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June 22, 2015

VIA EMAIL & UNITED STATES MAIL

Secretary Matthew Rodriquez, Chair
Environmental Policy Council
1011 I Street
P.O. Box 2815
Sacramento, California 95812

Re: Comments of Growth Energy on Multimedia Evaluations of Biodiesel and Renewable Diesel

Dear Mr. Rodriquez:

I am writing on behalf of Growth Energy to provide comments on the Multimedia Evaluation of Biodiesel (the "MME"), which Growth Energy understands will be discussed at the California Environmental Policy Council's June 23, 2015, public hearing.

First, as explained in the declarations submitted by James M. Lyons on February 17, 2015, June 8, 2015, and June 19, 2015, concerning the Alternative Diesel Fuel regulation (the "ADF regulation"), and Low Carbon Fuel Standard (the "LCFS regulation"), the air quality analysis prepared by CARB staff is fatally flawed. (See, e.g., February 17, 2015, Decl. Lyons ¶¶ 12-15; *id.*, Attachment F; June 8, 2015, Decl. Lyons ¶¶ 6-12.)

Mr. Lyons' declarations also explain that the air quality analysis prepared by CARB staff in its Environmental Assessment for the ADF regulation and the LCFS regulation is different from that contained in the MME in several material respects. (See June 8, 2015, Decl. Lyons ¶¶ 13-15.)

Further, CARB did not provide several important documents, including analyses raising questions regarding the air quality analysis underlying the ADF regulation, to either the persons working on the MME, or the MME peer reviewers. Without these documents, the preparers of the MME, and the MME peer reviewers, are provided only a one-sided view of the regulations, and insufficient information to fully analyze the potential air quality impacts of the regulations. The documents CARB failed to disclose include, but are not limited to, (1) *NOx Emission Impacts of Biodiesel Blends*, Robert Crawford, Rincon Ranch Consulting (February 10, 2015); and (2) February 17, 2015, Declaration of James M. Lyons, with attachments, both of which are enclosed.

Due to the above issues, the Environmental Policy Council should not approve the MME at this time, and should instead require CARB to revise its air quality analysis to correct the existing flaws. The Environmental Policy Council should also require CARB to make all relevant analyses – not just those supporting CARB's position – available to both the preparers of the MME and the MME peer reviewers, prior to the Environmental Policy Council's consideration of the MME.

Respectfully submitted,

John P. Kinsey

Enclosures:

1. Declaration of James M. Lyons (June 19, 2015)

2. Declaration of James M. Lyons (June 8, 2015)

3. Declaration of James M. Lyons (February 17, 2015)

4. *NOx Emission Impacts of Biodiesel Blends*, Robert Crawford, Rincon Ranch Consulting (February 10, 2015)

5. *NOx Emissions Impact of Soy- and Animal-based Biodiesel Fuels: A Re-Analysis*, Robert Crawford, Rincon Ranch Consulting (December 10, 2013)

6. California Air Resources Board, Initial Statement of Reasons, ADF Regulation , Main Text (January 2, 2015)

7. California Air Resources Board, Initial Statement of Reasons, ADF Regulation, Appendix B [Technical Supporting Information] (January 2, 2015)

Attachment 1

STATE OF CALIFORNIA

BEFORE THE AIR RESOURCES BOARD

Declaration of James M. Lyons

I, James Michael Lyons, declare as follows:

1. I make this Declaration based upon my own personal knowledge and my familiarity with the matters recited herein. It is based on my experience of nearly 30 years as a regulator, consultant, and professional in the field of emissions and air pollution control. A copy of my résumé can be found in Attachment A.

2. I am a Senior Partner of Sierra Research, Inc., an environmental consulting firm located at 1801 J Street, Sacramento, California owned by Trinity Consultants, Inc. Sierra specializes in research and regulatory matters pertaining to air pollution control, and does work for both governmental and private industry 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 at the Mobile Source Division of the California Air Resources Board (CARB).

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, 2) assessment of the impacts of changes in fuel composition and alternative fuels on engine emissions including emissions of green-house gases, 3) analyses of the unintended consequences of regulatory actions, and 4) the feasibility of compliance with air quality regulations.

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, factors affecting emissions from diesel vehicles, evaporative emission control system design and function, as well as combustion chamber system design. While at Sierra I have acted as a consultant on automobile air pollution control matters for CARB and for the United States Environmental Protection Agency. 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.

5. This Declaration summarizes the results of my review of the CARB Notice of Public Availability of Modified Text and Availability of Additional Documents for the Proposed Re-Adoption of the Low Carbon Fuel Standard Regulation on the Commercialization of Alternative Diesel Fuels (the LCFS Regulation) dated June 4,

2015. I have performed this review as an independent expert for Growth Energy. If called upon to do so, I would testify in accord with the facts and opinions presented here.

6. Based on my review of the changes proposed to the LCFS regulation by CARB, the elimination of the multimedia evaluation provisions from the LCFS through the deletion of Section 95490 and related deletions in Sections 95481(a)(59) and 95488(c)(4)(G)6.d. creates the potential for significant adverse environmental impacts to occur as the result of the introduction of new lower carbon intensity fuels. I have participated in every aspect of the development of the LCFS regulation in which a member of the public was allowed by CARB to participate. This change to the proposed regulation could not reasonably have been anticipated, based on the notice of proposed rulemaking and the supporting materials made available in December 2014.

7. The discussion of the need for the multimedia evaluation provisions that CARB staff is now proposing to delete is summarized in both the current Initial Statement of Reasons (ISOR) for re-adoption of the LCFS regulation as well as the ISOR prepared in 2009 for the original LCFS regulation. The language relevant to the multimedia evaluation provisions in both the current and 2009 ISOR is virtually identical. With respect to why the multimedia evaluation provisions were needed in the LCFS, both the ISOR for the re-adoption of the LCFS regulation[1] and the 2009 ISOR[2] state that:

> *The LCFS regulation incorporates this principle as a pre-sale prohibition applied to fuels that are subject to an ARB specification that is modified or adopted after adoption of the LCFS regulation. In such cases, regulated parties would be prohibited from selling the affected fuels in California to comply with the LCFS requirements until a multimedia evaluation is approved for those fuels pursuant to H&S §43830.8.*

Elimination of the multimedia evaluation provisions from the LCFS regulation as now proposed by CARB staff would permit fuel suppliers to sell new fuels in California in order to try to comply with the LCFS without ensuring that adverse environmental impacts associated with their use have been identified and properly mitigated. Such new fuels could include gasoline-butanol blends, alternative diesel fuels other than biodiesel and renewable diesel, and renewable natural gas fuels that fail to comply with CARB's existing natural gas fuel specifications. In addition, these potential impacts of the LCFS regulation were not considered in the Environmental Analysis prepared for the LCFS and ADF regulations.

8. There are several ways in which new fuels which could lead to adverse environmental impacts could be sold in California before the approval of a multimedia

1. [1] Page III-64

[2] Page V-32

evaluation pursuant to H&S §43830.8. The first of these is if the California Division of Measurement Standards (CDMS) rather than CARB adopts fuel specifications allowing the use of the new fuel. In the past, new fuels have been allowed in California through specifications enacted by CDMS that have not been required to undergo multimedia evaluation pursuant to H&S §43830.8. Biodiesel is one such fuel that has created adverse environmental impacts. Based on CARB staff estimates, in 2014, biodiesel use for compliance with the LCFS regulation allowed by CARB[3] without an approved multimedia evaluation pursuant to H&S §43830.8 resulted in increased NOx emissions of 1.2 tons per day statewide.[4] Increased NOx emissions due to the use of biodiesel for purposes of LCFS compliance have occurred since the inception of the LCFS program as a result of CARB's failure to adopt fuel specifications and complete the multimedia evaluation required pursuant to H&S §43830.8 despite having committing to do so as early as 2009.[5] Elimination of the requirements for approval of a multimedia evaluation before allowing new fuels to be sold for purposes of LCFS approval would allow other new fuels to be sold in California that, like biodiesel, create adverse environmental impacts before those impacts have been identified through the multimedia evaluation process. These potential environmental impacts created by the LCFS as a result the elimination of the LCFS multimedia evaluation requirements were not considered in the Environmental Assessment.

9. That the increases in NOx emissions resulting from biodiesel use in California without an approved multimedia evaluation were significant can be seen through a comparison of the criteria used to assess air quality impacts in areas of California outside the South Coast and San Joaquin Air Basins and the increases in NOx emissions estimated to result from biodiesel use. Using the Sacramento Metropolitan Air Quality Management District as an example,[6] the significance threshold for NOx emissions projects subject to CEQA is 65 pounds per day or 0.0325 tons per day. The 0.0325 tons per day threshold can be compared to both the 1.2 ton per day increase in NOx emissions due to biodiesel use estimated by CARB staff for 2014 statewide. Clearly, elimination of the requirements for multimedia evaluation for new fuels sold for LCFS compliance could lead to similar, and therefore significant, unmitigated, increases in NOx emissions or significant and unmitigated increases in emissions of other pollutants.

10. Another way in which new fuels could create potential adverse environmental impacts if the multimedia evaluation requirements are deleted is through the

[3] See *http://www.arb.ca.gov/fuels/diesel/altdiesel/20111003biodiesel%20guidance.pdf*

[4] See Table 1 of *http://www.arb.ca.gov/regact/2015/adf2015/signedadfnotice.pdf*

[5] See page V-33 of *http://www.arb.ca.gov/regact/2009/lcfs09/lcfsisor1.pdf*

[6] See *http://airquality.org/ceqa/ceqaguideupdate.shtml*

Developmental Engine Fuel Variance Program operated by CDMS.[7] Again, the multimedia evaluation requirements of H&S §43830.8 that apply to fuels for which CARB adopts specifications would not apply in this case and adverse environmental impacts can occur. Allowing new fuels that are part of this program to be sold for purposes of LCFS compliance without having an approved multimedia evaluation would increase the likelihood that fuel producers would seek to use this program and the likelihood that new fuel that leads to unmitigated adverse environmental impacts would be used in California. These potential environmental impacts that the LCFS regulation could create as a result of the proposed elimination of the multimedia evaluation requirements were not considered in the Environmental Assessment.

11. In addition, the Alternative Diesel Fuel regulation proposed by CARB staff creates another way by which new fuels with potential adverse environmental impacts could be sold in California for purposes of LCFS compliance should the multimedia evaluation requirements be eliminated. Currently, fuels involved in Stage 1 or Stage 2 of the LCFS regulation are not required to have completed a multimedia evaluation and therefore could not be sold for purposes of LCFS compliance until they reach Stage 3, at which point completion of a multimedia evaluation and adoption of fuel specifications by CARB are required. Elimination of the current multimedia evaluation requirements from the LCFS regulation as now proposed by CARB staff, would allow fuels in Stage 1 and Stage 2 to be sold for purposes of LCFS compliance before the potential adverse environmental consequences have been assessed or mitigated. Again, these potential environmental impacts due to the LCFS were not considered in the Environmental Assessment.

12. In summary, retention of the current LCFS requirements that new fuels have received an approved multimedia evaluation pursuant to H&S §43830.8 before being allowed to be sold for purposes of LCFS compliance is the only way to ensure that the LCFS is not responsible for use of these new fuels creating potential adverse environmental impacts.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 19th day of June, 2015 at Sacramento, California.

JAMES M. LYONS

[7] See *http://www.cdfa.ca.gov/dms/programs/petroleum/DevelopmentalFuels/RelevantLawsInstructionsChecklist.pdf*

Attachment 2

STATE OF CALIFORNIA

BEFORE THE AIR RESOURCES BOARD

Declaration of James M. Lyons

I, James Michael Lyons, declare as follows:

1. I make this Declaration based upon my own personal knowledge and my familiarity with the matters recited herein. It is based on my experience of nearly 30 years as a regulator, consultant, and professional in the field of emissions and air pollution control. A copy of my résumé can be found in Attachment A.

2. I am a Senior Partner of Sierra Research, Inc., an environmental consulting firm located at 1801 J Street, Sacramento, California owned by Trinity Consultants, Inc. Sierra specializes in research and regulatory matters pertaining to air pollution control, and does work for both governmental and private industry 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 at the Mobile Source Division of the California Air Resources Board (CARB).

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, 2) assessment of the impacts of changes in fuel composition and alternative fuels on engine emissions including emissions of green-house gases, 3) analyses of the unintended consequences of regulatory actions, and 4) the feasibility of compliance with air quality regulations.

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, factors affecting emissions from diesel vehicles, evaporative emission control system design and function, as well as combustion chamber system design. While at Sierra I have acted as a consultant on automobile air pollution control matters for CARB and for the United States Environmental Protection Agency. 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.

5. This Declaration summarizes the results of my review of the CARB Notice of Public Availability of Modified Text and Availability of Additional Documents for the Proposed Regulation on the Commercialization of Alternative Diesel Fuels (the ADF Regulation) dated May 22, 2015, and the California Environmental Protection Agency's Staff Report, Multi-Media Evaluation of Biodiesel, Prepared by the Multimedia Working

Group and dated May 2015, which has been added by CARB to the ADF rulemaking file. I have performed this critical review as an independent expert for Growth Energy. If called upon to do so, I would testify in accord with the facts and opinions presented here.

6. Based on my review of the changes proposed to the ADF regulation by CARB, the new exemption from mitigation requirements for B6 to B20 fuels provided through Section 2293(a)(5)(C) creates the potential for significant increases in NOx emissions from vehicles operating in areas outside the South Coast or San Joaquin Valley Air Basins. I have participated in every aspect of the development of the ADF regulation in which a member of the public was allowed by CARB to participate. The new exemption could not reasonably have been anticipated, based on the notice of proposed rulemaking and the supporting materials made available in December 2014.

7. CARB staff agrees on page 11 of the notice that the new exemption could result in increased NOx emissions. However, CARB staff claims on pages 11 to 13 of the notice that the agency has conducted "additional analysis" of NOx emissions related to a number of new issues, including the new exemption that will be added to the ADF Regulation record, and concluded that the overall impact of the ADF regulation on NOx emissions will be smaller than it originally estimated. Unfortunately, CARB has failed to provide the detailed information required for public review and comment. As a result, it was not possible for me to review the data and assumptions used by CARB staff, nor to reach a conclusion about the accuracy of the analysis that was purported to have been performed or the conclusions drawn from the analysis by CARB.

8. The notice claims, based on undisclosed "additional analysis," that increased emissions due to the new exemption will be mitigated on a statewide basis averaged over an entire year. Even assuming the "additional analysis" is correct, higher NOx emissions could occur due to the new exemption in areas outside the South Coast or San Joaquin Valley Air Basins which are not in attainment with federal and state ambient air quality standards for ozone. Although the South Coast and San Joaquin Valley Air Basins experience the highest ozone levels in the state, there are many other areas in non-attainment of the federal[1] and state[2] standards where increased NOx emissions could create adverse impacts on air quality.

9. CARB should be required to provide the necessary data to perform a careful assessment. Increased NOx emissions resulting from the new exemption could potentially be significant. This can be seen through a comparison of the criteria used to assess air quality impacts in areas of California outside the South Coast and San Joaquin Air Basins and the increases in NOx emissions estimated to result from biodiesel use. Using the Sacramento Metropolitan Air Quality Management District as an example,[3] the significance threshold for NOx emissions projects subject to CEQA is 65 pounds per day

[1] See http://www.arb.ca.gov/desig/adm/2013/fed_o3.pdf

[2] See http://www.arb.ca.gov/desig/adm/2013/state_o3.pdf

[3] See http://airquality.org/ceqa/ceqaguideupdate.shtml

or 0.0325 tons per day. Using the data in the row labeled "Emission Inventory (Diesel TPD)" in Table 1 of the CARB Notice, 0.0325 tons per day can be compared to both the 0.95 ton per day estimate for 2016 statewide increases in NOx due to the ADF regulation in Table 1 of the notice, and also the difference between that value and the 1.27 ton per day value that was CARB's original estimate. Clearly, if the new exemption results in the use of even a small amount of biodiesel in the Sacramento area without mitigation, the increase in NOx emissions could be significant. Further, similar situations where significant increases in NOx emissions occur in other ozone non-attainment areas outside of the South Coast and San Joaquin Air Basins can be expected.

10. The only way to ensure that increased NOx emissions due to the new exemption would not potentially lead to adverse air quality impacts in areas where it is allowed, and thus mitigate impacts to NOx caused by the exemption, would be to require that appropriate amounts of renewable diesel biodiesel are used in the same location and at the same time as the biodiesel provided for under the new exemption. The only way to ensure this would happen would be to require blending of renewable diesel into the biodiesel blends allowed under the new exemption. There is no such requirement in the ADF regulation.

11. Another major problem with CARB's "Updated ADF NOx Analysis" presented in Table 1 of the Notice is that CARB has failed to address a key flaw in its analysis of the adverse environmental impacts of biodiesel. This flaw relates to using a baseline for determining the significance of increased NOx emissions from biodiesel use where 65 million gallons of biodiesel are already in-use to conclude, as stated on page 47 of the Initial Statement of Reasons for the ADF regulation, that:

> *The net impacts of the proposal reduce NOx impacts from biodiesel, even assuming increased biodiesel volumes over the subsequent years. Estimated impacts under the proposal are less than the baseline (current year) and will continue to decrease as NTDE use increases in California.*

The correct baseline that is used everywhere else in the ISOR, as well as in the Multi-Media Evaluation and by the Peer Reviewers of that evaluation, is CARB diesel fuel containing **<u>no</u>** biodiesel. Given that the purpose of the ADF regulation is to establish specifications for fuels like biodiesel while identifying and ensuring mitigation of adverse environmental impacts, the no biodiesel baseline is clearly the correct baseline. Based on CARB's own "Updated ADF NOx Analysis," use of this baseline shows unmitigated NOx increases of about one ton per day statewide in California in 2015, 2016, and 2017, and at lower levels through 2020, despite its flaws. Further, as shown in my previous declaration, submitted to CARB prior to the ADF and LCFS public hearings in February 2015, the likely increases in NOx emissions are much larger and can be expected to continue indefinitely into the future.

When viewed in the context of the proper baseline, the data presented in Table 1 of the notice show that the proposed ADF regulation, even after CARB's update of its analysis, fails to mitigate increased NOx emissions due to biodiesel use. That CARB has erred in establishing the baseline for analysis of biodiesel NOx impacts is support by the ADF regulation itself, as sections 2293.5(a)(3)(C), 2293.5(b)(3)(C), 2293.5(b)(5)(B), 2293.5(b)(5)(D), and 2293.5(b)(6)(B), make it clear that increased emissions from an ADF will not be included in baseline. Rather, the baseline required to be used has to reflect conditions in place before the use of the ADF.

12. Notwithstanding the above, CARB's "additional analysis" is also fatally flawed for all of the other reasons set forth in my previous declaration and its attachments dated February 17th 2015, which was filed as part of Growth Energy's comments during the original 45 day comment period on the ADF regulation.

13. Turning to the Staff Report on the Multimedia Evaluation of Biodiesel that has only recently become available for public comment and is now being included in the ADF regulation record, I have reviewed the air quality assessment that is reported to have been prepared by CARB staff, and have found it to be both inconsistent with the analysis presented in the ADF ISOR as well as fatally flawed in that it fails to consider all of the available information regarding the impact of biodiesel on NOx emissions from what CARB refers to as New Technology Diesel Engines (NTDEs). As a direct result, the Supplemental External Scientific Peer Review of the air quality impacts of biodiesel is also flawed.

14. The primary conclusion of the Multimedia Evaluation of Biodiesel with respect to air quality is:

> *Based on a relative comparison between biodiesel and CARB diesel (containing no biodiesel), ARB staff concludes that with in-use requirements biodiesel, as specified in the multimedia evaluation and proposed regulation, does not pose a significant adverse impact on public health or the environment from potential air quality impacts.*

This statement clearly highlights the fundamental inconsistency between the baseline used in the ISOR analysis of air quality impacts, where the baseline included biodiesel use, and the baseline identified in the Multimedia Evaluation Staff Report which included no biodiesel. As noted above, the appropriate baseline is the one identified in the Multimedia Evaluation Staff Report.

15. Another major inconsistency between the Multimedia Evaluation and the ISOR is the fact that CARB failed to include much of the information found in Chapters 6 and 7, and in Appendices B and G of the ISOR, all of which addresses the impact of biodiesel on emissions and air quality in the Multimedia Evaluation. Key information omitted includes:

- The finding that NOx emission increases due to soy biodiesel are statistically significant based on all data considered on page 40 of the ISOR;

- The ton per day increases in NOx emissions due to the ADF shown in Tables 7.1 and B-1 of the ISOR;

- The Supplemental Statistical Analysis presented in Appendix G of the ISOR; and

- The following peer reviewed technical papers listed as references 21 through 24 for Chapter 6 of the ISOR, which contradict CARB's claims regarding the impact of biodiesel on NOx emissions from NTDEs:

  - Gysel, Nicholas et al., *Emissions and Redox Activity of Biodiesel Blends Obtained from Different Feedstocks from a Heavy-Duty Vehicle Equipped with DPF/SCR Aftertreatment and a Heavy-Duty Vehicle without Control Aftertreatment*, SAE 2014-01-1400, Published 04/01/2014.

  - McWilliam, Lyn and Zimmermann, Anton, *Emission and Performance Implications of Biodiesel Use in an SCR-equipped Caterpillar C6.6*, SAE 2010-012157 Published, 10/25/2010.

  - Mizushima, Norifumi and Nurata, Yutaka, *Effect of Biodiesel on NOx Reduction Performance of Urea-SCR system*, SAE 2010-01-2278, Published 10/25/2010.

  - Walkowicz, Kevin et al., *On-Road and In-Laboratory Testing to Demonstrate Effects of ULSD, B20, and B99 on a Retrofit Urea-SCR Aftertreatment System*, SAE 2009-01-2733.

CARB's failure to include and fully to address the foregoing information and analysis made it impossible for any external reviewers, who were relying upon CARB for full disclosure of all relevant data and information, to perform a credible scientific review of the emissions and air quality evaluation and the conclusions reached by CARB.

16. Similarly, CARB failed to include data and information directly relevant to the issues of biodiesel impacts on emissions and air quality provided during the public comment period on the ADF regulation in the materials considered in the Multimedia Evaluation Staff Report, and therefore by the external reviewers. Data and information provided during the public comment period that contradict CARB's findings regarding biodiesel NOx impacts on NTDEs that was not made part of the Multimedia Evaluation includes:

- "NOx Emission Impacts of Biodiesel Blends," Robert Crawford, Rincon Ranch Consulting, February 17, 2015; and

- Declaration of James M. Lyons, February 17, 2015, with attachments.

Again, CARB's failure to include this information also made it impossible for the Peer Reviewers, who were relying upon CARB for full disclosure of all relevant data and information, to perform a credible scientific review of the emissions and air quality evaluation and the conclusions reached by CARB.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 8th day of June, 2015 at Sacramento, California.

JAMES M. LYONS

ATTACHMENT A

RÉSUMÉ

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research
A Trinity Consultants Company
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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)

"Development of Vehicle Attribute Forecasts for 2013 IEPR," Sierra Research Report No. SR2014-01-01, prepared for the California Energy Commission, January 2014.

"Assessment of the Emission Benefits of U.S. EPA's Proposed Tier 3 Motor Vehicle Emission and Fuel Standards," Sierra Research Report No. SR2013-06-01, prepared for the American Petroleum Institute, June 2013.

"Development of Inventory and Speciation Inputs for Ethanol Blends," Sierra Research Report No. SR2012-05-01, prepared for the Coordinating Research Council, Inc. (CRC), May 2012.

"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.

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"Evaluation of Connecticut's Adoption of California's Greenhouse Gas Regulations on Criteria Pollutants and Precursor Emissions," Sierra Research Report No. SR2005-08-03, prepared for the Alliance of Automobile Manufacturers, August 26, 2005.

"Evaluation of New York's Adoption of California's Greenhouse Gas Regulations On Criteria Pollutants and Precursor Emissions," Sierra Research Report No. SR2005-07-04, prepared for the Alliance of Automobile Manufacturers, July 14, 2005.

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"Fuel Effects on Highway Mobile Source Air Toxics (MSAT) Emissions," Sierra Research Report No. SR2004-12-01, prepared for the American Petroleum Institute, December 23, 2004.

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Attachment 3

STATE OF CALIFORNIA

BEFORE THE AIR RESOURCES BOARD

Declaration of James M. Lyons

I, James Michael Lyons, declare as follows:

1. I make this Declaration based upon my own personal knowledge and my familiarity with the matters recited herein. It is based on my experience of nearly 30 years as a regulator, consultant, and professional in the field of emissions and air pollution control. A copy of my résumé can be found in Attachment A.

2. I am a Senior Partner of Sierra Research, Inc., an environmental consulting firm located at 1801 J Street, Sacramento, California owned by Trinity Consultants, Inc. Sierra specializes in research and regulatory matters pertaining to air pollution control, and does work for both governmental and private industry 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 at the Mobile Source Division of the California Air Resources Board (CARB).

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, 2) assessment of the impacts of changes in fuel composition and alternative fuels on engine emissions including emissions of green-house gases, 3) analyses of the unintended consequences of regulatory actions, and 4) the feasibility of compliance with air quality regulations.

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, factors affecting emissions from diesel vehicles, evaporative emission control system design and function, as well as combustion chamber system design. While at Sierra I have acted as a consultant on automobile air pollution control matters for CARB and for the United States Environmental Protection Agency. 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.

5. This Declaration summarizes the results of analyses I have performed regarding CARB staff's analysis of different aspects of the re-adoption of the Low Carbon Fuel Standard (LCFS) Regulation and Regulation on the Commercialization of Alternative Diesel Fuels (ADFs) as an independent expert for Growth Energy. If called upon to do so, I would testify in accord with the facts and opinions presented here.

6. Based on a review of the Initial Statement of Reasons (ISOR) for the LCFS regulation and the associated appendices, including the draft Environmental Analysis, it is clear that CARB staff failed to quantify the GHG emission reductions associated with the LCFS regulation itself. Rather, staff notes that the GHG reduction estimates provide are inflated as the result of the "double counting" of GHG reductions due to other regulatory programs.

7. Further, this review shows that CARB staff failed to perform a complete analysis of the potential air quality impacts associated with the LCFS regulation. More specifically, CARB staff's air quality analysis fails to quantitatively assess the impact of the LCFS and ADF on all emission sources that could be affected nor does it consider all of the pollutants for which emission changes might occur. A summary of the review is Attachment B to this declaration.

8. CARB staff rejected a proposed alternative to the LCFS regulation submitted by Growth Energy claiming that it will likely result in the same environmental benefits, but not ensure a transition to lower carbon intensity fuels that CARB staff claims is the main goal of the LCFS regulation. As discussed in detail in Attachment C to this declaration, CARB staff failed to perform any analysis of the Growth Energy Alternative and has provided no support for this finding. Because the Growth Energy Alternative provides greater environmental benefits and is expected to cost less than the LCFS regulation, it must be adopted by CARB instead of the LCFS regulation.

9. As part of the development of the ADF regulation, CARB staff examined the impacts of the proposed regulation on emissions of pollutants including oxides of nitrogen (NOx) emitted from heavy-duty diesel engines operating on blends of diesel fuel and biodiesel.

10. NOx emissions directly affect atmospheric levels of nitrogen dioxide, a compound for which a National Ambient Air Quality Standards (NAAQS) has been established. NOx emissions are also precursors to the formation of ozone and particulate matter, which are also pollutants for which NAAQS have been established. Areas of the South Coast and San Joaquin Valley air basins are in extreme and moderate non-attainment of the most recent ozone and fine particulate standards, respectively.

11. In the Initial Statement of Reasons (ISOR) for the ADF regulation and its' appendices, CARB staff summarized its analysis of increases in NOx emissions from heavy-duty diesel vehicles over the period from 2014 through 2023. The results of the staff's analysis are most clearly summarized in Table B-1 of Appendix B of the ISOR. This table shows that staff estimate that biodiesel use allowed under the ADF regulation will increase NOx emissions by 1.35 tons per day in 2014 and that the magnitude of this emission increase will drop to 0.01 ton per day by 2023.

12. I have performed a review of the staff's assessment of the NOx emission impacts of biodiesel use allowed under the ADF regulation presented in ISOR and its' appendices and find it to be fundamentally flawed such that it is not reliable. First, the bases for total diesel NOx emissions inventory is not described in the ISOR or in other

documents in the record. Second, CARB staff incorrectly assumes that the use of biodiesel in "New Technology Diesel Engines (NTDEs)" equipped with exhaust aftertreatment devices to lower NOx emissions will not lead to increased NOx emissions. Third, CARB staff incorrectly apply ratios of on-road vehicle travel by NTDEs from the now obsolete EMFAC2011 model to account for the amount of biodiesel used in all NTDEs including those found in non-road equipment. Fourth, to assess the overall impact of the ADF regulation on NOx emissions, CARB incorrectly subtracts NOx reductions resulting from the use of "renewable diesel fuel" from increases in NOx emissions resulting from the use of biodiesel.

13. In addition, I have performed a very conservative assessment of the NOx emission impacts of biodiesel use under the ADF that uses the latest CARB emissions models and corrects the flaws in the staff analysis, a summary of which is attached. The results of this assessment indicate that NOx increases from biodiesel will be much larger than those estimated by CARB staff and that the magnitude of the impacts will not decline over time as forecast by CARB staff. In addition, the analysis shows that the ADF regulation will lead to significant increases in NOx emissions in the South Coast and San Joaquin Valley air basins which are already in extreme non-attainment of the federal ozone NAAQS and moderate non-attainment of the federal fine particulate NAAQS. The details of both the review and revised emissions estimates are presented in Attachment D to this declaration.

14. In addition to identifying a fundamentally flawed analysis of the increases in NOx emissions from biodiesel use under the ADF, my review indicates that other elements of the staff's air quality and environmental analyses are also fundamentally flawed. These include incorrectly selecting 2014 as the baseline year for the environmental analysis, lacking documentation and using unsupported assumptions in determination of the NOx control level for biodiesel, and unnecessarily delaying the effective date for the implementation of mitigation requirements under the ADF regulation. All of these issues, which are discussed in detail in Attachment E, cause the adverse environmental impacts of the ADF regulation to be greater than purported by CARB staff.

15. Another important issue that I have identified with the ADF regulation is that it and the related LCFS and California Diesel regulations contain inconsistent and conflicting definitions and lack provisions requiring the determination, through testing, of the biodiesel content of commercial blendstocks. As a result, there is a clear potential for biodiesel blends to actually contain as much as 5% more biodiesel by volume than will be reported to CARB under the ADF regulation. A detailed discussion of the flaws in the ADF regulation that could allow this to occur is provided in Attachment F. Actual biodiesel levels above those reported under the ADF will lead to larger unmitigated increases in NOx emissions than have been estimated by either CARB staff or me.

16. CARB staff has rejected a proposed alternative to the ADF regulation submitted by Growth Energy, claiming that it will result in the same environmental benefits but be more costly than the staff proposal. As discussed in detail in Attachment G to this declaration, this finding is based on the same fundamentally flawed emissions

analysis performed by CARB staff that is discussed above. Given that the Growth Energy alternative is designed to mitigate all potential increases in NOx emissions (when assessed in light of a proper emissions analysis) due to biodiesel use under the ADF as soon as the regulation becomes effective, it yields greater and more timely environmental benefits than the staff proposal. In addition, the Growth Energy alternative would require the same mitigation techniques as the ADF regulation, but simply expands the circumstances under which they must be applied, and has an estimated cost-effectiveness equal to that of ADF regulation. Because the Growth Energy Alternative provides greater environmental benefits as cost-effectively as the ADF regulation, it must be adopted by CARB instead of the ADF regulation.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 17th day of February, 2015 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)

"Development of Vehicle Attribute Forecasts for 2013 IEPR," Sierra Research Report No. SR2014-01-01, prepared for the California Energy Commission, January 2014.

"Assessment of the Emission Benefits of U.S. EPA's Proposed Tier 3 Motor Vehicle Emission and Fuel Standards," Sierra Research Report No. SR2013-06-01, prepared for the American Petroleum Institute, June 2013.

"Development of Inventory and Speciation Inputs for Ethanol Blends," Sierra Research Report No. SR2012-05-01, prepared for the Coordinating Research Council, Inc. (CRC), May 2012.

"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.

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“Analysis of IRTA Report on Water-Based Automotive Products,” Sierra Research Report No. SR2006-08-02, prepared for the Consumer Specialty Projects Association and Automotive Specialty Products Alliance, August 2006.

“Evaluation of Pennsylvania’s Implementation of California’s Greenhouse Gas Regulations on Criteria Pollutants and Precursor Emissions,” Sierra Research Report No. SR2006-04-01, prepared for Alliance of Automobile Manufacturers, April 12, 2006.

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Attachment B

Review of CARB Staff's Analysis of the GHG and Air Quality Impacts of the LCFS Regulation

In developing the proposed Low Carbon Fuel Standard (LCFS) regulation for re-adoption, CARB staff purports to have performed an analysis of the impacts that the regulation will have on emissions of both greenhouse gases and air pollutants. However, as is documented below, a review the CARB analysis demonstrates that the staff's analysis is incomplete and unsuitable for use in determining whether or not all adverse impacts have been identified and properly quantified, and all mitigation measures have been appropriately considered.

Summary of the CARB Staff Air Quality Analysis

On December 30, 2014, CARB staff released the proposed LCFS regulation language and the accompanying Initial Statement of Reasons (ISOR), Draft Environmental Analysis, and other supporting documents. Staff's analysis of the impact of the LCFS proposed for re-adoption is contained in Chapter IV of the ISOR as well as in Chapter 4.3. of the Draft Environmental Analysis.

In Table IV-2 of Chapter IV of the ISOR, CARB staff provides unsupported estimates of the reduction in GHG emissions associated with the LCFS regulation proposed for re-adoption. However, by CARB staff's own admission, the estimates presented in Table IV-2:

> *…do not include a reduction to eliminate the double counting of the Zero Emission Vehicle mandate, the federal Renewable Fuels Standard program, the Pavley standards, or the federal Corporate Average Fuel Economy program.*

Given that CARB staff has failed to estimate and report the GHG reduction benefits of the LCFS regulation proposed for re-adoption separately from other regulations that also seek to reduce GHG emissions from mobile sources, the Board and the public do not know the actual benefits expected to result from the regulation nor can alternatives to the LCFS regulation be properly evaluated by CARB staff.

Turning to the air quality analysis in Chapter IV of the ISOR, CARB staff provides a general discussion of emissions associated with transportation fuel production at California refineries, as well as ethanol, biodiesel, renewable diesel, and potential cellulosic ethanol facilities. Emission factors in, terms of pollutant emissions per year per million gallons of fuel produced, are provided for some facilities. CARB staff also provides an undocumented analysis of NOx and $PM_{2.5}$ emissions associated with "*...the movement of fuel and feedstock in heavy-duty diesel trucks and railcars*" with and without the LCFS and ADF regulations in place. No other assessment of the air quality impacts associated with the LCFS is provided in the LCFS ISOR.

As noted above, the draft Environmental Analysis (EA) for the LCFS and ADF, which is Appendix D to both the LCFS and ADF ISORs, also addresses air quality in Chapter 4.3. Here, short term air quality impacts related to the construction of projects of various types related to the production and distribution of lower carbon intensity fuels under the LCFS are presented. There is, however, no analysis that indicates where these projects will be located within California, nor any quantitative assessment of the emission and environmental impacts beyond the following:

> *Based on typical emission rates and other parameters for abovementioned equipment and activities, construction activities could result in hundreds of pounds of daily NO_x and PM emissions, which may exceed general mass emissions limits of a local or regional air quality management district depending on the location of generation. Thus, implementation of new regulations and/or incentives could generate levels that conflict with applicable air quality plans, exceed or contribute substantially to an existing or projected exceedance of State or national ambient air quality standards, or expose sensitive receptors to substantial pollutant concentrations.*

There is also a general discussion of potential approaches to mitigation, which CARB staff concludes are outside of the agency's authority to adopt. Ultimately, the draft EA concludes that the "short-term construction-related air quality impacts…associated with the proposed LCFS and ADF regulations would be potentially significant and unavoidable."

The draft EA also purports to assess the long-term impacts of the LCFS and ADF regulations, but addresses and attempts to quantify only potential increases in NOx emissions due to the use of biodiesel fuels, and concludes with CARB staff ultimately claiming that the long term impacts of the LCFS and ADF on air quality will be "beneficial."

Review of the CARB Staff Air Quality Analysis

As summarized above, the air quality related analyses performed by CARB staff regarding the proposed LCFS regulation are both limited and cursory. In order to demonstrate that this is in fact the case, one has to look no further than the air quality analysis CARB staff performed in 2009 to support the original LCFS rulemaking.[1]

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[1] California Air Resources Board, Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume I: Staff Report: Initial Statement of Reasons, March 5, 2009 and Volume II: Appendices, March 5, 2009. See in particular, Chapter VII of the ISOR and Appendix F.

The first point of note is that in the 2009 ISOR, CARB staff presents quantification of the GHG reductions expected from the LCFS occurring both in California and worldwide in Tables VII-1 and VII-2. While, those estimates have no relevance to the current rulemaking given the differences in the two regulations, fundamental changes in CARB's expectations with respect to how fuel producers will comply with a LCFS regulations, as well as the evolution of methodologies for estimating GHG emissions, provide clear evidence that the GHG emission benefits of the proposed LCFS can and should be explicitly quantified without any "double counting" of the benefits due to other regulatory programs. It should also be noted that in the 2009 ISOR, CARB staff also breaks down the GHG emission benefits expected from specific substitutes for gasoline and diesel fuel.

Turning to the air quality analysis itself, the lack of documentation provided precludes any detailed review of the accuracy of the assumptions and methodologies underlying the analysis or any effort to attempt to reproduce the staff's results. Given this lack of documentation, additional information was requested from CARB. As part of this request, Sierra Research pointed out that pursuant to the requirements of AB 1085, the agency had provided far more detailed information for other recent major rulemakings, including the Advanced Clean Cars program, than it released regarding the LCFS and ADF proposals. Unfortunately, CARB staff choose not to provide any additional information related to the analyses underlying the proposed LCFS and ADF regulations.

Another striking contrast which highlights the superficiality of the air quality analysis performed for the re-adoption of the LCFS can be seen in the treatment of potential emission impacts associated with the development of biofuel production facilities in California. These impacts are particularly important because the form of the LCFS regulation provides incentives to build biofuel production facilities in areas of California that violate federal National Ambient Air Quality standards, rather than in other states that are in compliance with those standards. The incentive for locating biofuel plants in California is to avoid GHG emissions from fuel and/or feed stock transportation which result in higher carbon intensity values.

As noted above, the air quality analysis for the re-adoption of the LCFS presented in section IV of the ISOR provides only estimates for existing California biofuel production facilities and the potential emissions of NO_x, PM_{10}, and volatile organic compounds (VOCs) associated with a hypothetical "northern California" cellulosic ethanol plant. In contrast, in the 2009 ISOR, staff provides a quantitative estimate of the overall number and types of new biofuel production facilities expected to be built in California (Table VII-6 of the 2009 ISOR) as well as a distribution of the number and type of plants expected to be built in eight of the state's air basins and a map showing expected locations. The increases in emissions of not only NO_x, PM_{10}, and VOC, but also carbon monoxide (CO) and $PM_{2.5}$ associated with these biodiesel production facilities were quantified by CARB staff (Table V11-10 of the 2009 ISOR). Again, although the data presented in the 2009 LCFS ISOR are irrelevant with respect to the current re-adoption of the LCFS regulation, the same level of detail and scope of the analysis performed by CARB staff in 2009 should have at a minimum been applied to the current LCFS air quality analysis.

Another issue noted with the air quality analysis performed for the re-adoption of the LCFS is related to emission impacts associated with "fuel and feedstock transportation and distribution."

The total impact of the LCFS and ADF on NOx and $PM_{2.5}$ emissions from these activities, which constitute a long term operational impact on air quality, are quantified in Table IV-16 of the ISOR. However, the documentation provided describing how the staff's analysis was performed is insufficient to allow one to either review or reproduce it. Further, these emissions are not addressed in the appropriate section of the draft EA. Given that staff estimates that the LCFS/ADF will increase these emissions, they should be identified and assessed as part of the draft EA, particularly given that staff has concluded that the LCFS/ADF impacts on long term air quality are beneficial without considering fuel and feedstock transportation and distribution emissions. The current analysis of these emissions also falls far short of the level of detail shown in the analysis of the same issue performed by CARB staff in the 2009 ISOR, as can be seen in Table VII-11 where impacts on VOC, CO, PM_{10}, and oxides of sulfur (SO_x) were reported by low CI fuel type.

Again, as noted above, the only issue addressed with respect to long term LCFS/ADF air quality impacts in the draft EA are potential NOx emission increases due to the use of biodiesel blends. As discussed in detail elsewhere,[2] the analysis upon which the draft EA and its conclusions are based is fundamentally flawed. However, the air quality analysis in the draft EA is also incomplete in that it fails to address long term changes in motor vehicle emissions beyond those associated with biodiesel and renewable diesel. That such impacts should have been addressed for the current rulemaking can be seen from the CARB staff air quality analysis included in the 2009 ISOR and presentation, which included detailed estimates of motor vehicle impacts on VOC, CO, NOx, SOx, PM_{10}, and $PM_{2.5}$ (rather than just NOx and $PM_{2.5}$) as a function of vehicle and fuel type in Table VII-12.

In addition to the above, two other important issues are: 1) CARB staff's failure to even attempt to quantify construction emissions associated with biofuel production facilities in California after finding them to be potentially significant and unavoidable; and 2) to identify and quantify potential emission increases associated with an increase in the number of tanker visits to California ports as the result of the ADF and LCFS regulations. With respect to the former, a California specific tool, CalEEmod,[3] is readily available that could have been used by CARB staff in estimating construction impacts form biofuel plants located in California.

With respect to the latter, it should be noted that although CARB staff concluded in the 2009 LCFS air quality analysis that there would be "little to no change to emissions at ports," that analysis predates the current proposal[4] regarding the assignment of CI to crude oil which are likely to encourage crude oil shuffling; as well as CARB staff assumptions regarding increases in assumed volumes of renewable diesel fuel potentially coming to California from production facilities in Asia, and the potential for direct importation of cane ethanol into California from Brazil. These factors will undoubtedly result in increased tanker operations in California waters the emission impacts of which can be estimated using the Emissions Estimation Methodology for Ocean-Going Vessels available on CARB's emission inventory website. According to this source, 1,919 visits by crude oil and petroleum product tankers are forecast for 2015 with roughly 50% percent of those trips involving southern California ports that are part of the South

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[2] Declaration of James M. Lyons filed as comments to the ADF regulation.
[3] California Emissions Estimator Model, Users Guide, Version 2013.2, July 2013.
[4] See proposed section 95489, Title 17 CCR in LCFS ISOR Appendix A.

Coast air basin. The emissions estimated by CARB to be associated with one tanker visit to California are presented in Table 1. As shown, the tanker emissions associated with a single new visit far exceed the NOx, $PM_{2.5}$ and SOx significance thresholds. Given that multiple new tanker visits are likely to result from the LCFS and ADF regulations, these values demonstrate that CARB staff has failed to identify a potentially significant source that will created adverse air quality impacts in its draft EA.

Table 1
Comparison of Tanker Emissions During A Single Visit to California with South Coast Air Quality Management District Air Quality Significance Thresholds

Pollutant	Significance Threshold (lbs/day)	Tanker Emissions (lbs)
NOx	55	7,700
VOC	55	283
PM_{10}	150	290
$PM_{2.5}$	55	283
SOx	150	1,780
CO	550	629

Attachment C

The Growth Energy Alternative to the Proposed LCFS Regulation is the Least-Burdensome Approach that Best Achieves the Project Objectives at the Least Cost That Must be Adopted

As part of the rulemaking process leading to CARB staff's proposed re-adoption of the LCFS regulation, staff was required to solicit and consider alternatives to the proposed regulation. Growth Energy submitted such an alternative. While CARB staff acknowledged that the Growth Energy alternative could provide equivalent reductions in GHG emissions, the agency rejected it from further consideration or analysis by stating only that it was insufficient to transition California to alternative, lower carbon intensity fuels. As discussed below, CARB staff's premise for rejecting the Growth Energy alternative is incorrect. Further, given that the Growth Energy Alternative achieves the same environmental benefits through reductions in GHG emissions as the LCFS regulation, likely at the same or lower cost, it should have been analyzed by CARB staff, in which case it would have to be adopted as the least-burdensome approach the best achieves the project objectives at the least cost.

Background

On May 23, 2014, CARB published a "Solicitation of Alternatives for Analysis in the LCFS Standardized Regulatory Impact Assessment" which is attached. On June 5, CARB published a response to a request from Growth Energy extending the deadline for the submission of alternatives from June 5, 2014 to June 23, 2014. On June 23, 2014, Growth Energy submitted an alternative regulatory proposal for the LCFS regulation (which is attached) to CARB in response to the agency's solicitation. On December 30, 2014, CARB staff published both the ISOR for the LCFS regulation as well as a document entitled "Summary of DOF Comments to the Combined LCFS/ADF SRIA and ARB Responses," which is Appendix E to the LCFS ISOR. Appendix E discusses the Growth Energy LCFS alternative and CARB's reason for its rejection.

The staff's assessment of the Growth Energy (GE) Alternative published in Appendix E of the LCFS ISOR is as follows (emphasis added):

> *The proposed alternative assumes that the exclusive goal of the LCFS proposal is to achieve GHG emissions reductions without regard to source. If that were the case, this would be a viable alternative to the LCFS and would be assessed in this analysis. It is likely true that the estimated GHG emissions reductions appearing in the 2009 LCFS Initial Statement of Reasons (California Air Resources Board, 2009) could be achieved by the AB 32 Cap-and-Trade Program, along with the other programs cited by Sierra Research and Growth Energy. The LCFS proposal, however, was designed to address the carbon intensity of transportation*

fuels. Transportation in California was powered almost completely by petroleum fuels in 2010. Those fuels were extracted, refined, and distributed through an extensive and mature infrastructure. Transitioning California to alternative, lower-carbon fuels requires a very focused and sustained regulatory program tailored to that goal. The other regulatory schemes the alternative would rely on are comparatively "blunt instruments" less likely to yield the innovations fostered by the LCFS proposal. In the absence of such a program, post-2020 emissions reductions would have to come from a transportation sector that would, in all likelihood, have emerged from the 2010-2020 decade relatively unchanged.

In the absence of an LCFS designed to begin the process of transitioning the California transportation sector to lower-carbon fuels starting in 2010, post-2020 reductions would be difficult and costly to achieve. This is why the primary goals of the LCFS are to reduce the carbon intensity of California fuels, and to diversify the fuel pool. A transportation sector that achieves these goals by 2020 will be much better positioned to achieve significant GHG emissions reductions post 2020.

ARB is required to analyze only those alternatives that are reasonable and that meet the goals of the program as required by statute. An initial assessment of the program indicates the goals of the LCFS proposal can be achieved by keeping the program "…separate of the AB 32 Cap-and-Trade system initially (at least first 10 years) in order to stimulate innovation and investment in low-GWI [global warming intensity] fuel (or transportation) technologies."[16] Due to the strong justifications that the Cap-and-Trade program alone generates neither the CI reductions nor fuel in the transportation sector, this alternative will not be assessed in this document.

Reference 16 in the above citation is given as:

A Low-Carbon Fuel Standard for California, Part 2: Policy Analysis – FINAL REPORT, University of California Project Managers: Alexander E. Farrell, UC Berkeley; Daniel Sperling, UC Davis. Accessed: 7-15-2015 http://www.energy.ca.gov/low_carbon_fuel_standard/

Discussion

Given that there is no analysis or other support provided by CARB staff for the assertions it makes in rejecting the Growth Energy alternative other than the one reference, which dates to 2007—before either the original LCFS or Cap-and-Trade regulation were adopted was reviewed. The discussion of interactions between a LCFS program with AB32 regulations from the reference is provided below. As can be determined by the reader, the discussion was written before the AB32 regulations were adopted, and the basic concern expressed is that the lower cost of achieving the same GHG reductions from a broader program will be lower than the cost of doing the same from the LCFS program. Further, the concern expressed regarding lifecycle emission under the LCFS was explicitly addressed in the Growth Energy alternative.

5.2 Interactions with AB32 regulations

RECOMMENDATION 16: The design of both the LCFS and AB32 polices must be coordinated and it is not possible to specify one without the other. However, it is clear that if the AB32 program includes a hard cap, the intensity-based LCFS must be separate or the cap will be meaningless. Including the transport sector in both the AB32 regulatory program and LCFS will provide complementary incentives and is feasible. CARB will soon be developing regulations under AB32 to control GHG emissions broadly across the economy, most likely through a cap-and-trade system plus a set of regulatory policies. Thus, emissions from electricity generation, oil production, refining, and biofuel production are likely to be regulated directly under AB32. These energy production emissions are "upstream" in a fuel's life cycle (while emissions from a vehicle are "downstream"). The recent Market Advisory Committee report recommends including all CO2 emissions from transportation, including tailpipe emissions.

The LCFS regulates consumption emissions—the full life cycle emissions associated with products consumed in California, while it is expected that sector-specific emission caps will be imposed by AB 32 on production emissions—the emissions that are directly emitted within the borders of the state. The different types of boundaries used by these regulations causes certain upstream emissions to be double regulated under the LCFS and AB32. However, the potential for double regulation only applies to fuel production processes in the state of California or other jurisdictions where legislation similar to AB 32 also applies. We agree with the Market Advisory Committee that the LCFS and AB32 regulations will provide complementary incentives and that transportation emissions of GHGs should be included in the AB32 program.

There is no inherent conflict between the LCFS and AB32 caps; both are aimed at reducing GHG emissions and stimulating innovation in low-carbon technologies and processes. However, there are some differences. Most importantly, the LCFS is designed to stimulate technological innovation in the transportation sector specifically, while the broader AB32 program will stimulate technological innovation more broadly. The concerns associated with market failures and other barriers to technological change in the transportation sector (discussed in Section 1.3 of Part 1 and Section 2.3 of Part 2) are the motivation for adopting the sector-specific LCFS. These concerns suggest separating the LCFS from the AB32 emission caps.

The second key difference is that as a product standard using a lifecycle approach, the LCFS includes emissions that occur outside of the state such as *those associated with biofuel feedstock production and the production of imported crude oil. These emissions will not be included in the AB32 regulations.*

The third difference is in expected costs. In the absence of transaction costs and other market imperfections, economic theory suggests that a broader cap-and-trade program will be less costly than a narrower one. By allowing more sectors and more firms to participate in a market for emission reductions, one reduces the cost to achieve a given level of emission reductions -- suggesting that the LCFS be linked to the broader AB 32 regulatory system. In addition, commercially available low-carbon options exist in the electricity and other sectors, but not in transportation fuels (see Part 1 of this study, Section 1.3).

The specific regulations and market mechanisms used to implement AB32 are not yet determined, so it is not possible at this time to specify how the LCFS should interact with them. The ARB should carefully consider the differences in incentives and constraints that the combination of rules will create.

Returning to the issue of diversification of the transportation fuel sector, CARB concerns are directly refuted by Growth Energy's submission. As noted on pages 9 and 10, ethanol will be added to California gasoline, and renewable diesel and biodiesel will be blended into California diesel fuel as the result of the federal RFS program. The range of fuels and feedstocks from which they are produced under the RFS will be diverse. For example, the following fuel/feedstock pathways, among others, are currently recognized by U.S. EPA under the RFS:[1,2,3,4,5]

- Ethanol from
  - Corn
  - Sugar cane
  - Grain sorghum
  - Celluosic materials

- Biodiesel from
  - Camelina oil
  - Soy bean oil
  - Waste oils, fats and greases
  - Corn oil
  - Canola/rapseed oil

- Renewable diesel from
  - Waste oils, fats and greases

[1] EPA-420-F-13-014
[2] EPA-420-F-14-045
[3] EPA-420-F-12-078
[4] EPA-420-F-11-043
[5] EPA-420-F-10-007

- Renewable gasoline from
    - Crop residue and municipal solid waste

- Renewable natural gas from
    - Landfills
    - Digesters

As can be seen from Appendix B to the LCFS ISOR, these are many of the fuels that CARB staff also expects to be used in California under the LCFS. Similarly, electricity and hydrogen will be used as transportation fuels in California given the states regulatory mandates for the production of vehicles that operate on these fuels under the Advanced Clean Cars program. Further, in later years these fuels are expected to be required in heavy-duty vehicles as CARB adopts regulations under its proposed Sustainable Freight Transport Initiative, the purpose of which is stated by CARB staff as follows:

> *The purpose of the Strategy is to identify and prioritize actions to move California towards a sustainable freight transport system that is characterized by improved efficiency, zero or near-zero emissions, and increased competitiveness of the logistics system.*

It should also be noted that fuel providers in California will still be incentivized to provide these fuels in California under the Growth Energy alternative in order to reduce the number of GHG credits they will be required to retire under cap-and-trade program.

Finally, on pages 15 and 16, Growth Energy's proposal for addressing the loss of upstream emission benefits from the LCFS regulation is explicitly discussed.

Given that the Growth Energy alternative:

1. Provides, as determined by CARB staff, the same GHG reductions as the LCFS regulation; and

2. Is expected to result in lower costs of compliance than the LCFS.

CARB must adopt the Growth Energy alternative as it better achieves the stated project objectives in an equally cost-effective manner.

Attachment D

Review of CARB Staff Estimates of NOx Emission Increases Associated with the Use of Biodiesel in California Under the Proposed ADF Regulation

In developing the proposed Alternative Diesel Fuel (ADF) regulation, CARB staff has performed a statewide analysis of the increase in NOx emissions that is currently occurring in California due to the use of biodiesel, as well as the increases in NOx emissions that can be expected in the future due to the continued use of biodiesel in California under the proposed ADF regulation. As documented below, a review of the CARB staff analysis performed by Sierra Research demonstrates that the staff's analysis is fatally flawed and cannot be relied upon. Given this, Sierra Research has performed an analysis, also documented below, that demonstrates there will be substantial increases in NOx emissions if the ADF regulation is implemented as proposed. The significance in the NOx emissions increase associated with the use of biodiesel under the proposed ADF is clear given the dramatic reductions which CARB, the South Coast Air Quality Management District, and the San Joaquin Air Pollution Control District are seeking given their "extreme" non-compliance status with respect to the federal National Ambient Air Quality Standard for ozone.[1] This significance is also reinforced by a comparison of the estimated increase in NOx emissions from biodiesel under the proposed ADF regulation with the benefits of proposed and adopted NOx control measures intended for implementation on a statewide basis as well as in the South Coast and San Joaquin Valley air basins, respectively.

Review of the CARB Staff Analysis

On December 30, 2014, CARB staff released the proposed ADF regulation language and the accompanying Initial Statement of Reasons (ISOR), technical and economic support information, and draft environmental analysis. Staff's analysis of the impact of the proposed ADF regulation on NOx emissions and supporting information and assumptions are contained in Chapters 6 and 7 of the ISOR, as well as Appendix B entitled "Technical Supporting Information."

The first issue that was identified with the staff's emissions analysis is that the information and data supplied by CARB staff are insufficient to determine exactly how the analysis was performed. Specifically, CARB staff provides no source for the values in Table B-1 labeled "Emission Inventory (Diesel TPD)," which are key to the analysis. As illustrated below, a clear understanding of what diesel sources (e.g., on-road heavy-duty, non-road, marine, locomotives, etc.) are included in the "inventory" is critical to assessing the accuracy of the staff's analysis.

[1] It should be noted that the CARB statewide analysis fails to provide any estimate of the impacts of increased NOx emissions from the ADF regulation in these air basins, where the agency has stated that massive reductions in NOx emissions are required to achieve compliance with federal air quality standards.

Given the lack of documentation regarding the source of the diesel emission inventory values, additional information regarding this analysis as well as other analyses associated with the ADF and Low Carbon Fuel Standard (LCFS) rulemakings was requested. As part of this request, Sierra Research pointed out that pursuant to the requirements of AB 1085, the agency had provided far more detailed information for other recent major rulemakings, including the Advanced Clean Cars program, than it released regarding the LCFS and ADF proposals. Unfortunately, CARB staff choose not to provide any additional information related to the analyses underlying the proposed LCFS and ADF regulations.[2]

Despite the lack of all the information necessary to fully review the CARB staff analysis, it was possible to discern some key assumptions and the general methodology that was applied. The following key assumptions were identified:

1. Actual biodiesel use and the total demand for diesel fuel and substitutes in California will exactly match that forecast by CARB staff in the "illustrative compliance scenarios" developed as part the LCFS rulemaking;[3]

2. Actual renewable diesel use in California will exactly match that forecast by CARB staff in the "illustrative compliance scenarios" developed as part the LCFS rulemaking;[2]

3. Forty percent of renewable diesel delivered to California will be used directly by refiners to comply with the requirements of CARB's existing diesel fuel regulations[4] while the remaining 60% will be blended into fuel that complies with the diesel fuel regulations downstream of refineries;

4. The use of biodiesel up to the B20 level in New Technology Diesel Engines[5] (NTDEs, which employ exhaust aftertreatment systems to reduce NOx emissions) will not result in any increase in NOx emissions;

5. The use of biodiesel in heavy-duty diesel engines other than NTDEs—which are referred to by CARB staff as "legacy vehicles"—will increase NOx linearly with increasing biodiesel blend content, up to a 20% increase for B100;

[2] See attached emails from Jim Lyons of Sierra to Lex Mitchel and other CARB staff from January 2015.
[3] These are presented in Appendix B to the LCFS ISOR.
[4] Sections 2281 to 2284, Title 13, California Code of Regulations.
[5] Proposed section 2293.3 Title 13 CCR (see Appendix A to the LCFS ISOR) defines a New Technology Diesel Engines as:

a diesel engine that meets at least one of the following criteria:

(A) Meets 2010 ARB emission standards for on-road heavy duty diesel engines under section 1956.8.
(B) Meets Tier 4 emission standards for non-road compression ignition engines under sections 2421, 2423, 2424, 2425, 2425.1, 2426, and 2427.
(C) Is equipped with or employs a Diesel Emissions Control Strategy (DECS), verified by ARB pursuant to section 2700 et seq., which uses selective catalytic reduction to control Oxides of Nitrogen (NOx).

6. The blending of renewable diesel downstream of refineries will reduce NOx emissions from legacy vehicles, with each 2.75 gallons of renewable diesel blended offsetting the emissions increase associated with each gallon of biodiesel used; and

7. During the period from 2018 to 2020, 30 million gallons of biodiesel will be blended to the B20 level for use in legacy vehicles each year, and will therefore be subject to the mitigation requirements of the proposed ADF regulation and will not cause an increase in NOx emissions. Furthermore, this volume will increase to 35 million gallons per year from 2021 to 2023.

Based on the above assumptions, CARB staff followed the methodology steps outlined below for estimating biodiesel impacts.

1. The fraction of legacy vehicles in a given year is determined by subtracting the percentage of vehicle miles traveled by on-road heavy-duty vehicles with NTDEs from 100%.

2. The fraction of legacy vehicles from Step 1 is multiplied by the total volume of biodiesel assumed to be consumed in a given year to yield the number of gallons of biodiesel used in legacy vehicles in that year.

3. For years 2018 and later, the amount of biodiesel assumed to be sold as emissions-mitigated B20 in a given year is subtracted from the total volume of biodiesel used in legacy vehicles in that year.

4. The total volume of renewable diesel assumed to be sold in a given year is multiplied by the percentage of legacy vehicles in that year and then multiplied by 0.6 to account for renewable diesel used in refineries to yield the amount of renewable diesel creating reductions in NOx emissions from legacy vehicles in that year.

5. The amount of renewable diesel used in legacy vehicles is then divided by 2.75 to determine the number of gallons of biodiesel for which NOx emissions have been offset for that year.

6. The number of gallons of biodiesel for which NOx emissions have been offset, as determined in Step 5, is then subtracted from the amount of biodiesel used in legacy vehicles, as determined in Step 3, to yield the total number of gallons of biodiesel used in legacy vehicles that cause increased NOx emissions for that given year.

7. The biodiesel volume from Step 6 is multiplied by the assumed NOx increase of 20% for B100 and then divided by the total volume of diesel fuel forecast to be used in that year to get the percentage increase in diesel emissions for that year.

8. The value from Step 7 is multiplied by the assumed Diesel Emissions inventory for that year to yield the final estimate of increased NOx emissions due to biodiesel in units of tons per day for the entire state of California.

Using the above methodology, CARB staff estimates that use of biodiesel in California led to a 1.36 ton per day increase in NOx emissions in 2014, and that the proposed ADF regulation will reduce the magnitude of that increase through 2023 down to 0.01 ton per day.[6]

The review of the staff's emission analysis identified two major issues in addition to the lack of documentation regarding how the diesel "Emission Inventory" values used by staff were developed:

1. Assuming that biodiesel use in NTDEs at levels up to B20 will not increase NOx emissions; and

2. Assuming that biodiesel NOx emissions are offset by the use of renewable diesel fuel.

Beginning with NTDEs, it has been demonstrated[7] that the available data indicate not only that NOx emissions from NTDEs will increase with the use of biodiesel in proportion to the amount of biodiesel present in the blend, but also that the magnitude of the increase on a percentage basis will be much greater than that observed for "legacy vehicles." At the B20 level where CARB staff assumed that there will be no NOx increase, the best current estimate is that NTDE NOx emissions will be increased by between 18% and 22%. CARB staff's failure to account for increased NOx emissions from NTDEs renders the staff's emission analysis meaningless in terms of assessing the adverse environmental impacts of the proposed ADF regulation. Another problem with CARB staff's treatment of NTDEs is that they have incorrectly assumed that the penetration of NTDEs into the on-road fleet is equal to that in the non-road fleet. NTDE penetration rates into the non-road fleet will be delayed due to the later effective date of the Tier 4 Final standards, relative to the 2010 on-road standards, and by the fact that while newer trucks dominate on-road heavy-duty vehicle operation, that effect does not occur in the non-road vehicle population.

Similarly, there are fundamental flaws with CARB staff's assumption that the use of renewable diesel will offset increased NOx emissions due to the use of biodiesel. First, it must be noted that there is nothing in either the proposed ADF regulation or the proposed LCFS regulation that mandates the use of any volume of biodiesel in California, much less the use of the exact ratio of renewable diesel to biodiesel assumed by CARB staff in its emissions analysis. Second, based on a review of the ADF and LCFS ISORs and supporting materials, there is no apparent basis for the staff's assumption that 40% of renewable diesel used in California will be used by refiners to aid in compliance with CARB's existing diesel fuel regulations, and that 60% will be blended downstream of refineries. To the extent that fuel producers choose to blend renewable diesel in California, one would expect them to do so by purchasing renewable diesel for use at their

[6] Table B-1, Appendix B of the ADF ISOR.
[7] "NOx Emission Impacts of Biodiesel Blends," Rincon Ranch Consulting, February 17, 2015.

refineries where they can benefit from the other desirable properties of this fuel beyond its low carbon intensity (CI) value (e.g., high cetane number and fungibility with diesel fuel at all blend levels), rather than by purchasing LCFS credits generated by downstream blenders of renewable diesel fuel.

To illustrate the magnitude of the significance of CARB's flawed assumptions regarding NTDEs and renewable diesel, if one simply and extremely conservatively assumes that NTDE NOx increases will be the same on a percentage basis as legacy vehicles and eliminates the NOx offsets assumed from renewable diesel, the NOx increases expected from biodiesel increase from 1.35 tons per day statewide in 2014 to approximately 3.44 tons per day—a factor of about 2.65. For 2023, estimated NOx emission increases due to biodiesel rise to about 0.87 tons per day, or about 100 times more than the 0.01 tons per day CARB staff estimated. However, as documented below, a more rigorous analysis indicates that far greater increases in NOx emissions are likely.

Detailed Analysis of Increases in NOx Emissions from Biodiesel Use

Given the flawed assumptions and undocumented sources of data associated with CARB staff's analysis of the emission impacts associated with biodiesel under the proposed ADF, Sierra Research undertook a detailed analysis of the same issue. The first step in this analysis was identifying the most current methods and tools for estimating NOx emissions from on- and non-road diesel engines operating in California for which biodiesel use is expected to increase NOx emissions.

On-Road Heavy-Duty Diesel Vehicles – On December 30, 2014, CARB officially released the final version of the EMFAC2014 model for estimating on-road emissions in California, which has replaced the now obsolete EMFAC2011 model that CARB staff relied upon for certain elements of its emission analysis. In releasing EMFAC2014, CARB staff noted a number of changes intended to improve the accuracy of the model relative to EMFAC2011. First, EMFAC2014 accounts for CARB's adoption of recent mobile source rules and regulations that lower future NOx emission estimates, including the Advanced Clean Cars program and the 2014 Amendments to the Truck and Bus Regulation. In addition, EMFAC2014 now estimates off-cycle emissions of SCR-equipped vehicles (i.e., NTDEs) by reflecting higher NOx emissions during low speed operation and cold starts.[8]

Given the above, Sierra selected EMFAC2014 for estimating NTDE emissions directly in this assessment. It was used to generate annual average NOx emissions, in tons per day, for the South Coast and San Joaquin Valley Air Basins, and the entire state for the years 2015, 2020, and 2023. Emission estimates were obtained for light-heavy-duty, medium-heavy-duty, and heavy-heavy-duty trucks, as well as school, urban, and transit buses. Output by "model year" was used to differentiate NOx emissions of legacy vehicles from those of NTDEs, which were defined as 2010 and later model-year vehicles consistent with the definition in proposed section 2293.2 Title 13, CCR (see Appendix A to the LCFS ISOR).

[8] Email from ARB EMFAC2014 Team, November 26, 2014.

Off-Road Diesel Equipment and Engines – The process of estimating emissions from off-road equipment and engines in California is much less straightforward than for on-road vehicles, as the most recent CARB models have been separated by equipment type and updated at various points in time as part of the rulemaking process associated with the development of regulations for different source categories.

In addition to having been developed and last updated at different points in time, some of the methodologies do not output data with sufficient detail (e.g., emissions by engine model year) to differentiate between "legacy vehicles" and NTDEs, which, in the case of off-road sources, are defined by CARB staff in proposed section 2293.2 Title 13 CCR as being compliant with Tier 4 final emission standards for non-road compression ignition (i.e., diesel) engines under sections 2421, 2423, 2424, 2425, 2425.1, 2426, and 2427 Title 13 CCR.[9] The effective dates of these standards vary as a function of engine power rating, as shown in Table 1. It should be noted that compliance with the Tier 4 Final standards by engines below 50 horsepower in general does not require the use of the SCR technology[10] that CARB has used to define "NTDEs." Therefore, all engines in this category were assumed to respond to biodiesel in the same way as legacy vehicles, despite the fact that they meet Tier 4 final standards and are technically classified as NTDEs by CARB under the ADF regulation. As discussed below, this again reduced the magnitude of the biodiesel NOx impact.

Table 1
Effective Dates of Tier 4 Final Standards

Horsepower Range	Model Year
50-75	2013
76-175	2015
176-750	2014
Over 751	2015

Table 2 summarizes current state of CARB inventory models and methodologies for off-road diesel emission sources by equipment/engine sector[11] and indicates which outputs have sufficient detail to differentiate between emissions from legacy vehicles and NTDEs. As shown, only the general off-road equipment (construction, industrial, ground support, and oil drilling equipment), cargo handling equipment, and agricultural equipment sectors could be included in the Sierra analyses for the South Coast and San Joaquin Valley Air Basins. For the statewide inventory, it was possible to include transportation refrigeration units (TRUs) as well. Given that all diesel emission categories could not be included in the Sierra analysis, it should be noted that the results of the analysis presented below are conservative in that they do not account for the full magnitude of the increase in NOx emissions related to biodiesel use in California.

[9] See ISOR Appendix A.
[10] See *http://www.arb.ca.gov/diesel/tru/tru.htm#mozTocId341892.*
[11] All models can be downloaded at *http://www.arb.ca.gov/msei/categories.htm* .

The CARB off-road emissions inventory tools were configured to include the impacts of the most recent regulatory actions in each sector, and were executed to provide estimates of annual average day NOx emissions for both legacy and NTDE vehicles for calendar years 2015, 2020, and 2023 occurring in the South Coast and San Joaquin Valley Air Basins, as well as the entire state.

Key Assumptions: The Sierra analysis of the emission impacts of biodiesel use in California relies on the following two key assumptions:

1. B5 will be in use on a statewide basis in 2015, 2020, and 2023;

2. At the B5 level, NOx emissions from legacy vehicles will be increased by 1%, and by 5% from NTDEs.

Table 2
Summary of Current California Off-Road Diesel Emission Inventory Methodologies

Category	CARB Model/Database Tool	Capable of Differentiating Legacy Vehicle and NDTE Emissions
In-Use Off-Road Equipment	2011 Inventory Model	Yes
Cargo Handling Equipment	2011 Inventory Model	Yes
Transportation Refrigeration Units	2011 TRU Emissions Inventory	Yes – but not capable of estimating emissions by air basin
Agricultural Equipment	OFFROAD2007	Yes
Stationary Engines	2010 StaComm Inventory Model	No
Locomotives	NA	No
Commercial Harborcraft	2011 CHC/CA Crew and Supply Vessel/CA Barge and Dredge Inventory Databases	No
Ocean-Going Vessels	2011 Marine Emissions Model	No

The assumption regarding B5 was based on the fact that it represents the highest blend allowed under the ADF without mitigation, at least during the summer months. That this assumption is reasonable can be seen by comparing CARB's current and previous assumptions of biodiesel use: in the current LCFS compliance scenario,[3] the staff assumes a range from about B3 in 2015 to about B4 in 2020; in 2009,[12] the staff assumed approximately B1 in 2015 and B5 in 2020; and

[12] CARB, Proposed Regulation to Implement the Low Carbon Fuel Standard, Volume II, Appendices, March 5, 2009.

in 2011,[13] approximately B10 in 2015 and B20 in 2020 were assumed. Furthermore, the Sierra results can be scaled to reflect lower or higher non-mitigated biodiesel levels by multiplying them by the ratio of the assumed biodiesel level to B5.

The assumptions of a 1% and 5% increase at B5 for legacy vehicles and NTDEs, respectively, are based on the analysis of Rincon Ranch Consulting,[7] where 5% represents the mid-point of the range of estimates.

Diesel Emission Inventory and Biodiesel Impacts

The results of the Sierra analysis for the statewide diesel inventory for 2015, 2020, and 2023 are presented in Table 3 along with the undocumented values published by CARB staff.[6] As shown, the Sierra values are lower than those used by CARB staff. This is expected to some degree given that the Sierra analysis does not include, as explained above, some diesel source categories; however, the difference cannot be reconciled given the lack of information made available by CARB staff regarding its analysis.

Table 3
Statewide Diesel Emissions tons/day

	2015	2020	2023
Sierra Analysis	621	436	277
CARB Table B-1, Appendix B ADF ISOR	863	634	496

Table 4 compares the results of Sierra's analysis with the results of the CARB staff's analysis. As shown, the differences are large and are due primarily to two factors: 1) the staff's assumption regarding biodiesel impacts on NTDE NOx emissions, which is contradicted by the available data; and 2) the differences in the assumed levels of biodiesel use. The impact of the latter difference can also be seen in the results presented in Table 4, where results from the Sierra analysis scaled to reflect the lower biodiesel use rates assumed by CARB staff are presented. Again, even with this adjustment, the results of the Sierra analysis indicate much greater NOx impacts under the proposed ADF. Finally, it should be recalled that because of limitations with CARB's emission inventory methods for off-road sources, not all sources of diesel emissions that could be impacted by biodiesel use under the ADF have been accounted for, and the actual impacts will be greater than those shown in Table 4.

[13] CARB, Low Carbon Fuel Standard 2011 Program Review Report, December 8, 2011.

Table 4 Statewide Increase in NOx Emissions Due to Biodiesel tons/day			
	2015	2020	2023
Sierra Analysis – B5	9.18	9.73	8.75
Sierra Analysis at CARB Assumed Biodiesel Levels from Table B-1	4.70	7.15	6.15
CARB Table B-1, Appendix B ADF ISOR	1.29	0.39	0.01

The results of the Sierra analysis are shown graphically in Figures 1a through c for the entire state as well as the South Coast and San Joaquin air basins, respectively. These figures also show the relative contributions of legacy vehicles and NTDEs to the total estimated for each area and year. As shown, the contributions of NTDEs to increased NOx emissions are substantial in 2015, and dominate the impacts in 2020 and 2023. Further data supporting these results are provided in Tables 6 through 8 at the end of this attachment.

Figure 1a
Results of Sierra Analysis of Statewide NOx Increases Due to Biodiesel Use under the Proposed ADF Regulation

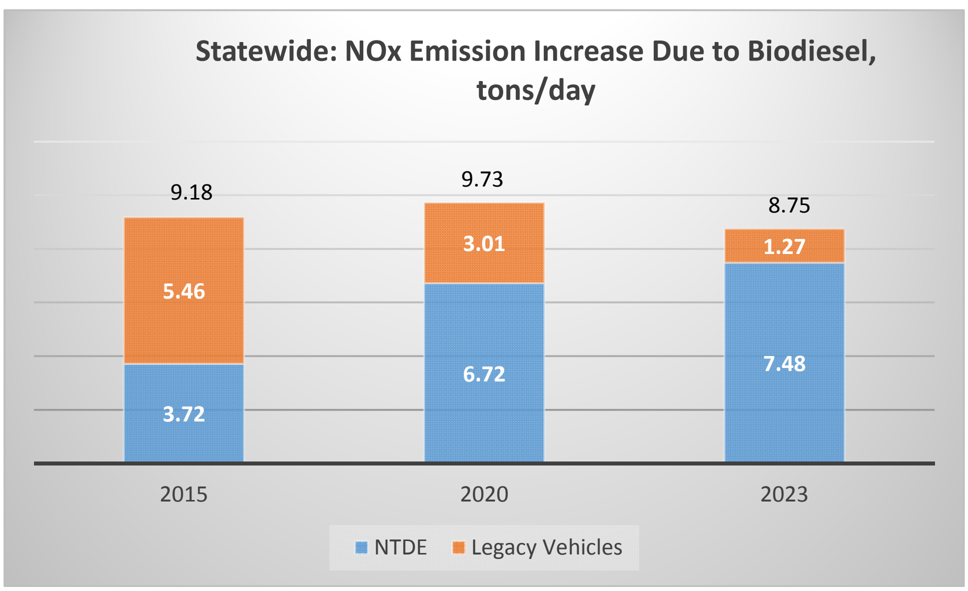


Figure 1b
Results of Sierra Analysis of South Coast Air Basin NOx Increases Due to Biodiesel Use under the Proposed ADF Regulation

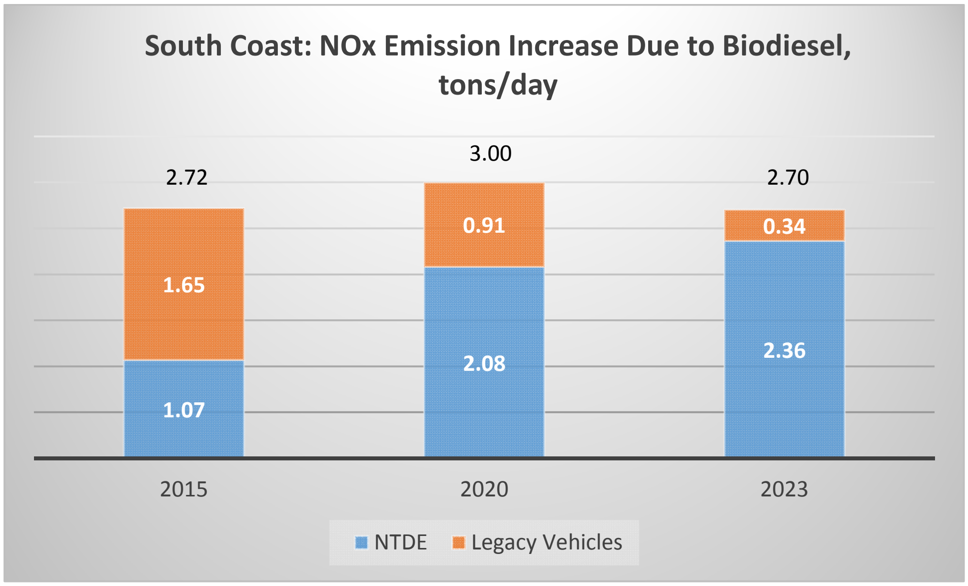
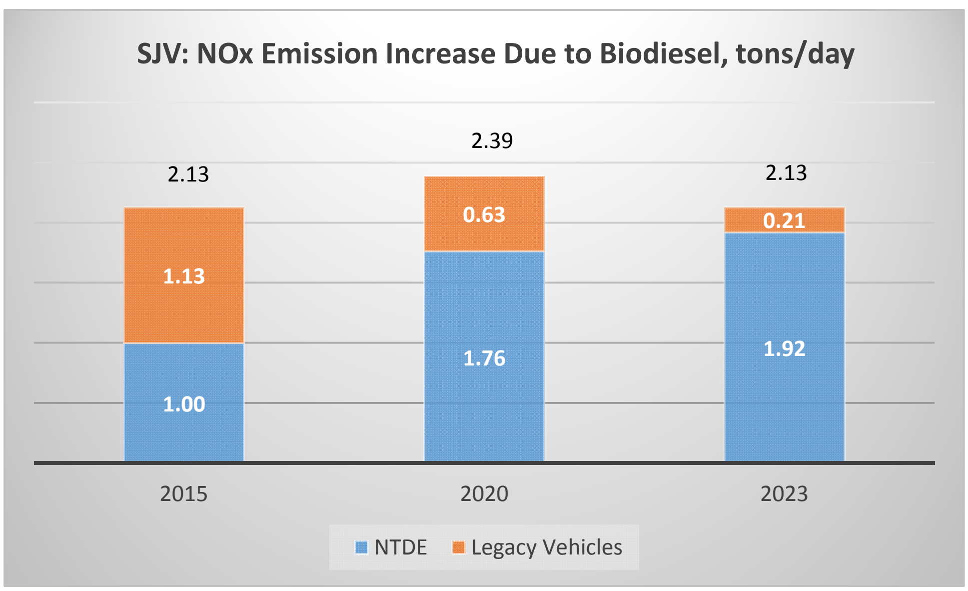


Figure 1c
Results of Sierra Analysis of San Joaquin Valley Air Basin NOx Increases Due to Biodiesel Use under the Proposed ADF Regulation



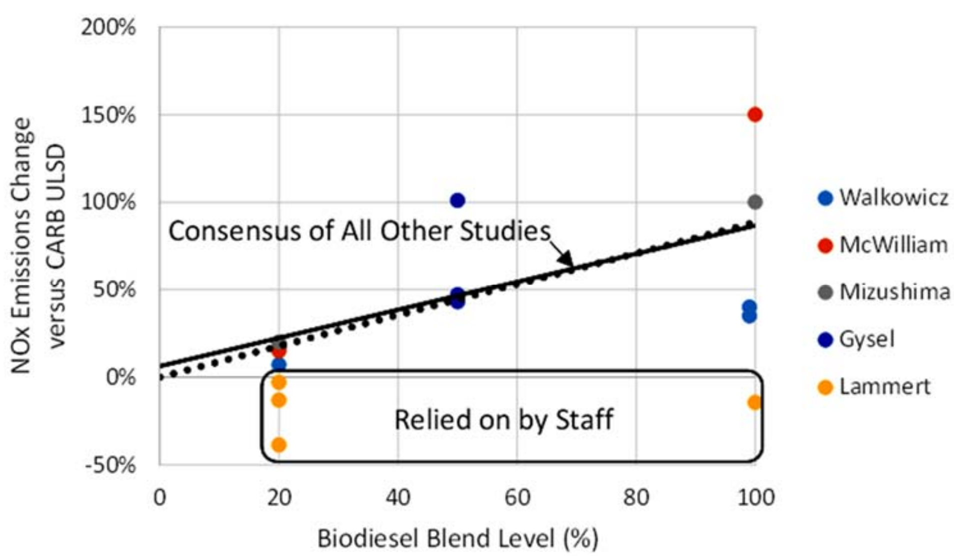
As indicated above, the Sierra analysis uses the results from an assessment of existing data regarding biodiesel impacts on NOx emissions from NTDEs performed by Rincon Ranch Consulting. The key findings of that analysis are shown in Figure 2 (reproduced with permission), which establishes that the available data for biodiesel impacts on NTDE NOx emissions follow a linear relationship just as they do for legacy vehicles.

In contrast to the data upon which the Sierra analysis rests, the basis of CARB staff's assumption regarding biodiesel impacts on NTDE emissions rests on the following excerpts from the ADF ISOR:

> *Research also indicates that the use of biodiesel up to blends of B20 in NTDEs results in no detrimental NOx impacts. Therefore, the proposed regulation also includes a process for fleets and fueling stations to become exempted from the in-use requirements for biodiesel blends up to B20 as long as they can demonstrate to the satisfaction of the Executive Officer that they are fueling at least 90 percent light or medium duty vehicles or NTDEs.*
>
> *Staff proposes to take a precautionary approach and in the light of data showing there may be a NOx impact at higher biodiesel blends but not at lower biodiesel blends, staff is limiting the conclusion of no detrimental NOx impacts in NTDEs to blends of B20 and below.*

Clearly, if CARB staff were truly taking a "precautionary approach" to the issue of biodiesel impacts on NTDE NOx emissions, they would also rely on the results of the analysis summarized in Figure 2.

Figure 2
The Impact of Biodiesel on NTDE NOx Emissions



The assumption made by CARB staff regarding biodiesel impacts on NDTE NOx emissions has additional ramifications beyond those shown above by the results of the Sierra analysis. As set forth in proposed section 2293.6, Title 13 CCR (see ISOR Appendix A), the mitigation requirements for biodiesel up to the B20 level will be dropped when NTDEs account for 90% of heavy-duty vehicle miles travelled in California (expected by staff to be 2023) and use of B20 without mitigation will be allowed in all fleets of centrally fueled vehicles comprised of more than 90% NTDEs. Given this, use of unmitigated biodiesel blends of up to B20 in NTDEs may be common under the proposed ADF regulation. The potential significance of these provisions of the staff proposal with respect to the potential for NOx increases is shown in Figures 3a through 3c, which illustrate the estimated increases in NDTE NOx emissions as a function of biodiesel content up to B20 for the state, the South Coast air basin, and the San Joaquin Valley air basins, respectively, for the years 2015, 2020, and 2023.

As shown, the potential NOx increases from extensive use of higher level biodiesel blends in NTDEs is quite large. Furthermore, although the results shown in Figures 3a through 3c are maximum potential impacts, they can again be simply scaled for other cases. For example, in order to estimate statewide NOx increases from B20 use in 50% rather than 100% of NTDEs, one would simply multiply the value of 30 tons per day by 0.5 (50/100) to arrive at a 15 ton per day increase. Finally, it should be noted that the values in Figures 3a through 3c reflect both on- and off-road NTDEs as described above for the Sierra analysis of B5 impacts.

Figure 3a
Results of Sierra Analysis of Statewide NOx Increases Due to Biodiesel Use in All NTDEs under the Proposed ADF Regulation

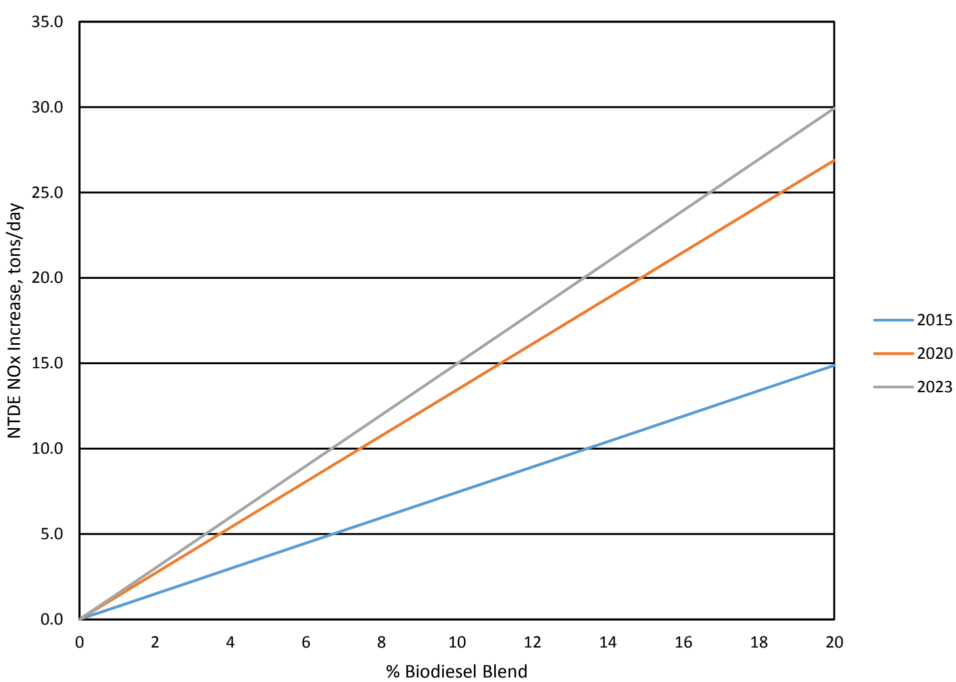


Figure 3b
Results of Sierra Analysis of South Coast Air Basin NOx Increases Due to Biodiesel Use in All NTDEs under the Proposed ADF Regulation

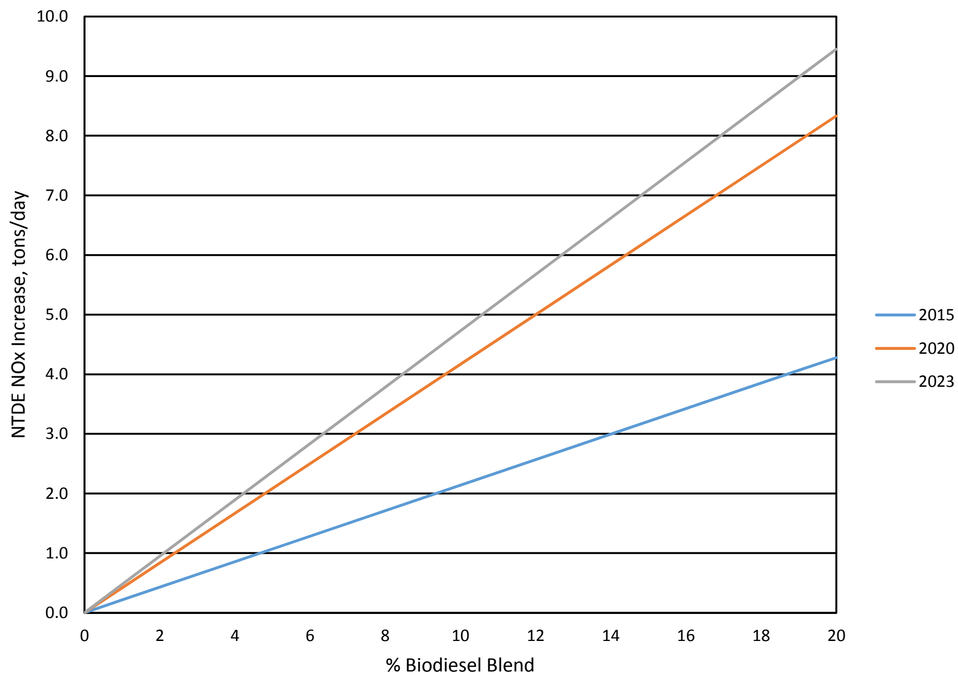
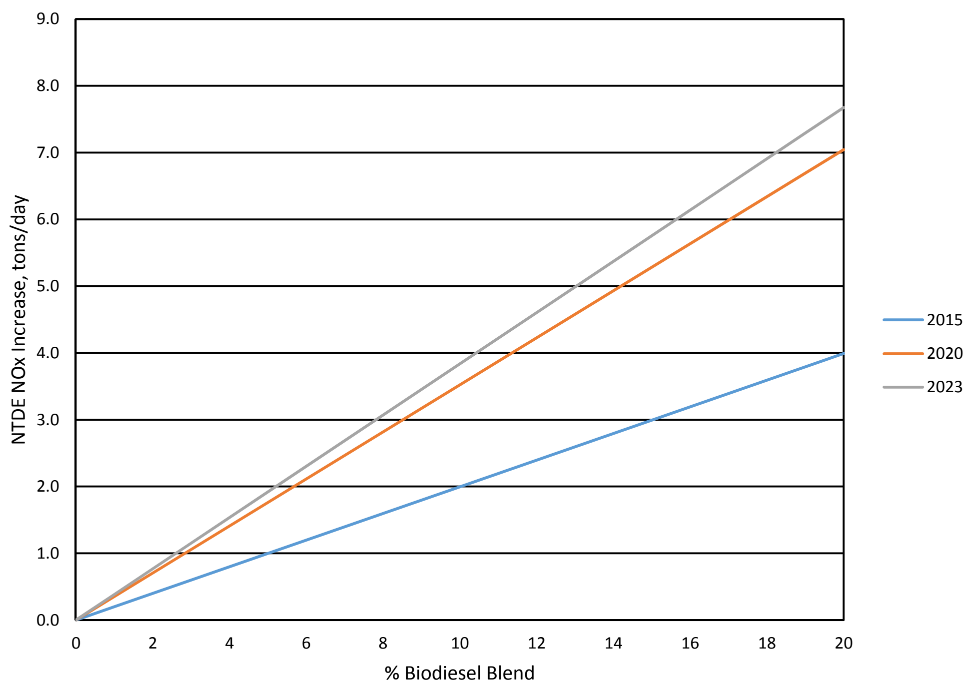


Figure 3C
Results of Sierra Analysis of San Joaquin Valley Air Basin NOx Increases Due to Biodiesel Use in All NTDEs Under the Proposed ADF Regulation



Significance of Increases in NOx Emissions Caused by Biodiesel

As illustrated above, the proposed ADF regulations are likely to lead to substantial increases in NOx emissions for the state as a whole, as well as in the South Coast and San Joaquin Valley air basins, which are in extreme nonattainment of the federal standard for ozone and experience the state's highest levels of ozone and other pollutants. The significance of the NOx increases from biodiesel can be seen by comparing those increases with air quality planning documents.

Perhaps the best initial point of reference comes from CARB's "Vision for Clean Air"[14] prepared in conjunction with the South Coast Air Quality Management District and the San Joaquin Valley Unified Air Pollution Control District. This report addresses potential control strategies that will be required to bring these extreme ozone nonattainment areas into compliance. According to the Vision report, NOx emissions will have to be reduced by 80% to 90% from 2010 levels in both the South Coast and San Joaquin Valley areas in order to achieve ozone compliance. Furthermore, in working to identify potential control strategies, the three regulatory agencies chose to focus **only** on ways to reduce NOx emissions (and not hydrocarbon emissions) because, in their words, *"NOx is the most critical pollutant for reducing regional ozone and fine particulate matter."* Given this, CARB staff's proposal to allow any NOx emission increases from the use of biodiesel is difficult to understand.

CARB staff's proposal becomes even more difficult to understand when the emission increases from biodiesel are compared to the emission benefits from adopted and proposed control measures. As an illustration, the NOx reductions expected from transportation control measures in the South Coast Basin that are part of the district's Air Quality Plan[15] are compared in Table 5 to estimated NOx emission increases under the ADF based on Sierra's analysis of B5. As shown, the increases due to biodiesel are far larger than the reductions from transportation control measures and completely offset the benefits of those measures that must be implemented as the result of their being included in the Air Quality Plan.

Table 5
Comparison of NOx Reductions from South Coast Transportation Control Measures (TCMs) and Estimated NOx Increases from Biodiesel Under the Proposed ADF Regulation

Calendar Year	NOx Reduction from TCMs, tons/day	NOx Increase due to Biodiesel tons/day
2014/2015	-0.7	2.72
2019/2020	-1.4	3.00
2023	-1.5	2.70

[14] California Air Resources Board, Vision for Clean Air: A Framework for Air Quality and Climate Planning, June 27, 2012.
[15] See South Coast 2012 AQMP. Appendix IV C. *http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2012-air-quality-management-plan/final-2012-aqmp-(february-2013)/appendix-iv-(c)-final-2012.pdf*

Similarly, the approximately two ton per day NOx increase estimated from the use of biodiesel in the San Joaquin Valley under the ADF can be compared to planned and implemented NOx control measures,[16,17] many of which have emission benefits on the order of two tons per day or less. Again, it should also be noted that the potential NOx emission increases allowed under the proposed ADF from extensive use of B20 in NDTEs without mitigation are far greater than the fleetwide impacts associated with the use of B5.

[16] San Joaquin Valley Air Pollution Control District, 2007 Ozone Plan and Appendices and Updates.
[17] San Joaquin Valley Air Pollution Control District, 2010 Ozone Mid-Course Review, June 2010.

Table 6
Results of Sierra Research Statewide Analysis

Statewide Total NOx Emissions Inventory, tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	493.3	345.0	204.9
Construction/Mining/Drilling	75.8	56.6	43.6
Cargo Handling Equipment (CHE)	4.02	3.13	2.70
Transportation Refrigiration Units (TRU)	13.33	11.25	12.26
Agricultural Equipment	34.35	19.75	13.44
TOTAL	620.8	435.7	276.9

Statewide NTDE NOx Emissions Inventory, tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	73.0	127.2	138.2
Construction/Mining/Drilling	0.8	5.5	9.0
Cargo Handling Equipment (CHE)	0.26	0.89	1.22
Transportation Refrigiration Units (TRU)	0.00	0.00	0.00
Agricultural Equipment	0.21	0.85	1.23
TOTAL	74.4	134.4	149.6

Statewide NOx Emissions Increase Due to B5 , tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	7.8550	8.5374	7.5764
Construction/Mining/Drilling	0.7916	0.7850	0.7962
Cargo Handling Equipment (CHE)	0.0506	0.0668	0.0757
Transportation Refrigiration Units (TRU)	0.1333	0.1125	0.1226
Agricultural Equipment	0.3520	0.2317	0.1837
TOTAL	9.18	9.73	8.75

Statewide NTDE NOx Emission Increase Due to B5, tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	3.6523	6.3596	6.9092
Construction/Mining/Drilling	0.0424	0.2735	0.4507
Cargo Handling Equipment (CHE)	0.0131	0.0444	0.0609
Transportation Refrigiration Units (TRU)	0.0000	0.0000	0.0000
Agricultural Equipment	0.0106	0.0427	0.0617
TOTAL	3.72	6.72	7.48

Statewide Legacy Vehicle NOx Emission Increase Due to B5, tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	4.2027	2.1778	0.6672
Construction/Mining/Drilling	0.7492	0.5115	0.3454
Cargo Handling Equipment (CHE)	0.0375	0.0224	0.0148
Transportation Refrigiration Units (TRU)	0.1333	0.1125	0.1226
Agricultural Equipment	0.3414	0.1890	0.1220
TOTAL	5.46	3.01	1.27

Table 7
Results of Sierra Research South Coast Air Basin Analysis

South Coast Total NOx Emissions Inventory, tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	153.0	107.9	62.3
Construction/Mining/Drilling	28.0	21.5	15.9
Cargo Handling Equipment (CHE)	3.21	2.53	2.20
Agricultural Equipment	2.18	1.23	0.84
TOTAL	186.4	133.1	81.3

South Coast NTDE NOx Emissions Inventory, tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	20.8	38.7	42.8
Construction/Mining/Drilling	0.3	2.1	3.3
Cargo Handling Equipment (CHE)	0.24	0.79	1.08
Agricultural Equipment	0.01	0.05	0.07
TOTAL	21.4	41.7	47.3

South Coast NOx Emission Increase Due to B5 , tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	2.3624	2.6270	2.3340
Construction/Mining/Drilling	0.2931	0.2993	0.2929
Cargo Handling Equipment (CHE)	0.0416	0.0568	0.0652
Agricultural Equipment	0.0223	0.0144	0.0113
TOTAL	2.72	3.00	2.70

South Coast NTDE NOx Emission Increase Due to B5, tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	1.0410	1.9352	2.1385
Construction/Mining/Drilling	0.0161	0.1056	0.1673
Cargo Handling Equipment (CHE)	0.0118	0.0393	0.0539
Agricultural Equipment	0.0006	0.0026	0.0037
TOTAL	1.07	2.08	2.36

South Coast Legacy Vehicle NOx Emission Increase Due to B5, tons/day			
	2015	**2020**	**2023**
Trucks (LHD1, LHD2, MHD, HHD, Buses)	1.3213	0.6918	0.1955
Construction/Mining/Drilling	0.2770	0.1938	0.1256
Cargo Handling Equipment (CHE)	0.0298	0.0175	0.0112
Agricultural Equipment	0.0216	0.0118	0.0076
TOTAL	1.65	0.91	0.34

Table 8
Results of Sierra Research San Joaquin Valley Analysis

San Joaquin Valley Total NOx Emissions Inventory, tons/day			
	2015	2020	2023
Trucks (LHD1, LHD2, MHD, HHD, Buses)	103.9	77.1	43.9
Construction/Mining/Drilling	14.0	12.1	9.4
Cargo Handling Equipment (CHE)	0.09	0.06	0.06
Agricultural Equipment	14.81	8.58	5.82
TOTAL	132.8	97.8	59.2

San Joaquin Valley NTDE NOx Emissions Inventory, tons/day			
	2015	2020	2023
Trucks (LHD1, LHD2, MHD, HHD, Buses)	19.7	33.7	35.9
Construction/Mining/Drilling	0.1	1.1	1.9
Cargo Handling Equipment (CHE)	0.00	0.01	0.01
Agricultural Equipment	0.09	0.36	0.53
TOTAL	20.0	35.2	38.4

San Joaquin Valley NOx Emission Increase Due to B5 , tons/day			
	2015	2020	2023
Trucks (LHD1, LHD2, MHD, HHD, Buses)	1.8277	2.1196	1.8769
Construction/Mining/Drilling	0.1459	0.1661	0.1696
Cargo Handling Equipment (CHE)	0.0010	0.0011	0.0011
Agricultural Equipment	0.1517	0.1003	0.0793
TOTAL	2.13	2.39	2.13

San Joaquin Valley NTDE NOx Emission Increase Due to B5, tons/day			
	2015	2020	2023
Trucks (LHD1, LHD2, MHD, HHD, Buses)	0.9857	1.6862	1.7973
Construction/Mining/Drilling	0.0075	0.0560	0.0941
Cargo Handling Equipment (CHE)	0.0001	0.0005	0.0007
Agricultural Equipment	0.0046	0.0182	0.0264
TOTAL	1.00	1.76	1.92

San Joaquin Valley Legacy Vehicle NOx Emission Increase Due to B5, tons/day			
	2015	2020	2023
Trucks (LHD1, LHD2, MHD, HHD, Buses)	0.8421	0.4333	0.0796
Construction/Mining/Drilling	0.1384	0.1101	0.0755
Cargo Handling Equipment (CHE)	0.0009	0.0005	0.0004
Agricultural Equipment	0.1471	0.0822	0.0529
TOTAL	1.13	0.63	0.21

Attachment E

Assessment of CARB's Environmental Analysis and ADF Mitigation Requirements

In developing the proposed Alternative Diesel Fuel (ADF) regulation, CARB staff has performed an environmental analysis and included mitigation requirements intended to eliminate the adverse environmental impacts associated with increased NOx emissions resulting from the use of biodiesel under the ADF.

The environmental analysis is fundamentally flawed in that staff incorrectly selected 2014 as the baseline year and performed the analysis in light of biodiesel usage levels in that year. As documented below, CARB staff has long been aware that biodiesel use leads to increases in NOx emissions, and promised but failed to act to address those emissions through enactment of an ADF regulation as early as 2009. There is no basis for an agency to use its failure to promptly act to address an environmental issue of which it was clearly aware as grounds to change the baseline for assessing its' proposed effort to address that issue. This is even more apparent given that CARB staff acknowledges that a key function of the LCFS regulation is to incent low carbon intensity fuels including biodiesel which has to date generated 13% of all credits issued by CARB under the LCFS.[1] Given this, the proper baseline for assessing the ADF regulation should be 2009 when CARB first stated it would regulate biodiesel use and when, by CARB staff's own admission, little biodiesel was used in California and NOx emissions were minimal.

The mitigation requirements of the ADF regulation are equally flawed. First, they are based on CARB's staff's fundamentally flawed emission analysis, and second their implementation is unreasonably delayed until 2018—more than ten years after CARB staff was aware that biodiesel use in California would lead to increased NOx emissions.

History of the ADF Regulation

Although the U.S. Environmental Protection Agency (EPA) published a report in 2002 showing that biodiesel use increases NOx emissions linearly with increasing biodiesel content,[2] the earliest document found on the CARB website indicates that agency discussions regarding the need to adopt regulations addressing NOx began at least as early as February 2004.[3] This led to the first meeting of the Biodiesel Work Group in April 2004.[4] A summary of that discussion

[1] See Page III-2 of the LCFS ISOR.
[2] See EPA, A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions (available at http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf).
[3] See CARB, Public Consultation Meeting Regulatory and Non-Regulatory Fuels Activities at 26-29 (Feb. 25, 2004) (available at http://www.arb.ca.gov/fuels/diesel/022504arb.pdf).
[4] See CARB Ltr. (Mar. 18, 2004) (available at http://www.arb.ca.gov/fuels/diesel/altdiesel/041204altdslwsh.pdf).

published at the time[5] it occurred indicates that topics discussed included ways to mitigate NOx emission increases associated with biodiesel use.

In 2006, CARB published a draft guidance document regarding the use of biodiesel in California,[6] at which time the agency simply decided not to address increased NOx emissions until biodiesel use became more widespread.[7] At that time, CARB instead could have ensured that there would be no NOx increases from biodiesel use by simply requiring those interested in selling biodiesel in California to demonstrate that they could formulate biodiesel blends in a way that did not increase NOx emissions, which is one of the approaches CARB is now considering.[8]

The first time CARB was scheduled to adopt regulations addressing this issue was in November 2009; this is indicated on page 12 of CARB's 2009 Rulemaking Calendar,[9] which includes the following summary:

> *Staff will propose motor vehicle fuel specifications for biodiesel and renewable diesel. These specifications are necessary for the implementation of the Low Carbon Fuel Standard regulation (to be considered at the March 2009 Hearing).*

No action was taken by CARB in 2009 and the planned adoption date was moved to June 2010; this is evidenced by CARB's 2010 Rulemaking Calendar,[10] which lists the regulatory item on page 11. This time the summary reads:

> *The staff will propose adoption of new motor vehicle fuel specifications for biodiesel and renewable diesel. These specifications are necessary to ensure that the use of these fuels will not increase emissions of criteria and toxic air pollutants when used as a motor vehicle fuel.*

Again, no action was taken by CARB in 2010 and the planned adoption date was moved to November 2011; this is evidenced by CARB's 2011 Rulemaking Calendar,[11] which lists the regulatory item on page 14. This time the summary reads:

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[5] See *CVS News*, at 27-31 (May 2004) (available at http://www.sierraresearch.com/documents/cvs_news_may_2004.pdf).
[6] See CARB, Draft Advisory on Biodiesel Use (Nov. 14, 2006) (available at http://www.arb.ca.gov/fuels/diesel/altdiesel/111606biodsl_advisory.pdf).
[7] See CARB, Suggested ARB Biodiesel Policy (May 24, 2006) (available at http://www.arb.ca.gov/fuels/diesel/altdiesel/052406arb_prsntn.pdf).
[8] See California Environmental Protection Agency, Discussion of Conceptual Approach to Regulation of Alternative Diesel Fuels (Feb. 15, 2013).
[9] See CARB, 2009 Rulemaking Calendar Schedule (available at http://www.arb.ca.gov/regact/2009rulemakingcalendar.pdf).
[10] See CARB, 2010 Rulemaking Calendar Schedule (available at http://www.arb.ca.gov/regact/2010rulemakingcalendar.pdf).
[11] See CARB, 2011 Rulemaking Calendar Schedule (available at http://www.arb.ca.gov/regact/2011rulemakingcalendar.pdf).

The Low Carbon Fuel Standard incents the use of biodiesel and renewable diesel, for which there are no current emissions–based fuel specifications. Staff will propose fuel specifications for both of these diesel blendstocks.

Yet again, no action was taken by CARB in 2011 and the planned adoption date was moved to November 2012; this is evidenced by CARB's 2012 Rulemaking Calendar,[12] which lists the regulatory item on page 14. This time the summary reads:

Rulemaking to establish commercial fuel specifications for blends of commercial diesel fuel and neat biodiesel in amounts greater than five volume percent.

Yet again, no action was taken by CARB in 2012 and, for the fourth consecutive year, the item was scheduled to be presented to the Board—the CARB Rulemaking Calendar for 2013[13] indicates on page 8 that the Board is currently scheduled to consider adoption of amendments to the agency's Alternative Diesel Fuel Regulations in September 2013. This time the summary reads:

Proposed new motor vehicle alternative diesel fuel specifications and commensurate amendments to the diesel fuel regulations.

Unlike the previous years, during 2013 CARB staff did begin to take action to actually develop a regulation that it purported would address increases in NOx emissions resulting from biodiesel use. The hearing notice[14] and Initial Statement of Reasons[15] for the proposed ADF regulation were published in October 2013, in advance of a Board hearing to be held on December 12-13, 2013. However, that hearing was postponed to until March 20, 2014,[16] and then the entire rulemaking was abandoned prior to the March 2014 hearing.[17]

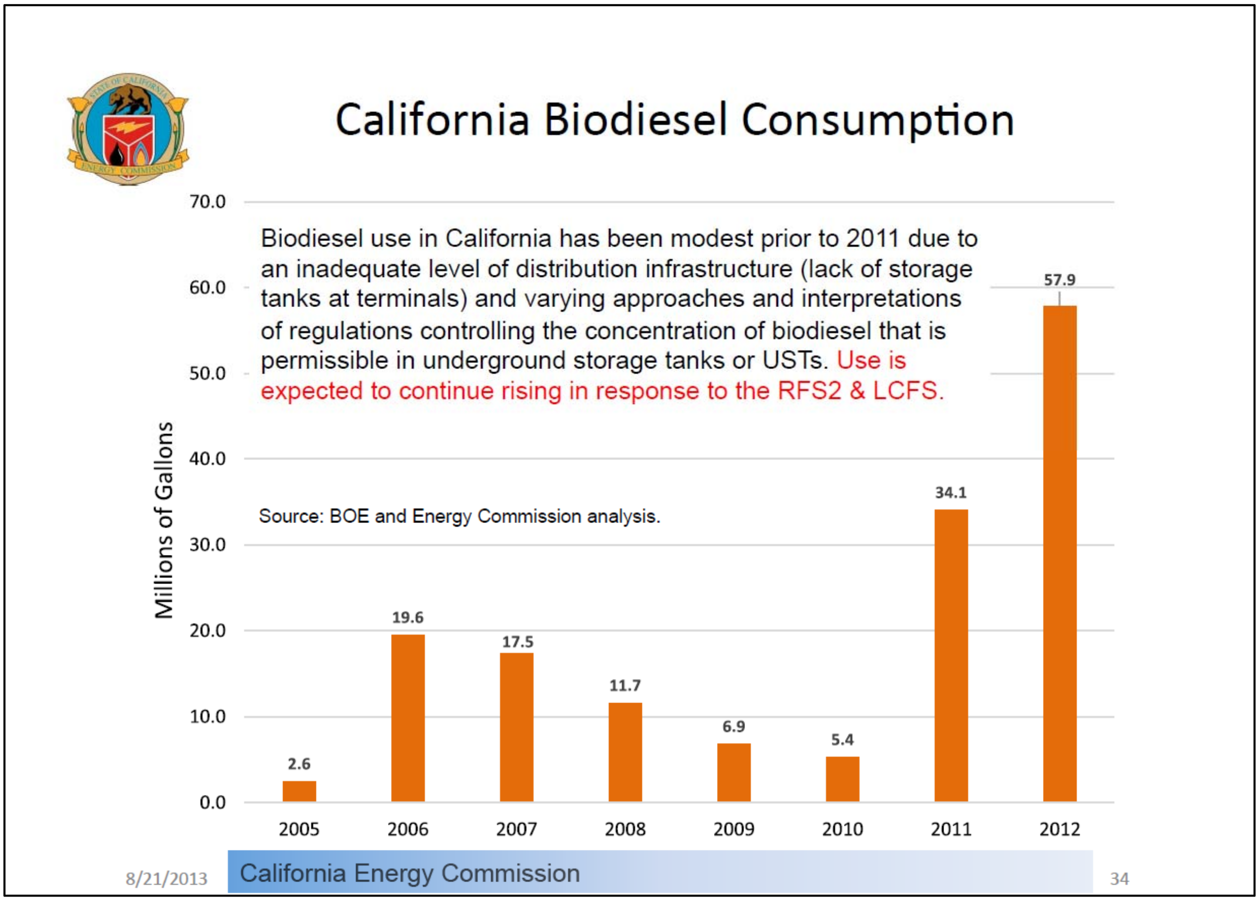
History of Biodiesel Use

Although CARB does not disclose the amounts of biodiesel used in California prior to 72 million gallons estimated in 2014 in the ADF rulemaking documents (see ISOR Appendix B), data for 2005 to 2012 are available from the California Energy Commission.[18] These data are shown in Figure 1 below. As shown, biodiesel use in California increased dramatically in 2006 when CARB staff indicated that it would not regulate biodiesel, and then decreased until the LCFS

[12] See CARB, 20012 Rulemaking Calendar Schedule (available at http://www.arb.ca.gov/regact/2012rulemakingcalendar.pdf).
[13] See CARB, 2013 Rulemaking Calendar Schedule (available at http://www.arb.ca.gov/regact/2013rmcal.pdf).
[14] See http://www.arb.ca.gov/regact/2013/adf2013/adf2013notice.pdf
[15] See http://www.arb.ca.gov/regact/2013/adf2013/adf2013isor.pdf
[16] See http://www.arb.ca.gov/regact/2013/adf2013/adf2013postpone.pdf
[17] See http://www.arb.ca.gov/regact/2013/adf2013/NDNPadf2013.pdf
[18] See http://www.energy.ca.gov/2013_energypolicy/documents/2013-08-21_workshop/presentations/06_Schremp_Biofuels.pdf

took effect in 2011 at which point it again increased dramatically. Clearly, the appropriate baseline year for analysis of the ADF regulation is 2009 or 2010 when CARB first committed to adopting a regulation to address biodiesel NOx impacts, not any later year after which substantial increases in biodiesel use occurred in response to the LCFS.

Figure 1
Biodiesel Consumption in California as Reported by the California Energy Commission



The NOx increases resulting from CARB's failure to regulate biodiesel during the period from 2005 to 2014 are summarized in Table 1. The values presented are approximate and are based on the Sierra Research methodology for 2015 adjusted to account for differences in biodiesel use as well as the absence of NTDE engines in years prior to 2010. Biodiesel use for 2014 is taken from Appendix B of the ADF ISOR, and the estimated use for 2013 assumed linear growth in biodiesel use from 2012 to 2014. Significant increases in NOx emissions from 2011 to 2014 can be seen from a comparison of the values presented in Table 1 with the values presented in Table B-1 of Appendix B to the ADF ISOR. These increased NOx emissions from 2011 to 2014 total 782, 1032, and 3,463 tons for the San Joaquin Valley, South Coast, and entire state, respectively.

Table 1 Estimated Increases in NOx Emissions Due to Biodiesel Use in California from 2005 to 2014 (tons per year)			
Calendar Year	Statewide	South Coast	San Joaquin Valley
2005	31	9	7
2006	234	70	50
2007	209	63	45
2008	140	42	30
2009	82	25	18
2010	65	19	14
2011	447	134	98
2012	825	246	184
2013	1000	298	227
2014	1191	354	273
Total	4225	1260	945

Proposed ADF Mitigation Requirements

Under the proposed ADF regulation,[19] mitigation is generally required for "low-saturation" biodiesel blends with diesel fuel above B5 (e.g., B6 and higher) during the summer, and above B10 (e.g., B11 and higher) during the winter, unless the fuels are used in vehicles with new technology diesel engines in which case mitigation is not required for levels up to B20. For "high-saturation" biodiesel blends with diesel fuel, mitigation is required year-round above B10 (e.g., B11 and higher) again, unless the fuels are used in vehicles with new technology diesel engines in which case mitigation is not required for levels up to B20. However, no mitigation is required for any biodiesel blend sold in California prior to January 1, 2018.

According to the ADF ISOR,[20] CARB staff selected these levels based on an "analysis" for which no detail or documentation has been provided, and that reportedly included consideration of the impacts of new technology diesel engines (NTDEs) and the use of renewable diesel as "offsetting factors." Although it is impossible to thoroughly review an analysis which is not described in detail, in this case it can still be demonstrated to be fundamentally flawed. As discussed elsewhere, CARB incorrectly assumes that NOx emissions from NTDEs are unaffected by biodiesel despite the fact that available data show statistically significant increases in NOx emissions. Further, CARB cannot rely on the use of renewable diesel as mitigation for NOx increases from biodiesel as there is nothing in the ADF or the LCFS regulation that mandates the use of any volume of renewable diesel in California, nor which links the amount of renewable diesel used to the amount of biodiesel used. Further, neither the ADF nor LCFS regulations ensure that fuel producers will use biodiesel in a manner that provides surplus

[19] Proposed section 2293.6 Title 13, CCR in ISOR Appendix A.
[20] Chapter 6, Part H.

reductions[21] in NOx emissions. Given that CARB's reliance on "offsetting factors" is fundamentally flawed, the agency's "Determination of NOx Control Level for Biodiesel" is also fundamentally flawed. Another problem with the "determination" is that CARB staff claims to have performed an "analysis" for which no detail or documentation is provided, indicating that the higher blend level threshold for mitigation that applies to "low-saturation" blends during the winter months will not result in adverse air quality impacts. Again, it is not possible to critically review an analysis which is not described in detail; further, the information provided in this analysis is so insufficient that it is not even possible to develop an appropriate set of comments.

In addition to the flaws in CARB staff's analysis of what mitigation should be applied to address the increased NOx emissions associated with biodiesel use, CARB staff is arbitrarily delaying the date on which mitigation is required by two years from the expected effective date of the ADF regulation. According to ADF ISOR, CARB staff claim the reason for this delay is:

> *ARB is also proposing the in-use requirements come into effect on January 1, 2018, as time is needed to overcome logistical and other issues in implementation of in-use requirements. For example, use of the additive Di-tert-butyl peroxide (DTBP) will require replacement of steel tanks with stainless steel tanks, permitting of hazardous substance storage, approval by local fire agencies, additional additization infrastructure, and logistical business changes to acquire the additive. All of this is expected to take around 2 years to complete. Another method of compliance is re-routing higher blends to NTDEs. Research shows that the use of biodiesel in blends up to B20 in NTDEs results in no detrimental NOx impacts. This and other methods of complying with the in-use requirements, such as certification of additional options are also expected to take 2 years or more. Because compliance with the in-use options would be infeasible during initial implementation on January 1, 2016, only recordkeeping and reporting provisions will be implemented initially. The in-use requirements are proposed to come into effect on January 1, 2018.*

It is not clear why CARB staff believes that a two year delay in the implementation of mitigation requirements is required under the ADF regulation when the maximum delay in the implementation of new requirements under the LCFS regulation, which will much more dramatically impact fuel producers than the ADF requirements, is only one year, until January 1, 2017. Further, as the biodiesel industry has been on notice that CARB intended to impose NOx mitigation requirements for over ten years, it is not clear why such measures cannot be required from the expected January 1, 2016 effective date of the proposed regulation.

The impact of the failure to immediately require Biodiesel mitigation under the ADF regulation is shown in Table 2. These values are based on the Sierra Research emissions methodology which assumes statewide use of B5. As discussed elsewhere, these impacts

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[21] In order to generate surplus reductions in NOx, renewable diesel would have to be blended into diesel fuel downstream of refineries, and although CARB staff has assumed that this will occur they have provided no basis for that assumption.

are significant in that the increases are as large or larger than those sought from emission control measures implemented of under consideration by CARB and local air pollution control agencies in the South Coast and San Joaquin Valley air basins.

Table 2
Potential NOx Increases Due to CARB's Failure to Require Immediate Biodiesel Mitigation Under the ADF
(tons per year)

	Statewide	South Coast	San Joaquin Valley
2016	3405	1013	796
2017	3460	1034	815
Total	6866	2047	1612

Attachment F

Potential for Actual Biodiesel Blend Levels to Exceed Levels Purported Under the Proposed ADF Regulation

In order to properly understand and mitigate the adverse environmental impacts of biodiesel blends sold in California, it is critical that the actual amount of biodiesel present in a blend be accurately known. Despite this, the proposed ADF regulation fails to adequately ensure that the actual biodiesel content of biodiesel blends—and therefore their adverse environmental impacts—will be accurately known or appropriately mitigated. As discussed below, significant changes are required to definitions used in the proposed LCFS and ADF regulations, and new testing, recordkeeping, and reporting requirements need to be added to the ADF regulation to prevent the blending of biodiesel with fuels that already contain undisclosed amounts of biodiesel.

Background

CARB regulations at §2281 and §2282, Title 13, California Code of Regulations apply to vehicular diesel fuel sold in California and define "diesel fuel" as follows:

> *"Diesel fuel" means any fuel that is commonly or commercially known, sold or represented as diesel fuel, including any mixture of primarily liquid hydrocarbons – organic compounds consisting exclusively of the elements carbon and hydrogen – that is sold or represented as suitable for use in an internal combustion, compression-ignition engine."*[1]

The proposed LCFS regulation contains the following definitions that are relevant to biodiesel blends (See ISOR Appendix A):[2]

> *"B100" means biodiesel meeting ASTM D6751-14 (2014) (Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels), which is incorporated herein by reference.*
>
> *"Biodiesel" means a diesel fuel substitute produced from nonpetroleum renewable resources that meet the registration requirements for fuels and fuel additives established by the Environmental Protection Agency under section 211 of the Clean Air Act. It includes biodiesel meeting all the following:*

[1] 13 CCR §2281(b)(1) and §2282(b)(3)
[2] See proposed §95481, Title 17, California Code of Regulations

(A) Registered as a motor vehicle fuel or fuel additive under 40 Code of Federal Regulations (CFR) part 79;
(B) A mono-alkyl ester;
(C) Meets ASTM D6751-08 (2014), Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels, which is incorporated herein by reference;
(D) Intended for use in engines that are designed to run on conventional diesel fuel; and
(E) Derived from nonpetroleum renewable resources.

"Biodiesel Blend" means a blend of biodiesel and diesel fuel containing 6 percent (B6) to 20 percent (B20) biodiesel and meeting ASTM D7467-13 (2013), Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20), which is incorporated herein by reference.

"Diesel Fuel" (also called conventional diesel fuel) has the same meaning as specified in California Code of Regulations, title 13, section 2281(b).

"Diesel Fuel Blend" means a blend of diesel fuel and biodiesel containing no more than 5 percent (B5) biodiesel by weight and meeting ASTM D975-14a, (2014), Standard Specification for Diesel Fuel Oils, which is incorporated herein by reference.

Finally, the proposed ADF regulation contains the following definitions that are relevant to biodiesel blends:[3]

"Alternative diesel fuel" or "ADF" means any fuel used in a compression ignition engine that is not petroleum-based, does not consist solely of hydrocarbons, and is not subject to a specification under subarticle 1 of this article.

"Biodiesel" means a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats that is 99-100 percent biodiesel by volume (B100 or B99) and meets the specifications set forth by ASTM International in the latest version of Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels D6751 contained in the ASTM publication entitled: Annual Book of ASTM Standards, Section 5, as defined in California Code of Regulations, title 4, section 4140(a), which is hereby incorporated by reference.

"Biodiesel Blend" means biodiesel blended with petroleum-based CARB diesel fuel or non-ester renewable diesel.

[3] See proposed §2293.2(a), Title 13, California Code of Regulations

"Blend Level" means 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").

"B5" means a biodiesel blend containing no more than five percent biodiesel by volume.

"B20" means a biodiesel blend containing more than five and no more than 20 percent biodiesel by volume.

"CARB diesel" means 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 California Code of Regulations, title 13, section 2281 et seq. "CARB diesel" may include: non-ester renewable diesel; gas-to-liquid fuels; Fischer-Tropsch diesel; diesel fuel produced from renewable crude; CARB diesel blended with additives specifically formulated to reduce emissions of one or more criteria or toxic air contaminants relative to reference CARB diesel; and CARB diesel specifically formulated to reduce emissions of one or more criteria or toxic air contaminants relative to reference CARB diesel.

Discussion

The first issue related to the potential for uncertainty and inaccuracy in actual biodiesel content of fuels sold in California involves the different definitions that have been proposed for the term "biodiesel" under the proposed LCFS and ADF regulations. Although the two definitions may be functionally equivalent, they should be made the same under both the LCFS and ADF regulations unless CARB staff can articulate a compelling need for the use of different definitions to describe the same thing.

More importantly, the term "Biodiesel Blend" in the proposed LCFS regulation directly conflicts with the use of the same exact term in the proposed ADF regulation: a "Biodiesel Blend" under the LCFS regulations contains at least 6% biodiesel, while a "Biodiesel Blend" under the ADF is a diesel fuel containing any biodiesel. Furthermore, the LCFS regulation defines "Diesel Fuel Blend" as a blend of diesel fuel and up to 5% biodiesel, while such a fuel would be considered "CARB diesel" under the ADF regulation. Again, this haphazard use of the same term to describe fundamentally different fuels and different terms to describe the same fuel will assuredly lead to confusion in practice regarding the actual content of biodiesel available in California.

Further confusion is created by the definitions of "Biodiesel Blend" and "Blend Level" under the proposed ADF regulation. "Biodiesel Blend" is defined as a mixture of biodiesel and an undefined fuel referred to as "petroleum-based CARB diesel." "Blend

Level" applies to blends of all fuels subject to the ADF regulation, including biodiesel, and is defined as the ratio of an "Alternative diesel fuel" mixed with "CARB diesel." However, as noted above, "CARB diesel" may already contain as much as 5% biodiesel under the proposed ADF regulation. Furthermore, the definition of "Blend Level" includes no reference to the fuel termed "petroleum-based CARB diesel" that appears in the definition of "Biodiesel Blend" under the ADF—instead, it refers to "CARB diesel," which, as noted above, may contain as much as 5% biodiesel. Obviously, the addition of biodiesel to a fuel already containing some amount of biodiesel up to 5% will cause the actual biodiesel content to be higher than the blender expects; this, in turn, will lead to more significant adverse environmental impacts than expected. It is also clear that CARB staff mean for the definition of "Blend Level" to apply to "Biodiesel Blends," as that definition uses an example based on biodiesel (B20) to demonstrate the practical meaning of "Blend Level."

Finally, under the proposed ADF regulation, "B20" is nonsensically defined as a fuel that contains between 6% and 20% biodiesel, which directly contradicts the definition of "Blend Level" in same regulation. There appears to be no need for this definition or the definition of B5 in the proposed ADF regulation.

As outlined above, the proposed CARB LCFS and ADF regulations fail completely in clearly defining the four fuels that are of fundamental importance to ensuring that the biodiesel content of a fuels sold in California—and hence the adverse environmental impacts associated with their use—is accurately known. Instead, the proposed regulations make it likely that biodiesel blenders will unknowingly use fuels that already contain an unknown amount of biodiesel (up to 5%) in blending and that the actual biodiesel content of biodiesel blends may be as much as 5% greater than that represented by the blender and reported to CARB under the ADF regulation. This is significant because, as discussed in other attachments to this declaration, the increases in NOx emissions and associated adverse environmental impacts caused by biodiesel blends become larger in direct proportion to the amount of biodiesel present.

Both the LCFS and the ADF regulation must clearly define the four fuels described below.

1. ***"Diesel fuel"* –** This should defined as under 13 CCR §2281(b)(1) and §2282(b)(3).

2. ***"Biodiesel"*** or "***B100"* –** It appears that this could be properly defined through changes to the definitions currently proposed in the LCFS and ADF regulations; this is what should be blended only with "diesel fuel" to create a "Biodiesel Blend."

3. ***"CARB diesel"* –** This is accurately defined under the proposed ADF regulation, but under no circumstances should it be allowed to be blended with biodiesel or any other ADF. It should be renamed to clearly differentiate it from "diesel fuel" such that no reasonable person would understand that it could be legally mixed with any ADF.

4. ***"Biodiesel Blend"* –** This should refer to the "Blend Level" and must correspond to the actual amount of "Biodiesel" or "B100" in terms of percentage by volume in the final blend with "diesel fuel."

In addition to modifying the definitions as described above, the ADF regulation must also be modified to ensure that biodiesel blenders do not intentionally or unintentionally blend biodiesel into fuels that already contain biodiesel. This can easily be achieved by adding requirements to proposed §2293.8 Title 13, CCR, to require that any "diesel fuel" to be used in blending with biodiesel be tested for the presence of biodiesel prior to blending. Similarly, that section should be modified to include reporting and record keeping requirements for biodiesel blenders that document that they have used only biodiesel-free "diesel fuel" in all of their blending operations.

Attachment G

The Growth Energy Alternative to Proposed ADF Regulation is the Least-Burdensome Approach that Best Achieves the Project Objectives at the Least Cost That Must be Adopted

As part of the rulemaking process leading to CARB staff's proposed ADF regulation, staff was required to solicit and consider alternatives to the proposed regulation. Growth Energy submitted such an alternative which CARB staff acknowledged provided equivalent or superior reductions in NOx emissions from biodiesel use but rejected as being more costly. However, as is documented in detail below, CARB staff made fundamental errors in its' assessment of the Growth Energy Alternative, which will in fact provide greater reductions in NOx emissions from biodiesel use than the staff's proposed ADF regulation but do so with equal cost-effectiveness. (Equal cost-effectiveness means that the dollars spent per unit mass of NOx emissions eliminated will be the same.) Given that the Growth Energy alternative provides greater environmental benefits, which in turn substantially lessen the ADF's significant impacts, and is equally cost-effective as the staff's proposed ADF regulation, the Growth Energy Alternative rather than the staff proposal should be adopted by CARB.

Background

On July 29, 2014, CARB published a "Solicitation of Alternatives for Analysis in the Alternative Diesel Fuel Standardized Regulatory Impact Assessment" which is attached. On August 15, 2014, Growth Energy submitted an alternative regulatory proposal for the ADF regulation (which is attached) to CARB in response to the agency's solicitation. On December 30, 2014, CARB staff published both the ISOR for the ADF regulation as well as a document entitled "Summary of DOF Comments to the Combined LCFS/ADF SRIA and ARB Responses" which is Appendix E to the ADF ISOR, both of which include information related to staff's decision to reject the alternative to the ADF regulation proposed by Growth Energy.

The staff's assessment of the Growth Energy (GE) Alternative published in Appendix E of the ADF ISOR is as follows (emphasis added):

> ***Benefits:***
>
> ***ARB finds that the GE alternative would meet the emissions goals of the ADF proposal and achieve roughly the same emissions benefits as the ADF proposal. The GE alternative may achieve marginally more emissions benefits if biodiesel were to be widely used as an additive under the ADF proposal. Although the GE alternative is simpler than the ADF proposal, the GE alternative is unnecessarily strict; ARB's analysis of the science does not find that there are NO_X increases with B5 animal biodiesel or biodiesel used in NTDEs, so***

requiring mitigation for these does not achieve any additional emissions benefit versus the ADF proposal.

Costs:

The GE alternative would require mitigation of more fuel than the ADF proposal; regulated parties would incur more costs to mitigate non-animal- and animal-based biodiesel similarly and setting the significance level for both at one percent. Additionally, the NTDE exemption would increase the volumes of fuels to be mitigated, further increasing the direct costs on regulated parties.

Economic Impacts:

The REMI results also indicate that the combined LCFS/ADF proposal has no discernible difference from the GE alternative. Employment, GSP, and output differ only slightly and represent a difference of less than one tenth of one percent. Given that the GE alternative has higher direct costs, the combined LCFS/ADF alternative is preferred.

Cost-Effectiveness:

The GE alternative costs more than the ADF proposal, because it requires mitigation of more biodiesel than the ADF proposal. The GE alternative does not result in any more emissions reductions than the ADF proposal and as such is less cost effective than the ADF proposal.

Reason for Rejection:

ARB rejects the GE alternative because it costs more than the ADF proposal and does not achieve additional emissions benefits*.*

The reason for rejection of the Growth Energy (GE) alternative presented in the ADF ISOR itself is as follows:

This alternative proposal retains the same biodiesel NOx mitigation options as the ADF proposal*. However, under the GE alternative, animal and non-animal biodiesel would be treated equally and require NOx mitigation for all biodiesel blends, including blends below B5.* ***ARB rejects this alternative because the costs are significantly higher than the ADF proposal and do not achieve additional emissions benefits.*** *During the development of this regulation, staff considered alternatives to the proposal and determined that the proposal represents the least-burdensome approach that best achieves the objectives at the least cost.*

Finally, it should be noted that the stated intention of the ADF regulation according to CARB staff in the ADF ISOR is as follows (emphasis added):

*The ADF regulation is intended to create a framework for these low carbon diesel fuel substitutes to enter the commercial market in California, **<u>while mitigating any potential environmental or public health impacts</u>**.*

<u>Discussion</u>

As indicated above, the stated reason why CARB staff rejected the Growth Energy alternative to the proposed ADF regulation is because CARB staff believed it would require that actions be taken to mitigate increased NOx emissions from biodiesel under circumstances where CARB staff incorrectly assumed there would no increased emissions due to biodiesel use on under the ADF. However, as is clearly demonstrated in another attachment to the declaration of James M. Lyons,[1] CARB staff's analysis and assumptions of the increases in NOx emissions that will result for the ADF regulation is fatally flawed as is CARB's basis for rejection of the Growth Energy Alternative.

As shown by the Sierra emissions analysis, once the flaws in the CARB emissions analysis are corrected, it becomes clear that the ADF regulation will allow significant and unmitigated increases in NOx emissions to occur throughout California including areas such as the South Coast and San Joaquin air basins which experience the worst air quality in the state. As CARB staff itself admits, the Growth Energy alternative would require mitigation in exactly those areas where CARB staff was lead to believe it was not required based on its flawed emissions analysis. CARB staff also admits the Growth Energy alternative is based on the same mitigation options contained in the ADF regulation, which CARB staff has already determined to be technically feasible and cost-effective. However, the Growth Energy Alternative is superior to the ADF regulation because it expands the conditions under which this mitigation has to be applied in order to eliminate the potential for any increase in NOx emissions due to biodiesel use to a less-than-significant level. The Growth Energy Alternative therefore precludes any adverse environmental impacts due to increased NOx emissions, which is exactly what CARB staff has asserted the ADF regulation is intended to do.

Given that the Growth Energy alternative:

1. Provides complete mitigation of potential NOx emission increases due to biodiesel use under the ADF and any associated adverse environmental impacts; and

2. Relies on the same mitigation strategies proposed by CARB staff which staff has found to be technically feasible and cost-effective,

CARB must adopt the Growth Energy alternative as it better achieves the stated project objectives in an equally cost-effective manner.

[1] Review of CARB Staff Estimates of NOx Emission Increases Associated with the Use of Biodiesel in California under the Proposed ADF Regulation.

Attachment 4

NOx EMISSIONS IMPACTS OF BIODIESEL BLENDS

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February 10, 2015

NOx EMISSIONS IMPACTS OF BIODIESEL BLENDS

Table of Contents

List of Figures

List of Tables

NOx EMISSION IMPACTS OF BIODIESEL BLENDS

1. EXECUTIVE SUMMARY

The purpose of the Alternative Diesel Fuels (ADF) rulemaking, according to the Air Resources Board (ARB), is to create a regulatory framework that will permit biodiesel and other low-carbon, alternative diesel fuels to "enter the commercial market in California, while mitigating any potential environmental or public health impacts." [1]

The work presented in this report assesses the impacts of biodiesel use on NOx emissions from conventional and new technology diesel engines. It was performed by Rincon Ranch Consulting under subcontract to Sierra Research at the request of Growth Energy.

At present, most diesel fuel and biodiesel is consumed in conventional diesel engines that do not have exhaust gas after-treatment to reduce NOx emissions. The consensus of the literature is that biodiesel will increase NOx emissions by amounts that depend on the blending percentage (how much biodiesel is present in the diesel fuel) and the type of biodiesel feedstock (soy versus animal sources). NOx increases of 1-2% are expected from soy biodiesel at blend levels of B5 to B10 with smaller increases expected, in general, from animal biodiesel at the B5 to B10 level.

Over time, new technology diesel engines (NTDEs) equipped with exhaust gas after-treatment controls for NOx will increasingly make up the heavy duty fleet in response to other ARB programs. While baseline emissions from these engines will be reduced compared to conventional engines, the consensus of the literature available today is that use of biodiesel will still increase NOx emissions above the reduced baseline. At the B20 level, the NOx increase appears to be greater on a percentage basis than would be expected in conventional diesel engines.

The results of this work indicate the following with respect to conventional diesel engines:

- Soy biodiesels will increase NOx emissions at the B5 and B10 levels by approximately 1% and 2%, respectively. This work and Staff's analysis concur in both the conclusion and the estimated levels of NOx increase at B5 and B10. Soy biodiesels in this blend range require NOx mitigation on a per-gallon basis in order to prevent increases in NOx emissions.

- The consensus of the research community is that the effect of soy biodiesel on NOx emissions is continuous and linear with respect to the blending percentage. NOx

[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. January 2, 2015. http://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf. Page 11.

increases have been observed at levels as low as B1.[2] The statistical analysis performed for ARB by Rocke supports this conclusion and estimates that soy biodiesel will increase NOx emissions by about 0.2% for each 1% biodiesel in the blend (0.99% for each 5% biodiesel).

In spite of this consensus, the Staff proposal requires NOx mitigation for soy-based biodiesel only above the B5 level in summer months and above the B10 level in winter months. Soy biodiesel blended at the B5 and lower levels would not require mitigation in any circumstance. The ADF regulatory framework must require mitigation of soy-based biodiesels at all blend levels if it is to ensure that such fuels do not increase NOx emissions.

- The effect of animal-based biodiesel on NOx emissions is more complicated than for soy-based blends. As the available literature demonstrates, some animal-based biodiesels will increase NOx emissions while other animal biodiesels will not. While Staff's proposal would establish B10 as the control level for animal-based biodiesel (e.g., mitigation would be required year-round for blends above B10), the available data do not support Staff's conclusion that there will not be increases in NOx emissions from B10 and lower blends. Given the Staff proposal, the only way to ensure that animal-based biodiesel does not increase NOx emissions is to require mitigation at all blend levels.
- Staff presents information indicating that animal biodiesels decrease NOx by 0.2% on average and that the emissions change in comparison to CARB diesel fuel is not statistically significant. The average and the test for statistical significance are both flawed by the failure to consider the varying effects that animal feedstocks have on Cetane Number (CN). The absence of CN as a variable in Staff's analysis leads Staff to wrongly conclude that animal biodiesels will not increase NOx below the B10 level.
- It is well established that increasing CN will reduce NOx emissions from diesel engines. Whether an animal biodiesel will increase NOx depends primarily on the extent to which the feedstock blending increases the CN of the blended fuel. Soy and animal biodiesel blends are not categorically different fuels once the differing effect of soy- and animal-feedstocks on CN is taken into account.

With respect to new technology diesel engines (NTDEs):

- Staff is incorrect in concluding that biodiesel use will not increase NOx in NTDEs. This conclusion is based on a highly selective reading of the technical literature (choosing one of four available studies) and relies on the one study in which the laboratory was not well equipped to measure the low levels of tailpipe NOx emissions from NTDEs.
- A fair reading of the technical literature indicates that B20 biodiesel will increase NOx emissions by about 20% in NTDEs. The four best studies estimate that B20 biodiesel

[2] McCormick 2002 tested a Fisher-Tropsch (FT) base fuel blended at the B1, B20, and B80 levels. Although the very high FT cetane number (≥75) takes it out of the range of commercial diesel fuels, the study nevertheless measured higher NOx emissions at the B1 level than it did on the FT base fuel.

increases NOx by 18-22% in NTDEs and that the increase is statistically significant. This is a greater percentage NOx increase in proportion to blend level than the increase caused by soy biodiesel in conventional diesel engines (1% at B5, 2% at B10 and ~4% at B20).

- The technical literature also indicates that one should expect NOx emissions to increase at blend levels below B20, with the size of the NOx increase being proportionate to blend level. At the B5 level, NOx emissions from NTDEs are expected to increase by about 5%.
- Staff makes no mention of the concern that use of biodiesel fuels in NTDEs may lead to the loss of NOx conversion efficiency in urea-SCR systems by shifting the NO_2/NOx ratio to lower values. Staff's proposal to allow B20 biodiesel to be used in NTDEs without mitigation potentially places at risk the investment in NOx after-treatment systems to meet the stringent NOx certification levels now in effect.

This analysis demonstrates that the proposed regulations will not "ensure that the use of biodiesel due to LCFS will not result in increases in NOx emissions in California." In fact, the regulations will result in increased NOx emissions in California from the following:

- B5 and lower soy biodiesels year round;
- B6 to B10 soy biodiesels in winter;
- At least some B10 and lower animal biodiesels year-round; and
- B20 and lower biodiesels of all types in NTDEs.

To our knowledge, ARB has not formulated a position on the level of NOx increase from alternative diesel fuel that is too small to warrant concern. A point of comparison for the NOx increases permitted by the proposed ADF regulations is the ARB program for Reformulated Gasoline (RFG). The RFG program permits alternative gasoline formulations to be sold in the California market provided they are demonstrated to be emissions equivalent to a reference gasoline using the Predictive Model for RFG. The emissions analysis differs somewhat for winter and summer gasoline, but in no instance may the alternative formulation increase emissions of the pollutants considered by more than 0.05%.

The biodiesel NOx emission increases permitted under the proposed ADF regulations dwarf the 0.05% threshold applied to RFG. Soy biodiesel will increase NOx by more than 0.05% at blend levels above 0.25% biodiesel (B0.25). Some animal biodiesels will increase NOx by 0.05% or more at blend levels twice as high (B0.5). The NOx emissions increase in NTDEs appears to be substantially greater on a percentage basis, so that biodiesels will exceed the 0.05% threshold at much lower blend levels.

In the ISOR, Staff uses the term "low saturation" to refer to soy and other feedstocks with $CN < 56$ and "high saturation" to refer to feedstocks, including animal sources, with $CN \geq 56$. Classification based on saturation is useful because of its association with CN. By itself, however, it does not alleviate the concerns regarding NOx increases from unmitigated fuels.

The analysis presented here indicates that CN changes induced by biodiesel blending have a large influence on the size of the NOx increase that is observed. Soy (low saturation) biodiesels adversely affect CN leading to larger NOx increases; animal (high saturation) biodiesels increase CN leading to smaller NOx increases. In fact, soy and animal biodiesels are not categorically different fuels once their differing effect on blend CN is taken into account.

It is strongly recommended that ARB consider as part of the ADF 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. The analysis documented in this report provides a possible form for a biodiesel predictive model.

2. NOX EMISSIONS FROM CONVENTIONAL DIESEL ENGINES

2.1 ARB Analysis in Support of the Proposed Regulations

In support of the proposed regulations, ARB commissioned an analysis of the available NOx emissions data by David M. Rocke, PhD. The results of the analysis are reported in Appendix G: Supplemental Statistical Analysis[3] to the ISOR. The analysis used NOx emission measurements on ULSD, B5, and B10 fuels in conventional diesel engines from five studies. The dataset is substantially the same as that used by Rincon Ranch Consulting in the analysis presented later in this section.

The Rocke analysis formulated a series of statistical models involving log(NOx) as the dependent variable and used a statistical approach termed Mixed Effects modeling to estimate the coefficient values. The Mixed Effects approach has statistical advantages over more commonly used methods when dealing with unbalanced datasets, as is the case here. A number of different models were specified, estimated, and the results compared in order to ensure that conclusions drawn from the analysis do not depend upon the model specifications.

For soy-based biodiesel, the Rocke study concludes that soy fuels increase NOx by 1% at B5 and by 2% at B10. The study also demonstrated that the NOx increase is linearly related to the blend level. The slope was estimated to be 0.99% for each 5% biodiesel in a blend and was highly significant statistically ($p \ll 0.001$). These results agree with the Rincon Ranch analysis presented later in this report. <u>There is no controversy with regard to the NOx impact of soy-based biodiesel.</u> Soy biodiesel will increase NOx emissions at all blend levels by about 0.2% for each 1% biodiesel in the blend.

With respect to animal biodiesel, the Rocke study concludes that animal biodiesel does not increase NOx emissions at B5 or B10. The emission changes that are observed are not statistically significant. <u>There is controversy here because the Rocke analysis did not account for the effect of feedstock blending on the CN of the tested fuels</u>. The CN change compared to ULSD is a fixed effect that must be accounted for because the four animal feedstocks that have been used in the technical literature show substantially different cetane behavior in blending.

[3] http://www.arb.ca.gov/regact/2015/adf2015/adf15appg.pdf.

The case for cetane as an explanatory variable for NOx emissions in animal blends is made in Section 2.2.4 of this report. It is well established that increasing CN will reduce NOx emissions from diesel engines. For example, ARB has shown that the additive DTBP can be used to raise CN and mitigate NOx increases caused by biodiesel blending. Whether an animal biodiesel will increase NOx depends primarily on the extent to which the feedstock blending increases CN of the blended fuel. The two animal blends that showed the smallest CN gain over ULSD caused statistically significant NOx increases in the engines tested. The one animal blend that showed the largest CN gain was certified to be NOx neutral, while the animal blend with the next largest CN gain may or may not be NOx neutral. Cetane appears to blend linearly when using soy feedstocks, so that the CN gain over ULSD is highly correlated with blend level. The same is not true for animal feedstocks, where highly non-linear blending behavior has been observed.

The Rocke analysis used a Mixed Effects model to estimate the NOx emissions change at B5 and B10. For animal blends, it concluded that the observed emission changes are not statistically significant. Implicit in the approach is the assumption that the fuels being tested are different, individual realizations from a homogenous population. In this instance, the residual variation not accounted for by the blend level is a random effect representing the scatter in test results due to a variety of factors. The statistical significance of the blend level effect (a fixed effect) is judged in comparison to the residual variation. When the residual variation is large in comparison to the fixed effect, the latter is said to be not statistically significant.

The assumption of a homogenous population is appropriate for soy-based biodiesels. One soybean is much like the next, and the only appreciable differences among soy fuels will result from the methods of preparation. However, the assumption of homogeneity is not appropriate for animal-based biodiesels, which can be drawn from a variety of animal sources and prepared in different ways. The non-homogeneity is seen most readily in the greatly different cetane responses of biodiesel fuels:

- In the McCormick 2005 and Durbin 2011 studies, the animal feedstocks increased the CN of the biodiesel blends by small amounts. These fuels led to statistically significant increases in NOx.
- In the Durbin 2013A study, blending at the B5 level was sufficient to raise the CN of the blend by 8 numbers to reach the cetane level of the feedstock itself. This fuel was certified as NOx neutral at B5.
- The animal feedstock used in the Karavalakis 2014 study was intermediate in its CN effect and also intermediate in its NOx effect.

Because the ARB and Rocke studies have not included cetane as an explanatory variable for animal-based biodiesels, the residual variation term has been enlarged since a portion of it could be accounted for by including a fixed-effects term for cetane. With an enlarged estimate of the residual variance, the studies more easily find that the fixed effect of blend level is not statistically significant.

The absence of cetane as an explanatory variable also affects other methods of analysis used by Rocke. In a t-test comparison of emission differences between biodiesel and ULSD, Rocke finds two cases in which animal B5 changes NOx by statistically significant amounts (one increasing NOx and the other decreasing NOx) and one such case in animal B10 (decreasing NOx), while the other cases show no statistically significant change compared to the base fuel. The study wrongly concludes that these results demonstrate no or little systematic evidence for B5 or B10 animal to increase NOx emissions. In fact, these cases are systematically related to the CN gain of the animal blends in comparison to the base fuel.

The Rocke analysis was well planned and executed, and we concur with the conclusions drawn for soy-based blends. Because the analysis for animal-based blends is flawed by omission of a cetane variable, it should be revised to address CN gain. We expect that a revised analysis will shed further light on the circumstances in which animal-based biodiesels will and will not increase NOx emissions.

2.2 Rincon Ranch Analysis of ARB NOx Emissions Data

In July 2014, ARB released two datasets that represent the fruit of its efforts to compile the available biodiesel NOx emissions test data on conventional heavy-duty truck (HDT) engines. This report and the companion file *"Biodiesel Emissions Analysis Technical Summary 102014.pdf,"* which is attached to and incorporated in this report, 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.

The analysis presented below focused on whether soy and animal blends will increase NOx at low blend levels in conventional diesel engines. 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 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.

2.2.1 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 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.

2.2.2 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, are 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. The statistical analyses 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.

2.2.3 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[4] statistically for one engine.

- 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 some animal blends will significantly increase NOx emissions, while other animal blends will not. The fundamental issue is then understanding what the NOx impact of a particular animal biodiesel blend will be.

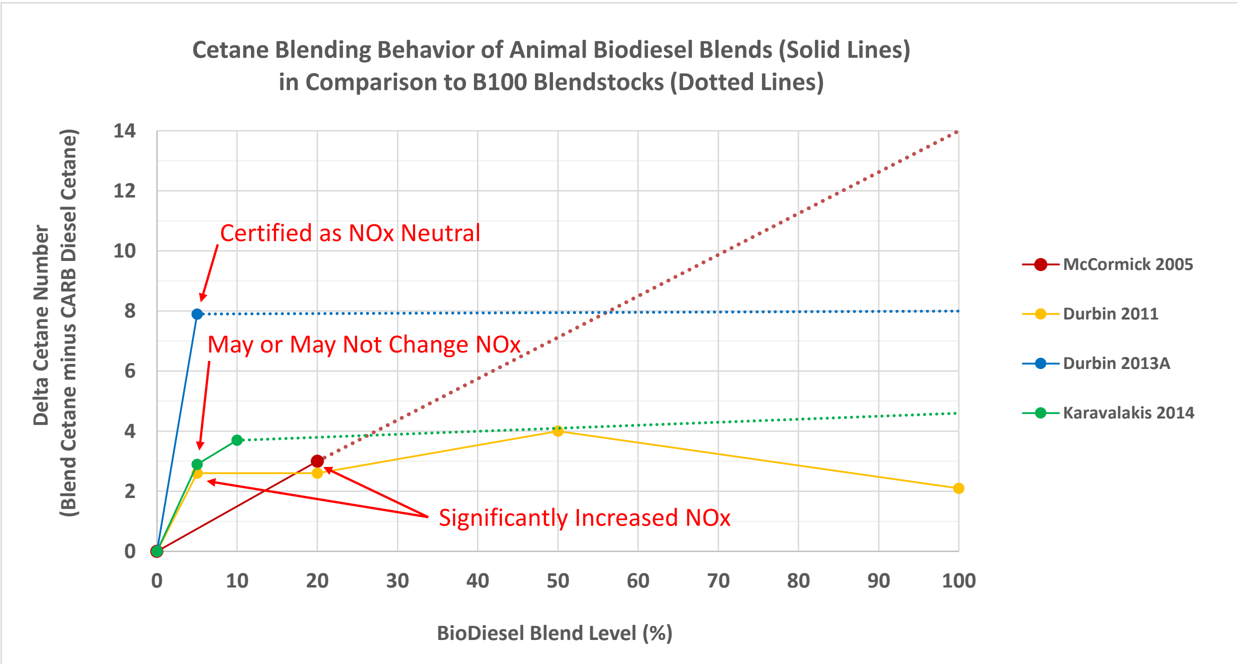
The effect of feedstock blending on the CN of the resulting animal blend is the reason for the apparently discordant results among the studies. Figure 1 plots the four series of animal blends used in the studies, with blend level on the horizontal axis and the change in blend CN (relative to CARB diesel) 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.

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 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% blending. The Karavalakis 2014 B5 blend (green) had an intermediate CN benefit and may or may not change NOx.

[4] 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.

Figure 1. Cetane Blending Behavior of Animal Blends (Solid Lines) Compared to B100 Feedstocks (Dotted Lines)



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.

Staff's use of the terms low saturation (for soy) and high saturation (for animal) to classify biodiesel is useful to differentiate between feedstocks that will tend to decrease CN and those that will tend to increase it. However, it is not a sufficient step in that the CN change at each blend level is the determinative factor for NOx emissions, not the CN of the feedstock itself. Soy feedstocks appear to blend linearly with respect to cetane; however, animal feedstocks often lead to a highly non-linear CN response, as shown in Figure 1.

2.2.4 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 increase the CN of the blend above that of the CARB diesel and the CN change can be large at low blend levels. Soy feedstocks generally decrease 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 soy and animal blends are not categorically different fuels once their differing effect on CN is taken into accounted. 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 one percent biodiesel in a blend at constant CN. A *c* coefficient was included to represent the change in NOx emissions for each one number change in CN compared to CARB diesel at constant blend level. 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 one 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% at constant blend level. This result is completely consistent with earlier work[5] on the relationship between CN and NOx emissions in HDT engines, which also found that +5 CNs will decrease NOx emissions by 1.5% in base fuels with CN ~50.

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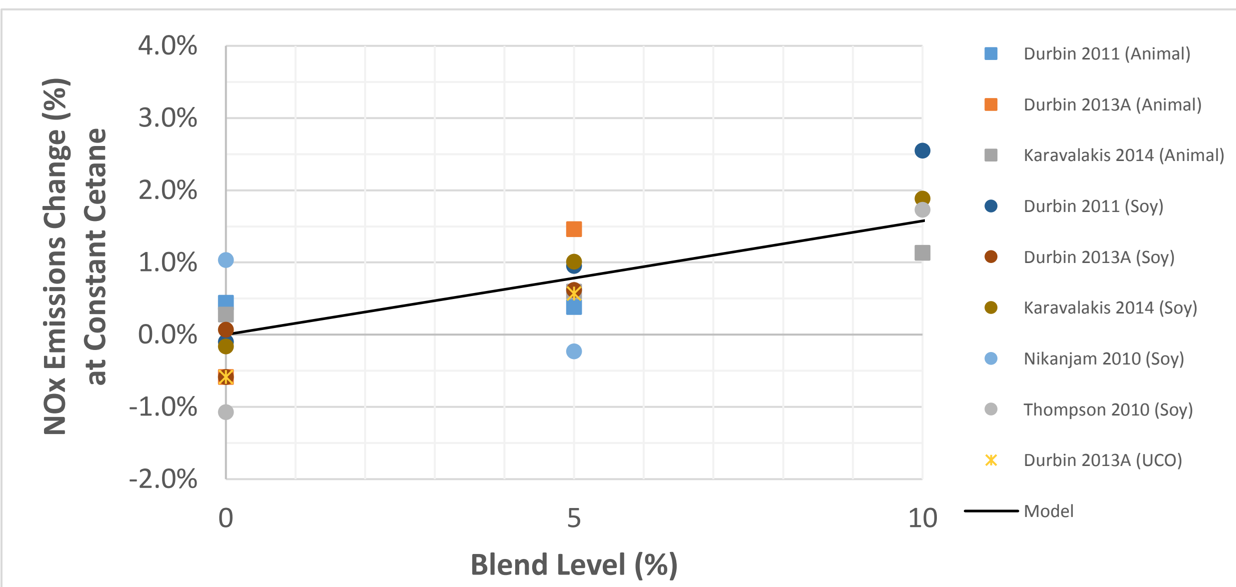
[5] The Effect of Cetane Number Increase Due to Additives on NOx Emissions from Heavy-Duty Highway Engines. EPA420-R-03-002. February 2004. Figure IV.A-1.

- 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. 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.

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.

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; however, other factors may be involved in determining the NOx impact for a given feedstock, including differences in the

FAME (fatty acid methyl ester) 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. Furthermore, 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.

3. NOX EMISSIONS IN NEW TECHNOLOGY DIESEL ENGINES

Staff's position is that biodiesel will not increase NOx emissions in NTDEs at levels up to and including B20. Its assessment is stated in the ISOR as follows:

> *Engines that meet the latest emission standards through the use of Selective Catalytic Reduction (SCR) have been shown to have no significant difference in NOx emissions based on the fuel used. A study conducted by the NREL looked at two Cummins ISL engines that were equipped with SCR, and found that NOx emissions control eliminates fuel effects on NOx, even for B100 and even in fuels compared against a CARB diesel baseline.*[20] *However, a recent study at UC Riverside tested B50 blends and found a NOx increase with a 2010 Cummins ISX.*[21] *The UC Riverside study did not look at blends below B50. Staff proposes to take a precautionary approach and in the light of data showing there may be a NOx impact at higher biodiesel blends but not at lower biodiesel blends, Staff is limiting the conclusion of no detrimental NOx impacts in NTDEs to blends of B20 and below. Additional studies on NTDEs have been completed, however since they included either retrofit engines or non-commercial engines Staff did not include their results in this analysis*.[22,23,24] (Page 24)

Staff's reliance on Lammert 2012 (Ref. 20) is misplaced because the NREL lab was not equipped to measure the low NOx emission levels of the test vehicles, as the abstract of the Lammert paper clearly notes.[6] In fact, none of the emission changes observed in the study (with one exception) were statistically significant due to the high standard errors that necessarily exist when measurements are made close to the level of detection. In this instance, the failure to observe statistically significant NOx emissions increases from biodiesel at the B20 level is not a demonstration that such increases do not exist.

This specific shortcoming of the Lammert study is why its negative results are in conflict with the finding of the UC Riverside study (Gysel 2014) cited by Staff and the three other studies (Walkowicz 2009, McWilliam 2010, Mizushima 2010) that Staff dismissed. With respect to the

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[6] "SCR systems proved effective at reducing NOx to near the detection limit on all duty cycles and fuels, including B100." Lammert 2012, Abstract.

three other studies, we see no reason why they should be dismissed. It is not the case that factory-designed NOx after-treatment systems will reduce NOx levels to below the detection limit of well-equipped labs (see Gysel 2014 and engine certification testing). Testing conducted using retrofit NOx after-treatment systems that achieve representative levels of NOx control, as in these studies, is entirely suitable for determining whether biodiesel increases tailpipe NOx emissions on a percentage basis. Having a different absolute level of emissions does not preclude reliable measurement of a percentage change.

When all available studies are included, a consensus of the literature is that biodiesel at the B20 level will increase NOx emissions from NTDEs in most, if not all cases. Lammert 2012 is the one study at odds with the rest of the literature. A range of biodiesel types were used in the studies. NOx increases should be expected at the B20 level for all biodiesel types until such time as additional research indicates differential impacts for biodiesels derived from different sources

3.1 Review of the NTDE Literature

The following sections briefly summarize the NTDE testing conducted in the studies and the conclusions drawn on the NOx emissions impact of biodiesel fuels. Testing of conventional diesel engines without NOx after-treatment is not considered, nor is testing on non-California fuels (low aromatics ULSD was considered equivalent to CARB ULSD). Appendix Table B presents a list of the studies included in the NTDE dataset and the author references used in citations here.

Walkowicz 2009. Chassis dynamometer testing was conducted using a 2005 International 9200i tractor equipped with and without a retrofit diesel oxidation catalyst (DOC) and urea-SCR NOx after-treatment system. On-road emissions measurements also were made using a RAVEM portable emissions measurement system. A ULSD base fuel was tested, as were B20 and B99 biodiesel blends. The type of biodiesel (soy or animal) was not specified, but was mostly likely soy-based as this is the feedstock most common in the market and in engine research.

- Under loaded, on-road conditions, biodiesel increased NOx by 17% at B20 and by about 40% at B99. At B20, the increase was marginally significant ($p=0.10$); at B99, the increase was statistically significant ($p=0.05$).
- Chassis dyno testing was done 24 months later at an ARB lab. The vehicle was determined to have high oil consumption, and lubricating oil was likely present in the exhaust stream. On the UDDS cycle, biodiesel increased NOx by 7% at B20 (marginally significant at $p=0.07$) and by 35% at B99 (highly significant, $p<0.01$).

The authors concluded "The use of biodiesel did result in higher NOx emissions than the use of ULSD (in tests with statistical significance)." The B20 test results did not reach the usual $p=0.05$ level for statistical significance, but were marginally significant ($0.05 < p \leq 0.10$).

McWilliam 2010. A Caterpillar 6.61 engine equipped with DOC and urea-SCR NOx after-treatment was tested using the European non-road transient cycle (NRTC). The fuels used were ULSD plus B20 and B100 biodiesels blended from a rapeseed methyl ester. Figure 9 of the paper shows tailpipe NOx emissions of the vehicle in g/kWh units. Reading from the graph because numerical emission values were not given, tailpipe NOx emissions increase ~15% at B20 and ~150% at B100. Based on the narrow error bars shown in the figure, both of these increases are statistically significant.

This study was conducted by Caterpillar because previous work had highlighted the potential for biodiesel to have an adverse impact on the NOx conversion efficiency of urea-SCR after-treatment systems. Thus, reductions in conversion efficiency have the potential to increase NOx emissions by amounts that exceed that caused by the biodiesel itself. At B20, only a 1% loss of conversion efficiency was noted, but a substantial 6% loss was observed at B100.

The authors of this paper concluded "Additional control strategies will be necessary to correct for NOx increases during biodiesel operation on installations requiring compliance regardless of fuel used."

Mizushima 2010. An inline 4-cylinder diesel engine equipped with DOC, diesel particulate trap (DPT), and urea-SCR NOx after-treatment system was tested using the JE-05 exhaust emissions test cycle used for heavy-duty vehicles in Japan. The fuels used were ULSD plus B20 and B100 blended from waste vegetable oil (WVO). Figure 4 of the paper shows tailpipe NOx emissions of the engine in g/kWh units. NOx emissions are highly linear with biodiesel blending level. Reading from the graph because numerical emission values were not given, tailpipe emissions increase ~20% at B20 and ~100% at B100. The paper does not address the statistical significance of these results.

With respect to NOx conversion efficiency, the study noted a drop from 76% on ULSD to 47% at B100, with a smaller but still measurable drop at B20. The impact on NOx conversion efficiency was linked to the effect of biodiesel in lowering the overall NO_2/NOx ratio at the SCR inlet leading to reduced conversion efficiency.

The authors drew no conclusions regarding the NOx emissions effects of B20 biodiesel as the focus of their research was on the B100 fuel.

Lammert 2012. The NREL study examined NOx emissions from transit buses on both EPA and CARB diesel fuels, B20 soy blends of each, and B100 soy. Chassis dynamometer testing was conducted using the Manhattan Bus (MAN), Orange County Transit Authority (OCTA) and UDDS test cycles. Two of the buses were NTDEs, including a 2010 Cummins ISL and 2011 Gillig/Cummins ISL. Only the 2010 Cummins was tested using the CARB ULSD base fuel and the biodiesel fuels.

NOx emission results for the 2010 Cummins bus are shown in Figure 10 of the paper. For B20, NOx emissions decreased compared to CARB ULSD on all three cycles (MAN, OCTA, and UDDS), and for B100 on the MAN cycle (OCTA and UDDS were not tested). None of the differences were statistically significant except for B20 on the UDDS cycle, and the standard errors plotted in the figure are large in comparison to the emission averages.

The authors explain the non-significance of their results as follows:

> *For much of the cycle NOx would be at or near the detection limit of the laboratory equipment, which resulted in a 95% confidence interval error that was high relative to the value of the cycle emissions.* (Page 6)

One of the authors' conclusions is that SCR NOx after-treatment appears to nearly negate the effect of fuels on NOx emissions. Another conclusion is that SCR NOx after-treatment also negates any duty cycle effect on NOx. (Page 8) For buses without NOx after-treatment, NOx emissions are strongly related to the kinetic intensity (load) of the test cycle. This result is consistent with all past vehicle and engine research studies, which show that NOx emissions are increased when a diesel engine is operated under increased load. However, no such relationship is observed for SCR-equipped buses. Increased load will increase engine-out NOx levels in an SCR-equipped bus. Unless this is accompanied by an increase in NOx conversion efficiency, tailpipe NOx emissions should also increase. <u>Neither conclusion is reliable because of the study's problems in measuring NOx emissions even on ULSD fuel</u>.

<u>**Gysel 2014**</u>. A 2010 Cummins ISX-15 equipped with DOC, DPF and urea-SCR NOx after-treatment was tested on CARB ULSD and B50 biodiesel blended from soy, waste cooking oil (WCO) and animal fat feedstocks. Chassis dynamometer testing was performed at CE-CERT using the UDDS test cycle.

Figure 7 of the paper shows the NOx emissions measured on ULSD and the three B50 biodiesel blends. The soy and WCO B50 blends increased NOx by 43% and 101%, respectively, with both increases being highly statistically significant ($p<0.01$). The animal B50 blend increased NOx by 47%, which was marginally significant ($p=0.065$). The authors' conclude that "Overall, NOx emissions exhibited increases with biodiesel for both vehicles with the differences in NOx emissions relative to CARB ULSD being statistically significant for the new Cummins ISX-15 engine." (Page 6)

The authors note the negative results reported by Lammert 2012 as being in contrast to those of their study, "which shows that there is a relatively strong fuel effect with the B50 blends compared to CARB ULSD from the Cummins ISX-15 engine with SCR." (Page 6). They also note the following:

> *The NOx increase with biodiesel for SCR-equipped engines is usually attributed by a reduction of exhaust temperature and the change of NO_2/NO ratio in NOx emissions [38]. In general, the lower exhaust temperatures with biodiesel will lower the oxidation rates of NO to NO_2 from the DOC. It has been shown that a NO_2/NOx ratio below 0.5 significantly changes SCR reaction chemistry lowering the SCR removal efficiency of NOx [39]. Walkowicz et al. [40] found increases in NOx emissions of 7% with B20 and 26% with B99 compared to ULSD for a heavy-duty diesel vehicle equipped with a 2004 Caterpillar 400 hp C13 engine. For the same vehicle equipped with a urea-based SCR system, NOx increases were very similar on a percentage basis, with B20 and B99 having 7% and 27%, respectively, higher NOx than ULSD.* (Page 6)

The authors continue to say:

> *The trend of increasing NOx emissions for biodiesel blends is consistent with a wide range of studies found in the literature. Comprehensive investigations conducted by Mueller et al. [41] and Sun et al. [42] confirmed that biodiesel promotes a combustion process that is shorter and more advanced than conventional diesel, which contributes to the formation of thermal NOx. The higher NOx emissions with biodiesel for both vehicles could also be a consequence of the higher oxygen content in biodiesel, which enhances the formation of NOx. The lower volatility of biodiesel compared to diesel fuel could also contribute to decreased fractions of premixed burn, as a result of fewer evaporated droplets during the ignition delay period [43]. Another contributing factor for NOx emissions increase could be the engine control module (ECM), which may dictate a different injection strategy based on the lower volumetric energy content of biodiesel. Eckerle et al. [44] suggested that a higher fuel flow is required with biodiesel compared to diesel fuel for an engine to achieve the same power. The ECM interprets this higher fuel flow as an indicator of higher torque, and therefore makes adjustments to engine operating parameters that, under certain operating conditions, increase NOx emissions.* (Page 6).

The engineering mechanisms described by the authors indicate that biodiesel should be expected to increase NOx emissions in NTDEs at blend levels below the B50 examined in the study. There is no basis in these mechanisms to believe that biodiesel will not increase NOx emissions at B20 but will increase NOx emissions at B50.

3.2 Consensus on Biodiesel NOx Impacts

Table 2 presents a summary of the available literature on the NOx emissions impact of biodiesel at the B20 blend level. Four of the five studies tested B20 fuels on NTDEs. Staff choose to rely on the one study in which NOx emissions were at or near the detection limit of the laboratory equipment for much of the test cycle on each fuel and to dismiss the other three studies "… since they included either retrofit engines or non-commercial engines …". The study that was retained did not observe a NOx increase because it had trouble measuring NOx emissions from the NTDE tested. The studies that were dismissed showed consistent NOx emission increases in the range of 10-20% at B20.

Staff notes the Gysel study, which found significantly increased NOx emissions at B50 compared to CARB ULSD, as its reason for setting the biodiesel control level at B20 for NTDEs. However, Staff did not note the study's discussion indicating that the Lammert results were in contrast to their results and to the results of other studies in the literature. Nor did Staff note the discussion of mechanisms by which biodiesel is believed to increase NOx emissions in NTDEs. These mechanisms include a reduction of the NO_2/NOx ratio that leads to loss of NOx conversion efficiency in urea-SCR systems, promotion of a combustion process that contributes to increased formation of thermal NOx, higher NOx emissions due to the oxygen content of biodiesel, and the lower volatility and lower volumetric energy content of biodiesel. These mechanisms indicate that biodiesel can be expected to increase NOx emissions in NTDEs at blend levels below the B50 examined in the study.

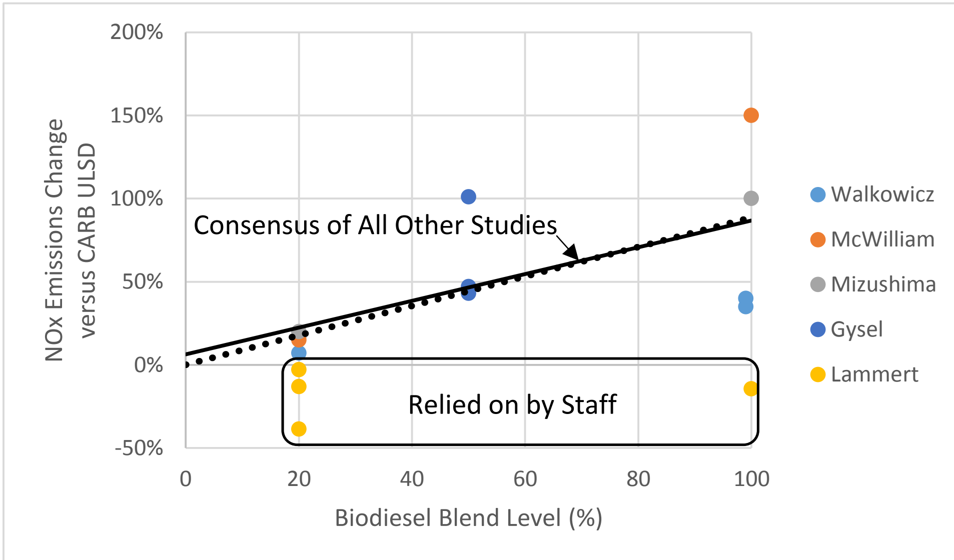
Table 2. Summary of NTDE Literature on NOx Emissions Impact of B20

	B20 NOx Emissions Change (%) versus CARB ULSD	Comments
Studies Relied on by Staff		
Lammert 2012	NOx emissions decrease on three cycles	UDDS cycle decrease is statistically significant. NOx emissions on all fuels were at or near the detection limit of the laboratory equipment.
Gysel 2014	B20 not tested	The paper discusses how biodiesel effects NOx emissions. These mechanisms suggest that biodiesel should increase NOx emissions at levels below B50.
Studies Dismissed by Staff		
Walkowicz 2009	+17% on-road + 7% chassis dyno	Both results are marginally significant ($0.10 \leq p < 0.05$)
McWilliam 2010	~15% increase	European transient cycle
Mizushima 2010	~20% increase	Japanese heavy-duty test cycle

Figure 3 summarizes the impact of biodiesel on NTDE NOx emissions at all blend levels. The four studies (excluding Lammert 2012) establish a linear relationship between NOx emissions and blend level. The first trend line (solid black) passes very nearly through the origin without being constrained to do so. The second trend line (dotted black) is constrained to pass through the origin. While there is substantial scatter around the trend lines, the consensus of the four studies is that biodiesel increases NOx by 18-22% at B20, by 45-50% at B50, and by 90-100% at B100.

In spite of this consensus, Staff chose to rely only on the Lammert 2012 study, which shows that biodiesel decreases NOx emissions at both the B20 and B100 blend levels. This is the study that had difficulty measuring NOx emissions because NOx was at or near the detection limit of the laboratory equipment for much of the test cycle on all fuels.

Figure 3. The Impact of Biodiesel on NTDE NOx Emissions



To test the statistical significance of the trend lines shown in the figure, conventional regression analysis was conducted using the data reported by four of the studies (Lammert 2012 excluded) as summarized in Table 3. Regression A corresponds to the figure's solid trend line and is not constrained to pass through the origin. Its slope is +0.80% increase per 1% biodiesel in the blend; it is statistically significant at the p=0.035 level. Regression B corresponds to the dotted trend line and is constrained to pass through the origin. Its slope is +0.89% increase per 1% biodiesel, and it is statistically significant at the p<0.001 level. The two regression models predict a 22% and 18% increase, respectively, in NOx emissions at B20 in NTDEs.

Table 3. Statistical Significance of Biodiesel NOx Effect in NTDEs

	Intercept	Significance	Slope (% NOx Increase per 1% biodiesel)	Significance	Predicted NOx Increase at B20
Regression A	6.4	p = 0.80	+0.80% (±0.32%)	p = 0.035	22%
Regression B	None	n/a	+0.89% (±0.16%)	p <0.001	18%

A fair reading of the technical literature would lead Staff to expect that biodiesel will increase NOx emissions in NTDEs by about 20% at B20 and by proportionately smaller amounts at blend levels below B20. At the B5 level, the impact is expected to be an increase in NOx emissions of about 5%. At the B20 level, the NOx increase appears to be greater on a percentage basis than would be expected in conventional diesel engines (1% at B5, 2% at B10, and ~4% at B20). The loss of NOx conversion efficiency when biodiesel fuels are used is one likely reason for the greater impact.

4. SUMMARY AND CONCLUSIONS

The key conclusions of this study are summarized below with respect to conventional diesel engines and new technology diesel engines.

Conventional Diesel Engines

- Soy and animal blends are not categorically different fuels once their differing effect on blend CN is 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. As shown here, the magnitude of the NOx impact observed depends on both the blend level and the change in CN that results from blending of the biodiesel feedstock.
- Soy blends clearly and significantly increase NOx by ~1% at B5 and by ~2% at B10. The effect is continuous and linear with respect to the blend level at all levels above ULSD. Soy blends require mitigation at all levels to offset increased NOx emissions.
- Staff's proposal requires NOx mitigation in summer months for soy fuels at blend levels greater than B5. Because soy fuels increase NOx at all blend levels, mitigation should be required for B5 and lower blends to prevent 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 CN effect (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 demonstration that feedstock blending raises CN enough to offset potential NOx increases.

New Technology Diesel Engines

- Staff is incorrect in concluding that biodiesels will not increase NOx in NTDEs. The Staff conclusion is based on a highly selective reading of the technical literature that relies on the one study in which the laboratory was not well equipped to measure the low levels of tailpipe NOx emissions from NTDEs.

- There is greater reason to exclude the study Staff relied on than the three studies that Staff excluded. If that is done, there are no test data at the B20 level or below in NTDEs and no basis whatsoever to permit biodiesel fuels in NTDEs in California.
- While the available data are limited, the four best studies (excluding Lammert 2012) support the conclusion that biodiesel increases NOx by 18-22% at B20 and that the increase is statistically significant. Staff has no basis to claim that no NOx impacts are associated with biodiesel at the B20 level and below in NTDEs.
- A fair reading of the technical literature would lead Staff to expect that biodiesel will increase NOx emissions by about 20% at B20 and by proportionately smaller amounts at lower blend levels. This is a greater percentage NOx increase in proportion to blend level than the increase caused by soy biodiesel in conventional diesel engines (1% at B5, 2% at B10, and ~4% at B20).
- Staff makes no mention of the concern that the use of biodiesel fuels may lead to the loss of NOx conversion efficiency in urea-SCR after-treatment systems by shifting the NO_2/NOx ratio to lower values. Conversion losses were observed at B20 in two of the studies.

Based on the results summarized above, it is strongly recommended that ARB consider as part of the ADF 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 substantial additional work is needed to:

- Demonstrate that blends mitigated using DTBP obey the same model; and
- Further assess the impacts of biodiesel produced from animal feedstocks on both CN gain in blends as well as NOx emissions.

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 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. 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.

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APPENDIX TABLE A: REFERENCES TO LITERATURE ON CONVENTIONAL DIESEL ENGINES

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

APPENDIX TABLE B: REFERENCES TO LITERATURE ON NEW TECHNOLOGY DIESEL ENGINES

Author	Title	Feedstocks Studied	Blends Studied
Walkowicz 2009	On-road and In-Laboratory Testing to Demonstrate Effects of ULSD, B20 and B99 on a Retrofit Urea-SCR Aftertreatment System	Soy?	B20, B99
McWilliam 2010	Emissions and Performance Implications of Biodiesel Use in an SCR-equipped Caterpillar C6.6	Rapeseed	B20, B100
Mizushima 2010	Effect of Biodiesel on NOx Reduction Performance of Urea-SCR System	WVO	B20, B100
Lammert 2012	Effect of B20 and Low Aromatic Diesel on Transit Bus NOx Emissions Over Driving Cycles with a Range of Kinetic Intensity	Soy	B20, B100
Gysel 2014	Emissions and Redox Activity of Biodiesel Blends Obtained from Different Feedstocks from a Heavy-Duty Vehicle Equipped with DPF/SCR Aftertreatment and a Heavy-Duty Vehicle without Control Aftertreatment	Soy, WCO, animal	B50

Attachment 5

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

December 10, 2013

Prepared for:

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

prepared for:

Sierra Research, Inc.

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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.*

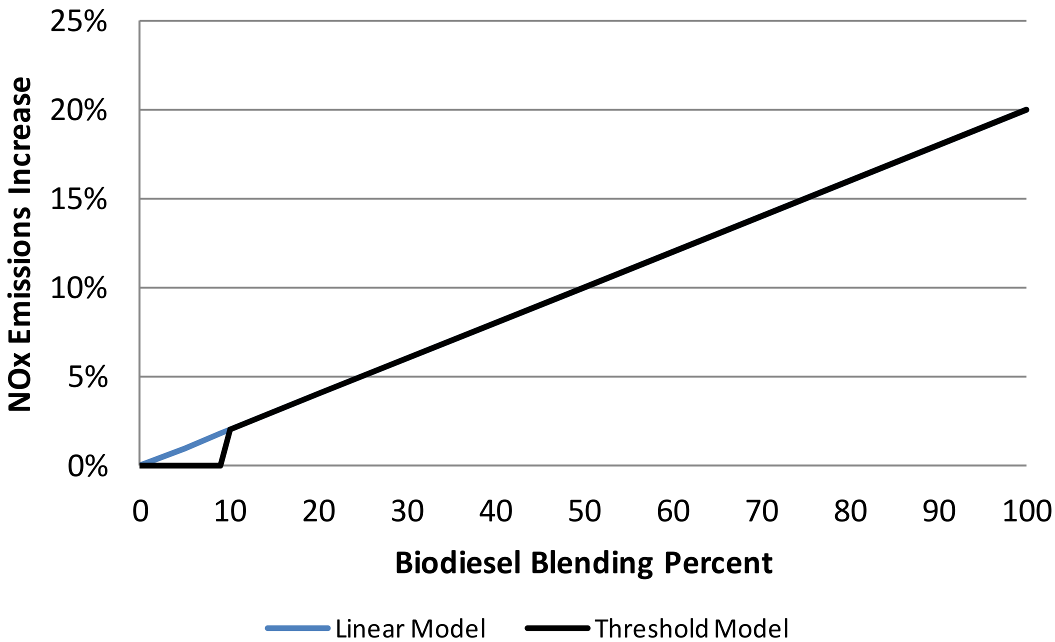
[2] Ibid. p. 3.

[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

[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.

[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] "*CARB B5 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.

###

[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

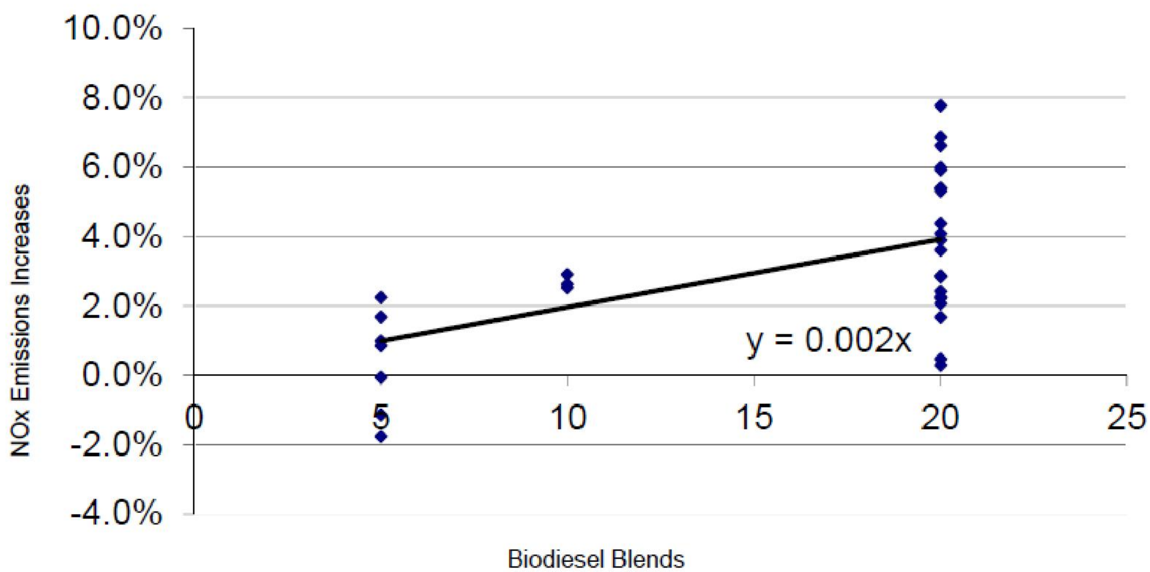
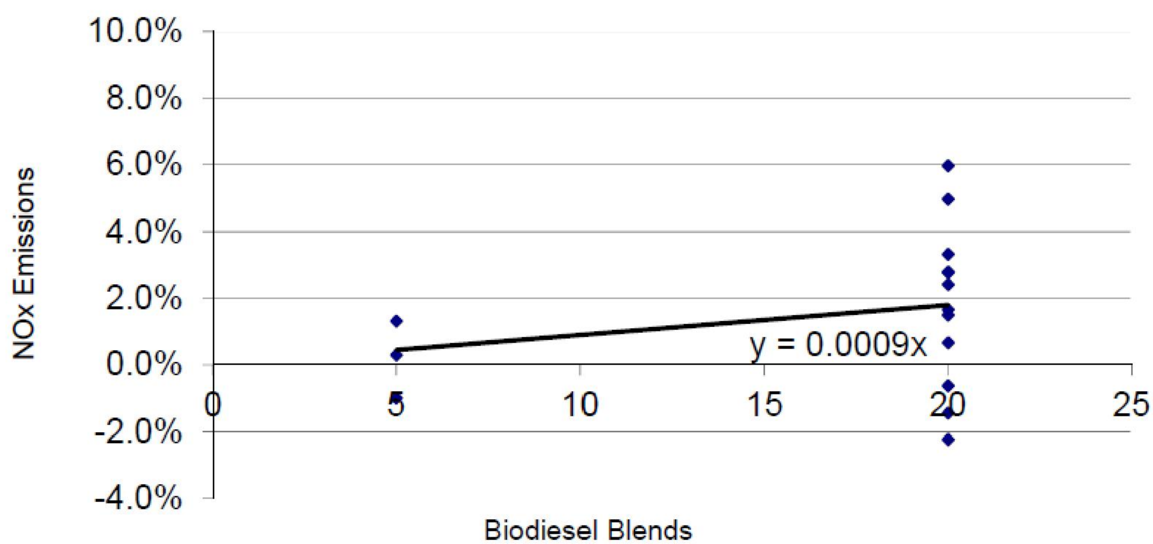


Figure B.3: NOx Impact of Animal Biodiesel Blended in High Cetane Base Fuel



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

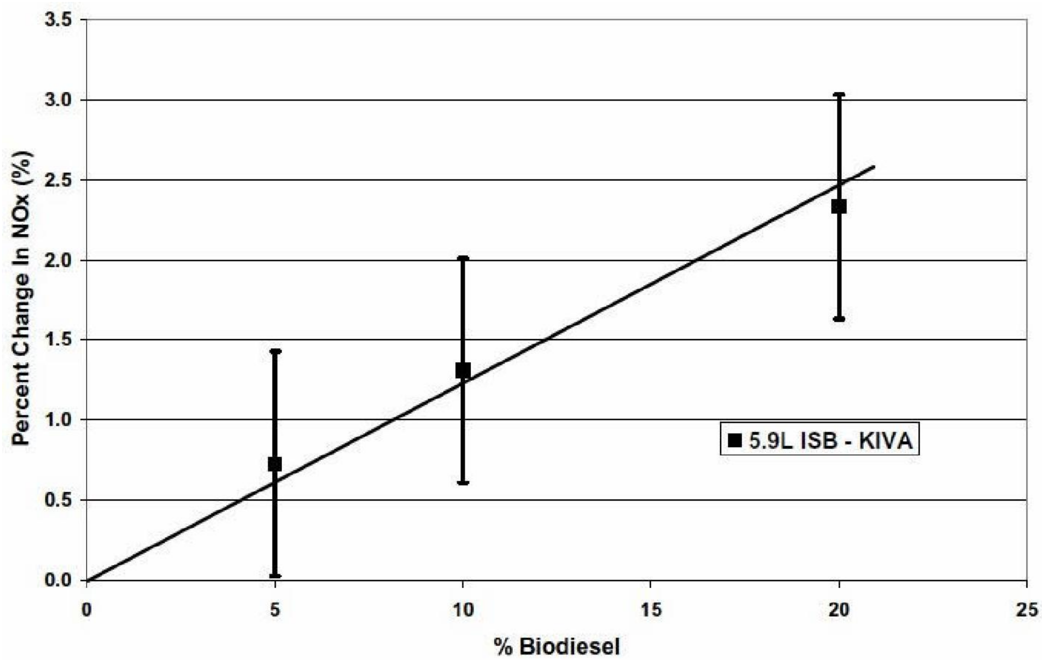
This study tested a variety of fuels on a 1994 7.3L Navistar T444E engine. Of the high-cetane base fuels, one base fuel (Diesel A, off-road LSD) was blended and tested at levels of B20, B50, and B100. NOx emissions were significantly increased for all of the blends. The other base fuel (CA Diesel) was 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.

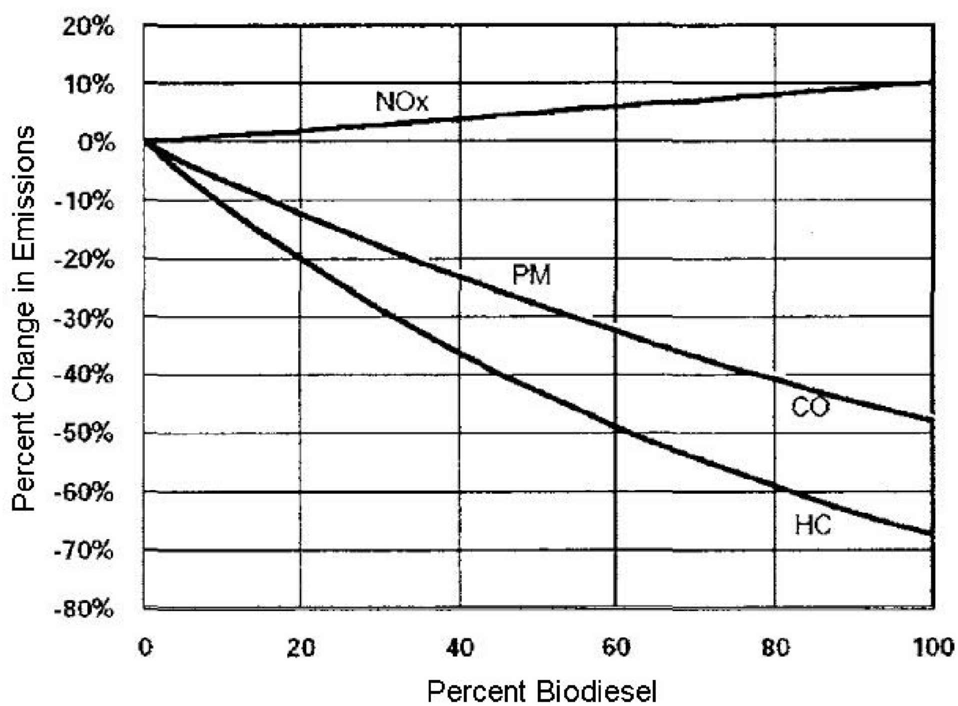
This study also tested a Fisher-Tropsch (FT) base fuel blended at the B1, B20, and B80 levels. Although the very high cetane number (≥75) takes it out of the range of commercial diesel fuels, it is interesting to note that the study measured higher NOx emissions at the B1 level than it did on the FT 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).

###

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)

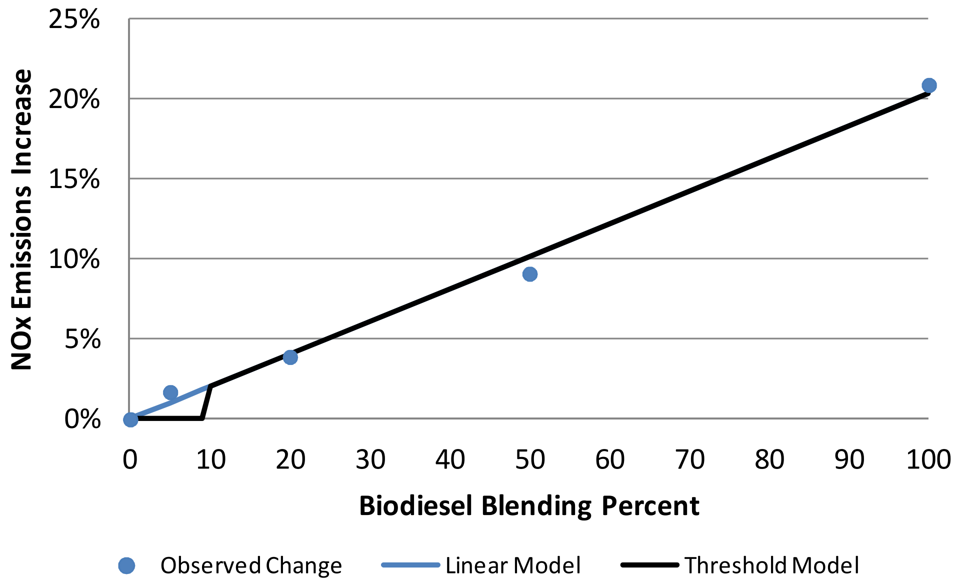
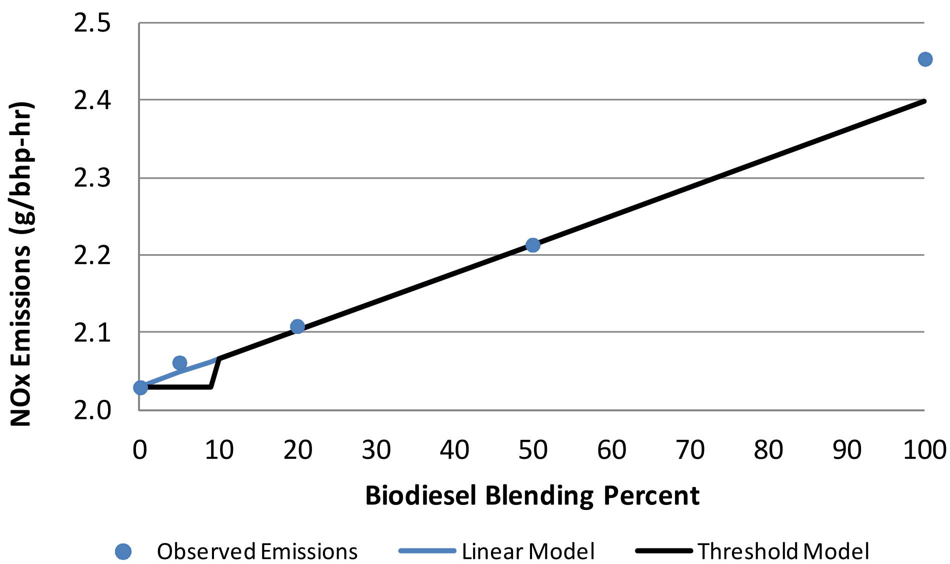


Figure 3-1b
Re-assessment of 40 mph Cruise Cycle NOx Emissions Increases for Soy-Biodiesel Blends (2006 Cummins Engine)



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)

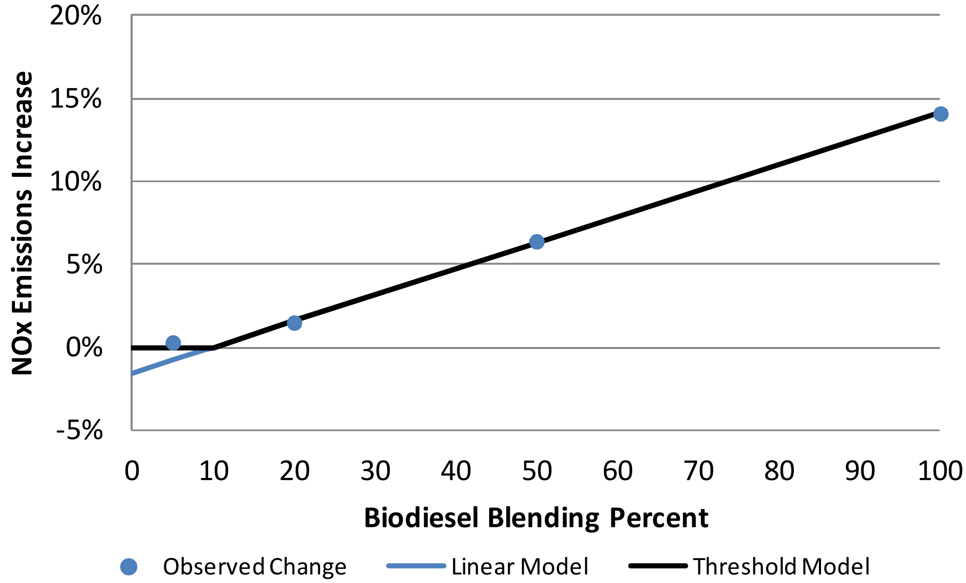
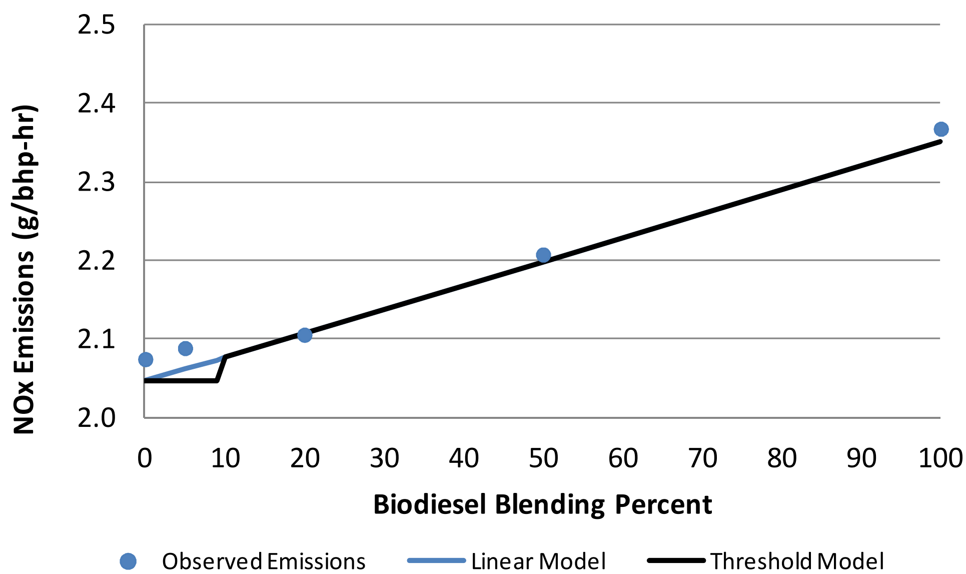


Figure 3-2b
Re-assessment of FTP NOx Emissions Increases for Animal-based Biodiesel Blends (2006 Cummins Engine)



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)

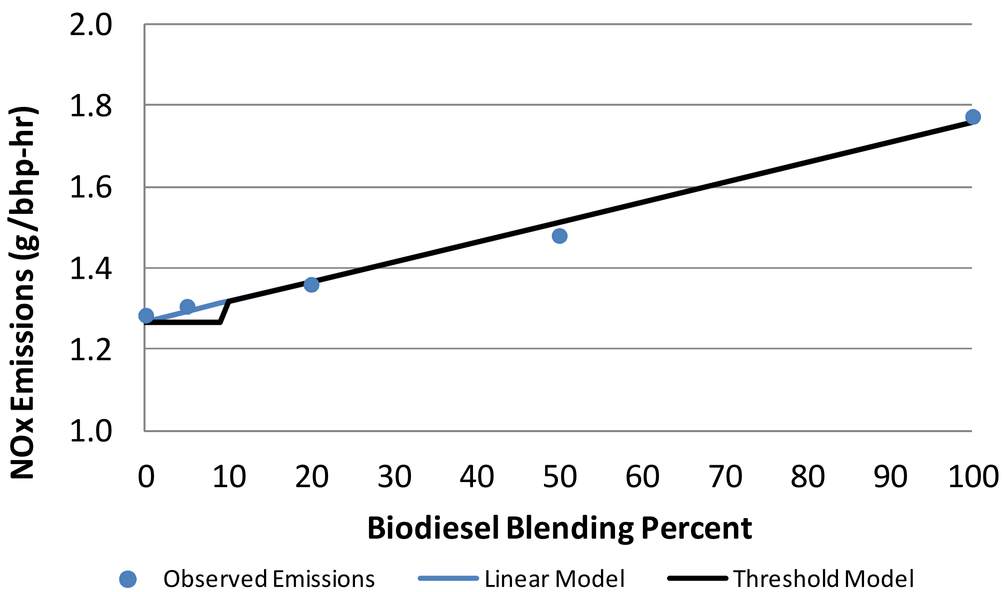
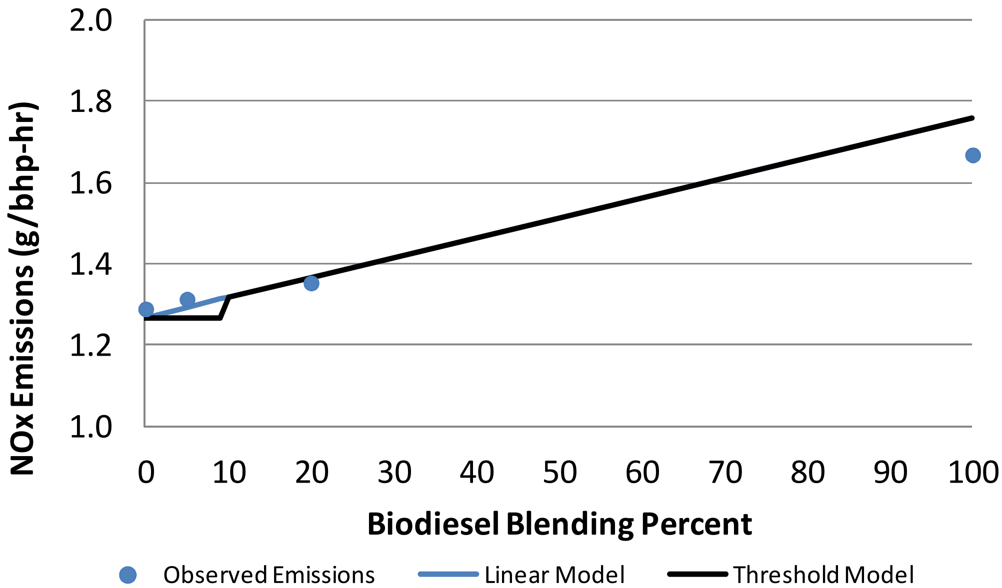


Figure 3-3b
Re-assessment of FTP Cycle NOx Emissions Increases for Animal-based Biodiesel Blends (2007 MBE4000 Engine)



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.

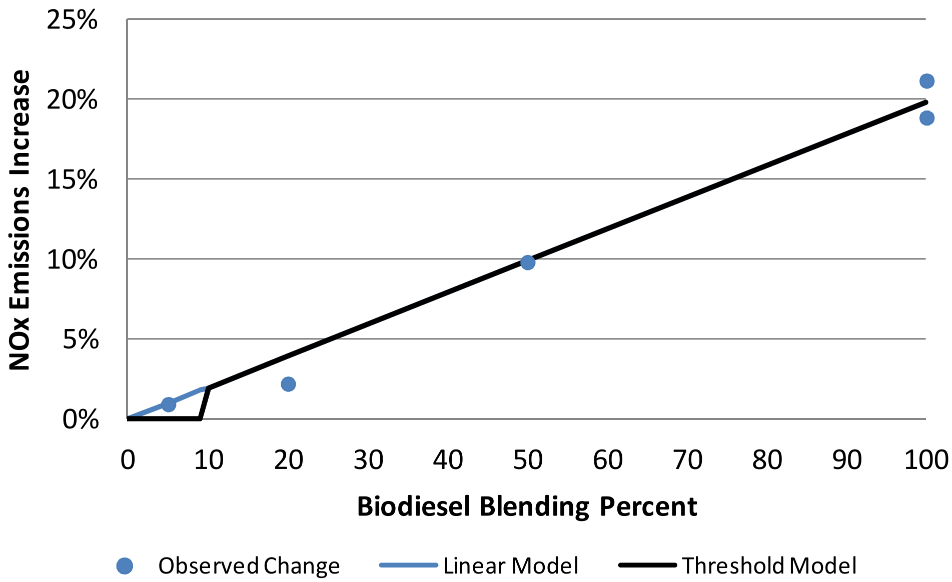
The second test series involved ULSD, B5, B20, and B100 fuels. Measured emissions data are not given in Appendix I, so we must work with the calculated percent changes in NOx emissions tabulated in Durbin 2011. Table 3-8 reproduces the NOx emission results reported in Table ES-8 of Durbin 2011 for the 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).

<u>Primary work areas</u>: 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>U.S. Energy Market Analysis</u>

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.

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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.

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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)*

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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.

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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 6

Proposed Regulation on the Commercialization of Alternative Diesel Fuels

Staff Report: Initial Statement of Reasons




Industrial Strategies Division

Oil and Gas and GHG Mitigation Branch & Transportation Fuels Branch

Release Date: January 2, 2015

To Be Considered by the Board: February 19 or 20, 2015

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State of California
Air Resources Board

Staff Report: Initial Statement of Reasons for Proposed Rulemaking

Proposed Regulation on the Commercialization of Alternative Diesel Fuels

Date of Release: January 2, 2015
Scheduled for Consideration: February 19 or 20, 2015

Location:

California Air Resources Board
Byron Sher Auditorium
1001 I Street
Sacramento, California 95814

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Air Resources Board

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Table of Contents

<u>Table of Appendices:</u>

Table of Figures:

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EXECUTIVE SUMMARY

The staff of the Air Resources Board (ARB or Board) is proposing a regulation to govern the commercialization of motor vehicle alternative diesel fuels (ADF) in California. Through California's fuel policies, consumers are beginning to see increasingly cleaner fuels as well as more options for fueling their motor vehicles. The ADF regulation is intended to create a framework for these low carbon diesel fuel substitutes to enter the commercial market in California, while mitigating any potential environmental or public health impacts. ADFs are those alternative diesel fuels that do not have an established ARB fuel specification in effect prior to January 1, 2016. The proposed regulation consists of two major parts:

1) A three stage process for ADFs to be introduced into the California market including, if necessary, a determination of mitigation measures to ensure no degradation in air quality.
2) In-use requirements for biodiesel as the first ADF

Although this will be a new regulation, the proposal consolidates many current administrative and regulatory practices into one regulation that provides a clear framework for commercialization of ADFs. The formal framework is necessary for two primary reasons. First, programs such as California's Low Carbon Fuel Standard (LCFS) and the federal Renewable Fuels Standard (RFS) are expected to incentivize the rapid development of ADFs. Many of these fuels provide criteria pollutant and toxic air contaminant emission reductions in addition to their greenhouse gas (GHG) benefit. Second, some ADFs may have adverse effects under certain circumstances. For these reasons, ARB is proposing the regulation to ensure that ADFs are commercialized in California under specific requirements and conditions that avoid potential adverse impacts while realizing the benefits that ADFs can provide.

The first ADF that will be subject to in-use requirements under this framework is biodiesel. Fuel specifications and other requirements for future ADFs will be incorporated into this regulation through additional rulemakings. Biodiesel has particulate matter (PM) and GHG benefits, however testing by ARB and others show that biodiesel can increase oxides of nitrogen (or NOx) under certain circumstances and without considering offsetting factors. These effects are only observed in older (pre-2010) vehicles. As new technology diesel engines are phased in through other ARB programs such as the Truck and Bus Regulation, the NOx impacts will be reduced until they are negligible. ARB expects the in-use specifications to sunset around 2023. Until that time, the in-use specifications will reduce NOx from current levels and Californians will continue to experience the PM and GHG benefits.

There has been confusion between biodiesel and renewable diesel; however, these are two distinct fuels. Renewable diesel and biodiesel are both biomass based diesel fuel replacements and can be confused with each other, but the distinctions are important. Although the two fuels use the same feedstocks (e.g. animal tallow, used cooking oil, soybean oil), they are produced using different production processes with resulting products having different chemical properties and environmental attributes. Renewable diesel is not considered an ADF as it consists solely of hydrocarbons and is chemically indistinguishable from conventional diesel. Renewable diesel has been shown to decrease emissions of GHGs, PM, hydrocarbons, and carbon monoxide and, in contrast to biodiesel, renewable diesel has also been shown to reduce NOx. Because renewable diesel is not an ADF, it would not be subject to in-use requirements and is expected to increase significantly over time, with associated co-benefits of reduced air pollutants.

The availability of both renewable diesel and biodiesel will help fulfill our climate goals, provide fuel diversity, contribute PM emission reduction benefits, and, with the implementation of this regulation, have no degradation of air quality from current levels.

What are we proposing?

The proposed regulation would require an ADF to proceed through a three-stage process that evaluates the fuel for environmental impacts prior to use above a minimum threshold amount in California. As part of that evaluation process, the regulation establishes measures that apply to maintain current air quality protections. Many of the provisions in this regulation are already required under existing State law. The three stages of this process are described below.

Stage 1: Pilot Program. In this stage, an ADF applicant(s) would apply to ARB for a pilot program under which no more than 1 million gallons total of the ADF could be used in the State in well-defined fleets within a year. During that time, the applicant would conduct required testing and emissions evaluations. The application process includes disclosure of the chemical composition of the ADF, as well as other important information, which would enable staff to conduct a screening analysis. This screening analysis is intended to help staff determine whether use of the ADF presents a potential adverse impact to the public health or environment. Advancement to Stage 2 requires the ADF applicant to fulfill the Stage 1 requirements and enter into an agreement with the Executive Officer (EO) to complete and satisfy specified terms and conditions, such as additional emissions testing, which will apply during the second stage.

Stage 2: Fuel Specification Development. In this stage, an ADF proponent(s) would apply for a broader, but still limited, agreement allowing use of up to 30 million gallons of that ADF per year in a larger fleet. The larger volume and sample fleet would allow for more comprehensive testing and analyses that would inform a multimedia evaluation; help develop consensus standards for the ADF; identify what circumstances, if any, could result in an adverse impact on public health or the environment; and, if necessary, determine appropriate mitigation options. During this stage, ARB staff would determine, if necessary, a pollutant control level for a particular pollutant of concern.

Stage 3: Commercial Sales. This stage is split into Stage 3A and Stage 3B. Stage 3A is applicable to ADFs for which ARB staff has identified a pollutant control level. An ADF sold in California under this stage would be subject to potential sales conditions and mitigation measures that are based on the pollutant control level(s) determined in

Stage 2. By contrast, Stage 3B is applicable to ADFs for which no pollutant control level is necessary. Accordingly, ADFs in Stage 3B can be used at any blend level and without any conditions of use or mitigation measures.

An ADF subject to Stage 3A is subject to enhanced monitoring and recordkeeping. The ARB staff would use such monitoring and records, along with other market and fleet data, to determine whether the pollutant control level has been reached.

Staff has determined that certain blends of biodiesel, the first ADF to be subject to the proposed regulation, can increase NOx under certain circumstances and in the absence of offsetting factors. However, ARB staff has also determined that NOx associated with these biodiesel blends are offset by a number of factors. Accordingly, ARB staff has designed the proposed regulation to ensure that biodiesel can be commercialized without an increase in NOx. The proposed regulation provides for a proper accounting of offsetting factors already occurring in the California market and the appropriate application of in-use requirements.

Accounting for feedstock saturation and offsetting factors such as renewable diesel usage and fuel use by newer heavy duty trucks, biodiesel can be used in lower blends levels without triggering in-use specifications. In-use specifications are necessary above a five percent blend level (B5) for low saturation biodiesel and a B10 level for high saturation biodiesel during ozone season and above B10 for all biodiesel in low ozone season.

Why are we taking this action?

Consumption of ADFs, such as biodiesel, is expected to increase in the coming years due to a variety of policy incentives including the RFS, LCFS, and potentially the continuance of federal blending tax credits. These fuels will help California meet its climate and petroleum reduction goals, provide fuel diversity, and contribute PM benefits. As such, it is important to ensure that the full commercialization of these fuels do not increase air pollution or cause other environmental concerns. The proposed regulation will ensure this by subjecting new ADFs to a rigorous, phased environmental review with specific terms and conditions. As part of the environmental review, staff will determine whether the ADF has a “pollutant control level” for the pollutant of concern, which is defined to be that level of ADF use which could lead to an increase in the pollutant of concern. In that case, staff will identify the terms of the pollutant control level and define the specific in-use requirements, when conditions warrant mitigation. This regulation will ensure that ADFs avoid potential adverse impacts while realizing the benefits that ADFs can provide in terms of reductions in GHGs and PM and increase in fuel diversity in the state.

Who is affected by this proposed regulation?

The regulation applies primarily to producers and importers of alternative diesel fuels. If necessary, the applicant producer or importer would be responsible for applying any mitigation measures that may be required under a Stage 3A scenario. Retail marketers and distributors of alternative diesel fuels are generally not affected by the in-use requirements unless they are also conducting fuel blending. Retailers and distributors may be required to do some of the required recordkeeping and monitoring, but these generally would apply to the higher blends of an ADF (e.g., for marketers of biodiesel in blends above B10).

What are the costs of this proposed regulation?

Staff expects the costs directly attributable to this proposed regulation to be minimal. Regulatory costs are primarily due to some increases in reporting, recordkeeping and testing of ADFs, as well as costs for in-use requirements affecting some biodiesel blends. Many of the requirements of this regulation already exist under other State law, and, as such, are not an additional cost of this regulation. For example, much of the reporting associated with this regulation is already required to comply with the LCFS regulation or other State or federal programs. The requirement for a multimedia evaluation of new ADFs is already required by ARB pursuant to Health and Safety Code (H&SC) section 43830.8, and development of consensus standards is already required by existing regulations implemented by the California Department of Food and Agriculture. The differences between existing law and this proposed regulation is primarily the enhanced monitoring required and a more streamlined route to the commercial market.

Staff also estimated potential costs of in-use control for biodiesel use. Staff's analysis shows that with full implementation of the in-use requirements in 2018, biodiesel used in B5 blends incur no in-use requirement costs, only minimal recordkeeping costs. Higher blends above B5 may have a small cost per gallon. For 2018, the projected costs for complying with the in-use requirements are about $3 million on 180 million gallons of biodiesel, or less than two cents per gallon. Beyond 2018, the cost for biodiesel blends above B5 is projected to decrease to zero because the in-use requirement will sunset upon near full fleet penetration of new technology diesel engines in California.

CHAPTER 1. INTRODUCTION

A. Air Quality

Due to its unique geography, California has unique air pollution challenges. Ambient air quality standards designed to protect public health have been established for several pollutants in the State. Although California has made substantial progress, in many parts of the State air pollution exceeds these ambient air quality standards. To attain the ambient air quality standards, the California Air Resources Board (ARB or Board) has designed a multi-faceted strategy, including emission reductions from mobile sources and motor vehicle fuels. The ARB uses its legal authority to regulate emissions from motor vehicle fuels in the State when appropriate to reduce air pollution. To date, ARB has developed fuel quality standards for gasoline, diesel and several alternative motor vehicle fuels.

In anticipation of increasing biodiesel use and additional alternative motor vehicle fuels in California, ARB staff recognizes the need for a new regulation to maintain air quality benefits for future commercial substitute diesel fuels.

B. Alternative Motor Vehicle Fuels

There is a trend in California toward increasing consumption of alternative motor vehicle fuels in place of conventional petroleum-based gasoline and diesel fuels. This trend is primarily due to economic incentives and policies at the State and national level that incent the use of lower polluting, less toxic, and lower carbon intensity fuels in the commercial market. A more detailed discussion of these new fuels is presented in Chapters 2 through 4. As a result of this diversification, some diesel fuel substitutes have started to enter commerce in California without clear regulatory requirements to ensure there are no detrimental impacts to air pollution as a result of their use. In response to this, ARB staff is proposing a new Alternative Diesel Fuel (ADF) regulation that will put the proper regulatory structure into place to ensure no detrimental impacts to air quality as California moves toward increased alternative motor vehicle fuels consumption.

C. Alternative Diesel Fuels Overview

In general, alternative diesel fuels are a category of motor vehicle fuels that are not conventional diesel and do not solely consist of hydrocarbons. While there are a few alternative diesel fuels in existence today, biodiesel is by far the most prevalent. While renewable diesel is also an innovative diesel fuel replacement, it consists solely of hydrocarbons and is virtually indistinguishable from conventional diesel; therefore, renewable diesel is not considered an alternative diesel fuel under this proposed regulation.

Biodiesel and renewable diesel are both low carbon fuels that can be produced domestically. Using conventional feed stocks, these fuels provide carbon intensities about 25 percent lower than petroleum diesel fuel. Using waste feedstocks, the carbon intensity can be as much as 80 percent lower than petroleum diesel fuel. Biodiesel and renewable diesel also decrease emissions of harmful air pollutants. Blends of biodiesel and renewable diesel have been shown to decrease the emission rates of particulate matter, hydrocarbons and carbon monoxide. Renewable diesel has also been shown to reduce NOx.

1. Biodiesel

Biodiesel has already been in use in California for several decades. Waste restaurant grease is frequently confused with biodiesel. Grease is referred to as straight vegetable oil (SVO), which has a long history of use in diesel engines. Peanut oil, a type of SVO, was the fuel that powered Rudolph Diesel's original compression ignition engine at the 1911 World Fair.

Although SVO can be used in most diesel engines, its use leads to durability issues, such as clogging of fuel injectors and fatty engine deposits. To create a fuel that is more appropriate for the modern diesel engine, SVO must be chemically converted to a form that has improved combustion properties through a process called transesterifcation. In order to accomplish this conversion, the SVO, or other feed stock, is chemically converted to fatty acid methyl esters (FAME) by reacting the SVO with methanol and a catalyst. The resulting FAME biodiesel is much cleaner burning and less viscous, reducing or eliminating many of the problems caused by SVO.

Biodiesel feed stocks such as animal tallow and waste vegetable oil contain high concentrations of triglycerides, which is the main component of fats and oils. These feed stocks can be processed into biodiesel and depending upon the specific feed stock, there may be a range of emissions effects. For example, soybean oils tend to produce higher NOx emitting biodiesel than animal tallow.

2. Renewable Diesel

In addition to biodiesel, ARB considered renewable diesel during this rulemaking. Renewable diesel uses essentially the same feed stocks that are used to make biodiesel, but instead of the transesterification reaction, renewable diesel is produced by hydroprocessing, which results in a fuel containing pure hydrocarbons, paraffinic compounds and nearly no aromatics. Renewable diesel has few of the disadvantages normally associated with biodiesel such as poor cold weather performance, biological degradation or oxidation stability. However, renewable diesel exhibits poor lubricity and generally must be used in a lubricated mixture or have a lubricity additive incorporated in the fuel. Finally, renewable diesel is generally more homogeneous and does not exhibit the chemical variability of biodiesel made from different production feedstocks.

D. Low Carbon Fuel Standard Litigation

On July 15, 2013, the State of California Court of Appeal, Fifth Appellate District (Court) issued its opinion in POET, LLC versus California Air Resources Board (2013) 218 Cal.App.4th 681. Among the issues in the lawsuit was the treatment of biodiesel in the original LCFS regulation. The judge's opinion was that ARB did not adequately address biodiesel NOx emissions that could potentially result from implementation of the LCFS. The Court held that the LCFS would remain in effect and that ARB can continue to implement and enforce the 2013 regulatory standards while it takes steps to cure California Environmental Quality Act and Administrative Procedure Act issues associated with the original adoption of the regulation. In addition to the general impetus of this regulation to protect air quality, it is also designed to fulfill the court's requirements and to remedy issues with NOx emissions from biodiesel. Implementation of this regulation will ensure that the use of biodiesel due to LCFS will not result in increases in NOx emissions in California.

E. Development Process for the Proposed Regulation

Staff evaluation of ADFs and biodiesel began in the early 2000s. During the informal rulemaking process, ARB staff conducted numerous meetings of the Multimedia Working Group (MMWG), multiple public workshops, and numerous meetings with individual stakeholders to discuss a proposed regulation. The MMWG is an inter-agency group responsible for oversight of multimedia evaluations. Below is a timeline of the public actions taken leading up to this proposal, each of the meetings below included opportunities for public comment, which were considered when developing the proposed ADF regulation.

Table 1.1: ADF Regulatory Development Timeline

Date	**Meeting**
2004-2005	Two Biodiesel Work Group Meetings
2006-2007	Five Meetings of the Biodiesel Work Group
2008-2009	Six Meetings of the Biodiesel Work Group
2010	Two Biodiesel Rulemaking Workshops
December 8, 2010	Multimedia Evaluation Meeting
October 4, 2011	Released Biodiesel Guidance Document
February 15, 2013	ADF Concept Paper
April 23, 2013	ADF Rulemaking Workshop
June 13, 2013	ADF Rulemaking Workshop
September 5, 2013	ADF Rulemaking Workshop
February 13, 2014	ADF Rulemaking Workshop
April 17, 2014	ADF Rulemaking Workshop
July 1, 2014	Webinar/Biodiesel Emissions Characteristic Study
October 20, 2014	ADF Rulemaking Workshop
November 21, 2014	Final ADF Rulemaking Workshop and Proposed Draft Regulatory Language

For each of the rulemaking meetings above, over 7,000 individuals or companies were notified and invited to participate. Each of these meetings was well attended by a variety of stakeholders including refiners, oil marketers, alternative fuel producers, non-governmental organizations, academia, and other State agencies. Notices for the workshops, and associated materials, were posted to ARB's biodiesel and renewable diesel webpage at: http://www.arb.ca.gov/fuels/diesel/altdiesel/biodiesel.htm, and emailed to subscribers of our "altdiesel" listserve. Rulemaking workshops were made available to remote attendees by either webcast or webinar in all cases.

In addition to the public meetings, staff had many meetings with stakeholders, attended trade meetings, and exchanged technical information on a regular basis with staff from other State agencies, academia, industry groups, and non-governmental organizations. As a result of this extensive communication with the affected entities, the proposal contained herein is based upon feedback from nearly every corner of the regulated industry as well as other impacted organizations and individuals that are affected by actions concerning or regulate the fuels industry.

Staff also conducted a Standardized Regulatory Impact Assessment (SRIA) in combination with the LCFS. As required by Senate Bill 617 (Chapter 496, Status of 2011), ARB conducted a SRIA and received public feedback and comments from the Department of Finance.

As part of the SRIA process, ARB solicited public input on alternative ADF approaches, including 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. Alternative approaches submitted to ARB were considered as staff prepared a SRIA. The combined SRIA of Low Carbon Fuel Standard and ADF summary is posted at: http://www.dof.ca.gov/research/economic_research_unit/SB617_regulation/2014_Major_Regulations/documents/ADF_DF_131_SUMMARY.PDF

F. Organization of This Report

This report is organized into twelve chapters with five appendices. We start with four chapters of background and introduction followed by chapters for description of the proposed regulation, alternatives considered, technology assessment, environmental assessment, multimedia assessment, economic impacts analysis of this proposed regulation and concluding with a summary and rationale for the regulation as well as a references chapter. The five appendices include Proposed Regulation Order, Technology Assessment, Economic Assessment, Standardized Regulatory Impact Assessment and California Environmental Quality analysis.

CHAPTER 2. CALIFORNIA MANDATES ON AIR QUALITY

A. Ambient Air Quality Standards

Ambient air quality standards (AAQS) are established to protect even the most sensitive individuals in our communities. An air quality standard defines the maximum amount of a pollutant that can be present in outdoor air without harm to the public's health. Both the ARB and the U.S. Environmental Protection Agency (U.S. EPA) are authorized to and have set ambient air quality standards. California has established AAQS standards for certain pollutants such as fine particulate matter (PM_{10}), ozone, carbon monoxide and sulfur dioxide, which are more protective of public health than federal ambient air quality standards. California has also set standards for some pollutants that are not addressed by federal standards in addition to six criteria pollutants that are on National AAQS list.

Air pollution harms the health of California residents, damages agricultural crops, forests and other plants, and creates the haze that reduces visibility. A large body of scientific evidence associates air pollution exposure with a variety of harmful health effects. To address air pollution, both the California ARB and the U.S. EPA have adopted ambient (outdoor) air quality standards. These legal limits on outdoor air pollution are designed to protect the health and welfare of Californians.

B. Greenhouse Gases and Climate Change

California Global Warming Solutions Act of 2006 (AB 32) outlined the process by which the Board would reduce GHG emissions in California to 1990 levels by 2020 - a reduction of approximately 30 percent by 2020, and then an 80 percent reduction below 1990 levels by 2050. Required actions are codified in H&SC section 38500 through 38599, and Executive Orders S-3-05 and B-16-2012. Some specific provisions of AB 32 included the following responsibilities of ARB:

- Prepare and approve a scoping plan for achieving the maximum technologically feasible and cost-effective reductions in GHG emissions from sources or categories of sources of GHG by 2020 (H&SC §38561); and
- Identify the statewide level of GHG emissions in 1990 to serve as the emissions limit to be achieved by 2020 (H&SC §38550); and
- Adopt a regulation requiring the mandatory reporting of GHG emissions (H&SC §38530); and
- Identify and adopt regulations for discrete early actions that could be enforceable on or before January 1, 2010 (H&SC §38560.5).

AB 32 also requires ARB to develop a Scoping Plan (H&SC §38561) which lays out California’s strategy for meeting the GHG reduction goals. The Scoping Plan must be updated every five years and in December 2008, the Board approved the initial Scoping Plan, which included a suite of measures to sharply cut GHG emissions. In May 2014, ARB approved the First Update to the Climate Change Scoping Plan (Update), which builds upon the initial Scoping Plan with new strategies and recommendations. The Update highlights California's progress toward meeting the near-term 2020 GHG emission reduction goals, highlights the latest climate change science and provides direction on how to achieve long-term emission reduction goal described in Executive Order S-3-05. Low Carbon Fuel Standard Program was one of the discrete early actions identified by ARB pursuant to AB 32.

CHAPTER 3. CALIFORNIA MOTOR VEHICLE DIESEL FUEL POLICIES

This chapter provides a summary of various State policies that affect motor vehicle diesel fuel and specifically the development of the ADF regulation. These policies broadly include statutes, regulations, or initiatives that impact the development of the ADF regulation.

A. California Health and Safety Code

California Senate and Assembly bills pertinent to motor vehicle diesel fuels are codified in the California Health and Safety Code (H&SC). These statutes are then administered as rules and regulations in the California Code of Regulations (CCR). The relevant statutes and regulations are provided below but are primarily contained in H&SC Division 26, Parts 1, 2, and 5; and CCR Division 3, Titles 13 and 17.

1. Development of Diesel Fuel Regulations

H&SC Sections 39600, 39601, 43013, 43018, 43101, and 43833 authorize the Board to adopt motor vehicle diesel fuel regulations. Section 43013 is the primary source of ARB's legal authority to adopt and implement motor vehicle fuel specifications, motor vehicle emission standards, and in-use performance standards for the control of air contaminants and sources of air pollution which the Board has found to be necessary, cost effective, and technologically feasible.

Section 43018 expands ARB's authority to adopt whatever control measures pertaining to fuels that are technologically feasible, cost-effective, and necessary to attain the state AAQS by the earliest practicable date.

2. Fuels Multimedia Evaluation

H&SC section 43830.8 requires the state Board to conduct a multimedia evaluation before adopting any regulation that establishes motor vehicle fuel specifications. Section 43830.8(b) defines “multimedia evaluation” as “the identification and evaluation of any significant adverse impact on public health or the environment, including air, water, or soil, that may result from the production, use, or disposal of the motor vehicle fuel that may be used to meet the state board's motor vehicle fuel specification.”

Section 43830.8 also requires the California Environmental Policy Council (CEPC or Council) to review the multimedia evaluation and determine if any significant adverse impact on public health or the environment may result from a proposed regulation. If the Council determines that the proposed regulation will cause a significant adverse impact on public health or the environment, or that alternatives exist that would be less adverse, the Council shall recommend alternative or mitigating measures to reduce the adverse impact on public health and the environment.

B. Low Carbon Fuel Standard

In January 2007, Executive Order S-01-07 called for a low carbon fuel standard for transportation fuels to be established for California. The Executive Order specifies a reduction of at least 10 percent in the average carbon intensity of the State's transportation fuels by 2020.

The Executive Order instructed the California Environmental Protection Agency to coordinate activities between the University of California (UC), the California Energy Commission (CEC), and other state agencies to develop and propose a draft compliance schedule to meet the 2020 target. Furthermore, it directed ARB to consider initiating regulatory proceedings to establish and implement the LCFS. The ARB identified the LCFS as a discrete early action measure and approved it on April 23, 2009. The LCFS regulation reduces the carbon intensity of transportation fuels used in the State by an average of 10 percent by the year 2020 to be in line with Executive Order S-01-07.

California's LCFS is expected to reduce GHG emissions from the transportation sector in California by about 16 million metric tons (MMT) in 2020. These reductions account for almost 20 percent of the total GHG emission reductions needed to achieve the State's mandate of reducing GHG emissions to 1990 levels by 2020. In addition, the LCFS is designed to reduce California's dependence on petroleum, create a lasting market for clean transportation technology, and stimulate the production and use of alternative, low carbon fuels in California.

The LCFS is designed to provide a framework that uses market mechanisms, based on carbon intensity – a full lifecycle accounting of a fuel's carbon emissions relative to its energy potential, to spur the steady introduction of lower carbon fuels. The framework establishes performance standards that fuel producers and importers must meet each year beginning in 2011. Since the regulation went into effect, regulated parties have operated under the LCFS program with no significant compliance issues.

To date, the LCFS is working as designed and intended. Fuel producers are innovating and achieving reductions in their fuel pathway carbon intensities, an effect the LCFS regulation is expressly designed to encourage.

The LCFS, as well as other policies and incentives, are prompting the development and use of new ADFs in the State. As such, it is important to ensure that the full commercialization of these fuels do not adversely affect air quality or cause other environmental concerns. The proposed ADF regulation helps ensure this by subjecting new ADFs to rigorous environmental review and a comprehensive multimedia evaluation. In response to the LCFS, biodiesel production is projected to increase. As the LCFS and other policies continue to incentivize the use of ADFs, the proposed regulation will maintain air quality protections and address potential environmental and public health impacts.

Under the LCFS, biodiesel and emerging ADFs represent an important strategy for meeting annual compliance standards and will continue to be an essential part of California's fuel pool. The ADF regulation not only provides regulatory certainty for biodiesel and biodiesel blends, but also provides a clear pathway to streamline the commercialization of new ADFs in the future.

1. ADF Role within the Low Carbon Fuel Standard Program

The proposed ADF regulation is separate and not a part of the LCFS regulation, however the two are interconnected. The LCFS (among other policies and regulations) is expected to drive demand for biodiesel, renewable diesel, and other low carbon fuels. As a result of the increased use of biodiesel in recent years, interest has developed on the impacts of these fuels, especially as it relates to NOx emissions which had been identified as a potential concern. As such the proposed ADF regulation is a response in part to the LCFS and increased demand for biodiesel, as well as potential future demand for other ADFs.

2. Low Carbon Fuel Standard Litigation

Since the initial adoption of the LCFS in 2009, ARB has been involved with two separate lawsuits. The first, Rocky Mountain Farmers Union vs. Corey, relates to a federal lawsuit that challenges the LCFS on the grounds that the regulations were preempted by the federal Clean Air Act and the federal Energy Independence and Security Act and violated the dormant Commerce Clause. On December 29, 2011, the District Court granted Rocky Mountain Farmers Union's request for a preliminary injunction and American Fuels & Petrochemical Manufacturers Association's partial motion for summary judgment, concluding that the LCFS violated the dormant Commerce Clause of the U.S. Constitution. On September 18, 2013, the Ninth Court of Appeals reversed the District Court's opinion that held that the LCFS violated the dormant Commerce Clause and remanded the case for trial. The Ninth Circuit reversed on all but the Clean Air Act preemption claims and remanded for entry of partial summary judgment in favor of ARB.

A second lawsuit, POET, LLC vs. CARB was initiated on December 23, 2009, on the grounds that ARB violated the Administrative Procedure Act (APA) and California Environmental Quality Act (CEQA) during the adoption process. On July 15, 2013, the State of California Court of Appeal, Fifth Appellate District (Court) issued its opinion in POET, LLC v. California Air Resources Board (2013) 218 Cal.App.4th 681. The Court held that the LCFS would remain in effect and that ARB can continue to implement and enforce the 2013 regulatory standards while it takes steps to comply with APA and CEQA statutes.

Among the issues in the POET, LLC vs. CARB lawsuit was the treatment of biodiesel in the original LCFS regulation. The Court concluded that ARB violated CEQA by deferring the formulation of mitigation measures for NOx emissions from biodiesel without committing to specific performance criteria for judging the efficacy of the future mitigation measures. In addition to the general impetus of this ADF regulation to protect air quality, it is also designed to fulfill the court's requirements and to address issues with NOx emissions from biodiesel. Implementation of this proposed regulation will ensure that the use of biodiesel subject to LCFS will not result in increases in NOx emissions in California relative to current conditions.

Also, in response to the Court's directive, ARB staff will propose re-adoption of the LCFS regulation in 2015. This will allow ARB to comply with all procedural requirements imposed by CEQA and the APA. As stated earlier, the Court held the 2013 regulatory standards in place until the LCFS regulation can be re-adopted. Since the LCFS is scheduled to be presented to the Board in early 2015, the new LCFS requirements are schedule to go into effect January 1, 2016.   As part of the LCFS re-adoption effort, new elements and amendments are also being considered.

C. California Diesel Fuel Programs

Diesel and biodiesel are regulated by multiple state agencies in California. This section gives an overview of major state regulations affecting ADF use in California.

1. ARB Regulations

As the state air pollution agency, ARB is authorized to adopt standards, rules, and regulations to achieve the maximum degree of emission reduction possible from vehicular and other mobile sources in order to accomplish the attainment of the State ambient air quality standards at the earliest practicable date. ARB regulations can be found under California Code of Regulations (CCR) Division 3, Titles 13 and 17.

a. California Reformulated Diesel Fuel

In November 1988, the Board approved regulations limiting the aromatic hydrocarbon content to 10 percent by volume with a 20 percent limit for small refiners. These diesel fuel regulations, which became effective in 1993, are a necessary part of the State's strategy to reduce air pollution through the use of clean fuels, lower-emitting motor vehicles, and off-road equipment. The regulation includes provisions that enable diesel fuel producers and importers to comply through alternative diesel formulations that may cost less. The alternative specifications must result in the same emission benefits as the 10 percent aromatic standard (or in the case of small refiners, the 20 percent standard).

On July 24, 2003, the Board approved amendments to the California diesel fuel regulations. The amendments reduced the sulfur content limit from 500 ppmw to 15 ppmw for diesel fuel sold for use in California in on-road and off-road motor vehicles starting in mid-2006. The lower sulfur limit aligned the California requirement with the on-road diesel sulfur limit adopted by the U.S. EPA, but expanded the limit to include off-road motor vehicle diesel fuel. The new sulfur standard enabled the use of the emissions control technology, such as particulate filters, used for 2007 and subsequent model-year heavy-duty engines and vehicles.

In 2005, the Board also adopted a measure that applied the diesel fuel standards to harborcraft and intrastate locomotives.

b. Alternative Fuels

"Alternative fuel" generally means any motor vehicle transportation fuel that is not gasoline or diesel fuel. This includes, but is not limited to, those fuels that are commonly or commercially known or sold as one of the following: M-100 fuel methanol, M-85 fuel methanol, E-100 fuel ethanol, E-85 fuel ethanol, biodiesel, compressed natural gas (CNG), liquefied natural gas (LNG), liquefied petroleum gas (LPG), or hydrogen.

The quality of alternative motor vehicle fuels is subject to ARB-approved composition specifications under Title 13, California Code of Regulations, Sections 2292.1 through 2292.6, as follows:

- M-100 fuel methanol (13 CCR §2292.1),
- M-85 fuel methanol (13 CCR §2292.2),
- E-100 fuel ethanol (13 CCR §2292.3),
- E-85 fuel ethanol (13 CCR §2292.4),
- compressed natural gas (13 CCR §2292.5), and
- liquefied petroleum gas (13 CCR §2292.6).

Biodiesel is considered to be an alternative diesel fuel, but there are currently no ARB standards for biodiesel fuel.

2. SWRCB Regulations

The California State Water Resources Control Board (SWRCB) regulates the storage of diesel and biodiesel in Underground Storage Tanks (UST). These tanks must undergo compatibility testing by an independent certification lab, such as Underwriters Laboratory, for any new fuel that may be stored in them. B5 has undergone such a certification. Fuels above B6 have not undergone independent certification and there is no current activity to obtain certification, as such B6-B20 blends of biodiesel are generally stored above ground.

3. CDFA Regulations

The Division of Measurement Standards (DMS) of the California Department of Food and Agriculture (CDFA) regulates diesel and biodiesel for compliance with California specifications and measurement. DMS is statutorily obligated to adopt specifications for new fuels when an independent specification organization, such as ASTM, sets specifications for that fuel.

In 2008, ASTM international developed three biodiesel specifications. First, ASTM updated its specifications for B-100 blendstock, D6751-08, “Standard Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels.” Second, ASTM approved revisions to D975-08, “Standard Specification for Diesel Fuel Oils,” which would subject biodiesel blends from B1 to B5 to the same specification as regulation diesel fuel. Finally, ASTM adopted new fuel specifications for B-6 to B-20 in D7467-08, “Standard Specification for Diesel Fuel Oil Biodiesel Blend (B6 to B20).”

DMS conducted a rulemaking to adopt ASTM D6751 Standard Specification for Biodiesel fuel Blend Stock (B100) for use in Middle Distillate Fuels. DMS has also adopted ASTM D7467 Standard Specification for Diesel Fuel Oil, Biodiesel Blends (B6-B20). ASTM D975, Standard Specification for Diesel Fuel Oils, allows up to B5 to be used and has also been adopted by ASTM.

4. OSFM Regulations

The Office of the State Fire Marshal regulates diesel and biodiesel storage, dispensing, and vapor recovery. All diesel and biodiesel facilities must follow California building and fire code and adhere to the specific provisions regarding diesel and biodiesel.

5. Air Quality Improvement Program (AB 118)

The *California Alternative and Renewable Fuel, Vehicle Technology, Clean Air, and Carbon Reduction Act of 2007* (Assembly Bill (AB) 118) establishes two funding programs for alternative fuels and vehicle technologies.[1] The Air Quality Improvement Program (AQIP) is a voluntary incentive program administered by the ARB. Through AQIP, ARB invests in clean vehicle and equipment projects that reduce criteria pollutant and air toxic emissions, often with concurrent climate change benefits. For current information on annual funding plans and guidelines, please visit ARB’s Air Quality Improvement Program website at http://www.arb.ca.gov/msprog/aqip/aqip.htm.
The Alternative and Renewable Fuel and Vehicle Technology Program (ARFVTP), administered by the CEC, is a competitive grant program that provides as much as $100 million annually towards innovative transportation and fuel technologies. The CEC’s program is governed by its AB 118 Investment Plan, through which the CEC has provided nearly $415 million to date in funding for production and infrastructure projects involving diesel substitutes, including biodiesel and renewable diesel.[2] For more information on total funding amounts and clean transportation projects to date, please visit the CEC’s ARFVTP website at http://www.energy.ca.gov/drive/index.html.

[1] Assembly Bill 118; Núñez, Chapter 750, Statutes of 2007
[2] California Energy Commission, *2014-2015 Investment Plan Update for the Alternative and Renewable Fuel and Vehicle Technology Program*, p. 1, April 2014

CHAPTER 4. FEDERAL POLICIES AFFECTING MOTOR VEHICLE DIESEL FUEL

This chapter summarizes various Federal policies that affect motor vehicle diesel fuel and may specifically impact the ADF regulation. The policies covered in this chapter include pertinent federal fuel regulations, standards, and requirements.

A. Federal Fuel Registration

U.S. EPA regulations establish fuel registration and formulation requirements.
U.S. EPA requires that all diesel fuels and fuel additives for on-road motor vehicle use be registered in accordance with 40 Code of Federal Regulation (CFR) Part 79. To become registered, a new fuel must apply for registration and meet “substantially similar” requirements as either conventional gasoline or diesel fuel. The “substantially similar” requirement means that the fuel must be of mostly the same composition as the fuel it is displacing, which in the cases depicted under this regulatory proposal would be diesel fuel. Any biodiesel used in California must also be registered as a fuel with U.S. EPA.

The registration requirements for diesel fuels apply to fuels composed of more than 50 percent diesel fuel by volume, and their associated fuel additives. Manufacturers may enroll a fuel or fuel additive in a group of similar fuels and fuel additives through submission of jointly-sponsored testing and analysis conducted on a specific product, for which additives would be measured in parts per million (ppm). In addition, the regulation requires a cetane index of at least 40 or an aromatic hydrocarbon content of no greater than 35 volume percent. All on-road motor vehicle diesel fuel sold or supplied in the United States, except in Alaska, must comply with representative specifications for all products in that group.

B. Federal Regulations Affecting Diesel Fuel Quality

U.S. EPA motor vehicle diesel fuel standards, contained in 40 CFR Part 80 Subpart I, requires on-road motor vehicles diesel fuel to have a sulfur content of no greater than 15 ppmv.

The diesel fuel sulfur regulations require refiners, importers, distributors, and retailers who produce, import, sell, store, or transport diesel fuel to meet the standards specified in the diesel regulations. Sulfur standards were phased in from 2006 to 2010, and were designed to ensure widespread availability of highway diesel fuel containing 15 ppm sulfur or less.

C. Federal Renewable Fuels Standard

Congress adopted the Renewable Fuels Standard (RFS) in 2005 and strengthened it (RFS2) in December 2007 as part of the Energy Independence and Security Act of 2007 (EISA). The RFS2 contains, among other provisions, requirements for increasing volumes of biofuels every year, up to a required volume of 36 billion gallons by 2022. New categories of renewable fuel were also established with separate volume requirements for each category.

Successful implementation of the RFS2 will result in significant quantities of low carbon intensity biofuels that could be used toward compliance with California's LCFS. In addition, successful implementation would also signal that the necessary technological breakthroughs to produce second and third generation biofuels have occurred.

1. Renewable Fuel Volume Requirements

The RFS2 requires fuel producers to use a progressively increasing amount of biofuel, culminating in at least 36 billion gallons of biofuel by 2022[3]. The U.S. EPA must establish regulations to ensure that the transportation fuel sold in, or imported into, the United States contains a minimum volume of renewable fuels as required under the EISA of 2007. Responsible parties under the U.S. EPA regulations relating to biofuels include refiners, blenders, and importers of transportation fuels.[4] RFS2 differentiates between "conventional biofuel" (corn-based ethanol) and "advanced biofuel." Advanced biofuel is renewable fuel, other than corn-based ethanol, with lifecycle greenhouse gas emissions that are at least 50 percent less than greenhouse gas emissions produced by gasoline or diesel. Starting in 2009, a progressively increasing portion of renewable fuels must be advanced biofuels, such as cellulosic ethanol.

2. Renewable Fuels GHG Requirements

The RFS2 requires GHG reductions for the various categories of renewable fuels, but only in discrete "bins" (e.g., both advanced biofuel and biomass-based diesel must achieve a life-cycle GHG emission-reduction threshold of 50 percent).[5] This federal program does not use a carbon intensity standard like the LCFS. As noted, there are specific requirements for the different classifications of renewable fuels. In general, these specifications are set relative to the baseline lifecycle GHG emissions for gasoline and diesel fuel sold or distributed in 2005. The lifecycle GHG emissions are specifically defined as:

> *"The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions (including direct emissions and significant indirect emissions such as significant emissions from land use changes), as determined by the Administrator, related to the full fuel lifecycle, including all stages of fuel and feedstock production and distribution, from feedstock generation or extraction through the distribution and delivery and use of the finished fuel to the ultimate*

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[3] *Energy Independence and Security Act of 2007,* section 202 (a)(2)(B)(i)(I)

[4] U.S. Environmental Protection Agency, Office of Transportation and Quality. *EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond,* EPA-420-F-10-007. February 2010

[5] U.S. Environmental Protection Agency, Office of Transportation and Quality. *EPA Lifecycle Analysis of Greenhouse Gas Emissions from Renewable Fuels,* EPA-420-F-10-006. February 2010

consumer, where the mass values for all greenhouse gases are adjusted to account for their relative global warming potential."[6]

There are four general classifications of renewable fuels defined in RFS2: renewable fuels, advanced biofuels, cellulosic biofuels, and biomass-based diesel.

3. Renewable Biomass Definition

The RFS2 defines renewable fuel as fuel that is produced from renewable biomass. Renewable biomass is then defined as each of the following[7]:

- Planted crops and crop residue harvested from agricultural land cleared or cultivated at any time prior to the enactment of this sentence that is either actively managed or fallow, and nonforested.
- Planted trees and tree residue from actively managed tree plantations on non-federal land cleared at any time prior to enactment of this sentence, including land belonging to an Indian tribe or an Indian individual, that is held in trust by the United States or subject to a restriction against alienation imposed by the United States.
- Animal waste material and animal byproducts.
- Slash and pre-commercial thinnings that are from non-federal forestlands, including forestlands belonging to an Indian tribe or an Indian individual, that are held in trust by the United States or subject to a restriction against alienation imposed by the United States, but not forests or forestlands that are ecological communities with a global or State ranking of critically imperiled, imperiled, or rare pursuant to a State Natural Heritage Program, old growth forest, or late successional forest.
- Biomass obtained from the immediate vicinity of buildings and other areas regularly occupied by people, or of public infrastructure, at risk from wildfire.
- Algae.
- Separated yard waste or food waste, including recycled cooking and trap grease

One aspect of the definition of renewable biomass is that there are significant federal incentive funds for producing advanced biofuels. To qualify for these incentives, the renewable fuels must be produced from renewable biomass.

4. U.S. EPA Rulemakings Implementing the RFS2

U.S. EPA is responsible for implementing the volume requirements in the RFS2. Section 211(o) of the Clean Air Act (CAA or the Act), as amended, requires the

[6] *Energy Independence and Security Act of 2007*, Title II-Energy Security Through Increased Production of Biofuels; Subtitle A Section 201 (1)(H).
[7] *Energy Independence and Security Act of 2007*, Title II-Energy Security Through Increased Production of Biofuels; Subtitle A Section 201 (1)(I).

U.S. EPA Administrator to annually determine a renewable fuel standard and publish the standard in the Federal Register. Based on this standard, each obligated party determines the volume of renewable fuel that it must ensure is consumed as motor vehicle fuel. This standard is calculated as a percentage, by dividing the amount of renewable fuel that the Act requires to be blended into gasoline for a given year by the amount of gasoline expected to be used during that year, including certain adjustments specified by the Act.

a. RFS2 Volume Requirement - 2013

In August 2013, U.S. EPA finalized the 2013 renewable fuel standards which established the 2013 annual percentage standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. [8]: Note that the 16.55 billion gallons of renewable fuel required in 2013 was projected to include approximately 1.7 billion gallons of biodiesel and renewable diesel. In April 2014, U.S. EPA took direct final action to revise the 2013 cellulosic biofuel standard. The final 2013 volumes are shown in Table 4.1 below.

Table 4.1: Volumes Used to Determine the Final 2013 Percentage Standards

Category	Volume*
Cellulosic Biofuel	810,185 gal
Biomass-based Diesel	1.28 billion gal
Advanced Biofuel	2.75 billion gal
Renewable Fuel	16.55 billion gal

*All volumes are ethanol-equivalent, except for biomass-based diesel which is actual.

The U.S. EPA also used the applicable volumes that are specified in the statute to set the percentage standards for advanced biofuel and total renewable fuel for 2013.[9] The percentage standards required under the RFS program represent the ratio of renewable fuel volume to non-renewable gasoline and diesel volume. The 2013 standards are shown in Table 4.2 below.

Table 4.2: Final Percentage Standards for 2013

Category	Percent
Cellulosic Biofuel	0.0005%
Biomass-based Diesel	1.13%
Advanced Biofuel	1.62%
Renewable Fuel	9.74%

b. RFS2 Volume Requirements - 2014

[8] U.S. Environmental Protection Agency, Office of Transportation and Quality. *EPA Finalizes 2013 Renewable Fuel Standards,* EPA-420-F-13-042. August 2013

[9] U.S. Environmental Protection Agency, Office of Transportation and Quality. *EPA Issues Direct Final Rule for 2013 Cellulosic Standard,* EPA-420-F-14-018. April 2014

In November 2013, U.S. EPA proposed 2014 percentage standards for cellulosic biofuel, biomass-based diesel, advanced biofuel, and renewable fuels.[10] The projected 2014 volumes used to determine the proposed percentage standards are shown in Table 4.5 below:

Table 4.3: Volumes Used to Determine the Proposed 2014 Percentage Standards

Category	Proposed Volume*	Projected Range
Cellulosic Biofuel	17 million gal	8-30 million gallons
Biomass-based Diesel	1.28 billion gal	1.28 billion gallons**
Advanced Biofuel	2.20 billion gal	2.0-2.51 billion gallons
Renewable Fuel	15.21 billion gal	15.00-15.52 billion gallons

* All volumes are ethanol-equivalent, except for biomass-based diesel which is actual
** U.S. EPA is requesting comment on alternative approaches and higher volumes

The percentage standards represent the ratio of renewable fuel volume to non-renewable gasoline and diesel volume. The proposed 2014 standards are shown in Table 4.6 below.

Table 4.4: Proposed Percentage Standards for 2014

Category	Percent
Cellulosic Biofuel	0.010%
Biomass-based Diesel	1.16%
Advanced Biofuel	1.33%
Renewable Fuel	9.20%

The proposed 2014 standards were submitted to the Office of Management and Budget of interagency review in August 2014. However, in November 2014, the U.S. EPA announced that it will not be finalizing the 2014 standards until 2015.

D. Federal Trade Commission Labeling Requirements

The EISA of 2007 required Federal Trade Commission (FTC) to adopt regulations pertaining to the labeling of biodiesel and biomass-based diesel at retail dispensing outlets. This regulation was enacted under Title 16, Code of Federal Regulations, Part 306.12. The regulation requires labeling of biodiesel and biomass-based diesel if the blend level is above 5 percent. Specifically it requires labeling of blend B6 to B20 and blends above B20 are required to be labeled by the exact amount of biodiesel for example B63. Biomass-based diesel labeling requirements are parallel but independent of biodiesel volume.

[10] U.S. Environmental Protection Agency. *2014 Standards for the Renewable Fuel Standard Program; Proposed Rule.* Federal Register. Volume 78, No. 230. Part II. 40 CFR 80. November 29, 2013

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CHAPTER 5. DESCRIPTION OF PROPOSED REGULATION

A. Overview of Proposed Regulation

The primary purpose of the proposed regulation is to create a framework that allows for innovation and diversity in the California diesel fuel pool while ensuring the introduction of ADFs is managed responsibly by setting up a three stage process to evaluate environmental impacts of ADFs. Additionally, this rulemaking will establish in-use specifications for biodiesel as part of Stage 3A requirements of the proposed regulation.

B. Applicability

The proposed regulation will apply to all producers, importers, blenders and distributors of ADFs in the State of California. Fuel that meets a specification under the alternative fuels regulation 13 CCR 2292 are not considered ADFs and are thus not subject to this regulation. It is ARB's intention that this proposed regulation be in effect at all points of sale, offer, or supply in the California fuel distribution infrastructure.

C. Definitions

For the purposes of sections 2293 through 2293.9, the definitions in H&SC sections 39010 through 39060 shall apply, except as otherwise specified in subarticle 1:

Section (a) covers the definitions in the proposed regulation.

Section (b) is a glossary of acronyms used in the proposed regulation.

D. Applicable Requirements for Alternative Diesel Fuels

It is the goal of this proposed regulation to ensure that there are no adverse environmental impacts of ADFs as they are introduced into California. This proposed regulation relies on a three-stage introduction of ADFs, through which the environmental impacts will be determined and, if necessary, any adverse impacts minimized.

1. Stage 1 (Pilot Program)

The first stage of this proposed regulation is referred to as a pilot program. Any new ADF proponent may apply to setup a pilot program in order to begin testing of their fuel in California. The pilot program will limit the amount of a new ADF, not to exceed the energy equivalent of one million gallons of diesel fuel, used in well-defined fleets. The pilot program will last for one year, with three opportunities to renew for six months each. The application for a pilot program includes public disclosure of many properties of the fuel that may affect its impact to the environment (e.g., density, distillation curve, and water-octanol partition coefficient). The EO will use this information to conduct a preliminary review of the fuel to determine whether it is appropriate for use in California and if any potential risks resulting from the use of the fuel in a pilot program are outweighed by any potential benefits of the fuel. The EO will issue an Executive Order if the pilot program application is approved. The Executive Order will contain the necessary terms and conditions of additional testing based on the properties of the fuel. Completion of the terms of the Executive Order will be required prior to advancing to Stage 2. Applicants under a Stage 1 Executive Order will also be required to submit quarterly reports on how much fuel is being used.

2. Stage 2 (Fuel Specification Development)

Once an ADF applicant completes the terms of a Stage 1 Executive Order, they may apply for an updated Executive Order to move to Stage 2. The Stage 2 Executive Order will include a limit on the amount of that fuel that may be sold in California, to be determined by the EO but not to exceed the energy equivalent of 30 million gallons of diesel.

During Stage 2, an ADF applicant would be required to: (1) complete a multimedia evaluation, (2) achieve adoption of consensus standards, (3) obtain approval for use from 75 percent of engine manufacturers who produce engines in which the ADF is expected to be used, and (4) identify appropriate specifications for the fuel.

During Stage 2, ARB would make a determination of potential adverse emissions impacts from use of the ADF in question, using emissions data assembled during a multimedia evaluation. If it is determined that an ADF has been shown to have no potential adverse emissions impacts, the ADF would then be eligible to apply to advance to Stage 3B. If, however, it has determined there are potential adverse emissions impacts for the ADF or ADF blends, the ADF would be eligible to apply to advance to Stage 3A.

3. Stage 3 (Commercial Sales)

After completing the requirements of Stage 2, an ADF proponent may apply to the EO to move their fuel to Stage 3. If a determination of potential adverse emissions impacts was made under Stage 2, the EO may declare intent to advance the fuel to Stage 3A where an evaluation to determine whether there are adverse emissions impacts considering the effects of offsetting factors will commence. If the EO determines there are adverse emissions impacts the appropriate specifications and/or in-use requirements will be established by rulemaking. Throughout the course of a Stage 3A rulemaking, the volume limits from Stage 2 shall apply. In a Stage 3A rulemaking the EO shall consider, at a minimum, the offsetting effects of feedstocks, other fuel use, and vehicle effects when determining the appropriateness of establishing specifications and/or in-use requirements.

If the ADF was found to have no potential adverse emissions impacts, the EO may advance the ADF to Stage 3B by issuing an Executive Order with the specific provisions of the no potential adverse impacts determination. In Stage 3B, there are no limits on the fuel volume a proponent may sell or supply for use in California. Stage 3B consists of reporting and recordkeeping for an ADF.

E. Biodiesel as an Alternative Diesel Fuel

Biodiesel will have completed all of the relevant steps that are outlined in Stage 2 of the proposed regulation by the time this proposed regulation is in full effect. Potential adverse impacts have been identified. As such, ARB is proposing to regulate biodiesel at stage 3A. Because of the potential adverse emissions impacts identified for NOx emissions, ARB is proposing to establish specifications and in-use requirements for biodiesel and its blends.

ARB is also proposing the in-use requirements come into effect on January 1, 2018, as time is needed to overcome logistical and other issues in implementation of in-use requirements. For example, use of the additive Di-tert-butyl peroxide (DTBP) will require replacement of steel tanks with stainless steel tanks, permitting of hazardous substance storage, approval by local fire agencies, additional additization infrastructure, and logistical business changes to acquire the additive. All of this is expected to take around 2 years to complete. Another method of compliance is re-routing higher blends to NTDEs. Research shows that the use of biodiesel in blends up to B20 in NTDEs results in no detrimental NOx impacts. This and other methods of complying with the in-use requirements, such as certification of additional options are also expected to take 2 years or more. Because compliance with the in-use options would be infeasible during initial implementation on January 1, 2016, only recordkeeping and reporting provisions will be implemented initially. The in-use requirements are proposed to come into effect on January 1, 2018.

Staff's statistical analysis found that for certain vehicles biodiesel has potential adverse emissions impacts on NOx in any blends of low saturation biodiesel (un-additized CN <56) but not in blends of high saturation biodiesel (un-additized CN ≥56) up to B10. Staff has also found that there exist offsetting factors, in the form of renewable diesel and NTDEs that are expected to reduce and eventually eliminate any NOx increase from low level blends (B5 or less) of low saturation biodiesel. In order to ensure that the use of higher blends of biodiesel do not increase NOx emissions, staff is proposing NOx control levels above which per gallon in-use requirements would be instituted. Table 5.1 below shows the proposed NOx control levels based on feedstock and time of year.

Table 5.1: NOx Control Levels

	Control Level (April 1 to October 31)	Control Level (November 1 to March 31)
Low Saturation BD	B5	B10
High Saturation BD	B10	B10

In the period between November 1 and March 31, NOx control for reduction of ozone is less necessary. In order to maximize the PM reductions from biodiesel and allow increased flexibility for the biodiesel industry, ARB is proposing a control level of B10 for all biodiesel during this period.

Staff expects increasing use of NTDEs to eliminate biodiesel's NOx impact over time, thus the proposed biodiesel provisions include a sunset provision. ARB is proposing that the NOx control levels would sunset when EMFAC 2011 (ARB's model for estimating emissions from California on-road vehicles) shows more than 90 percent of Vehicle Miles Travelled (VMT) by NTDEs. The sunset provision is expected to trigger in 2023. However, staff has also proposed a review to be completed by December 31, 2019 in order to make sure that the offsetting factors are on track and that the in-use requirements for biodiesel are operating as expected.

Research indicates that the use of biodiesel in light- or medium-duty vehicles results in no detrimental NOx impacts. Research also indicates that the use of biodiesel up to blends of B20 in NTDEs results in no detrimental NOx impacts. Therefore, the proposed regulation also includes a process for fleets and fueling stations to become exempted from the in-use requirements for biodiesel blends up to B20 as long as they can demonstrate to the satisfaction of the Executive Officer that they are fueling at least 90 percent light or medium duty vehicles, or NTDEs.

CHAPTER 6. TECHNOLOGY ASSESSMENT

A. Introduction

This chapter summarizes the process by which ARB developed the conclusions on the NOx impacts of the use of biodiesel. This process includes the studies that ARB has sponsored, the additional studies upon which we based our analysis, as well as the statistical methods and study selection criteria that we used.

B. Emissions Studies Literature Review

Multiple studies have looked at the impact of biodiesel on heavy-duty diesel vehicle NOx emissions. The National Renewable Energy Lab (NREL) and the U.S. EPA have both examined the literature to determine these effects. Neither of these databases focused primarily on the effects of using CARB diesel as the base fuel. To fill this knowledge gap, ARB staff conducted a literature search that addresses the impacts of biodiesel use on NOx emissions in heavy duty engines using California diesel as the base fuel. It is important to focus on studies which use CARB diesel as the baseline, since multiple studies, such as the NREL and EPA studies referenced above, have found that base fuel impacts the presence and magnitude of a biodiesel NOx impact.

1. Criteria for Choosing Relevant Studies

The literature search focused on biodiesel blends B20 and below and characterized studies by their baseline fuel properties. Studies looking at B20 and below were chosen as the focus, since these are the fuels which are currently legal commercially. Studies that used either explicitly CARB diesel or a diesel fuel that was tested to have a cetane number of at least 49 were included in the analysis. Non-CARB diesel that had a cetane number of at least 49 was determined by staff to be similar enough to CARB diesel in NOx emissions to treat as CARB diesel for the purposes of this analysis, including showing similar emissions result when testing biodiesel blends derived from these fuels.

The studies included in this analysis were all performed using an engine dynamometer with commercially available engines, and no engine modifications. Engine dynamometer data were chosen over chassis dynamometer data because they eliminate some variability and as such are able to get a more accurate representation of true fuel to fuel variances. For example, since chassis dynamometer requires a person driving who would attempt to match an acceleration curve and engine dynamometer curves are performed by a computer, driver to driver variability is eliminated. Studies using test cycles based on a single speed and mode were excluded from this analysis because their results do not transfer well to real world emissions. Instead studies that used test cycles such as the Federal Test Procedure (FTP) or Urban Dynamometer Drive Schedule (UDDS) were selected because these cycles vary load and engine speed over the cycle in order to approximate real world operation.

2. Major Studies

Below is a list of the studies that met the stated criteria for inclusion in this analysis from our literature search.

Table 6.1: Major Studies from Literature Search

Author	Title	Publication	Year
Clark	Transient Emissions Comparisons of Alternative Compression Ignition Fuels	SAE 1999-01-1117	1999
Durbin	Biodiesel Characterization and NOx Mitigation Study	UC Riverside, prepared for CARB	2011
Durbin	CARB B5 Biodiesel Preliminary and Certification Testing	UC Riverside, prepared for CARB	2013
Durbin	CARB B20 Biodiesel Preliminary and Certification Testing	UC Riverside, prepared for CARB	2013
Eckerle	Effects of Methyl Ester Biodiesel Blends on NOx Emissions	SAE 2008-01-0078	2008
Karavalakis	CARB B5 Biodiesel Characterization Study	UC Riverside, prepared for CARB	2014
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
Nikanjam	Performance and Emissions of Diesel and Alternative Diesel Fuels in a Heavy-duty Industry-Standard Older Engine	SAE 2010-01-2281	2010
Nuzkowski	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: 1049-1060	2009
Thompson	Neat Fuel Influence on Biodiesel Blend Emissions	Int J Engine Res Vol. 11: 61-77	2010

In order to better understand emissions from biodiesel, ARB considered NOx data from literature studies as well as ARB studies from a wide range of vehicles feedstocks and test cycles. Table 6.2 below summarizes the testing matrix that was completed in studies included in the literature search.

Table 6.2: Summary of Testing Included in Literature Search

Application	Engine	Feedstocks	Test Cycles
On-road chassis	Caterpillar C15 Cummins ISM DDC MBE4000 Cummins ISX	Animal Soy Renewable diesel GTL	UDDS FTP 40mph Cruise 50mph Cruise
On-road HD engine	Cummins ISM DDC MBE4000 DDC Series 60	Animal Soy	UDDS FTP SET
Non-road engine	John Deere 4084 Kubota TRU	Animal Soy	ISO 8178-4

These studies found that most of the emissions from biodiesel are reduced from the CARB diesel baseline, including PM, CO, HC, and most toxic species. However, NOx was found to increase for certain biodiesel blend levels and feedstocks. Generally, it was found that soy based biodiesel blends had greater NOx emissions than those derived from animal based biodiesel. The results of these studies apply specifically to heavy-duty vehicles that do not use post-exhaust NOx emissions control, therefore the results of this study should not be extended to NTDEs or Light-duty and Medium-duty vehicles.

3. Effect of Base Fuel on Emissions

EPA 2002[11] examined the effect that base fuel has on the emissions results of biodiesel blends and found that using clean base diesel, such as CARB diesel, may impact the results in NOx emissions from biodiesel. As a result of this conclusion, ARB staff began looking into the effect that biodiesel might have on blends used within the State of California specifically. California's diesel fuel tends to be lower in aromatic hydrocarbon content and higher in cetane number than federal diesel. These two properties are important in the formation of NOx. After extensive testing and review, staff confirms EPA's original analysis and finds that the effects of biodiesel on NOx with CARB diesel as a base fuel are greater than the effects using federal diesel as a base fuel. As an example, EPA 2002 found NOx increases of about two percent in B20 derived from soy when federal diesel is the base fuel, whereas ARB's literature review finds NOx increases of about four percent in B20 derived from soy when CARB diesel is the base fuel. These results are discussed more in section C of this chapter.

C. NOx Emissions Data Analysis

ARB staff re-analyzed original data from three engine dynamometer studies that look at B5 to examine whether biodiesel blends yield different NOx emissions from conventional diesel fuel.[12,13,14] Staff chose to focus on engine studies because the

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[11] U.S. Environmental Protection Agency, *A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions*, 2002

[12] Durbin et al., *Biodiesel Characterization and NOx Mitigation Study,* October 2011

variability in emission measurements is smaller than for vehicles. A small change in emissions due to biodiesel would require a larger sample size to detect if vehicle data were used.

Our analysis focused primarily on soy B5, since soy is expected to be the dominant feed stock, and the existence of a significant effect at the 5% blend level would imply the existence of an effect at higher blend levels. Staff analyzed each blend level separately, and did not make any assumptions about whether the relationship between blend level and NOx emissions is linear or not.

Engine type and drive cycle have a significant impact on NOx emissions, and differences from one study to another can lead to large variations in emissions. We therefore controlled for these three variables in the statistical model. Out of several possible ways to reflect this in the model, we chose a simple approach: we treated the combination of engine type, drive cycle and study as a single categorical variable which we called the "experiment", and considered each experiment as yielding an independent estimate of the difference in NOx emissions between soy B5 and conventional diesel.

Past experience with emissions data suggests that transforming emissions by taking logarithms (or equivalently, working with percent differences instead of absolute differences) is appropriate. Staff confirmed this with model diagnostics.

Staff used a linear mixed effects model, with experiment as a random effect, fuel type as a fixed effect, and the natural logarithm of NOx emissions as the response, to estimate the difference in NOx emissions from soy B5 relative to CARB diesel.[15,16] Staff used R statistical software, specifically the `lmer` model fitting routine from R's `lme4` package.[17,18] The result: B5 yields approximately 1% higher NOx emissions than CARB diesel, and the increase is highly statistically significant (confidence level > 99.9999%).

Staff performed numerous sensitivity checks on the results. Staff tried several different formulations of the mixed model, as well as other statistical models. Staff also experimented with including other data sets that were not used for the final analysis. In each case soy B5 yielded around 1% higher NOx emissions than CARB diesel, and in each case the result was statistically significant.

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[13] Durbin et al., *CARB B5 Biodiesel Preliminary and Certification Testing*, April 2013
[14] Karavalakis et al., *CARB Comprehensive B5/B10 Biodiesel Blends Heavy-Duty Engine Dynamometer Testing*, June 2014
[15] Nester et al.,(1996). *Applied Linear Statistical Models*, Fourth Edition, Irwin. US
[16] Draper N, Smith H (1998). *Applied Regression Analysis*. Third Edition, Wiley Interscience. US
[17] R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. http://www.R-project.org/
[18] Bates et al., (2014). lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1-7 http://CRAN.R-project.org/package=lme4

As a further check against ARB staff's results, ARB contracted with Prof. David Rocke of U.C.Davis to analyze the same data set and derive independent conclusions. Prof. Rocke's analysis is attached as Appendix F. His results matched ARB staff's: soy B5 yielded approximately 1% higher NOx emissions than CARB diesel. The increase was highly statistically significant (confidence level > 99.9999%).

Further analysis of other biodiesel blends yielded the following results:

Soy B10	approximately 2% higher than CARB diesel
Animal B5	no statistical difference
Animal B10	no statistical difference

These results are consistent with a linear relationship between blend level and NOx emissions for soy blends in the 5-10% range. However, no data were available for blend levels below 5%, and it is not possible to establish whether the relationship is linear in the 0-5% range.

It should be noted that this testing demonstrates the results of a specific fuel formulation on specific engines in controlled laboratory conditions. To translate this to any potential real-world emission impact requires consideration of many factors (e.g., number of NTDE engines, amount of renewable and other low-NOx diesel, amount of low saturation vs high saturation biodiesel, and any NOx-reducing additives).

The complex mechanisms creating NOx increases at different biodiesel levels are not completely understood. The NOx emissions appear to be affected primarily through thermodynamic interactions, yet other factors have also been proposed. For example, Bunce et. al.,[19] looked at engine factors such as air to fuel ratio, EGR fraction, rail pressure and start of injection, as well as cetane number, soot radiation, bulk modulus, Engine Control Module feedback, and adiabatic flame temperature as factors that could serve to control engine NOx emissions. The complex interactions created by the fuel and engine system demonstrate the uncertainty inherent in translating the results of laboratory testing to real world emissions effects. The consistent and highly significant findings for NOx give certainty that there is an effect compared to CARB diesel.

D. Biodiesel Emissions in Heavy-Duty Diesel Engines

Below staff presents emissions effects of biodiesel based on the literature search described in section B of this chapter. The average data below are based on averages of the data found in the literature search and are not weighted as they were in the statistical analysis above. These results should thus be used as estimates of the effect of biodiesel as no attempt was made to weight them according to representativeness of the engines tested in the California Heavy duty vehicle fleet. For the rest of this chapter staff refers to soy biodiesel as low saturation biodiesel, and animal biodiesel as high saturation biodiesel. This is explained more fully in section 4.

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[19] Bunce et al, *Stock and Optimized Performance and Emissions with 5% and 20% Soy Biodiesel Blends in a Modern Common Rail Turbo-Diesel Engine,* Energy Fuels, 2010, *24* (2), pp 928–939

1. NOx Emissions

Biodiesel blend level was found to be directly related to NOx emissions level. Additionally, the NOx emissions from biodiesel were found to be dependent upon the saturation level of the biodiesel feedstock: high saturation feedstocks (animal in the studies) had less NOx emissions than low saturation feedstocks (soy and other lower cetane number feedstocks). Engine and duty cycle did not have substantial impacts on the NOx emissions. Table 6.3 below shows NOx emissions based on biodiesel blend levels and feedstock saturation.

Table 6.3: Biodiesel NOx Emissions by Blend Level and Feedstock Saturation

(ΔNOx Emissions)	**B5**	**B10**	**B20**
Low Saturation	1.1%	1.8%	4.0%
High Saturation	-0.2%	0.1%	1.5%

2. PM Emissions

Biodiesel blend level was found to be inversely correlated to PM emissions. Biodiesel feedstock or test method did not seem to substantively affect PM emissions. In 2007 and later engines equipped with PM filters, it was difficult to identify any meaningful differences in PM emissions between CARB diesel and biodiesel. Table 6.4 below shows PM emissions results by blend level.

Table 6.4: PM Reductions by Biodiesel Blend Level in pre-2007 Engines

(ΔPM Emissions)	**B5**	**B10**	**B20**
Pre-2007 Engines	-4.7%	-8.9%	-19.0%

3. VOC Emissions

Biodiesel blends generally had lower VOC emissions than CARB diesel, however in 2007 and later engines with PM filters it was difficult to identify any trends, likely because PM filters generally also include diesel oxidation catalysts which are designed to reduce VOCs. Effects of feedstocks and test cycles were not clear. Table 6.5 below shows VOC emissions in pre-2007 engines.

Table 6.5: VOC Emissions by Biodiesel Blend Level in pre-2007 Engines

(ΔVOC Emissions)	**B5**	**B10**	**B20**
Pre-2007 Engines	-2.2%	-3.1%	-10.1%

4. Effect of Biodiesel Properties on Emissions

NOx emissions from biodiesel are influenced by the feedstock from which the biodiesel is produced. Chemically the main properties of the biodiesel that are related to NOx appear to be the level of saturation and the chain length. Biodiesel is produced in such a way that several properties of the feedstock (e.g., saturation level, chain length) are retained in the biodiesel product. These chemical properties influence physical properties in fuel delivery and combustion that are important to the way the engine operates and thus relate to NOx emissions. The physical properties of interest include modulus of incompressibility, fuel atomization, and ignition delay; these properties are intercorrelated.

Rather than specifying feedstocks and their specific relationship with NOx emissions, which can pose technical and logistical difficulties for determination and tracking, it is preferable to separate biodiesel feedstocks and their NOx emissions potential using performance based properties. Staff is aware of two performance properties that have been shown to be reasonably well correlated to NOx emissions differences between feedstocks: Cetane number and iodine value. Neither of these properties are direct indicators of NOx emissions, but are surrogate values for predicting the chemical and physical properties which are related to NOx emissions. Cetane number has been shown to be a better indicator of NOx emissions differences than iodine number, but has problems when the fuels are additized with cetane enhancing additives.

Durbin 2011 showed that use of the cetane enhancing additive DTBP mitigated the NOx increases from a soy biodiesel. That same study showed that another cetane enhancing additive, 2-ethylhexyl nitrate (2-EHN), did not mitigate the NOx increases from a soy biodiesel. In fact, there were no differences between unnaditized biodiesel blends and additized biodiesel blends using 2-EHN. This result shows that the difference in NOx emissions from biodiesel is not based solely on cetane number of the mixture but on the properties of the biodiesel. Therefore, if cetane is used as an indicator of the NOx differences between biodiesel feedstocks, it should be measured prior to addition of cetane enhancing additives.

Alternatively, iodine number may be used to predict NOx differences between biodiesel feedstocks since it is not sensitive to cetane enhancing additives and is a measure of saturation of a fuel. Iodine number also has potential issues since it only addresses biodiesel saturation, and does not include the important effects of biodiesel chain length. However, this may not be an issue as the currently most frequently used feedstocks are very similar in chain length (primarily C16 and C18), and is not likely to become a problem unless more exotic feedstocks such as coconut oil (primarily C12) become popular. Staff proposes to use unadditized cetane number as the determinant of saturation level, since it is more frequently tested for by biodiesel producers and is more closely correlated to NOx emissions than iodine number.

5. Comparison of Vehicle Chassis to Engine Data

Vehicle chassis dynamometer and engine dynamometer are two popular methods of measuring the work exerted during emissions testing. In both cases, the goal is to relate the amount of emissions to some relevant value, generally grams/mile for chassis dynamometer and gram/brake horsepower hour for engine dynamometer. While chassis dynamometer certainly has its place and is able to better distinguish vehicle to vehicle differences, due to the use of the whole vehicle in testing, it adds greatly to the variability of testing, due to the driver, transmission and other sources of variability not present in engine testing. Therefore, when testing for fuel specific effects it is most appropriate to use engine dynamometer testing. As such, staff's analysis of specific numeric quantification of biodiesel emissions testing relies upon engine dynamometer studies.

It should be noted that although chassis dynamometer studies were not relied upon for quantification of emissions effects of biodiesel, staff examined several studies that included results using chassis dynamometer and they were directionally similar to the results staff got using engine data.

6. Emissions in New Technology Diesel Engines

Engines that meet the latest emission standards through the use of Selective Catalytic Reduction (SCR) have been shown to have no significant difference in NOx emissions based on the fuel used. A study conducted by the NREL looked at two Cummins ISL engines that were equipped with SCR, and found that NOx emissions control eliminates fuel effects on NOx, even for B100 and even in fuels compared against a CARB diesel baseline.[20] However, a recent study at UC Riverside tested B50 blends and found a NOx increase with a 2010 Cummins ISX.[21] The UC Riverside study did not look at blends below B50. Staff proposes to take a precautionary approach and in the light of data showing there may be a NOx impact at higher biodiesel blends but not at lower biodiesel blends, staff is limiting the conclusion of no detrimental NOx impacts in NTDEs to blends of B20 and below. Additional studies on NTDEs have been completed, however since they included either retrofit engines or non-commercial engines staff did not include their results in this analysis.[22,23,24]

7. Renewable Diesel NOx Emissions

Renewable diesel (as well as Gas-to-liquid diesel) has been found to decrease NOx emissions relative to CARB diesel. Durbin 2011 found that use of pure renewable diesel or GTL fuel reduced NOx emissions by about 10 percent relative to CARB diesel, and was found to be fairly linear according to blend level. Additionally as part of the

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[20] Lammert et al., *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

[21] Gysel et al., *Emissions and Redox Activity of Biodiesel Blends Obtained from Different Feedstocks from a Heavy-Duty Vehicle Equipped with DPF/SCR Aftertreatment and a Heavy-Duty Vehicle without Control Aftertreatment,* SAE 2014-01-1400 Published 04/01/2014

[22] McWilliam et al., Emission and Performance Implications of Biodiesel Use in an SCR-equipped Caterpillar C6.6 2010-012157 Published 10/25/2010

[23] Mizushima et al., *Effect of Biodiesel on NOx Reduction Performance of Urea-SCR System* 2010-01-2278 Published 10/25/2010

[24] Walkowicz et al., *On-Road and In-Laboratory Testing to Demonstrate Effects of ULSD, B20, and B99 on a Retrofit Urea-SCR Aftertreatment System*, SAE Int. 2009-01-2733

mitigation testing in that study, it was found that blends containing at least 2.75 gallons of renewable diesel per gallon of biodiesel were NOx neutral compared to CARB diesel.

E. Biodiesel Effects in Light and Medium Duty Vehicles

Light-duty and medium-duty vehicles have been found not to experience increases in NOx due to the use of biodiesel. For example, a study performed on three light-duty vehicles using different biodiesel blends found no significant and consistent pattern in NOx emissions based on blend levels across the different engines, blends and cycles.[25,26]

F. Biodiesel Effects in Non-road and Stationary Engines

1. Emissions from Non-road Engines

Durbin 2011 included two non-road engines in its test matrix, a John Deere 4084 and a Kubota TRU engine. Generally, the trends and magnitude of emissions for these engines were similar to those for the study as a whole. In general, NOx emissions increased, PM and HC emissions decreased with increasing biodiesel blend levels. The table below shows selected emissions for the John Deere and Kubota TRU engines, from a soy feedstock.

Table 6.6. Emissions from non-road engines on soy biodiesel

Engine	Blend Level	NOx	p-value	PM	p-value	HC	p-value
John Deere	B20	2.82%	0.021	-23.25%	0.028	-5.22%	0.498
	B50	7.63%	0.000	-31.75%	0.013	-15.12%	0.104
	B100	13.76%	0.000	-55.93%	0.000	-27.54%	0.001
Kubota TRU	B20	2.25%	0.086	-6.91%	0.011	-5.68%	0.153
	B100	18.89%	0.000	-40.30	0.000	-58.53%	0.000

2. Emissions from Stationary Engines

Stationary engines were not tested as part of staff's studies on biodiesel and no data were found on them during the literature search. As a conservative measure staff assumes that biodiesel also increases NOx at similar rates in stationary engines as in on-road and non-road engines.

G. NOx Emission Control Techniques

As a result of the Mitigation Study completed by UC Riverside and ARB, several technically feasible options were identified that would ensure no NOx increase as a

[25] Nikanjam et al, *Performance and Emissions of Diesel and Alternative Diesel Fuels in Modern Light-Duty Vehicles*, SAE 2011-24-0198, 2011
[26] Durbin et al., *Regulated Emissions from Biodiesel Fuels from On/Off-road Applications*, Atmospheric Environment, Volume 41, p. 5647-5658, 2007

result of biodiesel use. The options that were identified reduce NOx to parity with conventional CARB diesel by using additives or altering the baseline fuel.

The Mitigation study found that a blend of 1 percent di-tert butyl peroxide in B20 yielded NOx emissions that were equivalent to the CARB diesel baseline. Additionally, the Mitigation Study found that a blend of 55 percent renewable diesel, 25 percent CARB diesel and 20 percent biodiesel was equivalent to the CARB diesel baseline. Additionally, 2-ethylhexyl nitrate (2-EHN) was tested to determine whether it would also be able to mitigate the NOx from biodiesel blends since it is also a cetane improver. However, the fuels containing 2-EHN had essentially the same NOx emissions as those without additives. The difference between the NOx emissions of these blends compared to baseline CARB diesel is shown in the Table 6.3 below.

Table 6.7: NOx Emissions of Mitigation Measures

Fuel Blend	NOx Diff % from CARB diesel	p-value
B20 1%DTBP	0.0 %	0.959
C25 R55 B20	-0.8 %	0.029
B20 1% 2-EHN	6.3 %	0.000

In addition to the use of additives, staff is including certification procedures to allow for innovation and to allow the market to determine the best option for mitigation while ensuring no increase in NOx from the use of biodiesel. The certification option is based on the CARB diesel certification procedures under title 13 CCR section 2282(g). The certification requires a minimum of 20 tests each on a CARB diesel reference fuel and a candidate fuel. This number of replicates ensures that any emissions differences between the candidate fuel and the reference diesel are detected if they exist.

H. Determination of NOx Control Level for Biodiesel

Staff considered several factors in the analysis of what level of NOx control would be appropriate for biodiesel, primarily:

- NOx increase associated with biodiesel,
- Effects of high vs low saturation feedstocks,
- NOx reducing impacts of renewable diesel,
- Penetration rate of NTDEs,
- Reductions in emissions of pollutants other than NOx, and
- Feasibility of control methods.

When considering the impacts of biodiesel by feedstock, ARB determined that most of the biodiesel used in California would be low saturation biodiesel, which was found to have NOx increases at B5 with no clear point of NOx neutrality with CARB diesel. To be conservative, ARB has assumed that all blends containing low saturation biodiesel caused NOx increase.

ARB considered the range of factors which affect NOx emissions from diesel engines in the commercial market. NTDEs, which are increasing in number in California, do not show increased NOx from biodiesel use up to B20. Additionally, renewable diesel, which is increasing in California in response to the LCFS, reduces NOx. Given their impact on NOx emissions, renewable diesel and NTDEs are considered offsetting factors. Staff's analysis was designed to determine the appropriate blend level considering the Nox controls achieved by the above offsetting factors. Staff's analysis concluded that existing trends regarding use of NTDEs and renewable diesel as well as other factors supports a NOx control level of B5 for low saturation and B10 for high saturation biodiesel from April 1st to October 31st, and B10 for low and high saturation biodiesel from November 1st to March 31st.

For biodiesel blends below the NOx control level no in-use requirements are proposed because their use would not increase NOx emissions in the environment above current conditions after considering offsetting factors. In-use requirements will, under staff's proposal, be required for use of blends higher than NOx control level. These requirements could be met through the use of the additive DTBP, targeting exempt fleets, or certification of alternative options. The proposal addresses the seasonality of potential detrimental air quality impacts primarily related to summer-time ozone, and therefore allows a higher B10 blend for both low and high-saturation biodiesel during the low ozone season. Staff's analysis suggests that there will likely be no secondary PM detriment from the higher blends allowed in the low ozone season and may be benefits due to the direct PM reductions from biodiesel.

The net impacts of the proposal reduce NOx impacts from biodiesel, even assuming increased biodiesel volumes over the subsequent years. Estimated impacts under the proposal are less than the baseline (current year) and will continue to decrease as NTDE use increases in California. This proposal provides the maximum feasible level of mitigation while still achieving GHG and PM emission reductions.

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CHAPTER 7. AIR QUALITY AND ENVIRONMENTAL JUSTICE

A. Introduction

This chapter outlines the expected air quality impacts of the proposed regulation as well as an analysis of potential effects of the ADF regulation on environmental justice and local communities. The CEQA related requirements and findings are discussed in Chapter 8 as well as the attached Environmental Analysis document attached in Appendix D.

B. Air Quality

One of the primary goals of the ADF regulation is to ensure no significant environmental impacts as a result of the use of ADFs. As such ARB is proposing an environmental review process through the three stage evaluation of ADFs, as well as provisions for biodiesel as the first commercial ADF. Biodiesel provides important air quality benefits, primarily in the form of PM and GHG emissions reductions. Use of biodiesel is expected to contribute to ARB's short and long term air quality and climate goals.

Biodiesel has been found to increase NOx emissions in some circumstances, depending on feedstock, blend level, and vehicle technology. Staff anticipates that over the long term offsetting factors, such as NTDEs and renewable diesel, will grow as a result of other ARB regulations and will eliminate any adverse NOx impacts associated with the use of biodiesel. However, until the offsetting factors reach a critical point (90 percent of on-road heavy-duty VMTs operated by NTDE) there is a risk that use of higher blends of biodiesel (greater than B5) could result in NOx emissions higher than the current levels in 2014. In order to eliminate this risk, ARB is proposing a NOx control level that varies depending on the saturation level of the biodiesel feedstock and the time of year.

In 2014, staff estimates that approximately 72 million gallons of biodiesel and 120 million gallons of renewable diesel were consumed in California. These volumes combined with the use of NTDEs resulted in an increase in NOx of about 1.3 tons per day (TPD) and a decrease in PM of about 0.8 TPD statewide compared to use of CARB diesel alone. Once the proposed ADF and LCFS regulations are adopted staff anticipates that NOx emissions will decrease from current levels. As a result of the in-use requirements on biodiesel, staff expects that use of biodiesel above B5 will not result in NOx impacts. Table 7.1 shows the expected NOx impacts of biodiesel compared to 2014, including offsetting factors.

Table 7.1: Fuel Volumes and Resulting NOx emissions relative to 2014 levels

Million gallons	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Low Saturation B5	72	97	129	160	150	150	150	150	150
RD	120	180	250	300	320	360	400	500	550
NTDE VMT %	40%	51%	60%	66%	71%	75%	80%	85%	89%
Net NOx TPD	0.0	-0.06	-0.08	-0.09	-0.51	-0.75	-0.9	-1.17	-1.26

The result of staff's analysis concludes that the proposed LCFS and ADF regulations will have long term air quality benefits with reductions in NOx expected as well as reductions in PM and GHG emissions.

C. Environmental Justice and Local Communities

Government Code section 65040.12(e) defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. ARB is committed to supporting the achievement of environmental justice. In 2001, the Board adopted a framework for incorporating environmental justice into the ARB's programs consistent with the directives of State law. [27] Although ARB's environmental justice policies apply to all communities in California, they recognize that environmental justice issues have been raised more often in the context of low-income and minority communities.

As a result of ARB's work with the public, the business sector, local government, and air districts, California's ambient air is the cleanest since air quality measurements have been recorded.[28] Whereas the Los Angeles area experienced 148 smog alerts in 1970, by the year 2000, there was not a single smog alert.[29] However, large numbers of Californians live in areas that continue to experience episodes of unhealthy concentrations of ozone and PM2.5.

For this analysis, we note as an initial matter that any community in proximity to operations involving diesel fueled vehicles is already experiencing incremental risks from exposure to diesel particulate matter (PM). In 1998, ARB identified diesel PM as a toxic air contaminant with no safe threshold of exposure, which means that any diesel PM exposure may increase lifetime cancer risk for affected communities. Consequently, ARB embarked on a comprehensive diesel risk reduction program in the

[27] California Air Resources Board, Report, *Policies and Actions for Environmental Justice*, 2001
[28] California Air Resources Board, *History of Air Resources Board*, Website, http://www.arb.ca.gov/knowzone/history.htm, November 16, 20120 (accessed October 4, 2013)
[29] California Air Resources Board, Video file, *Clearing California Skies Updated*, http://www.arb.ca.gov/videos/clskies.htm (accessed October 4, 2013)

early 2000s, implementing a number of stationary, mobile, and portable diesel engine standards; fleet emission controls; and diesel fuel requirements designed to address such risks.

This proposed rulemaking is designed to maintain the air quality protections already in place under ARB's existing diesel fuel regulations. This includes, but is not limited to, maintaining protections in the only two areas nationwide whose air quality nonattainment status has been classified as "extreme," the San Joaquin Valley Air Basin and the South Coast Air Basin. Both areas have active environmental justice groups that have lobbied ARB to take aggressive action in pursuit of reduced toxic emission releases and attainment of ambient standards to ease air quality-related health burdens on their communities.

The air quality impacts of this regulatory proposal promote environmental justice by maintaining current protections for California's air quality in areas that are simultaneously the most adversely affected with respect to ground level ozone and home to many minority and low-income groups. At the same time, the proposed rulemaking provides a clear legal pathway to the commercialization of innovative, lower carbon diesel fuel substitutes. These innovative substitutes will reduce GHG emissions, and many of them also provide benefits in the form of additional reductions in PM, CO, NOx, toxic air contaminants, and other air pollutants.

As noted in Chapter 6, ADFs have the potential to reduce exposure to pollutants when used as a replacement for conventional diesel. To the extent that the proposed regulation expedites the introduction of ADFs as replacements for conventional diesel, all communities will benefit from improved air quality. In general, staff anticipates that any impacts resulting from the proposed regulation will be beneficial in nature, as a result of introducing new, lower-emitting ADFs.

To further ensure maintenance of air quality protections at the community level, the proposed regulation contains provisions that require a new ADF proponent to disclose comprehensive information about the ADF and the proponent's plan for limited fleet testing of that fuel. This comprehensive and detailed level of information required to be submitted before testing begins will permit ARB staff to assess the potential impacts such vehicle fleet studies could have on the most sensitive communities. Pertinent to the sensitive communities is a provision in the proposal that requires disclosure, in the Stage 1 and Stage 2 phases, of the ZIP codes in which the applicant proposes to conduct the limited vehicle fleet testing. The ARB staff will consider the proposed ZIP codes, along with the feasibility of conducting the fleet tests in alternative locations, as part of the Stage 1 and Stage 2 approval process. Depending on a number of factors, including the nature of the candidate ADFs and the extent of the fleet test, ARB staff may suggest or require a different location for the study as appropriate and feasible.

Based on staff's assessment of current and future ADFs, such as biodiesel and dimethyl ether, it is likely that new ADFs will exhibit less PM emissions relative to conventional diesel. In such cases, communities will benefit from lower cancer risk associated with the replacement of diesel fuel with ADFs. Likewise, communities will also benefit from any reductions in other criteria and toxic air pollutants associated with ADF use. The State mandated multimedia assessment will determine whether future ADFs will exhibit any increases in other toxic compounds, which may warrant additional controls. Moreover, since the proposed regulation provides for a more orderly process than currently exists towards commercialization, ARB would have more oversight over the approval of any ADF use in local communities and can ascertain whether additional requirements should apply to safeguard against any adverse impacts.

In addition to governing the approval and use of future ADFs, the proposed regulation would also explicitly identify biodiesel as the first ADF commercialized under this regulation. Biodiesel has an extensive history of environmental evaluation and consensus standard development. Indeed, much of the proposed regulation is modeled on ARB staff's experience in evaluating biodiesel over the years. As a result, the proposed regulation would explicitly identify biodiesel as a Stage 3A ADF, "Commercial Sales Subject to Mitigation," in recognition of the fact that biodiesel already has effectively undergone the requirements in Stage 1 and 2.

As discussed in Chapter 6 and the multimedia evaluation, biodiesel has been shown to reduce PM, HC, CO and greenhouse gases from diesel engines. Therefore, replacing diesel with biodiesel provides an immediate reduction in toxic cancer risk that is proportional to the percent reduction in PM emissions. Likewise, reductions in HC and CO also help communities by lowering near source and regional concentrations of ozone and CO.

Being the first commercially recognized ADF under the proposed regulation, biodiesel will have positive long term overall air quality impacts and benefits for all communities, and near term benefits to PM and GHG emissions. Staff expects that in the longer term (post 2022) no NOx mitigation will be necessary for biodiesel blends up to B20 due to the adoption of NTDEs.

In conclusion, the proposed ADF regulation is designed to ensure that the introduction and use of innovative ADFs in California, including biodiesel, will have no significant adverse environmental or public health impacts, as the heavy duty diesel fleet transitions to NTDEs. This conclusion applies at the State level as a whole, at the various air basin and regional levels, and at the local community level. As a result, the proposed regulation maintains the environmental and human health protections that are already provided under the existing diesel fuel regulations.

CHAPTER 8. ENVIRONMENTAL ANALYSIS

The Air Resources Board (ARB), as the lead agency for the proposed regulation, has prepared an environmental analysis under its certified regulatory program (17 CCR 60000 – 60008) to comply with the requirements of the California Environmental Quality Act (CEQA). ARB's regulatory program, which involves the adoption, approval, amendment, or repeal of standards, rules, regulations, or plans for the protection and enhancement of the State's ambient air quality has been certified by the California Secretary for Natural Resources under Public Resources Code section 21080.5 of CEQA (14 CCR 15251(d)). ARB, as a lead agency, prepares a substitute environmental document (referred to as an "Environmental Analysis" or "EA") as part of the Staff Report to comply with CEQA (17 CCR 60005).

The Draft Environmental Analysis (EA) for the proposed regulation is included in Appendix D to this Staff Report.   The Draft EA provides a single coordinated programmatic environmental analysis of an illustrative, reasonably foreseeable compliance scenario that could result from implementation of the proposed Alternative Diesel Fuel (ADF) regulation and the proposed re-adoption of the Low Carbon Fuel Standard (LCFS) regulation. The proposed ADF and LCFS regulations have two separate regulatory notices and staff reports and will be considered by the Board in separate proceedings. This approach is consistent with CEQA's requirement that an agency consider the whole of an action when it assesses a project's environmental effects, even if the project consists of separate approvals (14 CCR 15378(a)).

The Draft EA states that implementation of the proposed regulations could result in beneficial impacts to GHGs through substantial reductions in emissions from transportation fuels in California from 2016 through 2020 and beyond, long-term beneficial impacts to air quality through reductions in criteria pollutants, and beneficial impacts to energy demand. The Draft EA also states the proposed regulations could result in less than significant or no impacts to mineral resources, population and housing, public services, and recreation; and potentially significant and unavoidable adverse impacts to aesthetics, agriculture resources, biological resources, cultural resources, geology and soils, hazards and hazardous materials, hydrology and water quality, land use and planning, noise, transportation and traffic, and utilities, and short-term construction-related air quality impacts primarily related to the construction projects and minor expansions to existing operations that are reasonably foreseeable as a result of the proposed regulations.

Written comments on the Draft EA will be accepted starting January 2, 2015 through 5 p.m. on February 17, 2015. The Board will consider the Final EA and responses to comments received on the Draft EA before taking action to adopt an ADF regulation.

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CHAPTER 9. MULTIMEDIA EVALUATION

H&SC section 43830.8 prohibits ARB from adopting any regulation that establishes motor vehicle fuel specifications unless that regulation is subject to a multimedia evaluation and reviewed by the CEPC. Pursuant to Public Resources Code section 71017(b), the CEPC was established as a seven-member body comprised of the Secretary for Environmental Protection; the Chairpersons of the ARB and SWRCB; and the Directors of the Office of Environmental Health Hazard Assessment (OEHHA), the Department of Toxic Substances Control (DTSC), the Department of Pesticide Regulation (DPR), and the Department of Resources Recycling and Recovery (CalRecycle). Key components of the evaluation process are the identification and evaluation of significant adverse impacts on public health or the environment and the use of best available scientific data.

A. General Overview

"Multimedia evaluation" means the identification and evaluation of any significant adverse impact in public health or the environment, including air, water, and soil, that may result from the production, use, and disposal of a motor vehicle fuel that may be used to meet the state board's motor vehicle fuel specifications (H&SC §43830.8(b)).

1. Multimedia Working Group

The California Environmental Protection Agency (Cal/EPA) formed the interagency multimedia working group (MMWG) to oversee the multimedia evaluation process. The MMWG includes representatives from the ARB, SWRCB, OEHHA, and DTSC. The MMWG also consults with other Cal/EPA agencies and experts as needed.

During a multimedia evaluation, ARB staff are responsible for the air quality impact assessment and overall coordination of the MMWG. SWRCB staff are responsible for the evaluation of surface water and groundwater quality and potential impacts. OEHHA staff are responsible for evaluating potential public health impacts. DTSC staff are responsible for evaluating potential hazardous waste and soil impacts.

2. California Environmental Policy Council

Before ARB adopts a regulation that establishes new fuel specifications, the CEPC must determine if the proposed fuel specification poses a significant adverse impact on public health or the environment. In making its determination, the CEPC must consider the following:

- emissions of air pollutants, including ozone-forming compounds, particulate matter, toxic air contaminants, and greenhouse gases,
- contamination of surface water, groundwater, and soil,
- disposal of waste materials, including agricultural residue, forest biomass, and municipal solid waste, and

- MMWG staff report and peer review comments.

The CEPC must complete its review of the evaluation within 90 calendar days following notice from ARB that it intends to adopt the regulation. If the CPEC determines that the proposed regulation will cause a significant adverse impact on public health or the environment, or that alternatives exist that would be less adverse, the CEPC shall recommend alternative measures to reduce the impact.

3. External Scientific Peer Review

H&SC section 43830.8(d) requires an external scientific peer review to be conducted on the multimedia evaluation in accordance with H&SC section 57004. The purpose of the peer review is to determine whether the scientific portions of the staff report are based upon "sound scientific knowledge, methods, and practices (HSC section 57004(d)(2))."

B. Summary of the Biodiesel and Renewable Diesel Multimedia Evaluation

As part of the ADF regulation, staff intends to establish fuel quality specifications for biodiesel. Therefore, a multimedia evaluation of biodiesel and renewable diesel fuel was conducted pursuant to H&SC section 43830.8 and the *Guidance Document and Recommendations on the Types of Scientific Information Submitted by Applicants for California Fuels Environmental Multimedia Evaluations,* ("Multimedia Evaluation Guidance Document").[30]

The MMWG prepared two staff reports entitled, "*Draft Staff Report: Multimedia Evaluation of Biodiesel*" (Biodiesel Staff Report)[31] and "*Draft Staff Report: Multimedia Evaluation of Renewable Diesel*" (Renewable Diesel Staff Report).[32] The draft staff reports consist of the MMWG's assessment of the biodiesel and renewable diesel multimedia evaluations conducted by the UC Berkeley and UC Davis, and the MMWG's analysis of potential significant adverse impacts on public health and the environment.

The MMWG's conclusions and recommendations are based on the results of the multimedia evaluation and the information provided in the UC final reports entitled, "*California Biodiesel Multimedia Evaluation Final Tier III Report*" (Biodiesel Final Report)[33] and "*California Renewable Diesel Multimedia Evaluation Final Tier III Report*" (Renewable Diesel Final Report).[34]

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[30] U.C. Berkeley, U.C. Davis, Lawrence Livermore National Laboratory, *Guidance Document and Recommendations on the Types of Scientific Information Submitted by Applicants for California Fuels Environmental Multimedia Evaluations*, June 2008
[31] Multimedia Working Group, California Environmental Protection Agency. *Staff Report: Multimedia Evaluation of Biodiesel"* November 2013
[32] Multimedia Working Group, California Environmental Protection Agency. *Staff Report: Multimedia Evaluation of Renewable Diesel"* November 2013
[33] U.C. Berkeley, U.C. Davis, *California Biodiesel Multimedia Evaluation Final Tier III Report*, May 2013
[34] U.C. Berkeley, U.C. Davis, *California Renewable Diesel Multimedia Evaluation Final Tier III Report*, April 2012

1. Biodiesel Multimedia Evaluation

The MMWG completed their assessment of the biodiesel multimedia evaluation and potential impacts on public health and the environment. The evaluation is a relative comparison between biodiesel and CARB diesel.

The MMWG concludes that the use of biodiesel fuel in California, as specified in the biodiesel multimedia evaluation, does not pose a significant adverse impact on public health or the environment relative to CARB diesel.

Each agency's individual assessments and conclusions are summarized below:

- Air Emissions Evaluation. ARB staff assessed potential air quality impacts and made conclusions based on their assessment of various emissions test results and air quality data, including criteria pollutants, toxic air contaminants, and greenhouse gas emissions data. ARB staff concludes that biodiesel reduces PM, CO, and HC emissions and may increase NOx emissions in some blends.

- Water Evaluation. SWRCB staff assessed potential surface water and groundwater impacts and made conclusions based on their assessment of potential water impacts and materials compatibility, functionality, and fate and transport information. SWRCB staff concludes that there are minimal additional risks to beneficial uses of California waters posed by biodiesel than that posed by CARB diesel.

- Public Health Evaluation. OEHHA staff assessed potential public health impacts and made conclusions based on their assessment of potential impacts on atmospheric carbon dioxide and combustion emissions results. OEHHA staff concludes that the substitution of biodiesel for CARB diesel reduces the rate of addition of carbon dioxide to the atmosphere and reduces the amount of PM, benzene, ethyl benzene, and polycyclic aromatic hydrocarbons (PAHs) released into the atmosphere, but may increase emissions of NOx for certain blends. Limited emission testing resulted in a non-statistical increase in acrolein for a higher B50 biodiesel blend level (i.e., confidence interval less than 95%). Furthermore, the statistical analysis for acrolein emission results was compared to only one data point for the control sample.

- Soil and Hazardous Waste Evaluation. DTSC staff assessed soil and hazardous waste impacts and made conclusions based on their evaluation of hazardous waste generation and potential impacts on the fate and transport of biodiesel fuel in the subsurface soil from unauthorized spills or releases. DTSC concludes that biodiesel aerobically biodegrades more readily than CARB diesel, has potentially higher aquatic toxicity for a small subset of tested species, and generally has no significant difference in vadose zone infiltration rates.

2. Renewable Diesel Multimedia Evaluation

The MMWG completed their assessment of the renewable diesel multimedia evaluation in support of low NOx standard. The evaluation is a relative comparison between renewable diesel and CARB diesel.

The MMWG concludes that the use of renewable diesel fuel in California, as specified in the renewable diesel multimedia evaluation, does not pose a significant adverse impact on public health or the environment relative to CARB diesel.

Each agency's individual assessments and conclusions are summarized below:

- Air Emissions Evaluation. ARB staff assessed potential air quality impacts and made conclusions based on their assessment of various emissions test results and air quality data, including criteria pollutants, toxic air contaminants, and greenhouse gas emissions data. ARB staff concludes that renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts.

- Water Evaluation. SWRCB staff assessed potential surface water and groundwater impacts and made conclusions based on their assessment of potential water impacts and materials compatibility, functionality, and fate and transport information. SWRCB staff concludes that there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel.

- Public Health Evaluation. OEHHA staff assessed potential public health impacts and made conclusions based on their analysis of toxicity testing data and combustion emissions results. OEHHA staff concludes that PM, benzene, ethyl benzene, and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than CARB diesel.

- Soil and Hazardous Waste Evaluation. DTSC staff assessed soil and hazardous waste impacts and made conclusions based on their evaluation of hazardous waste generation and potential impacts on the fate and transport of biodiesel fuel in the subsurface soil from unauthorized spills or releases. DTSC concludes that renewable diesel is free of ester compounds and has low aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel.

C. Biodiesel and Renewable Diesel Peer Review

The peer review process was initiated by submittal of a request memorandum to the manager of the Cal/EPA Scientific Peer Review Program. The memorandum was prepared by ARB as the lead agency of the MMWG and included a summary of the nature and scope of the requested review, descriptions of the scientific issues to be addressed, and a list of recommended expertise. Upon approval, the University of California, through an interagency agreement with Cal/EPA, identified seven reviewers to complete the review of the biodiesel and renewable diesel multimedia evaluations.

The MMWG requested reviewers to address the Biodiesel and Renewable Diesel Staff Reports separately. Therefore, each reviewer completed two separate reviews, accordingly, for a total of 14 reviews.

In general, the peer reviewers determined that the conclusions and recommendations made by the MMWG were based upon sound scientific knowledge, methods, and practices, including the overall finding that the use of biodiesel and renewable diesel fuel in California, as specified in the biodiesel and renewable diesel multimedia evaluation, respectively, do not pose a significant adverse impact on public health or the environment relative to CARB diesel.

The complete set of peer review comments are posted on the *Fuels Multimedia Evaluation Meetings and Documents* webpage.[35] Individual peer review comments are categorized under the following general topics:

- Air quality
- Public health
- Water quality
- Soil and hazardous waste
- Multimedia evaluation
- Staff report
- Source reports
- Proposed regulation

The MMWG are preparing written responses to each of the comments. The complete set of peer review comments and MMWG responses will be included in the staff reports as new chapters, including any revisions to the staff reports that were made to address comments, where appropriate.

D. Current Status and Next Steps

The Biodiesel Staff Report is currently undergoing supplemental external peer review and internal MMWG analysis. Upon completion of the MMWG's review and

[35] Air Resources Board. *Fuels Multimedia Evaluation Meetings and Documents* webpage: http://www.arb.ca.gov/fuels/multimedia/meetings/meetings.htm

assessment of additional biodiesel studies and comments from the initial peer review, ARB intends to update and modify the Biodiesel Staff Report.

The supplemental external peer review of biodiesel will focus on the modifications to the MMWG's assessment of the biodiesel multimedia evaluation and the scientific basis for which the proposed modifications are based.

The supplemental peer review is currently scheduled from January to February 2015. Once all peer review comments are received, the MMWG will prepare written responses and make any revisions to the staff report, as needed. After all comments have been addressed, the MMWG will finalize the staff reports for submittal to the CEPC. The Cal/EPA will then convene a public meeting of the CEPC to consider the results of the peer reviews and the overall multimedia evaluation of biodiesel and renewable diesel fuel. Based on the evaluation and public comments, the CEPC will determine if the proposed regulation will cause a significant adverse impact on public health or the environment.

CHAPTER 10. ECONOMIC IMPACTS ASSESSMENT

A. Summary of Economic Impacts

In preparing this economic analysis, staff considered the costs of complying with the general provisions prescribed for Stage 1, Stage 2, and Stage 3 (as described in Chapter 5) of the proposed regulation. The compliance costs are determined on a fuel-by-fuel basis and will depend on whether a new ADF achieves full commercial development and successfully completes all three stages. Full commercialization of new ADFs in California will depend on successful resolution of a myriad of technical issues including, but not limited to, vehicle performance, fuel infrastructure compatibility, public health and environmental issues. If a new ADF completes all three prescribed stages, then only minimal recordkeeping and reporting above and beyond requirements that are already required under other State and Federal mandates will be the costs attributable to this regulation. These reporting requirements would be satisfied with reporting currently done through the Low Carbon Fuel Standard Reporting Tool (LRT) used to claim LCFS credits.

Because the majority of the provisions in all three stages are already required under existing State and Federal programs, staff estimates that the overall cost of the regulation to commercialize a future ADF will be minimal for the majority of ADF producers or distributors and would mainly account for additional, or “enhanced,” recordkeeping. Other than biodiesel, no other ADF has undergone more than a preliminary analysis akin to Stage 1 of this proposal. The environmental impacts of those potential fuels are unknown, as that is determined in Stage 2 during the multimedia evaluation. For an ADF under Stage 3B, there will be minimal costs attributable to the proposed regulation because those ADFs would be subject to the same reporting requirements as all other commercial motor vehicle fuels, and no costs if reporting is done via the LRT. Without knowing the type of ADF and associated volumes that may come to market in the future, pollutant control costs cannot be estimated for those fuels commercialized under Stage 3A. Since biodiesel is the first commercialized ADF to be regulated under this proposal, the cost for biodiesel suppliers to comply with the regulation is addressed in this chapter as the costs of the regulation.

As noted, biodiesel has already undergone the equivalent of the proposal’s Stages 1 and 2. Accordingly, biodiesel would be sold in the California market under Stage 3A upon this proposed regulation becoming effective. Staff propose to incorporate certain provisions in Stage 3A to ensure NOx emissions from biodiesel use do not cause any significant adverse impacts. These include per gallon NOx emission control requirements from April 1st through October 31st, for low saturation biodiesel blends above B5, as well as for blends above B10 for high saturation biodiesel. From November 1st through March 31st, the in-use requirements are relaxed and permit both low and high saturation biodiesel blends up to B10 for use without these in-use requirements. The current California biodiesel market currently uses and is projected to continue using the majority of the biodiesel produced in the state to create blends below B5, and therefore, we project limited costs due to NOx control requirements.

Biodiesel and biodiesel blends are being currently sold in California without regulatory oversight to safeguard against potential adverse emissions impacts, including NO_x. As such, the biodiesel industry has not invested in the additive blending infrastructure required for NO_x emissions controls, nor have they pursued certifications of low NO_x emissions biodiesel formulas. This absence of any NOx emissions controls infrastructure was brought up in the National Biodiesel Board's (NBB) submittal of an alternative to the proposed regulation, which also recommended a lead-in period. Given the current lack of NO_x emissions controls infrastructure, staff proposes that the in-use requirements not take effect until 2018, or two years after the implementation date of the regulation. Staff believes that two years is sufficient to provide the biodiesel industry with time to invest in the infrastructure necessary for additive handling and blending; to develop and pursue certifications for new NOx reduction options; and to adopt potential commercial changes such as focusing on exempted NTDE fleets. Also, this two year period is in keeping with established ARB policy, as many other ARB regulations have also provided similar grace periods to their affected industries; allowing them time to adjust their business practices and minimize adverse fiscal impacts, especially in cases where no regulatory oversight existed before.

The proposed regulation is not expected to have a significant adverse economic impact on California businesses or their competitiveness. However, the proposed ADF regulation will have some minimal economic costs to ADF fuel providers, including producers, distributors, and possibly retailers. In addition, consumers and government agencies that opt to fuel their fleets with biodiesel blends requiring NO_x emissions controls may experience an increase in fuel costs provided their fleets consist of heavy duty vehicles without NTDEs, though these costs are small. ARB determined that the regulation does not pose any requirements that will have an adverse economic impact. The highest cost year of the regulation is 2018 with a cost of $3,071,000 to produce both B10 and B20 blends. This represents less than one-one hundredth of the economic activity in California in 2018. Additionally, the direct costs to the industry are a small portion of the industry revenues and can likely be absorbed by either the ADF business or passed along to consumers. Finally, these additional costs will likely be offset by the revenue from credit generation in the LCFS program and therefore not impact the regulated entities significantly.

B. Major Regulations

ARB is subject to two separate major regulation requirements, identified below:

For a major regulation proposed on or after November 1, 2013, a standardized regulatory impact assessment (SRIA) is required. A major regulation is one "that will have an economic impact on California business enterprises and individuals in an amount exceeding fifty million dollars ($50,000,000) in any 12-month period between the date the major regulation is filed with the Secretary of State through 12 months after the major regulation is estimated to be fully implemented, as estimated by the agency." (Govt. Code Section 11342.548). This requirement is triggered if either the direct, indirect and induced costs, or taken separately, the benefits exceed $50 million. The economic impacts of this regulation may exceed $50 million, and therefore the regulation is treated as major according to the Government Code. In response, ARB prepared and submitted a SRIA to the Department of Finance[36].

For purposes of Health and Safety Code Section 57005(b), “major regulation” means any regulation that will have an economic impact (compliance cost) on the state’s business enterprises in an amount exceeding ten million dollars ($10,000,000), as estimated by the board, department, or office within the agency proposing to adopt the regulation in the assessment required by subdivision (a) of Section 11346.3 of the Govt. Code. This regulation may impose compliance costs that exceed $10 million and therefore the regulation is treated as major for the Health and Safety Code.

C. Economic Impacts Assessment

As discussed in Chapter 5, biodiesel is currently the only ADF identified as subject to the proposed regulation. Given the fact that biodiesel currently has consensus standards, is completing a multimedia assessment, and has an identified NOx emissions impact and in-use pollutant control strategies, staff proposes to recognize biodiesel as a Stage 3A commercial ADF subject to in-use requirements under specified conditions.

Therefore, only the cost of biodiesel compliance in Stage 3A would be attributable to the proposed regulation, and drives all the actual costs of the regulation. This means that the cost of biodiesel as the first commercial ADF will be primarily the cost of enhanced monitoring with minor costs due to in-use requirements. As staff discussed in Chapter 6, in-use requirements for NO_x control are unlikely to be utilized for most of the biodiesel sold in the state. In the unlikely scenario of blends requiring NO_x controls reaching wide scale market share in the future, the cost of these controls would also be attributable to the proposed regulation. NO_x control costs are presented in Appendix C.

Staff projects the same overall volumes of pure biodiesel (B100) will be produced as in business as usual. However, the blend levels will be adjusted downward to meet the provisions outlined in this regulation. Staff identified the following options that may occur in reaction to the ADF regulation:

Option 1: Businesses will use NO_x emissions controls and continue selling at the same level. Staff believes the majority of businesses will not opt to use NO_x emissions controls given that other options are less costly and therefore more feasible. These businesses will have an option to sell biodiesel blends up to B10 in the winter months.

Option 2: Businesses will continue selling blends with in-use requirements such as B20 at existing volumes by targeting NTDE fleets with exemptions from the in-use requirements. Many of the existing retailers (and therefore distributors), are already working with functionally exempt fleets. For example, staff discovered that many B20

[36] SRIA: http://www.dof.ca.gov/research/economic_research_unit/SB617_regulation/2014_Major_Regulations/

fueling pumps cannot accommodate HDVs because of low ceiling clearance and inaccessible facilities. As such, these retailers could seek exemptions that allow them to continue selling B20 to the medium and light duty vehicles, which these retail pumps are designed to accommodate. For the retailers that can accommodate HDVs, some change in their business practices will have to occur, such as establishing a dedicated lane for NTDEs that wish to use biodiesel blends such as B20. These business will also the option to sell biodiesel blends up to B10 in the winter months

Option 3: Businesses will stop selling B20 and only offer lower blends. For the retailers they may lose some business, which is likely negligible as the consumers of these fuels will likely transition from B20 to lower blends. The distributors will be able to stay in business, but have to change their business practices to accommodate a change to lower blends. For instance: they will likely have to distribute lower blends by truck, potentially leading to increased truckloads. These business also will have an option to sell biodiesel blends up to B10 in the winter months

Staff believes the reality will be a mix of these options. This chapter assumes the following scenario, which is evaluated in detail in this chapter:

Staff estimates that in 2018 the market share of biodiesel blends requiring NO_x controls will be around 17 percent (30 million gallons out of 180 of the total biodiesel volumes sold in the state), with volumes projected to remain steady until 2021 when total biodiesel volumes increase to 185 million gallons. These volumes then remain at 185 million gallons until 2023 when NTDE VMT exceeds 90 percent of total VMT in EmFAC 2011. At that point the in-use requirements will sunset and use of B20 will be allowed without in-use requirements.

- For all seasons, high saturation biodiesel has a NOx emissions control requirement at the level of B10. Staff assumes high saturation biodiesel will be sold at B10 with only the cost of testing to verify the high saturation exemption to the requirement for NOx emissions controls at the B5 level.
- The projection of VMT by NDTEs is 71 percent in 2018. Assuming some portion of these vehicles will be targeted by the B20 industry, coupled with additional B20 use in light and medium-duty vehicles, staff calculates 8 million gallons of B100 used in B20 will be exempted for all seasons in 2018. The VMT by NTDE's increases in the subsequent years from 75 percent in 2019 to 98 percent in 2023. As the VMT of the NTDE fleets increases, so will the proportion of biodiesel volumes with exemptions to the in-use requirements.
- The final 9 million gallons of low saturation biodiesel will be divided between winter and summer. Assuming slightly less biodiesel is used in the winter; staff assumes 4 million gallons in winter and 5 million in summer. The summer use will require a NOx emissions control of 5 percent DTBP per gallon of B100. The remaining 4 million will be used in winter as B10 without any in-use requirements.

This scenario is summarized in the table below, using volumes projected for 2018:

Table 10.1 Summary of Costs for 2018

Million Gallons of biodiesel blended above B5	**Category of Use**	**Requirement**	**Cost in 2018**
5	High-saturation use in summer as B10	Testing to verify high saturation*	$215,000
8	Low-saturation used in exempted fleets and vehicles in all seasons	Use in exempted fleets such as NTDEs, medium and light duty vehicles	Recordkeeping (included as part of $56,000.00)
5	Low-saturation use in summer as B20	5% DTBP per gallon of B100	$2,800,000
12	Low-saturation use in winter as B10	No NOx controls in winter for B10 and below (Nov 1-March 31)	Recordkeeping (included as part of $56,000.00)
Total: 30 million gallons			Total: $3,071,000**

* See Appendix C for testing costs methodology
** Includes reporting and recordkeeping costs for 150 million gallons of B100 used for blends below

As mentioned earlier, staff assumes the volumes of biodiesel with NO_x controls to decrease as the volumes of biodiesel used in exempted fleets such as NTDEs, medium and light duty vehicles increase each year. The table below reflects the changing scenario on increased NTDEs and the subsequent reduction in costs. Table 10.2 demonstrates how the volumes, and associated costs, of high saturation biodiesel for summer use and NO_x controls for low saturation biodiesel decreased while the volumes of low saturation biodiesel blends in exempted fleets increased; when compared to table 10.1. In 2023, only the cost of recordkeeping and reporting would apply due to the sunset provision.

In addition to the in-use requirement costs listed in Tables 10.1 and 10.2, the industry will face additional recordkeeping costs, which are outlined below. Following this discussion, this chapter will identify the costs as indicated in the table above.

Table 10.2 Summary of Costs for 2021

Million Gallons of biodiesel blended above B5	Category of Use	Requirement	Cost in 2021
2	High-saturation use in summer as B10	Testing to verify high saturation*	$86,000
14	Low-saturation used in exempted fleets and vehicles in all seasons	Use in exempted fleets such as NTDEs, medium and light duty vehicles	Recordkeeping (included as part of $56,000.00)
2	Low-saturation use in summer as B20	5% DTBP per gallon of B100	$1,120,000
12	Low-saturation use in winter as B10	No NOx controls in winter for B10 and below (Nov 1-March 31)	Recordkeeping (included as part of $56,000.00)
30			$1,262,000**

* See Appendix C for testing costs methodology
** Includes reporting and recordkeeping costs for 150 million gallons of B100 used for blends below

1. Cost of Enhanced Recordkeeping

Because staff is proposing to allow commercialization of biodiesel under Stage 3A with in-use requirements for low and high saturation biodiesel blends, detailed market sales and related information would be required from biodiesel producers to track blend levels and compliance with the in-use requirements. We anticipate similar compliance costs if pollutant controls are identified for future ADFs that are approved for commercialization under this regulation. For an ADF with no such controls identified, there will be no costs attributable to the proposed regulation because those ADFs would be subject to the same reporting requirements as all other commercial motor vehicle fuels. Biodiesel retailers will not experience any quantifiable costs for enhanced recordkeeping once a transition from Stage 3A to Stage 3B occurs.

As shown in Table 10.3, staff estimates that a typical cost for enhanced recordkeeping for each producer will be about $1,600 annually. For the 12 producers and 23 blender distributors we are aware of, we estimate the total cost for recordkeeping to be $56,000 per year. This number was reached using the prevailing wage for an environmental engineer of $40.00 an hour and an estimate of 40 hours needed to comply with the enhanced recordkeeping.

Table 10.3: Estimate of Annual Cost of Enhanced Recordkeeping*

Increased Annual Recordkeeping Hrs.	Cost per Hr**	Annual Cost per Producer and Blender/Distributor	Total Annual Cost for all Recordkeeping
40	$40.00	$1,600	$56,000

* Enhanced monitoring consists of: monthly biodiesel sales volumes by blend (B5, B10, B20, B100); geographic location of respective biodiesel blend sales; Sales of biodiesel produced from animal tallow feedstocks

** Prevailing wage for environmental engineer (source: http://www.bls.gov/ooh/architecture-and-engineering/environmental-engineers.htm)

2. Cost of NOx Emissions Controls for Biodiesel

a. High-saturation for use in all seasons

The 2018 projected biodiesel volumes of 180 million gallons consist of 150 million B100 gallons dedicated to biodiesel blends below the blend levels requiring NO_x emissions controls and 30 million B100 gallons used to create blends above that level. Of these 30 million gallons, 5 million gallons are potential high saturation biodiesel due to their marketability as B10 with only the cost of testing required (cost of testing is laid out in Appendix B). Staff expects most of this high saturation biodiesel to be sold as B10, which does not require more expensive NOx controls. So the resultant cost would be:

5 million gallons * $0.043/ gallon = $215,000

b. Low-Saturation Use in Summer

This will require DTBP additization at the cost of $0.112 per gallon of B20 (see Appendix C for the per gallon calculation). Staff assumes, that in 2018, 5 million gallons of low saturation B100 will be used in the summer and require NOx emissions controls. This means that 5 million gallons of B100, or 25 million gallons of B20 will cost the industry:

$0.112 per gallon. (B20 * 25 million gallons = $2,800,000)

Based on the analysis presented in Chapter 6, staff concludes that using additives such as DTBP is the least likely compliance option for blends with NOx emissions control requirements, due to the high cost of additives and infrastructure needed for additization blending. However, due to demand for these blends by certain government agencies and companies with policies that encourage “green” fuels, some additization will occur. A detailed cost analysis of the NOx control option using additive, as well as the certification option, can be found in Appendix C and is summarized in Table 10.4. The cost of ADF certification is not included as a direct cost because biodiesel producers are not required to pursue that option. It would be a producer’s decision to develop a certified low-NOx formula under a research and development protocol, which can be viewed as the cost of doing business.

c. Low-Saturation Use in Winter

Because the requirement for the winter allows a higher blend, the producers would likely not use additives for NOx controls but instead sell at the B10 blend level. Therefore, no additional costs above the recordkeeping would be incurred in the winter. Due to cloud point issues with biodiesel in cold weather, business as usual is typically the use of blends with a lower percentage than 20 percent by volume. However, because California has a fairly mild climate, blends of B10 in areas such as Southern California and the San Francisco Bay Area would not be expected to decrease in the winter. These areas also happen to be where the majority of biodiesel is consumed.

3. Potential Adverse Economic Impacts Directly Affecting Business

Biodiesel industries downstream from the producers such as blenders or jobbers, distributors, and retailers, are not expected to experience any costs during the first two years of the regulation. However, in 2018, when in-use requirements for certain biodiesel blends take effect, businesses that did not modify their business practices or seek exemptions to in-use requirements for blends above B5 for low saturation biodiesel, or B10 for high saturation biodiesel, can be expected to incur costs and/or losses. These costs or losses may include: costs of additizing the blends they sell, the costs of adopting new business practices, and the loss of business from not offering B20.

In addition to the measures businesses can take to reduce any adverse economic impacts resulting from the 2018 requirements of the proposal, others may find increased opportunities. Staff does not expect total biodiesel volumes in the State to decrease as a result of the regulation, but rather to be diverted from blends with in-use requirements to blends below B5, or to exempt fleets.

4. Impacts on Small Business

Tables 10.4 and 10.5 on the next page list several businesses that support biodiesel use in California, including 12 biodiesel producers and 23 biodiesel distributor/blenders operating in the State. Twenty-two of these are small businesses, seven are not, and six are unknown, based on the definition for small businesses (GC 11342.610). The list of producers and distributors was derived from Biodiesel magazine[37] and National Biodiesel Board's lists of biodiesel producers[38] and distributors[39].

[37] Biodiesel Magazine, *USA Plants* http://www.biodieselmagazine.com/plants/listplants/USA/page:1/sort:state/direction:asc (accessed November 4, 2014)
[38] National Biodiesel Board, *Biodiesel Plants Listing*, http://www.biodiesel.org/production/plants/plants-listing (accessed November 4, 2014)

Table 10.4: Biodiesel Producers

Biodiesel Producers	Small Business
Baker Commodities, Inc.	No
Bay Biodiesel, LLC	Yes
Biodiesel Industries of Ventura, LLC	Yes
Community Fuels	unknown
Crimson Renewable Energy, L.P.	Yes
Geogreen Biofuels, Inc.	Yes
Imperial Western Products, Inc.,	Yes
New Leaf Biofuel, LLC	No
Noil Energy Group, Inc.	Yes
North Star Biofuels, LLC	unknown
Simple Fuels Biodiesel	Yes
Yokayo Biofuels	Yes

Table 10.5: List of Distributors

Biodiesel Distributors	Small Business
Argo Energy	Unknown
Beck Oil, Inc	Unknown
Downs Energy	Yes
Eel River Fuels, Inc.	Yes
General Petroleum Corporation	No
Goodspeed Auto-Fuel Systems, Inc.	No
Inter-State Oil Co.	No
Interstate Oil Company	Yes
Lee Escher Oil Co	Yes
NAPA Valley Petroleum, Inc.	No
New West Petroleum	Unknown
New West Petroleum	Yes
Pearson Fuels	Yes
Promethean Biofuels Cooperative Corporation	Unknown
Ramos Oil Company Inc.	Yes
Royal Petroleum Company	Yes
RTC Fuels, LLC (Pearson)	Yes
SC Fuels	Yes
Sirona Fuels	No
Southern Counties Oil Co.	Yes
Supreme Oil Co.	Yes
Tom Lopes Distributing, Inc.	Yes
W. H. Breshears, Inc.	No

[39] National Biodiesel Board, *Biodiesel Distributor Listings*, http://www.biodiesel.org/using-biodiesel/finding-biodiesel/locate-distributors-in-the-us/biodiesel-distributor-listings (accessed November 4 , 2014)

Many of the biodiesel fuel providers will take advantage of the two-year grace period to change business practices and thus incur minimal costs from recordkeeping. For instance, retail fuel providers that sell B20 at fueling stations that only accommodate light duty vehicles could work with a biodiesel producer to target customers of light duty vehicle fleets. This would allow the fuel producers and fuel providers to continue selling blends up to B20 at said stations.

5. Total Cost of Biodiesel Under Proposed Regulation

The total cost of the biodiesel regulation is identified for two time periods. The first time period addresses costs in 2016 and 2017 which are the years before the in-use requirement provisions take effect. The second time period is from 2018 through 2023 when provisions for in-use requirements, including NOx emissions controls, take effect until the sun setting of the regulation.

Based on the estimates above, we expect the total cost of biodiesel as the first commercial ADF regulation to be the cost of enhanced monitoring at $1,600 per year per producer and blender/distributor, or $56,000 total cost per year for all producers and distributors, and the cost of using NOx controls. Upon implementation of the ADF regulation in 2016, the annual biodiesel production is projected to be 129 million gallons (see Appendix B, Table B1) for an incremental biodiesel cost of less than one cent per gallon. These costs would remain steady through 2017.

In 2018, the projected volume increases to 180 million gallons for an incremental cost of less than one cent per gallon for recordkeeping. However, in 2018, in-use requirements take effect for NOx emissions control on certain biodiesel blends. From 2019 through 2020, projected volumes remain steady at 180 million gallons and from 2021 until the sunset provision in 2023, the volumes remain steady at 185 million gallons. However, it should be noted that from 2019 through 2023, the VMT of NTDEs is projected to increase considerably, due to other CARB regulations, which will allow for more biodiesel blends to be sold to exempted fleets with costs for in-use requirements. This would reduce the overall costs of NOx controls. The total cost of the regulation in 2018 is expected to reach $3,071,000. Each year thereafter, starting in 2019 will result in a reduction in costs from the previous year because of the increasing exemptions from NTDE fleets.

6. Potential Economic Costs to Consumers

As noted, we expect individual consumers would incur minimal or no costs as a result of the proposed regulation. Fuel suppliers already blend up to five percent biodiesel by volume in the CARB diesel that is offered throughout the state. Higher blends of biodiesel are currently sold at a price premium relative to CARB diesel, but such premiums exist in the absence of the proposed regulation. Therefore, the proposal should not adversely affect retail prices for biodiesel blends based on the anticipated minimal costs discussed above. Consumers that own either light or medium duty vehicles will not likely experience an increase in cost for biodiesel blends up to B20, because these fleets qualify for exemptions from in-use requirements.

D. Cost Effectiveness

Cost effectiveness is typically defined as the dollars spent to reduce a unit mass of a specified pollutant. Because the proposal is designed to maintain current environmental protections rather than achieve additional air pollution reductions, the concept of cost-effectiveness does not apply to the proposal. Nevertheless, upon implementation of the proposed ADF regulation in 2016, the regulatory costs of compliance (up to the low tens of thousands of dollars per year), if passed on to the consumer, would yield a per-gallon impact that is small (e.g., $56,000 per year /129 million gallons per year or less than one cent per gallon with full pass-through).

In 2018, when in-use requirements take effect the cost on a per gallon basis would increase, then go back down in subsequent years (e.g., $3,071,000 per year /180 million gallons per year or less than 2 cents per gallon increase if full pass-through).

No alternative considered by the agency would be more effective in carrying out the purpose for which the regulation is proposed or would be as effective as or less burdensome to affected private persons than the proposed regulation.

F. Reasons for Adopting Regulations Different from Federal Regulations

A main objective of the proposed ADF regulation is to consolidate existing requirements, supplemented with minor additional data requirements and enhanced recordkeeping provisions, to provide a clear, legal pathway to commercialization for new ADFs. As noted, many of the proposed regulatory requirements already exist in various State and federal programs.

Table 10.6 shows the existing applicable mandates, which require the same information required under the proposed regulation. However, under the proposed regulation, information generally would be required early in the phase-in process and before the ADF is commercialized in California to allow for screening of environmental and public health impacts. For purposes of this cost analysis, staff did not consider the costs of meeting the existing applicable mandates that overlap with the requirements under the proposal.

For example, H&SC section 43830.8 currently requires a multimedia evaluation to be conducted for any fuel before the ARB can establish motor vehicle fuel specifications for any particular fuel. Thus, while a multimedia evaluation is required under Stage 2 of the proposed regulation, the cost of that evaluation is not attributable to this rulemaking.

Table 10.6: Applicable Requirements from Various State and Federal Mandates

	Proposed Regulation	FTC[1] Labeling	DMS Fuels[2] Authority	DMS Fuel[3] Variance	H&S Code 43830.8[4]
Test Program Application	x			x	
- Test Plan (vehicle ID, fuels, duration, etc.)	x			x	
- Fuel Chemical Properties	x			x	
- U.S.EPA Registration[5]	x				
- Reporting & Recordkeeping	x	x	x	x	
Consensus Fuel Specification Development	x			x	
Enforcement of ASTM Stds.			x		
Fuel Quality Testing	x		x	x	
Pump Labeling (biodiesel blends)		x			
Multimedia Evaluation[6]	x				x
Determination of Pollution Control Levels	x				x
Enhanced Reporting	x				

1. Federal Trade Commission regulation on biodiesel pump labeling under 16 CFR Part 306.
2. CA Dept. of Food & Ag.-Div. of Measurement Stds. authority to enforce ASTM fuel quality stds. under CCR, title 4, §§ 4140, 4148, 4200, 4202-4205.
3. CDFA-DMS administration of developmental fuel variance program under CCR, title 4, §§4144, 4147 - 4148.
4. Multimedia evaluation requirements under Health & Safety Code §43830.8.
5. USEPA fuels and additives registration program under 40 CFR Part 79.
6. Also requires lifecycle analysis, release scenarios & emissions testing.

Another set of State mandates affecting the enforcement of potential ADFs pertains to regulatory requirements promulgated by the California Department of Food and Agriculture, Division of Measurement Standards (DMS). Under California Code of Regulations (CCR), Title 4, sections 4140-4149 and 4200-4205, DMS has the responsibility to enforce the consensus (ASTM) standards for the fuels listed therein, including biodiesel. Therefore, costs for meeting the ASTM standards or developing consensus standards for future ADFs are attributable to the DMS regulations.

The DMS also administers a program that is similar to the proposed Stage 1 requirements. Known as the developmental fuel variance (DFV), this program is authorized under Title 4 CCR, Sections 4144, 4147 and 4148. The DFV program allows unconventional motor vehicle fuels to be used in limited quantities to develop data in support of the development of consensus standards for those fuels. Stage 1 of the proposed regulation requires the same information as that required under the DFV, as well as some additional information. Thus, staff's analysis for the proposal does not consider the portion of the costs that would already be incurred under the DFV program.

Two federal programs also apply to ADFs that would be subject to the proposal. First, U.S. EPA requires a gasoline, diesel, or additive supplier to register under 40 CFR 79 prior to the sale or supply of such fuel products in California. Similarly, the proposed regulation would require U.S. EPA registration before an ADF could be sold or supplied in California under Stage 1. Second, the FTC specifies particular labeling requirements on individual pumps that dispense B6-B20 and blends above B20 (no labeling requirements for B5 and below). For enforcement purposes, fuel marketers are required to maintain volume sales and other fuel content records for these labeled pumps. The proposed regulation contains recordkeeping, testing, and reporting requirements that would piggyback on these existing federal requirements.

Alternative diesel fuels that meet the criterion for a Stage 3A will be required to conduct enhanced recordkeeping to monitor progress towards meeting any pollutant emissions levels that would require pollutant controls. The level of enhanced recordkeeping, and the cost of the pollutant controls (when applicable), will be a case-by-case determination because different ADFs have different chemistries.

G. Impacts to California State or Local Agencies

Several state agencies operate large fleets, often with many alternative fuel vehicles included in their fleet. Staff contacted several State agencies to determine biodiesel usage and received responses from some, but not all of the agencies contacted. Those that did respond did not indicate any usage of biodiesel blends with in-use requirements, and thus higher cost. During this period, staff became aware that Caltrans was the State agency using the most biodiesel. According to a 2013 report, "Caltrans Activities to Address Climate Change[40]", Caltrans is the biggest user of biodiesel in the State and is only using B5 blends currently; although they've used B20 blends in the past. As such, Caltrans would not incur any additional costs due to this regulation. In addition, the University of California system was contacted and staff was informed that the majority of their biodiesel use was B5, and that the majority of their fleet was vehicles eligible for an exemption to in-use requirements.

[40] Department of Transportation *Caltrans Activities to Address Climate Change Reducing Greenhouse Gas Emissions and Adapting to Impacts*, April 2013

Staff also contacted local municipalities and found that with the exception of San Francisco, all of the municipalities that responded did not use biodiesel blends above B5. Anecdotal evidence suggests that some school districts may be using biodiesel blends with in-use requirements. Therefore only those few agencies opting to use biodiesel blends with in-use requirements may incur some minor costs; though these can likely be absorbed in existing budgets. If these same agencies opt to use CARB diesel or lower blends of biodiesel, they could incur a costs savings.

CHAPTER 11. ANALYSIS OF REGULATORY ALTERNATIVES

As required by Senate Bill 617 (Chapter 496, Status of 2011), State agencies must conduct a Standardized Regulatory Impact Assessment (SRIA) when a proposed regulation has an economic impact exceeding $50 million in any 12-month period between the date the major regulation is estimated to be filed with the Secretary of State through12 months after the regulation is estimated to be fully implemented. The Department of Finance is required to review the completed SRIA submitted by agencies and provide comment(s) to the agency on the extent to which the assessment adheres to the regulations adopted by Finance. Rules implementing these requirements are found at title 1, sections 2000-2004 of the California Code of Regulations.

As part of the SRIA process, ARB solicited public input on alternative ADF approaches, including 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. Alternative approaches submitted to ARB were considered as staff prepared a SRIA. The combined SRIA of Low Carbon Fuel Standard and ADF summary is posted at: http://www.dof.ca.gov/research/economic_research_unit/SB617_regulation/2014_Major_Regulations/documents/ADF_DF_131_SUMMARY.PDF

Staff solicited public input and received two alternatives to the proposal that were considered as part of the SRIA process. The full analysis and comparison is located in Appendix D. The alternatives are summarized below:

A. Alternative Submitted by Growth Energy

The first alternative considered was submitted by Growth Energy (GE). Key provisions are listed below, along with the reason for rejecting this alternative in the following paragraphs.

- Treating animal- and non-animal-based biodiesel the same: setting the significance level for both at zero percent, as compared to the ADF proposal, which sets the significance level at B5 for non-animal-based biodiesel and B10 for animal-based biodiesel; and
- Eliminating the provisions for exemptions based on the use of NTDEs, as compared to the ADF proposal, which provides exemptions for biodiesel used in NTDEs; and
- Eliminating the sunset provision of the ADF proposal, whereas the ADF proposal would likely end mitigation for biodiesel in 2024.

This alternative proposal retains the same biodiesel NOx mitigation options as the ADF proposal. However, under the GE alternative, animal and non-animal biodiesel would be treated equally and require NOx mitigation for all biodiesel blends, including blends below B5. ARB rejects this alternative because the costs are significantly higher than the ADF proposal and do not achieve additional emissions benefits. During the development of this regulation, staff considered alternatives to the proposal and determined that the proposal represents the least-burdensome approach that best achieves the objectives at the least cost.

B. Alternative Submitted by National Biodiesel Board

The second alternative considered was submitted by the National Biodiesel Board (NBB). Key provisions are listed below, along with the reason for rejecting this alternative in the following paragraphs.

- Setting a significance level threshold for biodiesel at 10% biodiesel blend (B10) for all biodiesel feedstocks;
- Establishing an effective blend level that accounts for the impact of NTDEs, RD, and animal biodiesel, vs per-gallon mitigation in the ADF proposal; and
- Including a three-year phase-in period for the regulation.

This alternative would treat animal- and non-animal-based biodiesel the same by setting a significance level for both at 10 percent annually by volume. The alternative also includes a three-year phase-in period; accordingly, there are no costs for biodiesel mitigation in the first three years. For this alternative, mitigation would not be necessary until the statewide biodiesel content is up to 10 percent; after which the 10 percent any additional biodiesel would be mitigated using the same options available in the ADF proposal.

Because this alternative achieves substantially fewer emissions benefits than the ADF proposal, it does not meet the goals of the ADF proposal and ARB rejects the NBB alternative.

C. Conclusions

No alternatives were presented that would achieve the same emissions benefits and lessen any adverse impact on small businesses that may occur due to the regulation. However, the phase-in period suggested in the NBB proposal was modified to two years and included in the regulation to ensure ample time for small businesses to prepare and alter their business models to minimize their costs.

CHAPTER 12. SUMMARY AND RATIONALE

The Proposed ADF regulation is designed to allow a streamlined path to commercialization for alternative diesel fuels, while ensuring no increase in air pollution from those fuels. This section discusses the requirements and rationale for each provision of the proposed regulation.

Subarticle 1. Specifications for Alternative Motor Vehicle Fuels

Summary and Rationale for Subarticle 1
Article 1 is being renamed Subarticle 1 as part of splitting the article for clarity. Additionally, minor changes were made to accommodate the subarticle renaming and authority cited was added for clarity.

Subarticle 2. Commercialization of Alternative Diesel Fuels

Section 2293 Purpose

Summary of section 2293
Section 2293 states the purpose of the proposed regulation.

Rationale for section 2293
This section is needed to inform the regulated public and other market participants of the proposed regulation's intent.

Section 2293.1 Applicability

Summary of section 2293.1
Subsection(a) establishes January 1, 2016, as the effective date of the proposed regulation, as well as laying out general requirements for alternative diesel fuels (ADFs) in California.

Rationale for section 2293.1
This section is needed to establish the implementation date, and general requirements that will apply to ADFs in California.

Section 2293.2 Definitions

Summary of section 2293.2
This section introduces definitions to the terms used in the regulation as well as the acronyms used in the proposed regulation.

Rationale for section 2293.2
It is necessary that ARB defines terms as applicable to the Alternative Diesel Fuels regulation. Several of these terms are used in the same manner as other articles and titles in the California Code of Regulations, Government Code sections or statutes. It is necessary for ARB to be consistent with existing definitions to the extent that they apply to this regulation.

Section 2293.3 Exemptions

Summary of section 2293.3

Section 2293.3 introduces the list of exemptions that apply to this proposed regulation.

Rationale for section 2293.3

This section is necessary for clarity of which fuels or additives are not subject to the regulation. The exempted fuels are already regulated elsewhere.

Section 2293.4 General Requirements Applicable to All ADFs

Summary of section 2293.4

This section outlines the provisions that apply to all ADFs in California

Rationale for section 2293.4

This section is necessary to ensure that it is clear that other applicable local, State, and federal requirements, including some specifically listed requirements, apply in addition to the provisions outlined in the proposed regulation.

Section 2293.5 Phase-In Requirements

Summary of section 2293.5

Section 2293.5 states that ADFs intended for use in motor vehicles that do not meet the requirements of this regulation by having a fuel specification or approved Executive Order in place cannot be sold without being in violation of this regulation.

Rationale for section 2293.5

This section is necessary to introduce the different stages of the regulation and the Executive Order requirements in Stage 1. The goal of this comprehensive process is to foster the introduction of new, lower polluting ADF fuels by allowing the limited sales of innovative ADFs in stages while emissions, performance, and environmental impacts testing is conducted. This testing is intended to develop the necessary real-world information to quantify the environmental and human health benefits from using new ADFs, determine whether these fuels have adverse environmental impacts relative to conventional CARB diesel, and identify any vehicle/engine performance issues such fuels may have.

Summary of section 2293.5(a)

Subsection (a) outlines the requirements of Stage 1: Pilot Program. This is the first in a series of 3 stages leading to potential commercialization of ADFs, and includes an initial analysis, submittal of relevant data, and a limited use of ADF allowed.

Rationale for section 2293.5(a)

This section is needed to communicate clearly the requirements for application, acceptance, and completion of Stage 1 for ADF proponents who are initially proposing an ADF for use. The purpose of this stage is to allow limited, small fleet use of innovative fuels while requiring screening tests and assessments to quickly determine whether there will be unreasonable potential impacts on air quality, the environment and vehicular performance. Such data will help inform more extensive testing and analysis to be conducted in Stage 2. This Stage 1 is modeled after the existing ARB regulation that provides limited, fuel test program exemptions under 13 CCR 2259. The required submittals allow ARB and the public to evaluate the rigor of any proposed testing plan.

Summary of section 2293.5(b)
Subsection (b) outlines the requirements of Stage 2: Development of Fuel Specification. This is the second in a series of 3 stages leading to potential commercialization of ADFs, and includes rigorous environmental testing, development of standards, determination of environmental impacts, and increased use of ADF allowed.

Rationale for section 2293.5(b)
Subsection (b) is needed to communicate clearly the requirements for application, acceptance, and completion of Stage 2 for ADF proponents who are getting closer to commercial operation. The purpose of this stage is to allow limited but expanded fleet use of an ADF that has successfully undergone the Stage 1 pilot program. Stage 2 candidate ADFs undergo additional emissions and performance testing to better characterize potential impacts on air quality, the environment and vehicular performance. This testing and assessment will be conducted pursuant to a formal multimedia evaluation leading to the development of a fuel specification, as appropriate. Further, the multimedia evaluation will be the basis for determining whether the candidate ADF has potential adverse emissions impacts. The determination of potential adverse emissions impacts determines whether the candidate ADF can proceed to Stage 3A or Stage 3B. The required submittals will allow ARB and the public to evaluate the rigor of the proposed testing.

Summary of section 2293.5(c)
Subsection 2293.5(c) outlines the requirements of Stage 3A: Commercial Sales Subject to in-use Requirements. This is the culminating stage for ADFs that have been found to have potential adverse emissions impacts, and includes provisions for determination of in-use requirements and or fuel specifications if they are determined to be necessary.

Rationale for section 2293.5(c)
Subsection (c) is needed to communicate clearly the requirements for full commercialization of ADFs that have been found to have potential adverse emissions impacts.

Summary of section 2293.5(d)
Subsection 2293.5(d) outlines the requirements of Stage 3B: Commercial Sales Not Subject to In-use Requirements. This is the culminating stage for ADFs that have either been found to have no potential adverse emissions impacts or that have been found in Stage 3A to have no adverse emissions impacts. ADFs subject to this stage have limited reporting requirements.

Rationale for section 2293.5(d)
Subsection (d) is needed to communicate clearly the requirements for full commercialization of ADFs that will have no adverse emissions impacts relative to conventional CARB diesel. The provision makes the reporting consistent with reporting requirements in place for existing motor vehicle fuels.

Section 2293.6 In-use Requirements for Specific ADFs Subject to Stage 3A

Summary of section 2293.6
Section 2293.6 includes provisions for any ADF that has undergone the 3-stage process for commercialization and has been determined to be in Stage 3A with in-use requirements.

Rationale for section 2293.6
This section is needed to implement the provisions of Stage 3A once an ADF has completed the 3-stage commercialization process.

Summary of section 2293.6(a)
Subsection 2293.6 (a) contains the in-use requirements that apply to biodiesel as the first commercial ADF. This subsection includes a phase-in period, pollutant control levels, provisions for feedstock differences, a sunset provision, a process for exemption from the in-use requirements for biodiesel, and a mid-term review of the biodiesel provisions.

Rationale for section 2293.6(a)
Subsection (d) is needed to implement the solutions to the adverse emissions impacts associated with biodiesel. These adverse emissions impacts vary based on feedstock and engines, as such specific provisions for each of these are included.

Section 2293.7 Specifications for Alternative Diesel Fuels

Summary of section 2293.7
Section 2293.7 is a lead sentence to be completed in subsections 2293.7(a) and (b) that provide the specifications that must be met by ADFs, if not under a mitigation strategy in effect.

Rationale for section 2293.7
This section is needed to provide a framework for subsequent subsections.

Summary of section 2293.7(a)
Section 2293.7(a) is a title line for biodiesel the specification subsection.

Rationale for section 2293.7(a)
This section is needed to provide a framework for subsequent subsections.

Section 2293.8 Reporting and Recordkeeping

Summary of section 2293.8

Section 2293.8 (a) states that the applicable sampling methodology set forth in 13 CCR section 2296 shall be used for sampling of fuel properties as required by the Executive Order.

Rationale for section 2293.8

This subsection is needed to provide the applicant with guidance regarding their sampling requirements.

Section 2293.9 Severability

Summary of section 2293.9

Section 2293.8 states that each part of this subarticle shall be deemed severable, and in the event that any part of this subarticle is held to be invalid, the remainder of this subarticle shall continue in full force and effect.

Rationale for section 2293.9

This subsection is needed to inform the applicant of their responsibility to adhere to all applicable requirements of this regulation, in the event that any part of this subarticle shall be deemed severable.

Subarticle 3. Ancillary Provisions

Section 2294. Equivalent Test Methods

Summary of and Rationale for section 2294

This is former section 2293 renumbered to section 2294 and grouped under new subarticle 3 for consistency and ease of reading.

Section 2295. Exemptions for Alternative Motor Vehicle Used in Test Programs

Summary of and Rationale for section 2295

This is former section 2293.5 renumbered to section 2295 and grouped under new subarticle 3 for consistency and ease of reading. This section facilitates innovation and testing for new fuels.

Appendix 1 In-use Requirements for Pollutant Emissions Control

Summary of Appendix 1

Appendix 1 outlines the in-use requirements that apply to ADFs operating under Stage 3A.

Rationale for Appendix 1

Appendix 1 is needed to identify the options that are available for complying with the provisions of Stage 3A

Summary of Appendix 1 (a)

This section includes the in-use requirement options that are available to biodiesel, currently additive blending and certification procedures.

Rationale for Appendix 1 (a)

This section is needed to convey the amount of additive needed to comply with in-use requirements for biodiesel based on time of year, feedstock, and blend level. The certification procedures are needed to provide flexibility for new in-use options that can be rigorously demonstrated to be effective.

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CHAPTER 13. REFERENCES

Note: The references are listed according to the footnote they correspond to in the ISOR. Not all footnotes are references and are only listed here to maintain the numbering system used for the ISOR footnotes. The footnotes that are not references are listed as "Explanatory Footnote."

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Chapter 6. Technology Assessment
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Chapter 11. Analysis of Regulatory Alternatives

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Chapter 12. Summary and Rationale

No Reference Cited

Attachment 7

APPENDIX B

TECHNICAL SUPPORTING INFORMATION

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1. Biodiesel NOx Emissions Calculation

As part of staff's determination of the effect of biodiesel on NOx emissions a methodology was developed that takes into account varying factors including offsetting effects. As part of this analysis staff takes the illustrative fuel volumes from the LCFS re-adoption and the projected Vehicle Miles Travelled (VMT) of NTDEs in EmFAC 2011. The renewable diesel volumes are adjusted by the amount expected to be consumed by refineries. These factors are used to determine the total NOx emissions impacts of biodiesel compared to the use of CARB diesel, as shown in the table below.

After January 1, 2018, biodiesel used above B5 (assumed to be B20) is controlled by in-use requirements and does not cause NOx. Thus this volume is subtracted from total biodiesel to determine the amount of biodiesel (BD) potentially causing NOx. The next step is to determine the amount of biodiesel used in legacy vehicles (non-NTDE). This is important because the NOx increase is seen in legacy vehicles not NTDE vehicles. The proportion of legacy vehicles is determined by subtracting the percentage of NTDEs from 100% to determine the percentage of legacy vehicles. The amount of fuel used in legacy vehicles is then determined by multiplying the percentage of legacy vehicles by the volume of biodiesel potentially causing NOx. The same calculation is then completed for RD. Staff assumed that 40 percent of renewable diesel is used in refineries, and as such does not reduce NOx since refineries may use the NOx benefit of RD in their CARB diesel formulations. The calculated RD used in legacy vehicles is divided by 2.75 to get the amount of RD offsetting BD. As discussed earlier, renewable diesel decreases NOx and the NOx increase from one gallon of biodiesel is offset by the NOx decrease from 2.75 gallons of renewable diesel. The amount of biodiesel offset by legacy RD is then subtracted from the BD amount used in legacy to result in the amount of biodiesel causing NOx. That total is divided by the liquid diesel demand and multiplied by the NOx increase of B100 to determine a %NOx increase from BD. The total change is then multiplied by the diesel portion of the emissions inventory to get NOx increase from biodiesel.

Table B-1: Biodiesel NOx Emissions Calculations

(Million gallons)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Total Biodiesel	72	97	129	160	180	180	180	185	185	185
B20 (No NOx post 2018)					30	30	30	35	35	35
BD Potentially causing NOx	72	97	129	160	150	150	150	150	150	150
RD Volume	120	180	250	300	320	360	400	500	550	600
Liquid Diesel Demand	3732	3788	3845	3903	3961	4021	4081	4142	4204	4267
	NOx emissions Calculations									
%NTDE (EmFAC 2011) (VMT)	40.09%	50.86%	59.87%	66.35%	71.26%	75.00%	79.78%	85.03%	88.74%	98.44%
BD used in legacy vehicles	43.1	47.7	51.8	53.8	43.1	37.5	30.3	22.5	16.9	2.3
%NOx increase (B100)	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
RD used in legacy	72	88	100	101	92	90	81	75	62	9
%RD used in refineries	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%
Legacy RD not used in refineries	43	53	60	61	55	54	49	45	37	6
Legacy BD offset by Legacy RD	16	19	22	22	20	20	18	16	14	2
%NOx increase from BD	0.15%	0.15%	0.16%	0.16%	0.12%	0.09%	0.06%	0.03%	0.02%	0.00%
Emissions Inventory (Diesel TPD)	916	863	818	772	726	680	634	588	542	496
NOx increase from BD (TPD)	1.35	1.29	1.27	1.26	0.84	0.60	0.39	0.17	0.09	0.01
Net NOx increase (from 2014)	0.00	-0.05	-0.08	-0.09	-0.50	-0.74	-0.95	-1.17	-1.26	-1.34
NOx increase from BD (TPY)	492	472	464	459	308	221	144	63	32	3

2. Biodiesel Emissions B5 and B10 Testing Results

As part of staff's determination of biodiesel impacts of low biodiesel blends, we released a spreadsheet of data gathered from all testing we were aware of from B5 and B10 biodiesel blends using a CARB diesel baseline. Those emissions results are included in Table B-2. These data are also available at: http://www.arb.ca.gov/fuels/diesel/altdiesel/20140725B5&B10studies_raw_all_pollutants_%20data.xlsx

Table B-2: Biodiesel B5 and B10 Blends Emissions Testing Results

All raw data on B5 and B10 from animal and soy feedstocks. Values are in g/bhp-hr.									
Fuel	Cycle	Engine	Work	THC	CO	NOx	PM	CO2	BSFC (gal/bhp-hr)
Durbin 2011- Biodiesel Characterization and NOx Mitigation Study									
B5 - Soy	CRUISE - 40mph	2006 Cummins ISM	42.980	0.249	0.613	2.079	0.045	586.063	0.060
			43.210	0.248	0.617	2.044	0.045	579.506	0.059
CARB ULSD	CRUISE - 40mph	2006 Cummins ISM	43.146	0.247	0.582	2.040	0.046	569.448	0.058
			43.372	0.249	0.618	2.012	0.048	573.429	0.058
			43.150	0.257	0.607	2.031	0.049	577.056	0.059
B5 - Soy	CRUISE - 50mph	2006 Cummins ISM	34.379	0.180	0.451	1.776	0.049	539.299	0.055

			34.238	0.181	0.511	1.674	0.054	548.853	0.056
			34.210	0.184	0.481	1.790	0.051	541.312	0.055
			34.193	0.183	0.479	1.791	0.050	542.130	0.055
			34.302	0.184	0.472	1.660	0.052	547.319	0.056
			34.214	0.183	0.474	1.669	0.051	550.718	0.056
CARB ULSD	CRUISE - 50mph	2006 Cummins ISM	34.367	0.181	0.475	1.767	0.052	537.155	0.055
			34.285	0.179	0.458	1.777	0.052	540.383	0.055
			34.265	0.182	0.454	1.757	0.053	538.915	0.055
			34.345	0.190	0.464	1.826	0.053	547.919	0.056
			34.283	0.191	0.505	1.676	0.056	552.006	0.056
			34.249	0.190	0.481	1.677	0.056	552.186	0.056
B5-Soy	FTP	2006 Cummins ISM	26.570	0.300	0.742	2.146	0.074	633.678	0.065
			26.715	0.295	0.676	2.139	0.066	630.990	0.064
			26.556	0.295	0.694	2.146	0.067	635.459	0.065
			26.488	0.282	0.687	2.155	0.066	631.014	0.064
			26.616	0.284	0.686	2.157	0.066	629.410	0.064
			26.621	0.287	0.686	2.137	0.066	631.529	0.064
CARB ULSD	FTP	2006 Cummins ISM	26.650	0.280	0.698	2.076	0.072	624.986	0.064
			26.598	0.286	0.694	2.067	0.072	625.364	0.064
			26.457	0.288	0.710	2.090	0.074	630.497	0.064
			26.525	0.293	0.715	2.076	0.073	629.674	0.064
			26.603	0.297	0.690	2.092	0.073	633.139	0.064
			26.676	0.293	0.673	2.093	0.077	631.495	0.064
			26.593	0.296	0.705	2.097	0.073	634.048	0.064
			26.703	0.289	0.673	2.083	0.070	623.705	0.063
			26.589	0.294	0.681	2.088	0.071	630.334	0.064
			26.656	0.296	0.691	2.068	0.071	627.629	0.064
			26.590	0.298	0.714	2.113	0.072	630.587	0.064
			26.640	0.298	0.689	2.110	0.070	632.011	0.064
			26.639	0.300	0.703	2.112	0.072	633.399	0.064
			26.688	0.306	0.730	2.123	0.073	635.859	0.065
			26.797	0.302	0.686	2.105	0.070	631.540	0.064
			26.675	0.304	0.698	2.104	0.072	633.093	0.064
			26.720	0.298	0.673	2.092	0.070	627.904	0.064
			26.655	0.299	0.682	2.128	0.071	633.331	0.064
			26.660	0.301	0.699	2.106	0.070	631.359	0.064

			26.600	0.293	0.698	2.114	0.071	629.096	0.064
			26.476	0.296	0.717	2.109	0.072	630.787	0.064
			26.691	0.300	0.698	2.099	0.072	628.385	0.064
			26.558	0.289	0.716	2.093	0.071	633.251	0.064
			26.637	0.295	0.725	2.078	0.073	633.116	0.064
			26.662	0.294	0.735	2.080	0.080	632.255	0.064
			26.559	0.294	0.747	2.104	0.073	636.271	0.065
			26.574	0.295	0.693	2.105	0.072	634.493	0.065
			26.605	0.289	0.713	2.109	0.070	633.036	0.064
			26.544	0.290	0.711	2.113	0.071	635.431	0.065
			26.580	0.292	0.711	2.130	0.069	634.065	0.064
			26.620	0.297	0.691	2.105	0.070	636.511	0.065
			26.714	0.293	0.699	2.118	0.071	633.708	0.064
			26.611	0.296	0.683	2.128	0.071	635.402	0.065
B5 - Soy	FTP	2007 MBE4000	28.647	0.005	0.070	1.309	0.000	578.991	0.059
			28.679	0.006	0.046	1.303	0.000	578.899	0.059
			28.535	0.006	0.065	1.312	0.000	581.532	0.059
			28.667	0.005	0.066	1.305	0.000	580.041	0.059
			28.606	0.005	0.065	1.307	0.000	581.602	0.059
			28.674	0.006	0.051	1.306	0.001	580.839	0.059
CARB ULSD	FTP	2007 MBE4000	28.638	0.003	0.073	1.305	0.001	580.798	0.059
			28.535	0.004	0.074	1.295	0.000	579.591	0.059
			28.635	0.003	0.078	1.291	0.000	578.233	0.059
			28.611	0.005	0.067	1.295	0.001	580.980	0.059
			28.542	0.005	0.073	1.295	0.001	580.184	0.059
			28.569	0.004	0.091	1.293	0.001	580.473	0.059
B10-Soy	FTP	2006 Cummins ISM	26.629	0.274	0.707	2.149	0.062	632.076	0.065
			26.643	0.277	0.665	2.154	0.059	630.411	0.064
			26.726	0.277	0.692	2.152	0.054	631.084	0.064
			26.697	0.276	0.679	2.150	0.060	628.027	0.064
			26.689	0.275	0.699	2.164	0.062	629.416	0.064
			26.544	0.282	0.700	2.164	0.062	634.349	0.065
CARB ULSD	FTP	2006 Cummins ISM	26.650	0.280	0.698	2.076	0.072	624.986	0.064
			26.598	0.286	0.694	2.067	0.072	625.364	0.064
			26.457	0.288	0.710	2.090	0.074	630.497	0.064
			26.525	0.293	0.715	2.076	0.073	629.674	0.064

			26.603	0.297	0.690	2.092	0.073	633.139	0.064
			26.676	0.293	0.673	2.093	0.077	631.495	0.064
			26.593	0.296	0.705	2.097	0.073	634.048	0.064
			26.703	0.289	0.673	2.083	0.070	623.705	0.063
			26.589	0.294	0.681	2.088	0.071	630.334	0.064
			26.656	0.296	0.691	2.068	0.071	627.629	0.064
			26.590	0.298	0.714	2.113	0.072	630.587	0.064
			26.640	0.298	0.689	2.110	0.070	632.011	0.064
			26.639	0.300	0.703	2.112	0.072	633.399	0.064
			26.688	0.306	0.730	2.123	0.073	635.859	0.065
			26.797	0.302	0.686	2.105	0.070	631.540	0.064
			26.675	0.304	0.698	2.104	0.072	633.093	0.064
			26.720	0.298	0.673	2.092	0.070	627.904	0.064
			26.655	0.299	0.682	2.128	0.071	633.331	0.064
			26.660	0.301	0.699	2.106	0.070	631.359	0.064
			26.600	0.293	0.698	2.114	0.071	629.096	0.064
			26.476	0.296	0.717	2.109	0.072	630.787	0.064
			26.691	0.300	0.698	2.099	0.072	628.385	0.064
			26.558	0.289	0.716	2.093	0.071	633.251	0.064
			26.637	0.295	0.725	2.078	0.073	633.116	0.064
			26.662	0.294	0.735	2.080	0.080	632.255	0.064
			26.559	0.294	0.747	2.104	0.073	636.271	0.065
			26.574	0.295	0.693	2.105	0.072	634.493	0.065
			26.605	0.289	0.713	2.109	0.070	633.036	0.064
			26.544	0.290	0.711	2.113	0.071	635.431	0.065
			26.580	0.292	0.711	2.130	0.069	634.065	0.064
			26.620	0.297	0.691	2.105	0.070	636.511	0.065
			26.714	0.293	0.699	2.118	0.071	633.708	0.064
			26.611	0.296	0.683	2.128	0.071	635.402	0.065
B5 - Animal	FTP	2006 Cummins ISM	26.756	0.286	0.677	2.079	0.070	621.722	0.065
			26.676	0.292	0.681	2.093	0.070	625.282	0.065
			26.590	0.297	0.685	2.085	0.069	626.072	0.066
			26.570	0.297	0.683	2.093	0.068	627.470	0.068
			26.652	0.300	0.715	2.099	0.071	624.219	0.068
			26.672	0.299	0.674	2.087	0.069	623.306	0.068
CARB ULSD	FTP	2006 Cummins ISM	26.453	0.299	0.724	2.099	0.076	628.314	0.066
			26.585	0.305	0.693	2.087	0.075	628.067	0.066
			26.583	0.308	0.742	2.085	0.076	629.575	0.066

			26.577	0.302	0.713	2.089	0.072	626.206	0.064
			26.629	0.302	0.710	2.074	0.079	623.568	0.063
			26.629	0.302	0.710	2.062	0.079	623.568	0.063
B5 - Animal	FTP	2007 MBE4000	28.601	0.005	0.062	1.311	0.001	581.793	0.059
			28.574	0.008	0.074	1.308	0.001	583.817	0.059
			28.605	0.006	0.070	1.313	0.000	583.982	0.059
			28.480	0.006	0.068	1.316	0.001	587.733	0.060
			28.571	0.005	0.080	1.319	0.000	585.563	0.060
			28.508	0.005	0.077	1.317	0.000	585.178	0.059
CARB ULSD	FTP	2007 MBE4000	28.575	0.004	0.076	1.295	0.001	584.790	0.059
			28.609	0.005	0.073	1.289	0.000	583.101	0.059
			28.545	0.008	0.069	1.290	0.000	584.206	0.059
			28.589	0.006	0.096	1.301	0.001	581.388	0.059
			28.639	0.004	0.089	1.301	0.000	581.705	0.059
			28.524	0.004	0.083	1.307	0.000	583.545	0.059
TRU Study (part of 2011 Biodiesel Characterization and NOx Mitigation Study)									
B5-Soy	ISO 8178-4 C1	1999 Kubota TRU	No data	1.381	6.054	8.635	1.584	619.027	No data
			No data	1.472	6.304	9.000	1.602	621.212	No data
			No data	1.374	5.825	8.784	1.383	621.924	No data
			No data	1.325	5.671	9.109	1.531	621.025	No data
			No data	1.334	6.162	8.538	1.491	622.661	No data
			No data	1.135	6.371	8.671	1.630	626.671	No data
			No data	1.287	6.299	8.592	1.573	630.638	No data
			No data	1.252	6.101	8.692	1.570	629.242	No data
CARB ULSD	ISO 8178-4 C1	1999 Kubota TRU	No data	1.336	5.944	9.055	1.549	620.206	No data
			No data	1.475	5.697	8.987	1.513	619.158	No data
			No data	1.292	5.673	8.714	1.390	623.035	No data
			No data	1.375	6.363	8.816	1.496	624.634	No

										data
			No data	1.343	5.658	8.622	1.506	622.925	No data
			No data	1.241	6.486	8.503	1.585	622.932	No data
			No data	1.243	6.602	8.393	1.608	628.286	No data
			No data	1.134	6.594	8.648	1.615	625.054	No data
			No data	1.204	6.147	8.574	1.428	626.399	No data
			No data	1.117	6.345	8.328	1.610	625.471	No data
			No data	1.335	6.568	8.711	1.723	632.989	No data
John Deere Study (part of 2011 Biodiesel Characterization and NOx Mitigation Study)									
B5 - Animal	ISO 8178-4 C1	2009 John Deere 4045HF	58.025	0.140	1.249	2.640	0.108	654.301	No data
			59.576	0.175	1.166	2.694	0.095	648.814	No data
			59.050	0.129	1.178	2.538	0.100	640.811	No data
			59.298	0.137	1.242	2.694	0.105	654.543	No data
			58.674	0.132	1.310	2.626	0.113	653.924	No data
			57.484	0.143	1.222	2.651	0.098	664.292	No data
CARB ULSD	ISO 8178-4 C1	2009 John Deere 4045HF	58.862	0.169	1.187	2.690	0.076	642.608	No data
			59.538	0.159	1.267	2.685	0.106	646.342	No data
			59.098	0.156	1.214	2.699	0.106	652.373	No data
			58.744	0.217	1.311	2.612	0.107	660.206	No data
			59.672	0.129	1.148	2.648	0.109	637.148	No data
			58.530	0.133	1.323	2.632	0.114	655.929	No data
			58.890	0.135	1.239	2.647	0.099	651.141	No data

			58.841	0.141	1.264	2.722	0.124	649.127	No data
Durbin 2013 - CARB B5 Preliminary and Certification Testing									
B5 - Soy	FTP	2006 Cummins ISM	26.212	0.324	0.816	2.070	0.061	635.115	0.064
			26.128	0.330	0.805	2.067	0.063	636.837	0.064
			26.179	0.335	0.824	2.071	0.063	636.466	0.064
			26.215	0.332	0.801	2.061	0.062	636.491	0.064
			26.214	0.337	0.827	2.065	0.064	636.176	0.064
			26.125	0.339	0.795	2.086	0.063	637.625	0.064
CARB ULSD	FTP	2006 Cummins ISM	26.174	0.317	0.807	2.035	0.067	631.578	0.064
			26.205	0.320	0.813	2.051	0.064	631.097	0.064
			26.267	0.325	0.813	2.034	0.066	631.778	0.064
			26.315	0.317	0.792	2.034	0.066	630.574	0.063
			26.263	0.317	0.787	2.044	0.065	633.602	0.064
			26.157	0.322	0.797	2.064	0.065	635.144	0.064
B5- Animal	FTP	2006 Cummins ISM	26.252	0.347	0.802	1.999	0.062	636.928	0.065
			26.227	0.340	0.780	2.049	0.063	635.310	0.065
			26.202	0.341	0.815	2.055	0.065	637.443	0.065
			26.076	0.309	0.807	2.062	0.062	636.773	0.065
			26.147	0.312	0.807	2.060	0.062	638.336	0.065
			26.207	0.312	0.789	2.050	0.064	638.461	0.065
CARB ULSD	FTP	2006 Cummins ISM	26.174	0.317	0.807	2.035	0.067	631.578	0.064
			26.205	0.320	0.813	2.051	0.064	631.097	0.064
			26.267	0.325	0.813	2.034	0.066	631.778	0.064
			26.315	0.317	0.792	2.034	0.066	630.574	0.063
			26.263	0.317	0.787	2.044	0.065	633.602	0.064
			26.157	0.322	0.797	2.064	0.065	635.144	0.064
B5 - Animal	FTP	2006 Cummins ISM	26.141	0.317	0.734	2.054	0.064	640.411	0.065
			26.235	0.317	0.747	2.059	0.064	637.502	0.065
			26.201		0.710	2.035	0.062	637.357	
			26.237		0.745	2.024	0.066	637.880	

			26.193	0.309	0.731	2.023	0.064	637.041	0.065
			26.269	0.315	0.766	2.022	0.065	636.276	0.065
			26.243	0.303	0.751	2.028	0.065	636.613	0.065
			26.222	0.303	0.714	2.019	0.063	637.752	0.065
			26.267	0.307	0.769	2.030	0.064	635.646	0.064
			26.181	0.291	0.738	2.047	0.064	640.168	0.065
			26.197	0.326	0.740	2.036	0.065	637.503	0.065
			26.184	0.332	0.713	2.032	0.065	638.464	0.065
			26.287	0.308	0.750	2.014	0.064	636.100	0.065
			26.288	0.312	0.808	2.049	0.067	637.861	0.065
			26.241	0.327	0.711	2.035	0.065	630.743	0.064
			26.353	0.323	0.722	2.022	0.064	627.978	0.064
			26.213	0.310	0.758	2.039	0.064	638.419	0.065
			26.232	0.311	0.719	2.031	0.064	640.299	0.065
			26.270	0.326	0.702	2.030	0.064	632.213	0.064
			26.154	0.323	0.708	2.056	0.065	635.355	0.064
CARB ULSD	FTP	2006 Cummins ISM	26.173	0.322	0.771	2.044	0.068	638.055	0.064
			26.245	0.339	0.755	2.040	0.069	630.006	0.063
			26.246	0.283	0.780	2.044	0.067	635.655	0.064
			26.302		0.760	2.036	0.067	634.929	
			26.283		0.771	2.033	0.067	635.720	
			26.320	0.336	0.757	2.046	0.067	635.816	0.064
			26.235	0.312	0.803	2.051	0.065	636.990	0.064
			26.326	0.329	0.809	2.049	0.067	634.778	0.064
			26.249	0.325	0.799	2.031	0.067	638.402	0.064
			26.268	0.341	0.777	2.056	0.067	633.363	0.064
			26.262	0.337	0.805	2.051	0.070	632.077	0.064
			26.239	0.349	0.781	2.044	0.069	630.199	0.063
			26.332	0.315	0.795	2.037	0.066	635.121	0.064
			26.363	0.335	0.760	2.033	0.067	628.785	0.063
			26.192	0.332	0.773	2.046	0.067	633.752	0.064
			26.176	0.350	0.784	2.069	0.068	638.577	0.064
			26.246	0.321	0.793	2.046	0.064	635.479	0.064
			26.300	0.335	0.780	2.044	0.068	637.581	0.064
			26.321	0.336	0.810	2.043	0.068	636.569	0.064
			26.278	0.350	0.804	2.043	0.071	635.689	0.064
Karavalakis and Durbin 2014 - CARB Comprehensive B5/B10 Biodiesel Blends Heavy-Duty Engine Dynamometer Testing									
B5 -	FTP	2006	26.609	0.158	0.672	2.109	0.064	626.926	0.064

Soy		Cummins ISM							
			26.590	0.157	0.675	2.108	0.064	625.733	0.064
			26.705	0.172	0.675	2.103	0.065	621.435	0.064
			26.623	0.168	0.683	2.106	0.065	623.839	0.064
			26.801	0.161	0.686	2.101	0.063	622.351	0.064
			26.621	0.161	0.671	2.094	0.074	624.650	0.064
			26.653	0.175	0.651	2.114	0.064	624.660	0.064
			26.614	0.171	0.665	2.122	0.064	627.011	0.064
CARB ULSD	FTP	2006 Cummins ISM	26.656	0.144	0.680	2.091	0.066	626.286	0.063
			26.666	0.172	0.674	2.083	0.067	623.633	0.063
			26.659	0.167	0.702	2.080	0.070	622.790	0.063
			26.718	0.179	0.666	2.079	0.068	620.006	0.063
			26.683	0.149	0.675	2.087	0.068	625.166	0.063
			26.509	0.175	0.680	2.081	0.069	625.365	0.063
			26.623	0.171	0.667	2.093	0.068	624.758	0.063
			26.620	0.177	0.683	2.092	0.021	623.524	0.063
B5 - Soy	UDDS	2006 Cummins ISM	5.341	0.428	1.979	6.075	0.101	805.284	0.083
			5.318	0.425	1.958	6.089	0.115	806.198	0.083
			5.285	0.454	1.995	6.140	0.118	803.728	0.082
			5.388	0.436	1.912	5.829	0.114	789.118	0.081
			5.327	0.414	1.929	6.160	0.110	802.930	0.082
			5.300	0.406	2.054	6.171	0.120	815.394	0.084
			5.395	0.462	1.982	5.915	0.116	786.343	0.081
			5.376	0.438	1.861	6.096	0.119	793.979	0.081
CARB ULSD	UDDS	2006 Cummins ISM	5.401	0.393	1.845	6.024	0.086	795.862	0.081
			5.389	0.443	1.878	6.102	0.113	791.042	0.080
			5.367	0.474	2.093	5.844	0.113	793.163	0.080
			5.232	0.461	1.903	6.076	0.109	814.959	0.083
			5.331	0.463	1.921	6.064	0.115	796.322	0.081
			5.306	0.396	1.881	6.042	0.099	804.611	0.082
			5.298	0.443	2.069	5.978	0.111	806.123	0.082
			5.378	0.429	1.848	5.940	0.113	788.578	0.080
			5.339	0.460	1.963	5.874	0.109	789.834	0.080
B5 - Soy	SET	2006 Cummins	124.510	0.058	0.353	1.866	0.035	527.587	0.054

		ISM							
			124.719	0.059	0.354	1.875	0.035	528.600	0.054
			124.548	0.067	0.351	1.863	0.036	527.730	0.054
			124.543	0.064	0.354	1.852	0.036	529.935	0.054
CARB ULSD	SET	2006 Cummins ISM	124.399	0.067	0.352	1.861	0.036	530.775	0.054
			124.586	0.071	0.371	1.842	0.039	531.263	0.054
			124.570	0.065	0.363	1.847	0.038	529.526	0.053
			124.546	0.072	0.356	1.862	0.039	530.713	0.054
B5 - Soy	FTP	1991 DDC60	24.041	0.056	1.566	4.460	0.124	549.100	0.056
			24.060	0.056	1.548	4.450	0.061	550.680	0.056
			24.108	0.054	1.522	4.423	0.060	545.378	0.056
			23.885	0.059	1.527	4.460	0.061	547.776	0.056
			24.152	0.054	1.571	4.477	0.059	546.983	0.056
			24.089	0.054	1.548	4.479	0.061	547.319	0.056
			24.003	0.054	1.521	4.468	0.060	545.599	0.056
			24.088	0.054	1.514	4.429	0.059	543.807	0.056
CARB ULSD	FTP	1991 DDC60	24.090	0.056	1.659	4.413	0.067	551.036	0.056
			23.956	0.056	1.602	4.421	0.066	550.577	0.056
			24.055	0.056	1.586	4.401	0.066	549.490	0.056
			24.054	0.056	1.582	4.411	0.067	546.202	0.055
			24.109	0.054	1.615	4.399	0.064	546.887	0.055
			23.999	0.057	1.585	4.432	0.065	547.842	0.055
			24.110	0.055	1.556	4.416	0.059	542.331	0.055
			24.030	0.055	1.549	4.394	0.066	543.799	0.055
B5 - Soy	UDDS	1991 DDC60	3.914	0.208	2.123	11.206	0.039	686.604	0.070
			3.922	0.214	2.162	11.344	0.052	687.872	0.071
			3.936	0.213	2.102	11.378	0.036	682.080	0.070
			3.825	0.226	1.984	12.080	0.046	706.644	0.072
			3.940	0.202	2.107	11.191	0.037	682.656	0.070
			3.955	0.208	2.004	11.181	0.043	677.613	0.070
			3.808	0.217	2.212	11.851	0.036	711.225	0.073
			3.883	0.206	1.929	12.027	0.042	692.957	0.071
CARB ULSD	UDDS	1991 DDC60	3.907	0.196	2.138	11.177	0.033	687.912	0.070
			3.966	0.207	1.925	11.003	0.026	671.689	0.068
			3.940	0.216	1.951	11.457	0.043	688.026	0.070
			3.960	0.214	1.999	11.107	0.036	676.508	0.069

			3.995	0.197	1.976	10.903	0.026	670.123	0.068
			4.026	0.195	1.919	10.843	0.028	665.558	0.067
			3.985	0.210	1.987	11.529	0.042	677.009	0.069
			3.901	0.209	1.863	11.404	0.028	685.082	0.069
B5 - Soy	SET	1991 DDC60	96.561	0.024	1.501	7.415	0.018	472.264	0.048
			96.527	0.024	1.532	7.353	0.019	472.815	0.049
			96.736	0.023	1.471	7.420	0.019	471.757	0.048
			96.716	0.023	1.522	7.354	0.019	471.178	0.048
CARB ULSD	SET	1991 DDC60	96.754	0.023	1.546	7.381	0.020	475.016	0.048
			96.564	0.025	1.558	7.308	0.023	472.114	0.048
			96.621	0.024	1.543	7.410	0.020	473.600	0.048
			96.522	0.024	1.524	7.324	0.019	470.655	0.048
B10 - Soy	FTP	2006 Cummins ISM	26.689	0.159	0.675	2.126	0.061	626.427	0.064
			26.710	0.156	0.677	2.128	0.060	625.609	0.064
			26.610	0.171	0.673	2.128	0.061	625.517	0.064
			26.643	0.167	0.665	2.121	0.061	625.227	0.064
			26.669	0.165	0.676	2.104	0.060	622.391	0.063
			26.686	0.164	0.674	2.116	0.060	623.945	0.063
			26.689	0.173	0.665	2.104	0.059	620.955	0.063
			26.679	0.074	0.696	2.068	0.062	624.381	0.063
CARB ULSD	FTP	2006 Cummins ISM	26.569	0.150	0.690	2.086	0.069	628.285	0.063
			26.643	0.174	0.698	2.081	0.068	624.724	0.063
			26.681	0.171	0.695	2.085	0.068	623.383	0.063
			26.644	0.182	0.690	2.093	0.070	624.493	0.063
			26.687	0.156	0.677	2.064	0.067	623.122	0.063
			26.643	0.179	0.680	2.061	0.068	621.981	0.063
			26.634	0.176	0.680	2.061	0.069	623.280	0.063
			26.696	0.067	0.700	2.041	0.069	620.977	0.063
B10 - Soy	UDDS	2006 Cummins ISM	5.286	0.441	1.868	6.189	0.110	833.226	0.085
			5.209	0.427	2.058	6.249	0.115	821.626	0.084
			5.276	0.464	1.926	6.192	0.120	798.438	0.081
			5.452	0.429	1.835	5.969	0.114	773.917	0.079
			5.257	0.428	2.105	6.166	0.114	812.722	0.083

			5.329	0.438	1.962	6.114	0.118	803.185	0.082
			5.383	0.431	1.989	6.032	0.107	782.687	0.080
			5.263	0.431	2.035	6.174	0.120	806.079	0.082
CARB ULSD	UDDS	2006 Cummins ISM	5.418	0.406	2.076	5.701	0.091	777.837	0.079
			5.371	0.448	1.834	5.802	0.107	783.911	0.079
			5.377	0.451	1.791	5.966	0.113	785.636	0.080
			5.425	0.501	1.799	5.795	0.114	771.695	0.078
			5.322	0.394	1.929	6.061	0.092	797.735	0.081
			5.284	0.463	2.055	6.051	0.117	800.415	0.081
			5.213	0.459	1.918	5.976	0.118	810.873	0.082
			5.290	0.487	1.917	6.036	0.124	795.973	0.081
B10 - Soy	SET	2006 Cummins ISM	124.050	0.069	0.335	1.891	0.033	532.803	0.054
			124.267	0.065	0.340	1.895	0.034	530.683	0.054
			124.366	0.055	0.342	1.905	0.033	531.303	0.054
			124.334	0.066	0.344	1.893	0.033	534.490	0.054
CARB ULSD	SET	2006 Cummins ISM	124.516	0.071	0.361	1.857	0.042	528.103	0.053
			124.296	0.072	0.360	1.864	0.039	531.702	0.054
			124.589	0.058	0.329	2.057	0.035	528.118	0.053
			124.394	0.071	0.362	1.844	0.039	533.069	0.054
B10 - Soy	FTP	1991 DDC60	23.951	0.051	1.466	4.535	0.040	545.347	0.056
			23.950	0.051	1.447	4.545	0.055	546.778	0.056
			24.100	0.053	1.424	4.480	0.057	542.826	0.055
			23.874	0.053	1.446	4.535	0.059	549.990	0.056
			24.133	0.048	1.443	4.487	0.054	545.646	0.056
			24.125	0.051	1.445	4.495	0.055	546.297	0.056
			23.966	0.052	1.407	4.489	0.058	547.050	0.056
			24.127	0.053	1.437	4.468	0.059	545.045	0.056
CARB ULSD	FTP	1991 DDC60	23.997	0.053	1.549	4.446	0.066	544.742	0.055
			24.077	0.052	1.521	4.493	0.063	543.284	0.055
			24.037	0.056	1.486	4.458	0.066	543.312	0.055
			24.024	0.053	1.495	4.421	0.065	544.388	0.055
			23.994	0.051	1.572	4.399	0.064	547.771	0.055
			24.008	0.051	1.554	4.449	0.067	548.299	0.056
			24.107	0.057	1.470	4.440	0.067	543.195	0.055

			24.149	0.055	1.498	4.386	0.067	545.515	0.055
B10 - Soy	UDDS	1991 DDC60	3.892	0.282	2.067	11.537	0.033	688.438	0.070
			4.019	0.235	2.035	11.222	0.051	673.671	0.069
			3.969	0.187	1.973	11.338	0.030	671.496	0.068
			4.025	0.188	1.911	11.408	0.042	668.260	0.068
			3.919	0.206	2.061	11.316	0.026	684.954	0.070
			3.831	0.218	2.106	11.710	0.035	701.493	0.072
			3.894	0.206	2.009	11.373	0.027	685.500	0.070
			3.953	0.211	1.937	11.523	0.034	678.714	0.069
CARB ULSD	UDDS	1991 DDC60	3.851	0.240	2.184	11.454	0.048	633.992	0.064
			3.967	0.184	1.916	10.878	0.032	655.914	0.066
			3.941	0.193	1.900	11.356	0.035	674.042	0.068
			3.889	0.179	2.038	11.332	0.038	680.864	0.069
			3.919	0.206	1.932	11.252	0.037	683.429	0.069
			3.898	0.207	1.997	11.152	0.026	678.309	0.069
			3.906	0.220	1.967	11.528	0.041	685.783	0.070
			3.790	0.214	2.079	11.620	0.032	702.421	0.071
B10 - Soy	SET	1991 DDC60	96.569	0.022	1.452	7.533	0.019	476.304	0.049
			96.443	0.024	1.509	7.559	0.020	475.018	0.048
			96.856	0.021	1.435	7.554	0.018	475.960	0.048
			96.720	0.022	1.477	7.512	0.003	478.397	0.049
CARB ULSD	SET	1991 DDC60	96.725	0.022	1.591	7.483	0.022	474.525	0.048
			96.788	0.032	1.589	7.376	0.022	469.362	0.048
			96.725	0.022	1.547	7.465	0.020	476.633	0.048
			96.700	0.024	1.518	7.435	0.020	475.701	0.048
B5 - Animal	FTP	2006 Cummins ISM	26.576	0.168	0.683	2.120	0.064	630.523	0.064
			26.534	0.168	0.674	2.105	0.065	630.943	0.064
			26.624	0.164	0.683	2.125	0.063	632.268	0.064
			26.642	0.164	0.672	2.114	0.064	630.484	0.064
			26.568	0.182	0.673	2.045	0.065	631.032	0.064
			26.633	0.188	0.689	2.059	0.065	628.851	0.064
			26.614	0.176	0.699	2.090	0.065	626.289	0.064
			26.567	0.173	0.658	2.094	0.063	629.711	0.064
CARB ULSD	FTP	2006 Cummins	26.503	0.151	0.688	2.115	0.068	634.665	0.064

		ISM							
			26.569	0.171	0.731	2.084	0.070	629.277	0.064
			26.529	0.180	0.746	2.100	0.072	628.960	0.064
			26.529	0.176	0.687	2.102	0.069	630.814	0.064
			26.528	0.181	0.698	2.061	0.068	632.022	0.064
			26.686	0.178	0.688	2.093	0.067	626.835	0.063
			26.581	0.177	0.677	2.157	0.069	629.277	0.064
			26.566	0.185	0.675	2.098	0.067	628.862	0.064
B5 - Animal	UDDS	2006 Cummins ISM	5.276	0.398	1.791	5.879	0.047	793.351	0.081
			5.261	0.404	1.910	6.131	0.066	801.409	0.082
			5.276	0.417	1.890	5.842	0.048	785.816	0.080
			5.391	0.402	2.031	5.796	0.071	778.393	0.079
			5.339	0.387	1.953	5.783	0.052	785.094	0.080
			5.316	0.404	1.799	5.866	0.068	789.823	0.080
			5.363	0.426	1.906	5.753	0.048	778.155	0.079
			5.311	0.423	1.813	5.838	0.068	791.837	0.081
CARB ULSD	UDDS	2006 Cummins ISM	5.407	0.384	1.856	5.901	0.065	772.271	0.078
			5.258	0.432	1.851	6.103	0.050	787.975	0.080
			5.230	0.431	2.213	6.220	0.069	807.599	0.082
			5.200	0.464	1.967	6.016	0.054	800.607	0.081
			5.306	0.351	1.853	5.990	0.056	787.114	0.080
			5.311	0.429	1.861	5.866	0.049	783.355	0.079
			5.432	0.422	1.862	5.786	0.066	777.663	0.079
			5.379	0.422	1.792	5.800	0.050	776.020	0.079
B5 - Animal	SET	2006 Cummins ISM	124.369	0.072	0.336	1.872	0.035	529.411	0.054
			124.429	0.070	0.354	1.805	0.036	529.477	0.054
			124.482	0.060	0.341	1.891	0.034	527.182	0.054
			124.577	0.061	0.343	1.870	0.035	528.558	0.054
CARB ULSD	SET	2006 Cummins ISM	124.284	0.069	0.356	1.866	0.039	535.371	0.054
			124.604	0.074	0.362	1.859	0.039	528.769	0.053
			124.719	0.072	0.357	1.830	0.038	529.177	0.053
			124.748	0.063	0.358	1.873	0.037	529.000	0.053
B5 -	FTP	1991	24.184	0.048	1.433	4.428	0.056	535.039	0.054

Animal		DDC60							
			24.091	0.048	1.456	4.456	0.057	539.868	0.055
			24.108	0.055	1.442	4.438	0.059	541.703	0.055
			24.045	0.054	1.450	4.425	0.059	544.376	0.055
			23.872	0.051	1.481	4.480	0.058	545.117	0.056
			24.105	0.051	1.409	4.434	0.056	542.039	0.055
			24.018	0.052	1.449	4.446	0.057	542.838	0.055
			24.071	0.051	1.426	4.419	0.057	542.198	0.055
CARB ULSD	FTP	1991 DDC60	24.018	0.052	1.591	4.476	0.063	541.193	0.055
			24.103	0.049	1.494	4.408	0.063	539.320	0.055
			24.066	0.049	1.511	4.412	0.064	535.697	0.054
			23.942	0.055	1.551	4.485	0.067	544.347	0.055
			24.117	0.052	1.514	4.453	0.062	551.908	0.056
			24.167	0.062	1.517	4.411	0.063	539.619	0.055
			24.113	0.053	1.522	4.417	0.063	540.678	0.055
			23.983	0.048	1.531	4.439	0.063	545.836	0.055
B5 - Animal	UDDS	1991 DDC60	3.914	0.188	1.955	11.164	0.029	684.679	0.070
			3.952	0.200	1.925	11.201	0.041	682.338	0.070
			3.932	0.266	2.049	11.114	0.036	676.580	0.069
			3.937	0.186	1.779	11.579	0.042	670.579	0.068
			3.980	0.183	1.840	10.813	0.033	670.036	0.068
			3.957	0.193	1.876	10.997	0.045	676.072	0.069
			3.879	0.214	1.884	11.208	0.026	680.907	0.069
			4.021	0.195	1.818	11.382	0.031	656.703	0.067
CARB ULSD	UDDS	1991 DDC60	3.824	0.196	2.213	11.417	0.035	696.574	0.071
			3.916	0.214	2.079	11.407	0.032	682.352	0.069
			4.051	0.200	1.885	11.370	0.041	661.985	0.067
			3.998	0.202	1.937	11.162	0.027	666.428	0.068
			3.978	0.182	1.985	10.971	0.035	663.656	0.067
			3.919	0.203	2.017	11.148	0.040	679.634	0.069
			3.929	0.217	1.886	11.558	0.041	684.333	0.069
			3.906	0.207	1.963	11.320	0.023	676.747	0.069
B5 - Animal	SET	1991 DDC60	96.721	0.023	1.439	7.463	0.019	470.279	0.048
			96.704	0.024	1.456	7.416	0.019	471.616	0.048
			96.746	0.022	1.433	7.446	0.019	471.109	0.048
			96.738	0.023	1.473	7.378	0.019	467.864	0.048
CARB ULSD	SET	1991 DDC60	96.632	0.024	1.500	7.451	0.019	472.005	0.048

			96.712	0.024	1.485	7.398	0.020	470.693	0.048
			96.574	0.024	1.496	7.462	0.020	474.082	0.048
			96.677	0.024	1.472	7.354	0.021	470.321	0.048
B10 - Animal	FTP	2006 Cummins ISM	26.651	0.160	0.638	2.104	0.057	630.806	0.064
			26.578	0.156	0.645	2.100	0.058	631.728	0.064
			26.605	0.171	0.658	2.090	0.058	627.752	0.064
			26.494	0.167	0.645	2.117	0.052	633.290	0.065
			26.508	0.181	0.644	2.091	0.058	627.280	0.064
			26.505	0.178	0.643	2.082	0.060	627.336	0.064
			26.598	0.170	0.640	2.095	0.058	626.243	0.064
			26.667	0.192	0.648	2.080	0.061	625.159	0.064
CARB ULSD	FTP	2006 Cummins ISM	26.525	0.153	0.682	2.097	0.068	634.590	0.064
			26.655	0.171	0.670	2.072	0.065	622.399	0.063
			26.560	0.175	0.673	2.086	0.067	626.814	0.063
			26.504	0.187	0.688	2.083	0.069	628.489	0.064
			26.544	0.181	0.719	2.109	0.072	636.609	0.064
			26.611	0.202	0.699	2.016	0.069	624.279	0.063
			26.610	0.193	0.667	2.067	0.067	624.932	0.063
			26.513	0.212	0.675	2.088	0.068	625.125	0.063
B10 - Animal	UDDS	2006 Cummins ISM	5.245	0.453	1.703	5.926	0.046	796.750	0.081
			5.340	0.464	1.715	5.737	0.063	784.883	0.080
			5.279	0.503	1.697	5.692	0.047	782.658	0.080
			5.262	0.488	1.764	5.981	0.055	796.833	0.081
			5.368	0.390	1.669	5.743	0.050	786.368	0.080
			5.213	0.420	1.786	5.994	0.068	814.041	0.083
			5.268	0.419	1.755	5.954	0.045	795.621	0.081
			5.174	0.428	1.752	5.950	0.067	813.832	0.083
CARB ULSD	UDDS	2006 Cummins ISM	5.300	0.440	1.911	5.813	0.059	781.133	0.079
			5.277	0.423	1.813	5.986	0.048	788.031	0.080
			5.285	0.443	1.900	5.860	0.065	790.256	0.080
			5.311	0.454	1.826	5.785	0.046	779.762	0.079
			5.357	0.410	1.934	5.792	0.052	786.706	0.080
			5.267	0.451	1.861	5.879	0.051	797.890	0.081
			5.233	0.460	1.971	6.181	0.066	811.293	0.082

			5.379	0.450	1.813	5.743	0.035	774.032	0.078
B10 - Animal	SET	2006 Cummins ISM	124.261	0.069	0.345	1.827	0.034	531.664	0.054
			124.348	0.064	0.333	1.867	0.033	529.263	0.054
			124.357	0.065	0.341	1.884	0.032	530.668	0.054
			124.476	0.064	0.329	1.873	0.032	528.502	0.054
CARB ULSD	SET	2006 Cummins ISM	124.729	0.058	0.369	1.853	0.037	527.956	0.053
			124.731	0.070	0.364	1.849	0.038	530.162	0.054
			124.532	0.067	0.368	1.858	0.037	534.031	0.054
			124.313	0.073	0.357	1.845	0.037	533.580	0.054
B10 - Animal	FTP	1991 DDC60	24.124	0.047	1.473	4.424	0.056	542.028	0.055
			24.060	0.048	1.453	4.452	0.054	544.795	0.056
			24.051	0.048	1.421	4.448	0.054	542.634	0.055
			24.006	0.048	1.386	4.457	0.053	544.899	0.056
			23.872	0.054	1.449	4.499	0.054	549.573	0.056
			24.088	0.053	1.450	4.461	0.054	544.840	0.056
			24.070	0.050	1.423	4.436	0.055	543.600	0.056
			24.151	0.050	1.395	4.423	0.054	542.167	0.055
CARB ULSD	FTP	1991 DDC60	24.166	0.050	1.652	4.391	0.066	543.834	0.055
			24.049	0.050	1.522	4.412	0.062	542.739	0.055
			24.091	0.050	1.531	4.421	0.062	543.979	0.055
			24.111	0.050	1.523	4.415	0.062	542.676	0.055
			24.034	0.057	1.596	4.429	0.064	546.817	0.055
			24.123	0.054	1.521	4.415	0.062	541.290	0.055
			24.125	0.051	1.519	4.411	0.062	542.416	0.055
			24.021	0.053	1.523	4.429	0.064	544.966	0.055
B10 - Animal	UDDS	1991 DDC60	3.964	0.204	1.909	10.964	0.027	674.078	0.069
			3.861	0.212	1.878	11.397	0.034	688.934	0.070
			3.940	0.204	1.811	11.029	0.025	677.519	0.069
			3.956	0.202	1.893	11.185	0.037	678.280	0.069
			4.004	0.187	1.949	10.819	0.027	670.699	0.069
			3.900	0.200	1.873	11.328	0.043	688.469	0.070
			3.827	0.207	1.983	11.625	0.020	703.553	0.072
			3.948	0.212	1.890	11.596	0.022	680.697	0.070
CARB	UDDS	1991	3.973	0.208	2.006	11.178	0.040	678.454	0.069

ULSD		DDC60							
			3.918	0.210	2.012	11.319	0.031	683.226	0.069
			3.965	0.215	1.920	11.300	0.040	673.661	0.068
			3.898	0.205	2.034	11.343	0.027	685.868	0.070
			3.972	0.188	1.960	11.107	0.025	675.660	0.068
			3.820	0.216	2.066	11.425	0.024	693.672	0.070
			4.011	0.199	1.840	11.435	0.029	672.133	0.068
			3.908	0.209	1.908	11.408	0.018	685.454	0.069
B10 - Animal	SET	1991 DDC60	96.519	0.022	1.415	7.531	0.019	476.564	0.049
			96.458	0.022	1.442	7.489	0.019	477.808	0.049
			96.573	0.022	1.435	7.488	0.019	476.079	0.049
			96.341	0.021	1.477	7.432	0.019	476.800	0.049
CARB ULSD	SET	1991 DDC60	96.834	0.022	1.536	7.484	0.020	475.231	0.048
			96.733	0.024	1.510	7.402	0.020	471.576	0.048
			96.747	0.023	1.580	7.485	0.021	474.469	0.048
			96.647	0.023	1.582	7.362	0.022	476.991	0.048
2010 Performance and emissions of diesel and alternative diesel fuels									
Raw data were not available to ARB, average data are shown below where available. Study is available in published literature.									
B5 - Soy	FTP	1991 DDC60	Not Avail.	Not Avail.	Not Avail.	4.514	Not Avail.	Not Avail.	Not Avail.
CARB ULSD	FTP	1991 DDC60	Not Avail.	Not Avail.	Not Avail.	4.596	Not Avail.	Not Avail.	Not Avail.
B5 - Soy	SET	1991 DDC60	Not Avail.	Not Avail.	Not Avail.	7.528	Not Avail.	Not Avail.	Not Avail.
CARB ULSD	SET	1991 DDC60	Not Avail.	Not Avail.	Not Avail.	7.532	Not Avail.	Not Avail.	Not Avail.
Thompson 2010 - Neat Fuel Influence on Biodiesel Blend Emissions									
Raw data were not available to ARB, average data are shown below where available. Study is available in published literature (BSFC is in g/bhp-hr)									
B10 - Soy	FTP	1992 DDC60	Not Avail.	0.086	2.685	4.500	0.201	Not Avail.	169.277
CARB Like	FTP	1992 DDC60	Not Avail.	0.087	2.811	4.370	0.223	Not Avail.	167.040
B10 - Soy	SET	1992 DDC60	Not Avail.	Not Avail.	Not Avail.	8.662	0.0729	Not Avail.	Not Avail.
CARB	SET	1992	Not	Not	Not	8.446	0.0855	Not Avail.	Not

Like		DDC60	Avail.	Avail.	Avail.				Avail.