emissions.

Based on examination of all of the studies cited by CARB as the basis for its proposal to exempt biodiesels below B10 from mitigation, it is clear that the available research points to the expectation that both soy- and animal-based biodiesel blends will increase NOx emissions in proportion to their biodiesel content, including at the B5 level. CARB's own test data demonstrate that B5 will significantly increase NOx emissions in at least some engines.

Based on data in the CARB Biodiesel Characterization report, soy-based biodiesels will increase NOx emissions by about 1% at B5 (and 2% at B10), while animal-based biodiesels will increase NOx emissions by about one-half as much: 0.45% at B5 (and 0.9% at B10). All of the available research says that the NOx increases are real and implementation of mitigation measures will be required to prevent increases in NOx emissions due to biodiesel use at blending levels below B10.

Finally, we note that CARB has not published fully the biodiesel testing data that it relied on in support of the Proposed Rule and thereby has failed to adequately serve the interest of full public disclosure in this matter. The CARB-sponsored testing reported in Durbin 2011 is the sole source of B5 testing cited by CARB as support for the Proposed Rule. Durbin 2011 publishes only portions of the measured emissions data in a form that permits re-analysis; it does not publish any of the B5 data in such a form. It has not been possible to obtain the remaining data through a personal request to Durbin or an official public records request to CARB and, to the best of our knowledge, the data are not otherwise available online or through another source.

CARB should publish all of the testing presented in Durbin 2011 and any future testing that it sponsors in a complete format that allows for re-analysis. Such a format would be (a) the measured emission values for each individual test replication; or (b) averages across all test replications, along with the number of replications and the standard error of the individual tests. The first format (individual test replications) is preferable because that would permit a full examination of the data including effects such as test cell drift over time. Such publication is necessary to assure that full public disclosure is achieved and that future proposed rules are fully and adequately informed by the data.

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[8]As discussed in Section 3.3, the pair-wise t-test is not the preferred method for demonstrating statistical significance.

1.3 Review of 2013 CARB B5 Emission Testing

In December 2013, after the release of the ISOR and in response to an earlier Public Records Act request, CARB released a copy of new CARB-sponsored emission testing conducted by Durbin and others at the University of California CE-CERT[9]. The purpose of the study was "... to evaluate different B5 blends as potential emissions equivalent biodiesel fuel formulations for California."[10] Three B5 blends derived from soy, waste vegetable oil (WVO), and animal biodiesel stocks were tested on one 2006 Cummins ISM 370 engine using the hot-start EPA heavy-duty engine dynamometer cycle. A preliminary round of testing was conducted for all three fuels followed by emissions-equivalent certification testing per 13 CCR 2282(g) for two of the fuels. As noted by Durbin: "[t]he emissions equivalent diesel certification procedure is robust in that it requires at least twenty replicate tests on the reference and candidate fuels, providing the ability to differentiate small differences in emissions."[11]

Soy and WVO B5 Biodiesel

The B5-soy and B5-WVO fuels were blended from biodiesel stocks that were generally similar to the soy-based stock used in the earlier CARB Biodiesel Characterization Study (Durbin 2011) with respect to API gravity and cetane number. In the preliminary testing, the two fuels "...showed 1.2-1.3% statistically significant [NOx emissions] increases with the B5-soy and B5-WVO biodiesel blends compared to the CARB reference fuel."[12] The B5-WVO fuel caused the smaller NOx increase (1.2%) and was selected for the certification phase of the testing. There, it "... showed a statistically significant 1.0% increase in NOx compared to the CARB reference fuel"[13] and failed the emissions-equivalent certification due to NOx emissions.

Animal B5 Biodiesel

The B5-animal derived fuel was blended from an animal tallow derived biodiesel that was substantially different from the animal based biodiesel used in the earlier Durbin study, and was higher in both API gravity and cetane number. The blending response for cetane number was also surprising, in that blending 5 percent by volume of a B100 stock (cetane number 61.1) with 95% of CARB ULSD (cetane number 53.1) produced a B5 fuel blend with cetane number 61.

In preliminary testing, the B5-animal fuel showed a small NOx increase which was not statistically significant, causing it to be judged the best candidate for emissions-equivalent certification. In the certification testing, it "...showed a statistically

[9] "CARBB5 Biodiesel Preliminary and Certification Testing." Prepared by Thomas D. Durbin, G. Karavalakis and others. Prepared for Alexander Mitchell, California Air Resources Board. July 2013. This study is not referenced in the ISOR, nor was it included in the rule making file when the hearing notice for the ADF regulation was published in October 2013.
[10] Ibid, p. vi.
[11] Ibid, p. viii.
[12] Ibid, p. 8.
[13] Ibid, p. 9.

significant 0.5% reduction in NOx compared to the CARB reference fuel"[13] and passed the emissions-equivalent certification. The NOx emission reduction for this fuel blend appears to be real for this engine, but given the differences between the blendstock and the animal based biodiesel blendstock used in the earlier Durbin study it is unclear that it is representative for animal-based biodiesels in general..

Summary

The conclusions drawn in the preceding section are not changed by the consideration of these new emission testing results. For plant-based biodiesels (soy- and WVO-based), the new testing provides additional and statistically significant evidence that B5 blends will increase NOx emissions at the B5 level. The result of decreased NOx for the B5 animal-based blend stands out from the general trend of research results reviewed in this report. However:

- The same result – reduced NOx emissions for some fuels and engines – has sometimes been observed in past research, as evidenced by the emissions data considered by CARB staff in ISOR Figure B.3 (reproduced in Figure 2.1 below). As shown, some animal-based B5 and B20 fuels reduced NOx emissions while others increased NOx emissions with the overall conclusion being that NOx emissions increase in direct proportion to biodiesel content of the blends and that there is no emissions threshold.

- Increasing cetane is known to generally reduce NOx emissions and has already been proposed by CARB as a mitigation strategy for increased NOx emissions from biodiesel[14]. The unusual cetane number response in the blending and the high cetane number of the B5-animal fuel may account for the results presented in the recently released study.

Considering the broad range of plant- and animal-based biodiesel stocks that will be used in biodiesel fuels, we conclude that the available research (including the recently released CARB test results) indicates that unrestricted biodiesel use at the B5 level will cause real increases in NOx emissions and that countermeasures may be required to prevent increases in NOx emissions due to biodiesel use at blending levels below B10.

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[14] For example, see Durbin 2011 Section 7.0 for a discussion of NOx mitigation results through blending of cetane improvers and other measures.

2. CARB LITERA TURE REVIEW

The Staff ISOR explains that the Appendix B Technology Assessment is the basis for CARB's conclusion that biodiesels below B10 have no significant impact on NOx emissions. The assessment is based on data from seven studies (identified in Table 2-1) that tested high-cetane diesel fuels. The first study (Durbin 2011) is the Biodiesel Characterization Study that was conducted for CARB, while the others were obtained through a literature search.

Tab le 2-1
List of Studies from High-Cetane Liter ature Sear ch

Primary Author	Title	Published	Year
Durbin	Biodiesel Mitigation Study	Final Report Prepared for Robert Okamoto, M.S. and Alexander Mitchell, CARB	2011
Clark	Transient Emissions Comparisons of Alternative Compression Ignition Fuel	SAE 1999-01-1117	1999
Eckerle	Effects of Methyl Ester Biodiesel Blends on NOx Emissions	SAE 2008-01-0078	2008
McCormick	Fuel Additive and Blending Approaches to Reducing NOx Emissions from Biodiesel	SAE 2002-01-1658	2002
McCormick	Regulated Emissions from Biodiesel Tested in Heavy-Duty Engines Meeting 2004 Emissions	SAE 2005-01-2200	2005
Nuszkowski	Evaluation of the NOx emissions from heavy duty diesel engines with the addition of cetane improvers	Proc. I Mech E Vol. 223 Part D: J. Automobile Engineering, 223, 1049-1060	2009
Thompson	Neat fuel influence on biodiesel blend emissions	Int J Engine Res Vol. 11, 61-77.	2010

Source: Table B.2 of Durbin 2011

Figure 2-1 reproduces two exhibits from Appendix B that show increasing trends for NOx emissions with the biodiesel blending level. Based on the slopes of the trend lines,

Figure 2-1
NOx Emission Increases Observed in Biodiesel Research Cited in Staff ISOR

Figure B.2: NOx Impact of Soy Biodiesel Blended in High Cetane Base Fuel

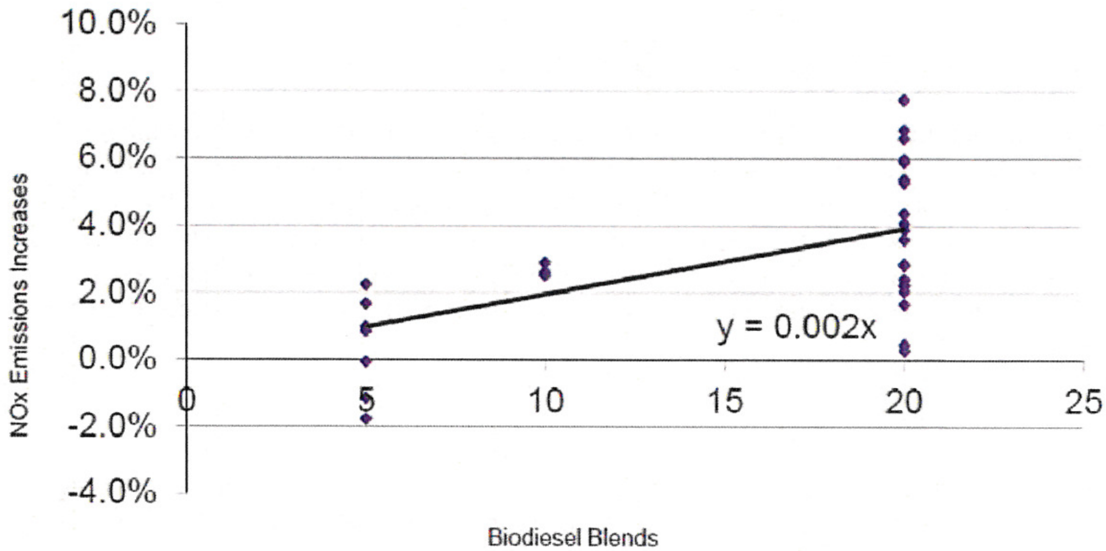
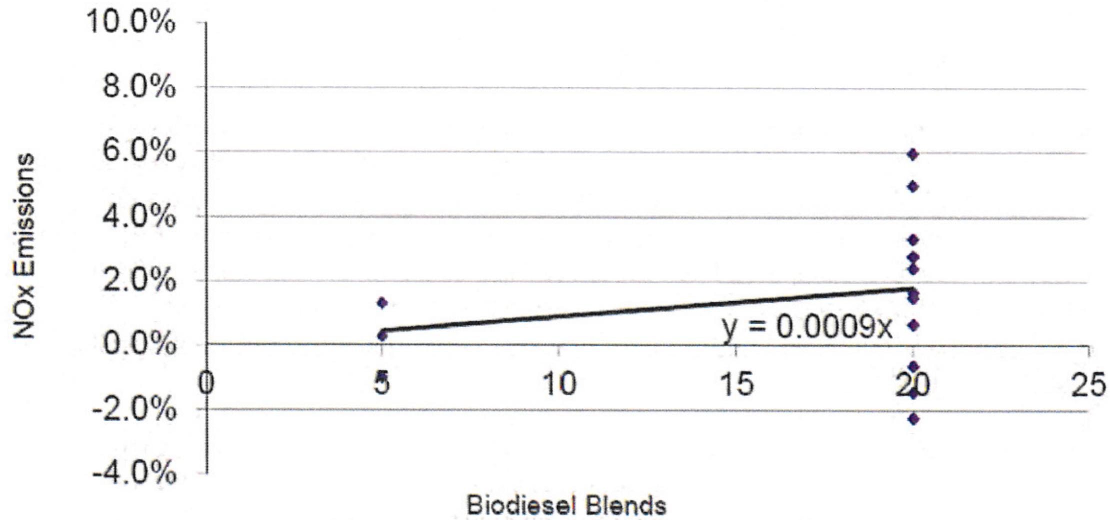


Figure B.3: NOx Impact of Animal Biodiesel Blended in High Cetane Base Fuel



Source: Figures B.2 and B.3 of Appendix B: Technology Assessment

soy-based biodiesels are shown to increase NOx emissions by approximately 1% at B5, 2% at B10, and 4% at B20. Animal-based biodiesels are shown to increase NOx emissions by about one-half as much: 0.45% at B5, 0.9% at B10, and 1.8% at B20. Although there is substantial scatter in the results, these data do not appear to support the Staff Threshold Model that biodiesel does not increase NOx emissions at B5 but does so at B10.

We will examine the Durbin 2011 study at some length in Section 3. In this section, we look at each of the other studies cited by the Staff to find out what the studies say about NOx emissions impacts at and below B10.

2.1 Review of Literature Cited in the ISOR

The Staff literature search sought and selected testing that used fuels with cetane levels comparable to California diesel fuels; the Staff does not, however, list those fuels or provide the data that support the tables and figures in Appendix B of the ISOR. Therefore, we have necessarily made our own selection of high-cetane fuels in the course of reviewing the studies. The key testing and findings of each study are summarized below, with a specific focus on what they tell us about NOx emission impacts at B10 and below.

2.1.1 Clark 1999

This study tested a variety of fuels on a 1994 7.3L Navistar T444E engine. Of the high-cetane base fuels, one base fuel (Diesel A, off-road LSD) was blended and tested at levels of B20, B50, and B100. NOx emissions were significantly increased for all of the blends. The other base fuel (CA Diesel) was tested only as a base fuel. Its NOx emissions were 12% below that of Diesel A, making it is unclear whether Diesel A is representative of fuels in CA. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

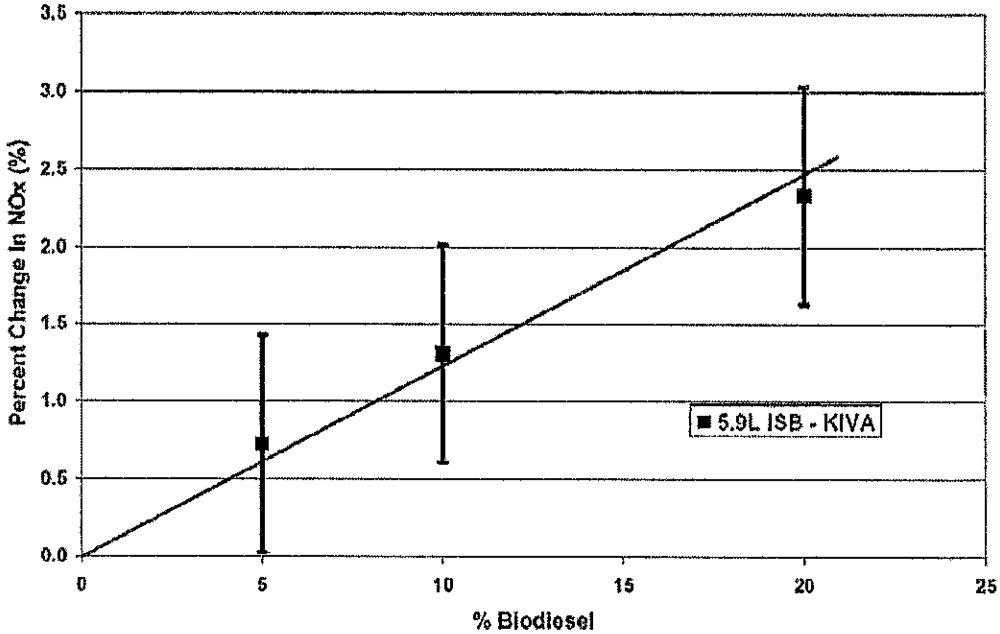
2.1.2 Eckerle 2008

This study tested low and mid/high-cetane base fuels alone and blended with soy-based biodiesel at the B20 level. The Cummins single-cylinder test engine facility was used in a configuration representative of modern diesel technology, including cooled EGR. Testing was conducted under a variety of engine speed and load conditions. FTP cycle emissions were then calculated from the speed/load data points. The test results show that B20 blends increase NOx emissions compared to both low- and high-cetane base fuels. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

The study notes that two other studies "show that NOx emissions increase nearly linearly with the increase in the percentage of biodiesel added to diesel fuel." Eckerle's Figure 21 (reproduced below as Figure 2-2) indicates a NOx emissions increase at B5, which is the basis for the statement in the abstract that "Results also show that for biodiesel blends containing less than 20% biodiesel, the NOx impact over the FTP cycle is proportional to

the blend percentage of biodiesel." The authors clearly believe that biodiesel fuels have NOx emission impacts proportional to the blending percent at all levels including B5.

Figure 2-2
Impact of Biodiesel Blends on Percent NOx Change for the 5.9L ISB Engine Operation Over the FTP Cycle



Source: Figure 21 of Eckerle 2008

2.1.3 <u>McCormick 2002</u>

This study tested low- and mid-cetane base fuels alone and blended with soy- and animal-based biodiesel at the B20 level. The testing was conducted on a 1991 DDC Series 60 engine using the hot-start U.S. heavy-duty FTP. NOx emission increases were observed for both fuels at the B20 level. Mitigation of NOx impacts was investigated by blending a Fisher-Tropsch fuel, a 10% aromatics fuel and fuel additives. <u>This study conducted no testing of the NOx emissions impact from commercial biodiesels at the B10 level or below</u>.

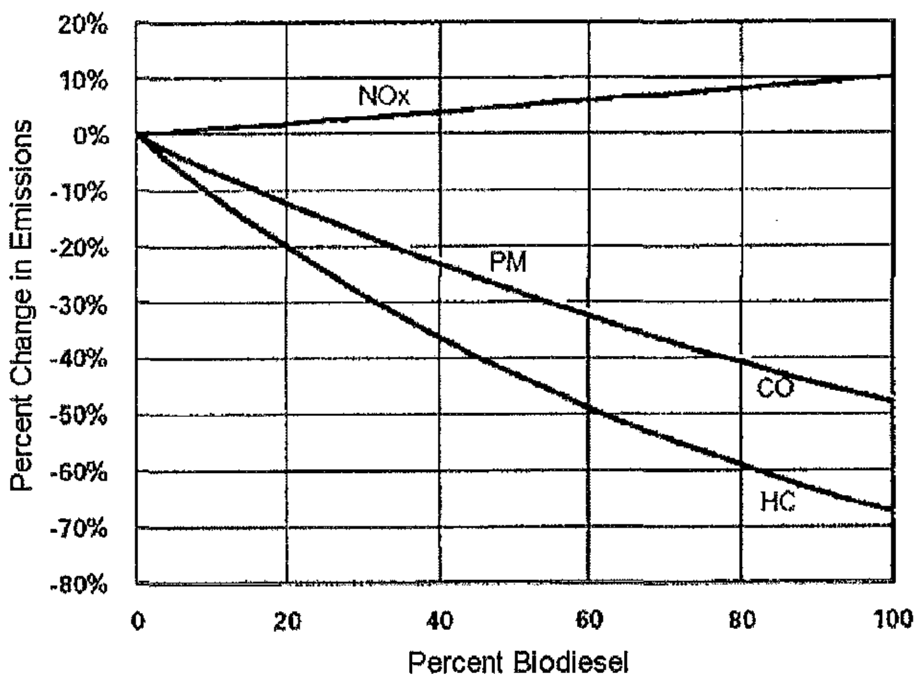
This study also tested a Fisher-Tropsch (FT) base fuel blended at the B1, B20, and B80 levels. Although the very high cetane number (≥75) takes it out of the range of commercial diesel fuels, it is interesting to note that the study measured higher NOx emissions at the B1 level than it did on the FT base fuel and substantially higher NOx emissions at the B20 and B80 levels. While the B1 increase was not statistically significant given the uncertainties in the emission measurements (averages of three test runs), <u>it is clear that increased NOx emissions have been observed at very low blending levels</u>.

2.1.4 McCormick 2005

This study tested blends of soy- and animal-based biodiesels with a high-cetane ULSD base fuel at B10 levels and higher. Two engines were tested – a 2002 Cummins ISB and a 2003 DDC Series 60, both with cooled EGR. The hot-start U.S. heavy-duty FTP test cycle was used. The majority of testing was at the B20 level with additional testing at the B50 and B100 levels. One soy-based fuel was tested at B10. The study showed NOx emission increases at B10, B20, and higher levels. The study also investigated mitigation of NOx increases. This study conducted no testing of the NOx emissions impact from biodiesels below the B10 level.

The authors present a figure (reproduced as Figure 2-3) in their introduction that shows their summary of biodiesel emission impacts based on an EPA review of heavy-duty engine testing. It shows NOx emissions increasing linearly with the biodiesel blend percentage.

Figure 2-3
Trend in HC, CO, NOx and PM Emissions with Biodiesel Percent



Source: McCormick 2005

2.1.5 Nuszkowski 2009

This study tested five different diesel engines: one 1991 DDC Series 60, two 1992 DDC Series 60, one 1999 Cummins ISM, and one 2004 Cummins ISM. Only the 2004 Cummins ISM was equipped with EGR. All testing was done using the hot-start U.S. heavy-duty FTP test cycle. The testing was designed to test emissions from fuels with and without cetane-improving additives. Although a total of five engines were tested, the base diesel and B20 fuels were tested on only two engines (one Cummins and one DDC Series 60) because there was a limited supply of fuel available. NOx emissions increased on the B20 fuel for both engines. A third engine (Cummins) was tested on B20 and B20 blended with cetane improvers to examine mitigation of NOx emissions. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

2.1.6 Thompson 2010

This study examined the emissions impacts of soy-based biodiesel at the B10 and B20 levels relative to low-cetane (42), mid-cetane (49), and high-cetane (63) base fuels using one 1992 DDC Series 60 engine. The emissions results were measured on the hot-start U.S. heavy-duty FTP cycle. The study found that NOx emissions were unchanged (observed differences were not statistically significant) at B10 and B20 levels for the low- and mid-cetane fuels. NOx emissions increased significantly at B10 and B20 levels for the high-cetane fuels. This study conducted no testing of the NOx emissions impact from biodiesels at levels below B10.

2.2 Conclusions Based on Studies Obtained in Literature Search

From the foregoing summary of the studies cited by Staff, we reach the conclusions given below.

1. None of the six studies measured the NOx emissions impact from commercial-grade biodiesel at blending levels below B10, and only two studies tested a fuel at the B10 level. All other testing was at the B20 level or higher. Because none tested a B5 (or similar) fuel, none is capable of providing direct evidence regarding NOx emissions at B5 or other blending levels below B10.

2. These studies provide no data or evidence supporting the validity of Staff's Threshold Model that biodiesel below B10 does not increase NOx emissions. In fact, all of the studies are consistent with the contention that biodiesel increases NOx emissions in proportion to the blending percent.

3. Two of the studies present evidence and arguments that the NOx impact from biodiesel is a continuous effect that is present even at very low blending levels and will increase at higher levels in proportion to the blending percentage. One study tested a Fischer-Tropsch biodiesel blend at B1 and observed NOx emissions to increase (but not by a statistically significant amount).

###

3. CARB BIODIESEL CHARACTERIZATION STUDY

3.1 Background

CARB sponsored a comprehensive study of biodiesel and other alternative diesel blends in order "… to better characterize the emissions impacts of renewable fuels under a variety of conditions."[15] The study was designed to test eight different heavy- duty engines or vehicles, including both highway and off-road engines using engine or chassis dynamometer testing. Five different test cycles were used: the Urban Dynamometer Driving Schedule (UDDS), the Federal Test Procedure (FTP), and 40 mph and 50 mph CARB heavy-heavy-duty diesel truck (HHDDT) cruise cycles, and the ISO 8178 (8 mode) cycle. Table 3-1 (reproduced from Table ES-1 of Durbin 2011) documents the scope of the test program. Because the Staff relied only on engine dynamometer testing in its Technology Assessment, only the data for the first four engines (shaded) are considered here.

Table 3-1
A Breakdown of the Test Engines for the Different Categories of Testing

2006 Cummins ISM[a]	Heavy-duty on-highway	Engine dynamometer	
2007 MBE4000	Heavy-duty on-highway	Engine dynamometer	
1998, 2.2 liter, Kubota V2203-DIB	Off-road	Engine dynamometer	
2009 John Deere 4.5 L	Off-road	Engine dynamometer	
2000 Caterpillar C-15	Heavy-duty on-highway	Chassis dynamometer	Freightliner chassis
2006 Cummins ISM	Heavy-duty on-highway	Chassis dynamometer	International chassis
2007 BME4000	Heavy-duty on-highway	Chassis dynamometer	Freightliner chassis
2010 Cummins ISX15	Heavy-duty on-highway	Chassis dynamometer	Kenworth chassis

Source: Table ES-1 of Durbin 2011, page xxvi
Notes:
[a] Data for the first four engines (shaded) are considered in this report.

[15] Durbin 2011, p. xxiv.

The original goal of this report was to subject all of the NOx emission testing in Durbin 2011 to a fresh re-analysis. However, it was discovered that Durbin 2011 did not report all of the data that were obtained during the program and are discussed in the report. The chassis dynamometer testing was conducted at the CARB Los Angeles facility. Emission results for the chassis dynamometer testing are presented in tabular and graphical form, but the report does not contain the actual emissions test data. For the engine dynamometer testing, some of the measured emission values are not reported even though the emission results are reported in tabulated or graphical form. Requests for the missing data were directed to Durbin in a personal request and to CARB through an official records request. No information has been provided in response and we have not been able to obtain the missing data from online or other sources.

For this report, we have worked with the data in the forms that are provided in Durbin 2011 as being the best-available record of the results of the CARB study. Because Staff used only data obtained in engine dynamometer testing, the analysis presented in this report has done the same. Nevertheless, the results of the chassis dynamometer testing are generally supportive of the results and conclusions presented here. Durbin 2011 notes:

> "... The NOx emissions showed a consistent trend of increasing emissions with increasing biodiesel blend level. These differences were statistically significant or marginally significant for nearly all of the test sequences for the B50 and B100 fuels, and for a subset of the tests on the B20 blends."[16]

Durbin notes that emissions variability was greater in the chassis dynamometer testing, which leads to the sometimes lower levels of statistical significance. There was also a noticeable drift over time in NOx emissions that complicated the results for one engine.

3.2 Data and Methodology

Table 3-2 compiles descriptive information on the engine dynamometer testing performed in Durbin 2011. The experimental matrix involves four engines, two types of biodiesel fuels (soy- and animal-based), and up to four test cycles per engine. However, the matrix is not completely filled with all fuels tested on all engines on all applicable test cycles. The most complete testing is for the ULSD base fuel and B20, B50, and B100 blends. There is less testing for the B5 blend, and B5 is tested using only a subset of cycles. For this reason, we first examine the testing for ULSD, B20, B50, and B100 fuels to determine the overall impact of biodiesels on NOx emissions. We then examine the more limited testing for B5 to determine the extent to which it impacts NOx emissions.

This examination is limited by the form in which emissions test information is reported in Durbin 2011. A complete statistical analysis can be conducted only for the two on-road engines for which Appendices G and H of Durbin 2011 provide measured emissions, and for a portion of the testing of the Kubota off-road engine for which Appendix I provides

[16] Durbin 2011, p. 126.

Table 3-2
Experimental Matrix for Heavy-Duty Engine Dynamometer
Testing Reported in Durbin 2011

Engine	Biodiesel Type	Fuels Tested	Test Cycles	Notes
On-Road Engines				
2006 Cummins ISM	Soy	ULSD, B20, B50, B100, B5	UDDS, FTP, 40 mph, 50 mph	B5 tested on 40 mph and 50 mph cruise cycles
	Animal	ULSD, B20, B50, B100, B5	UDDS, FTP, 50 mph	B5 tested only on FTP.
2007 MBE4000	Soy	ULSD, B20, B50, B100, B5	UDDS, FTP, 50 mph	B5 tested only on FTP.
	Animal	ULSD, B20, B50, B100, B5		B5 tested only on FTP.
Off-Road Engines				
1998 Kubota V2203-DIB	Soy	ULSD, B20, B50, B100, B5	ISO 8178 (8 Mode)	none
	Animal	Not tested		
2009 John Deere	Soy	ULSD, B20, B50, B100	ISO 8178 (8 Mode)	B5 not tested
	Animal	ULSD, B20, B5		none

measured emissions. The data needed to support a full re-analysis consist of measured emissions on each fuel in gm/hp-hr terms, which are stated in Durbin 2011 as averages across all test replications along with the number of replications and the standard error of the individual tests. With this information, the dependence of NOx emissions on biodiesel blending percent can be determined as accurately as if the individual test values had been reported and the appropriate statistical tests for the significance of results can be performed.

Regression analysis is used as the primary method of analysis. For each engine and test cycle, the emission averages for each fuel are regressed against the biodiesel blending percent to determine a straight line. The regression weights each data point in inverse proportion to the square of its standard error to account for differences in the number and reliability of emission measurements that make up each average. The resulting regression line will pass through the mean value estimated from the data (i.e., the average NOx emission level at the average blending percent), while the emission averages for each fuel may scatter above and below the regression line due to uncertainties in their measurement. The slope of the line estimates the dependence of NOx emissions on the blending percentage.

Where the data points closely follow a straight line and the slope is determined to be statistically significant, one can conclude that blending biodiesel with a base fuel will increase NOx emissions in proportion to the blending percent. The regression line can then be used to estimate the predicted emissions increase for a given blending percent. The predicted emissions increase is the value one would expect on average over many measurements and is comparable to the average emissions increase one would expect in a fleet of vehicles.

The same level of analysis is not possible for the testing on B5 fuel, which is reported as a simple average for the on-road engines and is not reported at all for the off-road engines. For the B5 fuel, Durbin 2011 presents emission test results in a tabulated form where the percentage change in NOx emissions has been computed compared to ULSD base fuel. This form supports the presentation of results graphically, but it does not permit a proper statistical analysis to be performed. Specifically, the computation of percentage emission changes will perturb the error distribution of the data, by mixing the uncertainty in measured emissions on the base fuel with the uncertainties in measured emissions on each biodiesel blend, and it can introduce bias as a result of the mixing. Further statistical analysis of the computed percent values should be avoided because of these problems. Therefore, a more limited trend analysis of the NOx emissions data for B5 and the John Deere engine is conducted.

3.3 2006 Cummins Engine (Engine Dynamometer Testing)

Table 3-3 shows the NOx emission results for the 2006 model-year Cummins heavy-duty diesel engine based on a re-analysis of the data for this report. As indicated by highlighting in the table, the relationship between increasing biodiesel content and increased NOx emissions for soy-based biodiesel is statistically significant at >95% confidence level[17] in all cases. For the animal-based biodiesel, the relationship is statistically significant at the 92% confidence level for the UDDS cycle, the 94% confidence level for the 50 mph cruise, and the >99% confidence level for the FTP cycle.

For the soy-based fuels, the R^2 statistics show that the emissions effect of biodiesel is almost perfectly linear with increasing biodiesel content over the range B20, B50, and B100. Although not as high for the animal-based fuels (because the emissions effect is smaller and measurement errors are relatively larger in comparison to the trend), the R^2 statistics nevertheless establish a linear increase in NOx emissions with increasing biodiesel content over the same range. The linearity of the response with blending percent is well supported by the many NOx emissions graphs contained in Durbin 2011.

The table also gives the estimated NOx emission increases for B5 and B10 as predicted by the regression lines. For soy-based fuels, the values are 1% for B5 (range 0.8% to 1.3% depending on the cycle) and 2% for B10 (range 1.6% to 2.6% depending on cycle).

[17] A result is said to be statistically significant at the 95% confidence level when the p value is reported as $p \leq 0.05$. At the $p \leq 0.01$ level, a result is said to be statistically significant at the 99% confidence level, and so forth.

Table 3-3 Re-Analysis for 2006 Cummins Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B20, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	Pct Change	Pct Change
Soy-based							
	UDDS	0.997	5.896	0.0100 [a]	0.001	0.8%	1.7%
	FTP	0.995	2.024	0.0052	0.003	1.3%	2.6%
	40 mph	1.000	2.030	0.0037	<0.0001	0.9%	1.8%
	50 mph	0.969	1.733	0.0028	0.016	0.8%	1.6%
Animal-based							
	UDDS	0.847	5.911	0.0021 [b]	0.080	0.2%	0.4%
	FTP	0.981	2.067	0.0031	0.001	0.7%	1.4%
	50 mph	0.887	1.768	0.0011	0.058	0.3%	0.6%

Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.
[b] Orange highlight indicates result is statistically significant at the 90% confidence level or better.

For animal-based fuels, the values are approximately one-half as large: 0.4% for B5 (range 0.2% to 0.7%) and 0.8% for B10 (range 0.4% to 1.4%). These predicted increases are statistically significant to the same degree as the slope of the regression line from which they are estimated. That is, the NOx increases predicted by the regression line for soy-based fuels are statistically significant at the 95% confidence level (or better) on all cycles and the predicted NOx increases for animal-based fuels are statistically significant at the 90% confidence level (or better) on all cycles and at the >99% confidence level for the FTP.

Because the limited data on B5 were not used to develop the regression lines for each cycle, and no test data on B10 are available, use of the lines to make predictions for B5 and B10 depends on their linearity over the range between ULSD and B20. Based on the R^2 statistics and the graphs in Durbin 2011, the slopes observed between ULSD and B20 are the same as the slopes observed between B20 and B100 for each of the test cycles. We believe that the linearity of the response with blending percent for values over the range ULSD to B100 would be accepted by the large majority of researchers in the field, as would the use of regression analysis to make predictions for B5 and B10.

The Durbin 2011 report takes a different approach for determining the statistical significance of NOx emission increases for each fuel. For each fuel tested, it computes a percentage change in emissions for NOx (and other pollutants) relative to the ULSD base fuel. It then determines the statistical significance of each observed change using a conventional t-test for the difference of two mean values (2-tailed, 2 sample equal

variance t-test). The t-test is conducted on the measured emission values before the percentage emission change is computed.

The t-test would be the appropriate approach for determining statistical significance if only two fuels were tested. However, it is a simplistic approach when three or more fuels are tested because it is applied on a pair-wise basis (B5 vs. ULSD, B20 vs. ULSD, etc.) and does not make use of all of the data that is available. It will have less power than the regression approach to detect emission changes that are real. This limitation is in one direction, however, in that the test is too weak when 3 or more data points are available, but a finding of statistical significance is valid when it occurs. As long as the linear hypothesis is valid, the regression approach should be the preferred method for analysis and for the determination of whether biodiesel blending significantly increases NOx emissions.

Because emission changes will be smallest for B5 (because of the low blending volume), the pair-wise t-test is most likely to fail to find statistical significance at the B5 level. In cases where the pair-wise t-test for B5 says that the emission change vs. ULSD is not statistically significant – but slope of the regression line is statistically significant – the proper conclusion is that additional B5 testing (to improve the precision of the emission averages) would likely lead to the detection of a statistically significant B5 emissions change using the t-test. In this case, the failure to find statistical significance using the t-test is not evidence that B5 does not increase NOx emissions.

For this engine, soy-based B5 was tested on the 40 mph and 50 mph cruise cycles and animal-based B5 was tested on the FTP. To examine this matter further, Table 3-4 reproduces NOx emission results reported in Tables ES-2 and ES-3 of Durbin 2011. Soy-based B5 was shown to increase NOx emissions on the 40 mph cruise cycle, but not on the 50 mph cruise cycle. Animal-based B5 was shown to increase NOx emissions on the FTP. Durbin 2011 noted (p. xxxii) that "[t]he 50 mph cruise results were obscured, however, by changes in the engine operation and control strategy that occurred over a segment of this cycle." Therefore, we discount the 50 mph cruise results and do not consider them further. Neither of the remaining B5 NOx emission increases (for the 40 mph Cruise and FTP cycles) were found to be statistically significant using the t-test, although the 40 mph cruise result for soy-based fuels comes close to being marginally significant (it would be statistically significant at an 86.5% level). The NOx emission increases at higher blending levels were found have high statistical significance (>99% confidence level).

This format, used throughout Durbin 2011 to report emission test data and to show the effect of biodiesel on emissions, is subject to an important statistical caveat. The percent changes are computed by dividing the biodiesel emission values by the emissions measured for the ULSD base fuel. Therefore, measurement errors in the ULSD measurement are blended with the measurement errors for each of the biodiesel fuels. The blending of errors in each computed percent change can bias the apparent trend of emissions with increasing biodiesel content. As will be shown in Section 3.3.2, we can see this problem in the animal-based B5 test data for this engine.

Table 3-4 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2006 Cummins Engine (Engine Dynamometer Testing)						
	Soy-based Biodiesel				Animal-based Biodiesel	
	40 mph Cruise		50 mph Cruise		FTP	
	NOx % Diff	p value	NOx % Diff	p value	NOx % Diff	p value
B5	1.7%	0.135	-1.1%	0.588	0.3%	0.298
B20	3.9% [a]	0.000	0.5%	0.800	1.5%	0.000
B50	9.1%	0.000	6.3%	0.001	6.4%	0.000
B100	20.9%	0.000	18.3%	0.000	14.1%	0.000

Source: Table ES-2 and ES-3 of Durbin 2011, p. xxviii
Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on the pair-wise t-test.

3.3.1 NOx Impact of Soy-based Biodiesel at the B5 Level

Figures 3-1a and 3-1b display the trend of NOx emissions with blending percent for the soy-based biodiesel on the 40 mph cruise cycle. Figure 3-1a plots the percentage increases as reported by Durbin 2011 in contrast to two different analytical models for the relationship:

- The Linear Model shown by the blue line; and
- The Staff Threshold model (black line), in which the NOx emission change is zero through B9 and then increases abruptly to join the linear model.

In Figure 3-1a, the linear model is an Excel trendline for the computed percent changes. While the data violate a key assumption for the proper use of regression analysis, this approach is the only way to establish a trendline given the form in which Durbin 2011 tabulates the data and presents the results of its testing.

Figure 3-1b plots the actual measured emission values in g/bhp-hr terms in contrast to the same two analytical models. Here, the linear model line is determined through a proper use of regression analysis, in which each emission average in g/bhp-hr terms is weighted inversely by the square of its standard error, using the data for ULSD, B20, B50 and B100 (i.e., excluding the B5 data point). In the case of this engine and biodiesel fuel, both forms of assessment show generally the same trend for NOx emissions as a function of blending percent. Although the NOx emission increases for B5 may fail the t-test for significance, emissions are increased at B5 and the B5 data point is fully consistent with the Linear Model. The Threshold model is clearly a less-satisfactory representation of the test data.

Figure 3-1a
Durbin 2011 Assessment: 40 mph Cruise Cycle NOx Emissions Increases for Soy-Biodiesel Blends (2006 Cummins Engine)

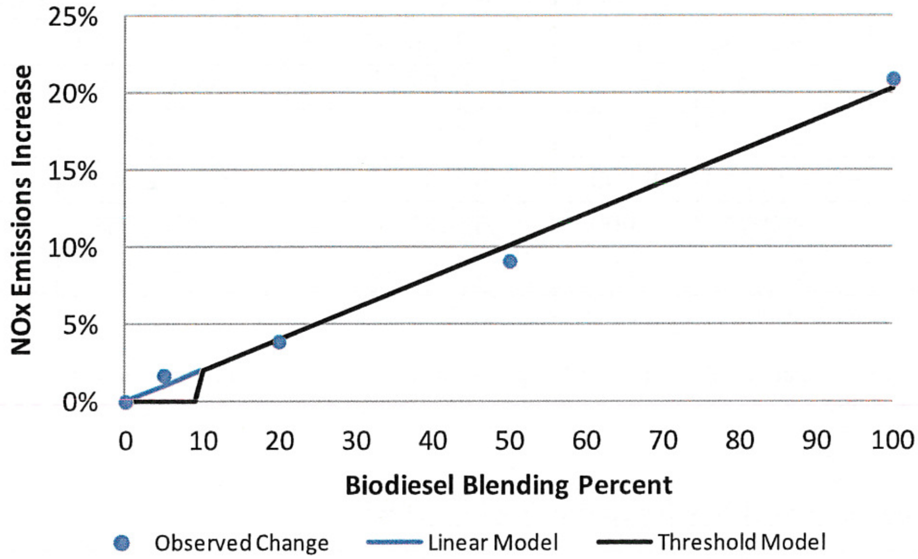
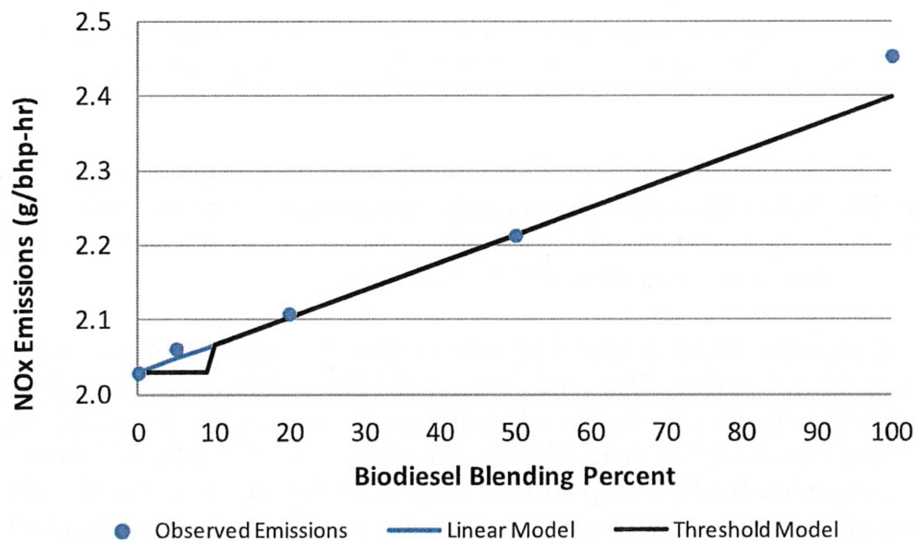


Figure 3-1b
Re-assessment of 40 mph Cruise Cycle NOx Emissions Increases for Soy-Biodiesel Blends (2006 Cummins Engine)



Note that the slope of the trendline (Figure 3-1a) is greater than the slope of the regression line (Figure 3-1b). In the latter figure, the B100 data point stands above the regression line, which passes below it. The regression line (but not the trendline) is fit in

a manner that accounts for the uncertainties in each data point, so that the line will pass closer to points that have smaller uncertainties and farther from points that have greater uncertainties. For these data, the B100 data point has the largest uncertainty (±0.026 g/bhp-hr) followed by the B20 data point (±0.025 g/bhp-hr). The other three data points (ULSD, B5, and B50) have uncertainties less than ±0.001 g/bhp-hr. The B20 data point happens to fall on the line, but the B100 data point is found to diverge above. Because the regression analysis can account for the relative uncertainties of the data points, it provides a more accurate and reliable assessment of the impact on NOx emissions.

3.3.2 NOx Impact of Animal-based Biodiesel at the B5 level

Figures 3-2a and 3-2b display the trend of NOx emissions with blending percent for the animal-based biodiesel on the FTP test cycle as reported by Durbin 2011 and as re-assessed in this report using regression analysis, respectively. As Figure 3-2a shows, the NOx percent change values reported by Durbin 2011 appear to follow the Staff Threshold model in that NOx emissions are not materially increased at B5, but are increased significantly at B20 and above. As a result, the blue trendline in the figure (fit from the B20, B50 and B100 data points) has a negative intercept.

Figure 3-2b paints a very different picture from the data. Here, the ULSD and B5 data points stand above the weighted regression line (blue) developed from the data for ULSD, B20, B50 and B100. In the data used to fit the regression line, the ULSD data point has the largest uncertainty (±0.013 g/bhp-hr) while the other three data points (B20, B50, and B100) have uncertainties of ±0.002 g/bhp-hr (one case) and ±0.001 g/bhp-hr (two cases). Considering all of the data, the B5 data point has the second highest uncertainty (±0.007 g/bhp-hr). The regression line closely follows a linear model with a high R^2 (0.981) considering the weighted errors, while the ULSD and B5 points lie above it.

Because the ULSD data point is subject to more uncertainty and appears to be biased high compared to the regression line, the NOx percent changes computed by Durbin 2011 are themselves biased. The trendline result in Figure 3-2a that appeared to be supportive of the Staff Threshold model now appears to be the result of biases in the ULSD and B5 emission averages.

Two important conclusions can be drawn from the foregoing:

1. Accurate and reliable conclusions regarding the impact of B5 on NOx emissions cannot be drawn from the computed percent changes that are reported in Durbin 2011. Nor can accurate and reliable conclusions be drawn from visual inspection of graphs that present such data. Weighted regression analysis of the measured emission values (g/bhp-hr terms) must be performed so that the uncertainties in emissions measurements can be fully accounted for.

2. When a weighted regression analysis is performed using the testing for this engine, there is no evidence that supports the conclusion that B5 blends will not increase NOx emissions. In fact, the data are consistent with the conclusion that biodiesel increases NOx emissions in proportion to the blending percent.

Figure 3-2a
Durbin 2011 Assessment: FTP NOx Emissions Increases for Animal-based Biodiesel Blends (2006 Cummins Engine)

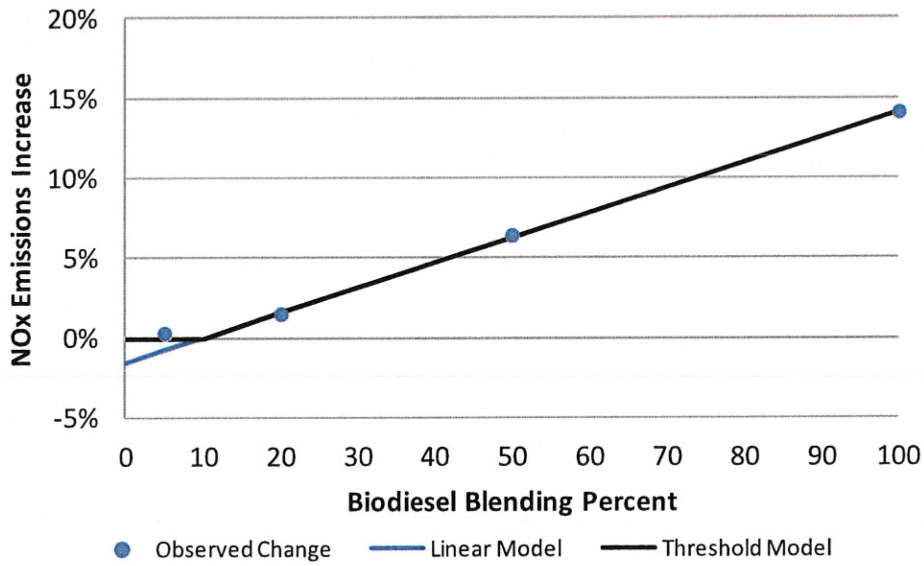
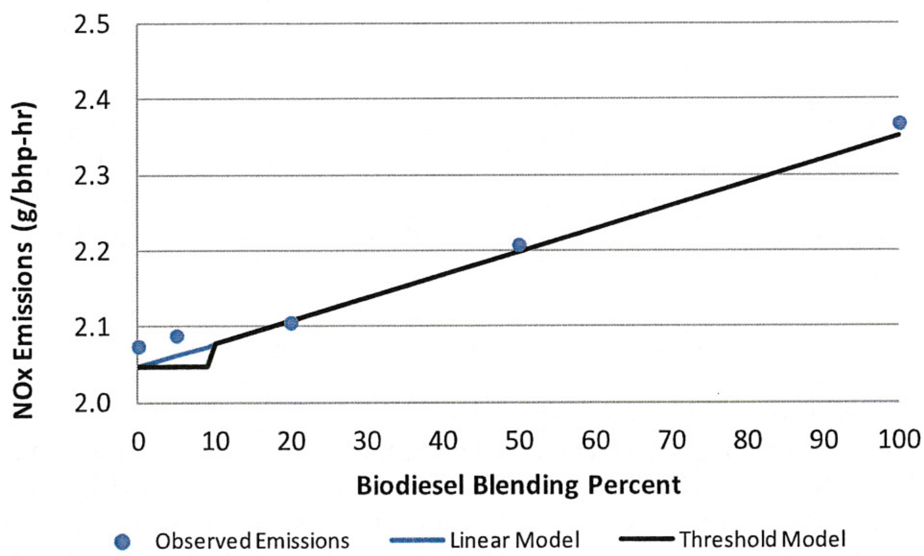


Figure 3-2b
Re-assessment of FTP NOx Emissions Increases for Animal-based Biodiesel Blends (2006 Cummins Engine)



3.4 2007 MBE4000 Engine (Engine Dynamometer Testing)

To analyze the data for the 2007 MBE4000 engine, it has proved necessary to remove two data points, one for the soy-based B20 fuel on the 50 mpg cruise cycle and one for the animal-based B50 fuel on the FTP test cycle:

- Appendix H reports the 50 mph cruise emission average for soy-based B20 to be 0.014 ± 0.020 g/bhp-hr. This value is implausible and wholly inconsistent with the NOx emission change of +6.9% reported in Table ES-4 of Durbin 2011, which would imply a NOx emission average of 1.21*1.069 = 1.30 g/bhp-hr.

- Appendix H reports the FTP emission average for the animal-based B50 fuel to be 2.592 ± 0.028 g/bhp-hr, which stands well above the other test data on animal-based biodiesel. This value is also inconsistent with the NOx emission change of +12.1% reported in Table ES-4 of Durbin 2011, which would imply a NOx emission average of 1.29*1.121 = 1.45 g/bhp-hr.

We believe these reported values are affected by typographical errors and have deleted them from the dataset used here.

With these corrections, Table 3-5 shows the results of the NOx emissions analysis for the 2007 model-year MBE4000 heavy-duty diesel engine. As indicated by highlighting in the table, the relationship between increasing biodiesel content and increased NOx emissions is statistically significant at >99% confidence level in two cases for soy-based biodiesel (the UDDS and FTP cycles) and at the 90% confidence level in one case (the 50 mph cycle). For the animal-based biodiesel, the relationship is statistically significant at the 96% confidence level for the UDDS cycle, the 98% confidence level for the FTP cycle, and >99% confidence level for the 50 mph cycle.

Durbin 2011 again notes a problem with the 50 mph cruise test results, saying (p. xxxii) that "[the NOx] trend was obscured, however, by the differences in engine operation that were observed for the 50 mph cruise cycle." Therefore, we will focus the discussion on the UDDS and FTP results.

For the soy-based fuels, the R^2 statistics show that the emissions effect of biodiesel is almost perfectly linear with increasing biodiesel content over the range from ULSD to B20, B50, and B100 for all cycles (including the 50 mph cruise). That is, the NOx emissions increase between ULSD and B20 shares the same slope as the NOx emissions increase between B20 and B100. For the animal-based biodiesel, the R^2 statistics also establish a linear increase in NOx emissions with increasing biodiesel content over the same range. The linearity of the response with blending percent is also well supported by the many NOx emissions graphs contained in Durbin 2011.

Table 3-5 Re-Analysis for 2007 MBE4000 Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B20, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	Pct Change	Pct Change
Soy-based							
	UDDS	0.989	2.319	0.0090 [a]	0.005	4.6%	9.1%
	FTP	0.998	1.268	0.0049	0.006	2.5%	5.0%
	50 mph	0.979	1.198	0.0054 [b]	0.092	2.7%	5.5%
Animal-based							
	UDDS	0.913	2.441	0.0036	0.044	2.0%	4.0%
	FTP	0.999	1.288	0.0038	0.020	2.5%	5.0%
	50 mph	0.994	1.205	0.0049	0.003	2.5%	5.0%

Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.
[b] Orange highlight indicates result is statistically significant at the 90% confidence level or better.

The table also gives the estimated NOx emission increases for B5 and B10 as predicted by the regression lines. For soy-based fuels, the values are ~3.5% for B5 (range 2.5% to 4.6% depending on the cycle) and ~7.5% for B10 (range 5.0% to 9.1% depending on cycle). For animal-based fuels, the values are approximately two-thirds as large: ~2.3% for B5 (range 2.0% to 2.5%) and ~4.5% for B10 (range 4.0% to 5.0%). The predicted increases are statistically significant to the same degree as the slope of the regression line from which they are estimated. That is, the predicted NOx increases are statistically significant at the >99% confidence level for soy-based fuels on the UDDS and FTP cycles and at the >95% confidence level for animal-based fuels on all cycles. The predicted NOx increase is statistically significant at the 90% confidence level for soy-based fuels on the 50 mph cruise cycle.

For this engine, soy- and animal-based B5 were tested on the FTP. Table 3-6 reproduces the NOx emission results reported in Tables ES-4 and ES-5 of Durbin 2011. While there are caveats on use of the pair-wise t-test, the FTP test data for this engine show NOx emissions at the B5 level for both soy- and animal-based fuels that are statistically significant at the 99% confidence level (or better) in this case. That is, the test data for this engine as reported by Durbin 2011 refute the Staff Threshold Model that biodiesel blends below B10 do not increase NOx emissions.

Table 3-6 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2007 MBE4000 Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel FTP		Animal-Based Biodiesel FTP	
	NOx % Diff	p value	NOx % Diff	p value
B5	0.9% [a]	0.007	1.3%	0.000
B20	5.9%	0.000	5%	0.000
B50	15.3%	0.000	12.1	0.000
B100	38.1%	0.000	29%	0.000

Source: Table ES-4/5 of Durbin 2011, p. xxix
Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test.

Figures 3-3a and 3-3b below compare the FTP data for this engine to the regression line representing the linear model (blue) and the Staff Threshold model (black) for both soy- and animal-based biodiesel. In both cases, the regression line was developed using the data for ULSD, B20, B50, and B100 (i.e., excluding the B5 data point). For both soy- and animal-based biodiesels, the data point for B5 falls on the established line, while the Staff Threshold model is inconsistent with the data. For this engine, it is clear that soy- and animal-based biodiesels increase NOx emissions at all blending levels.

Figure 3-3a
Re-assessment of FTP Cycle NOx Emissions Increases for Soy-based Biodiesel Blends (2007 MBE4000 Engine)

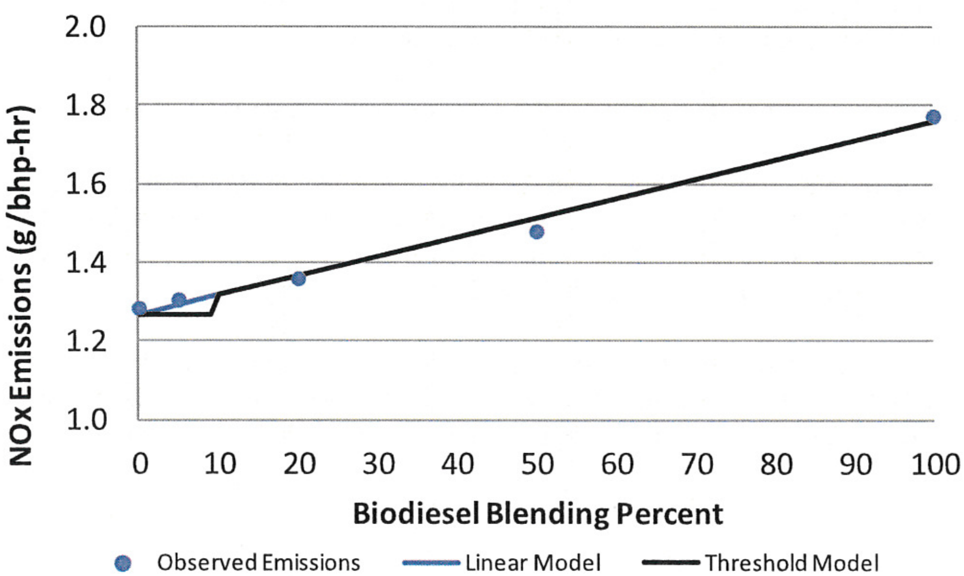
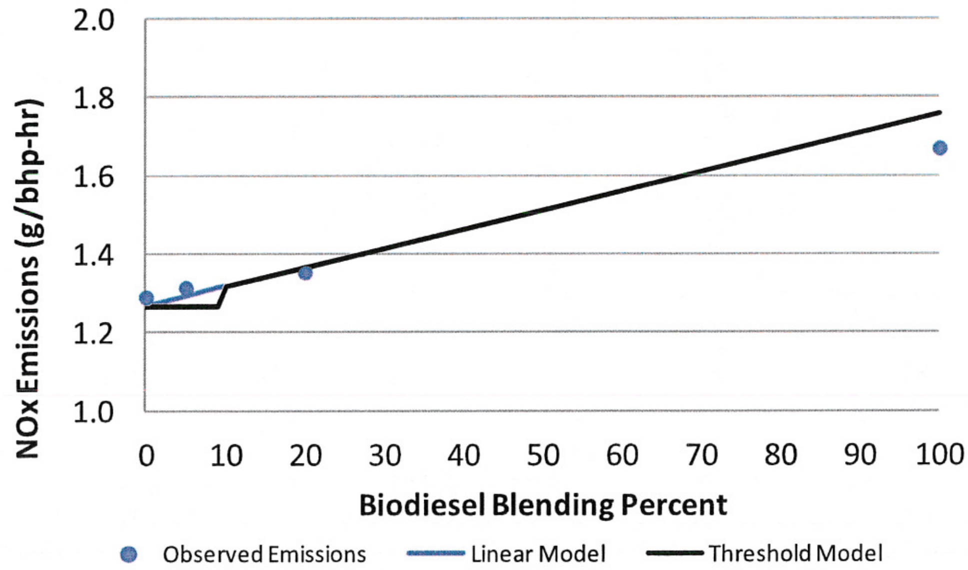


Figure 3-3b
Re-assessment of FTP Cycle NOx Emissions Incre ases for Ani mal-bas ed Biodiesel Blends (2007 MBE4000 En gine)



3.5 1998 Kubota TRU Engine (Engine Dynamometer Testing)

The 1998 Kubota V2203-DIB off-road engine was tested on the base fuel (ULSD) and soy-based biodiesel at four blending levels (B5, B20, B50, B100) in two different series using the ISO 8178 (8-mode) test cycle. Appendix I reports the measured emissions data only for the first series (ULSD, B50, B100). Using this subset of data, Table 3-7 summarizes the results of the re-analysis for this engine.

As for the other engines, the results of the analysis demonstrate the following:

- The high R^2 statistic shows that the emissions effect of biodiesel is almost perfectly linear over the range B50 and B100. That is, the slope from ULSD to B50 is the same as the slope from B50 to B100. The slope of the regression line is statistically significant at the 99% confidence level.

- NOx emissions are estimated to increase by 1.0% at the B5 level and by 2.1% at the B10 level. These estimated NOx emission increases are statistically significant to the same high degree as the regression slope on which they are based.

Table 3-7 Re-Analysis for 1998 Kubota V2203-DIB Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A Value	BioPct Slope B Value	p value	Predicted NOx Increase for B5 Pct Change	Predicted NOx Increase for B10 Pct Change
Soy-based	ISO 8178	0.999	12.19	0.0256 [a]	0.01	1.0%	2.1%

Notes:

[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.

The second test series involved ULSD, B5, B20, and B100 fuels. Measured emissions data are not given in Appendix I, so we must work with the calculated percent changes in NOx emissions tabulated in Durbin 2011. Table 3-8 reproduces the NOx emission results reported in Table ES-8 of Durbin 2011 for the two test series. For the second test series, biodiesel at the B5 level increased NOx emissions, but the result fails the pair-wise t-test for statistical significance. The NOx emission increase at the B20 level was statistically significant at the 90% confidence level, and the increase at the B100 level was statistically significant at the >99% confidence level. The significance determinations use the pair-wise t-test, which is subject to caveats, but this is the only method available to gauge significance because re-analysis of the computed percentage changes is not possible.

Table 3-8 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 1998 Kubota TRU Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel Series 1 ISO 8178		Soy-Based Biodiesel Series 2 ISO 8178	
	NOx % Diff	p value	NOx % Diff	p value
B5	Not tested		0.97%	0.412
B20	Not tested		2.25% [a]	0.086
B50	7.63% [b]	0.000	Not tested	
B100	13.76%	0.000	18.89%	0.000

Source: Table ES-8 of Durbin 2011, p. xxxviii

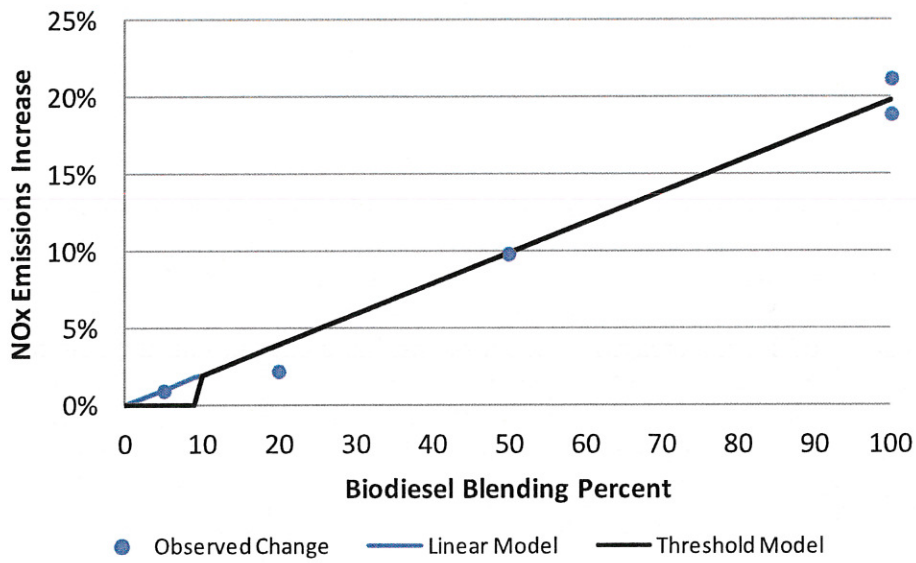
Notes:

[a] Orange highlight indicates result is statistically significant at the 90% confidence level or better based on pair-wise t-test.

[b] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test

Figure 3-4 displays the trend of NOx emissions with blending percent for the first and second test series combined. As the figure shows, the available data points scatter around the trendline determined from the emission change percentages (not from regression analysis). The B20 data point falls below the trend line while the two B100 data points bracket the trend line. It is not possible to explain the divergence of the B20 data point

Figure 3-4
Durbin 2011 Assessment: ISO 8178 Cycle NOx Emissions Increases for Soy-based Biodiesel Blends (1998 Kubota Engine, Test Series 1 and 2 Combined)



because the emissions data for the second test series are not published in Durbin 2011. The B5 data point clearly supports the Linear Model and is inconsistent with the Staff Threshold Model.

3.6 2009 John Deere Off-Road Engine (Engine Dynamometer Testing)

The only information on the 2009 John Deere off-road engine comes from the tabulation of calculated percentage emission changes. Table 3-9 reproduces these data from Table ES-7 of Durbin 2011. For the soy-based biodiesel, NOx emissions are significantly increased at the B20 and higher blend levels. The increase for B20 is statistically significant at the 90% confidence level and the increases for B50 and B100 are statistically significant at the >99% confidence level based on the pair-wise t-test. A soy-based B5 fuel was not tested.

Table 3-9 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2009 John Deere Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel ISO 8178		Animal-Based Biodiesel ISO 8178	
	NOx % Diff	p value	NOx % Diff	p value
B5	Not tested		-3.82	0.318
B20	2.82%[a]	0.021	-2.20	0.528
B50	7.63%	0.000	Not tested	
B100	13.76%	0.000	4.57	0.000

Source: Table ES-7 of Durbin 2011, p. xxxviii
Notes:
[a] **Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test.**

For animal-based biodiesel, the testing shows the unusual result that B5 and B20 appear to decrease NOx emissions, while B100 increases NOx. The B5 and B20 decreases are not statistically significant, while the B100 increase is statistically significant at the >99% confidence level. Durbin 2011 concludes:

> The animal-based biodiesel also did not show as great a tendency to increase NOx emissions compared to the soy-based biodiesel for the John Deere engine, with only the B100 animal-based biodiesel showing statistically significant increases in NOx emissions.[18]

Durbin 2011 does not discuss these results further and does not note any problems in the testing, making further interpretation of the results difficult. Figure 8-1 of Durbin 2011 presents the NOx results for this engine with error bars. First, we note that the figure appears to suggest that NOx emissions were increased on the B20 fuel in contradiction to the table above. Second, it is clear that the error bars are large enough that no difference in NOx emissions can be detected among ULSD, B5, and B20 fuels. Overall, this result could be consistent with the Staff Threshold Model through B5, but the failure to detect a NOx emission increase at B20 is not. Without further information, it is not possible to determine whether the result seen here is a unique response of the John Deere engine to animal-based biodiesel or is the result of a statistical fluctuation or an artifact in the emissions data.

3.7 Conclusions

The Biodiesel Characterization report prepared by Durbin et al. for CARB is an important source of information on the NOx emissions impact of biodiesel fuels in heavy-duty engines. It is the sole source of information on the NOx impact of B5 blends cited in the ISOR. When the engine dynamometer test data are examined for

[18] Durbin 2011, p. xx.

the three engines for which emissions test data have been published, we find clear evidence that biodiesel increases NOx emissions in proportion to the blending percent. Where B5 fuels were tested for these engines, NOx emissions are found to increase above ULSD for both soy- and animal-based blends in all three engines and by statistically significant amounts in one engine.

Specifically, a re-analysis of the NOx emissions test data demonstrates the following:

1. For the 2006 Cummins engine, biodiesel fuels are found to significantly increase NOx emissions for both soy- and animal-based blends by amounts that are proportional to the blending percent. This result indicates that biodiesels will increase NOx emissions at blending levels below B10. When B5 fuels were tested, NOx emissions were observed to increase but by amounts that fail to reach statistical significance according to the pair-wise test.[19] Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

2. For the 2007 MBD4000 engine, biodiesel fuels are found to significantly increase NOx emissions for both soy- and animal-based blends by amounts that are proportional to the blending percent. This result indicates that biodiesels will increase NOx emissions at blending levels below B10. When B5 fuels were tested, NOx emissions were observed to increase and by amounts that are found to be statistically significant using the pair-wise t-test.[13] <u>This result alone is sufficient to disprove the Staff Threshold Model</u>. Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

3. For the 1998 Kubota TRU (off-road) engine, soy-based biodiesel fuels are found to significantly increase NOx missions. Animal-based biodiesel was not tested. When a soy-based B5 fuel was tested, NOx emissions were observed to increase but by amounts that fail to reach statistical significance according to the pair-wise test.[13] Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

The measured emissions test data for the other off-road engine (2009 John Deere) are not contained in the Durbin 2011 report and CARB has not made them publicly available. Thus, a re-analysis was not possible. Based on the tables and figures in Durbin 2011, soy-based biodiesel fuels were shown to significantly increase NOx emissions at B20 levels and higher, but B5 was not tested. Testing of animal-based blends shows no change in NOx emissions at B5 and B20 levels, but B100 is shown to significantly increase NOx emissions. Durbin 2011 discusses this result only briefly, and it is unclear what conclusions can be drawn from it.

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[19] As discussed in Section 3.3, the pair-wise t-test is not the preferred method for demonstrating statistical significance.

APPENDIX A

RESUME OF ROBERT W. CRAWFORD

Education

1978 Doctoral Candidate, ScM. Physics, Brown University, Providence, Rhode Island
1976 B.A. Physics, Pomona College, Claremont, California

Professional Experience

1998-Present Independent Consultant

Individual consulting practice emphasizing the statistical analysis of environment and energy data with an emphasis on how data and statistics are properly used to make scientific inferences. Mr. Crawford provides support on statistical, data analysis, and modeling problems related to ambient air quality data and emissions from mobile and stationary sources.

Ambient Air Quality and Mobile Source Emissions – Mr. Crawford has worked with Sierra Research on elevated ambient CO and PM concentrations in Fairbanks AK and Phoenix AZ, including the effect of meteorological conditions on ambient concentrations, the relationship of concentrations to source inventories, and the use of non-parametric techniques to infer source location from wind speed and direction data. Ongoing work is employing Principal Components Analysis to elucidate the relationship between meteorology and $PM_{2.5}$ concentrations in Fairbanks. In the past year, this work led to creation of the AQ Alert System, a tool used by air quality staff to track $PM_{2.5}$ monitor concentrations during the day and to prepare AQ alerts over the next 3 days based on the meteorological forecast.

In past work for Sierra, he has also conducted studies of fuel effects on motor vehicle emissions for Sierra. For CRC, he determined the relationship between gasoline volatility and oxygen content on tailpipe emissions of late model vehicles at FTP and cold-ambient temperatures. For SEMPRA, he determined the relationship between CNG formulation and tailpipe emissions of criteria pollutants and a range of air toxics. Other work has included the design of vehicle surveillance surveys and determination of sample sizes, development of screening techniques similar to discriminant functions to improve the efficiency of vehicle recruitment, the analysis of vehicle failure rates measured in inspection & maintenance programs, and the statistical evaluation of data collected on freeway speeds using automated sensors.

Stationary Source Emissions – Over the past 5 years, Mr. Crawford has worked with AEMS, LLC on EPA's MACT and CISWI rulemakings for Portland Cement plants, in which significant issues related to data quality, data reliability, and emissions variability are evident. Key issues include the need to properly account for uncertainty and emissions variability in setting emission standards. He also supported AEMS in the

current EPA rulemaking on reporting of greenhouse gas emissions from semiconductor facilities, where the proper characterization of emission control device performance was a key issue. He is currently supporting AEMS in a regulatory process to re-determine emission standards for an industrial facility where the new standard will be enforced by continuous emissions monitoring (CEMS). At issue is how to set the standard in such a way that there will be no more than a small, defined risk that 30-day emission averages will exceed the limitations while emissions remain well-controlled .

Advanced Combustion Research – In recent work for Oak Ridge National Laboratory, Mr. Crawford conducted a series of statistical studies on the fuel consumption and emissions performance of Homogenous Charge Compression Ignition (HCCI) engines. One of these studies was for CRC, in which fuel chemistry impacts were examined in gasoline HCCI. In HCCI, the fuel is atomized and fully-mixed with the intake air charge outside the cylinder, inducted during the intake stroke, and then compressed to the point of spontaneous combustion. The timing of combustion is controlled by heating of the intake air. If R&D work can demonstrate a sufficient understanding of how fuel properties influence engine performance, the HCCI combustion strategy potentially offers the fuel economy benefit of a diesel engine with inherently lower emissions.

1979-1997 Energy and Environmental Analysis, Inc., Arlington, VA. Director & Partner (from 1989).

Primary work areas: Studies of U.S. energy industries for private and institutional clients emphasizing statistical analysis, business planning and computer modeling/forecasting. Responsible for the EEA practice area that provided strategic planning and forecasting services to major energy companies. Primary topical areas included: U.S. energy market analysis and strategic planning; gas utility operations; and natural gas supply planning.

U.S. Energy Market Analysis

During 1995-1997, Mr. Crawford directed EEA's program to provide comprehensive energy supply and demand forecasting for the Gas Research Institute (GRI) in its annual Baseline Projection of U.S. Energy Supply and Demand. Services included: development of U.S. energy supply, demand, and price forecasts; sector-specific analyses covering energy end-use (residential, commercial, industrial, transportation), electricity supply, and natural gas supply and transportation; and the preparation of a range of publications on the forecasts and energy sector trends.

From 1989 through 1997, he directed the use of EEA's Energy Overview Model in strategic planning and long-term market analysis for a client base of major energy producers, pipelines, and distributors in both the United States and Canada. The Energy Overview Model was used under his direction as the primary analytical basis for the 1992 National Petroleum Council study The Potential for Natural Gas in the United States. Mr. Crawford also provided analysis for clients on a wide range of other energy market issues, including negotiations related to an LNG import project intended to serve U.S. East Coast markets. This work assessed the utilization and economic value of seasonal

gas deliverability in order to develop LNG pricing formulas and evaluate the project's viability.

Other topical areas of work during his period of employment with EEA include:

Gas Load Analysis and Utility Operations – Principal investigator in a multi-year research program for the Gas Research Institute (GRI) that examined seasonal gas loads, utility operations, and the implications for transmission and storage system reliability and capacity planning.

Gas Transmission and Storage – Principal investigator for a study of industry plans for expansion of underground gas storage capacity in the post-Order 636 environment, including additions of depleted-reservoir and salt-formation storage, an engineering analysis of capital and operating costs for the projects, and unbundled rates for new storage services.

Natural Gas Supply Planning – Mr. Crawford was EEA's senior manager and lead analyst on gas supply planning issues for both pipeline and distribution companies, which included technical and analytic support in development and justification of gas supply strategies; and identification of optimal seasonal supply portfolios for Integrated Resource Planning proceedings.

Transportation Systems Research

Mr. Crawford also had extensive experience in motor vehicle fuel economy and emissions while at EEA. He participated for five years in a DOE research program on fuel economy, with emphasis on the evaluation of differences between laboratory and on-road fuel economy. His work included analysis of vehicle use databases to understand how driving patterns and ambient (environmental) conditions influence actual on-road fuel economy. He also developed a software system to link vehicle certification data systems to vehicle inspection and testing programs and participated in a range of studies on vehicle technology, fuel economy, and emissions for DOE, EPA, and other governmental agencies.

SELECTED PUBLICATIONS (emissions and motor vehicle-related topics)

Statistical Assessment of $PM_{2.5}$ and Meteorology in Fairbanks, Alaska: 2013 Update. Crawford and Dulla. Prepared for the Alaska Department of Environmental Conservation. (forthcoming).

Statistical Assessment of $PM_{2.5}$ and Meteorology in Fairbanks, Alaska. Crawford and Dulla. Prepared for the Alaska Department of Environmental Conservation. March 2012.

Principal Component Analysis: Inventory Insights and Speciated $PM_{2.5}$ Estimates. Crawford. Presentation at Air Quality Symposium 2011, Fairbanks and North Star Borough, Fairbanks, AK. January 2011.

Influence of Meteorology on $PM_{2.5}$ Concentrations in Fairbanks Alaska: Winter 2008-2009. Crawford. Presentation at Air Quality Symposium 2009, Fairbanks and North Star Borough, Fairbanks, AK. July 2009.

Analysis of the Effect of Fuel Chemistry and Properties on HCCI Engine Operation: A Re-Analysis Using a PCA Representation of Fuels. Bunting and Crawford. 2009. Draft Report (CRC Project AFVL13C)

The Chemistry, Properties, and HCCI Combustion Behavior of Refinery Streams Derived from Canadian Oil Sands Crude. Bunting, Fairbridge, Mitchell, Crawford, et al. 2008. (SAE 08FFL 28)

The Relationships of Diesel Fuel Properties, Chemistry, and HCCI Engine Performance as Determined by Principal Components Analysis. Bunting and Crawford. 2007. (SAE 07FFL 64).

Review and Critique of Data and Methodologies used in EPA Proposed Utility Mercury MACT Rulemaking, prepared by AEMS and RWCrawford Energy Systems for the National Mining Association. April 2004.

PCR+ in Diesel Fuels and Emissions Research. McAdams, Crawford, Hadder. March 2002. ORNL/TM-2002/16.

A Vector Approach to Regression Analysis and its Application to Heavy-duty Diesel Emissions. McAdams, Crawford, Hadder. November 2000. ORNL/TM-2000/5.

A Vector Approach to Regression Analysis and its Application to Heavy-duty Diesel Emissions. McAdams, Crawford, Hadder. June 2000. (SAE 2000-01-1961).

Reconciliation of Differences in the Results of Published Shortfall Analyses of 1981 Model Year Cars. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70045. October 1985

Short Test Results on 1980-1981 Passenger Cars from the Arizona Inspection and Maintenance Program. Darlington, Crawford, Sashihara. August 1984.

Seasonal and Regional MPG as Influenced by Environmental Conditions and Travel Patterns. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70045. March 1983.

Comparison of EPA and On-Road Fuel Economy -- Analysis Approaches, Trends, and Impacts. McNutt, Dulla, Crawford, McAdams, Morse. June 1982. (SAE 820788)

Regionalization of In-Use Fuel Economy Effects. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70032. April 1982.

1985 Light-Duty Truck Fuel Economy. Duleep, Kuhn, Crawford. October 1980. (SAE 801387)

PROFESSIONAL AFFILIATIONS

Member, Society of Automotive Engineers.

HONORS AND AWARDS

2006 Barry D. McNutt Award for Excellence in Automotive Policy Analysis. Society of Automotive Engineers.

US Patent 7018524 (McAdams, Crawford, Hadder, McNutt). Reformulated diesel fuels for automotive diesel engines which meet the requirements of ASTM 975-02 and provide significantly reduced emissions of nitrogen oxides (NO_x) and particulate matter (PM) relative to commercially available diesel fuels.

US Patent 7096123 (McAdams, Crawford, Hadder, McNutt). A method for mathematically identifying at least one diesel fuel suitable for combustion in an automotive diesel engine with significantly reduced emissions and producible from known petroleum blend stocks using known refining processes, including the use of cetane additives (ignition improvers) and oxygenated compounds.

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ATTACHMENT D

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America's Ethanol Supporters

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PHONE 202.545.4000 FAX 202.545.4001 GrowthEnergy.org

August 15, 2014

Via Electronic Mail

Mr. Alexander Mitchel
Transportation Fuels Branch
California Air Resources Board
1001 I Street
Sacramento, CA 95814

Re: Alternative Diesel Fuel Rulemaking

Dear Mr. Mitchell:

Please find attached the comments of Growth Energy in response to the staff's request for public input on alternatives to the 2013 regulatory proposal for the Alternative Diesel Fuel regulation. Growth Energy hopes to make a further submission regarding regulatory alternatives following the public consultation meeting to discuss biodiesel emissions testing sponsored by the Board.

Please place this letter and its attachments in the public docket that I understand the staff is establishing for materials it receives in connection with this rulemaking effort.

Sincerely,

David Bearden
General Counsel and Secretary

cc: Dr. Irena Asmundson (via Electronic Mail)
Mr. Michael S. Waugh (via Electronic Mail)

STATE OF CALIFORNIA

AIR RESOURCES BOARD

RESPONSE TO REQUEST FOR PUBLIC INPUT ON REGULATION OF ALTERNATIVE DIESEL FUEL

GROWTH ENERGY

AUGUST 15, 2014

Growth Energy's Response to Request for Public Input
On Regulation of Alternative Diesel Fuel

Growth Energy respectfully submits this response to the request by the staff of the California Air Resources Board ("CARB") for public input on alternatives to the staff's currently proposed method for regulating the use of alternative diesel fuel ("ADF") as part of compliance with the low-carbon fuel standard ("LCFS") regulation. The CARB staff presented its request for public comment in a notice dated July 29, 2014, and has established today as the deadline for that input. In these brief comments, Growth Energy assumes CARB's familiarity with and incorporates by reference its June 23, 2014 submission in response to a similar staff request concerning the LCFS regulation itself, as well as Growth Energy's submissions in an earlier phase of the ADF rulemaking in 2013.

I. Introduction and Background

The stated purpose of the July 29 notice is to seek input on regulatory alternatives pursuant to the 2011 amendments to the Government Code contained in SB 617. The proposed ADF regulation is intended to provide a legal pathway for new emerging diesel fuel substitutes to enter the commercial market in California, while managing and minimizing environmental and public health impacts, and to preserve the emission benefits derived from the CARB motor vehicle diesel regulations.[1] In light of that goal, the current ADF rulemaking as most recently described by CARB staff would establish:

- A general process governing the commercialization of new ADF formulations in California, and
- Specific requirements for biodiesel and biodiesel blends that are consistent with the general ADF process and that would mitigate increases in emissions of oxides

[1] *See* "Initial Statement of Reasons, Proposed Regulation on the Commercialization of New Alternative Diesel Fuel," October 23, 2013 available at http://www.arb.ca.gov/regact/2013/adf2013/adf2013isor.pdf.

> of nitrogen (NOx) from diesel engines and vehicles that have been identified to occur relative to conventional California diesel fuel from the use of biodiesel and biodiesel blends. [2]

There are no specific compositional requirements proposed for ADFs other than "biodiesel," inasmuch as none have yet sought to be commercialized in California.

CARB has a duty to mitigate any potential significant environmental impacts that could result from commercialization of biodiesel. Mitigation strategies will drive the costs and affect the benefits of the ADF regulation, and so the first step in the SB 617 process for the ADF regulation should be to develop a range of potential mitigation strategies. CARB has sponsored, but has not yet fully digested, a body of tests using biodiesel fuels. The CARB staff, for its part, has recently asserted that those tests have informed several major findings about mitigation strategies; nevertheless, the staff also acknowledges that some of its major findings are preliminary and subject to change because the data upon which they are based has only recently made available to the public. Nor has the CARB staff fully developed and explained its findings. Once the staff does so, it should then seek better-informed public input under SB 617.

Based on its current analysis, the CARB staff has indicated that it expects that the yet unpublished proposed ADF regulation will require NOx mitigation for biodiesel blends containing more than five percent of an animal-based biodiesel or more than one percent of soy-based or other types of biodiesel blends. Staff also indicates that it expects to propose an exemption for all biodiesel blends when used in vehicle fleets containing more than 95% "new technology diesel engines (NTDEs)"[3] from NOx mitigation requirements and a sunset clause

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2 *See* "Preliminary Rulemaking Proposal for Biodiesel Use as an Alternative Diesel Fuel," July 29, 2014 available at http://www.arb.ca.gov/fuels/diesel/altdiesel/20140729ADF_SRIA_Proposal.pdf.

3 In the October 23, 2013 Initial Statement Reasons, CARB staff defined NTDEs as meaning:

eliminating all NOx mitigation requirements "once NTDEs represent 95 percent of the heavy duty diesel engines in California."

The CARB staff's approach appears to rest on two beliefs: (i) no NOx increases occur in blends containing five percent or less of animal-based biodiesel or one percent or less of soy-based or other biodiesel; and (ii) there are no NOx increases from biodiesel use in NTDEs.

Turning first to the need to mitigate NOx emissions for animal-based biodiesel blends below five percent and below one percent for soy-based and other biodiesel blends, the flaws here are due to the fact that the CARB staff continues to cling to the concept of there being a "threshold" biodiesel blend level below which there are no increases in NOx emissions, rather than accepting that there is a linear relationship between NOx emissions and increases in biodiesel content. That the staff's "threshold" model is flawed with respect to both soy- and animal-based biodiesel blends and should be replaced by the linear model was made clear in a technical report prepared by Robert Crawford[4] that was submitted to CARB as part of Growth Energy's formal comments on the abandoned 2013 ADF rulemaking.

With respect to the impact of biodiesel on NOx emissions from NTDEs, CARB staff's major finding in this area — that biodiesel does not increase NOx emissions from NTDEs — continues to rely, as it did in the October 2013 rulemaking, on only one reference, a paper by

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a diesel engine that meets at least one of the following criteria:

(1) 2010 ARB emission standards for on-road heavy duty diesel engines under 13 CCR 1956.8,
(2) Tier 4 emission standards for non-road compression ignition engines under 13 CCR 2421, 2423, 2424, 2425, 2425.1, 2426, and 2427, or
(3) equipped with or employs a Diesel Emissions Control Strategy (DECS), verified by ARB pursuant to 13 CCR 2700 et seq., which uses selective catalytic reduction to control NOx.

4 Crawford, R., "NOx Emission Impact of Soy- and Animal-based Biodiesel Fuels: A Reanalysis," December 10, 2013.

Lammert *et al.*[5] The flaws in the basis for this major finding were explained in Growth Energy's submission in the 2013 ADF rulemaking.[6] A 2014 peer-reviewed publication authored by researchers from the University of California at Riverside[7] (Gysel, *et al.*) who report results from a study funded by the South Coast Air Quality Management District confirms that CARB staff's major finding in this area is flawed. With respect to biodiesel impacts on NOx emissions from NTDEs, Gysel *et al.* report large percentage increases in NOx emissions with biodiesel use in NTDEs and state:

> Lammert *et al.* showed that the effect of SCR aftertreatment negates the effect of fuels on NOx emissions when they tested a 2011 Cummins ISL engine on B20 and B100. This is in strong contrast to the current study vehicle shows that there is rather strong fuel effect with the B50 blends compared to CARB ULSD from the Cummins ISX-15 engine with SCR.

In addition, Gysel *et al.*, provides a discussion referencing at least four other peer-reviewed technical papers[8] which further confirm this flaw in the staff's finding, showing increases in

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5 Lammert, M., McCormick, R., Sindler, P. and Williams, A., "Effect of B20 and Low Aromatic Diesel on Transit Bus NOx Emissions Over Driving Cycles with a Range of Kinetic Intensity," *SAE Int. J. Fuels Lubr.* 5(3):2012, doi:10.4271/2012-01-1984.

6 As an expert stated in Growth Energy's submission:

> ... [T]he CARB staff's unequivocal statements regarding the impact of biodiesel on NOx emissions from all vehicles with NTDEs is simply not reasonable based on data from (1) a single study that (2) tested only two urban buses equipped with the same engine and (3) used instrumentation that was, at best, barely able to measure NOx emissions from the test vehicles in general, and clearly was not sensitive enough to reliably detect changes in NOx emissions due to use of different fuels. Nothing else in the rulemaking file supports the CARB staff's claim that there will not be increased NOx emissions from the use of biodiesel in NTDEs.

Declaration of James M. Lyons, ¶ 23 (Dec. 12, 2013).

7 Gysel, N., Karavalakis, G., Durbin, T., Schmitz, D., and Cho, A., "Emission and Redox Activity of Biodiesel Blends Obtained from Different Feedstocks from a Heavy-Duty Vehicle Equipped with DFS/SCR Aftertreatment and a Heavy-Duty Vehicle without Control Aftertreatment," SAE Technical Paper 2014-01-1400, April 1, 2014.

8 Walkowicz, K., Na, K., Robertson, W., Sahay, K., Bogdanoff, M., Weaver C., and Carlson, R., "On-road and In-Laboratory Testing to Demonstrate Effects of ULSD, B20 and B99 on a Retrofit Urea-SCR Aftertreatment System," SAE Technical Paper 2009-01-2733, November 2, 2009; McWilliam, L. and Zimmermann, A., "Emissions and Performance Implications of Biodiesel Use in an SCR-equipped Caterpillar C6.6," SAE Technical Paper 2010-01-2157, October 25, 2010; Mizushima, N., Murata, Y., Suzuki, H., Ishii, H., Goto, Y.,

NOx emissions from biodesel use with NTDEs. It should also be noted that the observed NOx increases from biodiesel use in NTDEs are consistent with the widely accepted linear model form which Crawford's report demonstrates is technical superior to CARB's flawed threshold model.

II. Necessary Changes in the CARB Staff's Approach

In light of the currently available data and the relevant literature, the CARB staff's current approach is insufficient to mitigate the impacts of biodiesel usage. On that basis, Growth Energy asks the staff to consider a regulatory alternative having the following three key elements:

1. Require that the mitigation strategies for increased NOx emissions be applied to all biodiesel and blends of biodiesel and diesel fuel where biodiesel was intentionally blended.[9]

2. Eliminate exemptions from NOx mitigation requirements for biodiesel used in vehicle fleets comprised of at least 95% NTDEs.

3. Eliminate the sunset provision for NOx mitigation requirements.

It is critical for the staff to evaluate the need for those three changes in light of other measures that CARB has adopted or is considering adopting to reduce NOx emissions, including the Advanced Clean Cars program and CARB's Sustainable Freight Transport Initiative which involve requirements for "zero-emission" heavy-duty vehicles.

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and Kawano, D., "Effect of Biodiesel on NOx Reduction Performance of Urea-SCR System," SAE Technical Paper 2010-01-2278, October 25, 2010.

[9] The reference to intentional blending has been included to ensure that mitigation is not required for inadvertent blends of biodiesel and diesel that could result from mixing of diesel with biodiesel remaining in storage tanks or in fuel transfer lines.

Growth Energy appreciates the opportunity to provide this input on alternatives to the current approach to developing an ADF regulation, and as noted above, plans to provide additional input once the CARB staff has reviewed the available data in one or more workshops.

Respectfully submitted,

GROWTH ENERGY

STATE OF CALIFORNIA

AIR RESOURCES BOARD

RESPONSE TO REQUEST FOR PUBLIC INPUT ON ALTERNATIVES TO THE LOW- CARBON FUEL STANDARD REGULATION

GROWTH ENERGY

JUNE 23, 2014

Executive Summary

The staff of the California Air Resources Board ("CARB") has identified the Low-Carbon Fuel Standard ("LCFS") as a "major regulation" that requires enhanced review for compliance with SB 617 (Calderon and Pavley), a 2011 amendment to the California Administrative Procedure Act (the "APA"). The California Department of Finance ("the Department") has published regulations that implement SB 617. Those regulations require rulemaking agencies like CARB to seek early public input on possible alternatives to the rules being developed by the rulemaking agencies.

Growth Energy, an association of the Nation's leading ethanol producers and other companies that serve America's need for renewable fuels, is submitting to the CARB staff a proposed alternative to the LCFS regulation that would allow the State to eliminate the LCFS program without loss of environmental benefits. Growth Energy's proposal recognizes important changes in the regulatory baseline for the control of greenhouse gas ("GHG") emissions that have occurred since 2009. In particular, the federal renewable fuels standard ("RFS") program, combined with the California cap-and-trade program and a number of California-specific vehicle- and engine-based regulations, now assure that California will receive most if not all of the direct GHG emissions reductions that can be attributed to the LCFS regulation. To the extent that CARB believes that there is still an emissions shortfall from elimination of the LCFS or that it has authority to address lifecycle GHG emissions occurring outside of California under state and federal law (which are issues not addressed in this submittal), Growth Energy proposes that CARB address those remaining issues by modifying the California GHG cap-and-trade regulations, which are now in effect in California and which apply to transportation fuels providers beginning in 2015.

Growth Energy's description of its proposed alternative to the LCFS regulation is as detailed as possible, given currently available information. In this submittal, Growth Energy urges the CARB staff to provide the additional information needed to provide further analysis of alternatives to the LCFS regulation.

Table of Contents

Page

Growth Energy's Response to Request for Public Input
On Alternatives to the Low-Carbon Fuel Standard Regulation

Growth Energy respectfully submits this response to the request by the staff of the California Air Resources Board ("CARB") for public input on alternatives to the low-carbon fuel standard ("LCFS") regulation. The CARB staff presented its request for public comment in a notice dated May 23, 2014, and has established today as the deadline for that input.

The CARB staff is seeking public input in connection with its proposal that CARB revise and readopt the LCFS regulation at a public hearing later this year. The purpose of the LCFS regulation, which the Board first adopted in 2009, is to achieve reductions in greenhouse gas ("GHG") emissions from the California transportation sector pursuant to the Global Warming Solutions Act of 2006, commonly called AB 32. Other regulations adopted since 2008 under AB 32 to achieve the same objectives as the LCFS regulation include the "cap and trade" regulation (17 C.C.R. §§ 95801-96022), the GHG emissions standards contained in the Advanced Clean Cars (or "ACC") program (13 C.C.R. §§ 1960.1-1962.2), and a set of regulations to control GHG emissions from heavy-duty vehicles and engines.[1]

<u>Overview</u>

Growth Energy has organized its analysis of alternatives to the LCFS regulation in this submission into four parts.

Part I of this submission briefly outlines the statutory and regulatory framework for the CARB staff's request for input on alternatives to the LCFS regulation. As explained in Part I, regulations adopted by the California Department of Finance pursuant to a recent amendment to the APA require CARB to seek and permit effective early public input on rulemaking concerning

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1 These include California's Heavy-Duty GHG regulations now completing the rulemaking process, a second phase of regulations that are under development, and the so-called "Tractor-Trailer" GHG regulation adopted in 2008. *See* http://www.arb.ca.gov/regact/2013/hdghg2013; http://www.arb.ca.gov/cc/hdghg/hdghg.htm.

"major" regulations, including the LCFS. That amendment was contained in SB 617 (Calderon and Pavley). The LCFS rulemaking, and this stage of the LCFS rulemaking, are particularly important, because this rulemaking is one of the first CARB rulemakings governed by SB 617. *See* pp. 4-7 below.

Part II of Growth Energy's submittal addresses some of the important factors that affect a regulatory alternatives analysis undertaken under SB 617. Since 2009, there have been significant changes in the "baseline" conditions for GHG regulation relevant to the LCFS program. As explained in Part II, most of the GHG emissions reductions sought by CARB when it adopted the LCFS regulation in 2009 will be provided by a combination of the federal renewable fuels standard ("RFS") program, along with California's cap-and-trade regulation, ACC program, and regulations limiting GHG emissions from heavy-duty vehicles and engines. Given that most, if not all, of the GHG emissions reductions sought by CARB in 2009 through the LCFS regulation are now assured by those other programs, the LCFS regulation has been rendered largely superfluous from an environmental perspective, even though it imposes huge financial burdens on the regulated community and requires a large commitment of resources by CARB. As a threshold matter, CARB should therefore carefully and fully consider whether, based on regulatory and program developments related to GHG emission control since 2009, there is any continuing need for the LCFS regulation. *See* pp. 8-14 below.

Part III of this submittal explains that, to the extent that the CARB staff finds any continuing need for the LCFS regulation to control GHG emissions, that need could be met instead through a simple modification of the cap-and-trade regulation. Taking that step -- modifying the cap-and-trade regulation -- would fully eliminate any conceivable remaining need for the LCFS regulation, while doing nothing to alter CARB's overall regulatory strategy to address GHG emissions from the California transportation sector. The GHG emissions reductions benefits of the LCFS program would be fully realized from the suite of other GHG regulations adopted federally and in California since 2009, and by the modification of the cap-and-trade program. The direct regulatory costs of the LCFS program are borne primarily by the California motor vehicle fuels marketing industry, which can to some extent pass those costs to its retail customers. Insofar as the LCFS program imposes costs on California businesses and consumers, the alternative presented here (relying on the cap-and-trade program) would not materially alter the allocation of costs and would at the same time reduce regulatory costs by eliminating an entire regulatory program (the LCFS regulation). Judging from the strong concern about the LCFS regulation expressed by oil industry stakeholders, the regulatory relief and reform proposed here warrants full consideration and further development. *See* pp. 14-20 below.

Part IV of Growth Energy's submittal recommends specific next steps that CARB should consider, including full involvement by the Chief Counsel's Office to ensure compliance with the APA. As will be apparent throughout this submittal, Growth Energy's analysis of regulatory alternatives can be no more detailed than the publicly available information about (i) the new version of the LCFS regulation that the CARB staff is considering for proposal to the Board, and (ii) the information that the CARB staff has provided about the benefits that it is attributing to the LCFS program. Contrary to the position taken in communications to Growth Energy by CARB's Transportation Fuels Section on this subject, very little information on the new version of the LCFS regulation or its estimated benefits -- which are critical to an effective SB 617 process -- has been provided to the public to date. In order to achieve substantial compliance with the APA, the CARB staff needs to provide the public with a full picture of its proposed new

LCFS regulation, and in particular describe any new features of the regulation intended to reduce compliance costs. The CARB staff also needs to completely identify for the public all benefits that it is attributing to the LCFS regulation that would bear on an SB 617 alternatives analysis. Then, after the public has had sufficient time to analyze the relevant information from CARB, the public should be permitted to provide updated regulatory alternative analyses, which the CARB staff should fully consider and address in the Standardized Regulatory Impact Assessment required by 1 C.C.R. § 2002. That approach would ensure compliance with the APA, without conflicting or otherwise undermining any other mandates or obligations applicable to the LCFS regulation. *See* pp. 20-24 below.

I. The Statutory Framework for the Regulatory Alternatives Analysis under SB 617

The CARB staff is seeking submittals from the public on regulatory alternatives to the LCFS regulation because it has a legal obligation to do so. For many years, section 11346.3 of the APA has provided in part as follows:

> (a) State agencies proposing to adopt, amend, or repeal any administrative regulation shall assess the potential for adverse economic impact on California business enterprises and individuals, avoiding the imposition of unnecessary or unreasonable regulations or reporting, recordkeeping, or compliance requirements. ...
>
> (2) The state agency, prior to submitting a proposal to adopt, amend, or repeal a regulation to the office, shall consider the proposal's impact on business, with consideration of industries affected including the ability of California businesses to compete with businesses in other states. For purposes of evaluating the impact on the ability of California businesses to compete with businesses in other states, an agency shall consider, but not be limited to, information supplied by interested parties.

Cal. Gov't Code § 11346.3(a)(2). Based on evidence that rulemaking agencies did not adequately consider the burdens that regulations impose on the public, in SB 617 the Legislature added a requirement that rulemaking agencies prepare a detailed assessment of the costs and benefits of any proposed major regulation, for review by the California Department of Finance ("the Department") ***before*** initiating the traditional informal rulemaking process. *See id.* § 11346.3(c). Those detailed assessments are called Standardized Regulatory Impact Assessments (or "SRIAs."). *See id.* § 11346.36. The Legislature also made it clear in SB 617 that the obligation to consider and use early public input on regulatory impacts could not be met by merely going through the formalities of seeking public input.[2]

The Department completed work on regulations to implement SB 617 in the fall of 2013. The Department's regulations require, among other steps, the following:

> The [rulemaking] agency shall also seek public input regarding alternatives from those who would be subject to or affected by the regulations ... prior to filing a notice of proposed action with OAL unless the agency is required to implement federal law and regulations which the agency has little or no discretion to vary. An agency shall document and include in the SRIA the methods by which it sought public input.

1 C.C.R. § 2001(d). As the rulemaking file for the Department's regulations implementing SB 617 shows, many state regulatory agencies, CARB not excepted, recognized that SB 617 (as implemented by the Department) would mean the end of "business as usual" in the California rulemaking process.[3]

In responding to objections from rulemaking agencies concerning the obligations created by its SB 617 regulations, the Department explained that "[i]nvolving the Department and affected parties early in the [rulemaking] process could result in the discovery of additional and

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[2] Thus, SB 617 deleted text from section 11346.3(a)(2) of the APA that, up to 2011, had provided that the APA's public-input requirements were not "inten[ded]" to "impose additional criteria on agencies" engaged in rulemaking. *See* Stats. 2011, c.496 (SB 617), subd. (a); Cal. Office of Admin. Law, *California Rulemaking Law under the Administrative Procedure Act* (2012) 57 (legislative history of section 11346.3).

[3] Several rulemaking agencies filed sharp objections to the Department's proposed regulations to implement SB 617 on the ground that the regulations would require major changes in the timing used by the agencies to develop regulations and to obtain public input. *See, e.g.*, Dep't of Finance, *Regulations to Implement SB 617 Re Major Regulations, Responses to 45-day Comment Period (Chart A)* (hereinafter "Chart A"), available at http://www.dof.ca.gov/research/economic_research_unit/SB617_regulation/documents/Response%20to%20Comments%20Chart A.pdf. The Department dealt fully with all those objections and made no material changes in its proposed regulations to implement SB 617.

perhaps more cost-effective alternatives to [a] proposed major regulation, consistent with the intent of SB 617."[4] Similarly, when rulemaking agencies (including CARB) objected to the burdens of preparing the early regulatory analyses of costs and benefits needed for an effective SB 617 process, the Department correctly concluded that the amended APA "clearly contemplates that an agency will have considered [regulatory] alternatives prior to filing a notice of a proposed action" with the Office of Administrative Law and publication of the regulatory notice for further public comment.[5] The Department also made it clear that under the SB 617 process, the "no action" alternative to regulation -- which is an outcome seldom if ever seen in a major California rulemaking -- had to receive full and fair consideration at the beginning of the rulemaking process.[6]

In requiring significant change in the California rulemaking process, the statute and the implementing regulations are salutary. The LCFS regulation in 2009 was typical of major rulemakings affecting the motor vehicle fuels industries in California. Beginning in 2008, CARB had convened a series of public consultation meetings prior to its formal proposal for rulemaking in March 2009. Not until publication of the Initial Statement of Reasons for the LCFS regulation, however, was the public given any opportunity to review the economic analysis of costs and benefits for the proposed regulation; the written comments on economic issues were due a scant 45 days later (in April 2009), and at the Board's April 2009 public hearing, most private-sector speakers were limited to five minutes to make a presentation to

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4 *See* Chart A at 24.

5 *Id.* at 27.

6 *Id.* at 47-48.

CARB. The public cannot have a significant role in serious economic analysis of a major regulation within such a constrained process.

Unsurprisingly, major economic assumptions and issues were not fully addressed within the time frame for written comments in March to April 2009, nor at the Board hearing. Among the assumptions and factors that could not as a practical matter be "pressure-tested" in the public comment process was the CARB staff's belief that advanced ethanol production methods would eventually drive down gasoline costs at the retail level and make the LCFS program cost-neutral for California consumers or even generate savings of up to $11 billion.[7] That assumption was unsound in 2009, and has since been disproven by experience.[8] Likewise, in the 2009 rulemaking, the CARB staff gave little attention to the ability of the federal RFS program to accomplish the same goals and purposes of the LCFS regulation, and offered largely opaque comparisons between the GHG reductions that the two programs could achieve. Now in its fifth year of implementation, the LCFS regulation has made little or no impact on the supply of lower-GHG fuels in California.[9] SB 617 and the Department's implementing regulations require the Board to improve the quality and depth of the economic analysis for major regulations like the LCFS program.

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7 Air Resources Board, *Proposed Regulation to Implement the Low Carbon Fuel Standard -- Staff Report: Initial Statement of Reasons* (hereinafter "ISOR") at ES-26.

8 As the ISOR itself noted, "Economic factors, such as tight supplies of lower-carbon-intensity fuels ... could result in overall net costs, not savings, for the LCFS." The fact that the cost savings forecast in 2009 proved ephemeral is implicit in the CARB staff's decision, less than two years after the regulation went into effect, to develop "cost reduction" features for the LCFS regulation, which would assist "regulated parties ... unable to meet their compliance obligations ... due to limited supplies of low carbon fuels or LCFS credits in the market." Air Resources Board, *Low Carbon Fuel Standard 2011 Program Review Report* (Dec. 8, 2011) (hereinafter "2011 Program Review") 16.

9 There have been substantial increases in the efficiency of Midwest corn ethanol production facilities since CARB first embarked on the LCFS rulemaking, and those increases have reduced the lifecycle GHG emissions of those facilities under some analyses; but those reductions in GHG emissions have been caused by market forces (the need to reduce energy consumption in order to remain competitive), not by virtue of the LCFS regulation. *See* note 25 below.

II. Factors Affecting the Regulatory Alternatives Analysis

According to the CARB staff, the goal of the LCFS regulation in 2009 was, and still remains, to "reduce the carbon intensity of transportation fuels used in California by at least 10 percent by 2020 from a 2010 baseline," and also to "support the development of a diversity of cleaner fuels with other attendant co-benefits."[10] Growth Energy sought clarification of the staff's description of the goals of the regulation for purposes of its input in the SB 617 process.[11] Lacking greater specificity or clarification, Growth Energy can only turn to the 2009 rulemaking, in which CARB quantified the "10 percent" target as being a reduction of 16 million metric tons of carbon dioxide equivalent ("MMTCO2eq") GHG emissions associated with combustion of transportation fuels in California, along with a 7 MMTCO2eq reduction in "upstream" emissions, yielding a total 23 MMTCO2eq reduction in worldwide annual GHG emissions in 2020.[12] As explained below, achieving the direct GHG emissions reduction attributed to the LCFS regulation in 2009 -- the 16 MMTCO2eq -- no longer requires the existence of the LCFS regulation.

A. Changes in the Regulatory Baseline Since 2009

The most significant development in the regulatory baseline since 2009 has been the adoption and full implementation of the federal renewable fuels standard program under the Energy Independence and Security Act of 2007, pursuant to a Final Rule adopted by the U.S.

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10 The staff identified that goal on June 5, 2014, well after the period for preparation of SB 617 public input had begun, in response to a specific request from Growth Energy. *See* Letter from D. Bearden to K. King, May 30, 2014 (included here as Attachment 1) *and* Letter from M. Waugh to D. Bearden, June 5, 2014 (included here as Attachment 2).

11 *See* Letter from D. Bearden to M. Waugh, June 11, 2014 (included here as Attachment 3). To date, no response to Mr. Bearden's letter of June 11, 2014, has been received.

12 *See* ISOR at VII-1. According to the 2009 ISOR, "These reductions account for a 10 percent reduction of the GHG emissions from the use of transportation fuel." *Id.* That 10 percent target, which the CARB staff also sometimes cites, originates in Executive Order S-01-07 of January 18, 2007. *See* Executive Order S-01-07, § 1, available at http://www.arb.ca.gov/fuels/lcfs/eos0107.pdf.

Environmental Protection Agency in 2010.[13] The federal RFS program assures an adequate supply of low-cost renewable fuel for California, *i.e.*, ethanol produced from corn starch at biorefineries located mainly in the Midwest.[14] Because ethanol produced by any method from any renewable feedstock has the same physical and chemical properties when used in motor fuel, gasoline blended with 10 percent ethanol will achieve the same reduction in exhaust or "tailpipe" GHG emissions regardless of the production process or renewable feedstock used to create the ethanol. Consequently, the portion of the 16 MMTCO2eq reduction in GHG emissions from the California transportation fleet operated on gasoline can and will be obtained by virtue of the federal RFS program.[15] Oil companies will continue to buy and blend ethanol into gasoline sold in California under the federal program even if there were no LCFS program, in order to comply with the federal RFS program. The portion of the California fleet operated on diesel fuel can also achieve its part of the 16 MMTCO2eq reduction in GHG emissions by virtue of the federal RFS

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[13] *See* U.S. EPA, *Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule*, 75 Fed. Reg. 14,669 (Mar. 26, 2010) .

[14] The RFS program, which in its early stages was effectively non-binding on ethanol usage, has begun to cause substantial increases in biofuel production. Total production of biofuels has increased steadily over the last year and a half, reaching approximately 16 billion gallons in the 12 months through April 2014. *See* http://www.epa.gov/otaq/fuels/rfsdata/.

[15] The term "fleet," as used here, includes off-road vehicles and engines in other equipment.

When the CARB staff considered the matter in 2009, it made a number of assumptions about the efficacy of the federal RFS program that need to be reconsidered. The most significant assumption, which was empirically unsupported, was that the federal program (which at the time was still under development) would provide only 30 to 40 percent of the GHG reductions that the staff predicted for the LCFS program. That assumption appears to have been based on a belief that without the LCFS regulation, only 11.3 percent of the advanced or cellulosic biofuels required nationwide by the RFS program would be consumed in California, while a substantially higher amount of those fuels would be drawn from the nationwide fuel pool to California as the result of the LCFS regulation. The advanced biofuels required by the RFS regulation that would be drawn to California by the LCFS program would have been used elsewhere in the absence of the LCFS program, leading to the same reductions in GHG emissions. To the extent that the cellulosic ethanol industry has experienced limits on achieving full commercial launch, those are national and even global economic and technical factors that the existence of the LCFS regulation has not to date, and will not in the future, be able to change or influence.

program, because the federal program results in blending biodiesel and renewable diesel into diesel fuel produced from petroleum.[16]

As for the portion of the California fleet powered in whole or in part with electricity or hydrogen, there is similarly no continuing need for the LCFS program, owing to other changes in the regulatory baseline since 2009. The Advanced Clean Cars program now assures that electricity and hydrogen will be full participants in the California transportation fuel pool. In 2009, CARB's baseline for the alternatives analysis of the LCFS regulation included the then-current version of the Board's regulations to control GHG emissions from new motor vehicles that had been adopted in 2004, and that set GHG emission standards for 2009 to 2016 model-year new vehicles, sometimes called the "Pavley standards." In addition, the baseline also included the then-current provisions of the agency's Zero Emission Vehicle ("ZEV") standards which require manufacturers offer electric and/or hydrogen fuel cell vehicles for sale in California. CARB has now adopted new-vehicle GHG standards applicable to 2017 to 2025 model-year new vehicles and has made significant revisions to the ZEV standards as part of the ACC rulemaking in 2012.[17]

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[16] One reason why California is assured of receiving an adequate supply of ethanol is that ethanol for use in gasoline commands a higher price -- the so-called "California premium" -- in California than in other parts of the United States, as can be readily seen from data available under contract or license from the Oil Price Information Service ("OPIS"). While there are many reasons why the "California premium" exists, one major reason is that refineries producing finished gasoline products for the California retail market tend to have higher production costs than other refineries.

[17] In its 2009 LCFS alternatives analysis, the CARB staff assumed that manufactures would sell more electric vehicles than required by the ZEV standards, as they existed in 2009. Vehicle manufacturer compliance with the ZEV, new vehicle GHG, and criteria emission standards is determined on a "fleet-average" basis. What this means is that to the extent that manufacturers sell more ZEVs than required, they can in turn sell greater numbers of less fuel efficient or higher emitting vehicles provided that they remain in compliance on average. In addition, manufacturers that over comply can sell "credits" to manufacturers that would not otherwise be in compliance. Therefore, even if the LCFS regulation might lead to greater demand and use of electric vehicles, there would be no net reduction in GHG emissions.

CARB has also taken and is taking a number of actions to reduce GHG emissions associated with the use of diesel fuel in heavy-duty vehicles which also need to be taken into account in the baseline for the 2014 LCFS analysis. The relevant measures include California's Tractor-Trailer regulation adopted in 2008 which requires use of aerodynamic improvement devices and low-rolling resistance tires, as well as the Phase I and the soon-to-be proposed Phase II heavy-duty GHG regulations that impose specific GHG emission requirements on new heavy-duty vehicles beginning with the 2014 model-year.[18]

B. Necessary Information for Development of a Detailed Alternative Program

In addition to properly defining the baseline for the alternatives analysis, it is important to have a clear and complete picture of the revised LCFS program that the CARB staff plans to propose. In addition to full information concerning the estimated benefits of the LCFS program (both in terms of GHG reductions and in any other relevant aspect), the currently unknown elements of that program include the following:

- Updated carbon intensity values for transportation fuels that will be included in the proposed 2014 LCFS regulation.
- The detailed form of any proposed "cost-containment" provisions which could allow parties subject to the LCFS regulation to comply with the program's standards, without actually achieving the CI reductions required under the regulation.
- CARB staff's current analysis of the manner in which regulated parties will most likely attempt to comply with the proposed 2014 LCFS.

[18] In addition to ensuring that the GHG emissions reductions associated with those regulations are properly accounted for in the baseline for the 2014 LCFS, CARB staff must also ensure that they properly account for the fact that compliance with the latter regulations is determined on a manufacturer fleet average basis in order to avoid improper assignment of GHG reductions to the 2014 LCFS regulation.

- A full description of any other intended goals of the LCFS regulation, such as stimulating "fundamental" changes in the "transportation fuel pool," along with the metrics to be used to measure progress and success in meeting those other goals.[19]

Contrary to the position taken in the CARB staff's recent correspondence with Growth Energy and in related postings on the CARB website, none of those elements have been disclosed to the public at present. In addition to providing that undisclosed information concerning its analysis, the CARB staff should address the following other pertinent questions, which follow from the foregoing review of changes in the regulatory baseline since 2009:

- Does the CARB staff agree that the federal RFS program would, in the absence of an LCFS regulation, assure some level of reductions in GHG exhaust emissions from the California in-use vehicle population that is operated on gasoline? If not, why not; and if so, what would be that level of GHG emissions reductions, on an annual or some other specific basis, if the LCFS program were to be discontinued at the end of 2015?
    - Does the staff have any disagreement with the position that the federal RFS program and the "California premium" (*see* note 15 above) would cause Midwest corn ethanol producers to continue preferentially to deliver ethanol to California, and cause the California gasoline marketing sector to blend that Midwest corn ethanol into gasoline up to the current 10 percent limit, even in the absence of the LCFS regulation? If so, what are the specific reasons why the staff disagrees?
    - Does the staff believe that the LCFS regulation would result in wider usage of E85 in California than the federal RFS program would cause, and if so, what is the empirical basis for that view?
    - Would a possible need for a diesel component to an LCFS program justify an unnecessary gasoline component for an LCFS program, and if so, why?
- The 2009 regulatory analysis predicted that ultra-low-CI fuels would be available and would bring the costs of the LCFS program down to the point where the program would be cost-neutral at the consumer level, or would result in savings of up to $11 billion.[20]

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[19] *See* Air Resources Board, *California's Low Carbon Fuel Standard -- Final Statement of Reasons* (hereinafter "FSOR") 24.

[20] *See* ISOR at ES-26.

Does that remain the CARB staff's position? If not, what will be the consumer costs of the staff's proposed revised LCFS regulation, predicted annually or in some other manner? What uncertainties and assumptions affect those cost estimates?

- Are the ACC program and other vehicle-based GHG reduction programs adopted to implement AB 32 designed to obtain, and will they obtain, the maximum technologically feasible and cost effective reductions in GHG emissions from the new vehicles that are subject to those standards? (*See, e.g.*, Cal. Health & Safety Code § 38562(a).) If not, why not? With the ACC program and other non-LCFS regulations discussed above in Part II. A. now in place, would the LCFS program actually produce any incremental increase in the displacement of liquid motor vehicle fuels by electricity in ZEVs or hybrid electric vehicles or hydrogen in fuel cell vehicles? If so, what are the relevant increases, and on what assumptions do the predicted increases depend? Why would a vehicle manufacturer that over-achieved the ZEV requirement not use the credit gained from the overachievement by selling a higher-emitting conventional vehicle fleet? To what extent would the staff attribute to the LCFS program any displacement of vehicle miles traveled in conventional vehicles by vehicles powered by fuel cells, and what is the basis for that prediction?

- The CARB staff sometimes refers to Executive Order S-07-01 as a basis for maintaining the LCFS regulation. Should the requirements of Executive Order S-07-01 be reconsidered in the current rulemaking process insofar as the Executive Order called for creation of the LCFS regulation? Does Executive Order S-07-01 limit in any way CARB's discretion in adopting and enforcing measures to implement AB 32? Does AB 32 require adoption and enforcement of the LCFS regulation, if the same GHG reductions that the LCFS regulation can achieve could be achieved by other means?

- To the extent that the LCFS program is still intended to stimulate "fundamental changes in the transportation fuel pool" in California,[21] to what extent had the program succeeded in its first five years? Is achieving that objective consistent with the potential "cost reduction" mechanisms under consideration for a revised LCFS regulation? How should the Department and the public try to weigh that objective against the potential costs for California consumers and businesses in meeting that objective?

Having now presented the above questions to the CARB staff, Growth Energy believes that the staff should address them in the SRIA for the Department, or concurrently in a separate submittal to the Department made available to the public, if the staff does not intend otherwise to respond to those questions. Each question bears on the need for the LCFS regulation, the costs and benefits of the LCFS regulation, or the legal authority that would limit the analysis of regulatory

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[21] *See* note 19 above.

alternatives. If the CARB staff does not believe that one or more of the above questions are relevant to the evaluation of regulatory alternatives, Growth Energy requests that the CARB staff explain why, with respect to each such question.

III. Regulatory Alternatives

The CARB regulations adopted since 2009 and the federal RFS program adequately provide for full control of the direct GHG emissions from the California vehicle fleet that the LCFS regulation may have been intended to control. In 2009, CARB claimed that the LCFS regulation would provide additional GHG reductions on a lifecycle basis; the "upstream" component of the GHG benefits attributed to the LCFS regulation in 2009 was 7 MMTCO2eq in 2020.[22]

Putting to one side the question whether CARB has legal authority to adopt and enforce a regulation to control GHG emissions occurring outside California, there are several reasons to question whether the LCFS regulation actually achieves any reduction in upstream emissions. As CARB has recognized, the LCFS regulation has to date caused "fuel shuffling" -- ethanol that might have been sold in California prior to the LCFS regulation is still being produced, and is sold somewhere else.[23] Ethanol production processes and pathways that have putatively higher upstream emissions have, at this point, neither terminated nor curtailed operations as a result of the LCFS regulation.[24] In addition, many Midwest corn ethanol biorefineries have qualified for

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[22] *See* ISOR at VII-1.

[23] *See* FSOR at 477 ("Without the wider adoption of fuel carbon-intensity standards, fuel producers are free to ship lower-carbon-intensity fuels to areas with such standards, while shipping higher-carbon-intensity fuels elsewhere. The end result of this fuel 'shuffling' process is little or no net change in fuel carbon-intensity on a global scale.") The "wider adoption" of LCFS-type standards to which CARB referred in the 2009 FSOR has not occurred.

[24] That is not to say, however, that the LCFS regulation is not injurious to the national market in ethanol, nor neutral in its impact on lifecycle GHG emissions. By causing fuel shuffling, the LCFS regulation disrupts the national market in ethanol, imposes costs, and increases transportation-related GHG emissions. Eventually, by effectively banning Midwest corn ethanol from California (if, for example, the LCFS for 2015 established in

lower-carbon-intensity LCFS "pathways" since 2009, on a scale that the CARB staff has admitted was "not expected in 2009."[25] Moreover, the estimates of upstream emissions attributed to Midwest corn ethanol in 2009 were grossly inflated: no one, including CARB, is still prepared to defend the indirect land-use change emissions factors accepted by CARB in 2009, and the current literature demonstrates that the "science" of indirect land-use change is too unreliable to be used as a basis for regulation.[26]

To the extent there is any remaining basis for attributing upstream GHG emissions reduction benefits to the LCFS regulation, those benefits certainly do not warrant the continuation or re-adoption of the LCFS regulation. The more efficient approach would be to adjust the cap-and-trade regulation in Title 17 of the *California Code of Regulations* to account for whatever increment of GHG emissions reductions would be forgone by eliminating the LCFS regulation.[27] To the extent necessary, modifications to the cap-and-trade regulation would be

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2009 were to be enforced), the LCFS regulation will leave California with no commercially viable method of complying with the standard; the staff appears to recognize this problem to some extent, with the currently ill-defined "cost reduction" features that it plans to propose. *See* Air Resources Board, *Low Carbon Fuel Standard Re-Adoption Concept Paper* (March 2014) at 6-7. The reduction in nationwide demand for Midwest corn ethanol will then also impose serious economic harm on the Midwest ethanol industry.

25 *See* 2011 Program Review at 169. The Midwest ethanol production facilities that have qualified for lower-carbon-intensity LCFS pathways have not done so through modifications in their production processes intended to obtain those special LCFS pathways: they have a competitive incentive to increase efficiency, and would have done increased their efficiency in the absence of the LCFS regulation. A Growth Energy member has demonstrated this point in the ongoing *Rocky Mountain* litigation involving some aspects of the LCFS regulation. *See* Declaration of Erin Heupel, P.E. (included here as Attachment 6) ¶¶ 5-6. Notably, in the *Rocky Mountain* litigation, CARB offered no competent evidence to the contrary. As Ms. Heupel also demonstrated, the specific features of the LCFS regulation will eventually force even the highest-efficiency Midwest corn production facilities out of the California market. *See id.* ¶¶ 9-11.

26 The CARB staff has begun to revise and to reduce the indirect land-use change emission factors that were included in the 2009 LCFS regulation. *See* letter from G. Cooper to K. Sideco, April 9, 2014, available at http://www.arb.ca.gov/fuels/lcfs/regamend14/rfa_04092014.pdf. It remains Growth Energy's position that the modeling methods used by CARB to generate indirect land-use change values are too unreliable for use in a regulation intended to comply with AB 32. *See* Letter from D. Bearden to J. Goldstene, May 10, 2010 (included here as Attachment 4).

27 In 2009, CARB received substantial comments on the relative inefficiency of the LCFS approach from one of its independent peer reviewers, who urged that CARB consider a cap-and-trade alternative. *See*, e.g., FSOR at 24 (review by Dr. John Reilly); *see also id.* (summarizing Dr. Reilly's review as stating, "The economic analysis

simple and straightforward. Initially, CARB should determine what, if any, upstream GHG reductions should be attributable to the LCFS regulation, using a scientifically reliable process. CARB would also need an appropriate estimate of the total GHG emissions expected from the use of gasoline and diesel fuel in 2020. A CARB emissions forecast prepared in 2010[28] indicates that total GHG emissions from gasoline and diesel fuel use in California are expected to be approximately 175 million metric tons in 2020 under business as usual conditions. Assuming that the generally required 22 percent reduction in emissions in 2020 under the cap-and-trade program[29] applies to gasoline and diesel fuel use, total 2020 emissions without the LCFS program would be about 135 million metric tons.

Continuing the analysis, and by way of example, suppose that the cap-and-trade regulation had to cover the entire annual 16 MMTCO2eq of GHG emissions that the CARB staff identified as the benefit of the LCFS regulation for 2020. That level of GHG control could be achieved by amending the cap-and-trade regulations to require providers of gasoline and diesel fuel to submit 151 (135+16) million metric tons of allowances – or in other words requiring gasoline and diesel fuel suppliers to surrender 1.11 (151/136) allowances for every ton of GHG emissions they report from the fuels they supply.[30]

[for the LCFS regulation] was done incorrectly. It does not meet [the] technical standards of economics. The baseline assumptions are mutually inconsistent, and if these assumptions were executed in a proper model it would show that the LCS was unnecessary.") CARB stated in 2009 that it would consider the role of cap-and-trade further in addressing the objectives of the LCFS program once the cap-and-trade regulations were completed. *See* FSOR at 452.

[28] *See* Air Resources Board, "California GHG Emissions -- Forecast 2008-2020 (updated Oct. 28, 2010), available at http://www.arb.ca.gov/cc/inventory/data/tables/2020_ghg_emissions_forecast_2010-10-28.pdf

[29] This is based on the general percentage reduction requirements established by CARB for total allowances issued. *See* Air Resources Board, "Overview of ARB Emissions Trading Program (October 2011), available at http://www.arb.ca.gov/newsrel/2011/cap_trade_overview.pdf

[30] The cap-and-trade regulation already begins to take effect for the gasoline and diesel fuel marketing sector in 2015.

The modifications to the existing text of the cap-and-trade regulation would be minor and limited to section 95852(d) of the regulation.[31] Further, the CARB staff at its discretion could also create a compliance offset program in order to incentivize low- carbon intensity fuels similar to those in place which incentivize other innovative GHG reduction strategies.[32] Insofar as one goal of the APA is to eliminate unnecessary regulation, this approach would well-serve the goals

[31] Thus, the text of section 95852(d), with the modification shown in italics, and assuming that the full 10 percent GHG emission reduction attributed to the LCFS regulation would be covered by cap-and-trade, would provide as follows:

> Suppliers of RBOB and Distillate Fuel Oils. A supplier of petroleum products covered under sections 95811(d) or 95812(d) has a compliance obligation *equal to 1.x allowances* for every metric ton CO_2e of GHG emissions included in an emissions data report that has received a positive or qualified positive emissions data verification statement or for which emissions have been assigned that would result from full combustion or oxidation of the quantities of the following fuels that are removed from the rack in California, sold to entities not licensed by the California Board of Equalization as a fuel supplier, or imported into California and not directly delivered to the bulk-transfer/terminal system as defined in section 95102 of MRR, except for products for which a final destination outside California can be demonstrated:

(1) RBOB;
(2) Distillate Fuel Oil No. 1; and
(3) Distillate Fuel Oil No. 2.

> *The value of "x" above will be established by Executive Officer by the prior October 31 for each year beginning with 2015 to ensure that actual GHG emissions from the use of RBOB and Distillate Fuel Oil No. 1 and Distillate Fuel Oil No. 2 are reduced to the level that would have been achieved had the Carbon Intensity of those fuels been reduced according to the following schedule relative to 2010.*

Required Carbon Intensity Reduction Relative to 2010	
Year	Reduction
2015	2.7%
2016	3.7%
2017	5.2%
2018	6.7%
2019	8.2%
2020	10.0%

As illustrated above for 2020, the value of "x" would be 0.11 and the compliance obligation for suppliers of gasoline and diesel fuels would be 1.11 times the number of tons of CO_2e emissions reported.

[32] *See* Air Resources Board, "Climate Change Programs -- Compliance Offset Program" (updated June 11, 2014), available at http://www.arb.ca.gov/cc/capandtrade/offsets/offsets.htm

of the APA. By eliminating the LCFS regulation, CARB would also free the California transportation fuel sector from continuing uncertainty about the availability and cost of ultra-low-carbon-intensity alternative fuels necessary for future compliance with the LCFS. As the Western States Petroleum Association ("WSPA") has stated:

> The LCFS, as envisioned by Governor Schwarzenegger in his Executive Order and as developed by the ARB, is infeasible. ... [S]taying the course now could result in disruptions in the transportation fuels markets. ... A successful fuels policy must protect against fuel supply disruptions, severe job losses in the state's refining industry and unacceptable economic harm to California and its citizens.[33]

While Growth Energy believes that its proposal has sufficient merit without endorsement by other organizations, the concerns expressed by WSPA are important. One benefit of the change that Growth Energy is proposing, and a benefit that is particularly important to Growth Energy and the enterprises it represents, is that elimination of the LCFS regulation would eliminate a major conflict between regulations adopted by California and the federal RFS program, a conflict that will only increase if the LCFS regulation is re-adopted.

In considering Growth Energy's proposal, and in addition to the questions presented in Part II of this submittal, the CARB staff should in the SRIA address the following questions:

- The CARB staff's May 23, 2014, notice soliciting public input for the SRIA sought "alternative LCFS approaches." (See Attachment 5.) Does the CARB staff believe the alternatives analysis for the SRIA and public submittals related to the SRIA must be confined to regulatory alternatives that include or would preserve in some form the LCFS regulation? If so, what is the basis for such a limitation?

- Other than emissions created in generating electricity for delivery in California, does AB 32 give CARB the authority to regulate upstream emissions occurring outside California, or to account for upstream emissions occurring outside

[33] The reference is to Executive Order S-01-07, with its "10 percent" by 2020 goal, which according to the CARB staff remains the target for the LCFS regulation. *See* Letter from G. Grey to K. Sideco, June 13, 2014 at 2, available at http://www.arb.ca.gov/fuels/lcfs/regamend14/wspa_06132014.pdf. WSPA has also stated that modification of the LCFS program through "cost reduction" provisions would "simply penalize fuel suppliers for not meeting an infeasible standard." *See* Letter from C. Reheis-Boyd to K. Sideco, April 11, 2014 at 10, available at http://www.arb.ca.gov/fuels/lcfs/regamend14/wspa_04112014.pdf.

California in adopting regulations to meet the statewide greenhouse gas emissions limit? (*See* Cal. Health & Safety Code § 38505(m), (n); 38562(a).) If AB 32 authorizes CARB to regulate or consider out-of-state GHG emissions attributed to ethanol production, does AB 32 also authorize CARB to address those emissions through the cap-and-trade regulation?

- Can the California cap-and-trade regulations be modified to provide the same numerical reductions in GHG emissions as the LCFS regulation? If not, why not?

- If the CARB staff is concerned that the state measures to control GHG emissions and the federal RFS program might not be fully implemented and enforced at some time in the future, would adoption of a revised LCFS regulation as a "backstop" measure, to be implemented only if those other programs are not meeting defined objectives, address that concern? If not, why not?

- If the CARB staff believes some regulated parties might prefer to comply with a revised LCFS regulation rather than a modified cap-and-trade regulation, could that issue be addressed by including a revised LCFS as a part of a regulatory alternative (with appropriate opt-in provisions) that would be an option for parties that did not wish to comply with a modified cap-and-trade regulation?

- What are the current and expected future levels of resources at CARB, in terms of personnel and other resources, that are allocated to the LCFS regulation? What would be the budgetary impact for CARB if the LCFS program were eliminated? What would be the budgetary impact for CARB caused by the change in the cap-and-trade regulation proposed here?

- To the extent the CARB staff would attribute other beneficial impacts, different from GHG emissions reductions, to the LCFS regulation, to whom do those benefits accrue? With regard to those other beneficial impacts, are California consumers benefitted and, if so, how and to what extent? With regard to those other beneficial impacts, are California businesses benefitted and if so, how and to what extent? Do those other beneficial impacts justify or support continuation of the LCFS regulation, and if so, what is the basis for CARB's authority to adopt and enforce the LCFS regulation to obtain those benefits? If those other beneficial impacts include the possibility that sources for alternative fuels will be increased or diversified, are there any peer-reviewed or other studies that support such a proposition? If not, what is the staff's basis for attributing such benefits to the LCFS regulation? Could those benefits be realized through the development of a compliance offset program under the cap-and-trade regulation?

As with the questions presented in Part II, the CARB staff's responses to these questions are important in understanding its evaluation of Growth Energy's proposal. If the CARB staff does not believe that one or more of the above questions are relevant to the evaluation of regulatory alternatives, Growth Energy requests that the CARB staff explain why, with respect to each such question.

IV. Next Steps

As noted at the outset of this submittal, Growth Energy's analysis of alternatives to the LCFS regulation can be no more detailed than the available information about the staff's intended revised LCFS regulation. If CARB does nothing further to facilitate the public input into the SB 617 process for use in the SRIA, it will not have substantially complied with the APA as amended by SB 617 and implemented in the Department's regulations.

In the CARB staff's first notice that it was ready to receive public input on regulatory alternatives, published on May 23, 2014, the staff set a deadline for that input of June 6, 2014 -- nine business days later. The staff indicated in that notice that the public should, among other things, "submit the quantities of low-CI fuels used each year" in the proposed alternative to the LCFS regulation, "as well as the associated cost and benefit information, and their sources." [34] According to the May 23 notice, that information was needed "to enable comparison of economic impacts."[35] The May 23 notice stated that the objective for public input should be to provide "alternative LCFS approaches," meaning "any approach that may yield the same or greater benefits than those associated with the proposed regulation, or that may achieve the goals at lower cost."[36]

The "proposed regulation" to which the May 23 proposal referred (i) had not been provided to the public for review as of May 23, nor (ii) has it been provided at any time since

[34] *See* Attachment 5.

[35] *Id.*

[36] *Id.*

May 23.[37] The May 23 notice was not accompanied by any information that provided the CARB staff's own prediction of "the quantities of low-CI fuels [that would be] used each year" under the CARB staff's proposed regulation, nor the benefits that the CARB staff attributed to the LCFS regulation. Growth Energy requested that the CARB staff give the public the information needed to prepare a complete SB 617 submission and requested that the public be given additional time to prepare SB 617 analyses after the necessary information was released.[38]

The CARB staff responded by extending the deadline for public submittals that would be addressed in the SRIA to June 23, 2014 (31 days after the May 23 notice), but did not provide any of the information requested by Growth Energy and needed to provide the type of input sought in the May 23 notice, and necessary under the Department's SB 617 regulations. Instead, the staff referred to the GHG emissions reductions targeted in the 2009 rulemaking, to a March 2014 "Concept Paper" that discussed the staff's approach to revision of the LCFS regulation, and to material provided to the public in connection with regulatory workshops held in ARB's offices.[39] The March 2014 Concept Paper raises more questions about the staff's approach than it answers: it included, for example, a general description of two different "cost reduction" concepts without indicating how either of them would work, how they would reduce costs, or how they would affect the GHG emissions reduction benefits of the LCFS program. If the March 2014 Concept Paper provided a basis for preparing SB 617 submittals, then there is no reason why the CARB staff should have waited until May 23 to solicit public input under the Department's regulations. Had the staff informed the public when it released the Concept Paper

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[37] The CARB staff has released some draft regulatory text for their proposed revised LCFS, but that partial text does not include, for example, the "cost reduction" feature intended for the new regulation, nor the carbon intensity values to be assigned to each alternative fuel.

[38] *See* Attachment 1.

[39] *See* Attachment 2.

and discussed the Concept Paper at one of its March 2014 regulatory workshops that the Concept Paper was intended to provide a basis for SB 617 input, Growth Energy (and perhaps other stakeholders) would have pointed out at that time that the Concept Paper was inadequate for that purpose; in that event, perhaps the CARB staff would have been able to provide the necessary information for public input into the SRIA.

The materials provided in connection with the regulatory workshops -- including the partial regulatory text released on May 28, after the staff had launched the public input process -- likewise do not provide the necessary information for detailed public submittals consistent with SB 617 and the Department's regulations. Growth Energy has studied those materials carefully, and with the greatest respect, would challenge the CARB staff to indicate where in those materials the staff identifies GHG emissions reduction targets for a revised LCFS regulation; where the staff identifies any other putative benefits of the LCFS regulation; and where in those materials the staff provides specific and concrete information about the impact of the "cost reduction" concepts on the quantities of alternative fuels that would be used in order to comply with the revised LCFS regulation, or permits a quantification of costs and benefits of a revised LCFS regulation that includes a cost-reduction feature.

Finally, it is important to address comments by the CARB staff at one recent workshop, which suggested that the timing of the current regulatory effort has been affected by the Board's need to comply with the mandate in litigation under the APA and the California Environmental Quality Act ("CEQA").[40] In that litigation, the Superior Court has allowed CARB all the time

[40] The case is *POET LLC et al. v. California Air Resources Board*, Case No. 09 CE CG 04659 (Sup'r Ct., Fresno County). The Writ of Mandate in that proceeding does not require CARB to commence or conclude rulemaking by a particular date, but to proceed in good faith without delay. The Writ of Mandate was issued more than six months ago, by which time CARB presumably knew that it had to comply with the Department's SB 617 regulations.

that the Board has requested in order to comply with the mandate. If CARB needs more time in order to conduct the SB 617 process in a manner that allows sufficient time for effective public input into the preparation of an SRIA, CARB should so inform the Superior Court. (Notably, in its filings with the Superior Court, CARB has not adverted to SB 617 or the Department's implementing regulations.) In addition, the CARB staff would surely agree that even before issuance of the mandate in that litigation, it was aware that it had major program review obligations for the LCFS regulation in 2014.[41] Particularly in light of those program review obligations, the CARB staff's inability to provide more information now to the public, needed to participate fully in the SB 617 process, seems inexcusable.

Against that backdrop, Growth Energy urges the CARB staff to reconsider its present approach to the SB 617 process, and specifically the staff's approach to obtaining public input for the SRIA. As the staff might expect, if one response to Growth Energy's proposed regulatory

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[41] In 2009, when it first adopted the LCFS regulation, the Board directed the CARB staff to conduct and to present by January 1, 2015 a "review of implementation of the LCFS program" that was to "include, at a minimum, consideration of the following areas:

"(1) The LCFS program's progress against LCFS targets;
"(2) Adjustments to the compliance schedule, if needed;
"(3) Advances in full, fuel-lifecycle assessments;
"(4) Advances in fuels and production technologies, including the feasibility and cost-effectiveness of such advances;
"(5) The availability and use of ultralow carbon fuels to achieve the LCFS standards and advisability of establishing additional mechanisms to incentivize higher volumes of these fuels to be used;
"(6) An assessment of supply availabilities and the rates of commercialization of fuels and vehicles;
"(7) The LCFS program's impact on the State's fuel supplies;
"(8) The LCFS program's impact on state revenues, consumers, and economic growth;
. . .
"(12) Significant economic issues; fuel adequacy, reliability, and supply issues; and environmental issues that have arisen; and
"(13) The advisability of harmonizing with international, federal, regional, and state LCFS and lifecycle assessments."

17 C.C.R. § 95489(a).

alternative is that Growth Energy's proposal lacks a detailed comparison with the costs, benefits, and cost-effectiveness of the staff's proposal in the SRIA, Growth Energy will attribute its lack of specificity to the staff's failure to provide the information needed to offer a more specific regulatory analysis. Because this is one of the first major rulemakings at CARB that is required to comply with SB 617 and the Department's SB 617 regulations, it is also important for the Department to take a proactive role in providing guidance to CARB, the stakeholders, and other members of the public interested in the LCFS program.

Respectfully submitted,

GROWTH ENERGY

NOx Emissions Impact of Soy- and Animal-based Biodiesel Fuels: A Re-Analysis

December 10, 2013

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NOX EMISSIONS IMPACT OF SOY- AND ANIMAL-BASED BIODIESEL FUELS: A RE-ANALYSIS

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NOX IMPACT OF SOY- AND ANIMAL-BASED BIODIESEL FUELS: A RE-ANALYSIS

Table of Contents

Page

List of Tables

List of Figures

1. EXECUTIVE SUMMARY

1.1 Background on the Proposed Rule

The California Air Resources Board (CARB) has proposed regulations on the commercialization of alternative diesel fuel (ADF) that were to be heard at the December 2013 meeting of the Board. The proposed regulations seek to "... create a streamlined legal framework that protects California's residents and environment while allowing innovative ADFs to enter the commercial market as efficiently is possible."[1] In this context ADF refers to biodiesel fuel blends. Biodiesel fuels are generally recognized to have the potential to decrease emissions of several pollutants, including hydrocarbons (HC), carbon monoxide (CO), and particulate matter (PM), but are also recognized to have the potential to increase oxides of nitrogen (NOx) unless mitigated in some way. NOx emissions are an important precursor to smog and have historically been subject to stringent emission standards and mitigation programs to prevent growth in emissions over time. A crucial issue with respect to biodiesel is how to "... safeguard against potential increases in oxides of nitrogen (NOx) emissions."[2]

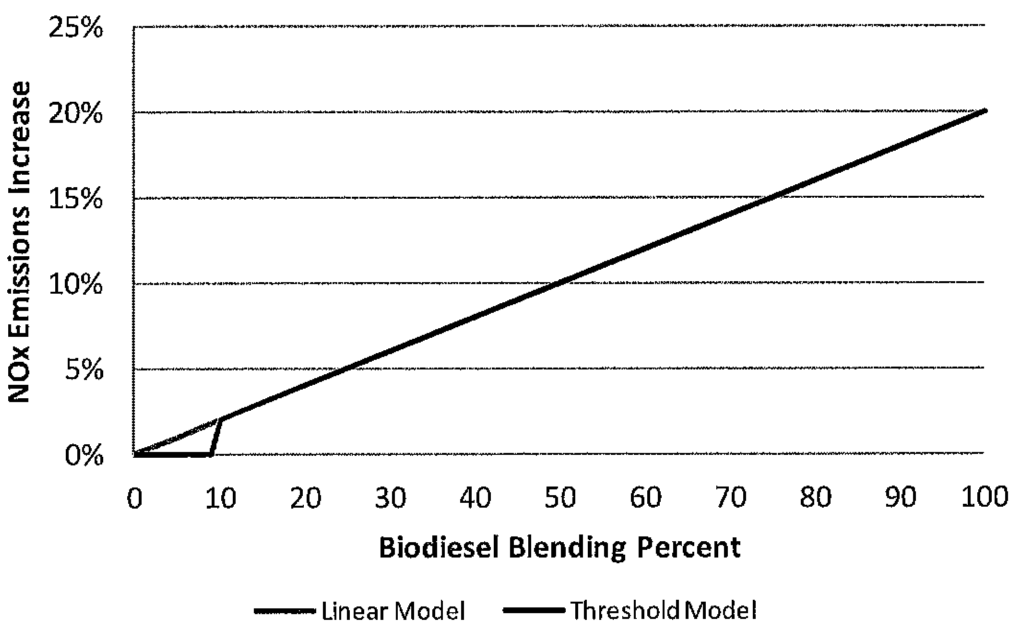
The proposed regulations are presented in the Staff Report: Initial Statement of Reasons (ISOR) for the Proposed Regulation on the Commercialization of New Alternative Diesel Fuels[3] (referenced as ISOR). Chapter 5 of the document describes the proposed regulations, which exempt diesel blends with less than 10 percent biodiesel (B10) from requirements to mitigate NOx emissions:

> There are two distinct blend levels relative to biodiesel that have been identified as important for this analysis. Based on our analysis to date, we have found that diesel blends with less than 10 percent biodiesel by volume (<B10) have no significant increase in any of the pollutants of concern and therefore will be regulated at Stage 3B (Commercial Sales not Subject to Mitigation). However, we have found that biodiesel blends of 10 percent and above (≥B10) have potentially significant increases in NOx emissions, in the absence of any mitigating factors, and therefore those higher blend levels will be regulated under Stage 3A (Commercial Sales Subject to Mitigation).[4]

[1] "Notice of Public Hearing to Consider Proposed Regulation on the Commercialization of New Alternative Diesel Fuels." California Air Resources Board, p. 3. http://www.arb.ca.gov/regact/2013/adf2013/adf2013notice.pdf.
[2] Ibid. p. 3.
[3] "Proposed Regulation on the Commercialization of New Alternative Diesel Fuels. Staff Report: Initial Statement of Reason." California Air Resources Board, Stationary Source Division, Alternative Fuels Branch. October 23, 2013. http://www.arb.ca.gov/regact/2013/adf2013/adf2013isor.pdf.
[4] Ibid, p. 22.

Existing research on the NOx emission effects of biodiesel has consistently been conducted under the hypothesis that the emission effect will be linearly proportional to the blending percent of neat biodiesel (B100) with the base diesel fuel. The Linear Model that has been accepted by researchers is shown as the blue line in Figure 1-1. The Staff position cited above is that biodiesel fuels do not increase NOx emissions until the fuel blend reaches 10% biodiesel. This so-called Staff Threshold Model departs from the Linear Model that underlies past and current biodiesel research by claiming that NOx emissions do not increase until the biodiesel content reaches 10 percent.

Figure 1-1
Linear and Staff Threshold Models for Biodiesel NOx Impacts



The Staff Threshold model is justified by the statement: "Based on our analysis to date, we have found that diesel blends with less than 10 percent biodiesel by volume (<B10) have no significant increase in any of the pollutants of concern." Other portions of the ISOR state that Staff will track "... the effective blend level on an annual statewide average basis until the effective blend level reaches 9.5 percent. At that point, the biodiesel producers, importers, blenders, and other suppliers are put on notice that the effective blend-level trigger of 9.5 percent is approaching and mitigation measures will be required once the trigger is reached."[5] Until such time, NOx emission increases from biodiesel blends below B10 will not require mitigation.

Section 6 of the ISOR presents a Technology Assessment that includes a literature search the Staff conducted to obtain past studies on the NOx impact of biodiesel in heavy-duty

[5] Ibid, p. 24.

engines using California diesel (or other high-cetane diesel) as a base fuel. Section 6.d presents the results of the literature search with additional technical information provided in Appendix B. The past studies include the Biodiesel Characterization and NOx Mitigation Study[6] sponsored by CARB (referenced as Durbin 2011).

The results of the Staff literature search are summarized in Table 1-1, which has been reproduced from Table 6.1 of the ISOR. For B5 and B20, the data represent averages for a mix of soy- and animal-based biodiesels, which tend to have different impacts on NOx emissions (animal-based biodiesels increase NOx to a lesser extent). For B10, the data represent an average for soy-based biodiesels only. Staff uses the +0.3% average NOx increase at B5 in comparison to the 1.3% standard deviation to conclude:

> Overall, the testing indicates different NOx impacts at different biodiesel percentages. Staff analysis shows there is a wide statistical variance in NOx emissions at biodiesel levels of B5, providing no demonstrable NOx emissions impact at this level and below. At biodiesel levels of B10 and above, multiple studies demonstrate statistically significant NOx increases, without additional mitigation.[7]

Table 1-1
Results of Literature Search Analysis

Biodiesel Blend Level	NOx Difference	Standard Deviation
B5	0.3%	1.3%
B10[a]	2.7%	0.2%
B20	3.2%	2.3%

Source: Table 6.1 of Durbin 2011
Notes:
[a] Represents data using biodiesel from soy feedstocks.

<u>The Staff conclusion is erroneous because it relies upon an apples-to-oranges comparison among the blending levels</u>. Each of the B5, B10, and B20 levels include data from a different mix of studies, involving different fuels (soy- and/or animal-based), different test engines, and different test cycles. The B5 values come solely from the CARB Biodiesel Characterization study, while the B10 values come solely from other studies. The B20 values are a mix of data from the CARB and other studies. The results seen in the table above are the product of the uncontrolled aggregation of different studies that produces incomparable estimates of the NOx emission impact at the three blending levels.

[6] "CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California: Biodiesel Characterization and NOx Mitigation Study." Prepared by Thomas D. Durbin, J. Wayne Miller and others. Prepared for Robert Okamoto and Alexander Mitchell, California Air Resources Board. October 2011.
[7] ISOR, p. 32.

As will be demonstrated in this report, the Staff conclusion drawn from the data in Table 1-1 is not supported by past or current biodiesel research, including the recent testing program sponsored by CARB. In fact, past and current studies indicate that biodiesel blends at any level will increase NOx emissions in proportion to the blending percent unless specifically mitigated by additives or other measures.

1.2 Summary and Conclusions

The following sections of this report examine the studies cited by CARB one-by-one. As evidenced from this review, it is clear that the data do not support the Staff conclusion and, indeed, the data refute the Staff conclusion in some instances. Specifically:

- There is no evidence supporting the Staff conclusion that NOx emissions do not increase until the B10 level is reached. Instead, there is consistent and strong evidence that biodiesel increases NOx emissions in proportion to the biodiesel blending percent.

- There is clear and statistically significant evidence that biodiesel increases NOx emissions at the B5 level in at least some engines for both soy- and animal-based biodiesels.

Considering each of the six past studies obtained from the technical literature and their data on high-cetane biodiesels comparable to California fuels, we find the following:

1. None of the six studies measured the NOx emissions impact from biodiesel at blending levels below B10. Only two studies tested a fuel at the B10 level. All other testing was at the B20 level or higher. Because none tested a B5 (or similar) fuel, none of them can provide direct evidence that NOx emissions are not increased at B5 or other blending levels below B10.

2. These studies provide no data or evidence supporting the validity of the Staff's Threshold Model that biodiesel below B10 does not increase NOx emissions. In fact, all of the studies are consistent with the contention that biodiesel increases NOx emissions in proportion to the blending percent.

3. Two of the studies present evidence and arguments that the NOx impact from biodiesel is a continuous effect that is present even at very low blending levels and will increase at higher levels in proportion to the blending percentage.

Considering the CARB Biodiesel Characterization report, we find that:

4. For the three engines where CARB has published the emission values measured in engine dynamometer testing, all of the data demonstrate that biodiesel fuels significantly increase NOx emissions for both soy- and animal-based fuels by amounts that are proportional to the blending percent. This is true for on-road and off-road engines and for a range of test cycles.

5. Where B5 fuels were tested for these engines, NOx emissions were observed to increase. NOx emission increases are smaller at B5 than at higher blending levels and the observed increases for two engines were not statistically significant by themselves based on the pair-wise t-test employed in Durbin 2011.[8] However, the testing for one of the engines (the 2007 MBE4000) showed statistically significant NOx emission increases at the B5 level for both soy- and animal-based blends.

By itself, the latter result is sufficient to disprove the Staff's contention that biodiesel blends at the B5 level will not increase NOx emissions.

Based on examination of all of the studies cited by CARB as the basis for its proposal to exempt biodiesels below B10 from mitigation, it is clear that the available research points to the expectation that both soy- and animal-based biodiesel blends will increase NOx emissions in proportion to their biodiesel content, including at the B5 level. CARB's own test data demonstrate that B5 will significantly increase NOx emissions in at least some engines.

Based on data in the CARB Biodiesel Characterization report, soy-based biodiesels will increase NOx emissions by about 1% at B5 (and 2% at B10), while animal-based biodiesels will increase NOx emissions by about one-half as much: 0.45% at B5 (and 0.9% at B10). All of the available research says that the NOx increases are real and implementation of mitigation measures will be required to prevent increases in NOx emissions due to biodiesel use at blending levels below B10.

Finally, we note that CARB has not published fully the biodiesel testing data that it relied on in support of the Proposed Rule and thereby has failed to adequately serve the interest of full public disclosure in this matter. The CARB-sponsored testing reported in Durbin 2011 is the sole source of B5 testing cited by CARB as support for the Proposed Rule. Durbin 2011 publishes only portions of the measured emissions data in a form that permits re-analysis; it does not publish any of the B5 data in such a form. It has not been possible to obtain the remaining data through a personal request to Durbin or an official public records request to CARB and, to the best of our knowledge, the data are not otherwise available online or through another source.

CARB should publish all of the testing presented in Durbin 2011 and any future testing that it sponsors in a complete format that allows for re-analysis. Such a format would be (a) the measured emission values for each individual test replication; or (b) averages across all test replications, along with the number of replications and the standard error of the individual tests. The first format (individual test replications) is preferable because that would permit a full examination of the data including effects such as test cell drift over time. Such publication is necessary to assure that full public disclosure is achieved and that future proposed rules are fully and adequately informed by the data.

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[8] As discussed in Section 3.3, the pair-wise t-test is not the preferred method for demonstrating statistical significance.

1.3 Review of 2013 CARB B5 Emission Testing

In December 2013, after the release of the ISOR and in response to an earlier Public Records Act request, CARB released a copy of new CARB-sponsored emission testing conducted by Durbin and others at the University of California CE-CERT[9]. The purpose of the study was "... to evaluate different B5 blends as potential emissions equivalent biodiesel fuel formulations for California."[10] Three B5 blends derived from soy, waste vegetable oil (WVO), and animal biodiesel stocks were tested on one 2006 Cummins ISM 370 engine using the hot-start EPA heavy-duty engine dynamometer cycle. A preliminary round of testing was conducted for all three fuels followed by emissions-equivalent certification testing per 13 CCR 2282(g) for two of the fuels. As noted by Durbin: "[t]he emissions equivalent diesel certification procedure is robust in that it requires at least twenty replicate tests on the reference and candidate fuels, providing the ability to differentiate small differences in emissions."[11]

Soy and WVO B5 Biodiesel

The B5-soy and B5-WVO fuels were blended from biodiesel stocks that were generally similar to the soy-based stock used in the earlier CARB Biodiesel Characterization Study (Durbin 2011) with respect to API gravity and cetane number. In the preliminary testing, the two fuels "...showed 1.2-1.3% statistically significant [NOx emissions] increases with the B5-soy and B5-WVO biodiesel blends compared to the CARB reference fuel."[12] The B5-WVO fuel caused the smaller NOx increase (1.2%) and was selected for the certification phase of the testing. There, it "... showed a statistically significant 1.0% increase in NOx compared to the CARB reference fuel"[13] and failed the emissions-equivalent certification due to NOx emissions.

Animal B5 Biodiesel

The B5-animal derived fuel was blended from an animal tallow derived biodiesel that was substantially different from the animal based biodiesel used in the earlier Durbin study, and was higher in both API gravity and cetane number. The blending response for cetane number was also surprising, in that blending 5 percent by volume of a B100 stock (cetane number 61.1) with 95% of CARB ULSD (cetane number 53.1) produced a B5 fuel blend with cetane number 61.

In preliminary testing, the B5-animal fuel showed a small NOx increase which was not statistically significant, causing it to be judged the best candidate for emissions-equivalent certification. In the certification testing, it "...showed a statistically

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[9] "CARBB5 Biodiesel Preliminary and Certification Testing." Prepared by Thomas D. Durbin, G. Karavalakis and others. Prepared for Alexander Mitchell, California Air Resources Board. July 2013. This study is not referenced in the ISOR, nor was it included in the rule making file when the hearing notice for the ADF regulation was published in October 2013.

[10] Ibid, p. vi.

[11] Ibid, p. viii.

[12] Ibid, p. 8.

[13] Ibid, p. 9.

significant 0.5% reduction in NOx compared to the CARB reference fuel"[13] and passed the emissions-equivalent certification. The NOx emission reduction for this fuel blend appears to be real for this engine, but given the differences between the blendstock and the animal based biodiesel blendstock used in the earlier Durbin study it is unclear that it is representative for animal-based biodiesels in general..

Summary

The conclusions drawn in the preceding section are not changed by the consideration of these new emission testing results. For plant-based biodiesels (soy- and WVO-based), the new testing provides additional and statistically significant evidence that B5 blends will increase NOx emissions at the B5 level. The result of decreased NOx for the B5 animal-based blend stands out from the general trend of research results reviewed in this report. However:

- The same result – reduced NOx emissions for some fuels and engines – has sometimes been observed in past research, as evidenced by the emissions data considered by CARB staff in ISOR Figure B.3 (reproduced in Figure 2.1 below). As shown, some animal-based B5 and B20 fuels reduced NOx emissions while others increased NOx emissions with the overall conclusion being that NOx emissions increase in direct proportion to biodiesel content of the blends and that there is no emissions threshold.

- Increasing cetane is known to generally reduce NOx emissions and has already been proposed by CARB as a mitigation strategy for increased NOx emissions from biodiesel[14]. The unusual cetane number response in the blending and the high cetane number of the B5-animal fuel may account for the results presented in the recently released study.

Considering the broad range of plant- and animal-based biodiesel stocks that will be used in biodiesel fuels, we conclude that the available research (including the recently released CARB test results) indicates that unrestricted biodiesel use at the B5 level will cause real increases in NOx emissions and that countermeasures may be required to prevent increases in NOx emissions due to biodiesel use at blending levels below B10.

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[14] For example, see Durbin 2011 Section 7.0 for a discussion of NOx mitigation results through blending of cetane improvers and other measures.

2. CARB LITERA TURE REVIEW

The Staff ISOR explains that the Appendix B Technology Assessment is the basis for CARB's conclusion that biodiesels below B10 have no significant impact on NOx emissions. The assessment is based on data from seven studies (identified in Table 2-1) that tested high-cetane diesel fuels. The first study (Durbin 2011) is the Biodiesel Characterization Study that was conducted for CARB, while the others were obtained through a literature search.

Tab le 2-1
List of Studies from High-Cetane Liter ature Sear ch

Primary Author	Title	Published	Year
Durbin	Biodiesel Mitigation Study	Final Report Prepared for Robert Okamoto, M.S. and Alexander Mitchell, CARB	2011
Clark	Transient Emissions Comparisons of Alternative Compression Ignition Fuel	SAE 1999-01-1117	1999
Eckerle	Effects of Methyl Ester Biodiesel Blends on NOx Emissions	SAE 2008-01-0078	2008
McCormick	Fuel Additive and Blending Approaches to Reducing NOx Emissions from Biodiesel	SAE 2002-01-1658	2002
McCormick	Regulated Emissions from Biodiesel Tested in Heavy-Duty Engines Meeting 2004 Emissions	SAE 2005-01-2200	2005
Nuszkowski	Evaluation of the NOx emissions from heavy duty diesel engines with the addition of cetane improvers	Proc. I Mech E Vol. 223 Part D: J. Automobile Engineering, 223, 1049-1060	2009
Thompson	Neat fuel influence on biodiesel blend emissions	Int J Engine Res Vol. 11, 61-77.	2010

Source: Table B.2 of Durbin 2011

Figure 2-1 reproduces two exhibits from Appendix B that show increasing trends for NOx emissions with the biodiesel blending level. Based on the slopes of the trend lines,

Figure 2-1
NOx Emission Increases Observed in Biodiesel Research Cited in Staff ISOR

Figure B.2: NOx Impact of Soy Biodiesel Blended in High Cetane Base Fuel

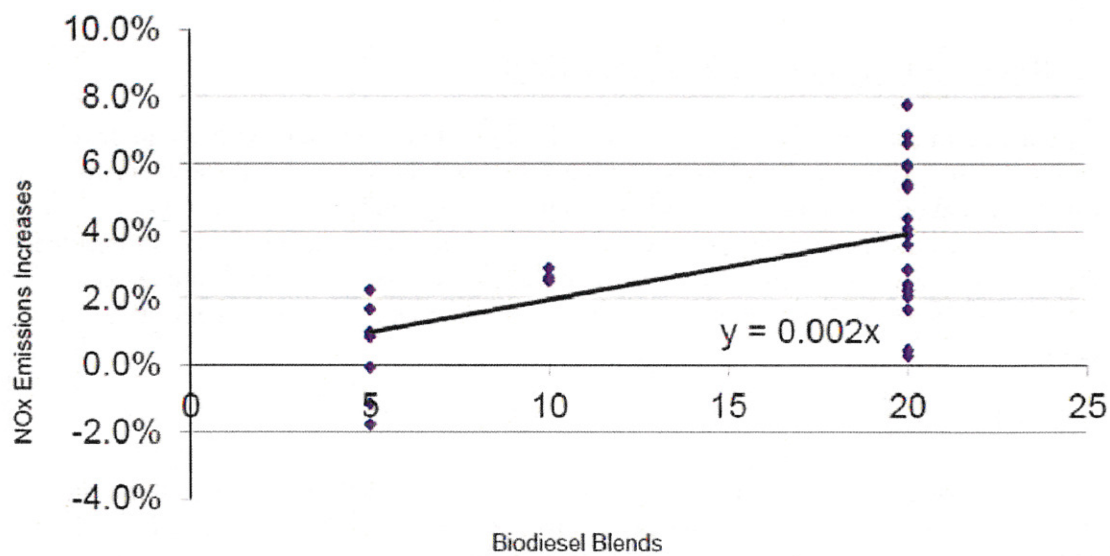
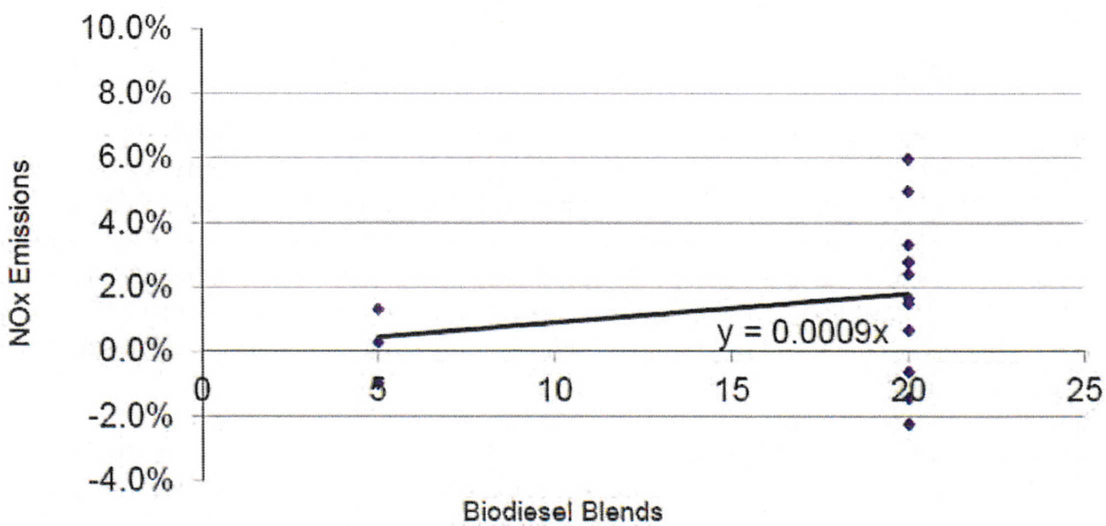


Figure B.3: NOx Impact of Animal Biodiesel Blended in High Cetane Base Fuel



Source: Figures B.2 and B.3 of Appendix B: Technology Assessment

soy-based biodiesels are shown to increase NOx emissions by approximately 1% at B5, 2% at B10, and 4% at B20. Animal-based biodiesels are shown to increase NOx emissions by about one-half as much: 0.45% at B5, 0.9% at B10, and 1.8% at B20. Although there is substantial scatter in the results, these data do not appear to support the Staff Threshold Model that biodiesel does not increase NOx emissions at B5 but does so at B10.

We will examine the Durbin 2011 study at some length in Section 3. In this section, we look at each of the other studies cited by the Staff to find out what the studies say about NOx emissions impacts at and below B10.

2.1 Review of Literature Cited in the ISOR

The Staff literature search sought and selected testing that used fuels with cetane levels comparable to California diesel fuels; the Staff does not, however, list those fuels or provide the data that support the tables and figures in Appendix B of the ISOR. Therefore, we have necessarily made our own selection of high-cetane fuels in the course of reviewing the studies. The key testing and findings of each study are summarized below, with a specific focus on what they tell us about NOx emission impacts at B10 and below.

2.1.1 Clark 1999

This study tested a variety of fuels on a 1994 7.3L Navistar T444E engine. Of the high-cetane base fuels, one base fuel (Diesel A, off-road LSD) was blended and tested at levels of B20, B50, and B100. NOx emissions were significantly increased for all of the blends. The other base fuel (CA Diesel) was tested only as a base fuel. Its NOx emissions were 12% below that of Diesel A, making it is unclear whether Diesel A is representative of fuels in CA. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

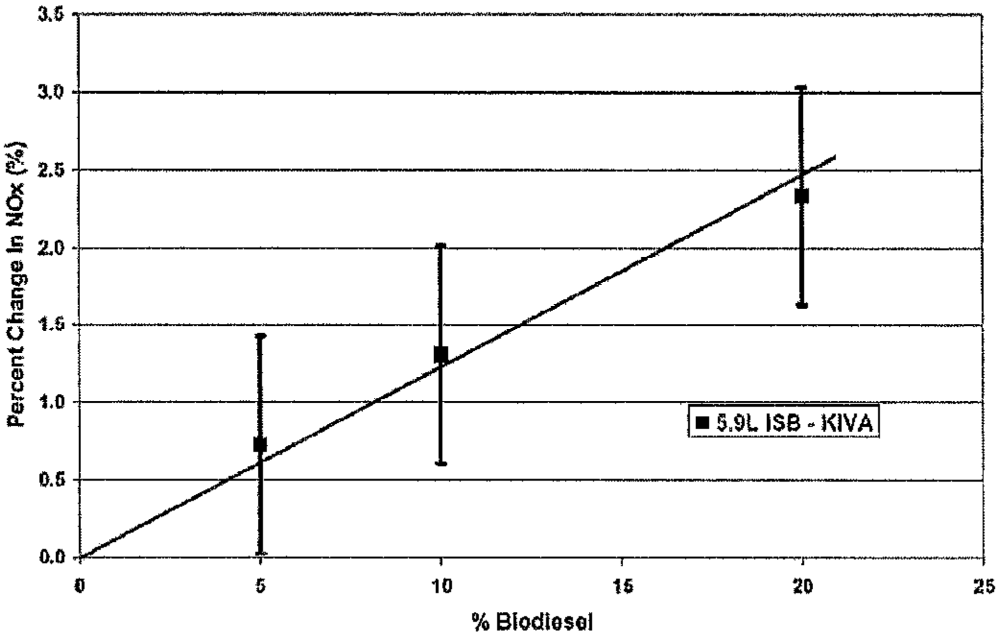
2.1.2 Eckerle 2008

This study tested low and mid/high-cetane base fuels alone and blended with soy-based biodiesel at the B20 level. The Cummins single-cylinder test engine facility was used in a configuration representative of modern diesel technology, including cooled EGR. Testing was conducted under a variety of engine speed and load conditions. FTP cycle emissions were then calculated from the speed/load data points. The test results show that B20 blends increase NOx emissions compared to both low- and high-cetane base fuels. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

The study notes that two other studies "show that NOx emissions increase nearly linearly with the increase in the percentage of biodiesel added to diesel fuel." Eckerle's Figure 21 (reproduced below as Figure 2-2) indicates a NOx emissions increase at B5, which is the basis for the statement in the abstract that "Results also show that for biodiesel blends containing less than 20% biodiesel, the NOx impact over the FTP cycle is proportional to

the blend percentage of biodiesel." The authors clearly believe that biodiesel fuels have NOx emission impacts proportional to the blending percent at all levels including B5.

Figure 2-2
Impact of Biodiesel Blends on Percent NOx Change for the 5.9L ISB Engine Operation Over the FTP Cycle



Source: Figure 21 of Eckerle 2008

2.1.3 McCormick 2002

This study tested low- and mid-cetane base fuels alone and blended with soy- and animal-based biodiesel at the B20 level. The testing was conducted on a 1991 DDC Series 60 engine using the hot-start U.S. heavy-duty FTP. NOx emission increases were observed for both fuels at the B20 level. Mitigation of NOx impacts was investigated by blending a Fisher-Tropsch fuel, a 10% aromatics fuel and fuel additives. This study conducted no testing of the NOx emissions impact from commercial biodiesels at the B10 level or below.

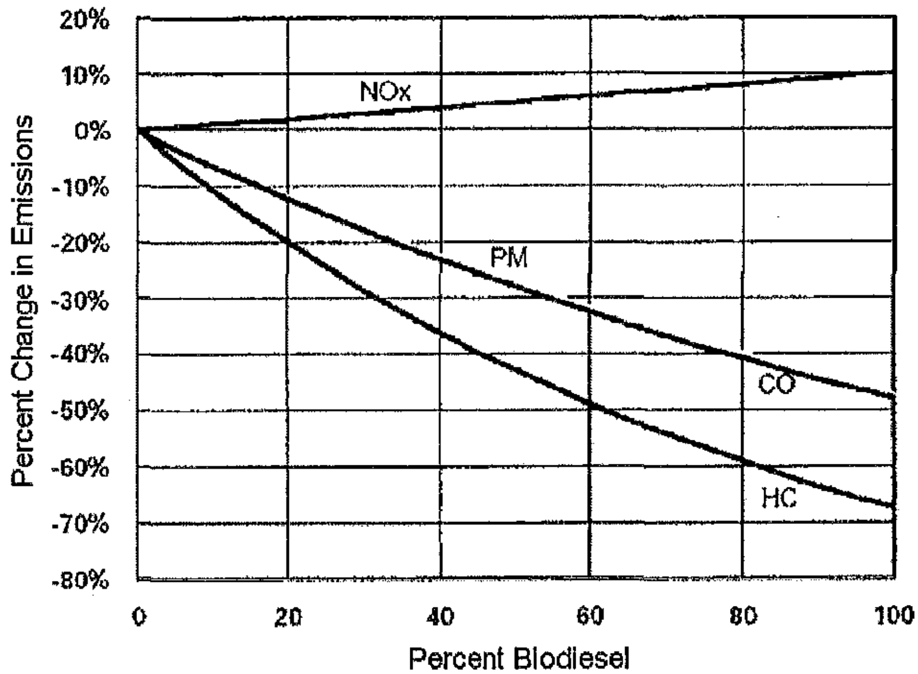
This study also tested a Fisher-Tropsch (FT) base fuel blended at the B1, B20, and B80 levels. Although the very high cetane number (≥75) takes it out of the range of commercial diesel fuels, it is interesting to note that the study measured higher NOx emissions at the B1 level than it did on the FT base fuel and substantially higher NOx emissions at the B20 and B80 levels. While the B1 increase was not statistically significant given the uncertainties in the emission measurements (averages of three test runs), it is clear that increased NOx emissions have been observed at very low blending levels.

2.1.4 McCormick 2005

This study tested blends of soy- and animal-based biodiesels with a high-cetane ULSD base fuel at B10 levels and higher. Two engines were tested – a 2002 Cummins ISB and a 2003 DDC Series 60, both with cooled EGR. The hot-start U.S. heavy-duty FTP test cycle was used. The majority of testing was at the B20 level with additional testing at the B50 and B100 levels. One soy-based fuel was tested at B10. The study showed NOx emission increases at B10, B20, and higher levels. The study also investigated mitigation of NOx increases. This study conducted no testing of the NOx emissions impact from biodiesels below the B10 level.

The authors present a figure (reproduced as Figure 2-3) in their introduction that shows their summary of biodiesel emission impacts based on an EPA review of heavy-duty engine testing. It shows NOx emissions increasing linearly with the biodiesel blend percentage.

Figure 2-3
Trend in HC, CO, NOx and PM Emissions with Biodiesel Percent



Source: McCormick 2005

2.1.5 Nuszkowski 2009

This study tested five different diesel engines: one 1991 DDC Series 60, two 1992 DDC Series 60, one 1999 Cummins ISM, and one 2004 Cummins ISM. Only the 2004 Cummins ISM was equipped with EGR. All testing was done using the hot-start U.S. heavy-duty FTP test cycle. The testing was designed to test emissions from fuels with and without cetane-improving additives. Although a total of five engines were tested, the base diesel and B20 fuels were tested on only two engines (one Cummins and one DDC Series 60) because there was a limited supply of fuel available. NOx emissions increased on the B20 fuel for both engines. A third engine (Cummins) was tested on B20 and B20 blended with cetane improvers to examine mitigation of NOx emissions. This study conducted no testing of the NOx emissions impact from biodiesels at the B10 level or below.

2.1.6 Thompson 2010

This study examined the emissions impacts of soy-based biodiesel at the B10 and B20 levels relative to low-cetane (42), mid-cetane (49), and high-cetane (63) base fuels using one 1992 DDC Series 60 engine. The emissions results were measured on the hot-start U.S. heavy-duty FTP cycle. The study found that NOx emissions were unchanged (observed differences were not statistically significant) at B10 and B20 levels for the low- and mid-cetane fuels. NOx emissions increased significantly at B10 and B20 levels for the high-cetane fuels. This study conducted no testing of the NOx emissions impact from biodiesels at levels below B10.

2.2 Conclusions Based on Studies Obtained in Literature Search

From the foregoing summary of the studies cited by Staff, we reach the conclusions given below.

1. None of the six studies measured the NOx emissions impact from commercial-grade biodiesel at blending levels below B10, and only two studies tested a fuel at the B10 level. All other testing was at the B20 level or higher. Because none tested a B5 (or similar) fuel, none is capable of providing direct evidence regarding NOx emissions at B5 or other blending levels below B10.

2. These studies provide no data or evidence supporting the validity of Staff's Threshold Model that biodiesel below B10 does not increase NOx emissions. In fact, all of the studies are consistent with the contention that biodiesel increases NOx emissions in proportion to the blending percent.

3. Two of the studies present evidence and arguments that the NOx impact from biodiesel is a continuous effect that is present even at very low blending levels and will increase at higher levels in proportion to the blending percentage. One study tested a Fischer-Tropsch biodiesel blend at B1 and observed NOx emissions to increase (but not by a statistically significant amount).

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3. CARB BIODIESEL CHARACTERIZATION STUDY

3.1 Background

CARB sponsored a comprehensive study of biodiesel and other alternative diesel blends in order "... to better characterize the emissions impacts of renewable fuels under a variety of conditions."[15] The study was designed to test eight different heavy- duty engines or vehicles, including both highway and off-road engines using engine or chassis dynamometer testing. Five different test cycles were used: the Urban Dynamometer Driving Schedule (UDDS), the Federal Test Procedure (FTP), and 40 mph and 50 mph CARB heavy-heavy-duty diesel truck (HHDDT) cruise cycles, and the ISO 8178 (8 mode) cycle. Table 3-1 (reproduced from Table ES-1 of Durbin 2011) documents the scope of the test program. Because the Staff relied only on engine dynamometer testing in its Technology Assessment, only the data for the first four engines (shaded) are considered here.

Table 3-1
A Breakdown of the Test Engines for the Different Categories of Testing

2006 Cummins ISM[a]	Heavy-duty on-highway	Engine dynamometer	
2007 MBE4000	Heavy-duty on-highway	Engine dynamometer	
1998, 2.2 liter, Kubota V2203-DIB	Off-road	Engine dynamometer	
2009 John Deere 4.5 L	Off-road	Engine dynamometer	
2000 Caterpillar C-15	Heavy-duty on-highway	Chassis dynamometer	Freightliner chassis
2006 Cummins ISM	Heavy-duty on-highway	Chassis dynamometer	International chassis
2007 BME4000	Heavy-duty on-highway	Chassis dynamometer	Freightliner chassis
2010 Cummins ISX15	Heavy-duty on-highway	Chassis dynamometer	Kenworth chassis

Source: Table ES-1 of Durbin 2011, page xxvi
Notes:
[a] Data for the first four engines (shaded) are considered in this report.

[15] Durbin 2011, p. xxiv.

The original goal of this report was to subject all of the NOx emission testing in Durbin 2011 to a fresh re-analysis. However, it was discovered that Durbin 2011 did not report all of the data that were obtained during the program and are discussed in the report. The chassis dynamometer testing was conducted at the CARB Los Angeles facility. Emission results for the chassis dynamometer testing are presented in tabular and graphical form, but the report does not contain the actual emissions test data. For the engine dynamometer testing, some of the measured emission values are not reported even though the emission results are reported in tabulated or graphical form. Requests for the missing data were directed to Durbin in a personal request and to CARB through an official records request. No information has been provided in response and we have not been able to obtain the missing data from online or other sources.

For this report, we have worked with the data in the forms that are provided in Durbin 2011 as being the best-available record of the results of the CARB study. Because Staff used only data obtained in engine dynamometer testing, the analysis presented in this report has done the same. Nevertheless, the results of the chassis dynamometer testing are generally supportive of the results and conclusions presented here. Durbin 2011 notes:

> "... The NOx emissions showed a consistent trend of increasing emissions with increasing biodiesel blend level. These differences were statistically significant or marginally significant for nearly all of the test sequences for the B50 and B100 fuels, and for a subset of the tests on the B20 blends."[16]

Durbin notes that emissions variability was greater in the chassis dynamometer testing, which leads to the sometimes lower levels of statistical significance. There was also a noticeable drift over time in NOx emissions that complicated the results for one engine.

3.2 Data and Methodology

Table 3-2 compiles descriptive information on the engine dynamometer testing performed in Durbin 2011. The experimental matrix involves four engines, two types of biodiesel fuels (soy- and animal-based), and up to four test cycles per engine. However, the matrix is not completely filled with all fuels tested on all engines on all applicable test cycles. The most complete testing is for the ULSD base fuel and B20, B50, and B100 blends. There is less testing for the B5 blend, and B5 is tested using only a subset of cycles. For this reason, we first examine the testing for ULSD, B20, B50, and B100 fuels to determine the overall impact of biodiesels on NOx emissions. We then examine the more limited testing for B5 to determine the extent to which it impacts NOx emissions.

This examination is limited by the form in which emissions test information is reported in Durbin 2011. A complete statistical analysis can be conducted only for the two on-road engines for which Appendices G and H of Durbin 2011 provide measured emissions, and for a portion of the testing of the Kubota off-road engine for which Appendix I provides

[16] Durbin 2011, p. 126.

<table>
<tr><th colspan="5">Table 3-2
Experimental Matrix for Heavy-Duty Engine Dynamometer Testing Reported in Durbin 2011</th></tr>
<tr><th>Engine</th><th>Biodiesel Type</th><th>Fuels Tested</th><th>Test Cycles</th><th>Notes</th></tr>
<tr><td colspan="5">On-Road Engines</td></tr>
<tr><td rowspan="2">2006 Cummins ISM</td><td>Soy</td><td>ULSD, B20, B50, B100, B5</td><td>UDDS, FTP, 40 mph, 50 mph</td><td>B5 tested on 40 mph and 50 mph cruise cycles</td></tr>
<tr><td>Animal</td><td>ULSD, B20, B50, B100, B5</td><td>UDDS, FTP, 50 mph</td><td>B5 tested only on FTP.</td></tr>
<tr><td rowspan="2">2007 MBE4000</td><td>Soy</td><td>ULSD, B20, B50, B100, B5</td><td rowspan="2">UDDS, FTP, 50 mph</td><td>B5 tested only on FTP.</td></tr>
<tr><td>Animal</td><td>ULSD, B20, B50, B100, B5</td><td>B5 tested only on FTP.</td></tr>
<tr><td colspan="5">Off-Road Engines</td></tr>
<tr><td rowspan="2">1998 Kubota V2203-DIB</td><td>Soy</td><td>ULSD, B20, B50, B100, B5</td><td rowspan="2">ISO 8178 (8 Mode)</td><td rowspan="2">none</td></tr>
<tr><td>Animal</td><td>Not tested</td></tr>
<tr><td rowspan="2">2009 John Deere</td><td>Soy</td><td>ULSD, B20, B50, B100</td><td rowspan="2">ISO 8178 (8 Mode)</td><td>B5 not tested</td></tr>
<tr><td>Animal</td><td>ULSD, B20, B5</td><td>none</td></tr>
</table>

measured emissions. The data needed to support a full re-analysis consist of measured emissions on each fuel in gm/hp-hr terms, which are stated in Durbin 2011 as averages across all test replications along with the number of replications and the standard error of the individual tests. With this information, the dependence of NOx emissions on biodiesel blending percent can be determined as accurately as if the individual test values had been reported and the appropriate statistical tests for the significance of results can be performed.

Regression analysis is used as the primary method of analysis. For each engine and test cycle, the emission averages for each fuel are regressed against the biodiesel blending percent to determine a straight line. The regression weights each data point in inverse proportion to the square of its standard error to account for differences in the number and reliability of emission measurements that make up each average. The resulting regression line will pass through the mean value estimated from the data (i.e., the average NOx emission level at the average blending percent), while the emission averages for each fuel may scatter above and below the regression line due to uncertainties in their measurement. The slope of the line estimates the dependence of NOx emissions on the blending percentage.

Where the data points closely follow a straight line and the slope is determined to be statistically significant, one can conclude that blending biodiesel with a base fuel will increase NOx emissions in proportion to the blending percent. The regression line can then be used to estimate the predicted emissions increase for a given blending percent. The predicted emissions increase is the value one would expect on average over many measurements and is comparable to the average emissions increase one would expect in a fleet of vehicles.

The same level of analysis is not possible for the testing on B5 fuel, which is reported as a simple average for the on-road engines and is not reported at all for the off-road engines. For the B5 fuel, Durbin 2011 presents emission test results in a tabulated form where the percentage change in NOx emissions has been computed compared to ULSD base fuel. This form supports the presentation of results graphically, but it does not permit a proper statistical analysis to be performed. Specifically, the computation of percentage emission changes will perturb the error distribution of the data, by mixing the uncertainty in measured emissions on the base fuel with the uncertainties in measured emissions on each biodiesel blend, and it can introduce bias as a result of the mixing. Further statistical analysis of the computed percent values should be avoided because of these problems. Therefore, a more limited trend analysis of the NOx emissions data for B5 and the John Deere engine is conducted.

3.3 2006 Cummins Engine (Engine Dynamometer Testing)

Table 3-3 shows the NOx emission results for the 2006 model-year Cummins heavy-duty diesel engine based on a re-analysis of the data for this report. As indicated by highlighting in the table, the relationship between increasing biodiesel content and increased NOx emissions for soy-based biodiesel is statistically significant at >95% confidence level[17] in all cases. For the animal-based biodiesel, the relationship is statistically significant at the 92% confidence level for the UDDS cycle, the 94% confidence level for the 50 mph cruise, and the >99% confidence level for the FTP cycle.

For the soy-based fuels, the R^2 statistics show that the emissions effect of biodiesel is almost perfectly linear with increasing biodiesel content over the range B20, B50, and B100. Although not as high for the animal-based fuels (because the emissions effect is smaller and measurement errors are relatively larger in comparison to the trend), the R^2 statistics nevertheless establish a linear increase in NOx emissions with increasing biodiesel content over the same range. The linearity of the response with blending percent is well supported by the many NOx emissions graphs contained in Durbin 2011.

The table also gives the estimated NOx emission increases for B5 and B10 as predicted by the regression lines. For soy-based fuels, the values are 1% for B5 (range 0.8% to 1.3% depending on the cycle) and 2% for B10 (range 1.6% to 2.6% depending on cycle).

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[17] A result is said to be statistically significant at the 95% confidence level when the p value is reported as $p \leq 0.05$. At the $p \leq 0.01$ level, a result is said to be statistically significant at the 99% confidence level, and so forth.

Table 3-3 Re-Analysis for 2006 Cummins Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B20, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	Pct Change	Pct Change
Soy-based							
	UDDS	0.997	5.896	0.0100 [a]	0.001	0.8%	1.7%
	FTP	0.995	2.024	0.0052	0.003	1.3%	2.6%
	40 mph	1.000	2.030	0.0037	<0.0001	0.9%	1.8%
	50 mph	0.969	1.733	0.0028	0.016	0.8%	1.6%
Animal-based							
	UDDS	0.847	5.911	0.0021 [b]	0.080	0.2%	0.4%
	FTP	0.981	2.067	0.0031	0.001	0.7%	1.4%
	50 mph	0.887	1.768	0.0011	0.058	0.3%	0.6%

Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.
[b] Orange highlight indicates result is statistically significant at the 90% confidence level or better.

For animal-based fuels, the values are approximately one-half as large: 0.4% for B5 (range 0.2% to 0.7%) and 0.8% for B10 (range 0.4% to 1.4%). These predicted increases are statistically significant to the same degree as the slope of the regression line from which they are estimated. That is, the NOx increases predicted by the regression line for soy-based fuels are statistically significant at the 95% confidence level (or better) on all cycles and the predicted NOx increases for animal-based fuels are statistically significant at the 90% confidence level (or better) on all cycles and at the >99% confidence level for the FTP.

Because the limited data on B5 were not used to develop the regression lines for each cycle, and no test data on B10 are available, use of the lines to make predictions for B5 and B10 depends on their linearity over the range between ULSD and B20. Based on the R^2 statistics and the graphs in Durbin 2011, the slopes observed between ULSD and B20 are the same as the slopes observed between B20 and B100 for each of the test cycles. We believe that the linearity of the response with blending percent for values over the range ULSD to B100 would be accepted by the large majority of researchers in the field, as would the use of regression analysis to make predictions for B5 and B10.

The Durbin 2011 report takes a different approach for determining the statistical significance of NOx emission increases for each fuel. For each fuel tested, it computes a percentage change in emissions for NOx (and other pollutants) relative to the ULSD base fuel. It then determines the statistical significance of each observed change using a conventional t-test for the difference of two mean values (2-tailed, 2 sample equal

variance t-test). The t-test is conducted on the measured emission values before the percentage emission change is computed.

The t-test would be the appropriate approach for determining statistical significance if only two fuels were tested. However, it is a simplistic approach when three or more fuels are tested because it is applied on a pair-wise basis (B5 vs. ULSD, B20 vs. ULSD, etc.) and does not make use of all of the data that is available. It will have less power than the regression approach to detect emission changes that are real. This limitation is in one direction, however, in that the test is too weak when 3 or more data points are available, but a finding of statistical significance is valid when it occurs. As long as the linear hypothesis is valid, the regression approach should be the preferred method for analysis and for the determination of whether biodiesel blending significantly increases NOx emissions.

Because emission changes will be smallest for B5 (because of the low blending volume), the pair-wise t-test is most likely to fail to find statistical significance at the B5 level. In cases where the pair-wise t-test for B5 says that the emission change vs. ULSD is not statistically significant – but slope of the regression line is statistically significant – the proper conclusion is that additional B5 testing (to improve the precision of the emission averages) would likely lead to the detection of a statistically significant B5 emissions change using the t-test. In this case, the failure to find statistical significance using the t-test is not evidence that B5 does not increase NOx emissions.

For this engine, soy-based B5 was tested on the 40 mph and 50 mph cruise cycles and animal-based B5 was tested on the FTP. To examine this matter further, Table 3-4 reproduces NOx emission results reported in Tables ES-2 and ES-3 of Durbin 2011. Soy-based B5 was shown to increase NOx emissions on the 40 mph cruise cycle, but not on the 50 mph cruise cycle. Animal-based B5 was shown to increase NOx emissions on the FTP. Durbin 2011 noted (p. xxxii) that "[t]he 50 mph cruise results were obscured, however, by changes in the engine operation and control strategy that occurred over a segment of this cycle." Therefore, we discount the 50 mph cruise results and do not consider them further. Neither of the remaining B5 NOx emission increases (for the 40 mph Cruise and FTP cycles) were found to be statistically significant using the t-test, although the 40 mph cruise result for soy-based fuels comes close to being marginally significant (it would be statistically significant at an 86.5% level). The NOx emission increases at higher blending levels were found have high statistical significance (>99% confidence level).

This format, used throughout Durbin 2011 to report emission test data and to show the effect of biodiesel on emissions, is subject to an important statistical caveat. The percent changes are computed by dividing the biodiesel emission values by the emissions measured for the ULSD base fuel. Therefore, measurement errors in the ULSD measurement are blended with the measurement errors for each of the biodiesel fuels. The blending of errors in each computed percent change can bias the apparent trend of emissions with increasing biodiesel content. As will be shown in Section 3.3.2, we can see this problem in the animal-based B5 test data for this engine.

Table 3-4 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2006 Cummins Engine (Engine Dynamometer Testing)						
	Soy-based Biodiesel				Animal-based Biodiesel	
	40 mph Cruise		50 mph Cruise		FTP	
	NOx % Diff	p value	NOx % Diff	p value	NOx % Diff	p value
B5	1.7%	0.135	-1.1%	0.588	0.3%	0.298
B20	3.9% [a]	0.000	0.5%	0.800	1.5%	0.000
B50	9.1%	0.000	6.3%	0.001	6.4%	0.000
B100	20.9%	0.000	18.3%	0.000	14.1%	0.000

Source: Table ES-2 and ES-3 of Durbin 2011, p. xxviii
Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on the pair-wise t-test.

3.3.1 NOx Impact of Soy-based Biodiesel at the B5 Level

Figures 3-1a and 3-1b display the trend of NOx emissions with blending percent for the soy-based biodiesel on the 40 mph cruise cycle. Figure 3-1a plots the percentage increases as reported by Durbin 2011 in contrast to two different analytical models for the relationship:

- The Linear Model shown by the blue line; and
- The Staff Threshold model (black line), in which the NOx emission change is zero through B9 and then increases abruptly to join the linear model.

In Figure 3-1a, the linear model is an Excel trendline for the computed percent changes. While the data violate a key assumption for the proper use of regression analysis, this approach is the only way to establish a trendline given the form in which Durbin 2011 tabulates the data and presents the results of its testing.

Figure 3-1b plots the actual measured emission values in g/bhp-hr terms in contrast to the same two analytical models. Here, the linear model line is determined through a proper use of regression analysis, in which each emission average in g/bhp-hr terms is weighted inversely by the square of its standard error, using the data for ULSD, B20, B50 and B100 (i.e., excluding the B5 data point). In the case of this engine and biodiesel fuel, both forms of assessment show generally the same trend for NOx emissions as a function of blending percent. Although the NOx emission increases for B5 may fail the t-test for significance, emissions are increased at B5 and the B5 data point is fully consistent with the Linear Model. The Threshold model is clearly a less-satisfactory representation of the test data.

Figure 3-1a
Durbin 2011 Assessment: 40 mph Cruise Cycle NOx Emissions Increases for Soy-Biodiesel Blends (2006 Cummins Engine)

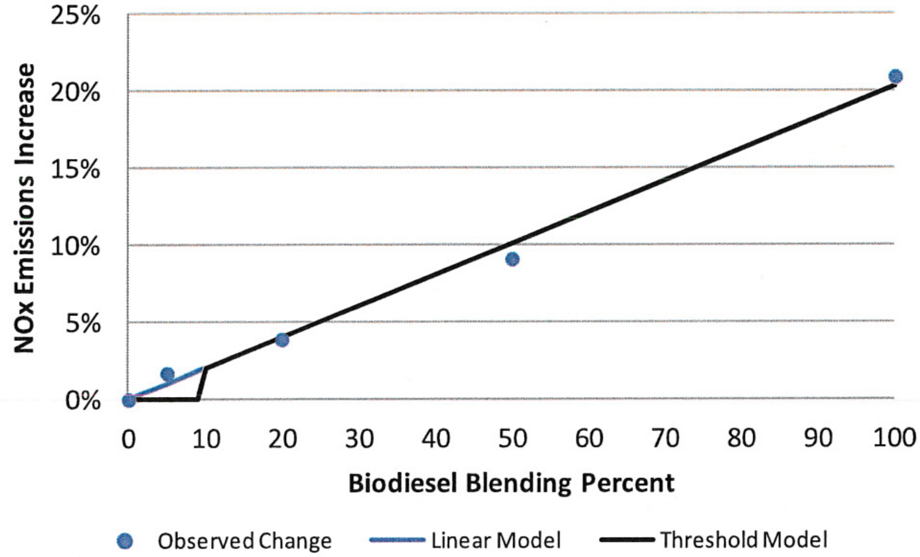
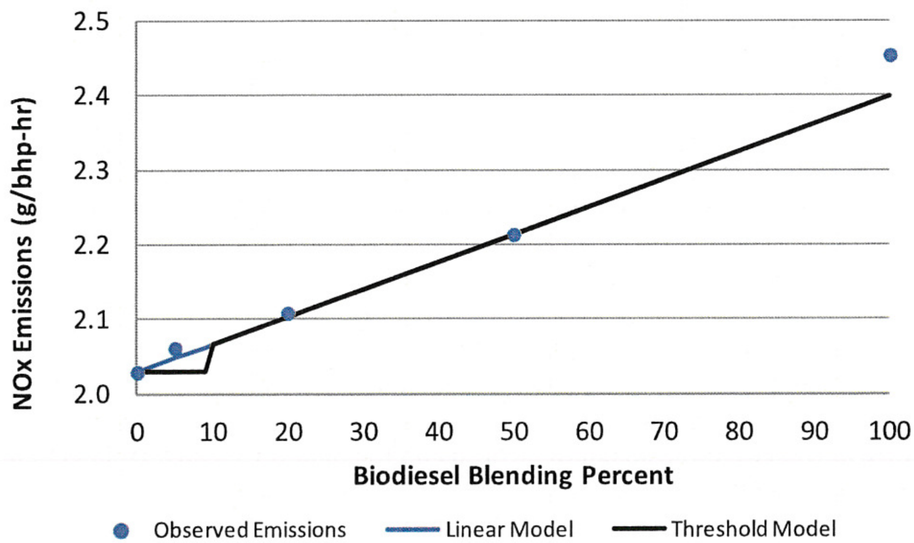


Figure 3-1b
Re-assessment of 40 mph Cruise Cycle NOx Emissions Increases for Soy-Biodiesel Blends (2006 Cummins Engine)



Note that the slope of the trendline (Figure 3-1a) is greater than the slope of the regression line (Figure 3-1b). In the latter figure, the B100 data point stands above the regression line, which passes below it. The regression line (but not the trendline) is fit in

a manner that accounts for the uncertainties in each data point, so that the line will pass closer to points that have smaller uncertainties and farther from points that have greater uncertainties. For these data, the B100 data point has the largest uncertainty (±0.026 g/bhp-hr) followed by the B20 data point (±0.025 g/bhp-hr). The other three data points (ULSD, B5, and B50) have uncertainties less than ±0.001 g/bhp-hr. The B20 data point happens to fall on the line, but the B100 data point is found to diverge above. Because the regression analysis can account for the relative uncertainties of the data points, it provides a more accurate and reliable assessment of the impact on NOx emissions.

3.3.2 NOx Impact of Animal-based Biodiesel at the B5 level

Figures 3-2a and 3-2b display the trend of NOx emissions with blending percent for the animal-based biodiesel on the FTP test cycle as reported by Durbin 2011 and as re-assessed in this report using regression analysis, respectively. As Figure 3-2a shows, the NOx percent change values reported by Durbin 2011 appear to follow the Staff Threshold model in that NOx emissions are not materially increased at B5, but are increased significantly at B20 and above. As a result, the blue trendline in the figure (fit from the B20, B50 and B100 data points) has a negative intercept.

Figure 3-2b paints a very different picture from the data. Here, the ULSD and B5 data points stand above the weighted regression line (blue) developed from the data for ULSD, B20, B50 and B100. In the data used to fit the regression line, the ULSD data point has the largest uncertainty (±0.013 g/bhp-hr) while the other three data points (B20, B50, and B100) have uncertainties of ±0.002 g/bhp-hr (one case) and ±0.001 g/bhp-hr (two cases). Considering all of the data, the B5 data point has the second highest uncertainty (±0.007 g/bhp-hr). The regression line closely follows a linear model with a high R^2 (0.981) considering the weighted errors, while the ULSD and B5 points lie above it.

Because the ULSD data point is subject to more uncertainty and appears to be biased high compared to the regression line, the NOx percent changes computed by Durbin 2011 are themselves biased. The trendline result in Figure 3-2a that appeared to be supportive of the Staff Threshold model now appears to be the result of biases in the ULSD and B5 emission averages.

Two important conclusions can be drawn from the foregoing:

1. Accurate and reliable conclusions regarding the impact of B5 on NOx emissions cannot be drawn from the computed percent changes that are reported in Durbin 2011. Nor can accurate and reliable conclusions be drawn from visual inspection of graphs that present such data. Weighted regression analysis of the measured emission values (g/bhp-hr terms) must be performed so that the uncertainties in emissions measurements can be fully accounted for.

2. When a weighted regression analysis is performed using the testing for this engine, there is no evidence that supports the conclusion that B5 blends will not increase NOx emissions. In fact, the data are consistent with the conclusion that biodiesel increases NOx emissions in proportion to the blending percent.

Figure 3-2a
Durbin 2011 Assessment: FTP NOx Emissions Increases for Animal-based Biodiesel Blends (2006 Cummins Engine)

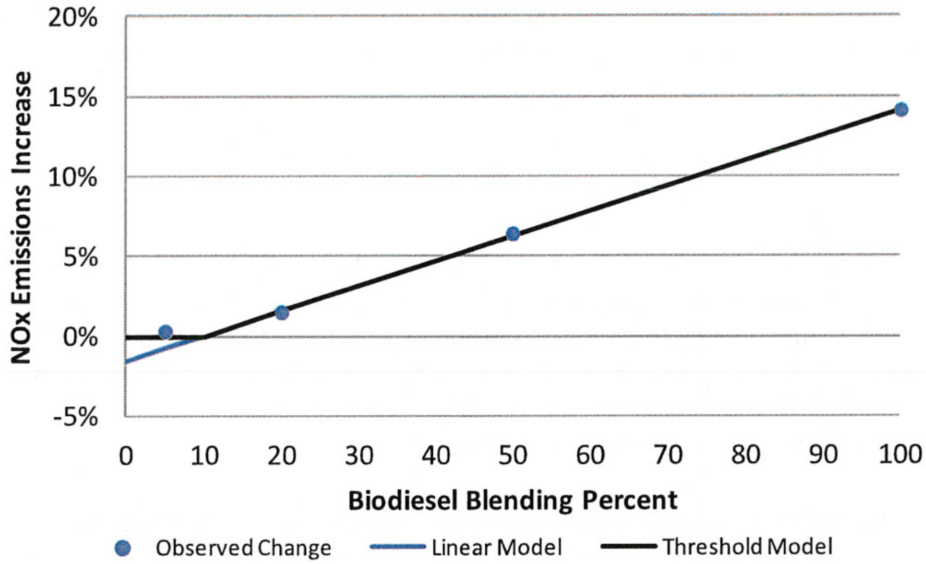
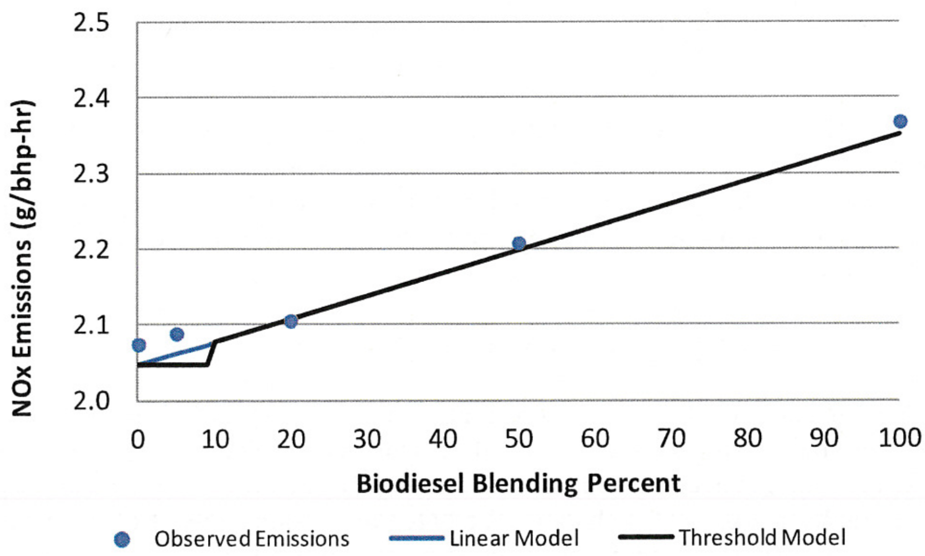


Figure 3-2b
Re-assessment of FTP NOx Emissions Increases for Animal-based Biodiesel Blends (2006 Cummins Engine)



3.4 2007 MBE4000 Engine (Engine Dynamometer Testing)

To analyze the data for the 2007 MBE4000 engine, it has proved necessary to remove two data points, one for the soy-based B20 fuel on the 50 mpg cruise cycle and one for the animal-based B50 fuel on the FTP test cycle:

- Appendix H reports the 50 mph cruise emission average for soy-based B20 to be 0.014 ± 0.020 g/bhp-hr. This value is implausible and wholly inconsistent with the NOx emission change of +6.9% reported in Table ES-4 of Durbin 2011, which would imply a NOx emission average of 1.21*1.069 = 1.30 g/bhp-hr.

- Appendix H reports the FTP emission average for the animal-based B50 fuel to be 2.592 ± 0.028 g/bhp-hr, which stands well above the other test data on animal-based biodiesel. This value is also inconsistent with the NOx emission change of +12.1% reported in Table ES-4 of Durbin 2011, which would imply a NOx emission average of 1.29*1.121 = 1.45 g/bhp-hr.

We believe these reported values are affected by typographical errors and have deleted them from the dataset used here.

With these corrections, Table 3-5 shows the results of the NOx emissions analysis for the 2007 model-year MBE4000 heavy-duty diesel engine. As indicated by highlighting in the table, the relationship between increasing biodiesel content and increased NOx emissions is statistically significant at >99% confidence level in two cases for soy-based biodiesel (the UDDS and FTP cycles) and at the 90% confidence level in one case (the 50 mph cycle). For the animal-based biodiesel, the relationship is statistically significant at the 96% confidence level for the UDDS cycle, the 98% confidence level for the FTP cycle, and >99% confidence level for the 50 mph cycle.

Durbin 2011 again notes a problem with the 50 mph cruise test results, saying (p. xxxii) that "[the NOx] trend was obscured, however, by the differences in engine operation that were observed for the 50 mph cruise cycle." Therefore, we will focus the discussion on the UDDS and FTP results.

For the soy-based fuels, the R^2 statistics show that the emissions effect of biodiesel is almost perfectly linear with increasing biodiesel content over the range from ULSD to B20, B50, and B100 for all cycles (including the 50 mph cruise). That is, the NOx emissions increase between ULSD and B20 shares the same slope as the NOx emissions increase between B20 and B100. For the animal-based biodiesel, the R^2 statistics also establish a linear increase in NOx emissions with increasing biodiesel content over the same range. The linearity of the response with blending percent is also well supported by the many NOx emissions graphs contained in Durbin 2011.

Table 3-5 Re-Analysis for 2007 MBE4000 Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B20, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	Pct Change	Pct Change
Soy-based							
	UDDS	0.989	2.319	0.0090 [a]	0.005	4.6%	9.1%
	FTP	0.998	1.268	0.0049	0.006	2.5%	5.0%
	50 mph	0.979	1.198	0.0054 [b]	0.092	2.7%	5.5%
Animal-based							
	UDDS	0.913	2.441	0.0036	0.044	2.0%	4.0%
	FTP	0.999	1.288	0.0038	0.020	2.5%	5.0%
	50 mph	0.994	1.205	0.0049	0.003	2.5%	5.0%

Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.
[b] Orange highlight indicates result is statistically significant at the 90% confidence level or better.

The table also gives the estimated NOx emission increases for B5 and B10 as predicted by the regression lines. For soy-based fuels, the values are ~3.5% for B5 (range 2.5% to 4.6% depending on the cycle) and ~7.5% for B10 (range 5.0% to 9.1% depending on cycle). For animal-based fuels, the values are approximately two-thirds as large: ~2.3% for B5 (range 2.0% to 2.5%) and ~4.5% for B10 (range 4.0% to 5.0%). The predicted increases are statistically significant to the same degree as the slope of the regression line from which they are estimated. That is, the predicted NOx increases are statistically significant at the >99% confidence level for soy-based fuels on the UDDS and FTP cycles and at the >95% confidence level for animal-based fuels on all cycles. The predicted NOx increase is statistically significant at the 90% confidence level for soy-based fuels on the 50 mph cruise cycle.

For this engine, soy- and animal-based B5 were tested on the FTP. Table 3-6 reproduces the NOx emission results reported in Tables ES-4 and ES-5 of Durbin 2011. While there are caveats on use of the pair-wise t-test, the FTP test data for this engine show NOx emissions at the B5 level for both soy- and animal-based fuels that are statistically significant at the 99% confidence level (or better) in this case. That is, the test data for this engine as reported by Durbin 2011 refute the Staff Threshold Model that biodiesel blends below B10 do not increase NOx emissions.

Table 3-6 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2007 MBE4000 Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel FTP		Animal-Based Biodiesel FTP	
	NOx % Diff	p value	NOx % Diff	p value
B5	0.9% [a]	0.007	1.3%	0.000
B20	5.9%	0.000	5%	0.000
B50	15.3%	0.000	12.1	0.000
B100	38.1%	0.000	29%	0.000

Source: Table ES-4/5 of Durbin 2011, p. xxix
Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test.

Figures 3-3a and 3-3b below compare the FTP data for this engine to the regression line representing the linear model (blue) and the Staff Threshold model (black) for both soy- and animal-based biodiesel. In both cases, the regression line was developed using the data for ULSD, B20, B50, and B100 (i.e., excluding the B5 data point). For both soy- and animal-based biodiesels, the data point for B5 falls on the established line, while the Staff Threshold model is inconsistent with the data. For this engine, it is clear that soy- and animal-based biodiesels increase NOx emissions at all blending levels.

Figure 3-3a
Re-assessment of FTP Cycle NOx Emissions Increases for Soy-based Biodiesel Blends (2007 MBE4000 Engine)

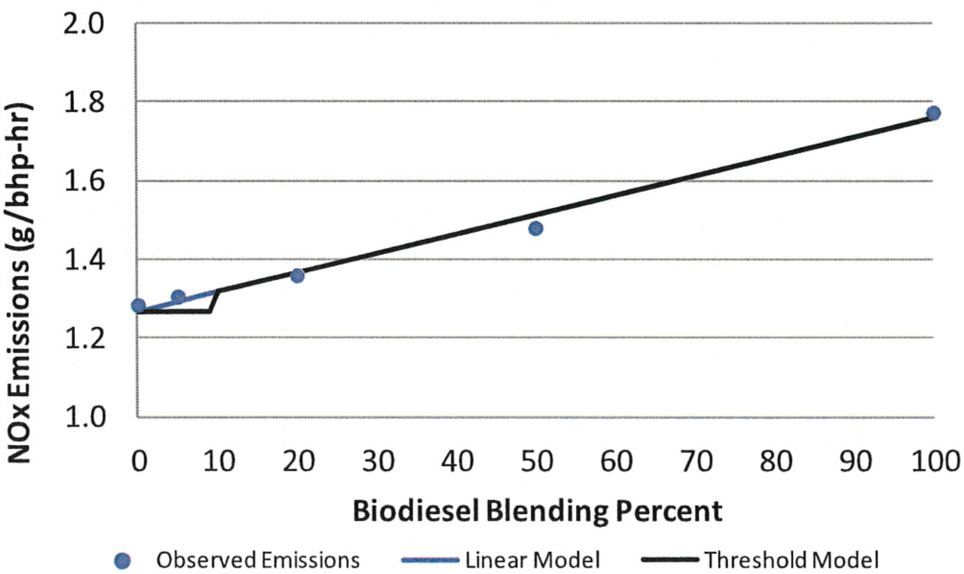
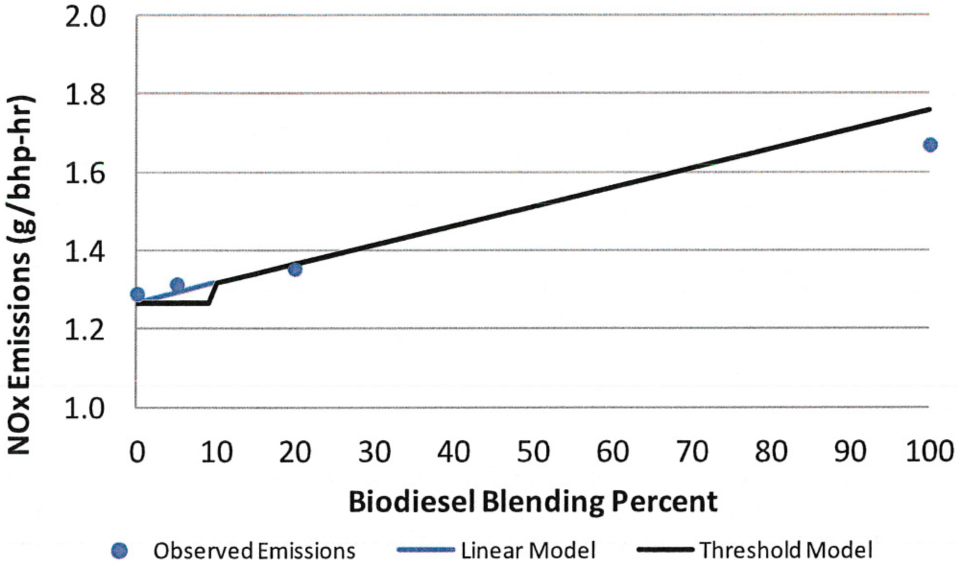


Figure 3-3b
Re-assessment of FTP Cycle NOx Emissions Increases for Animal-based Biodiesel Blends (2007 MBE4000 Engine)



3.5 1998 Kubota TRU Engine (Engine Dynamometer Testing)

The 1998 Kubota V2203-DIB off-road engine was tested on the base fuel (ULSD) and soy-based biodiesel at four blending levels (B5, B20, B50, B100) in two different series using the ISO 8178 (8-mode) test cycle. Appendix I reports the measured emissions data only for the first series (ULSD, B50, B100). Using this subset of data, Table 3-7 summarizes the results of the re-analysis for this engine.

As for the other engines, the results of the analysis demonstrate the following:

- The high R^2 statistic shows that the emissions effect of biodiesel is almost perfectly linear over the range B50 and B100. That is, the slope from ULSD to B50 is the same as the slope from B50 to B100. The slope of the regression line is statistically significant at the 99% confidence level.

- NOx emissions are estimated to increase by 1.0% at the B5 level and by 2.1% at the B10 level. These estimated NOx emission increases are statistically significant to the same high degree as the regression slope on which they are based.

Table 3-7 Re-Analysis for 1998 Kubota V2203-DIB Engine (Engine Dynamometer Testing) Model: NOx = A + B · BioPct Using ULSD, B50, and B100 fuels							
Biodiesel Type	Test Cycle	R^2	Intercept A	BioPct Slope B		Predicted NOx Increase for B5	Predicted NOx Increase for B10
			Value	Value	p value	Pct Change	Pct Change
Soy-based	ISO 8178	0.999	12.19	0.0256 [a]	0.01	1.0%	2.1%

Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better.

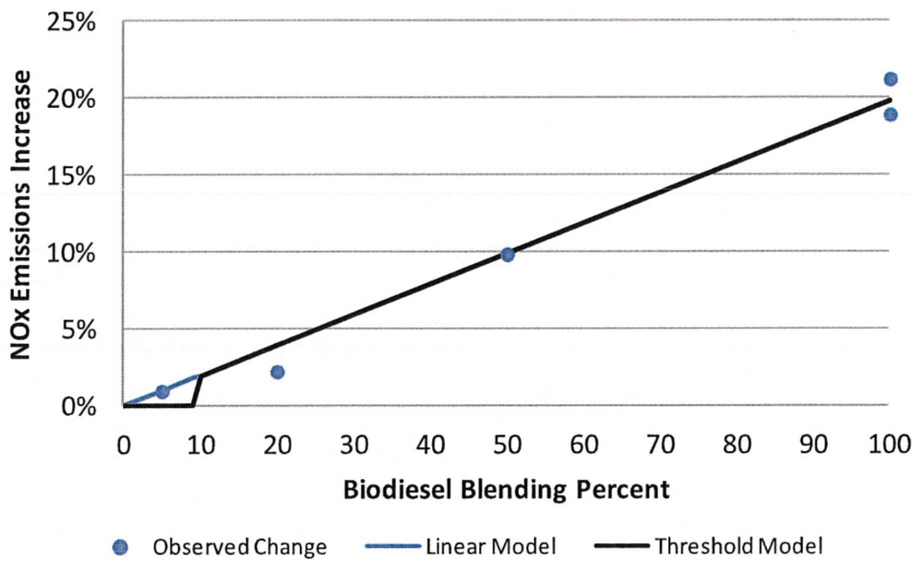
The second test series involved ULSD, B5, B20, and B100 fuels. Measured emissions data are not given in Appendix I, so we must work with the calculated percent changes in NOx emissions tabulated in Durbin 2011. Table 3-8 reproduces the NOx emission results reported in Table ES-8 of Durbin 2011 for the two test series. For the second test series, biodiesel at the B5 level increased NOx emissions, but the result fails the pair-wise t-test for statistical significance. The NOx emission increase at the B20 level was statistically significant at the 90% confidence level, and the increase at the B100 level was statistically significant at the >99% confidence level. The significance determinations use the pair-wise t-test, which is subject to caveats, but this is the only method available to gauge significance because re-analysis of the computed percentage changes is not possible.

Table 3-8 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 1998 Kubota TRU Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel Series 1 ISO 8178		Soy-Based Biodiesel Series 2 ISO 8178	
	NOx % Diff	p value	NOx % Diff	p value
B5	Not tested		0.97%	0.412
B20	Not tested		2.25% [a]	0.086
B50	7.63% [b]	0.000	Not tested	
B100	13.76%	0.000	18.89%	0.000

Source: Table ES-8 of Durbin 2011, p. xxxviii
Notes:
[a] Orange highlight indicates result is statistically significant at the 90% confidence level or better based on pair-wise t-test.
[b] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test

Figure 3-4 displays the trend of NOx emissions with blending percent for the first and second test series combined. As the figure shows, the available data points scatter around the trendline determined from the emission change percentages (not from regression analysis). The B20 data point falls below the trend line while the two B100 data points bracket the trend line. It is not possible to explain the divergence of the B20 data point

Figure 3-4
Durbin 2011 Assessment: ISO 8178 Cycle NOx Emissions Increases for Soy-based Biodiesel Blends (1998 Kubota Engine, Test Series 1 and 2 Combined)



because the emissions data for the second test series are not published in Durbin 2011. The B5 data point clearly supports the Linear Model and is inconsistent with the Staff Threshold Model.

3.6 2009 John Deere Off-Road Engine (Engine Dynamometer Testing)

The only information on the 2009 John Deere off-road engine comes from the tabulation of calculated percentage emission changes. Table 3-9 reproduces these data from Table ES-7 of Durbin 2011. For the soy-based biodiesel, NOx emissions are significantly increased at the B20 and higher blend levels. The increase for B20 is statistically significant at the 90% confidence level and the increases for B50 and B100 are statistically significant at the >99% confidence level based on the pair-wise t-test. A soy-based B5 fuel was not tested.

Table 3-9 Percentage Change in NOx Emissions for Biodiesel Blends Relative to ULSD: 2009 John Deere Engine (Engine Dynamometer Testing)				
	Soy-Based Biodiesel ISO 8178		Animal-Based Biodiesel ISO 8178	
	NOx % Diff	p value	NOx % Diff	p value
B5	Not tested		-3.82	0.318
B20	2.82%[a]	0.021	-2.20	0.528
B50	7.63%	0.000	Not tested	
B100	13.76%	0.000	4.57	0.000

Source: Table ES-7 of Durbin 2011, p. xxxviii
Notes:
[a] Blue highlight indicates result is statistically significant at the 95% confidence level or better based on pair-wise t-test.

For animal-based biodiesel, the testing shows the unusual result that B5 and B20 appear to decrease NOx emissions, while B100 increases NOx. The B5 and B20 decreases are not statistically significant, while the B100 increase is statistically significant at the >99% confidence level. Durbin 2011 concludes:

> The animal-based biodiesel also did not show as great a tendency to increase NOx emissions compared to the soy-based biodiesel for the John Deere engine, with only the B100 animal-based biodiesel showing statistically significant increases in NOx emissions.[18]

Durbin 2011 does not discuss these results further and does not note any problems in the testing, making further interpretation of the results difficult. Figure 8-1 of Durbin 2011 presents the NOx results for this engine with error bars. First, we note that the figure appears to suggest that NOx emissions were increased on the B20 fuel in contradiction to the table above. Second, it is clear that the error bars are large enough that no difference in NOx emissions can be detected among ULSD, B5, and B20 fuels. Overall, this result could be consistent with the Staff Threshold Model through B5, but the failure to detect a NOx emission increase at B20 is not. Without further information, it is not possible to determine whether the result seen here is a unique response of the John Deere engine to animal-based biodiesel or is the result of a statistical fluctuation or an artifact in the emissions data.

3.7 Conclusions

The Biodiesel Characterization report prepared by Durbin et al. for CARB is an important source of information on the NOx emissions impact of biodiesel fuels in heavy-duty engines. It is the sole source of information on the NOx impact of B5 blends cited in the ISOR. When the engine dynamometer test data are examined for

[18] Durbin 2011, p. xx.

the three engines for which emissions test data have been published, we find clear evidence that biodiesel increases NOx emissions in proportion to the blending percent. Where B5 fuels were tested for these engines, NOx emissions are found to increase above ULSD for both soy- and animal-based blends in all three engines and by statistically significant amounts in one engine.

Specifically, a re-analysis of the NOx emissions test data demonstrates the following:

1. For the 2006 Cummins engine, biodiesel fuels are found to significantly increase NOx emissions for both soy- and animal-based blends by amounts that are proportional to the blending percent. This result indicates that biodiesels will increase NOx emissions at blending levels below B10. When B5 fuels were tested, NOx emissions were observed to increase but by amounts that fail to reach statistical significance according to the pair-wise test.[19] Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

2. For the 2007 MBD4000 engine, biodiesel fuels are found to significantly increase NOx emissions for both soy- and animal-based blends by amounts that are proportional to the blending percent. This result indicates that biodiesels will increase NOx emissions at blending levels below B10. When B5 fuels were tested, NOx emissions were observed to increase and by amounts that are found to be statistically significant using the pair-wise t-test.[13] This result alone is sufficient to disprove the Staff Threshold Model. Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

3. For the 1998 Kubota TRU (off-road) engine, soy-based biodiesel fuels are found to significantly increase NOx missions. Animal-based biodiesel was not tested. When a soy-based B5 fuel was tested, NOx emissions were observed to increase but by amounts that fail to reach statistical significance according to the pair-wise test.[13] Graphical analysis demonstrates that NOx emissions measured for B5 fuels are consistent with the Linear Model, but not the Staff Threshold Model.

The measured emissions test data for the other off-road engine (2009 John Deere) are not contained in the Durbin 2011 report and CARB has not made them publicly available. Thus, a re-analysis was not possible. Based on the tables and figures in Durbin 2011, soy-based biodiesel fuels were shown to significantly increase NOx emissions at B20 levels and higher, but B5 was not tested. Testing of animal-based blends shows no change in NOx emissions at B5 and B20 levels, but B100 is shown to significantly increase NOx emissions. Durbin 2011 discusses this result only briefly, and it is unclear what conclusions can be drawn from it.

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[19] As discussed in Section 3.3, the pair-wise t-test is not the preferred method for demonstrating statistical significance.

APPENDIX A

RESUME OF ROBERT W. CRAWFORD

Education

1978 Doctoral Candidate, ScM. Physics, Brown University, Providence, Rhode Island
1976 B.A. Physics, Pomona College, Claremont, California

Professional Experience

1998-Present Independent Consultant

Individual consulting practice emphasizing the statistical analysis of environment and energy data with an emphasis on how data and statistics are properly used to make scientific inferences. Mr. Crawford provides support on statistical, data analysis, and modeling problems related to ambient air quality data and emissions from mobile and stationary sources.

Ambient Air Quality and Mobile Source Emissions – Mr. Crawford has worked with Sierra Research on elevated ambient CO and PM concentrations in Fairbanks AK and Phoenix AZ, including the effect of meteorological conditions on ambient concentrations, the relationship of concentrations to source inventories, and the use of non-parametric techniques to infer source location from wind speed and direction data. Ongoing work is employing Principal Components Analysis to elucidate the relationship between meteorology and $PM_{2.5}$ concentrations in Fairbanks. In the past year, this work led to creation of the AQ Alert System, a tool used by air quality staff to track $PM_{2.5}$ monitor concentrations during the day and to prepare AQ alerts over the next 3 days based on the meteorological forecast.

In past work for Sierra, he has also conducted studies of fuel effects on motor vehicle emissions for Sierra. For CRC, he determined the relationship between gasoline volatility and oxygen content on tailpipe emissions of late model vehicles at FTP and cold-ambient temperatures. For SEMPRA, he determined the relationship between CNG formulation and tailpipe emissions of criteria pollutants and a range of air toxics. Other work has included the design of vehicle surveillance surveys and determination of sample sizes, development of screening techniques similar to discriminant functions to improve the efficiency of vehicle recruitment, the analysis of vehicle failure rates measured in inspection & maintenance programs, and the statistical evaluation of data collected on freeway speeds using automated sensors.

Stationary Source Emissions – Over the past 5 years, Mr. Crawford has worked with AEMS, LLC on EPA's MACT and CISWI rulemakings for Portland Cement plants, in which significant issues related to data quality, data reliability, and emissions variability are evident. Key issues include the need to properly account for uncertainty and emissions variability in setting emission standards. He also supported AEMS in the

current EPA rulemaking on reporting of greenhouse gas emissions from semiconductor facilities, where the proper characterization of emission control device performance was a key issue. He is currently supporting AEMS in a regulatory process to re-determine emission standards for an industrial facility where the new standard will be enforced by continuous emissions monitoring (CEMS). At issue is how to set the standard in such a way that there will be no more than a small, defined risk that 30-day emission averages will exceed the limitations while emissions remain well-controlled .

Advanced Combustion Research – In recent work for Oak Ridge National Laboratory, Mr. Crawford conducted a series of statistical studies on the fuel consumption and emissions performance of Homogenous Charge Compression Ignition (HCCI) engines. One of these studies was for CRC, in which fuel chemistry impacts were examined in gasoline HCCI. In HCCI, the fuel is atomized and fully-mixed with the intake air charge outside the cylinder, inducted during the intake stroke, and then compressed to the point of spontaneous combustion. The timing of combustion is controlled by heating of the intake air. If R&D work can demonstrate a sufficient understanding of how fuel properties influence engine performance, the HCCI combustion strategy potentially offers the fuel economy benefit of a diesel engine with inherently lower emissions.

1979-1997 Energy and Environmental Analysis, Inc., Arlington, VA. Director & Partner (from 1989).

Primary work areas: Studies of U.S. energy industries for private and institutional clients emphasizing statistical analysis, business planning and computer modeling/forecasting. Responsible for the EEA practice area that provided strategic planning and forecasting services to major energy companies. Primary topical areas included: U.S. energy market analysis and strategic planning; gas utility operations; and natural gas supply planning.

U.S. Energy Market Analysis

During 1995-1997, Mr. Crawford directed EEA's program to provide comprehensive energy supply and demand forecasting for the Gas Research Institute (GRI) in its annual Baseline Projection of U.S. Energy Supply and Demand. Services included: development of U.S. energy supply, demand, and price forecasts; sector-specific analyses covering energy end-use (residential, commercial, industrial, transportation), electricity supply, and natural gas supply and transportation; and the preparation of a range of publications on the forecasts and energy sector trends.

From 1989 through 1997, he directed the use of EEA's Energy Overview Model in strategic planning and long-term market analysis for a client base of major energy producers, pipelines, and distributors in both the United States and Canada. The Energy Overview Model was used under his direction as the primary analytical basis for the 1992 National Petroleum Council study The Potential for Natural Gas in the United States. Mr. Crawford also provided analysis for clients on a wide range of other energy market issues, including negotiations related to an LNG import project intended to serve U.S. East Coast markets. This work assessed the utilization and economic value of seasonal

gas deliverability in order to develop LNG pricing formulas and evaluate the project's viability.

Other topical areas of work during his period of employment with EEA include:

Gas Load Analysis and Utility Operations – Principal investigator in a multi-year research program for the Gas Research Institute (GRI) that examined seasonal gas loads, utility operations, and the implications for transmission and storage system reliability and capacity planning.

Gas Transmission and Storage – Principal investigator for a study of industry plans for expansion of underground gas storage capacity in the post-Order 636 environment, including additions of depleted-reservoir and salt-formation storage, an engineering analysis of capital and operating costs for the projects, and unbundled rates for new storage services.

Natural Gas Supply Planning – Mr. Crawford was EEA's senior manager and lead analyst on gas supply planning issues for both pipeline and distribution companies, which included technical and analytic support in development and justification of gas supply strategies; and identification of optimal seasonal supply portfolios for Integrated Resource Planning proceedings.

Transportation Systems Research

Mr. Crawford also had extensive experience in motor vehicle fuel economy and emissions while at EEA. He participated for five years in a DOE research program on fuel economy, with emphasis on the evaluation of differences between laboratory and on-road fuel economy. His work included analysis of vehicle use databases to understand how driving patterns and ambient (environmental) conditions influence actual on-road fuel economy. He also developed a software system to link vehicle certification data systems to vehicle inspection and testing programs and participated in a range of studies on vehicle technology, fuel economy, and emissions for DOE, EPA, and other governmental agencies.

SELECTED PUBLICATIONS (emissions and motor vehicle-related topics)

Statistical Assessment of $PM_{2.5}$ and Meteorology in Fairbanks, Alaska: 2013 Update. Crawford and Dulla. Prepared for the Alaska Department of Environmental Conservation. (forthcoming).

Statistical Assessment of $PM_{2.5}$ and Meteorology in Fairbanks, Alaska. Crawford and Dulla. Prepared for the Alaska Department of Environmental Conservation. March 2012.

Principal Component Analysis: Inventory Insights and Speciated $PM_{2.5}$ Estimates. Crawford. Presentation at Air Quality Symposium 2011, Fairbanks and North Star Borough, Fairbanks, AK. January 2011.

Influence of Meteorology on $PM_{2.5}$ Concentrations in Fairbanks Alaska: Winter 2008-2009. Crawford. Presentation at Air Quality Symposium 2009, Fairbanks and North Star Borough, Fairbanks, AK. July 2009.

Analysis of the Effect of Fuel Chemistry and Properties on HCCI Engine Operation: A Re-Analysis Using a PCA Representation of Fuels. Bunting and Crawford. 2009. Draft Report (CRC Project AFVL13C)

The Chemistry, Properties, and HCCI Combustion Behavior of Refinery Streams Derived from Canadian Oil Sands Crude. Bunting, Fairbridge, Mitchell, Crawford, et al. 2008. (SAE 08FFL 28)

The Relationships of Diesel Fuel Properties, Chemistry, and HCCI Engine Performance as Determined by Principal Components Analysis. Bunting and Crawford. 2007. (SAE 07FFL 64).

Review and Critique of Data and Methodologies used in EPA Proposed Utility Mercury MACT Rulemaking, prepared by AEMS and RWCrawford Energy Systems for the National Mining Association. April 2004.

PCR+ in Diesel Fuels and Emissions Research. McAdams, Crawford, Hadder. March 2002. ORNL/TM-2002/16.

A Vector Approach to Regression Analysis and its Application to Heavy-duty Diesel Emissions. McAdams, Crawford, Hadder. November 2000. ORNL/TM-2000/5.

A Vector Approach to Regression Analysis and its Application to Heavy-duty Diesel Emissions. McAdams, Crawford, Hadder. June 2000. (SAE 2000-01-1961).

Reconciliation of Differences in the Results of Published Shortfall Analyses of 1981 Model Year Cars. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70045. October 1985

Short Test Results on 1980-1981 Passenger Cars from the Arizona Inspection and Maintenance Program. Darlington, Crawford, Sashihara. August 1984.

Seasonal and Regional MPG as Influenced by Environmental Conditions and Travel Patterns. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70045. March 1983.

Comparison of EPA and On-Road Fuel Economy – Analysis Approaches, Trends, and Impacts. McNutt, Dulla, Crawford, McAdams, Morse. June 1982. (SAE 820788)

Regionalization of In-Use Fuel Economy Effects. Prepared by Energy and Environmental Analysis, Inc. for the U.S. Department of Energy under Contract DE-AC01-79PE-70032. April 1982.

1985 Light-Duty Truck Fuel Economy. Duleep, Kuhn, Crawford. October 1980. (SAE 801387)

PROFESSIONAL AFFILIATIONS

Member, Society of Automotive Engineers.

HONORS AND AWARDS

2006 Barry D. McNutt Award for Excellence in Automotive Policy Analysis. Society of Automotive Engineers.

US Patent 7018524 (McAdams, Crawford, Hadder, McNutt). Reformulated diesel fuels for automotive diesel engines which meet the requirements of ASTM 975-02 and provide significantly reduced emissions of nitrogen oxides (NO_x) and particulate matter (PM) relative to commercially available diesel fuels.

US Patent 7096123 (McAdams, Crawford, Hadder, McNutt). A method for mathematically identifying at least one diesel fuel suitable for combustion in an automotive diesel engine with significantly reduced emissions and producible from known petroleum blend stocks using known refining processes, including the use of cetane additives (ignition improvers) and oxygenated compounds.

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Before the
California Air Resources Board

In re:)
)
Proposed Regulation on the)
Commercialization of Alternative)
Diesel Fuels (Public Hearing)
Scheduled for March 20, 2014))
)

Declaration of James M. Lyons

I, James M. Lyons, declare and state as follows:

1. I am an engineer with training and expertise in motor vehicle fuels, automotive emissions control, and automotive air pollution. I am a Senior Partner of Sierra Research, Inc. ("Sierra"), an environmental consulting firm located at 1801 J Street, Sacramento, California. Sierra specializes in research and regulatory matters pertaining to air pollution control, and does work for both governmental and private sector clients. I have been employed at Sierra Research since 1991. I received a B.S. degree in Chemistry from the University of California, Irvine, and a M.S. Degree in Chemical Engineering from the University of California, Los Angeles. Before joining Sierra in 1991, I was employed by the State of California in the Mobile Source Division of the California Air Resources Board ("CARB").

I. Introduction, Qualifications, and Materials Considered

2. I have prepared this Declaration and the analysis it contains for Growth Energy. I hold the opinions expressed in this Declaration with a reasonable degree of engineering and scientific certainty. I plan to request an opportunity to testify before CARB at the public hearing scheduled for this matter, so that I may answer any questions concerning my opinions and the analysis and sources on which I have based those opinions. I also request that CARB review and

respond to each part of the analysis and opinions presented in this Declaration before deciding what action to take on the CARB staff's proposed alternative diesel fuel ("ADF") regulation.

3. During my career, I have worked on many projects related to the following areas: (1) the assessment of emissions from on- and non-road mobile sources, including ships and locomotives; (2) analyses of the unintended consequences of regulatory actions; and (3) the feasibility of compliance with air quality regulations. I have also studied how the use of biodiesel fuels can influence exhaust emissions of oxides of nitrogen ("NOx") when used in vehicles and engines operated in California, and I have prepared and filed declarations regarding that issue in *POET LLC et al. v. California Air Resources Board*, an action in which I was a co-petitioner.

4. I have testified as an expert under state and federal court rules in cases involving CARB regulations for gasoline, Stage II vapor recovery systems and their design, combustion chamber system design, and issues related to emissions from heavy-duty vehicles and engines. While at Sierra I have acted as a consultant on automobile air pollution control matters for CARB and other governmental organizations. I am a member of the American Chemical Society and the Society of Automotive Engineers and have co-authored nine peer-reviewed monographs concerned with automotive emissions, including greenhouse gases and their control. In addition, over the course of my career, I have conducted peer-reviews of numerous papers related to a wide variety of issues associated with pollutant emissions and air quality. My résumé is attached as Attachment A.

5. I have reviewed a report being filed along with this Declaration by Growth Energy that has been prepared by Mr. Robert Crawford of Rincon Ranch Consulting, entitled *NOx Emissions Impact of Soy- and Animal-based Biodiesel Fuels: A Re-Analysis* (December

2013). I have also studied the CARB Initial Statement of Reasons ("ISOR" or "Staff Report") released to support the proposed ADF regulation, and the studies cited in the ISOR that are pertinent to Mr. Crawford's analysis. The additional materials I have considered to prepare this Declaration are identified as references.

6. Mr. Crawford's report examines the empirical basis for the CARB staff's claims that the use of biodiesel in California is unlikely to warrant environmental mitigation, and that the use of biodiesel blends below the ten percent blend level (B10) in California pursuant to the proposed ADF regulation will not result in increases in NOx emissions.

7. Mr. Crawford's report applies generally accepted methods of data analysis and demonstrates expertise in the subject-matter of the report; Mr. Crawford is an expert in the field in which he opines in his report; and his report is the type of analysis on which experts in the field of automotive emissions control rely.

II. Analysis and Opinions

A. Increases in NOx Emissions from Biodiesel Blends Below B10

8. As explained in detail in Mr. Crawford's report, a proper statistical analysis of the available emissions data relied upon by CARB staff in developing the proposed ADF regulation demonstrates that statistically significant increases in NOx emissions will result from biodiesel blends that contain less than ten percent biodiesel, including at the five percent level (B5) and below. In addition, Mr. Crawford's report demonstrates that NOx emissions increase in direct proportion of the amount of biodiesel in a blend and there is not, as CARB staff claims, a "threshold" below which biodiesel use in a blend will not increase NOx emissions. Given this, as I explain below in more detail, CARB staff should be proposing a Significance Level of zero, rather than ten percent, for biodiesel. Given the issues identified with the CARB staff analysis of

biodiesel impacts on NOx emissions by Mr. Crawford, CARB has no credible scientific basis upon which to adopt the ADF regulation as proposed with the biodiesel Significance Level set at ten percent.

9. CARB staff presents, in Figures B.2 and B.3 of the ISOR, regressions of all the available emissions data considered by CARB staff in developing the proposed ADF regulation. Based on Mr. Crawford's findings, the slopes of these regression lines can be used to calculate the increases in NOx emissions expected from the use of soy- and animal-based biodiesel as a function of biodiesel content in the blend. The values calculated for soy- and animal-based biodiesel at selected blends levels over the range from one percent to twenty percent are shown in Table 1.

Table 1
Expected Increases In NOx Emissions from Biodiesel Use Based on Available Emissions Data Considered by CARB Staff

	Percentage Increase in NOx Emissions	
Biodiesel Blend Level %	Soy-Based	Animal-Based
1	0.2	0.09
2	0.4	0.18
3	0.6	0.27
4	0.8	0.36
5	1	0.45
10	2	0.90
20	4	1.80

10. As shown in Table 1, the magnitude of the NOx increase for animal-based biodiesel is approximately half that observed for soy-based biodiesel. As also shown in Table 1, the emissions data considered by CARB show that increases in NOx emissions between about one and two percent occur at the proposed B10 significance threshold.

B. The "Effective Blend Level" Concept Provides No Assurance Against Increases in NOx Emissions Due to Biodiesel Use

11. The proposed ADF regulation relies on a concept called the "Effective Blend Level" (EB) for biodiesel to determine when mitigation would be required. The formula proposed by CARB staff for calculating the Effective Blend Level for biodiesel is found in proposed Section 2293.6(a) and is reproduced below.

$$EB = 100 \times \left[\frac{NBV - 0.5LN - 0.73RD - VM - 0.55AB}{TCV}\right]$$

As specified in Section 2293.6(a), the above formula is to be used to compute an annual average statewide value for the Effective Blend Level relative to the total volume of fuel used in compression ignition engines excluding alternative fuels such as natural gas and liquefied petroleum gas ("TCV") in the state during that year.

12. The calculation begins with establishing the net volume of biodiesel of all types used in California *excluding biodiesel used in blends of five percent or less* (NBV) — a step that has no scientific basis, as demonstrated by Mr. Crawford's analysis, and that, on its own, completely invalidates the use of the EB metric for the intended purpose. The NBV value is then further reduced by subtracting 50% of the volume of low NOx Diesel (LN) used statewide and 73% of the volume of renewable Diesel used statewide. The remainder is then further reduced by subtracting the volume of biodiesel of all types used in blends where steps have been taken to voluntarily mitigate NOx increases (VM) and then again by subtracting 55% of the volume of animal-based biodiesel (AB) to account for the smaller magnitude of the NOx emission increases observed with that fuel.[1] The final value is then divided by TCV (i.e., the total volume of fuel

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1 Those voluntary mitigation measures are assumed to have been taken before the so-called "Significance Level" is reached and mitigation would be required under the staff's proposal. *See* ¶ 13.

used in compression ignition engines excluding alternative fuels such as natural gas and liquefied petroleum gas in the state during that year) and multiplied by 100 to yield the Effective Blend Level on a percentage basis.

13. As specified in proposed Section 2293.5(c)(4), mitigation of NOx increases associated with biodiesel would be required only when the value of EB reaches 9.5 percent, which is 95% of the 10% Significance Level proposed for biodiesel.

14. There are a number of specific problems with the concept and calculation of the predicted Effective Blend Level that create the potential for significant increases in NOx emissions to result from the use of biodiesel in California; these are explained in detail below and should be addressed by CARB. As an initial matter, however, the overall problem with the EB concept will allow massive increases in the amount of biodiesel used in California without requiring any mitigation of the associated increase in NOx emissions. This can be seen readily by comparing CARB staff's projections of biodiesel use in California (Figure 6.2 of the ISOR) with CARB staff's projections regarding the Effective Blend Level for biodiesel (Figure 6.5 of the ISOR). Those two figures are reproduced below in Figure 1. As can been seen, despite the forecast nine-fold increase in annual biodiesel use in California from 50 million to 450 million gallons from 2013 to 2023 shown in Figure 6.2 of the ISOR, the forecast Effective Blend Level of biodiesel **decreases** to less than zero over virtually all of the period in question — meaning that, under the CARB staff's proposal, no mitigation of the increase in NOx emissions in California from biodiesel use will ever occur. CARB needs to confront and eliminate the EB concept from the staff's proposal, in light of this very simple demonstration of why the EB concept will not protect the environment against increases in NOx emissions.

Figure 1. CARB Biodiesel Forecasts

Figure 6.2: Statewide Biodiesel Volume

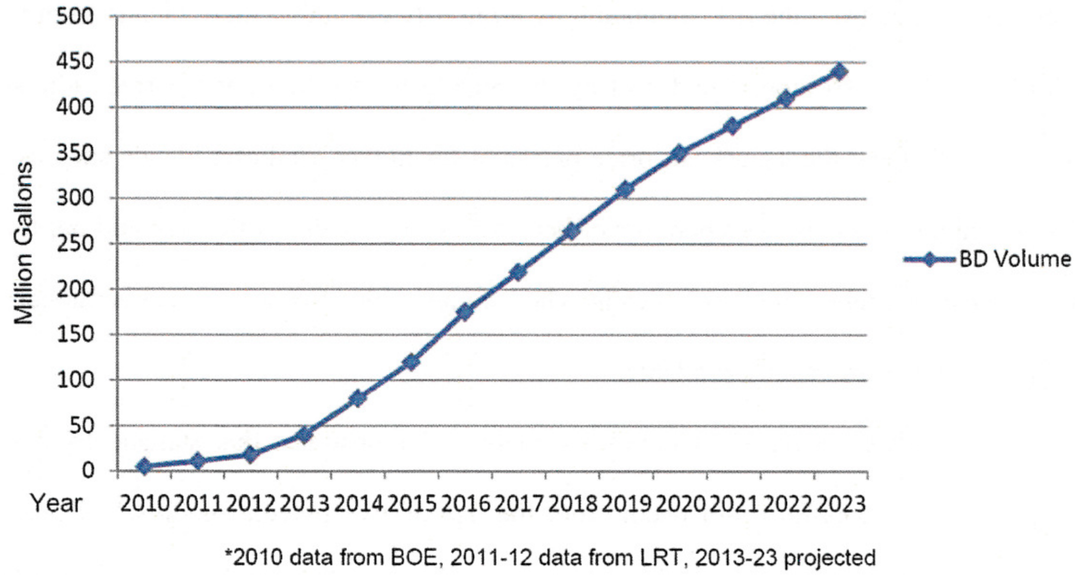
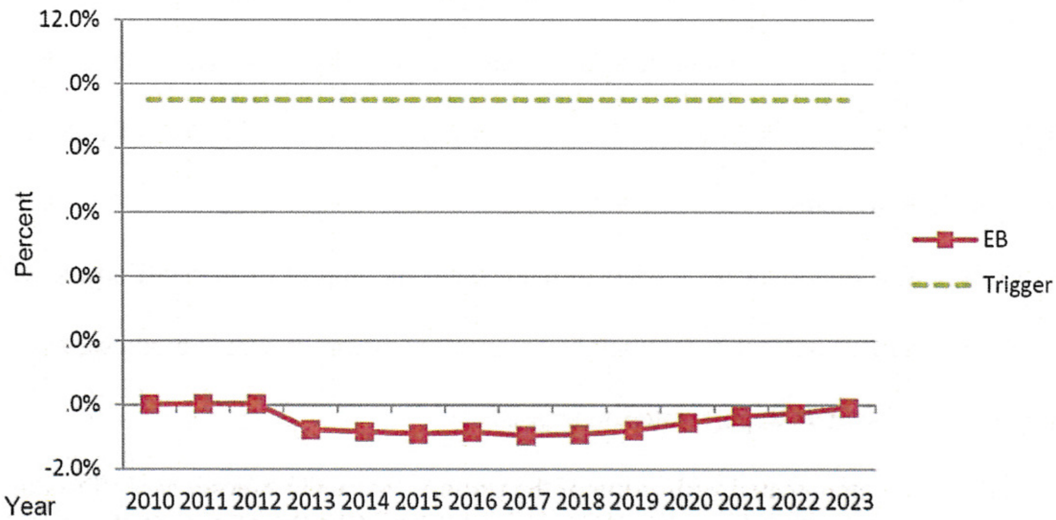


Figure 6.5: Effective Biodiesel Blend Level Forecast



Source: CARB Initial Statement of Reasons. Note that Figure 6.5 is reproduced directly from the ISOR, which is missing some increments on the y-axis.

15. Next, CARB needs to modify the proposed ADF regulation in order to address CARB staff's faulty assumption that biodiesel blends of up to five percent will have no impact on NOx emissions. With respect to five percent blends, CARB staff states on page ES-3 of the Staff

Report that "biodiesel used in blends at B9 or below, including the B5 (B0 to B5) in predominant use today, does not increase NOx." The Staff Report also attempts to justify the exclusion of five percent blends from the EB calculation by arbitrarily excluding these blends from the ADF regulation. That assertion is undercut by the Staff Report's frank and correct admission on page 51 that "[g]iven the significant price premium for higher biodiesel blends such as B20 or B100, it is highly unlikely that operators of heavy-duty, legacy diesel fleets would opt to use the more expensive, higher biodiesel blends when comparable, lower cost conventional CARB diesel or B5 blends are readily available."

16. As noted above, Mr. Crawford's analysis demonstrates that statistically significant increases in NOx emissions will occur from the use of five percent biodiesel blends and, as Table 1 shows, the available emissions data relied upon by CARB staff indicate that at the five percent blend level, biodiesel use is expected to increase NOx emission by between about 0.5 and one percent. There is no doubt that unmitigated NOx emission increases of this magnitude have the potential to create significant adverse environmental impacts in areas of California with severe air quality problems.

17. It is also important for CARB to understand the import of the staff's prediction that biodiesel blends of five percent or less will be the primary means by which biodiesel will be used in California. As the Staff Report states on page 30:

> Staff has communicated with many of the stations that sell biodiesel as well as the major terminal operators in the state, and has found that the vast majority of the biodiesel currently being sold in California and expected to be sold in the future is sold as blends of B5 or less.

The fact that most biodiesel used in California will be sold as blends of five percent biodiesel or less, coupled with the fact that – as Mr. Crawford has explained – the available data show statistically significant increases in NOx emissions from such blends, means that biodiesel use in

California under the proposed ADF regulation will result in unmitigated increases in NOx emissions. Again, the critical nature of the CARB staff's invalid assumption about the NOx impacts of blends at or below five percent simply cannot be ignored by CARB.

18. Even if it were correct that blends of B5 and less have no impact on NOx emissions, the EB calculation double-counts for the supposedly benign effect of those blends, and therefore makes mitigation even more unlikely. This can be illustrated by noting that CARB staff estimates that 450 million gallons per year of biodiesel will be used in California in 2023. (See Figure 6.2 of the Staff Report.) A recent California Energy Commission forecast[2] for total Diesel use in California in 2023 is about 4 billion gallons. On that basis, and without discounting for low NOx, renewable Diesel, or voluntary mitigation, the actual Effective Blend Level would be 11.25 percent and mitigation would be required for at least some biodiesel blends under the proposed ADF. Under CARB staff's approach, however, if a substantial portion of that biodiesel — for example, 50 percent — is five percent or lower blends, the Effective Blend Level drops to 5.6 percent and no mitigation of any kind is required for any biodiesel blends. That result is clearly incorrect, and the EB calculation must be modified to include, rather than exclude, B5 blends.

19. Another fundamental problem with the proposed EB calculation is that it is based on annual statewide average fuel use. NOx emissions have local and immediate impacts on air quality, with the questions of when and where they occur in the state being of critical importance with respect to the significance of those impacts. It follows directly that mitigation of NOx increases associated with biodiesel use must occur in the same area at the same time if air quality

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[2] See *http://www.energy.ca.gov/2011publications/CEC-600-2011-007/CEC-600-2011-007-SD.pdf*.

impacts are to be avoided. However, the EB completely fails to provide this assurance because CARB staff has either (1) ignored that reductions in NOx emissions from mitigation must take place at the same time and in the same area as NOx increases from biodiesel use, or (2) without support from anything in the rulemaking file, assumed that mitigation will occur in the same area and at the same time as the increases in NOx emissions.

20. To illustrate the problems the EB creates for mitigation, consider, for example, that under the proposed ADF regulation, increases in NOx emissions could occur from trucks operating on biodiesel in Los Angeles during August and exacerbate already high ambient ozone levels in that area. In turn, this increase in NOx emissions could be "mitigated" by reductions in NOx emissions from trucks operating on renewable diesel in the San Francisco area during December, when high ozone levels are not a problem. In this example, the EB concept would allow residents of Los Angeles to suffer adverse environmental impacts while the residents of San Francisco would realize no environmental benefit. Clearly the approach to mitigation designed into the EB concept by CARB staff makes no sense.

C. CARB Staff's Assumption that Biodiesel Use Will not Increase Emissions from New Technology Diesel Engines Is Not Adequately Supported

21. In the Staff Report, CARB staff makes frequent statements regarding the impact of biodiesel on NOx emissions from "new technology diesel engines" (or "NTDEs"). For example, on page ES-3 of the ISOR, the staff states categorically that "use of biodiesel in 2010-compliant engines and other so-called 'New Technology Diesel Engines' does not increase NOx, regardless of the biodiesel blend level." Only one reference, Lammert et al.,[3] is provided in the staff report

[3] Lammert, M., McCormick, R., Sindler, P. and Williams, A., "Effect of B20 and Low Aromatic Diesel on Transit Bus NOx Emissions Over Driving Cycles with a Range of Kinetic Intensity," *SAE Int. J. Fuels Lubr.* 5(3):2012,

(Continued...)

to support this and other, analogous, statements by CARB staff. As CARB staff acknowledges, this single study involved chassis dynamometer testing of only two urban buses with NTDEs, with both engines being the same model produced by the same manufacturer. The extrapolation of that limited testing to the entire population of heavy-duty Diesel vehicles with NTDEs used in different applications and with different engine designs produced by a number of different manufacturers is simply not credible or reliable.

22. In addition, the CARB staff fails to acknowledge the following statement made by the authors of the Lammert study about the measurement of NOx emissions: "For much of the cycle[,] NOx would be at or near the detection limit of the laboratory equipment which resulted in a 95 percent confidence interval that was high relative to the value of the cycle emissions." That effect, which can be clearly seen in Figures 10 and 11 of the Lammert study, renders the claim that there was no statistically significant increase in NOx emissions observed from the use of biodiesel in NTDEs an artifact attributable to the lack of sensitivity of the NOx measurement instrumentation used in the study.

23. In sum, the CARB staff's unequivocal statements regarding the impact of biodiesel on NOx emissions from all vehicles with NTDEs is simply not reasonable based on data from (1) a single study that (2) that tested only two urban buses equipped with the same engine and (3) used instrumentation that was, at best, barely able to measure NOx emissions from the test vehicles in general, and clearly was not sensitive enough to reliably detect changes in NOx emissions due to use of different fuels. Nothing else in the rulemaking file supports the CARB staff's claim that there will not be increased NOx emissions from the use of biodiesel in NTDEs.

I declare under penalty of perjury under the laws of California that the foregoing is true and correct to the best of my knowledge and belief.

Executed this 12th day of December 2013 at Sacramento, California.

James M. Lyons

ATTACHMENT A

sierra
research

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Résumé

James Michael Lyons

Education

1985, M.S., Chemical Engineering, University of California, Los Angeles

1983, B.S., Cum Laude, Chemistry, University of California, Irvine

Professional Experience

4/91 to present — Senior Engineer/Partner/Senior Partner
Sierra Research

Primary responsibilities include oversight and execution of complex analyses of the emission benefits, costs, and cost-effectiveness of mobile source air pollution control measures. Mr. Lyons has developed particular expertise with respect to the assessment of control measures involving fuel reformulation, fuel additives, and alternative fuels, as well as accelerated vehicle/engine retirement programs, the deployment of advanced emission control systems for on- and non-road gasoline- and Diesel-powered engines, on-vehicle evaporative and refueling emission control systems, and Stage I and Stage II service station vapor recovery systems. Additional duties include assessments of the activities of federal, state, and local regulatory agencies with respect to motor vehicle emissions and reports to clients regarding those activities. Mr. Lyons has extensive litigation experience related to air quality regulations, product liability, and intellectual property issues.

7/89 to 4/91 — Senior Air Pollution Specialist
California Air Resources Board

Supervised a staff of four professionals responsible for identifying and controlling emissions of toxic air contaminants from mobile sources and determining the effects of compositional changes to gasoline and diesel fuel on emissions of regulated and unregulated pollutants. Other responsibilities included development of new test procedures and emission standards for evaporative and running loss emissions of hydrocarbons from vehicles; overseeing the development of the state plan to control toxic emissions from motor vehicles; and reducing emissions of CFCs from motor vehicles.

4/89 to 7/89 Air Pollution Research Specialist
California Air Resources Board

Responsibilities included identification of motor vehicle research needs; writing requests for proposals; preparation of technical papers and reports; as well as monitoring and overseeing research programs.

9/85 to 4/89 Associate Engineer/Engineer
California Air Resources Board

Duties included analysis of vehicle emissions data for trends and determining the effectiveness of various types of emissions control systems for both regulated and toxic emissions; determining the impact of gasoline and diesel powered vehicles on ambient levels of toxic air contaminants; participation in the development of regulations for "gray market" vehicles; and preparation of technical papers and reports.

Professional Affiliations

American Chemical Society
Society of Automotive Engineers

Selected Publications (Author or Co-Author)

"Review of CARB Staff Analysis of 'Illustrative' Low Carbon Fuel Standard (LCFS) Compliance Scenarios," Sierra Research Report No. SR2012-02-01, prepared for the Western States Petroleum Association, February 20, 2012.

"Review of CARB On-Road Heavy-Duty Diesel Emissions Inventory," Sierra Research Report No. SR2010-11-01, prepared for The Ad Hoc Working Group, November 2010.

"Identification and Review of State/Federal Legislative and Regulatory Changes Required for the Introduction of New Transportation Fuels," Sierra Research Report No. SR2010-08-01, prepared for the American Petroleum Institute, August 2010.

"Technical Review of EPA Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis for Non-GHG Pollutants," Sierra Research Report No. SR2010-05-01, prepared for the American Petroleum Institute, May 2010.

"Effects of Gas Composition on Emissions from Heavy-Duty Natural Gas Engines," Sierra Research Report No. SR2010-02-01, prepared for the Southern California Gas Company, February 2010.

"Effects of Gas Composition on Emissions from a Light-Duty Natural Gas Vehicle," Sierra Research Report No. SR2009-11-01, prepared for the Southern California Gas Company, November 2009.

"Technical Review of 2009 EPA Draft Regulatory Impact Analysis for Non-GHG Pollutants Due to Changes to the Renewable Fuel Standard," Sierra Research Report No. SR2009-09-01, prepared for the American Petroleum Institute, September 2009.

"Effects of Vapor Pressure, Oxygen Content, and Temperature on CO Exhaust Emissions," Sierra Research Report No. 2009-05-03, prepared for the Coordinating Research Council, May 2009.

"Technical Review of 2007 EPA Regulatory Impact Analysis Methodology for the Renewable Fuels Standard," Sierra Research Report No. 2008-09-02, prepared for the American Petroleum Institute, September 2008.

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ATTACHMENT E

NOx Emission Impacts of Biodiesel Blends:
Technical Summary

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Issues Addressed

- Biodiesel NOx impact
  - How large is it?
  - Does it depend on dataset selection (which blend levels and studies to include)?
- Differences by blendstock type
  - Soy-based blends
  - Animal-based blends
- Emissions differences among animal-based feedstocks
- Are soy- and animal-based blends categorically different in their impact on NOx?
- Some implications for allowing biodiesels into California market

References to Literature

Author	Title	Feedstocks Studied	Blends Studied
Clark 1999	Transient Emissions Comparisons of Alternative Compression Ignition Fuel	Soy	B20
McCormick 2002	Fuel Additive and Blending Approaches to Reducing NOx Emissions from Biodiesel	Soy, UCO	B20
McCormick 2005	Regulated Emissions from Biodiesel Tested in Heavy-Duty Engines Meeting 2004 Emissions	Soy, Canola, Animal	B20
Eckerle 2008	Effects of Methyl Ester Biodiesel Blends on NOx Emissions	Soy	B20
Nuszkowski 2009	Evaluation of the NOx emissions from heavy duty diesel engines with the addition of cetane improvers.	Soy	B20
Nikanjam 2010	Performance and emissions of diesel and alternative diesel fuels	Soy	B5, B20
Thompson 2010	Neat fuel influence on biodiesel blend emissions	Soy	B10, B20
Durbin 2011	Biodiesel Characterization and NOx Mitigation Study	Soy, Animal	B5, B10, B20
Durbin 2013A	CARB B5 Preliminary and Certification Testing	Animal	B5
Durbin 2013B	CARB B20 Biodiesel Preliminary and Certification Testing	Soy, UCO	B20
Karavalakis 2014	CARB Comprehensive B5/B10 Biodiesel Blends Heavy-Duty Engine Dynamometer Testing	Soy, Animal	B5, B10

Datasets Used in Analysis

- ARB Individual Test Run Dataset ("raw data")
  - 4 tables: B5-soy, B10-soy, B5-animal, B10-animal
  - Individual test run measurements for the 3 UCR studies
  - Emission averages for other literature sources
- ARB Literature Dataset
  - Emission averages by engine, test cycle, and blend
  - Through B20 blend level
- We have added the following
  - Number of test replications for emission averages (estimated in some cases)
  - Cetane number for CARB Diesel, biodiesel blends, biodiesel feedstocks
  - Additional testing at B50 and B100 levels (where available).

NOx Impact of Soy-based Biodiesels

- The literature on soy-based blends is large and diverse (see Table 1):
  - 10 different studies (3 UCR studies sponsored by ARB)
  - 13 different vegetable feedstocks (10 soy, 2 UCO, 1 canola)
  - Conducted on a wide variety of engines in different labs
  - 7 different test cycles
- In spite of the diversity, the 3 UCR studies dominate the dataset.
  - The number of test replications (NReps) is used as a weighting factor in this analysis to reflect the better precision of results based on more tests.
  - When this is done, the UCR studies account for 82.5% of the literature dataset. The weight is even larger at the B5 and B10 levels, which come almost solely from the UCR studies.
- It is important to recognize that the effective diversity is less as a result of the weighting. The UCR studies examine only 3 different soy feedstocks.

Table 1: Scope of Emissions Testing for Soy-based Biodiesel

	Clark 1999	McCormick 2002	McCormick 2005	Eckerle 2008	Nuszkowski 2009	Nikanjam 2010	Thompson 2010	Durbin 2011	Durbin 2013A/B	Karavalakis 2014
Biodiesel Feedstocks	Soy	Soy, UCO	Soy, Canola	Soy	Soy	Soy	Soy	Soy	Soy, UCO	Soy
Blend Levels Tested	B20	B20	B20	B20	B20	B5, B20	B10, B20	B5, B20, B50, B100	B5, B20	B5, B10
Engines Tested	One	One	Two	One	Three	One	One	Two On-Road Two Off-Road	One	Two
Test Cycles	FTP	FTP	FTP	FTP	FTP	FTP, ESC	FTP, ESC	FTP, UDDS, 40mph, 50mph, ISO 8178	FTP	FTP, SET, UDDS
Test Replications on Biodiesel	3	9	9	3	9	16	12	172	36	80

NOx Impact of B5 Soy Blends Compared to CARB Diesel

- All B5 blends are soy-based
- The T-Test is the most direct method to assess the difference in mean NOx emissions (B5 vs. CARB Diesel) for individual engines
  - Requires that individual test runs (or standard deviations) be available. Cannot be applied to the Nikanjam data.
- B5 Soy blends clearly increase NOx emissions (see Table 2):
  - In 9 of 12 cases, NOx emissions are observed to increase
  - The NOx emission increases are statistically significant in 6 of the 9 cases (highly significant in 5 cases)
  - All NOx emission increases on the FTP cycle are statistically significant (when the test can be made)
  - None of the 3 observed NOx decreases is statistically significant.
- Conclusion: B5 Soy blends increase NOx emissions across a range of engines and test cycles.

Table 2. T-Test Results for NOx Impact of B5 Soy-based Blends

Source	Feedstock ID	Engine	Cycle	NReps (total)	ΔNOx (gm/bhp-hr)	Prob > |t|	Statistical Significance
Nikanjam 2010	Soy	1991 DDC 60	FTP	8	T-Test not applied. Requires test runs or standard deviations.		
Nikanjam 2010	Soy	1991 DDC 60	ESC	8	T-Test not applied. Requires test runs or standard deviations.		
Durbin 2011	Soy #1	1999 Kubota TRU	ISO 8178-4 C	19	+ 0.084	p = 0.41	Not significant
Durbin 2011	Soy #1	2006 Cummins ISM	40mph Cruise	5	+ 0.034	p = 0.14	Not significant
Durbin 2011	Soy #1	2006 Cummins ISM	50mph Cruise	12	- 0.020	p = 0.59	Not significant
Durbin 2011	Soy #1	2006 Cummins ISM	FTP	39	+ 0.046	p < 0.001	Highly significant
Durbin 2011	Soy #1	2007 MBE4000	FTP	12	+ 0.011	p = 0.001	Highly significant
Durbin 2013A	Soy #2	2006 Cummins ISM	FTP	12	+ 0.026	p = 0.002	Highly significant
Karavalakis 2014	Soy #3	1991 DDC 60	FTP	16	+ 0.045	p < 0.001	Highly significant
Karavalakis 2014	Soy #3	1991 DDC 60	SET	8	- 0.030	p = 0.36	Not significant
Karavalakis 2014	Soy #3	1991 DDC 60	UDDS	16	+ 0.035	p = 0.05	Significant
Karavalakis 2014	Soy #3	2006 Cummins ISM	FTP	16	+ 0.021	p < 0.001	Highly significant
Karavalakis 2014	Soy #3	2006 Cummins ISM	SET	8	- 0.011	p = 0.16	Not significant
Karavalakis 2014	Soy #3	2006 Cummins ISM	UDDS	17	+ 0.066	p = 0.23	Not significant

Note: The t-test analysis uses the ARB dataset of individual test runs ("raw data")

Composite NOx Impact of B5 Soy Blends Compared to CARB Diesel

- To estimate a composite impact across engines, a different statistical approach is needed that will account for the varying NOx emission levels of the engines and test cycles.
- Weighted regression analysis with dummy variables for N-1 engine/test cycle combinations "*i*" has been used to estimate Regression Model 1:

$$\log NOx = a + \sum_{i=2}^{N} \delta_i + b \cdot \delta_{B5}$$

where:

- Coefficients a and δ_i represent the average log *NOx* emission level on CARB Diesel for each engine/test cycle combination. (These values are not reported in the summary of results that follows.)
- $\delta_{B5} = 0$ for CARB Diesel tests; $\delta_{B5} = 1$ for B5 Soy tests
- Coefficient b gives the composite NOx impact of B5 Soy across engines/test cycles.

- The log *NOx* formulation assumes that the emissions impact on a percentage basis is proportional to blend level. The percentage impact on NOx emissions equals $100 \cdot [\exp(b)-1]$

Result for Composite B5 Soy Impact on NOx

- Based on the ARB test run dataset ("raw data")
  - The Nikanjam 2010 B5 testing (with weight of 4 for its NOx averages) can be included with the UCR testing (with weight of 1 for each test run).
- Regression Model 1 Result:
  - $R^2 = 0.9995$ (dominated by the dummy variables that represent the differing NOx emission levels among engines and test cycles)
  - Coefficient b for the δ_{B5} effect has the value: $+0.0096 \pm 0.0026$. The statistical significance is $p = 0.0003$ (highly significant).
- The equivalent percentage NOx increase is **+0.96%** at the B5 level
  - or 0.19% for each 1 percent biodiesel in a blend.

Composite NOx Impact of Soy Blends Through B10

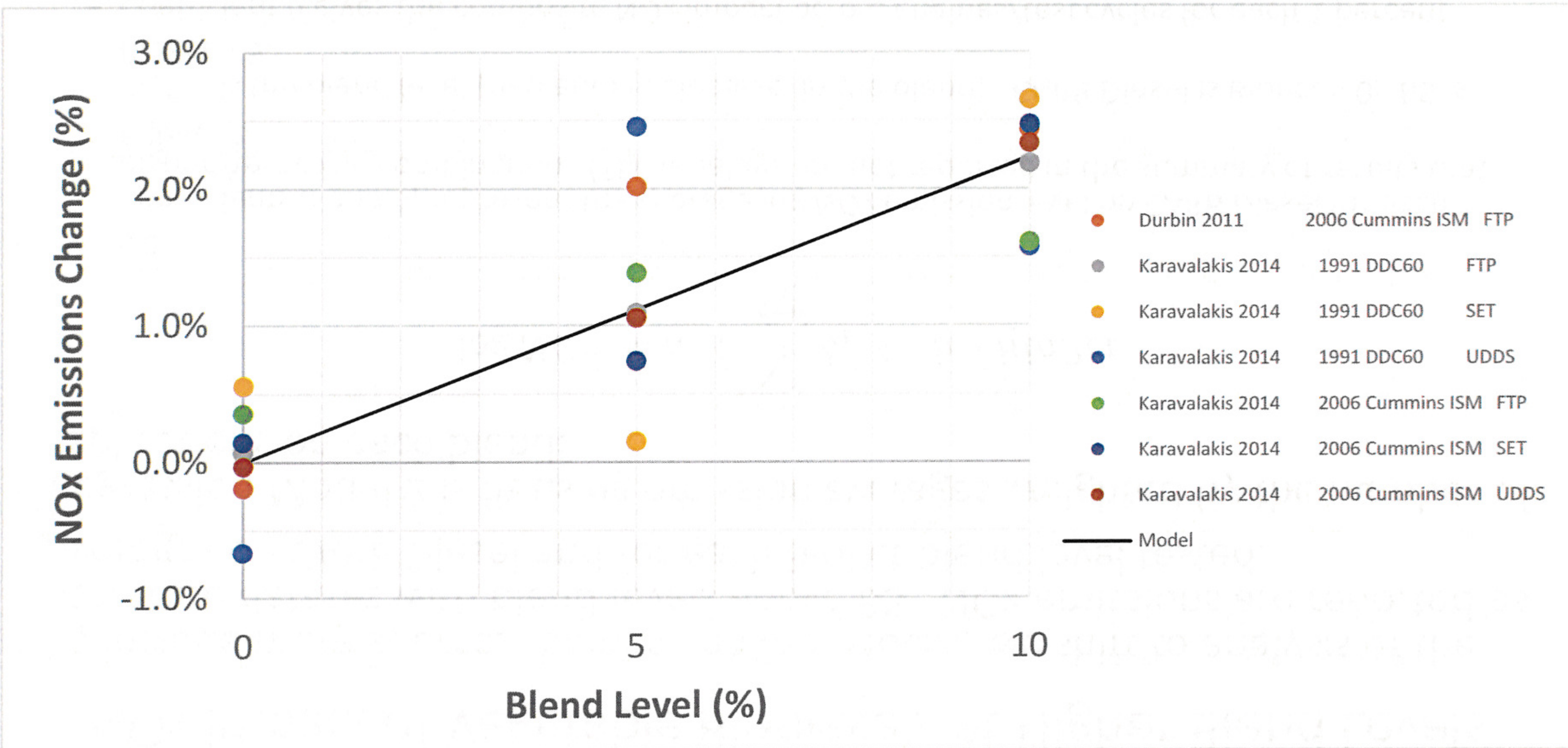
- To assess the composite NOx impact through B10, the regression model is modified to use blend level as the predictive variable. Here, the revised model is fit using the subset of data where individual tests are available ("raw data").
- Unweighted regression analysis with dummy variables for N-1 engine/test cycle combinations "*i*" has been used to estimate Regression Model 2:

$$\log NOx = a + \sum_{i=2}^{N} \delta_i + b \cdot BioPct$$

where:

- Coefficients a and δ_i represent the average log *NOx* emission level on CARB Diesel for each engine/test cycle combination. (These values are not reported in the summary of results that follows.)
- BioPct is the blend level (percentage biodiesel in the blend). CARB Diesel is BioPct = 0; B5 is BioPct = 5.
- Coefficient b gives the composite NOx impact across engines/test cycles for each 1 percent biodiesel in a blend.

Soy biodiesels cause statistically significantly increases in NOx emissions at B10, B5 and Lower blend levels



NOx Impact of Vegetable Biodiesels At Higher Blend Levels

- To include more sources, blends and feedstocks, we shift to analysis of the literature dataset with blend levels above B5. NOx emissions are reported as averages on CARB Diesel and for each BioPct blend level tested.
- Regression Model 2 is fit using emission averages weighted by the number of replications on each blend:

$$\log NOx = a + \sum_{i=2}^{N} \delta_i + b \cdot BioPct$$

where:

- Coefficients a and δ_i represent the average log *NOx* emission level on CARB Diesel for each engine/test cycle combination. (These values are not reported in the summary of results that follows.)
- BioPct is the blend level (percentage biodiesel in the blend). CARB Diesel is BioPct = 0; B5 is BioPct = 5.
- Coefficient b gives the composite NOx impact across engines/test cycles for each 1 percent biodiesel in a blend.

Composite Soy Impact on NOx at Higher Blend Levels

- Including all data through B100 gives the greatest diversity in sources, blends and feedstock.
- Result:
  - $R^2 = 0.9990$ (dominated by the dummy variables that represent the differing NOx emission levels among engines and test cycles)
  - Regression coefficient b for the BioPct effect has value: $+0.00220 \pm 0.00016$. The statistical significance is $p < 0.0001$ (highly significant).
- The equivalent percentage NOx increase is **+1.10%** at the B5 level
  - Or, 0.22% for each 1 percent biodiesel in a blend.
- This result is nearly the same as given by the regression analysis of the individual runs dataset through B5.

Composite Soy Impact on NOx at Higher Blend Levels

- The composite soy impact is also robust with respect to data selection (see Figure 1)
- Different choices for the dataset (test runs versus emissions averages) and the highest blend level to include (through B10, through B20, through B50, and through B100) give different results for the NOx slope with BioPct blending level. However, the results all fall within the errors bars of the estimate based on the B5 test runs alone.
- This indicates that the NOx response is linear with BioPct through high blend levels and that systematic differences among the studies are not large.
- Statistical tests show no difference among soy, UCO, and canola in their NOx impact. However, the UCO and canola samples are small and capable of detecting only large differences.

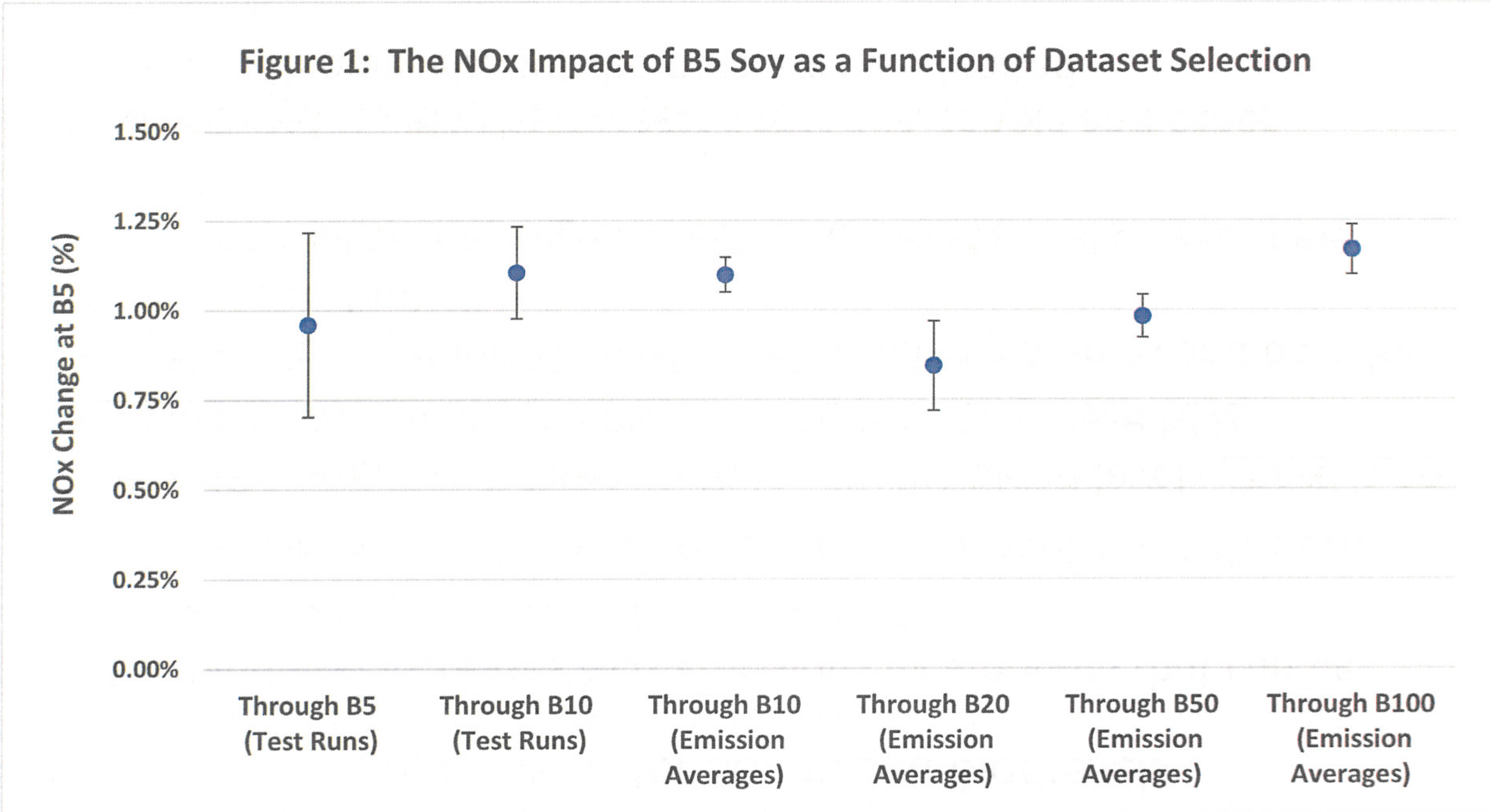


Figure 1: The NOx Impact of B5 Soy as a Function of Dataset Selection
NOx Change at B5 (%)
1.50%
1.25%
1.00%
0.75%
0.50%
0.25%
0.00%
Through B5 (Test Runs)
Through B10 (Test Runs)
Through B10 (Emission Averages)
Through B20 (Emission Averages)
Through B50 (Emission Averages)
Through B100 (Emission Averages)

Conclusions for Soy-based Biodiesels

- Soy biodiesel increases NOx emissions by amounts that can be estimated with good statistical confidence.
- NOx will increase ~1% on average at the B5 level and ~2% at B10.
- The NOx response is linear with the BioPct blend level. <u>There is no threshold level where soy biodiesel does not increase NOx.</u>
- This result is supported by all of the available studies and data (none disagree substantially)
  - Individual blends, engines and test cycles may still vary to some extent.
- NOx increases may be expected for UCO, canola and other vegetable biodiesels, but the data are very limited.

NOx Impact of Animal-based Biodiesel

- The literature on animal-based blends is much smaller than for soy (see Table 3):
  - Only 4 studies (3 UCR studies sponsored by ARB)
  - Only 4 animal feedstocks in total
  - Conducted primarily on engines at UCR CE-CERT (only 6 test replications conducted elsewhere)
  - A variety of test cycles
- The 3 UCR studies dominate the animal-blend dataset to a greater extent than for soy:
  - Counting test replications, the UCR studies account for 97.5% of the dataset. All of the data at the B5 and B10 levels comes from the UCR studies.
- There are notable differences among the four studies on the size of the NOx impact and its relationship to BioPct.
  - *The available studies may not permit a reliable, general understanding of the impacts of animal-based feedstocks.*

Table 3: Scope of Emissions Testing for Animal-based Biodiesels

	McCormick 2005	Durbin 2011	Durbin 2013A	Karavalakis 2014
Biodiesel Feedstock	Animal #1	Animal #2	Animal #3	Animal #4
Blend Levels Tested	B20	B5, B20, B50, B100	B5	B5, B10
Engines Tested	2 on-road	3 on-road, 1 off-road	1 on-road	1 on-road
Test Cycles	FTP	FTP, UDDS, 50 mph, ISO 8178	FTP	FTP, SET, UDDS
Test Replications on Biodiesel	6	126	26	80
NOx Increase Observed?				
At / Below B10	–	Yes	No	No
Above B10	Yes	Yes	–	–

NOx Impact of B5 Animal Compared to CARB Diesel

- The T-Test is the most direct method to assess differences in mean NOx levels between B5 and CARB Diesel for individual engines.
- The McCormick 2005 study tested the Animal #1 feedstock at the B20 level and found a statistically significant increase in NOx, but did not test at the B5 level considered here.
- Table 4 reports this comparison for animal-based biodiesels. Results:
  - Animal #2 *increases* NOx in 2 of 3 engines. The increase is highly significant for 1 engine.
  - Animal #3 *decreases* NOx in one engine. The increase is statistically significant at the p=0.05 level. The blend was certified as NOx neutral at B5.
  - Animal #4 *increases* NOx in 3 of 6 cases and *decreases* NOx in the other 3 cases. The results are inconclusive as none of the changes are statistically significant. The blend may or may not change NOx.

T-Test for NOx Impact of B5 Animal Blends

Source	Feedstock ID	Engine	Cycle	NReps (total)	ΔNOx (gm/bhp-hr)	Prob > |t|	Statistical Significance
Durbin 2011	Animal #2	2006 Cummins ISM	FTP	12	+ 0.0067	p = 0.29	Not Significant
Durbin 2011	**Animal #2**	**2007 MBE4000**	**FTP**	**12**	+ 0.0168	p < 0.001	Highly Significant
Durbin 2011	Animal #2	2009 John Deere	ISO 8178	13	- 0.0342	p = 0.21	Not Significant
Durbin 2013A	**Animal #3**	**2006 Cummins ISM**	**FTP**	**52**	- 0.0072	p = 0.054	Significant
Karavalakis 2014	Animal #4	1991 DDC 60	FTP	16	+ 0.0031	p = 0.81	Not Significant
Karavalakis 2014	Animal #4	1991 DDC 60	SET	8	+ 0.0095	p = 0.77	Not Significant
Karavalakis 2014	Animal #4	1991 DDC 60	UDDS	16	- 0.1119	p = 0.31	Not Significant
Karavalakis 2014	Animal #4	2006 Cummins ISM	FTP	16	- 0.0073	p = 0.61	Not Significant
Karavalakis 2014	Animal #4	2006 Cummins ISM	SET	8	+ 0.0025	p = 0.90	Not Significant
Karavalakis 2014	Animal #4	2006 Cummins ISM	UDDS	16	- 0.0993	P = 0.16	Not Significant

Notes: The t-test analysis uses the ARB dataset of individual test runs ("raw data")

NOx Impact of Animal Biodiesels Through B10

- Only Karavalakis 2014 reports testing on B5 <u>and</u> B10 to support an assessment of NOx impacts through B10. This involves a single animal feedstock (Animal #4) and cannot be generalized to a wider range of biodiesels.
- The analysis is based on Regression Model 2 which is linear in BioPct.
- For Animal #4, the NOx trend with BioPct is relatively flat through B10 (see Table 5).
  - The NOx slope is positive (NOx is increased) in 3 of 6 cases and negative (NOx is decreased) in 3 of 6 cases.
  - One slope (1991 DDC 60 on SET cycle) is positive and statistically significant.
- Conclusion: Animal #4 increases NOx through B10 in at least one engine and test cycle.

Table 5. NOx Trend Results Through B10 for An Animal Feedstock

Regression Model 2: $\log NOx = a + \sum_{i=2}^{N} \delta_i + b \cdot BioPct$

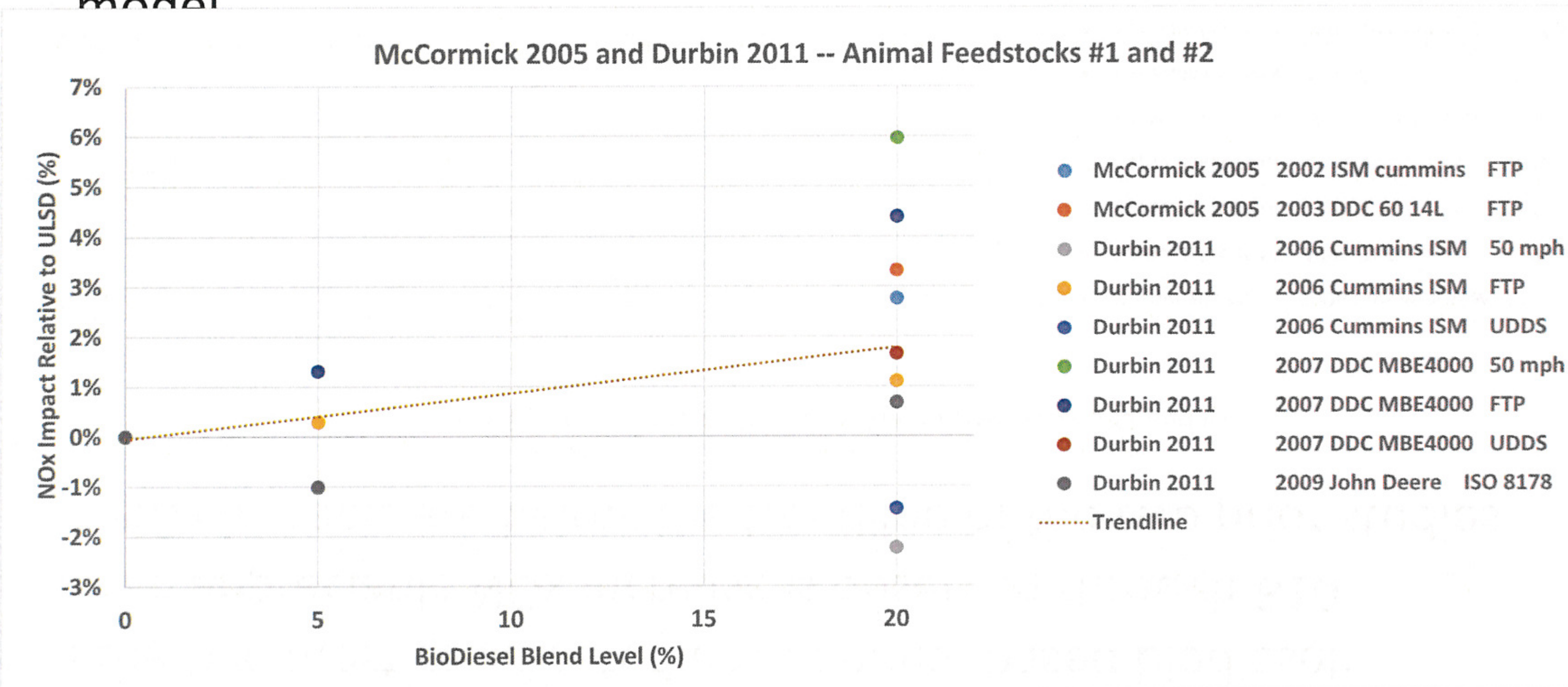
Source	Feedstock ID	Engine	Cycle	BioPct Slope (B) (gm/bhp-hr per % Biodiesel)	Prob > |t|	Statistical Significance
Karavalakis 2014	Animal #4	1991 DDC 60	FTP	+ 0.0012	p = 0.33	Not Significant
Karavalakis 2014	Animal #4	1991 DDC 60	SET	+ 0.0069	p = 0.05	Significant
Karavalakis 2014	Animal #4	1991 DDC 60	UDDS	- 0.0051	p = 0.67	Not Significant
Karavalakis 2014	Animal #4	2006 Cummins ISM	FTP	- 0.0006	p = 0.59	Not Significant
Karavalakis 2014	Animal #4	2006 Cummins ISM	SET	+ 0.0006	p = 0.77	Not Significant
Karavalakis 2014	Animal #4	2006 Cummins ISM	UDDS	- 0.0088	p = 0.19	Not Significant

Note: The regression analysis uses the ARB dataset of individual test runs ("raw data").

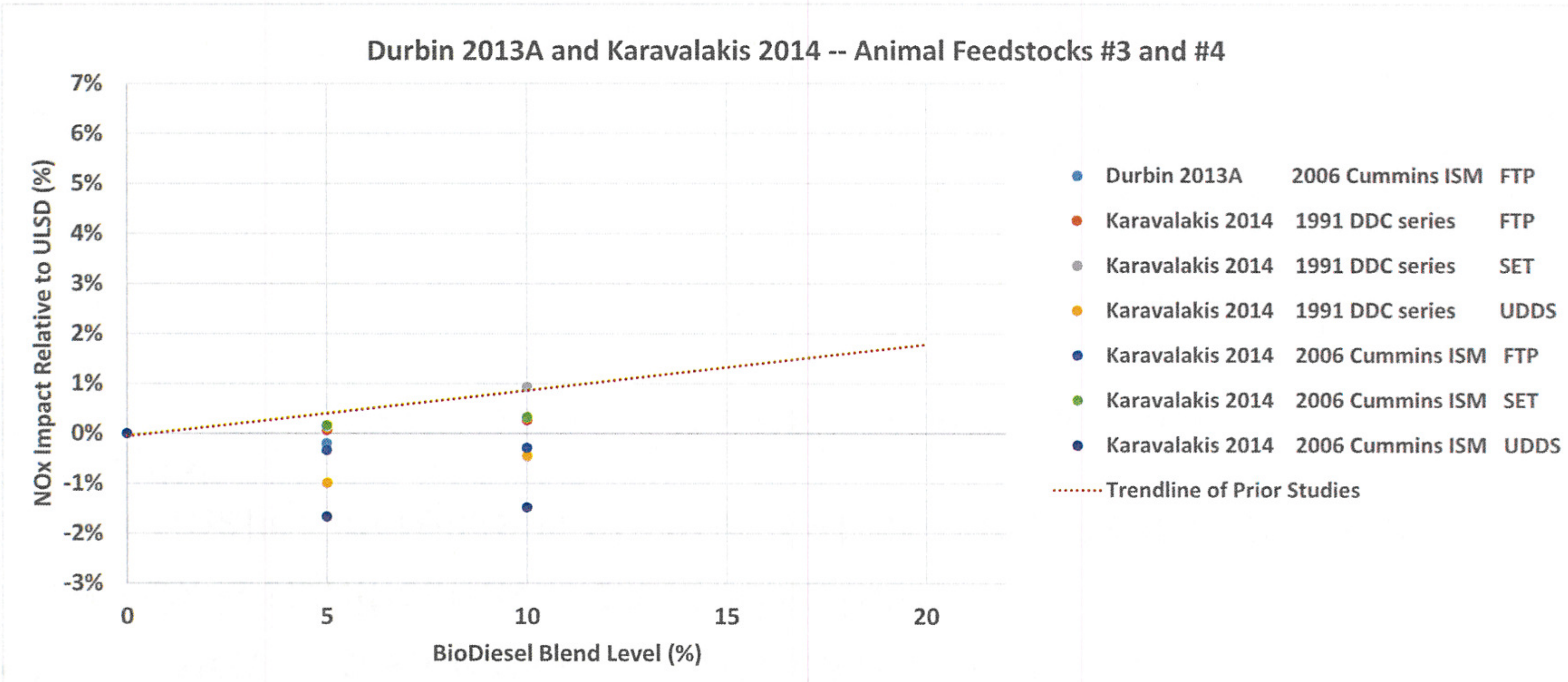
NOx Impact of Animal Biodiesels Through B20

- To include more sources, blends and feedstocks, we shift to analysis of the literature dataset. NOx measurements are reported as averages on CARB Diesel and for each BioPct blend level tested.
- Only graphical analysis is presented through B20 because most sources tested only two blend levels per feedstock (so regression analysis is not useful).
- As the following charts show, the latest ARB studies show substantially lower NOx impacts than the earlier studies and no clear trend with BioPct blend level.
- Each study tested a different animal feedstock. We interpret these results as indicating that the <u>NOx impact can vary in important ways from one animal feedstock to another</u>.

- In the first two studies of animal-based biodiesel:
  - NOx is significantly increased at B20
  - A smaller increase is observed at B5 consistent with a linear model



- In the two most-recent studies of animal-based biodiesel:
  - No appreciable NOx increase is observed through B10
  - NOx impacts are below the trendline of the two prior studies



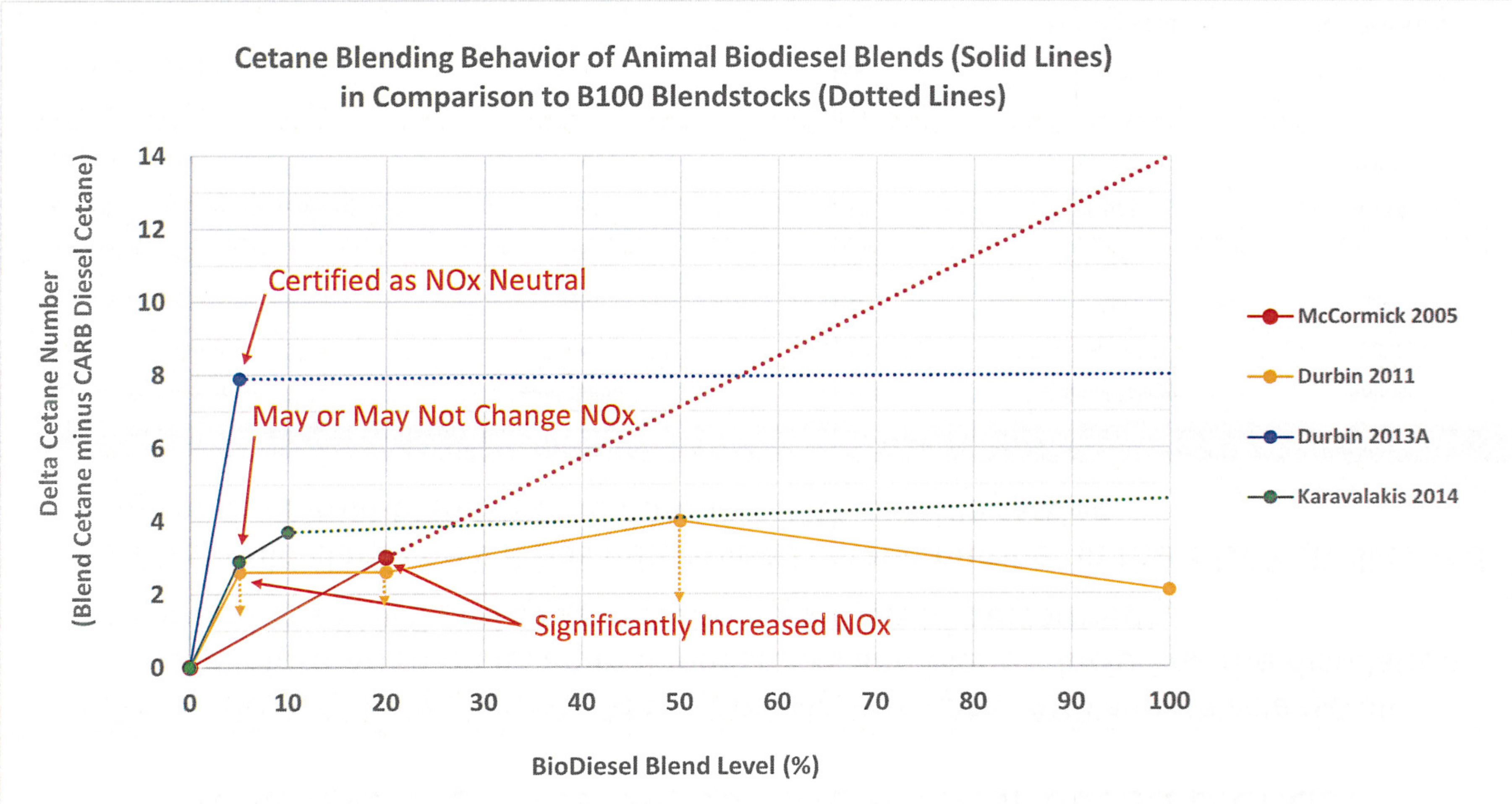
What is the Composite NOx Impact for Animal-based Biodiesel?

- It depends on the <u>blend level range that is considered</u>
- This choice determines the influence given to each study and animal feedstock in the estimate.
- Including higher blending levels (more studies, more feedstocks) gives a better ability to resolve the slope with blend level and may yield a more general result.
- Including only lower blending levels reduces the number of feedstocks and blends considered. Results may not be general.

	Highest Blend Level Considered			
	B10	B20	B50	B100
Weight Given to Studies				
McCormick 2005	0%	2%	2%	2%
Durbin 2011	15%	59%	63%	67%
Durbin 2013A	21%	10%	9%	8%
Karavalakis 2014	65%	30%	27%	24%
Composite BioPct Slope				
ΔNOx (%) per 1% Biodiesel	- 0.03%	+ 0.05%	+ 0.29%	+ 0.16%
Standard Error of Estimate	± 0.03%	± 0.03%	± 0.09%	± 0.06%
Prob > |t|	p = 0.35	p = 0.15	p < 0.01	p = 0.01
Statistically Significant?	No	No	Yes	Yes

A Better Understanding of Cetane Effects is Needed

- The higher cetane number of animal feedstocks is a likely reason that animal-based blends have lower NOx impacts than soy-based blends.
- Cetane is complicated and may or may not blend linearly with volume.
- The following chart shows that all of the UCR animal-based blends have a large cetane benefit, achieving most (or all) of the B100 cetane at low blend levels.
  - Lab differences could be involved. Durbin 2011 measured cetane for the blends at CE-CERT, while cetane for CARB Diesel and B100 was determined by an outside lab.
  - The large cetane boosts at low blend levels help to offset NOx increases.
- The McCormick 2005 animal feedstock behaves differently, with cetane blending linearly with BioPct in the B20 blend. The cetane benefit of this feedstock expected at the B5 level is small compared to the three UCR feedstocks.
- *What is the evidence that the rapid cetane boost observed for the UCR blends is real and representative of the cetane behavior of animal feedstocks available in the California market?*


Cetane Blending Behavior of Animal Biodiesel Blends (Solid Lines)
in Comparison to B100 Blendstocks (Dotted Lines)
Delta Cetane Number
(Blend Cetane minus CARB Diesel Cetane)
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
BioDiesel Blend Level (%)
Certified as NOx Neutral
May or May Not Change NOx
Significantly Increased NOx
McCormick 2005
Durbin 2011
Durbin 2013A
Karavalakis 2014

What Do We Know About the Animal-based blends?

- Not enough to fully understand the emissions results. ARB should release all available information on its animal feedstocks and blends, including the distillation curves and the FAME and oxygen content analysis (if performed).
- ARB should clarify how it has determined cetane number in the 3 UCR studies and confirm its animal-blend cetane numbers with outside testing.

	McCormick 2005	Durbin 2011	Durbin 2013A	Karavalakis 2014
Feedstock Description	Beef Tallow	Animal	Animal Tallow	Animal
B100 Cetane Number	65	57.9	61.1	58.0
Flash Point (°C)	159	164	144	165
Cloud Point (°C)	14	13	15	–
Kinematic Viscosity 40C (mm^2/s)	4.71	4.41	4.691	4.714
Specific Gravity	0.8754	–	0.8750	0.875
API Gravity	–	28.5	30.2	30.3
Distillation T90 (°C)	351	348	352	Not Reported
Iodine Number	56	Not Reported	Not Reported	Not Reported

Conclusions on NOx Impact of Animal-based Biodiesel Blends

- Animal-based biodiesels have smaller NOx impacts than soy-based blends. The tendency of animal feedstocks to increase cetane is a likely reason.
- The animal-blends dataset is much more limited than for soy, with only four different feedstocks examined in the entire literature.
- There is disagreement among the studies on the NOx impact of B5 animal blends:
  - One B5 blend has significantly increased NOx on one engine and test cycle.
  - One B5 blend has been certified as NOx neutral on one engine and test cycle.
  - Other B5 blends may or may not increase NOx depending on engine and test cycle
- We need to understand the cetane behavior in the UCR blends and what is representative of animal biodiesels in California before more general conclusions can be drawn for animal-based blends.

The Influence of Cetane on Biodiesel NOx Impacts

Cetane is a Key Driver of the NOx Impact for Biodiesel

- This section presents an analysis that demonstrates that soy- and animal-based blends are not categorically different once their differing effect on blend cetane is accounted for.
  - Soy-based feedstocks have more unsaturated carbon bonds and tend to reduce cetane below that of CARB Diesel, although some soy and other vegetable feedstocks can increase cetane.
  - Animal-based feedstocks are more highly saturated and tend to increase cetane above that of CARB Diesel in most cases.
- When a cetane term is added, soy- and animal-based blends can be represented by the same model.
- The preliminary analysis indicates a method of predicting which biodiesel blends will have the greatest impact on NOx emissions.

Cetane-based Model of the Biodiesel NOx Impact

- The analysis uses the complete literature dataset – all blends at blending levels through B20 – in a modified regression analysis.
- Regression Model 3 is fit using emission averages weighted by the number of replications on each blend:

$$\log NOx = a + \sum_{i=2}^{N} \delta_i + b \cdot BioPct + c \cdot \Delta Cetane$$

where:

- Coefficients a and δ_i represent the average log *NOx* emission level on CARB Diesel for each engine/test cycle combination. (These values are not reported in the summary of results that follows.)
- BioPct is the blend level (percentage biodiesel in the blend). CARB Diesel is BioPct = 0;

  B5 is BioPct = 5.
- ΔCetane is the change in cetane number of the blend compared CARB Diesel
- Coefficient b gives the composite NOx impact across engines/test cycles for each 1 percent biodiesel in a blend at constant cetane (i.e., ΔCetane = 0).
- Coefficient c gives an adjustment to NOx emissions in proportion to ΔCetane.

Result for Cetane-based Model of Biodiesel NOx Impacts

- Result: $R^2 = 0.9948$ (dominated by the dummy variables that represent the differing NOx emission levels among engines and test cycles)

Coefficient	Estimate	Prob > |t|	Statistical Significance
b	+ 0.00156	$p < 0.0001$	Highly Significant
c	- 0.00303	$p < 0.0001$	Highly Significant

- The NOx increase is 0.16% for each 1 percent biodiesel in a blend, or 0.8% for B5 <u>at constant cetane</u>.
  - Soy blends have an additional, adverse cetane effect on average that increases the NOx impact to ~1%.
  - Animal blends tend to increase Cetane, so have reduced NOx impacts in comparison.

Result for Cetane-based Model of Biodiesel NOx Impacts

- The c coefficient estimates that +5 Cetane Numbers will decrease NOx emissions by 1.5%.
  - Other work* also finds a 1.5% NOx reduction for +5 Cetane Numbers in base blends with Cetane levels of ~50.
- An increase of $-b/c = 0.5$ Cetane Numbers is needed to offset the NOx increase expected from each 1% biodiesel added. For B5, an increase of 2.5 Cetane numbers is required to offset the NOx increase.
- Statistical tests of the residuals indicate that the model explains all of the observed differences among biodiesel types (animal, soy, UCO, canola) and among studies.

* *The Effect of Cetane Number Increase Due to Additives on NOx Emissions from Heavy-Duty Highway Engines.* EPA420-R-03-002. February 2004. Figure IV.A.-1.

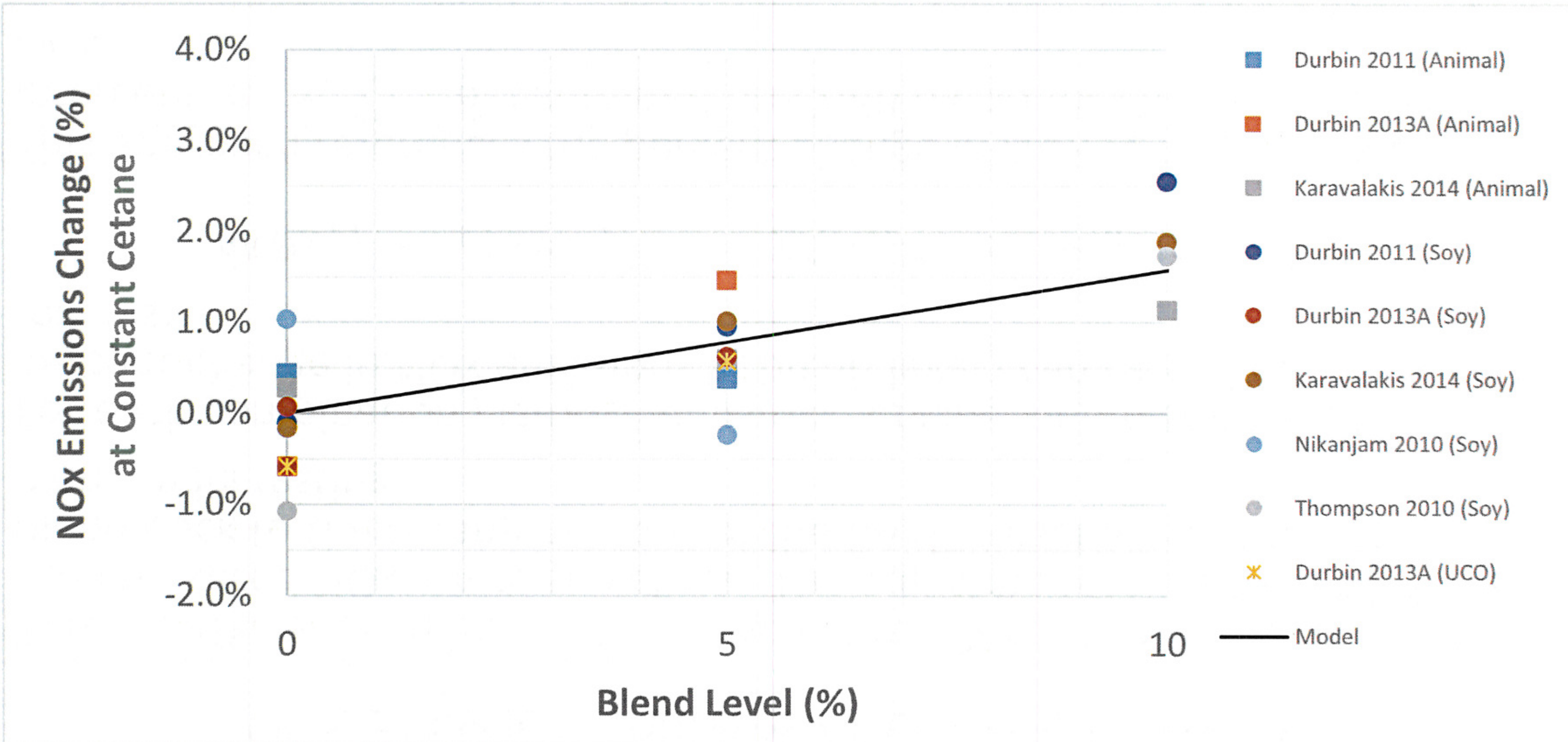
NOx Emission Changes At Constant Cetane

- The *c* coefficient can be used to remove the effect of cetane changes from the measured NOx emission values. The adjustment takes each biodiesel blend back to the cetane number of the CARB diesel used as the base blend in its testing.
- For each combination *i* (study, feedstock, engine, and test cycle), the percent change in NOx emissions at blend level *j* can be estimated as follows:

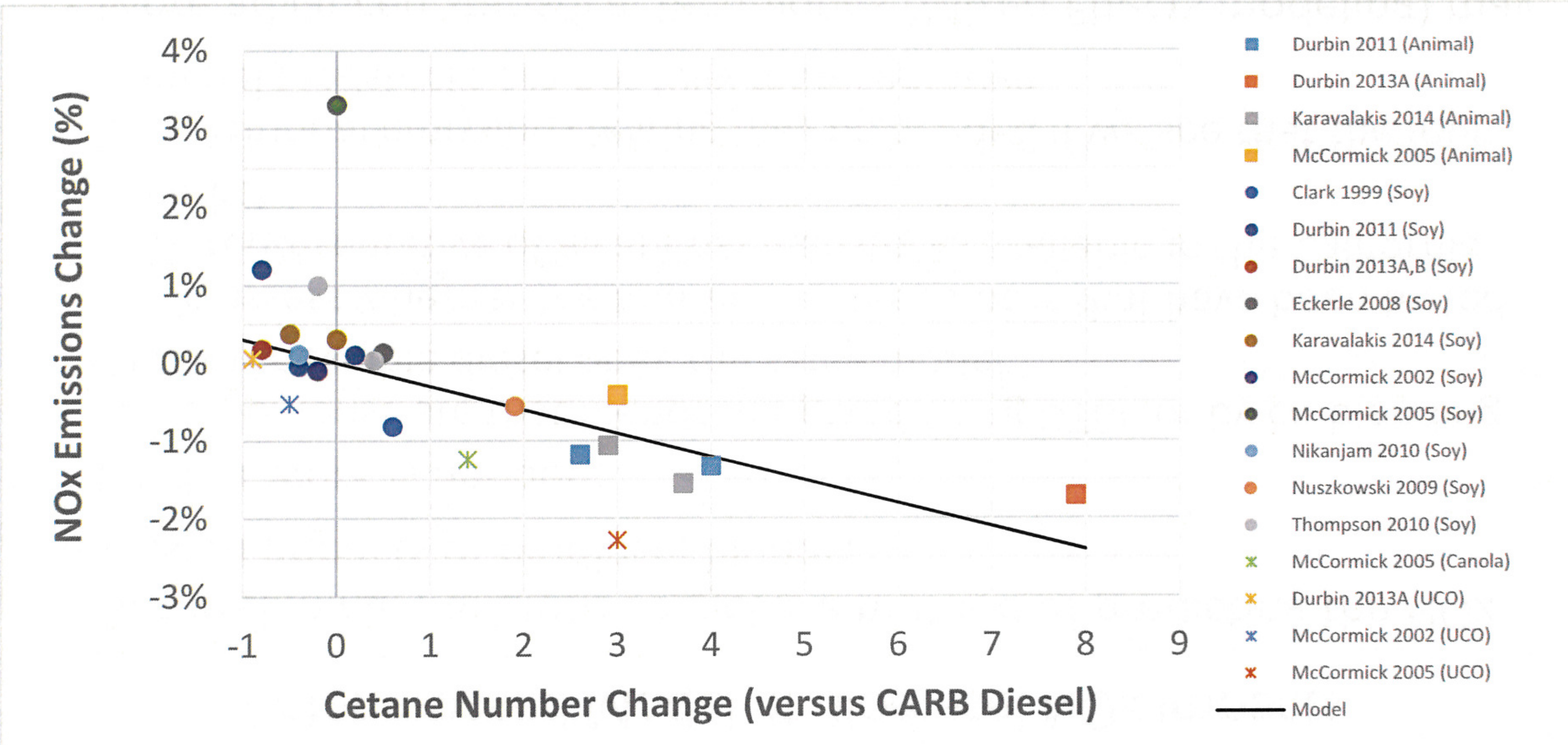
$$\Delta NOx_{i,j} = \exp\left[\ln NOx_{i,j} - (a_i + \sum_{i=2}^{N} \delta_i) - c \cdot \Delta Cetane_i\right] - 1$$

- This approach references the percent change in NOx to the emission intercept $a_i + \sum_{i=2}^{N} \delta_i$ estimated on CARB diesel for each engine/test cycle.
- Average percentage changes for each study, feedstock, engine, test cycle, and blend level are then plotted in the following figure.

There is no detectable difference among feedstock types when NOx emission changes are adjusted to constant Cetane Number



The Response of NOx to Cetane Number is the Same for Soy- and Animal-based Biodiesel Blends (When Adjusted for Blend Level)



Cetane-based Model of Biodiesel NOx Impacts

- Our preliminary analysis suggests a method of predicting the NOx emission impacts of biodiesel blends.
- Further work is needed:
  - To demonstrate that blends mitigated using DTBP or by co-blending with renewable diesel obey the same model
  - To assess whether the four animal feedstocks that have been tested are representative of all animal feedstocks available in the California market.
  - Additional emissions testing may be needed if we see that the four animal feedstocks are not fully representative.
- More advanced statistical techniques (Mixed Effects modeling) may also be needed, as used in the Predictive Model for gasoline.

Some Implications for Biodiesel in California

- Soy- and animal-based blends are not categorically different fuels once their differing effect on blend Cetane is accounted for.
- There is no threshold blend level where biodiesel fuels as a group do not increase NOx, whether soy- or animal-based.
- Soy-based blends clearly and significantly increase NOx by ~1% at B5 and by correspondingly larger amounts at higher blend levels. Soy blends <u>require</u> mitigation at all levels to offset increased NOx emissions.
- Animal-based blends are more complicated. The current research is limited and the evidence is mixed:
  - At least one B5 animal blend significantly increases NOx, while another has been certified as NOx neutral.
  - Other B5 animal blends may or may not increase NOx depending on their effect on Cetane Number (and possibly other factors).
- Animal-based blends cannot be assumed to have no impact on NOx emissions without an assessment of the impact of feedstock blending on Cetane number.

ATTACHMENT F

NOx Emission Impacts of Biodiesel Blends

1. Introduction

In the Alternative Diesel Fuels rulemaking, the California Air Resources Board (ARB) is attempting to create a regulatory framework that will permit biodiesel and other alternative diesel fuels to increase their penetration of the California market. Biodiesel is known to increase emissions of nitrogen oxides (NOx). NOx emissions are an important precursor to smog and have historically been subject to stringent emission standards and mitigation programs to prevent growth in emissions over time. A crucial issue with respect to biodiesel is how to "... safeguard against potential increases in oxides of nitrogen (NOx) emissions."[1]

In July 2014, ARB released two datasets that represent the fruit of their efforts to compile biodiesel NOx emissions test data available in the literature on heavy-duty truck (HDT) engines. This document and the companion file *"Biodiesel Emissions Analysis Technical Summary 102014.pdf"* present the results of a statistical analysis of the data sets released by ARB that was performed by Rincon Ranch Consulting at the request of Growth Energy.

This analysis focused on whether soy and animal blends will increase NOx at low blend levels. The following issues were examined:

- The NOx impacts of soy and animal blends at B5 and B10;
- The NOx emission differences observed among animal feedstocks and blends;
- For animal blends, the effect on NOx emissions of the Cetane Number (CN) change relative to base fuel that is caused by blending of the animal feedstock; and
- The development of a cetane-based model of the biodiesel NOx impacts of soy and animal blends.

The key results and conclusions of the study are summarized here. For additional information, the reader is directed to *"Biodiesel Emissions Analysis Technical Summary 102014.pdf"* which has been provided along with this document.

2. Data Used in the Analysis

As noted above, in July 2014, ARB released two datasets of NOx emissions data from testing of biodiesel blends in HDT engines. One file ("B5 & B10 Raw NOx Data") contains the subset of testing for B5 and B10 blends (soy and animal). The test data generated in the four ARB-sponsored UCR studies are present in the form of the individual test run measurements. Because test run information was not reported in their publications, the B5 soy data from Nikanjam 2010 and the B10 soy data from Thompson 2010 are present in the form of emission averages. No animal blends have been tested at the B5 or B10 levels except in the ARB-sponsored emissions testing. A second file ("2014 Biodiesel

[1] "Proposed Regulation on the Commercialization of New Alternative Diesel Fuels. Staff Report: Initial Statement of Reason." California Air Resources Board, Stationary Source Division, Alternative Fuels Branch. October 23, 2013. http://www.arb.ca.gov/regact/2013/adf2013/adf2013isor.pdf.

Literature Search Database") contains all of the biodiesel testing available in the literature through the B20 level (soy and animal), including ARB-sponsored testing and the literature search. The data are in the form of emission averages by engine, test cycle, feedstock type, and blend level.

For purposes of this analysis, the following information was added to the ARB datasets:

- The number of test replications for emissions averages for each study (estimated when the source did not report the number);
- The CN for CARB diesel, the biodiesel blends, and the biodiesel feedstocks; and
- Additional NOx emissions testing at the B50 and B100 levels (where available).

Appendix Table A presents a list of the studies included in the dataset and the author references used in citations here.

3. NOx Emissions from Soy Biodiesel Blends

Most past research on biodiesel emissions has focused on soy blends. As a result, the literature is relatively large and diverse. The dataset assembled by ARB is derived from 10 different studies, covers 13 different vegetable feedstocks (10 soy, 2 used cooking oil [UCO], 1 canola), and was conducted using 7 different test cycles on a wide variety of engines in different labs. Most of the data, in terms of number of data points, is derived from the three UCR studies (Durbin 2011, Durbin 2013B, and Karavalakis 2014) sponsored by ARB.

We subjected the soy dataset to a number of different analyses using different statistical techniques and selections of the data to ensure that the conclusions we drew were robust across analytical techniques and datasets. The statistical analysis included the T-Test for the difference in mean values (e.g., between B5 and CARB diesel) and linear regression analysis using several different models. The data subsets were selected to use either individual test runs or emission averages and to contain testing through maximum blend levels of B5, B10, B20, B50, and B100.

Our analyses show that there is a consensus among the studies on the NOx impact of soy biodiesel without regard to the specific analytical methods or data used. Soy biodiesel increases NOx emissions by amounts that can be estimated with good statistical confidence because of the large size of the available dataset. The key conclusions are as follows:

- Soy biodiesel increases NOx emissions by ~1% at B5 and ~2% at B10;
- NOx emissions increase in a linear fashion with increasing blend level to reach ~4% at B20 and proportionately larger values at higher blend levels; and
- There is no evidence in the data for a threshold level below which soy biodiesel does not increase NOx.

These conclusions are supported by all of the available studies and data. None of the studies disagree substantially, and while the results for individual blends, engines, and test cycles will vary to some extent, the evidence across a wide range of engines and test cycles is clear. NOx increases can be expected for UCO, canola, and other vegetable biodiesels, but the data are very limited and it is not possible to draw definitive conclusions for these blends.

4. NOx Emissions from Animal Biodiesel Blends

The literature on NOx emissions from animal blends is much smaller. It consists of only four studies, three of which (Durbin 2011, Durbin 2013A, and Karavalakis 2014) were sponsored by ARB. Except for the McCormick 2005 study, the emissions testing was conducted at the UCR CE-CERT lab. A variety of test cycles were used, but most of the testing was conducted on the hot-start FTP cycle. Table 1 presents a summary of the emissions studies for animal biodiesel.

Table 1. Scope of Emissions Testing for Animal Biodiesel

	McCormick 2005	Durbin 2011	Durbin 2013A	Karavalakis 2014
Biodiesel Feedstock	Animal #1	Animal #2	Animal #3	Animal #4
Blend Levels Tested	B20	B5, B20, B50, B100	B5	B5, B10
Engines Tested	2 on-road	3 on-road, 1 off-road	1 on-road	1 on-road
Test Cycles	FTP	FTP, UDDS, 50 mph, ISO 8178	FTP	FTP, SET, UDDS
Test Replications on Biodiesel	6	126	26	80
Is NOx Increase Observed?				
At / Below B10	–	Yes	**No**	**No**
Above B10	Yes	Yes	–	–

It is important to understand the limitations of this small dataset. Without the ARB-sponsored testing, we would have only the six test replications (individual runs) conducted in the McCormick 2005 study. While the three UCR studies accumulated 232 test replications, the work involved only three different animal feedstocks. Including the McCormick 2005 study, the entire literature on NOx emissions from animal biodiesel is based on only four different animal feedstocks. The small number is an important limitation because animal feedstocks are much less homogenous than soy due the greater variety possible in animal sources and compositions. Further, there are notable differences among the four studies as to whether animal biodiesel increases NOx at the B5 and B10 levels (as indicated by the red circles in the table).

As in the soy analysis, we subjected the animal biodiesel data to a number of different analyses using different statistical techniques and selections of the data to ensure that the conclusions we drew were robust. The T-Test is the most direct method to assess whether NOx emissions are higher at B5 compared to CARB diesel. Using the individual test run data available from the three UCR studies, we find the following for animal biodiesel at the B5 blend level:

- The animal feedstock used in Durbin 2011 increases NOx in 2 of 3 engines. The increase is highly significant[2] statistically for one engine.

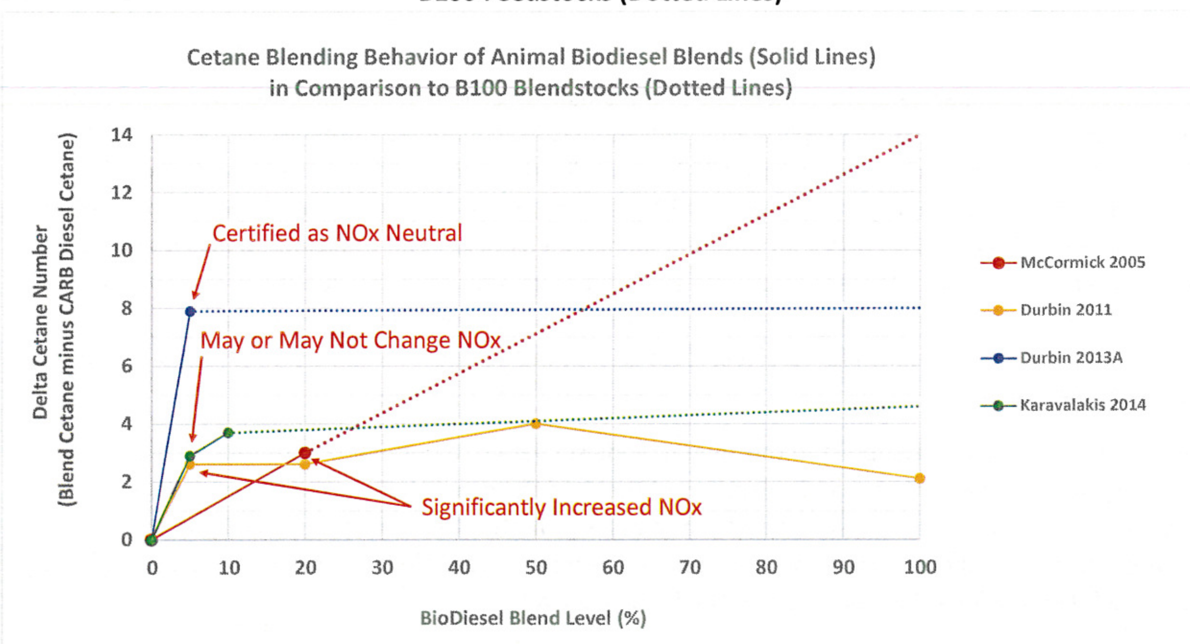
[2] The term "significant" is used in this report only to refer to statistical significance. When a result reaches the p=0.05 level, we can be 95 percent confident that it is real. In such case, and at smaller p values, the result is said to be statistically significant. "Significant" has been used by others to indicate that an emissions increase, even if real, is too small to warrant concern. For example, the Predictive Model for RFG will permit alternative gasoline formulations to increase NOx emissions by up to 0.05% and still be classified as emissions compliant. To our

- The animal feedstock used in Durbin 2013A decreases NOx in one engine. The decrease is statistically significant at the p=0.05 level and the blend was certified as NOx neutral at B5.
- The animal feedstock used in Karavalakis 2014 increases NOx in three of six cases and decreases NOx in the other three cases. None of the changes are statistically significant. The blend may or may not change NOx.

Contrary to Staff's assertion that no NOx increase occurs in B5 animal blends, it is clear that <u>some animal blends will significantly increase NOx emissions, while other animal blends will not</u>. The fundamental issue is then understanding what the NOx impact of a particular animal biodiesel blend will be.

The effect of feedstock blending on the CN of the resulting animal blend is the reason for the apparently discordant results among the studies. Figure 1 plots the four series of animal blends in the literature with the blend level on the horizontal axis and the change in blend CN (relative to CARB diesel) on the vertical axis. CN blended linearly to B20 for the McCormick feedstock, which showed a much smaller CN benefit than the feedstocks used by UCR – only three numbers at B20 (0.6 numbers at B5). In contrast, all three UCR animal blends achieve a large CN boost at low blending levels in which most or all of the CN benefit of the feedstock is achieved at B5.

Figure 1. Cetane Blending Behavior of Animal Blends (Solid Lines) Compared to B100 Feedstocks (Dotted Lines)



In Durbin 2011, the CNs for the blends are above that of the B100 feedstock. This result is probably caused by lab-to-lab differences (blend CN was determined at CE-CERT, while CN for CARB diesel and the

knowledge, ARB has not formulated a position on the level of NOx increase from alternative diesel fuel that is too small to warrant concern.

B100 feedstock were determined by an outside lab). The actual CN changes are surely lower than shown here – at or below +2 CNs.

The two animal feedstocks that caused statistically significant NOx increases have the smallest CN benefits: McCormick 2005 (red) at B20 and Durbin 2011 (yellow) at B5. The animal B5 blend that passed certification testing as NOx neutral in Durbin 2013A (blue) has the highest CN benefit, where it achieved the entire B100 CN at just 5 percent blending. The Karavalakis 2014 B5 blend (green) had an intermediate CN benefit and may or may not change NOx.

The blending behavior of the UCR blends is surprising in comparison to the McCormick study, and we find relatively little research on the CN blending behavior of animal feedstocks. All conclusions from this dataset will be influenced by the CN blending behavior of the specific animal feedstocks involved. For such conclusions to be reliable, we must be confident that the large CN boost reported for the UCR blends is both real and representative of all animal feedstocks in California. Also, only limited information is available on the sources and characteristics of the animal feedstocks.

To permit all parties to better understand the animal feedstocks that were tested, ARB should release all information that it has on the following:

- CNs (methods of determination and measured values) for the Durbin 2011 and other UCR studies;
- Physical and chemical properties of the animal feedstocks and biodiesel blends tested;
- The distribution of sources, characteristics, and properties in the population of animal feedstocks that are available for use in the California market; and
- How the specific animal feedstocks tested at UCR were selected, including any information that would demonstrate that the feedstock properties and their CN blending behavior are representative of the animal feedstock population available for use in California.

5. Development of a Cetane-based Model of NOx Impacts from Soy and Animal Biodiesel

The results presented above indicate the important role that CN plays in determining the NOx response for animal blends. Animal feedstocks tend to <u>increase</u> the CN of the blend above that of the CARB diesel and the CN change can be large at low blend levels. Soy feedstocks have generally adverse effects and tend to <u>decrease</u> the CN of the blend below that of the CARB diesel; for soy, the CN change at low blend levels can be smaller than the uncertainty in determining CN. The result of our work on a cetane-based model demonstrates that <u>soy and animal blends are not categorically different fuels once their differing effect on CN is accounted for</u>. Their NOx impacts can be represented by the same model as a function of blend level and the change in CN compared to CARB diesel.

The document that accompanies this report explains the development of the cetane-based model in some detail. In brief, it was developed using conventional linear regression analysis with log(NOx) emissions as the dependent variable. Intercept terms were included to represent the varying emission levels on CARB diesel for each combination of study, feedstock type, engine, and test cycle. A *b* coefficient was included to represent the change in NOx emissions for each 1 percent biodiesel in a blend <u>at constant CN</u>. A *c* coefficient was included to represent the change in NOx emissions for each 1 number change in CN compared to CARB diesel <u>at constant blend level</u>. Both soy and animal blends were included in the estimation, along with the small number of canola and UCO data points, at blend levels up to (and including) B20.

The model estimation shows that the *b* and *c* coefficients are highly significant statistically ($p < 0.0001$). The estimation results also show the following:

- The *b* coefficient has a value of +0.00156, which estimates that soy and animal biodiesel will increase NOx emissions by 0.16% for each 1 percent biodiesel at constant CN or by 0.8% at B5.
- The *c* coefficient estimates that +5 CNs will decrease NOx emissions by 1.5 percent at constant blend level. This result is completely consistent with earlier work[3] on the relationship between CN and NOx emissions in HDT engines, which also found that +5 CNs will decrease NOx emissions by 1.5 percent in base fuels with CN ~50.
- An increase of $-b/c = 0.5$ CNs is needed to offset the NOx increase expected from each 1% biodiesel added. For B5, an increase of 2.5 CNs is required to offset the expected NOx increase.

The results explain why soy and animal blends appear to be different fuels. Soy blends have an additional, adverse CN effect that increases their NOx impact to ~1% at B5. Animal blends will generally increase CN and that reduces their NOx impact to about one-half the soy level or less depending on the CN change caused by blending. The results also explain why some animal blends do not increase NOx emissions. If an animal feedstock increases CN by more than ~0.5 numbers for each 1% biodiesel blended, then the resulting fuel may not increase NOx emissions.

To demonstrate these conclusions, Figure 2 presents NOx emissions as a function of blend level for all fuels used to estimate the model once NOx emissions are adjusted for the CN change observed for each blend (animal blends are plotted as squares, soy blends as circles, and the non-soy vegetable blends as asterisks). For example, if an animal blend increased CN, then its NOx impact is increased as we return it to the base fuel CN. If a soy blend decreases CN, then its NOx impact is decreased as we return it to the base fuel CN. Once adjusted, percent changes in emissions are calculated. As seen in the figure, there is no discernable difference among feedstock types once CN changes are taken into account. Animal and soy blends scatter on both sides of the regression line, indicating that they obey the same blend level model.

Note the scatter of points around the regression line (which gives the "average" response). Some of the scatter is due simply to emissions measurement error. But other factors may be involved in determining the NOx impact for a given feedstock, including differences in the FAME composition and uncertainty in determining CN for the blends. If ARB were to adopt a predictive model to determine the CN improvement needed to mitigate NOx, it should use the model to evaluate a "worst case" feedstock, meaning a point near the upper end of the range at each blend level.

The most important conclusion of this work is that soy and animal biodiesel blends are not categorically different fuels. Their emissions effects are similar, but they show different NOx impacts because they have different effects on CN. Further, this work provides a potential answer to the problem that some animal blends will significantly increase NOx emissions, while other blends will not, by indicating what individual blends may do.

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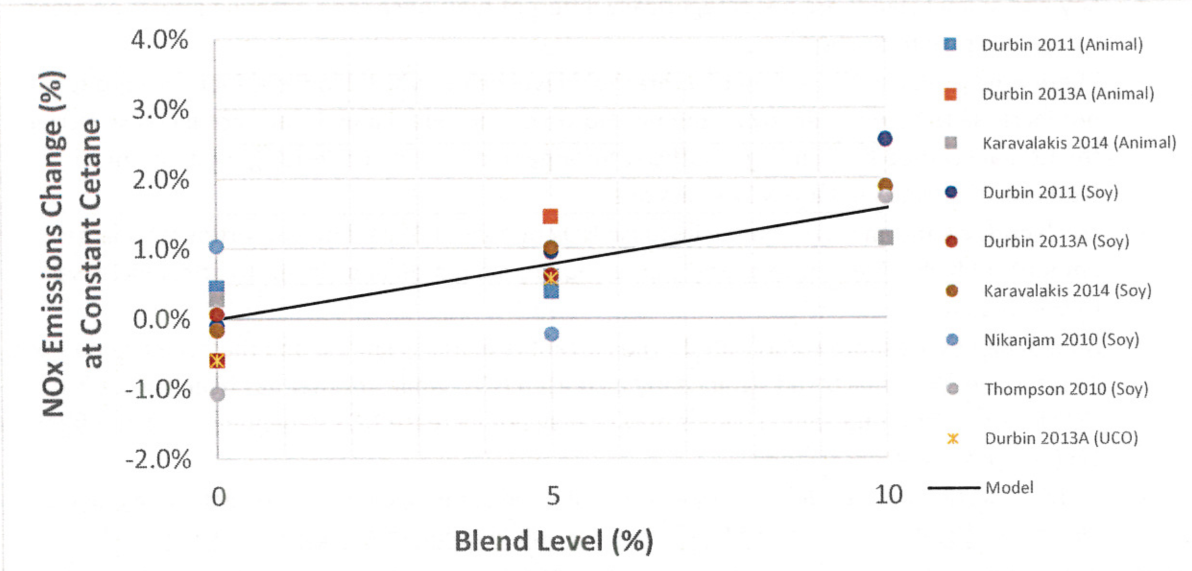
[3] *The Effect of Cetane Number Increase Due to Additives on NOx Emissions from Heavy-Duty Highway Engines.* EPA420-R-03-002. February 2004. Figure IV.A-1.

Figure 2. There Are No Detectable Differences Among Feedstock Types Once NOx Emissions Are Adjusted to Constant CN



Note: Animal blends are plotted as squares, soy blends as circles, and the non-soy vegetable blends as asterisks.

6. Summary and Conclusions

Based on the results summarized above, ARB must consider as part of the current rulemaking a regulatory structure in which the NOx impacts of soy and animal biodiesel are accounted for using a statistical model analogous to the Predictive Model for RFG. We see the cetane-based model presented here as a possible draft for a biodiesel predictive model, but further work is needed to:

- Demonstrate that blends mitigated using DTBP obey the same model; and
- Assess whether the four animal feedstocks that have been tested are representative of all animal feedstocks available in the California market.

Additional emissions testing may be needed if it is determined that the four animal feedstocks that have been tested are not representative of the population of animal feedstocks available for use in the California market.

Further, more advanced statistical techniques should be used as was done in developing the Predictive Model for California Reformulated gasoline. The dataset used here is highly unbalanced, meaning that there are varying numbers of data points for each combination of study, feedstock type, engine, and test cycle. In fact, only a fraction of all possible study/feedstock/engine/test cycle cells are represented by one or more data points. A technique known as Mixed Effects Modeling is appropriate in such cases and its use will assure that coefficient estimates are not biased by the unbalanced distribution of the data.

The key conclusions of this study are summarized below.

- Soy and animal blends are not categorically different fuels once their differing effects on blend CN are taken into account.
- There is no evidence in the data of a threshold level below which biodiesel fuels as a group do not increase NOx, whether soy or animal. However, individual blends may not increase NOx if the CN gain caused by blending is sufficiently large to offset the underlying tendency of all biodiesel blends to increase NOx emissions.
- Soy blends clearly and significantly increase NOx by ~1% at B5 and by proportionately larger amounts at higher blend levels. Soy blends require mitigation at all levels to offset increased NOx emissions.
- Animal blends are more complicated. The current research is limited and the evidence is mixed. At least one B5 animal blend significantly increased NOx, while another has been certified as NOx neutral. Other B5 animal blends may or may not increase NOx depending on their effect on CN (and possibly other factors).
- Staff's assertion that no NOx increase occurs at B5 in animal blends is incorrect. Some animal blends will significantly increase NOx emissions, while other animal blends will not.
- Animal blends cannot be assumed to have no impact on NOx emissions without a determination of the impact of feedstock blending on CN.

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APPENDIX TABLE A: REFERENCES TO LITERATURE

Author	Title	Feedstocks Studied	Blends Studied
Clark 1999	Transient Emissions Comparisons of Alternative Compression Ignition Fuel	Soy	B20
McCormick 2002	Fuel Additive and Blending Approaches to Reducing NOx Emissions from Biodiesel	Soy, UCO	B20
McCormick 2005	Regulated Emissions from Biodiesel Tested in Heavy-Duty Engines Meeting 2004 Emissions	Soy, Canola, Animal	B20
Eckerle 2008	Effects of Methyl Ester Biodiesel Blends on NOx Emissions	Soy	B20
Nuszkowski 2009	Evaluation of the NOx emissions from heavy duty diesel engines with the addition of cetane improvers.	Soy	B20
Nikanjam 2010	Performance and emissions of diesel and alternative diesel fuels	Soy	B5, B20
Thompson 2010	Neat fuel influence on biodiesel blend emissions	Soy	B10, B20
Durbin 2011	Biodiesel Characterization and NOx Mitigation Study	Soy, Animal	B5, B10, B20
Durbin 2013A	CARB B5 Preliminary and Certification Testing	Animal	B5
Durbin 2013B	CARB B20 Biodiesel Preliminary and Certification Testing	Soy, UCO	B20
Karavalakis 2014	CARB Comprehensive B5/B10 Biodiesel Blends Heavy-Duty Engine Dynamometer Testing	Soy, Animal	B5, B10