APPENDIX G

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SUPPLEMENTAL DISCLOSURE DISCUSSION OF OXIDES OF NITROGEN POTENTIALLY CAUSED BY THE LOW CARBON FUEL STANDARD REGULATION

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Date of Release: March 6, 2018

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A. EXECUTIVE SUMMARY

1. Background

This document addresses potential air quality impacts related to the Low Carbon Fuel Standard (LCFS), with a focus on estimating and disclosing specific potential air quality impacts from the program's inception. Additional California Environmental Quality Act (CEQA) analysis related to the proposed 2018 amendments to the LCFS and Alternative Diesel Fuels (ADF) regulations ("Proposed Amendments") may be found in a draft environmental analysis prepared for those amendments in Appendix D of this rulemaking package. This document shows that the California Air Resources Board's (CARB) suite of air quality rules, along with other factors, have led to a steady decrease in air pollution in California, and that the LCFS has supported this effort. It also shows that, in certain years, depending on the attribution methodology used to assign causation, the LCFS may have resulted in increases in certain air pollutants relative to a no-LCFS baseline. These effects are small, did not disrupt the overall decline in air pollution in California, and are tied to decreases to other air pollutants such that the overall effect was beneficial to human health. Nevertheless, CARB plans to fully remediate these potential past emissions increases, and outlines those plans in this document.

This disclosure document has been prepared in response to the modified writ of mandate issued by the Fresno County Superior Court (Superior Court) in *POET, LLC v. California Air Resources Board* on October 18, 2017[1] related to CARB's CEQA analysis for the Low Carbon Fuel Standard (LCFS) and also addresses the Alternative Diesel Fuels (ADF) regulations, which serves, among other things, to mitigate certain potential air quality impacts related the LCFS.[2] Specifically, the writ of mandate requires CARB to evaluate whether the "project as a whole (i.e., the original and modified [LCFS] regulations)"[3] is likely to have caused an increase in oxides of nitrogen (NOx) emissions in the past, and whether the project as a whole is likely to cause an increase in NOx emissions in the future. These potential emissions increases are directly related to the use of particular alternative diesel fuels, and so emissions related to those fuels are the focus of this document. The writ of mandate also requires CARB to address whether any increased NOx emissions had, or are likely to have, a significant adverse effect on the environment or are cumulatively considerable, and to develop mitigation measures

[1] Fresno County Superior Court Order Modifying and Reissuing the Writ, *POET, LLC. v. CARB*, No. 09 CECG 04659 JYH (October 18, 2017).

[2] The LCFS regulation is published at California Code of Regulations, title 17, § 95480 et seq. The ADF regulation is published at California Code of Regulations, title 13, § 2293 et seq.

[3] The original LCFS regulation refers to the LCFS regulation adopted in 2009 and amended in 2012. The modified LCFS regulation refers to the replacement LCFS regulation and the Alternative Diesel Fuels regulation adopted in 2015.

and discuss alternatives to the provisions in the regulations addressing diesel fuel and its substitutes. Consistent with the Superior Court's direction, CARB staff analyzed NOx emissions and potential impacts that could be attributed to implementation of the LCFS regulations, making assumptions, where necessary, that would attribute higher, rather than lower, NOx emissions to the LCFS. CARB then compared the resulting potential NOx emissions impacts to a baseline that reflects conditions existing at the time environmental analysis of the original LCFS regulation was commenced, as described in Section B.3. To ensure maximum transparency regarding potential impacts, staff used conservative assumptions—assumptions that maximize attribution of NOx emissions to the LCFS—throughout the analysis, potentially overstating the impacts attributable to the LCFS.

This document considers potential biodiesel NOx emissions for the entire history of LCFS regulations to date (original LCFS, amendments, and the 2015 LCFS) and compares those potential emissions to a 2007 baseline to identify any impacts. This approach accounts for any historical impacts while projecting impacts for the current version of the regulation (2015 LCFS). This document considers and describes a forward-looking mitigation measure, which is a proposed amendment to the ADF included in the Proposed Amendments. It also describes the remediation measures CARB proposes to take to address past NOx impacts that may be attributed to the LCFS. The potential environmental impacts of the full set of Proposed Amendments are analyzed separately and are available in the draft Environmental Analysis (Appendix D).

To provide a complete picture of environmental and health impacts, staff estimated and considered the extent to which the LCFS may have driven increases in California's statewide use of all biomass-based diesel fuels (i.e., biodiesel and renewable diesel) in the past, and the extent to which the LCFS may drive such increases in the future. Emissions and health impacts attributable to the LCFS were compared to baseline emissions and health impacts.

Following the identification of any increases in NOx emissions due to biomass-based diesel use attributable to the LCFS on a year-by-year basis, staff evaluated whether these NOx emissions increases likely had, or are likely to have, a significant adverse effect on the environment or are cumulatively considerable.[4]

Overall, biodiesel attributable to the LCFS is beneficial in terms of health impacts for all years considered. In fact, staff found that any use of biodiesel, with or without offsetting factors, would be considered beneficial in terms of overall health impacts because the health benefits from particulate matter (PM) reductions outweigh the health impacts from any NOx increases. That is, as an overall air quality matter, LCFS-attributable

[4] References to increases or decreases in NOx emissions due to the use of biomass-based diesel are referring to the incremental increases or decreases compared to the emissions that would have resulted from the use of conventional diesel instead.

biodiesel increases improved health outcomes in all years. However, in the interest of fuller disclosure and mitigation, staff considered NOx impacts independently of PM in developing significance findings in this document.

As noted above, staff utilized a conservative analytical approach that likely overestimates LCFS attributable impacts. Using that approach, staff concluded that potential increases in NOx emissions from biomass-based diesel use attributed to LCFS, considered in isolation from the overall air quality impacts of biodiesel use, may have had a significant adverse effect on the environment in 2012, 2015, and 2016. Staff also concluded that biomass-based diesel use attributed to the LCFS could cause significant adverse environmental impacts from 2023 onward, again considered independently of the PM reductions they deliver, if the ADF regulation is not modified. Staff also determined that, again under this conservative approach, NOx emissions from biomass-based diesel use attributed to the LCFS resulted in a potentially significant impact on cumulative long-term air quality. Again, as noted above, staff found that in all years analyzed, the health benefit from reductions in direct particulate matter (PM) emissions outweighed the potential adverse health impact due to increases in NOx, and resulted in net health benefits.

This document is organized into seven parts:

- Part A provides an overall summary of the background, analysis and results, remedial and mitigation measures, and alternatives analysis.
- Part B provides the context and background for this supplemental disclosure analysis and the issues addressed.
- Part C summarizes the methodologies developed for attribution of changes in biomass-based diesel (i.e., biodiesel and renewable diesel) use in California attributable to the LCFS.
- Part D is an estimation of the NOx and other emissions changes that correspond to Part C’s attribution of biomass-based diesel to the LCFS.
- Part E discusses the health outcomes corresponding to those emissions.
- Part F discusses alternatives.
- Part G lists the references cited in the document.

2. Summary of Additional Analysis Tools

To understand the effect the LCFS may have had in the past on biomass-based diesel consumption in California, and resulting impacts on air quality, staff conducted a variety of statistical tests using multiple regression analysis, testing a wide range of possible independent variables. This analysis is difficult due to confounding effects from simultaneous federal incentives (e.g., the federal Renewable Fuel Standard and federal tax credits) and analytical limitations (e.g., limited information on California biodiesel consumption over time). Therefore, it is challenging to determine with certainty how much, if any, biomass-based diesel use in California can be causally linked to the LCFS during the historical period using statistical techniques. To address the concerns identified in the modified writ of mandate, staff developed a reasonable attribution method to split the biomass-based diesel consumption between volumes attributable to the LCFS regulations and all other factors. Staff assessed two conceptual methodologies for attributing the LCFS share of biomass-based diesel use and selected the more environmentally conservative method for attribution—the one more likely to attribute more biodiesel and NOx emissions to the LCFS. As such, the estimates potentially overstate the impacts attributable to LCFS, and should be viewed as an upper-bound estimate of any potential impacts.

From the LCFS-attributable biomass-based diesel volumes, staff conservatively estimated the change in LCFS-attributed NOx emissions due to biomass-based diesel use relative to conventional diesel use (hereafter referred to as “LCFS NOx emissions”) on a year-by-year basis.[5,6] The increased annual LCFS NOx emissions were then analyzed to determine whether the increased emissions likely had, or are likely to have, a significant adverse effect on the environment or are cumulatively considerable.
To more comprehensively disclose the overall health impacts of biomass-based diesel attributable to the LCFS, staff also analyzed the impact of changes in LCFS-attributed PM emissions due to biomass-based diesel use relative to conventional diesel use (hereafter referred to as “LCFS PM emissions”).[7]

This analysis and its significance conclusions rely on multiple layers of assumptions – each with associated uncertainties.[8] In order to most comprehensively disclose potential environmental impacts consistent with the purposes of CEQA and the direction of the writ, staff consistently applied conservative assumptions and made conservative

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[5] As described in Section B.1.c, biodiesel use can result in a NOx emissions increase, while renewable diesel use can result in a NOx emissions reduction, relative to conventional diesel. The net NOx emissions change due to LCFS-attributed biomass-based diesel use in a given year depends on the LCFS-attributed volumes of biodiesel and renewable diesel in the given year.

[6] Staff made several assumptions that resulted in conservative estimates of LCFS-attributed biomass-based diesel use and related NOx emissions, including: assuming that all increases in biodiesel use in California beyond 2016 are due to the LCFS; using the attribution methodology (Method III) that results in the highest attribution of biomass-based diesel use to the LCFS regulations; assuming that all biodiesel use in California is low-saturation biodiesel, which results in higher NOx emissions than high-saturation biodiesel; and assuming that all biodiesel use occurs in heavy-duty vehicles, which results in higher NOx emissions than biodiesel use in light-duty and medium-duty vehicles.

[7] Both biodiesel and renewable diesel use reduce PM emissions relative to conventional diesel use, resulting in environmental and health benefits.

[8] Staff’s analysis includes projections of biomass-based diesel consumption and estimates of volumes attributable to the LCFS, LCFS NOx and PM emissions, and corresponding health impacts.

projections. This approach resulted in a conservative (i.e., high) estimate of potential NOx emissions and a maximal allocation of potential NOx emissions to the LCFS.

3. Summary of Backward-Looking Impact Analysis and Remedial Measures, and Forward-Looking Impact Analysis and Additional Mitigation Measures

This analysis identified potentially significant air quality impacts in the past and potentially significant air quality impacts in the future. Staff are proposing a regulatory amendment to avoid potentially significant future impacts from biodiesel, and will develop a mechanism to offset potential past NOx with remedial measures.

a. Past NOx Impacts and Backward-Looking Remedial Measures

The potentially significant air quality impacts resulting from historical LCFS NOx emissions occurred in the past. Due to the short atmospheric lifetime of NOx emissions,[9] it is not physically possible, and is therefore infeasible, to mitigate any specific potentially significant historical LCFS NOx emissions. If the proposed LCFS and ADF amendments are adopted, the projected NOx reductions related to biomass-based diesel attributed to the LCFS would offset the potential historical LCFS-attributed NOx emissions increases, but would not formally remediate these specific historical emissions in the sense of removing them from the air – as they have already naturally left the atmosphere.[10] Nevertheless, consistent with CARB's mission to promote and

[9] NOx emissions from sources near the surface of the Earth have a relatively short atmospheric lifetime, typically on the order of hours. Zhang et al. 2003. Impacts of Anthropogenic and Natural NOx Sources Over the U.S. on Tropospheric Chemistry. February 18. Available at: http://www.pnas.org/content/100/4/1505.full.pdf. Accessed: January, 2018.

[10] Staff's estimated potential historical LCFS-attributed NOx emissions increases (789 tons NOx total from 2007 - 2016) reflect individual years when LCFS-attributed NOx emissions were above the level of conventional diesel. Staff notes that historical LCFS-attributed NOx emissions decreases (518 tons NOx total from 2007 - 2016) also occurred during the historical period.

Staff estimated that the amendment to the ADF regulation as part of the Proposed Amendments would result in cumulative LCFS NOx emissions of -5,400 tons (i.e., a reduction in NOx emissions due to biomass-based diesel use attributed to the LCFS of 5,400 tons) during the period 2023 – 2025. This reduction is almost seven times the cumulative historical LCFS NOx emissions estimated by staff for the period 2007 – 2016, considering only years with potential historical LCFS-attributed NOx increases, as estimated under the most conservative scenario.

Similarly, staff estimated that the existing ADF regulation would result in a cumulative NOx emissions reduction of over 650 tons (approximately 83% of the cumulative historical LCFS NOx emissions, considering only years with historical LCFS-attributed NOx increases) for biodiesel use not attributed to the LCFS for the period from 2018 – 2025 under the most conservative scenario. Staff estimated that the amended ADF regulation would result in a cumulative NOx emission reduction of 990 tons (approximately 25% more than the cumulative historical LCFS NOx emissions, considering only years with historical protect public health and welfare through the effective and efficient reduction of air pollutants, CARB will pursue full remediation of all potential historical LCFS NOx emissions by seeking additional future reductions in the amount of the past emissions, conservatively estimated.[11] As such, CARB will remediate the potential past emissions through remedial measures supporting air district-level NOx mitigation projects targeting engines, such as the replacement of existing diesel engines with low-NOx engines.

This document concludes that the health benefits resulting from PM reductions associated with historic LCFS-attributed biodiesel use were substantial (247 total reduced premature deaths statewide over the period analyzed for the scenario that results in the highest potential cumulative LCFS NOx emissions). In addition to the substantial health benefits associated with biodiesel use, staff also notes the substantial environmental benefits resulting from greenhouse gas (GHG) reductions associated with biodiesel. Staff acknowledges the important role that biodiesel plays in improving public health and believes that the use of biodiesel on its own is beneficial to California, regardless of whether that use is in conjunction with renewable diesel.

b. Projected NOx Impacts and Forward-Looking Additional Mitigation Measures

Future NOx impacts due to LCFS-attributable biodiesel use are largely already projected to be mitigated in the current LCFS program by the advancement of new technology diesel engines (NTDE),[12] the Regulation on the Commercialization of Alternative Diesel Fuels (ADF regulation), and the anticipated NOx-offsetting increased use of renewable diesel. However, staff incorporated ADF regulation program design review into this analysis and found that, based on additional information and analysis of the off-road sector,[13] LCFS NOx emissions would be likely to increase following the activation of the sunset provision of the ADF's biodiesel in-use NOx mitigation requirements, as currently designed. This is due to the much longer estimated turnover period for off-road vehicles and equipment than was projected when the ADF regulation

LCFS-attributed NOx increases) for biodiesel use not attributed to the LCFS for the period from 2018 – 2025.

[11] In estimating the total amount of NOx emissions to be remediated, staff only considered years when historical LCFS NOx emissions were greater than zero (i.e., years when there were NOx emissions increases due to LCFS-attributed biomass-based diesel relative to conventional diesel). Staff's estimate of cumulative historical LCFS NOx emissions did not include historical years when LCFS NOx emissions were negative (i.e., when there were LCFS-attributed NOx emissions decreases).

[12] The use of biodiesel in older diesel engines not equipped with selective catalytic reduction (SCR) results in an increase in NOx emissions relative to use of conventional diesel. In this analysis, diesel engines with SCR are referred to as New Technology Diesel Engines (NTDE); engines without SCR are referred to as non-NTDEs

[13] See Appendix 5, Section A.1.

was developed.[14] Therefore, if the ADF regulation in-use requirements sunset as currently written, it is possible that biodiesel use attributable to the LCFS could cause a potentially significant air quality impact due to LCFS NOx emissions increases in the future.

CARB is proposing to mitigate projected future LCFS NOx emissions through an amendment to the ADF regulation included as part of a package of proposed amendments to the LCFS and the ADF regulations. This amendment would revise the sunset provision for the ADF regulation to indicate that the sunset of in-use requirements is based on penetration of NTDEs for both on-road vehicles and off-road vehicles and equipment. As a result of the proposed amendment to the ADF regulation, the sunset of in-use requirements in the ADF regulation would likely occur no earlier than 2030. During the rulemaking process, staff will continue to evaluate whether the sunset provision can be bifurcated for on-road vehicles versus off-road vehicles and equipment, which would result in an earlier anticipated sunset date for on-road vehicles while preventing any NOx increases above baseline.

With the implementation of the proposed ADF amendment NOx mitigation measure, the potentially significant future adverse impact to long-term air quality caused by LCFS-attributed biomass-based diesel use would be reduced to a less-than-significant level. Thus, with mitigation, those potential NOx emissions would not result in a cumulatively-considerable contribution to a significant adverse impact to future long-term air quality.

4. Summary of Alternatives Analysis

The purpose of a CEQA alternatives analysis is to evaluate alternatives that could reduce or avoid the project's significant environmental impacts.[15] While CEQA does not provide a clear framework for evaluating alternatives to address wholly past impacts, consistent with the most closely-applicable CEQA Guidelines[16] and with the writ of mandate, CARB has evaluated alternatives to the project (i.e., the original and modified

[14] In the current ADF regulation, in-use requirements for biodiesel blends up to B20 sunset when the vehicle miles travelled (VMT) by on-road NTDE heavy-duty vehicles in California reaches 90 percent of total VMT by the California on-road heavy-duty diesel vehicle fleet. The sunset does not account for adoption of NTDEs in the off-road sector because the penetration of biodiesel use and SCR technology in off-road engines was unclear at the time of the development of the ADF regulation. Staff's analysis information and data for the off-road sector developed subsequent to the original ADF regulation indicate that occurring at a slower rate than in the on-road sector. See: CARB. 2015. Responses to Comments on the Draft Environmental Analysis for the Low Carbon Fuel Standard and Alternative Diesel Fuel Regulations. September 21. P. 2-345. Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/earesponsetocomments.pdf Accessed: February, 2018.

[15] Cal. Pub. Resources Code § 21002.

[16] Title 14 CCR. Section 15126.6. .

LCFS regulations, as well as the ADF regulation) and to the Proposed Amendments (which includes mitigation through a proposed amendment to the ADF regulation) that address diesel fuel and its substitutes. CARB's alternatives analysis includes the alternatives discussed in the Initial Statement of Reasons for the proposed amendments and its supporting economic and regulatory documents, and alternatives discussed in the EA for those amendments, as well as evaluation of the following alternatives:

- No Project Alternative: Under this alternative, the LCFS would be set aside and the Proposed Amendments would not be adopted. Staff evaluated a similar alternative (i.e., the setting aside of the project) as part of the alternatives analysis for the 2015 LCFS adoption.[17]

- Exempt Biodiesel from the LCFS Alternative: Under this alternative, biodiesel would be exempted from the LCFS as part of the Proposed Amendments and, therefore, would not be eligible to generate credits. This alternative would maintain all other provisions of the project and Proposed Amendments, except for the proposed amendment to the ADF, which may not be adopted.[18]

- Require Mitigation for all Biodiesel Blends Alternative: Under this alternative, all biodiesel blends, regardless of biodiesel saturation level and season of the year, would require NOx mitigation by the LCFS to the level of conventional diesel. This alternative would maintain all other provisions of the project and Proposed Amendments except for the proposed amendment to the ADF, which would not be adopted, because it would be unnecessary.[19] Staff analyzed a very similar alternative as part of the alternatives analysis for the modified LCFS regulations in 2015.[20]

Staff's alternatives analysis focused the evaluation of feasible alternatives (i.e., alternatives to the mitigation in the Proposed Amendments that could be implemented in the future). However, because the alternative analysis also consists of actions that occurred in the past, staff also evaluated impacts for each alternative based on

[17] CARB. 2015. Appendix B – Final Environmental Analysis for the Low Carbon Fuel Standard and Alternative Diesel Fuel Regulations. September 21. Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/environmentalanalysis.pdf. Accessed: January, 2018.
[18] As described further in Section F.3.b.ii, this alternative would likely lead to a decrease in biodiesel consumption and an increase in renewable diesel use, resulting in a decrease in NOx emissions relative to a no-ADF-amendment scenario. This reduction in NOx emissions due to biomass-based diesel may eliminate the need for the proposed amendment to the ADF regulation, which was designed to reduce NOx emissions associated with biodiesel use in off-road engines.
[19] The full mitigation of NOx emissions due to biodiesel may preclude the need for the proposed amendment to the ADF regulation, which was designed to reduce NOx emissions associated with biodiesel use in off-road engines.
[20] CARB. 2015. Appendix B – Final Environmental Analysis for the Low Carbon Fuel Standard and Alternative Diesel Fuel Regulations. September 21. pp. 155-158 Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/environmentalanalysis.pdf. Accessed: January, 2018.

historical implementation (i.e., implementation of each alternative in place of or as part of the project adopted in 2009).

All of the alternatives considered above would provide either a lower incentive, or no incentive, for biodiesel use in California. These alternatives would reduce, or make it more difficult and expensive to generate, the GHG benefits associated with the project. These alternatives would not reduce historical NOx emissions due to biodiesel use attributed to the LCFS, because those emissions have already left the atmosphere. However, the No Project Alternative and Exempt Biodiesel from the LCFS Alternative would also likely result in future NOx emissions increases associated with non-LCFS-attributed biodiesel that would have been mitigated through the NOx specifications for biodiesel in the ADF regulation if the current LCFS Regulation and Proposed Amendments were in place.

All three alternatives would result in higher PM emissions, and therefore a decrease in PM-related health benefits, for all years due to decreased biodiesel use relative to the project. As noted above, the health benefits due to reductions in direct LCFS PM emissions outweigh the adverse health impacts due to increases in ozone and secondary PM formation from LCFS NOx emissions, even for years with increases in NOx emissions from LCFS-attributed biodiesel use. Given that NOx impacts due to the project are declining with the adoption of NTDEs and the use of NOx-reducing additives, the three alternatives are not, on balance, more protective of the environment and public health than the project. In addition, the No Project Alternative and Exempt Biodiesel from the LCFS Alternative would fail to meet many of the objectives of the project and Proposed Amendments.

B. BACKGROUND

1. The LCFS, Biodiesel, and LCFS Litigation

a. The LCFS and Alternative Diesel Fuels

The LCFS supports the development, production and use of lower carbon alternatives to petroleum-based fuels by establishing carbon intensity standards that become progressively more stringent each year. Fuel providers may comply by offering an array of fuels, but must ensure in the aggregate, the average carbon intensity of those fuels meets the applicable standard.

Biodiesel and renewable diesel are two alternatives to conventional diesel. While these two fuels can be made from the same materials, they are produced through different processes and have different physical properties. Both fuels result in lower greenhouse gas (GHG) emissions than conventional diesel. For that reason, Congress and the United States Environmental Protection Agency (U.S. EPA) have strongly encouraged, and even required, the use of progressively increasing volumes of these alternative diesel fuels since 2009.[21] These alternative diesel fuels also typically generate LCFS credits because of their lower GHG emissions.

CARB has made efforts from the beginning of the LCFS development process to understand, communicate, and mitigate any potential air quality impacts from alternative diesel fuels. These efforts continue in this document, and are informed by judicial instructions and clarifications. This background includes discussion of two sets of relevant judicial opinions relating to the initial LCFS and to a new LCFS subsequently adopted.

b. The First *POET* Decision and CARB's Efforts to Understand and Address Alternative Diesel Fuel Emissions

Ethanol industry petitioners challenged the adoption of the original LCFS, and the Superior Court resolved all claims in CARB's favor. The Fifth District Court of Appeal (Court of Appeal) disagreed as to four claims, but noted that CARB had "satisfied [the] vast majority of the applicable legal requirements."[22] Relevant here, the Court of Appeal held that CARB had improperly deferred the formulation of mitigation measures

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[21] See, e.g., 42 U.S.C. § 7545(o)(2)(B)(i)(I)(IV).
[22] *POET, LLC v. Cal. Air Resources Bd.* (2013) 218 Cal.App.4th 681, 697.

for biodiesel-related NOx emissions.[23] The Superior Court issued a writ of mandate requiring that CARB take corrective actions. Recognizing the environmental benefits of the regulation, the Court of Appeal required that the LCFS standards for 2013, the standards then in effect, remain operative while CARB corrected the errors.[24]

When CARB considered the original LCFS regulation, it was widely understood that biodiesel and renewable diesel can result in lower GHG emissions than conventional diesel. There were indications that the use of certain biodiesels in certain types of engines might increase emissions of NOx—a pollutant that contributes to smog formation—relative to the use of conventional diesel.[25] However, the extent of these increases and the conditions under which they might occur were not clear in 2009.[26] To address this uncertainty, CARB began "an extensive test program for biodiesel and renewable diesel" and committed to use the information from that study to "establish specifications to ensure there is no increase in NOx" from the implementation of LCFS.[27] That extensive test program had begun well before the Superior Court issued its writ. The first of these studies was completed in 2011, and two more studies were completed in 2013.[28] Using the information from these studies, CARB designed the ADF regulation to, among other things, address the NOx emissions consequences of biodiesel use.[29] CARB also designed a new version of an LCFS regulation to reflect the lessons learned from implementing the original LCFS.

After vetting its ideas in numerous pre-rulemaking public workshops, CARB released both proposed regulations—the ADF and the new LCFS along with an environmental analysis (EA) in late 2014. The environmental analysis treated the two proposed regulations as one "project" for CEQA purposes because of their interrelatedness.

The Board approved both new regulations in September of 2015. The Board also formally repealed the original LCFS regulation at the same time. That repeal was effective December 31, 2015, and the new LCFS and ADF regulations went into effect January 1, 2016.

[23] *Id.* at pp. 698-99.
[24] *Id.* at p. 762.
[25] CARB. 2009. Proposed Regulation to Implement the Low Carbon Fuel Standard – Staff Report: Initial Statement of Reasons, VII-19.
[26] See *id.;* see also *id.* at F-49.
[27] *Id.* at p. VII-19.
[28] CARB. 2015. Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons (ADF ISOR), 38.
[29] *Id.* at p. 11.

c. Discussion of Biodiesel Emissions in the 2014 Environmental Analysis

In the 2014 EA for the new LCFS and ADF regulations, CARB examined the emissions consequences of using biodiesel and renewable diesel as alternatives to conventional diesel. CARB found that the use of these alternative fuels reduces emissions of a number of pollutants, including diesel PM (a carcinogen), GHGs, and carbon monoxide.[30]

CARB also found that the use of renewable diesel results in lower NOx emissions than the use of conventional diesel.[31] Biodiesel, on the other hand, can increase NOx emissions compared to conventional diesel, when used in older heavy-duty engines.[32] Taking all of this into account, CARB designed the ADF regulation to require NOx-reducing measures, such as fuel additives, for biodiesel use above specified control levels.[33] Under the 2015 LCFS and ADF regulations, CARB projected that biodiesel-related NOx emissions would decrease from 2014 levels down to essentially zero by 2022, even while CARB anticipated that biodiesel use would continue to increase.[34]

CARB also noted that biodiesel use had increased dramatically, across the country, since 2009, in response to federal biodiesel incentives, including a volume mandate and a per-gallon tax credit.[35] California's use of biodiesel had increased during this period, although not at a rate proportional to the nation as a whole.[36] In fact, California was consuming *less* biodiesel, and more renewable diesel, than would otherwise have been expected based on the State's usual share of nationwide volumes of conventional transportation fuels.

Based on these facts, CARB concluded that the federal incentives had most likely been the primary driver of the increased use of biodiesel in California in the recent past and that California policies, including the original LCFS, were causing the State's market to favor renewable diesel over biodiesel as an alternative to conventional diesel during the

[30] Attachment D to Resolution 15-41: Findings and Statement of Overriding Consideration, 14; CARB. 2015. Appendix B: Final Environmental Analysis Prepared for the Low Carbon Fuel Standard and Alternative Diesel Fuel Regulations (2015 LCFS/ADF Final EA), 59-60; ADF ISOR 15-16, 49.
[31] 2015 LCFS/ADF Final EA at p. 59; ADF ISOR at p. 44.
[32] 2015 LCFS/ADF Final EA at pp. 30, 62; ADF ISOR at p. 40-41, 44-47, 70.
[33] ADF ISOR at p. 47.
[34] 2015 LCFS/ADF Final EA at p. 61; ADF ISOR Appendix B at p. B-4.
[35] 2015 LCFS/ADF Final EA at p. 61; ADF ISOR at p. 28-30.
[36] 2015 LCFS/ADF Final EA at p. 61-62.

recent historical period.[37] CARB hypothesized the same possible outcome regarding future biodiesel use, noting that "it is certainly possible that biodiesel use in California would continue at or near existing levels—or even increase—in the absence of an LCFS regulation."[38] CARB also noted that definitive determinations attributing specific volumes of biodiesel to a particular incentive program would be "unclear and impossible," to render with precision and certainty, given the number of simultaneous incentives at work.[39]

Although CARB concluded that the original LCFS regulation was not the driving force behind the State's increased historical use of biodiesel, CARB nonetheless calculated and disclosed the increase in total biodiesel-related NOx emissions from 2009 to 2014.[40] (AA 297, 299.) CARB also calculated and disclosed the total biodiesel-related NOx emissions likely to occur in California in the future[41] and adopted the ADF regulation to reduce those emissions, without regard to whether they might be caused by the new LCFS, the federal incentives, or other factors.[42] That approach is consistent with CARB's mission to improve air quality as well as CARB's previous actions to address NOx emissions from diesel fuels—including regulations and programs that speed up the replacement of older, dirtier engines with newer, less-polluting ones.[43,44]

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[37] 2015 LCFS/ADF Final EA at p. 61. Other market factors including the availability of renewable diesel blends compared to biodiesel blends, the ability of suppliers to ship large quantities of renewable diesel directly to California via barge, and biodiesel volume mandates in other states and the proximity to biodiesel production facilities may have also caused the State's market to favor renewable diesel over biodiesel as an alternative during the recent historical period.

[38] 2015 LCFS/ADF Final EA at p. 62.

[39] 2015 LCFS/ADF Final EA at p. 61.

[40] 2015 LCFS/ADF Final EA at p. 59, 61.

[41] 2015 LCFS/ADF Final EA at p. 61; ADF ISOR Appendix B at p. B-4.

[42] ADF ISOR at p. 23.

[43] ADF ISOR at p. 11.

[44] CARB has adopted several regulations and implemented several programs to reduce NOx emissions from diesel-fueled engines, including the Regulation for In-Use Off-Road Diesel Vehicles (adopted in 2007, with amendments adopted in 2011), the Regulation to Reduce Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use Heavy-Duty Diesel-Fueled Vehicles (adopted in 2011, with amendments adopted in in 2014), the Carl Moyer Program (implemented since 1998), the Goods Movement Emissions Reduction Program (implemented since 2008), and the Lower-Emission School Bus Program (implemented since 2008).

CARB. 2011. Final Regulation Order. Title 13 California Code of Regulations (CCR), section 2449.Regulation for In-Use Off-Road Diesel Vehicles. Available at: https://www.arb.ca.gov/regact/2010/offroadlsi10/finaloffroadreg.pdf. Accessed: September, 2017.

CARB. 2014. Final Regulation Order. Title 13, California Code of Regulations (CCR), Section 2025. Regulation to Reduce Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use Heavy-Duty Diesel-Fueled Vehicles. December 31. Available at: https://www.arb.ca.gov/msprog/onrdiesel/documents/tbfinalreg.pdf. Accessed: September, 2017.

d. The Court of Appeal's 2017 Decision

On November 23, 2015, CARB filed its return to the writ of mandate. The Superior Court discharged the writ, over petitioners' objections that CARB had not adequately addressed biodiesel-related NOx emissions. Petitioners appealed, and the Court of Appeal reversed the Superior Court's discharge of the writ. In a May 30, 2017 opinion (Opinion) the Court of Appeal directed CARB to identify how much, if any, of the increase in biodiesel use and related NOx emissions were caused by the original LCFS and will be caused by the new LCFS, and to address whether any LCFS-attributable increase in NOx emissions had, or are likely to have, a significant adverse effect on the environment or be cumulatively considerable.[45]

The additional analysis in this disclosure document responds to the Opinion and the related modified writ of mandate.

2. The LCFS "Project" for Purposes of this Disclosure Document

In its May 30, 2017 Opinion, the Court of Appeal clarified that "the term project in paragraph 3 of the writ" for purposes of the required biodiesel analysis "includes the whole of ARB's activity in promulgating and enforcing (1) the regulations originally adopted in 2009 and (2) the replacement regulations adopted in 2015."[46] Accordingly, this document evaluates the potential NOx emissions impacts of all biomass-based diesel activities and compliance responses associated with the original and new LCFS regulations.

3. Baseline Year Used for This Analysis

Pursuant to the Court of Appeal's direction that CARB disclose potential NOx emissions impacts starting from CARB's best understanding of physical conditions existing at the time the environmental analysis of the original LCFS regulations commenced, CARB staff is using 2007 as the baseline emissions conditions year, for purposes of this additional analysis. In its May 30, 2017 Opinion the Court of Appeal stated that:[47]

CARB. 2013. Carl Moyer Program Fact Sheet. Available at: https://www.arb.ca.gov/msprog/moyer/factsheets/moyer_program_fact_sheet.pdf. Accessed: February, 2018.

CARB. 2015. Proposition 1B: Movement Emission Reduction Program. Final 2015 Guidelines for Implementation. June. Available at: https://www.arb.ca.gov/bonds/gmbond/docs/prop_1b_goods_movement_2015_program_guidelines_for_implementation.pdf. Accessed: Febuary, 2018.

CARB. 2008. Lower-Emission School Bus Program, 2008 Guidelines. April. Available at: https://www.arb.ca.gov/bonds/schoolbus/guidelines/2008lesbp.pdf. Accessed: February, 2018.

[45] *POET, LLC v. Cal. Air Resources Bd.* (2017) 12 Cal.App.5th 52.

[46] 12 Cal.App.5th at 56 (footnote omitted).

[47] 12 Cal.App.5th at 79 (citations omitted).

> "The project in this case includes the original LCFS regulations. Thus, the normal baseline would be the physical conditions existing at the time the environmental analysis of the original LCFS regulations commenced. Exactly when CARB's environmental analysis commenced is not clear from the record. It probably occurred after January 2007, when Governor Schwarzenegger directed CARB to determine if a LCFS could be adopted as a discrete early action under the California Global Warming Solutions Act of 2006. It might have commenced in "August 2007 [when] CARB began consulting with the public about a LCFS." Thus, the normal, existing conditions baseline for NOx emissions might have described conditions existing in August 2007 or, if a full calendar year was used to define the baseline conditions, the NOx emissions from calendar year 2006."

A review of public activity conducted prior to the formal LCFS rulemaking period shows that CEQA analysis related to the first LCFS rulemaking was first discussed at a workshop held on December 2, 2008.[48,49] The year 2007 was thus the most recent full calendar year prior to the initiation of CARB's environmental analysis related to the first LCFS rulemaking. CARB typically uses full calendar years to define baseline conditions, and it is especially appropriate to do so for the LCFS regulations because regulated parties have full calendar years to achieve the applicable average carbon intensity standards. Given the Court of Appeal's direction, CARB staff determined 2007 to be the baseline NOx emissions year most representative of existing physical conditions at the time the environmental analysis of the original LCFS regulation commenced.

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[48] CARB. 2008a. Low Carbon Fuel Standard Workshop: Introduction/Schedule. December 2. Available at: https://www.arb.ca.gov/fuels/lcfs/120208_lcfsintro.pdf. Accessed: August, 2017.

[49] CARB. 2008b. Proposed Environmental Analysis Workplan for the California Low Carbon Fuel Standard. December 2. Available at: https://www.arb.ca.gov/fuels/lcfs/120208lcfs_environ.pdf. Accessed: August, 2017.

C. ATTRIBUTION OF BIOMASS-BASED DIESEL VOLUMES TO THE LCFS

1. Summary of the LCFS and Other Policies Supporting Biomass-Based Diesel

The LCFS supports the development, production and use of lower carbon alternatives to petroleum-based fuels by establishing carbon intensity standards that become progressively more stringent each year. LCFS credits, which are needed to demonstrate compliance, can be issued for the introduction of new low-carbon fuel to California, or through process improvements that reduce the carbon intensity of existing fuel. The LCFS was originally adopted in 2009 with reporting starting in 2010, and the first compliance year for reductions in carbon intensity occurring in 2011.

While the LCFS was being developed in California, biofuel policy at the national level was also evolving. The U.S. federal government adopted a variety of fuel production and blending incentives including volume mandates.[50,51,52] In 2005, biodiesel first began to receive a $1.00 per gallon tax credit due to the American Jobs Creation Act.[53] Subsequent revisions to the tax code have allowed biodiesel and renewable diesel volumes to claim a $1.00 per gallon tax credit for biodiesel blended for use in transportation fuel.[54] Since 2009, the tax credit was allowed to expire several times followed by retroactive re-instatement,[55] serving to continually support biomass-based diesel use in the U.S. through 2016. In 2007, the federal statute creating the Renewable Fuel Standard[56] was revised to include volume mandates for four categories of fuel, one of which is biomass-based diesel, a category that includes biodiesel and renewable diesel.[57] Final adoption of the new Renewable Fuel Standard (RFS) rule took place in 2010, requiring biomass-based diesel volumes for the first time in 2010.[58]

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[50] Public Law 114-113. Available from: https://www.congress.gov/public-laws/114th-congress
[51] 26 U.S. Code 6426. Available from: https://www.gpo.gov/fdsys/
[52] U.S. Environmental Protection Agency. *Renewable Fuel Standard.* <https://www.epa.gov/renewable-fuel-standard-program>. Last accessed: 2/6/2018
[53] Public Law 108-357. Available from: https://www.congress.gov/bill/108th-congress/house-bill/4520/text
[54] Public Law 112-240. Available from: https://www.congress.gov/bill/112th-congress/house-bill/8
[55] Irwin, S. "An Alternative View of Biodiesel Production Profits: The Role of Retroactively Reinstated Blender Tax Credits." *farmdoc daily* (7):57, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 29, 2017.
[56] Federal Register, Volume 75 No. 83. May 2007. https://www.gpo.gov/fdsys/pkg/FR-2007-05-01/pdf/E7-7140.pdf
[57] Public Law 110-140. Public Law 110-140. https://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf. *Accessed: May 24, 2017.*
[58] Federal Register, Volume 75 No. 58. March 2010. https://www.gpo.gov/fdsys/pkg/FR-2010-03-26/pdf/2010-3851.pdf. *Accessed: May 24, 2017.*

2. Summary of Methods for Attribution of Biomass-Based Diesel Volumes to LCFS

Given the simultaneous development and deployment of multiple incentive policies, attribution of effects to one policy or the other is difficult and cannot be done with complete certainty. Accordingly, CARB has developed an “upper-bound” conservative analysis that seeks to determine the maximal plausible degree to which changes in fuel volumes (and, hence, air quality impacts) may be attributed to the LCFS among these many incentives.

To attempt to isolate the effect that the LCFS regulations have had on biomass-based diesel volumes, it is important to identify the effect that other factors may have had on volume. Staff attempted to assess the effect the LCFS had on biomass-based diesel volumes by using three different approaches discussed in depth in **Appendix 1**. First, using statistical analysis, staff compared California biodiesel consumption trends to trends that have occurred in other regions of the United States that do not have an LCFS in place (Method I). Attribution of biomass-based diesel in California to the LCFS during the historical period in question is difficult, and the statistical analysis did not yield conclusive results that were statistically significant or appropriately rigorous. Therefore, in light of the inability of these methods to provide certainty, attribution of biomass-based diesel in California based on statistical analysis (Method I) was not considered further. Staff also developed two conceptual, non-statistical methods (Method I and Method II) in addition to the statistical method to attribute biomass-based diesel volumes to the LCFS that are more conservative (in the sense of attributing more responsibility to the LCFS than the statistical method would have). These methods estimated attribution of biomass-based diesel volumes to the LCFS based on basic economic reasoning and the mechanics that underlie the LCFS program. For Method II, These attributions included considerations related to the dollar per gallon value of the LCFS incentive relative to other incentives. For Method III, staff evaluated the LCFS credit price requirements necessary to overcome the cost of transporting fuel from the Midwest and from overseas to California. Details of staff’s attribution analysis methods are presented in **Appendix 1**. A more detailed discussion on the methods and results of staff’s statistical analysis are presented in **Appendix 2**. A list that summarizes each method is provided below.

- **Method I -** Statistical analysis using linear regression to assess significant effects.

- **Method II -** Conceptual analysis to assess the relative financial value of LCFS incentives compared to other fuel incentives

- **Method III -** Conceptual analysis to assess the LCFS incentive relative to fuel transport costs to supply fuel to California

3. Attribution Analysis Results

Based on the attribution analysis methods detailed in **Appendix 1**, **Tables 1** and **2** summarize the results of Methods II and III, respectively, used to estimate the percentages of biomass-based diesel attributed to the LCFS for 2010 - 2016. Post-2016, staff conservatively assumed that the LCFS program is responsible for any increase in the use of biomass-based diesel volumes in California beyond the 2016 volumes attributed to non-LCFS programs. Staff expects LCFS credit prices to remain strong as the LCFS CI reduction targets become more aggressive and compliance becomes more difficult. At the same time, future growth in the federal RFS mandate for biomass-based diesel is becoming more uncertain with the finalized EPA-proposed volume obligation for both 2018 and 2019 being held at only 2.1 billion gallons, following notices that solicited comment on potential reductions in the 2018 biomass-based diesel, advanced biofuel, and total renewable fuel volumes, and/or the 2019 biomass-based diesel volume. Moreover, staff notes renewal of the biodiesel tax credit, which expired at the end of 2016, is uncertain.

Table 1 - Summary of Estimates of LCFS's Attribution to Biodiesel Use for Methods II and III.

Year	Biodiesel Volume Percent Attributed to LCFS[59]	
	Method II	Method III
2010	0%	0%
2011	0%	0%
2012	4%	4%
2013	18%	56%
2014	16%	54%
2015	16%	75%
2016	31%	83%
Post-2016	All but 112 million gallons[60]	All but 29 million gallons[61]

[59] Attribution volume percentages of biomass-based diesel vary based on the projected future volumes. As discussed in Section C.3.a, staff evaluated two sets of projected future volumes. Therefore, for simplicity, Table 1 presents attribution of biodiesel to the LCFS for future years in units of volume.
[60] Based on 2016 biodiesel use attributed to federal programs, which consists of 69% of total California use of biodiesel or 112 million gallons.
[61] Based on 2016 biodiesel use attributed to federal programs, which consists of 29 million gallons of in-state production and no imports.

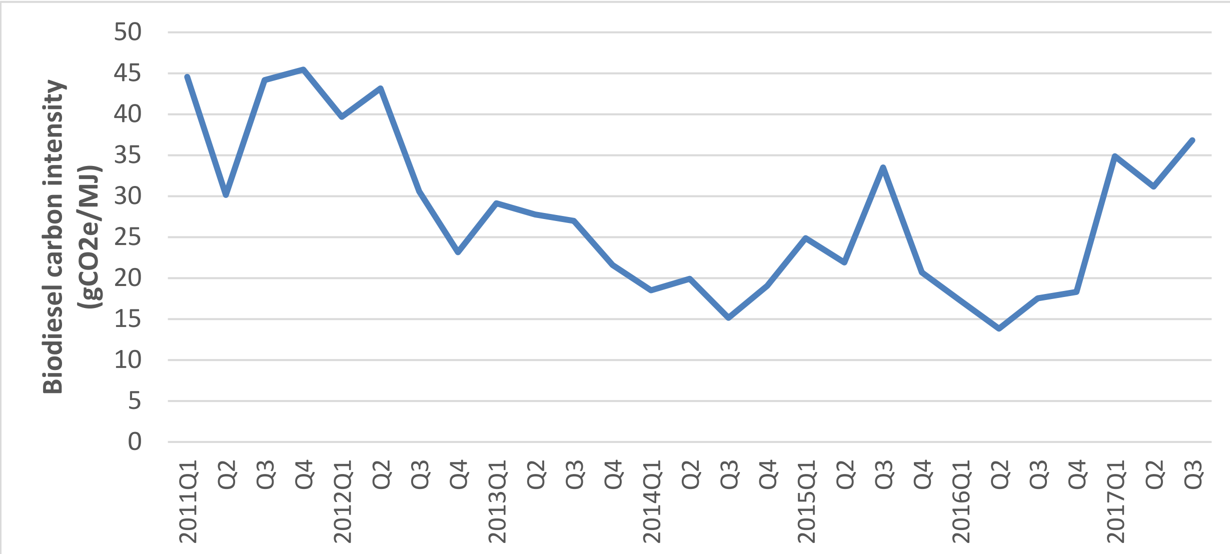
Table 2 - Summary of Estimates of LCFS's Attribution to Renewable Diesel Use for Methods II and III.

Year	Renewable Diesel Volume Percent Attributed to LCFS[62]	
	Method II	Method III
2010	0%	0%
2011	0%	0%
2012	4%	2%
2013	14%	82%
2014	13%	89%
2015	12%	75%
2016	25%	91%
Post-2016	All but 186 million gallons[63]	All but 23 million gallons[64]

Although the impact that the LCFS has had on biodiesel consumption remains ambiguous during this historical period, the LCFS has impacted carbon intensity for biodiesel pathways. As seen in **Figure 1**, the average carbon intensity of biodiesel supplied to California has declined overtime. This suggests that lower-carbon feedstock as well as process improvements are taking place to reduce the carbon intensity of biodiesel. Because the RFS and blenders tax credits do not include a mechanism to incentivize improvements in carbon intensity, this effect is more likely due to the LCFS.

[62] Attribution volume percentages of biomass-based diesel vary based on the projected future volumes. As discussed in Section C.3.a, staff evaluated two sets of projected future volumes. Therefore, for simplicity, Table 2 presents attribution of renewable diesel to the LCFS for future years in units of volume.
[63] Based on 2016 renewable diesel use attributed to federal programs, which consists of 75% of total California renewable diesel use or 186 million gallons.
[64] Based on 2016 renewable use attributed to federal programs, which consists of 23 million gallons of in-state production and no imports.

Figure 1 - Carbon Intensity of Biodiesel Supplied to California [65]



Given that the statistical models do not yield statistically significant results for the correlation of biodiesel use and LCFS credit prices, staff opted for a conservative and simple upper-bound attribution to take responsibility for biodiesel and renewable diesel volumes that may be attributable to the LCFS for the historical period. Staff believes that the attribution based on the analysis of California's domestic production and imports (Method III) is both logical from an economic perspective and, because it attributes more biodiesel, overall, to the LCFS than Method II, it is also more conservative from an environmental perspective with respect to NOx emissions increases relative to conventional diesel.[66] Therefore, staff used the results from Method III as a basis for subsequent analysis in this document. For completeness, staff also estimated the biomass-based diesel volumes and associated emissions and health impacts using the results from Method II.[67] The biomass-based diesel volumes and

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[65] Note: After adoption of the new LCFS in 2015, the carbon intensity values for biodiesel and renewable diesel changed for some feedstock due to improvements in modeling for indirect land-use change (LUC) and adjustments to the treatment of corn oil as a feedstock. This shift creates a discontinuity in the data starting in 2017. (Can be seen on the feedstock tab for LCFS quarterly data available from: https://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm.

[66] More conservative in the sense that Method III results in higher cumulative historical LCFS-attributed NOx emissions due to biomass-based diesel use than Method II. Staff estimated cumulative historical LCFS-attributed NOx emissions for the period 2007 – 2016 based on historical LCFS-attributed NOx emissions increases only, and did not include historical LCFS-attributed NOx emissions decreases.

[67] Estimated LCFS NOx emissions using Attribution Method II result in cumulative historical LCFS NOx emissions that are less than using Attribution Method III. Staff estimated cumulative historical LCFS-attributed NOx emissions for the period 2007 – 2016 based on historical LCFS-attributed NOx emissions increases only, and did not include historical LCFS-attributed NOx emissions decreases.

associated emissions and health impacts results based on Method III are presented below, and the results based on Method II are presented in **Appendix 3**.

a. Estimation of LCFS-Attributed Biomass-Based Diesel Volumes

Based on the results of the attribution analysis discussed in Section C.3, staff estimated biomass-based diesel volumes attributed to the LCFS for four scenarios. These four scenarios, summarized in **Table 3**, all use actual data for historical periods but represent a range of projected future total biomass-based diesel usage volumes and the percentages of those volumes attributed to the LCFS based on Attribution Methods II and III.

Table 3 - Summary of Biomass-Based Diesel Volume Scenarios Evaluated

Scenario	Basis for Total Biomass-Based Diesel and Conventional Diesel Volumes		Method of Attribution of Total Biomass-based diesel Volumes to the LCFS
	Historical (2007 – 2016)	Projected Future (2017 – 2025)[68]	
1	Reported actual	2015 LCFS EA – Illustrative Compliance Scenario	Method III (Overcoming transport costs)
2	Reported actual	2018 LCFS EA BAU Scenario	Method III (Overcoming transport costs)
3	Reported actual	2015 LCFS EA – Illustrative Compliance Scenario	Method II (Policy-based attribution)
4	Reported actual	2018 LCFS EA BAU Scenario	Method II (Policy-based attribution)

[68] Biomass-based diesel consumption data for California are not available for the entire year in 2017, and total annual biomass-based diesel volumes for 2017 are projected. Therefore 2017 is considered a future year for the purposes of this analysis.

LCFS-attributed biomass-based diesel volumes for Scenarios 1 and 2, which are based on the more conservative attribution method (Method III), are presented below.[69]

As indicated in **Table 3**, total historical biodiesel, renewable diesel, and conventional diesel volumes and total diesel demand[70] for all four scenarios are based on reported volume data. Prior to 2011, total biomass-based diesel and conventional diesel volumes are from the Board of Equalization (BOE) and reported in the LCFS 2011 Program Review Report (pre-2011).[71] For 2011 and later, total biomass-based diesel and conventional diesel volumes were reported to CARB through the LCFS Reporting Tool (LRT).[72] The total historical volumes of biodiesel, renewable diesel, and conventional diesel used in California from 2007 – 2016, in millions of gallons per year (MGPY), are provided in **Table 4**.

Table 4 – Historical Total Biomass-Based Diesel and Conventional Diesel Volumes Used in California, 2007 to 2016 (for all Scenarios)

Fuel	Historical Total Volumes by Year (MGPY)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Biodiesel	17	12	6.9	5.4	13	20	60	67	126	163
Renewable Diesel	0	0	0	0	1.8	8.8	117	113	165	248
Conventional Diesel	3,805	3,429	3,200	3,295	3,470	3,578	3,405	3,444	3,475	3,421
Total Diesel Demand[73]	3,822	3,441	3,207	3,300	3,485	3,607	3,582	3,624	3,767	3,832

69 Estimated LCFS NOx emissions using Attribution Method III result in cumulative LCFS NOx emissions that are greater than using Attribution Method II. . In determining the most conservative attribution method, staff estimated cumulative LCFS NOx emissions as the sum of LCFS-attributed NOx emissions increases only.
70 Total diesel demand represents the sum of biodiesel, renewable diesel, and conventional diesel volumes.
71 CARB. 2011. Low Carbon Fuel Standard 2011 Program Review Report. December 8. Available at: https://www.arb.ca.gov/fuels/lcfs/workgroups/advisorypanel/20111208_LCFS%20program%20review%20report_final.pdf. Accessed: August, 2017.
72 CARB. 2017. Low Carbon Fuel Standard Reporting Tool Quarterly Summaries. August 2. Available at: https://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm. Accessed: September, 2017.
73 Total diesel demand represents the sum of biodiesel, renewable diesel, and conventional diesel volumes.

Projected future total biodiesel, renewable diesel, and conventional diesel use in California for years 2017 - 2025 were based on two sets of volume estimates:

1. The 15-day changes to the Illustrative Compliance Scenario in the 2015 LCFS staff report (2015 LCFS EA scenario);[74] and

2. The business-as-usual (BAU) scenario evaluated as part of the environmental analysis for the 2018 LCFS Amendments (2018 LCFS EA BAU scenario).[75] These biodiesel, renewable diesel, and conventional diesel volumes were included to represent an updated projection of possible biomass-based diesel and conventional diesel volumes assuming a LCFS program that remains at 10 percent carbon intensity reduction post 2020.[76]

Future total biodiesel, renewable diesel, and conventional diesel volumes projected to be used in California from 2017 – 2025, based on estimates from the 2015 LCFS EA scenario and the 2018 LCFS EA BAU scenario, are shown in **Tables 5** and **6**, respectively.

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[74] CARB. 2014. Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Proposed Re-Adoption of the Low Carbon Fuel Standard, Appendix B: Development of Illustrative Compliance Scenarios and Evaluation of Potential Compliance Curves. Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15appb.pdf. Accessed: July, 2017.
[75] CARB. 2018. Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Proposed Amendments to the Low Carbon Fuel Standard, Appendix D: Environmental Analysis. March.
[76] The primary differences in biodiesel and renewable diesel projections from the 2015 LCFS EA scenario to the 2018 LCFS EA BAU scenario include increased biodiesel production due to CARB's knowledge of the introduction of a more cost-effective NOx reducing additive for ADF compliance and general updates to our expectations about the possible future supply of all fuels. Similar to the 2015 Illustrative Scenario, it is not a forecast of the only possible response to the regulation, but it is a plausible scenario by which compliance with the 2015 LCFS could be achieved. CARB believes the analysis presented below reflects a best estimate approach to future projections, given these uncertainties. Any uncertainties in compliance response would not alter the fundamental conclusions of this document because the proposed amendments to the ADF regulation work to produce full mitigation regardless of the particular compliance scenario in future, and the conservative upper-bound attribution methodology continues to operate for past emissions to ensure remediation.

Table 5 – Projected Future Total Biomass-Based Diesel and Conventional Diesel Volumes to be Used in California, 2017 to 2025, Scenario 1 (Based on 2015 LCFS EA Scenario Volumes)

Fuel	Projected Future Total Volumes by Year, Based on 2015 LCFS EA Scenario Volumes (MGPY)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biodiesel	160	180	180	180	185	185	185	190	190
Renewable Diesel	300	320	360	400	500	550	600	600	600
Conventional Diesel	3,443	3,461	3,481	3,501	3,457	3,469	3,482	3,541	3,606
Total Diesel Demand[77]	3,903	3,961	4,021	4,081	4,142	4,204	4,267	4,331	4,396

Table 6 – Projected Future Total Biomass-Based Diesel and Conventional Diesel Volumes to be Used in California, 2017 to 2025, Scenario 2 (Based on 2018 LCFS EA BAU Scenario Volumes)

Fuel	Projected Future Total Volumes by Year, Based on 2018 LCFS EA BAU Scenario Volumes (MGPY)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biodiesel	170	200	275	350	425	500	500	500	500
Renewable Diesel	350	450	550	650	750	850	950	1,050	1,150
Conventional Diesel	3,268	3,110	2,916	2,737	2,592	2,446	2,383	2,244	2,123
Total Diesel Demand[78]	3,788	3,760	3,741	3,737	3,767	3,796	3,833	3,794	3,773

Staff estimated the LCFS-attributed volumes of biodiesel and renewable diesel for Scenarios 1 and 2 by multiplying the total volumes of biodiesel and renewable diesel used in California by the percentages of biodiesel and renewable diesel attributed to the LCFS, as shown in **Equations A4-1** and **A4-2**, respectively, in **Appendix 4**. The total volumes of biodiesel and renewable diesel used in California during the historical and future periods are provided in **Tables 4 - 6**. The percentages of biodiesel and

[77] Total diesel demand represents the sum of biodiesel, renewable diesel, and conventional diesel volumes.
[78] Total diesel demand represents the sum of biodiesel, renewable diesel, and conventional diesel volumes.

renewable diesel attributed to the LCFS for Scenarios 1 and 2 (Attribution Method III) in years 2007 - 2016 were provided in **Tables 1** and **2**, respectively. For years 2017 - 2025, the percentages of biodiesel and renewable diesel attributed to the LCFS were estimated based on the conservative assumption that the LCFS program is responsible for any increase in the use of biomass-based diesel volumes in California beyond the 2016 volumes attributed to federal programs, as discussed in Section C.3 and shown in **Equations A4-3** and **A4-4**, respectively, in **Appendix 4**.[79]

Table 7 presents the LCFS-attributed volumes of biomass-based diesel for Scenarios 1 and 2 during the historical period (2007 – 2016),[80] and **Tables 8** and **9** present the LCFS-attributed volumes of biomass-based diesel for Scenarios 1 and 2, respectively, during the future period (2017 – 2025). LCFS-attributed values are presented as annual biomass-based diesel volumes used in California attributed to the LCFS, in MGPY, and as percentages of the total annual biomass-based diesel volumes used in California.

Table 7 – Historical LCFS-Attributed Biomass-Based Diesel Volumes and Percentages of Total Volumes, 2007 to 2016,[81] Scenarios 1 and 2

Fuel	Historical LCFS-Attributed Volumes and Percentages of Total Volumes by Year									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Biodiesel (MGPY)	0	0	0	0	0	0.80	34	36	95	135
% of Total Biodiesel	0%	0%	0%	0%	0%	4%	56%	54%	75%	83%
Renewable Diesel (MGPY)	0	0	0	0	0	0.18	96	101	124	226
% of Total Renewable Diesel	0%	0%	0%	0%	0%	2%	82%	89%	75%	91%

79 The estimation of the percentages of biodiesel and renewable attributed to the LCFS for Scenarios 1 and 2 from 2017 - 2025 rely on the volumes of biodiesel and renewable diesel attributed to non-LCFS programs in 2016 for Method III, provided in Tables 1 and 2, respectively.
80 Because historical biodiesel and renewable diesel volumes are based on reported data, these volumes are the same for all scenarios.
81 As described in **Appendix 1**, staff's attribution analysis indicated that there was no biodiesel and renewable diesel usage in California attributed to the LCFS prior to 2012.

Table 8 – Projected Future LCFS-Attributed Biomass-Based Diesel Volumes and Percentages of Total Volumes, 2017 to 2025, Scenario 1

Fuel	Projected Future LCFS-Attributed Volumes and Percentages of Total Volumes by Year								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biodiesel (MGPY)	131	151	151	151	156	156	156	161	161
% of Total Biodiesel	82%	84%	84%	84%	84%	84%	84%	85%	85%
Renewable Diesel (MGPY)	277	297	337	377	477	527	577	577	577
% of Total Renewable Diesel	92%	93%	94%	94%	95%	96%	96%	96%	96%

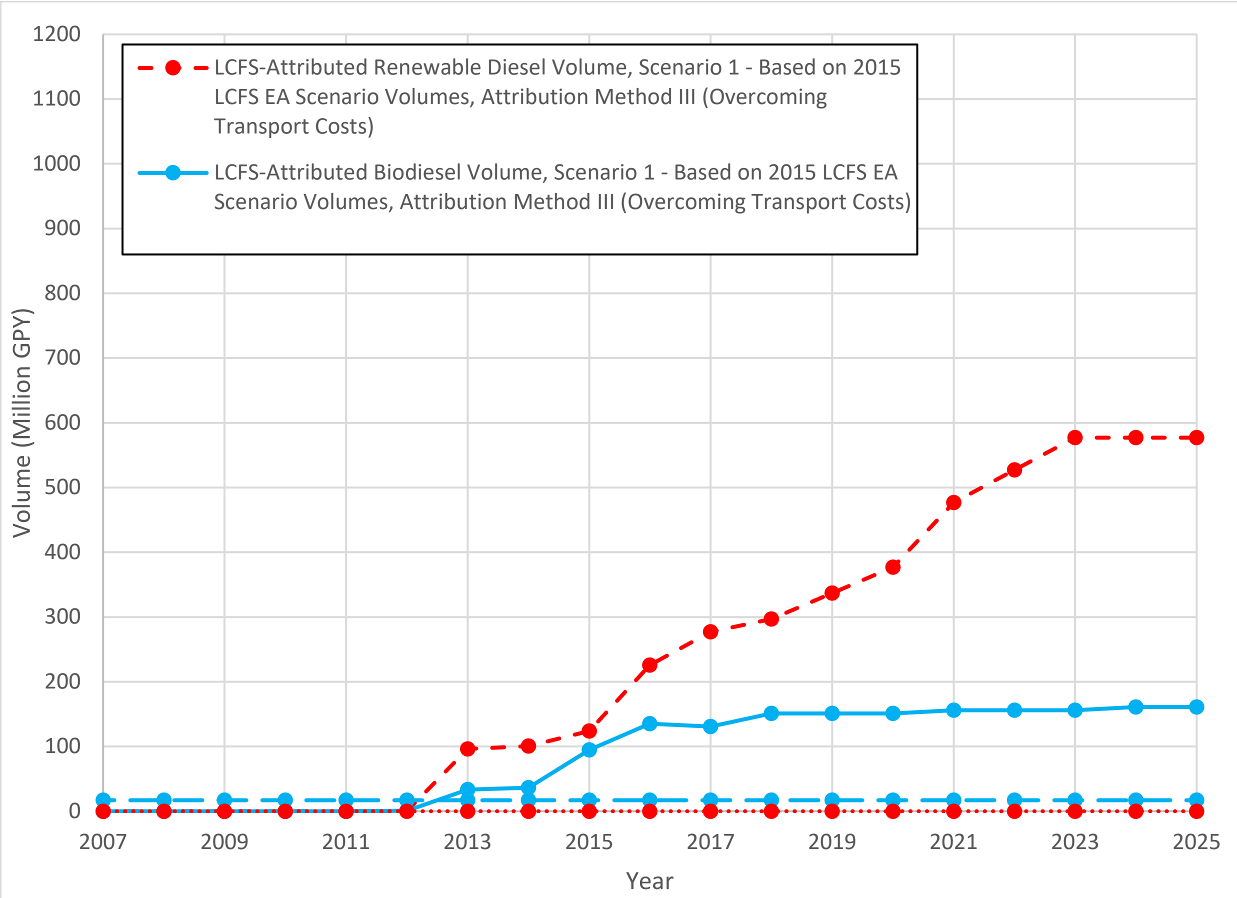
Table 9 – Projected Future LCFS-Attributed Biomass-Based Diesel Volumes and Percentages of Total Volumes, 2017 to 2025, Scenario 2

Fuel	Projected Future LCFS-Attributed Volumes and Percentages of Total Volumes by Year								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biodiesel (MGPY)	141	171	246	321	396	471	471	471	471
% of Total Biodiesel	83%	86%	89%	92%	93%	94%	94%	94%	94%
Renewable Diesel (MGPY)	327	427	527	627	727	827	927	1,027	1,127
% of Total Renewable Diesel	93%	95%	96%	96%	97%	97%	98%	98%	98%

b. Comparison of LCFS-Attributed Biomass-Based Diesel Volumes

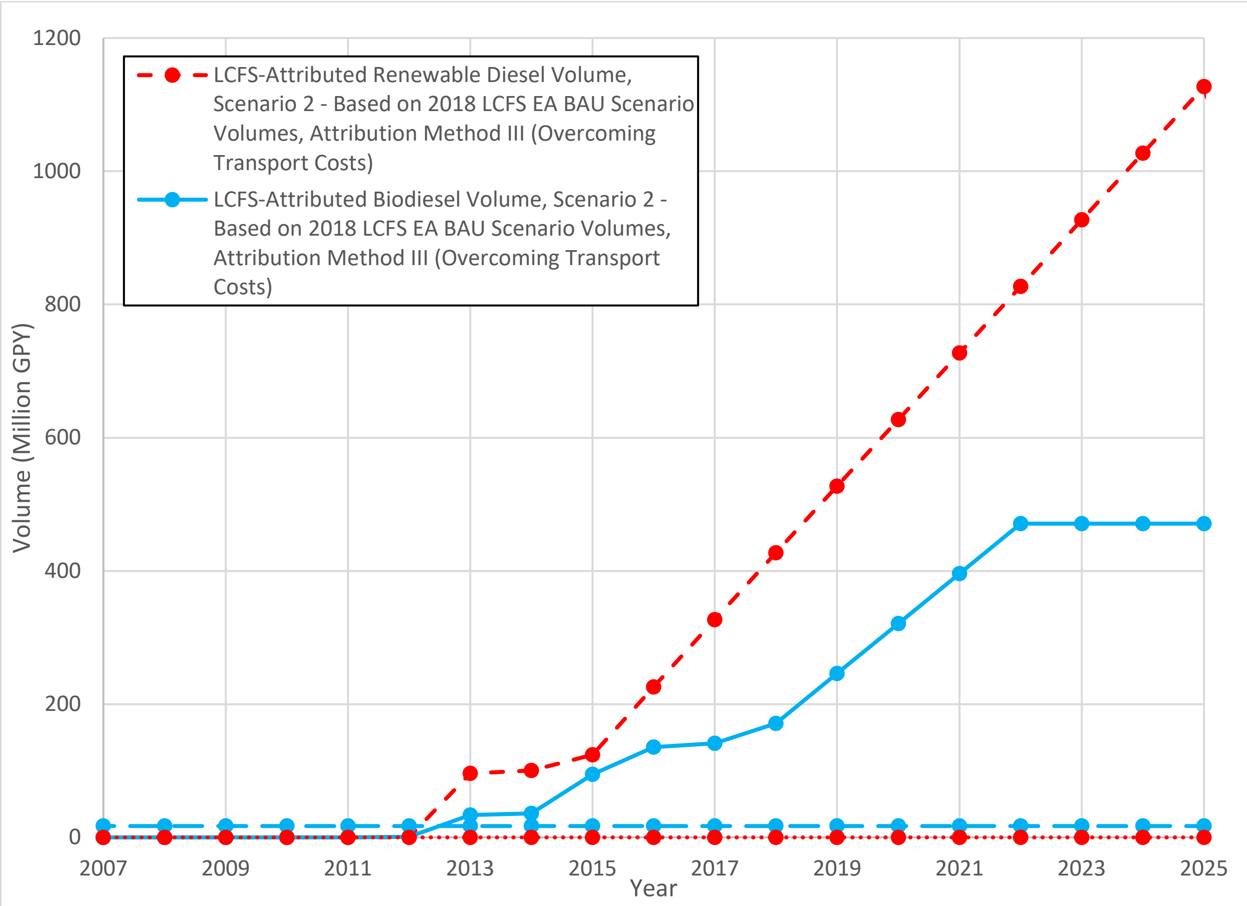
The LCFS-attributed biomass-based diesel volumes from 2007 to 2025 for Scenarios 1 and 2 are shown in **Figures 2** and **3**, respectively. **Figures 2** and **3** also show the total biodiesel and renewable volumes for 2007 as a comparison. **Figures 2** and **3** indicate that the LCFS-attributed biomass-based diesel volume trends are somewhat different for Scenarios 1 and 2. For instance, **Figure 2** (Scenario 1) indicates that the LCFS-attributed renewable diesel usage increases steadily over the time period from 2012 - 2023 and then levels off. LCFS-attributed biodiesel usage also increases steadily, but only from 2012 - 2016, after which it levels off and remains constant through 2025. **Figure 3** (Scenario 2) shows that LCFS-attributed renewable diesel usage increases steadily over the time period from 2012 – 2022, and at a much higher rate than Scenario 1. LCFS-attributed biodiesel usage levels off after 2022.

Figure 2 – LCFS-Attributed Biomass-Based Diesel Volumes for Scenario 1[82]



[82] As described in **Appendix 1**, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012.

Figure 3 – LCFS-Attributed Biomass-based diesel Volumes for Scenario 2[83]



[83] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012.

D. LCFS NOX AND PM EMISSIONS IMPACTS

1. Background on NOx and PM Emissions from Biomass-Based Diesels

The LCFS is part of a suite of CARB, federal, and district rules that, along with overall market trends, are steeply reducing air pollution emissions in California. This discussion focuses on a small part of that overall trendline, looking at ways the LCFS's effects on the fuels market may have caused that overall trend to vary slightly from a no-LCFS baseline. Thus, emissions increases discussed in this document are relative to an overall declining trend, are small relative to total decreases, and do not disrupt that overall trend. The analysis also looks, conservatively, at air pollution effects on a pollutant-by-pollutant basis. It is important to bear in mind that pollutants are actually co-emitted, and that the net public health effect of the LCFS has always been positive, because it produces substantial decreases in PM pollution; the benefits of these decreases outweigh the impacts of any NOx pollution on an overall public health basis.

With regard to this specific analysis: The use of diesel fuel generates diesel exhaust, which is comprised of a large number of pollutants, including NOx and PM. The combustion of biomass-based diesel, either as 100 percent biodiesel, 100 percent renewable diesel, or blended in various mixtures with conventional diesel, results in similar chemical species, including criteria pollutant emissions. However, the level of those emissions is different for biodiesel and renewable diesel compared to conventional diesel. Both biodiesel and renewable diesel generally emit less PM than conventional diesel. However, biodiesel use can emit more NOx than conventional diesel, depending on feedstock saturation level and engine type,[84] while renewable diesel use generally emits less NOx than conventional diesel.[85,86] The emissions levels vary depending on the blend levels,[87] and the engine type in which the fuels are used. The changes in NOx and PM emissions for different blend levels of biodiesel and

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[84] The use of biodiesel in non-NTDEs results in an increase in NOx emissions relative to use of conventional diesel. The use of biodiesel in NTDEs results in no change in NOx emissions relative to use of conventional diesel.

[85] CARB. 2015. Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons. January 2. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf

[86] NOx emissions test data for renewable diesel in NTDEs were not available (Durbin, 2011). Based on test data for biodiesel in NTDEs, staff conservatively assumed use of renewable diesel in NTDEs results in no change in NOx emissions relative to conventional diesel.

[87] Biodiesel blends are named according to the percentage of biodiesel in the blend. For example, B20 biodiesel contains 20 percent biodiesel. Similarly, renewable diesel blends are named according to the percentage of renewable diesel in the blend. For example, R5 renewable diesel contains 5 percent renewable diesel.

renewable diesel relative to conventional diesel are shown in **Tables 10** and **11**, respectively. The values in **Tables 10** and **11** generally represent conservative estimates of NOx and PM emissions changes (i.e., estimates that result in high NOx emissions changes and low PM emissions changes) for biodiesel and renewable diesel relative to conventional diesel.[88]

[88] NOx and PM emissions changes relative to conventional diesel were provided for on-road heavy-duty vehicles. Biodiesel use in on-road light-duty and medium-duty vehicles has been found not to result in changes in NOx emissions relative to conventional diesel. Biodiesel use in heavy-duty non-road engines has been found to result in NOx emissions increases that are lower than the increases for on-road heavy-duty engines and PM emissions decreases that are higher than the decreases for on-road heavy-duty engines. See CARB. 2015. Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons. January 2. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf

Table 10 – Biodiesel NOx and PM Emissions Relative to Conventional Diesel[89]

Engine Type	Biodiesel Saturation Level	NOx Emissions Change Relative to Conventional Diesel, %			PM Emissions Change Relative to Conventional Diesel,[90] %		
		B5	B10	B20	B5	B10	B20
Non-NTDE	Low	1.1%	1.8%	4.0%	-4.7%	-8.9%	-19%
Non-NTDE	High	-0.2%	0.1%	1.5%			
NTDE	Low	0.0%					
NTDE	High	0.0%					

89 CARB. 2015. Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons. January 2. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf (pp. 41-45).

90 PM emissions changes for biodiesel relative to conventional diesel were based on testing using pre-2007 engines without diesel filters. CARB (2015) indicates that, for 2007 and later engines equipped with PM filters, there were no meaningful differences in PM emissions between conventional diesel and biodiesel. However, Durbin (2011) indicates that PM emissions for these engines were essentially at the limit of detection, and the level of efficiency of the diesel particulate factor would have masked any fuel differences. For these reasons, staff believes that PM emissions changes for biodiesel use in pre-2007 engines without diesel particulate filters relative to conventional diesel use was also applicable to 2007 and later engines with diesel filters.

Table 11 – Renewable Diesel NOx and PM Emissions Relative to Conventional Diesel[91,92,93]

Engine Type	NOx Emissions Change Relative to Conventional Diesel,[94] %		PM Emissions Change Relative to Conventional Diesel,[95] %	
	R20	R100	R20	R100
Non-NTDE	-2.9%	-10%	-4.0%	-30%
NTDE	0.0%	0.0%		

The ADF regulation was developed to mitigate potential increases in NOx emissions due to biodiesel use by setting a pollutant control level, which defined a biodiesel blend level above which the use of biodiesel was subject to in-use requirements (e.g., addition of NOx-reducing additives such as di-tert-butyl peroxide). Staff designed the pollutant control level to fully mitigate potential NOx increases due to biodiesel when combined with other offsetting factors (i.e., renewable diesel use and turnover of non-NTDE engines).

NOx is regulated as an ozone precursor, and both CARB and U.S. EPA have set ambient air quality standards for ozone.[96] Many areas of California are currently designated as State or federal ozone non-attainment areas, and are subject to emissions reduction strategies for ozone outlined in the California SIP and air district-

[91] Changes in NOx and PM emissions for renewable diesel relative to conventional diesel are assumed to be linearly related to renewable diesel blend level based on the results of Durbin (2011).
[92] CARB. 2015. Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons. January 2. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf (pp. 44-45).
[93] Durbin et al. 2011. CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California, "Biodiesel Characterization and NOx Mitigation Study," Final Report. October. Available at: https://www.arb.ca.gov/fuels/diesel/altdiesel/20111013_CARB%20Final%20Biodiesel%20Report.pdf. Accessed: August, 2017.
[94] NOx emissions test data for renewable diesel in NTDEs were not available (Durbin, 2011). Based on test data for biodiesel in NTDEs, staff conservatively assumed use of renewable diesel in NTDEs results in no change in NOx emissions relative to conventional diesel.
[95] PM emissions test data for renewable diesel in NTDEs were not available (Durbin, 2011). Similar to biodiesel, staff assumed that PM emissions changes for renewable diesel use relative to conventional diesel use in pre-2007 engines are applicable for estimating PM emissions reductions associated with renewable diesel use in diesel-fueled mobile sources.
[96] CARB. 2016. Ambient Air Quality Standards. May. Available at: https://www.arb.ca.gov/research/aaqs/aaqs2.pdf. Accessed: September, 2017.

specific SIPs.[97,98] In addition to the strategies outlined in the SIPs, CARB and local air districts have developed and implemented strategies, programs and regulations (e.g., CARB Truck and Bus Regulation[99], CARB In-Use Off-Road Diesel-Fueled Fleets Regulation[100], Carl Moyer Program,[101] Goods Movement Emissions Reduction Program,[102] and Lower-Emission School Bus Program[103]) that have resulted in substantial annual reductions in ozone precursors, including NOx emissions.

The results of these regulations and programs are that the overall trend in NOx has been, and is expected to continue to be, strongly downward. **Figure 4** shows that statewide NOx emissions reductions from diesel-fueled mobile sources contribute substantially to overall statewide NOx emissions reductions. This figure also shows that diesel-fueled mobile source NOx emissions are expected to decrease by a factor of four from 2007 to 2025. **Figure 5** provides additional insight into the diesel-fueled mobile-source NOx emissions reductions over this period, indicating that adoption of NTDEs in on-road sources are the driver for diesel-fueled mobile source NOx emissions reductions.

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[97] CARB. 2017. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf. Accessed: September, 2017.

[98] Eight California air districts have prepared a SIP that details air district-specific strategies for coming into compliance with the federal 8-hour ozone standard. These SIPs are available at: https://www.arb.ca.gov/planning/sip/sip.htm

[99] CARB. 2014. Final Regulation Order. Title 13, California Code of Regulations (CCR), Section 2025. Regulation to Reduce Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use Heavy-Duty Diesel-Fueled Vehicles. December 31. Available at: https://www.arb.ca.gov/msprog/onrdiesel/documents/tbfinalreg.pdf. Accessed: September, 2017.

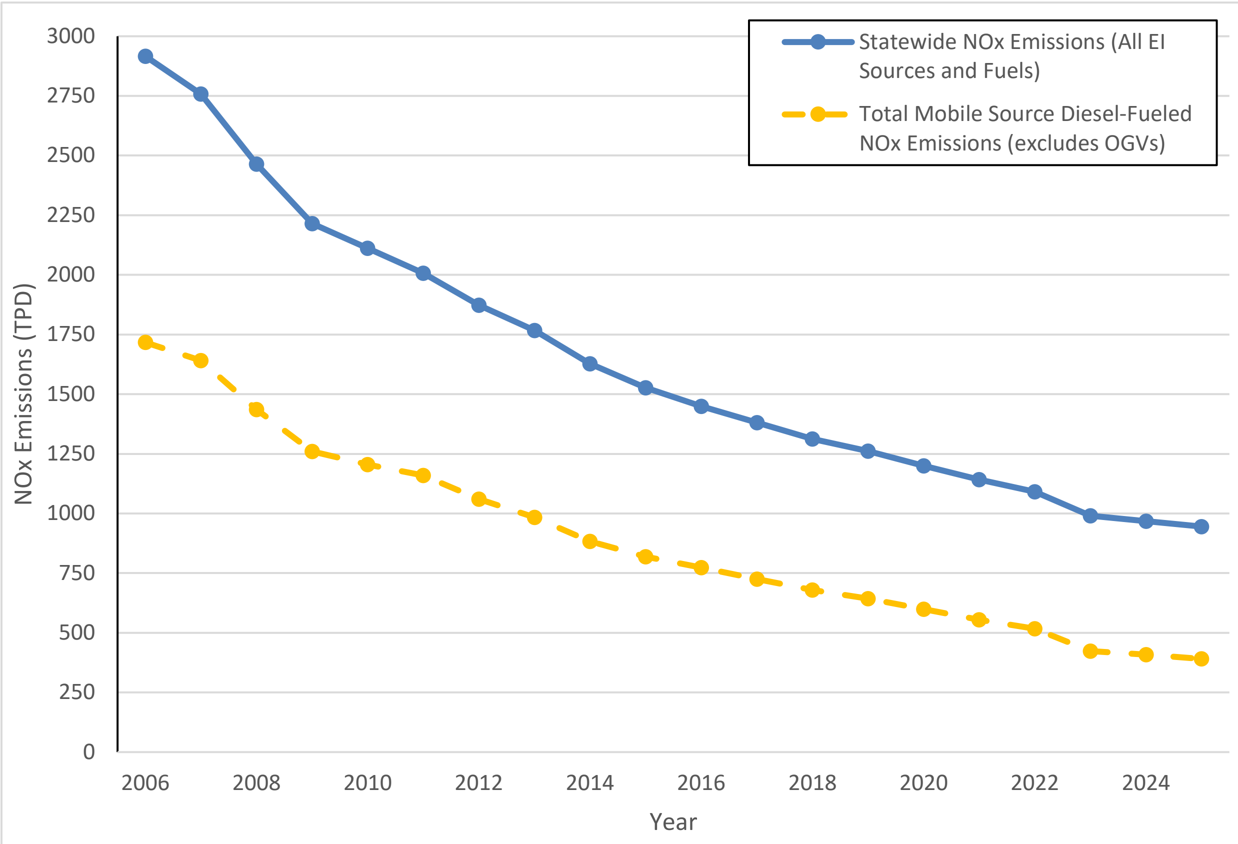
[100] CARB. 2011. Final Regulation Order. Title 13 California Code of Regulations (CCR), section 2449.Regulation for In-Use Off-Road Diesel Vehicles. Available at: https://www.arb.ca.gov/regact/2010/offroadlsi10/finaloffroadreg.pdf. Accessed: September, 2017.

[101] CARB. 2017. The Carl Moyer Program Guidelines, 2017 Revisions, Volume 1: Program Overview, Program Administration, and Project Criteria. May. Available at: https://www.arb.ca.gov/msprog/moyer/april2017_boarditem_proposedmoyerguidelines_vol1.pdf. Accessed: February, 2018.

[102] CARB. 2015. Proposition 1B: Movement Emission Reduction Program. Final 2015 Guidelines for Implementation. June. Available at: https://www.arb.ca.gov/bonds/gmbond/docs/prop_1b_goods_movement_2015_program_guidelines_for_implementation.pdf. Accessed: Febuary, 2018.

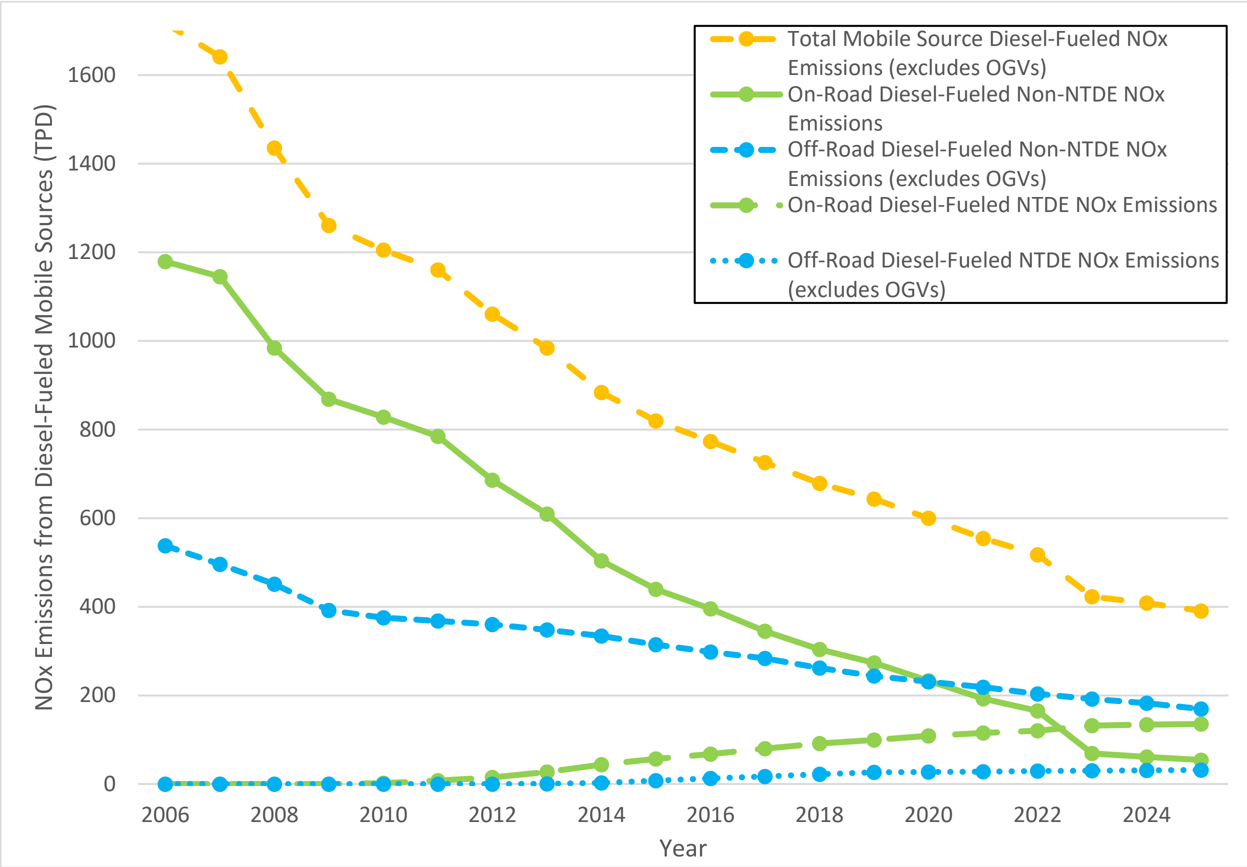
[103] CARB. 2008. Lower-Emission School Bus Program, 2008 Guidelines. April. Available at: https://www.arb.ca.gov/bonds/schoolbus/guidelines/2008lesbp.pdf. Accessed: February, 2018.

Figure 4 – Diesel-Fueled Mobile Source NOx Emissions and Total Statewide NOx Emissions (All Emission Inventory Sources and Fuels)[104]



[104] Annual average daily statewide NOx emissions data are from CARB's California Emissions Projection Analysis Model (CEPAM) developed for the 2016 SIP analysis. Available at: https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php. This inventory treats biomass-based diesel as conventional diesel for emissions estimation purposes.

Figure 5 – NTDE and non-NTDE NOx Emissions from On-Road and Off-Road Diesel-Fueled Mobile Sources (Excludes OGVs)[105]



2. Summary of LCFS NOx and PM Emissions Methodology

Staff estimated LCFS NOx and PM emissions on a year-by-year basis based on:

- The statewide biodiesel and renewable diesel usage volumes attributed to the LCFS that result in NOx and PM changes, expressed as percentages of the total statewide diesel demand;

- The estimated changes in NOx and PM emissions associated with the use of specific blend levels of biodiesel and renewable diesel relative to conventional diesel; and

[105] Annual average daily NOx emissions data for on-road and off-road diesel-fueled mobile sources are from CARB's CEPAM emissions inventory. Available at: https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php. This inventory treats biomass-based diesel as conventional diesel for emissions estimation purposes.

- Annual-average daily NOx and PM emissions for diesel-fueled mobile sources in each California air basin.

A detailed description of the methodology used to estimate changes in NOx and PM emissions resulting from LCFS-attributed biomass-based diesel use relative to conventional diesel use is provided in **Appendix 5**.

Staff analyzed NOx and PM emissions due to biomass-based diesel use that could be attributed to implementation of the original and modified LCFS regulations and compared these NOx and PM emissions to a baseline that reflects conditions existing at the time environmental analysis of the original LCFS regulation was commenced.

Staff evaluated the impacts of LCFS NOx and PM emissions due to biomass-based diesel use for the four scenarios shown in **Table 3** based on based on the significance criteria in Appendix G of the CEQA Guidelines.[106] The results for Scenarios 1 and 2, which are based on the method that attributes the most NOx emissions to the LCFS (Method III),[107] are presented below.

3. LCFS NOx and PM Emissions Impacts

a. LCFS NOx Emissions Impacts

Figures 6 and **7** show LCFS NOx emissions for biodiesel and renewable diesel separately as well as the net LCFS NOx emissions for biomass-based diesel for each year from 2007 - 2025 for Scenarios 1 and 2, respectively.[108] **Figures 6** and **7** indicate that historical biomass-based diesel use attributed to the LCFS for both scenarios resulted in three years (2012, 2015, and 2016) when NOx emissions increased relative to use of conventional diesel. For Scenario 1 (based on 2015 LCFS EA scenario volumes), **Figure 6** shows that LCFS NOx emissions reductions due to renewable diesel exceeded LCFS NOx emissions increases due to biodiesel for all other years in which these emissions impacts occur, providing a NOx emissions benefit during these years.

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[106] California Code of Regulations (CCR). 2017. Title 14, Appendix G. Environmental Checklist Form. https://govt.westlaw.com/calregs/Document/I1D6750F63775483A8F7861C335CD6854?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)

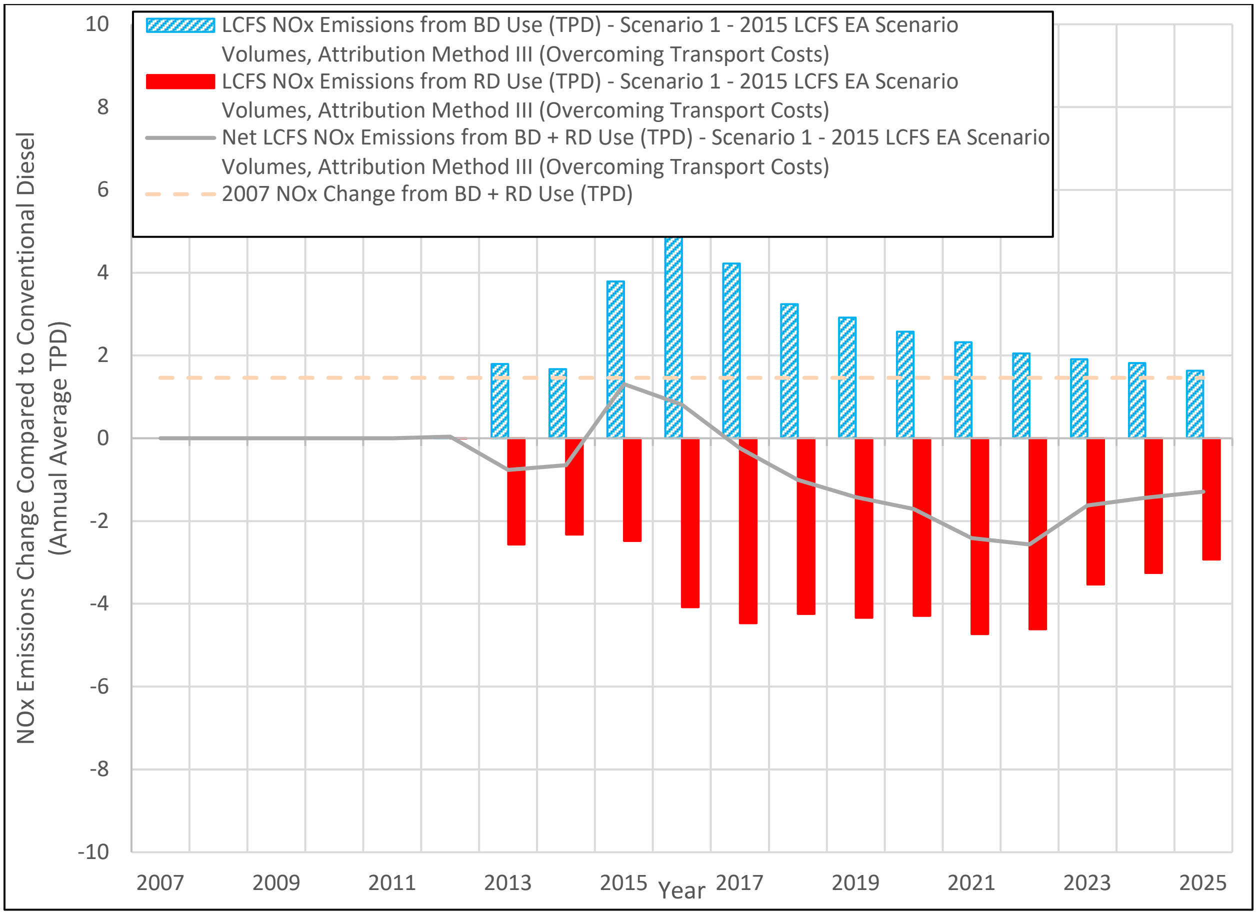
[107] Cumulative historical LCFS-attributed NOx emissions increases based on Attribution Method III are greater than LCFS-attributed NOx emissions increases based on Attribution Method II. However, Attribution Method III results in lower LCFS NOx emissions for 2013 and 2014 than Attribution Method II.

[108] LCFS NOx emissions from biodiesel are inclusive of other offsetting factors, including adoption of NTDE vehicles and ADF regulation in-use requirements.

For Scenario 2 (based on 2018 LCFS EA BAU scenario volumes), **Figure 7** shows that LCFS NOx emissions due to renewable diesel may not be sufficient to offset LCFS NOx emissions due to biodiesel for all future years if the ADF regulation in-use requirements are not in effect, resulting in a net NOx emissions increase for one additional year (2023) in Scenario 2.[109] However, cumulative LCFS NOx emissions over the period 2007 – 2025 show a NOx emissions reduction for both scenarios (4,700 tons reduction for Scenario 1 and 8,600 tons reduction for Scenario 2). Net annual LCFS NOx emissions are also less than the 2007 NOx emissions increase from biomass-based diesel use for both scenarios.

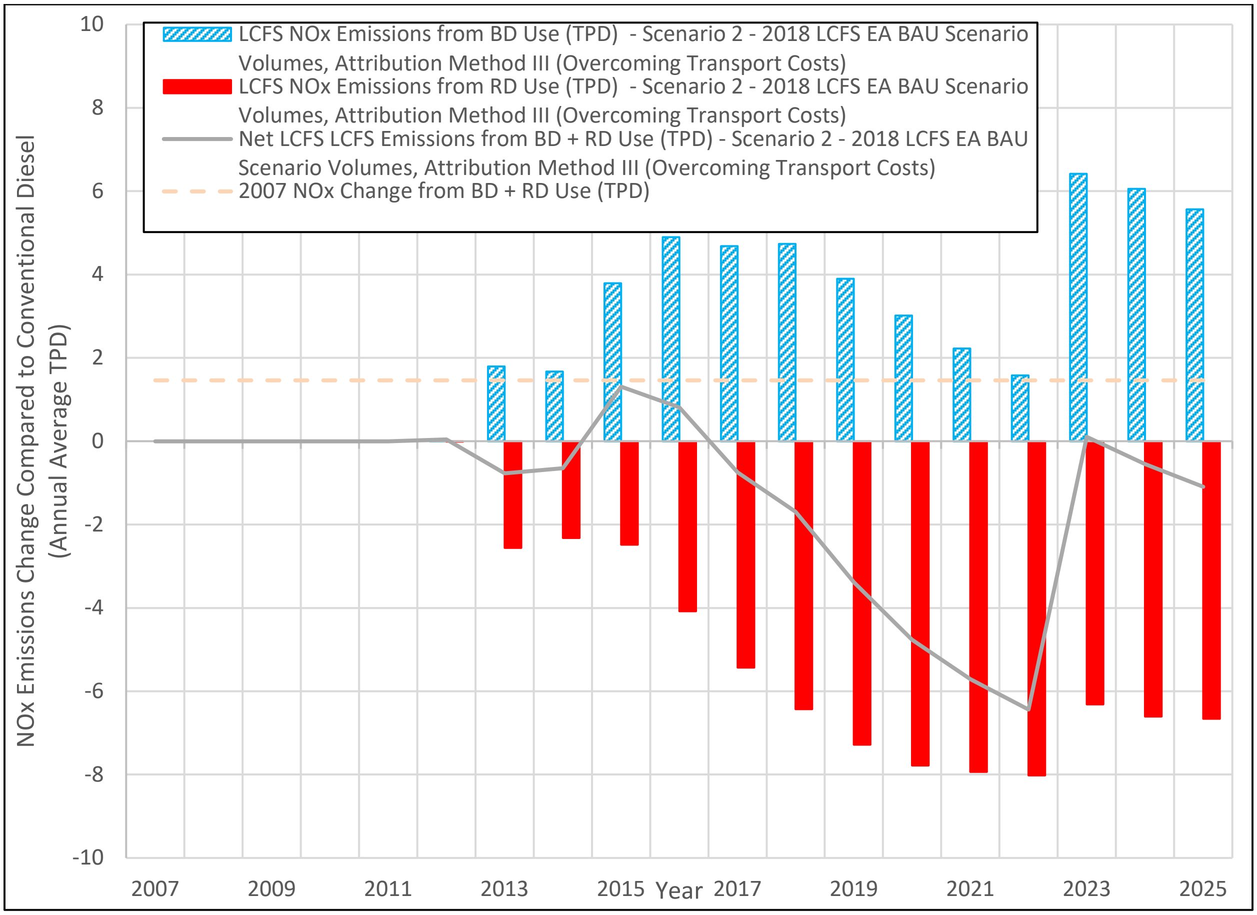
[109] CARB's analysis of projected biodiesel and renewable diesel consumption in California indicated LCFS NOx emissions beyond 2025 that could result in a potentially significant air quality impact. These LCFS NOx emissions, which were analyzed through 2030, would be mitigated by the proposed amendment to the ADF regulation described in Section D.4.b.

Figure 6 – LCFS-attributed Biomass-Based Diesel NOx Emissions for Scenario 1 - 2015 LCFS EA Scenario Volumes, Attribution Method III (Overcoming Transport Costs)[110]



[110] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in NOx emissions from biomass-based diesel use to the LCFS prior to 2012.

Figure 7 – LCFS-attributed Biomass-Based Diesel NOx Emissions for Scenario 2 - 2018 LCFS EA BAU Scenario Volumes, Attribution Method III (Overcoming Transport Costs)[111]



Staff evaluated the impacts of LCFS NOx emissions based on the significance criteria in Appendix G of the CEQA Guidelines.[112] Based on these criteria, LCFS NOx emissions would have a significant impact if they:

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[111] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in NOx emissions from biomass-based diesel use to the LCFS prior to 2012.
[112] California Code of Regulations (CCR). 2017. Title 14, Appendix G. Environmental Checklist Form. https://govt.westlaw.com/calregs/Document/I1D6750F63775483A8F7861C335CD6854?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)

1. Violate any air quality standard or contribute substantially to an existing or projected air quality violation;

2. Conflict with or obstruct implementation of the applicable air quality plan;

3. Result in a cumulatively considerable net increase of any criteria air pollutant for which the project region is non-attainment under an applicable national or California ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors);[113] or

4. Expose sensitive receptors to substantial pollutant concentrations.[114]

Staff's evaluation of these significance criteria is presented in Sections D.3.a.i - D.3.a.iii. For the purposes of CEQA compliance, and based on CARB's expert judgment, staff determined that LCFS NOx emissions associated with biomass-based diesel could have resulted in a potentially significant impact on long-term air quality in State- and federally-designated ozone non-attainment areas in California in certain historical years (2012, 2015, and 2016) and could result in a potentially significant impact from 2023 onward under the most conservative scenario.[115]

i. Impact of LCFS NOx Emissions on Meeting Air Quality Standards

NOx is regulated as an ozone precursor, and a subset of NOx (NO_2) is regulated as a criteria pollutant. Both CARB and U.S. EPA have set ambient air quality standards for ozone and NO_2 concentrations.[116] Many areas of California are currently designated as State and federal ozone non-attainment areas, and are subject to emissions reduction strategies for ozone, outlined in the California State Implementation Plan (SIP).[117]

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113 NOx is an ozone precursor. Most air districts in California have set quantitative CEQA thresholds for ozone precursors, including NOx emissions, to evaluate significance of emissions.

114 Health impacts of LCFS-attributed biomass-based diesel use are discussed in Section E.

115 Scenario 2, based on biomass-based diesel volumes from the 2018 LCFS EA BAU scenario and attribution of biomass-based diesel volumes to the LCFS using Method III (overcoming transport costs), results in the most conservative (highest) cumulative LCFS NOx emissions. In determining the most conservative scenario, staff estimated cumulative LCFS NOx emissions as the sum of LCFS-attributed NOx emissions increases only.

116 CARB. 2016. Ambient Air Quality Standards. May. Available at: https://www.arb.ca.gov/research/aaqs/aaqs2.pdf. Accessed: September, 2017.

117 CARB. 2017. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf. Accessed: September, 2017.

Currently, there are no State- or federally-designated NO_2 non-attainment areas in California.[118,119]

Staff evaluated the potential for LCFS-attributed biomass-based diesel NOx emissions to cause or substantially contribute to a potential violation of the State or Federal NO_2 or ozone standards by comparing LCFS NOx emissions to total statewide NOx emissions for the period from 2007 - 2025,[120] as shown in **Figure 8**. **Figure 8** indicates that maximum LCFS-attributed biomass-based diesel NOx emissions are less than 0.1 percent of total statewide NOx emissions for both scenarios. Assuming that NO_2 and ozone concentrations increase proportionally with increases in NOx emissions,[121] staff estimated that statewide NO_2 and ozone concentrations would increase by less than 0.1 percent statewide for both scenarios in any given year. **Figure 8** also shows LCFS NOx emissions that could result in statewide ozone concentration reductions under Scenarios 1 and 2 for a number of years.[122]

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[118] CARB. 2017. Area Designations for State Ambient Air Quality Standards – Nitrogen Dioxide. Available at: https://www.arb.ca.gov/desig/adm/2015/state_no2.pdf. Accessed: September, 2017.
[119] CARB. 2015. Area Designations for National Ambient Air Quality Standards – Nitrogen Dioxide. Available at: https://www.arb.ca.gov/desig/adm/2015/fed_no2.pdf. Accessed: September, 2017.
[120] Total statewide annual average daily NOx emissions data are from CARB's CEPAM emissions inventory. Available at: https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php. Statewide total NOx emissions are shown in Figure 9.
[121] The relationship between NOx emissions and ozone concentrations is complex, and depends on several other variables, including VOC concentrations, solar radiation, and temperature. For the purposes of this qualitative analysis, staff assumed that ozone concentrations would increase with NOx emissions increases, and would scale at less than a one-to-one ratio (e.g., ozone concentrations would increase at a lower rate than NOx emissions increases). Staff also notes that, under certain conditions (i.e., relatively low VOC/NOx ratios), ozone concentrations can increase with decreasing NOx emissions. See:

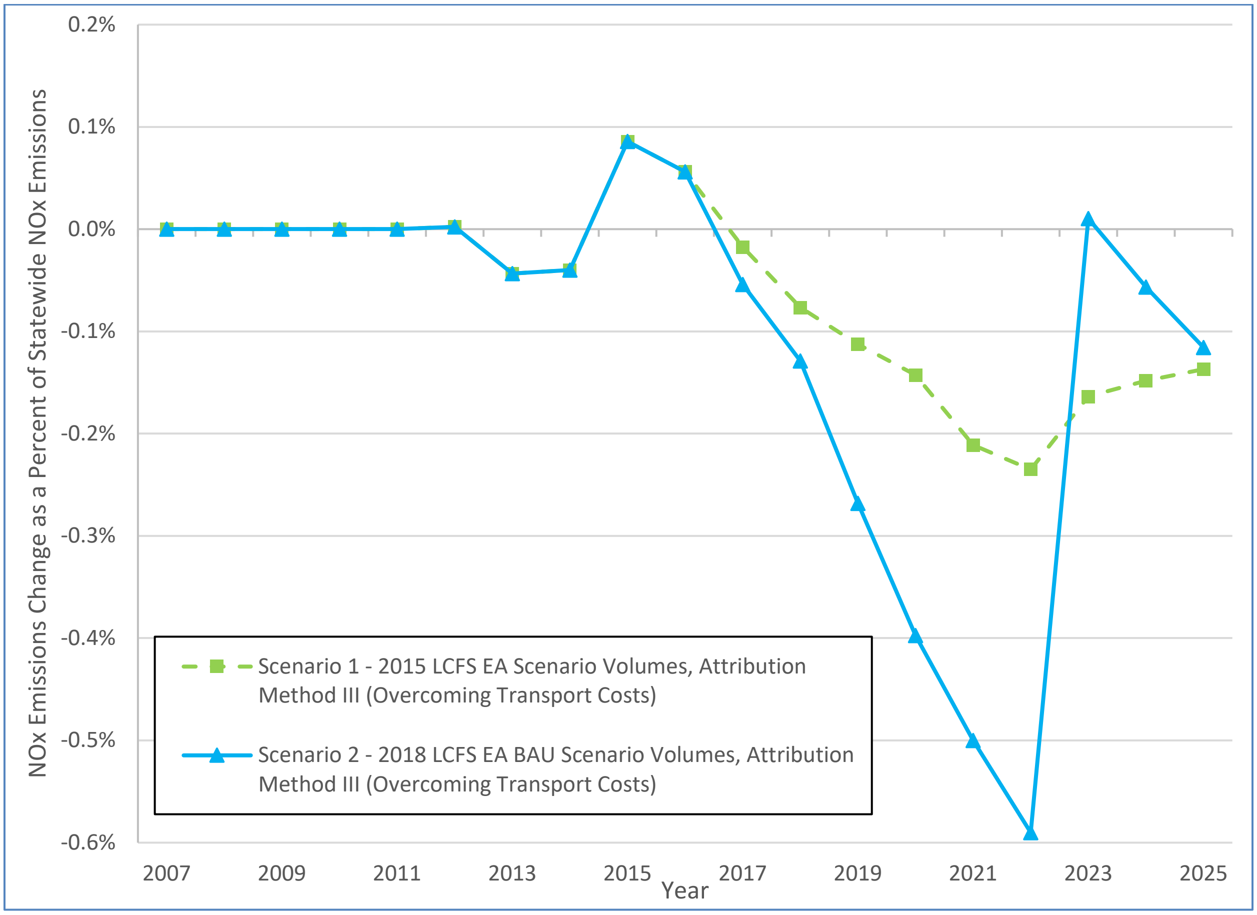
National Research Council. 1991. Rethinking the Ozone Problem in Urban and Regional Air Pollution. Washington, DC. The National Academies Press. pp. 163-168. Available at: https://www.nap.edu/catalog/1889/rethinking-the-ozone-problem-in-urban-and-regional-air-pollution. Accessed: September, 2017.

Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. pp. 14-16. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

[122] Under certain conditions (i.e., relatively low VOC to NOx concentration ratios), NOx emissions reductions result in increased ozone concentrations. See Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

Due to the likely broad geographical distribution of LCFS-attributed biomass-based diesel NOx emissions, staff anticipates that potential changes in NO_2 and ozone concentrations would likely occur over large geographical areas instead of spiking in certain areas.

Figure 8 – LCFS-attributed Biomass-Based Diesel NOx Emissions as a Percent of Total Statewide NOx Emissions, Scenarios 1 and 2[123]



[123] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in NOx emissions from biomass-based diesel use to the LCFS prior to 2012.

ii. Impact of LCFS NOx Emissions on Implementation of the Applicable Air Quality Plan

Assuming that ozone concentrations are proportional to NOx emissions,[124] staff evaluated the potential for LCFS-attributed biomass-based diesel NOx emissions to obstruct or delay attainment of the State and federal ozone standards by comparing LCFS-attributed biomass-based diesel NOx emissions to statewide NOx emissions reductions.[125] As indicated in **Figure 9**, LCFS-attributed biomass-based diesel NOx emissions could slow statewide NOx emissions reductions in certain years, up to a maximum of approximately two percent for both Scenarios 1 and 2. **Figure 9** also indicates that LCFS-attributed biomass-based diesel NOx could increase the rate of statewide NOx emission reductions in other years, by up to six to 12 percent for Scenarios 1 and 2, respectively.[126]

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[124] The relationship between NOx emissions and ozone concentrations is complex, and depends on several other variables, including VOC concentrations, solar radiation, and temperature. For the purposes of this analysis, staff assumed that ozone concentrations would increase with NOx emissions increases, and would scale at less than a one-to-one ratio (e.g., ozone concentrations would increase at a lower rate than NOx emissions increases). Staff also notes that, under certain conditions (i.e., relatively low VOC/NOx concentration ratios), ozone concentrations can increase with decreasing NOx emissions. See:

National Research Council. 1991. Rethinking the Ozone Problem in Urban and Regional Air Pollution. Washington, DC. The National Academies Press. pp. 163-168. Available at: https://www.nap.edu/catalog/1889/rethinking-the-ozone-problem-in-urban-and-regional-air-pollution. Accessed: September, 2017.

Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. pp. 14-16. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

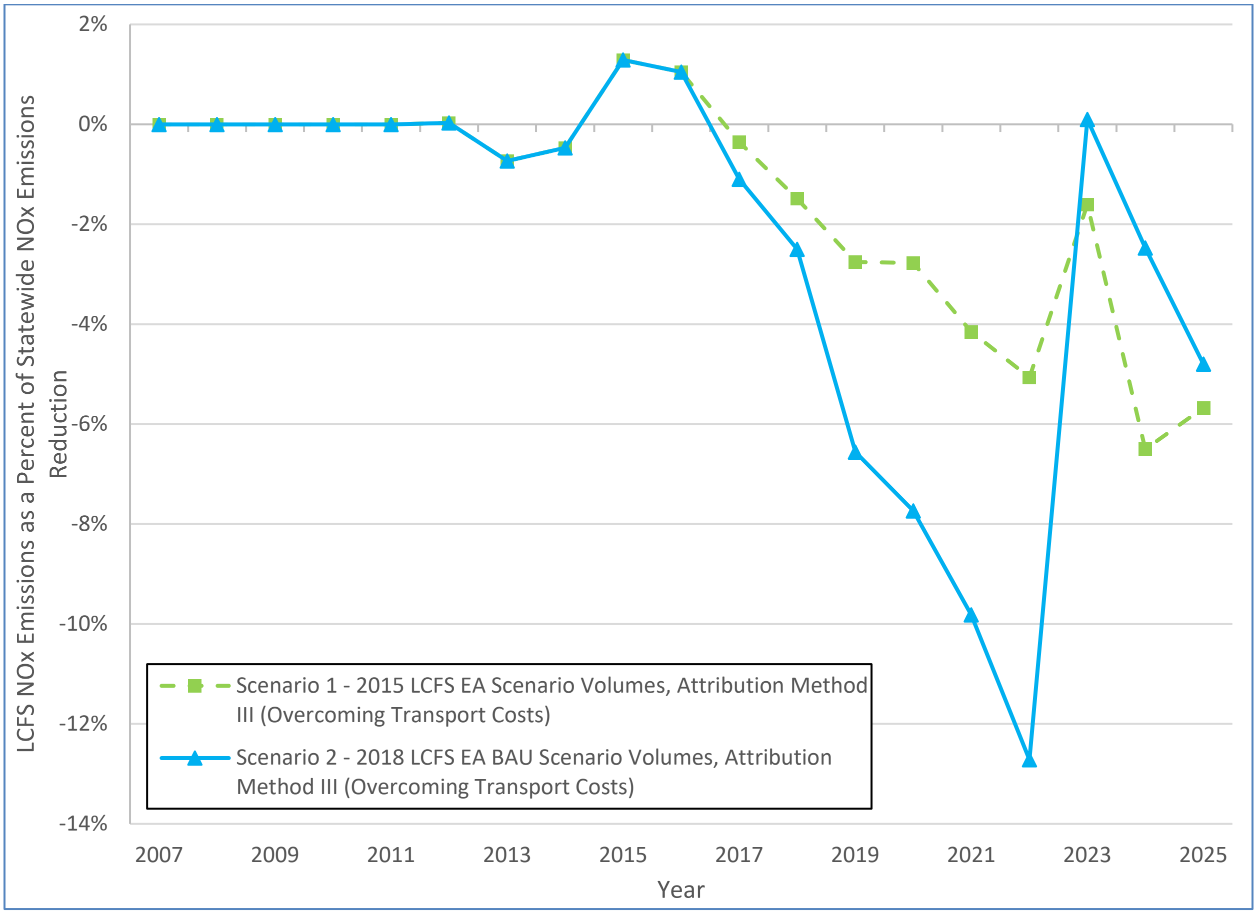
[125] Total statewide annual average daily NOx emissions reductions were estimated as the difference between statewide annual average daily NOx emissions for consecutive years.

[126] Staff notes that, under certain conditions (i.e., relatively low VOC/NOx concentration ratios), ozone concentrations can increase with decreasing NOx emissions. See:

National Research Council. 1991. Rethinking the Ozone Problem in Urban and Regional Air Pollution. Washington, DC. The National Academies Press. pp. 163-168. Available at: https://www.nap.edu/catalog/1889/rethinking-the-ozone-problem-in-urban-and-regional-air-pollution. Accessed: September, 2017.

Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. pp. 14-16. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

Figure 9 – LCFS-attributed Biomass-Based Diesel NOx Emissions as a Percent of Total Statewide NOx Emissions Reductions, Scenarios 1 and 2[127]



Because non-attainment areas are defined over much smaller geographical areas (i.e., by air basin or partial air basin as opposed to by state), staff also attempted to evaluate the potential impacts of LCFS NOx emissions by air basin. CARB's 2016 State Strategy for the State Implementation Plan provides ozone attainment dates for each non-attainment area from years 2015 to 2031.[128] Cumulative LCFS NOx emissions over the period 2007 – 2025 show a NOx emissions reduction for both scenarios (4,700 tons reduction for Scenario 1 and 8,600 tons reduction for Scenario 2). Additionally, LCFS NOx emissions, including the ADF amendments, in 2031 are expected to be reduced compared to the BAU scenario, therefore, LCFS NOx emissions would likely not

[127] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in NOx emissions from biomass-based diesel use to the LCFS prior to 2012.
[128] CARB. 2016. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf. Accessed: July, 2017.

contribute to obstruction or delay in meeting ozone standards for non-attainment areas with compliance dates closer to 2031 for either scenario.

For non-attainment areas with attainment dates prior to 2031, staff evaluated the potential for LCFS NOx emissions to obstruct or delay attainment of the State and federal ozone standards by estimating LCFS-attributed biomass-based diesel NOx emissions within each air basin as a percent of air basin-wide NOx emissions reductions for years when LCFS-attributed biomass-based diesel emissions were greater than zero (i.e., when there were NOx emissions increases due to LCFS-attributed biomass-based diesel use relative to conventional diesel use). These values represent the percentage of the total NOx emissions reduction occurring in each air basin that would be reduced by LCFS-attributed biomass-based diesel emissions within each air basin in a given year. The results of this analysis are presented in **Tables 12** and **13** for Scenarios 1 and 2, respectively. **Tables 12** and **13** indicate that increases in air basin LCFS-attributed biomass-based diesel NOx emissions are three percent or less of the total NOx emissions reduction in the given air basin for any individual year. **Tables 12** and **13** do not reflect LCFS-attributed biomass-based diesel NOx emissions less than zero (i.e., result in a NOx emissions decrease relative to conventional diesel) that occur in all other years during the period 2012 – 2025. These LCFS-attributed biomass-based diesel NOx emissions would further reduce total NOx emissions within each air basin.

Table 12 – LCFS-attributed Biomass-based Diesel NOx Emissions for Scenario 1 as a Percent of Total NOx Emissions Reductions in each Air Basin – 2012, 2015, and 2016[129]

Air Basin	Federal 8-hr Ozone Non-Attainment Area(s)[130]	Attainment Dates[131,132]	LCFS NOx Emissions as a Percent of Total NOx Emissions Reduction (%)		
			2012	2015	2016
Great Basin Valleys	None	-	>0%	1%	1%
Lake County	None	-	>0%	2%	1%
Lake Tahoe	None	-	>0%	1%	1%
Mojave Desert	Eastern Kern, Western Mojave Desert	2017, 2026	>0%	3%	2%
Mountain Counties	Mariposa, Western Nevada County	2017	>0%	2%	2%
North Central Coast	None	-	>0%	1%	1%
North Coast	None	-	>0%	1%	1%
Northeast Plateau	None	-	>0%	2%	1%
Sacramento Valley	Butte County, Sacramento Metro	2015, 2026	>0%	1%	1%
Salton Sea	Imperial County, Coachella Valley	2017, 2026	>0%	2%	2%
San Diego	San Diego County	2017	>0%	1%	1%
San Francisco Bay Area	San Francisco Bay Area	2015	>0%	1.%	1%
San Joaquin Valley	San Joaquin Valley	2031	>0%	1%	1%
South Central Coast	Eastern San Luis Obispo, Ventura County	2015, 2020	>0%	1%	1%
South Coast	South Coast Air Basin	2031	>0%	1%	1%

129 LCFS-attributed biomass-based diesel NOx emissions as a percent of total NOx emissions in each air basin for Scenario 1 provided only for years when LCFS NOx emissions are greater than zero (years 2012, 2015, and 2016).
130 CARB. 2015. Area Designations for National Ambient Air Quality Standards – 8-hour Ozone. December. Available at: https://www.arb.ca.gov/desig/adm/2015/fed_o3.pdf. Accessed: July, 2017.
131 Attainment dates provided for ozone non-attainment areas within each air basin based on the federal 8-hour ozone standard. CARB. 2016. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf (p. 21).
132 Non-attainment areas with a 2015 attainment date are considered marginal non-attainment areas. These areas have already met the 75 ppb 8-hour ozone standard and have no further SIP requirements.

Table 13 – LCFS NOx Emissions for Scenario 2 as a Percent of Total NOx Emissions Reductions in each Air Basin – 2012, 2015, 2016, and 2023[133]

Air Basin	Federal 8-hr Ozone Non-Attainment Area(s)[134]	Attainment Dates[135,136]	LCFS NOx Emissions as a Percent of Total NOx Emissions Reduction (%)			
			2012	2015	2016	2023
Great Basin Valleys	None	-	>0%	1%	1%	>0%
Lake County	None	-	>0%	2%	1%	>0%
Lake Tahoe	None	-	>0%	1%	1%	>0%
Mojave Desert	Eastern Kern, Western Mojave Desert	2017, 2026	>0%	3%	2%	>0%
Mountain Counties	Mariposa, Western Nevada County	2017	>0%	2%	2%	>0%
North Central Coast	None	-	>0%	1%	1%	>0%
North Coast	None	-	>0%	1%	1%	>0%
Northeast Plateau	None	-	>0%	2%	1%	>0%
Sacramento Valley	Butte County, Sacramento Metro	2015, 2026	>0%	1%	1%	>0%
Salton Sea	Imperial County, Coachella Valley	2017, 2026	>0%	2%	2%	>0%
San Diego	San Diego County	2017	>0%	1%	1%	>0%
San Francisco Bay Area	San Francisco Bay Area	2015	>0%	1.%	1%	>0%
San Joaquin Valley	San Joaquin Valley	2031	>0%	1%	1%	>0%
South Central Coast	Eastern San Luis Obispo, Ventura County	2015, 2020	>0%	1%	1%	>0%
South Coast	South Coast Air Basin	2031	>0%	1%	1%	>0%

iii. Comparison of LCFS-attributed Biomass-based Diesel NOx Emissions to Quantitative Emissions Thresholds

133 LCFS-attributed biomass-based diesel NOx emissions as a percent of total NOx emissions in each air basin for Scenario 2 provided for years when NOx emissions due to biodiesel and renewable diesel use attributed to the LCFS increase relative to conventional diesel use (years 2012, 2015, 2016, 2017, 2023, 2024, and 2025).

134 CARB. 2015. Area Designations for National Ambient Air Quality Standards – 8-hour Ozone. December. Available at: https://www.arb.ca.gov/desig/adm/2015/fed_o3.pdf. Accessed: July, 2017

135 Attainment dates provided for ozone non-attainment areas within each air basin based on the federal 8-hour ozone standard. CARB. 2016. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf (p. 21).

136 Non-attainment areas with a 2015 attainment date are considered marginal non-attainment areas. These areas have already met the 75 ppb 8-hour ozone standard and have no further SIP requirements.

CEQA processes typically evaluate local impacts of land use projects that extend over limited geographical areas (e.g., construction of a multi-unit residential complex or construction or modification of an industrial facility). Accordingly, most California Air Pollution Control Districts and Air Quality Management Districts, collectively referred to as “air districts”, have published quantitative thresholds for evaluation of criteria pollutant emissions, including NOx emissions, for such projects subject to CEQA. However, there are no similar quantitative thresholds available to evaluate criteria pollutant emissions from statewide projects, including statewide LCFS NOx emissions. In order to further evaluate the statewide LCFS-attributed biomass-based diesel NOx emissions shown in **Figures 6** and **7**, staff estimated the LCFS-attributed biomass-based diesel NOx emissions in each air district for Scenarios 1 and 2 and compared them to air district-specific CEQA significance thresholds for operational NOx emissions. Although CARB does not believe that the comparison of LCFS-attributed biomass-based diesel NOx emissions in each air district to air district-specific operational NOx emissions thresholds is an appropriate metric for determining significance of a statewide program, staff considered these comparisons in the significance evaluation for LCFS-attributed biomass-based diesel NOx emissions. **Figure 10** shows the LCFS-attributed biomass-based diesel NOx emissions for each air district where LCFS NOx emissions exceeded the air district-specific operational NOx emissions threshold for Scenarios 1 and 2. This figure indicates that LCFS-attributed biomass-based diesel NOx emissions exceed air district operational NOx thresholds in multiple air districts for multiple years in both scenarios. [137] Again, these district

[137] Operational NOx emissions significance thresholds are based on the following sources:

Bay Area Air Quality Management District. 2017. California Environmental Quality Act Air Quality Guidelines. May. Available at: http://www.baaqmd.gov/~/media/files/planning-and-research/ceqa/ceqa_guidelines_may2017-pdf.pdf?la=en. Accessed: August, 2017.

Butte County Air Quality Management District. 2014. CEQA Air Quality Handbook. October 23. Available at: https://bcaqmd.org/wp-content/uploads/CEQA-Handbook-Appendices-2014.pdf. Accessed: August, 2017.

Feather River Air Quality Management District. 2010. Indirect Source Review Guidelines. June 7. Available at: https://www.fraqmd.org/files/8c3d336a1/FINAL+version+ISR+Amendments.pdf. Accessed: August, 2017.

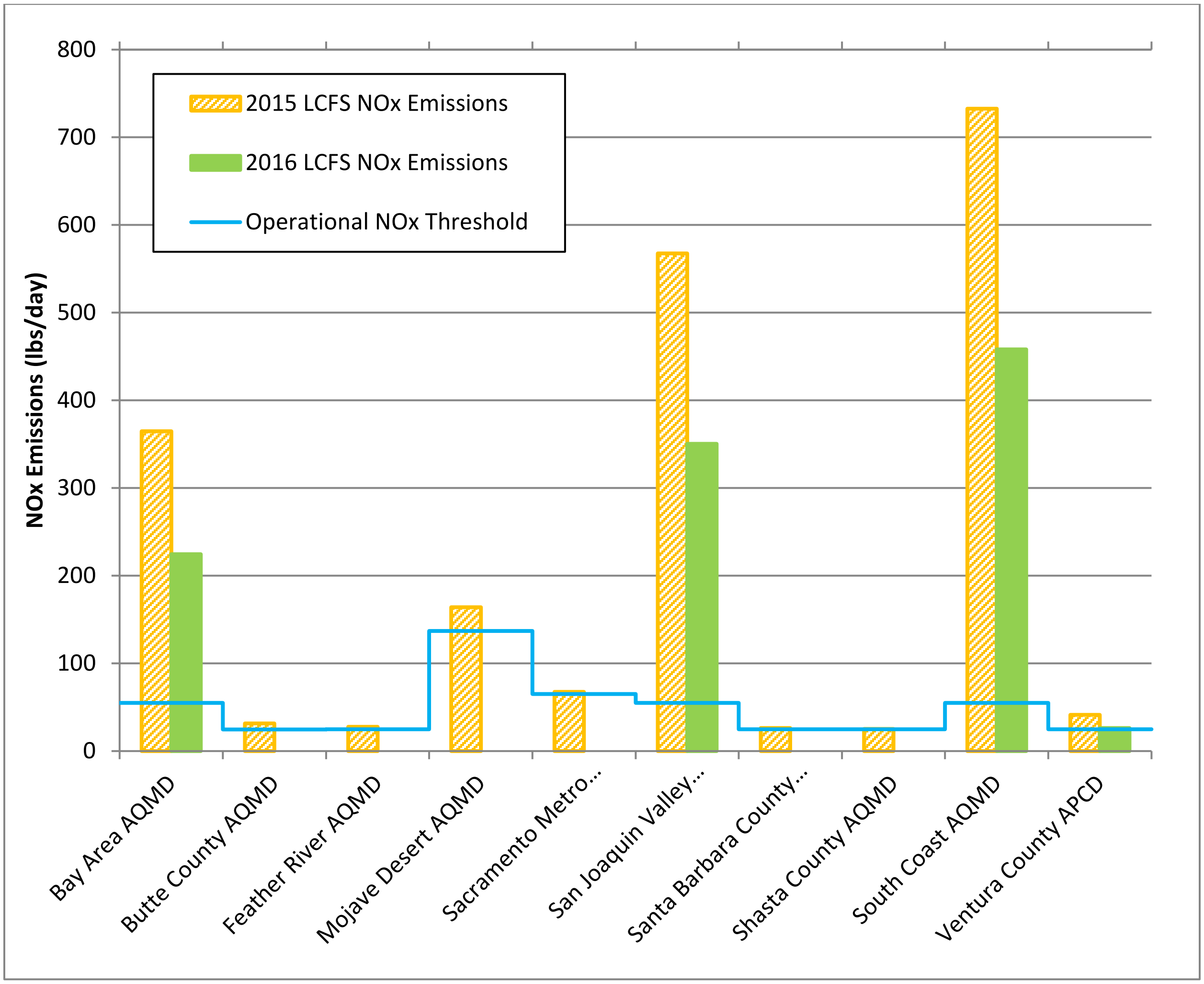
Sacramento Metropolitan Air Quality Management District. 2015. SMAQMD Thresholds of Significance Table. Available at: http://www.airquality.org/LandUseTransportation/Documents/CH2ThresholdsTable5-2015.pdf. Accessed: August, 2017.

San Joaquin Valley Air Pollution Control District. 2015. Air Quality Thresholds of Significance – Criteria Pollutants. Available at: http://www.valleyair.org/transportation/0714-GAMAQI-Criteria-Pollutant-Thresholds-of-Significance.pdf. Accessed: August, 2017.

County of Santa Barbara Planning and Development. 2015. Environmental Thresholds and Guidelines Manual. July. Available at: http://www.sbcountyplanning.org/permitting/ldpp/auth_reg/documents/Environmental%20Thresholds%20October%202008%20(Amended%20July%202015).pdf. Accessed: August, 2017.

thresholds are designed for individual permitting projects at individual stationary sources; it is not surprising that a statewide regulation affecting millions of vehicles and their emissions could exceed these thresholds overall – it is an apples and oranges comparison provided for illustrative purposes. CARB believes that regional and statewide impacts discussed elsewhere in this document provide a far better basis for comparison.

Figure 10 – Comparison of LCFS-attributed Biomass-based Diesel NOx Emissions to Air District CEQA Operational NOx Thresholds, Scenarios 1 and 2



South Coast Air Quality Management District. 2015. SCAQMD Air Quality Significance Thresholds. March. Available at: http://www.aqmd.gov/docs/default-source/ceqa/handbook/scaqmd-air-quality-significance-thresholds.pdf?sfvrsn=2. Accessed: August, 2015.
Ventura County Air Pollution Control District. 2003. Ventura County Air Quality Assessment Guidelines. October. Available at: http://www.vcapcd.org/pubs/Planning/VCAQGuidelines.pdf. Accessed: August, 2017.

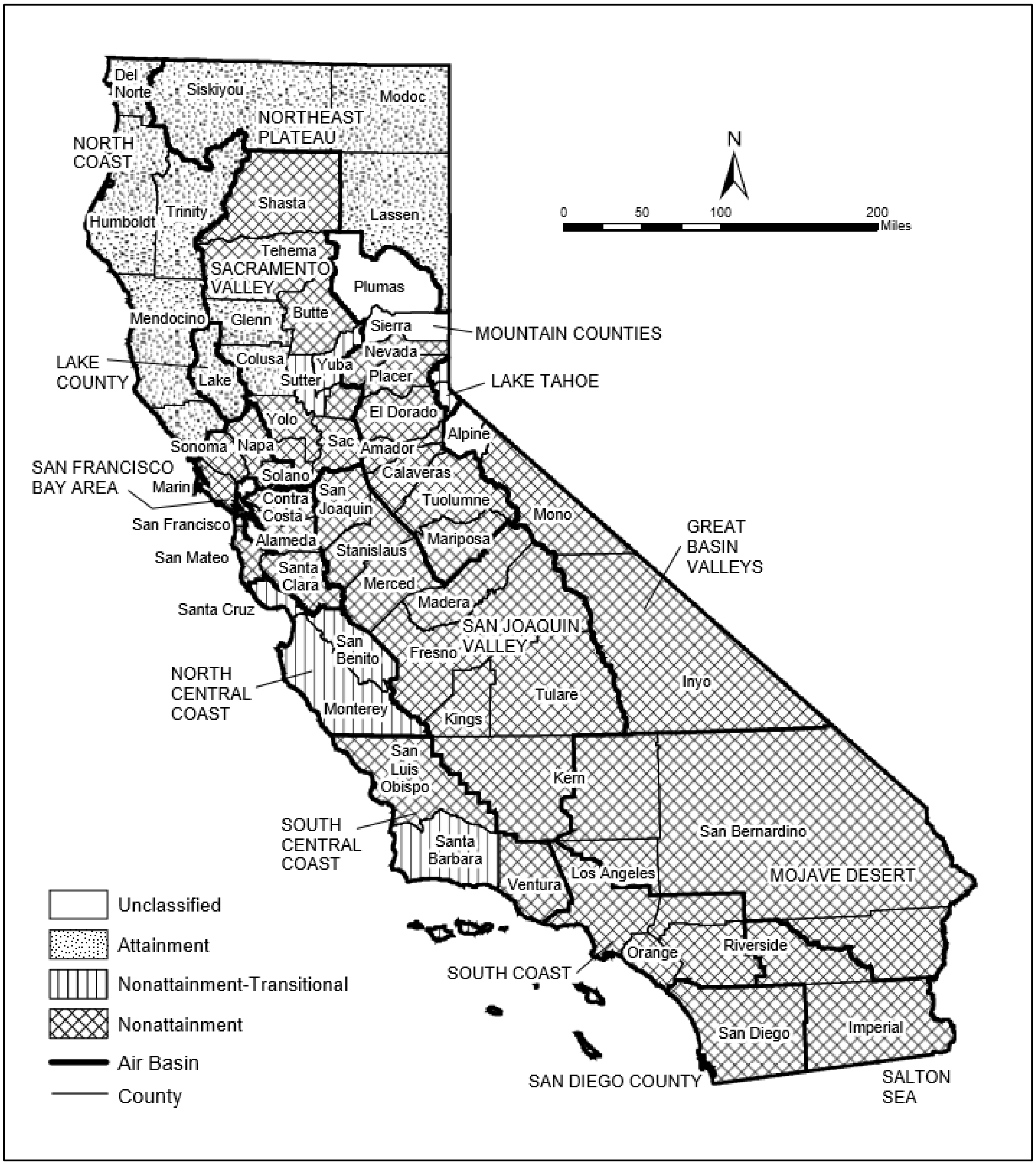
iv. Cumulative Impact of LCFS-attributed Biomass-based Diesel NOx Emissions

CEQA Guidelines section 15355(b) requires an analysis of "other closely related past, present, and reasonably foreseeable probable future projects." However, due to the programmatic nature of the NOx emissions impact analysis for LCFS-attributed biomass-based diesel, the statewide reach of the LCFS regulation, and the regional impacts of LCFS NOx emissions, the NOx emissions impact analysis for LCFS-attributed biomass-based diesel use is inherently cumulative in nature.

As indicated in **Figures 11** and **12**, many areas in California are located in State- and federally-designated ozone non-attainment areas, respectively. Thus, there is an existing, long-term significant air quality impact in these areas due to ozone.[138] Therefore, staff determined that the potentially significant impact of emissions due to biomass-based diesel use in historical and future years could result in a cumulatively considerable contribution to a significant adverse long-term air quality impact.

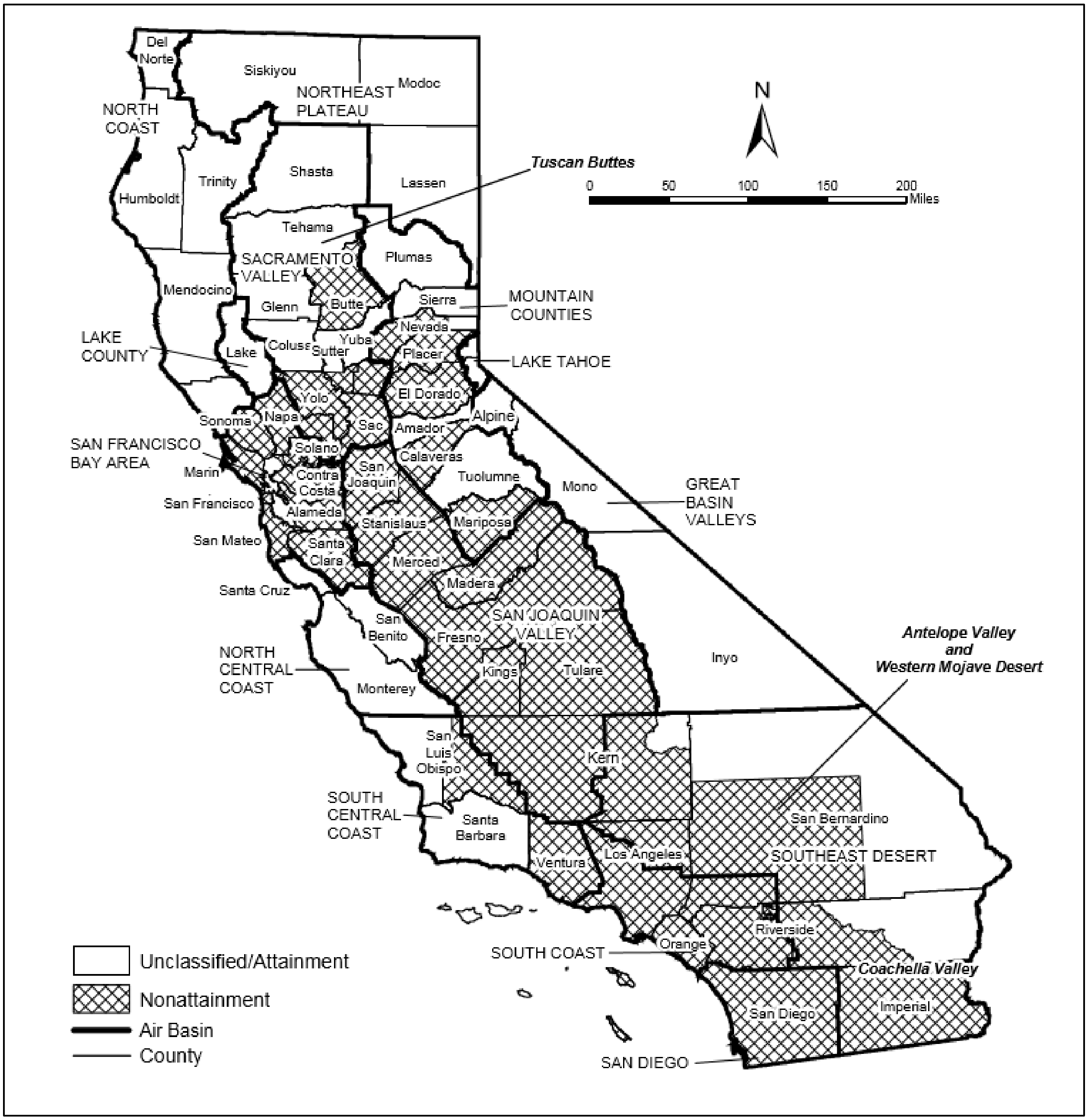
[138] As indicated in Section D.1, NOx is an ozone precursor. See CARB. 2015. Ozone and Ambient Air Quality Standards. October. Available at: https://www.arb.ca.gov/research/aaqs/caaqs/ozone/ozone.htm. Accessed: August, 2017.

Figure 11 – Area Designations for State Ozone Standards[139]



139 CARB. 2017. Area Designations for State Ambient Air Quality Standards - Ozone. Available at: https://www.arb.ca.gov/desig/adm/2016/state_o3.pdf. Accessed: September, 2017.

Figure 12 – Area Designations for Federal 8-Hour Ozone Standard[140]

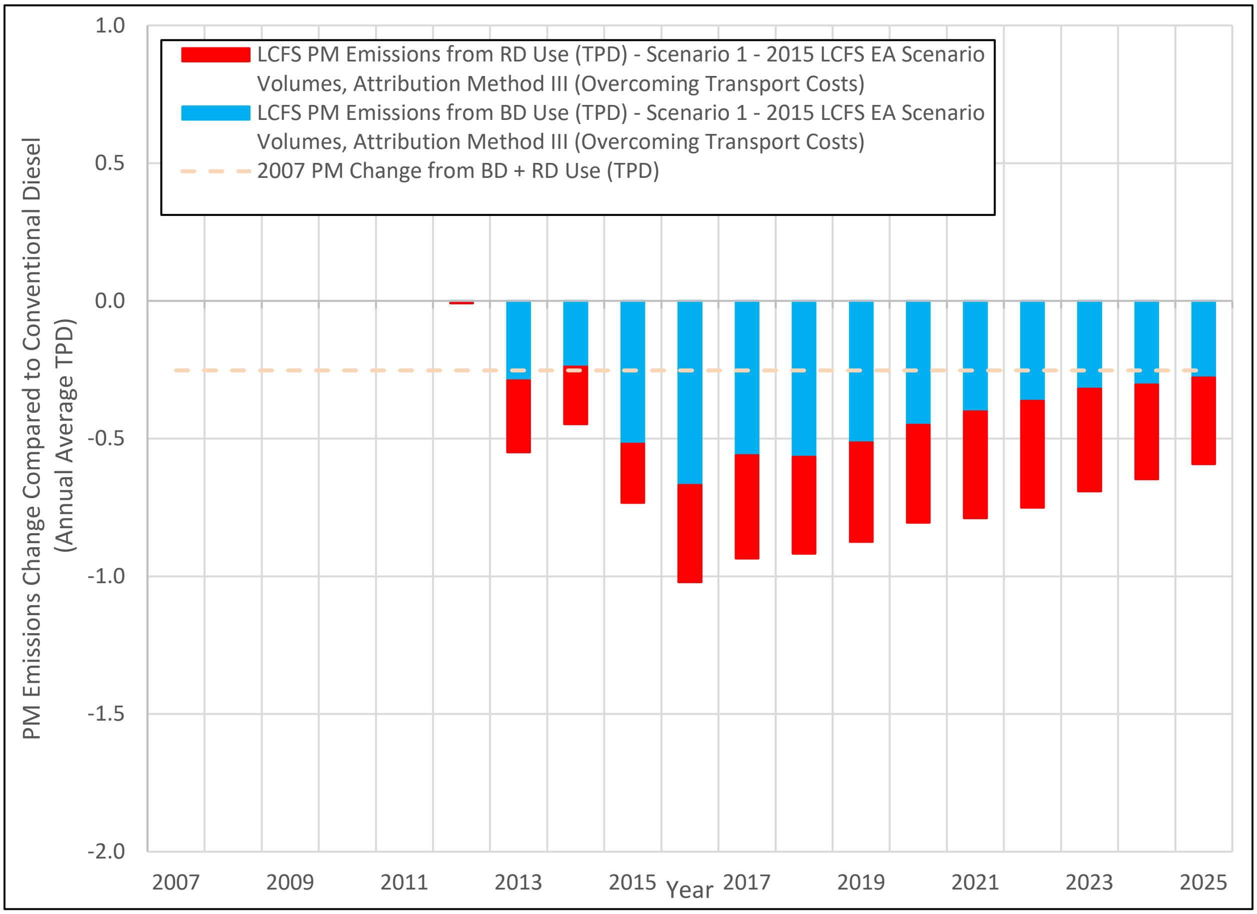


140 CARB. 2015. Area Designations for National Ambient Air Quality Standards – 8-Hour Ozone. Available at: https://www.arb.ca.gov/desig/adm/2015/fed_o3.pdf. Accessed: September, 2017.

b. LCFS-attributed Biomass-based Diesel PM Emissions Impacts

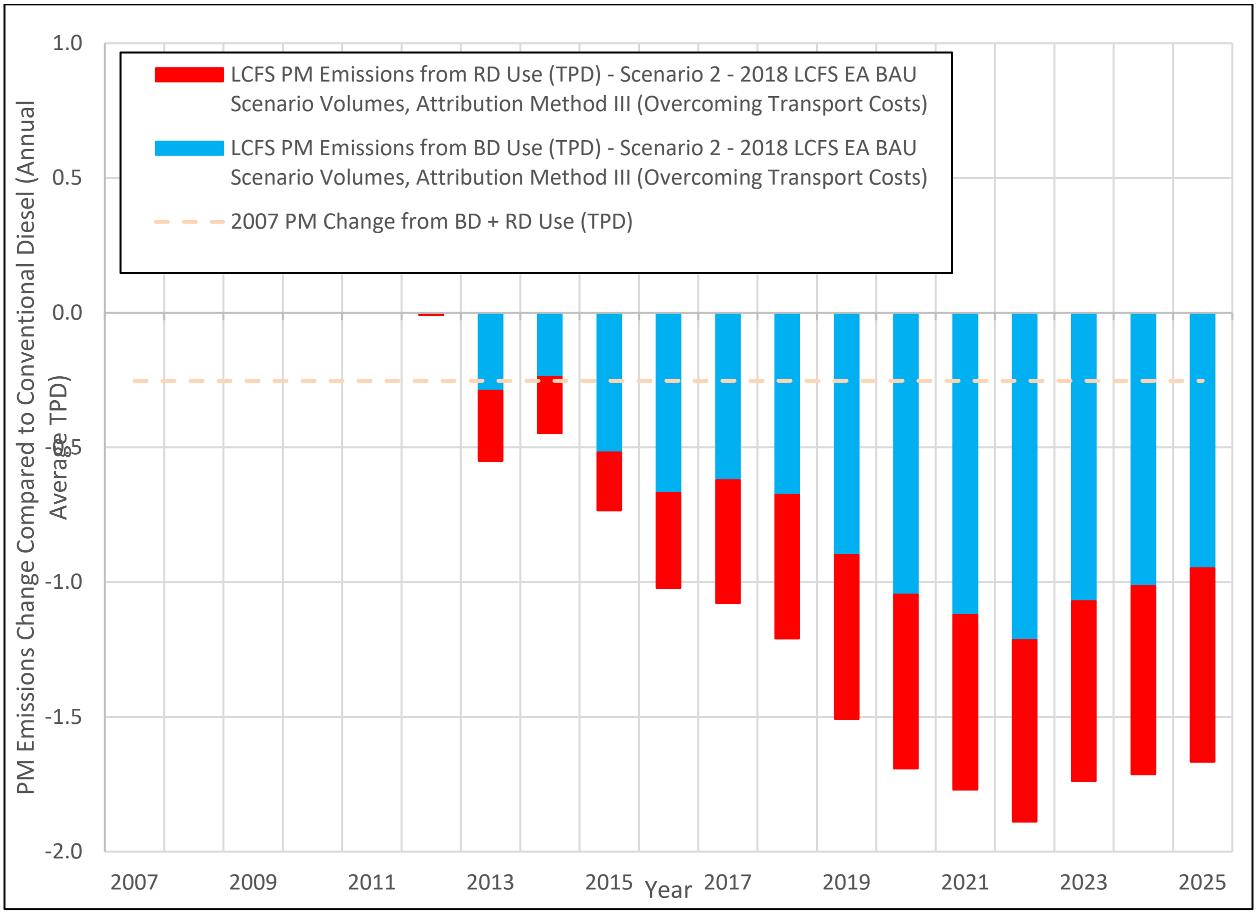
Figures 13 and **14** show LCFS-attributed PM emissions for biodiesel and renewable diesel separately as well as the net LCFS-attributed PM emissions for biomass-based diesel for each year from 2007 - 2025 for Scenarios 1 and 2, respectively. **Figures 13** and **14** indicate that LCFS-attributed biomass-based diesel PM emissions are zero or negative (i.e., provide a PM emissions benefit) for both scenarios for all years considered (i.e., 2007 - 2025). For both scenarios, LCFS-attributed biomass-based diesel PM emissions are lower than the 2007 PM emissions change due to biomass-based diesel use relative to conventional diesel. Based on the analysis above, staff determined that LCFS-attributed biomass-based diesel PM emissions resulted in environmentally beneficial impacts for Scenarios 1 and 2 for all historical years (i.e., from 2012 - 2016), and are also anticipated to result in environmentally beneficial PM impacts for Scenarios 1 and 2 for all future years (i.e., from 2017 - 2025).

Figure 13 – LCFS-attributed Biomass-based Diesel PM Emissions for Scenario 1 (2015 LCFS EA Scenario Volumes, Attribution Method III (Overcoming Transport Costs)[141]



[141] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in PM emissions from biomass-based diesel use to the LCFS prior to 2012.

Figure 14 – LCFS-attributed Biomass-based Diesel PM Emissions for Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Attribution Method III (Overcoming Transport Costs)[142]



4. LCFS-attributed Biomass-based Diesel NOx and PM Emissions Impacts Following Historical Remediation and Future Mitigation

a. Description of Remedial Measure to Offset Historical LCFS-attributed Biomass-based Diesel NOx Emissions

As discussed above, due to the short atmospheric lifetime of NOx emissions, it is not physically possible, and is therefore infeasible, to mitigate any specific potentially significant historical LCFS NOx emissions. The ADF, and proposed amendments to the ADF, would fully mitigate future NOx emissions. Nonetheless, additional remediation

[142] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in PM emissions from biomass-based diesel use to the LCFS prior to 2012.

efforts regarding these potential past emissions are appropriate, and can further improve air quality in the future. Therefore, CARB will offset historical potential LCFS-attributed biomass-based diesel NOx emissions through a remedial measure that funds air district-level NOx mitigation projects targeting engines, such as the replacement of existing diesel engines with low-NOx engines.

CARB will distribute funds to certain impacted California air districts to administer these NOx mitigation projects consistent with the Carl Moyer Air Quality Standards Attainment Program (Carl Moyer Program). CARB will also request that air districts spend the funds as expeditiously and efficiently as possible to generate cost-effective NOx emissions reductions that commence within a short period of time. The remedial measures would constitute a government funding mechanism, as the specific projects funded by the remedial measure would be selected by the air districts. CARB therefore cannot speculate as to the ultimate locations or specific projects selected for funding under this measure by the air districts, but CARB will be able to effectively track the reductions achieved under this measure, as it has consistently done with the Carl Moyer Program. The remedial measure itself would be designed to result in beneficial environmental impacts, as it would reduce NOx emissions in an amount sufficient to remediate historical potential LCFS-attributed biomass-based diesel NOx emissions. As CARB continues to further refine this remedial measure, CARB will provide a more detailed description of the measure, the process and timeline for implementation, and procedures for verifying emissions reductions, as well as the total amount of NOx emissions that will be remediated through the measure, in the final version of this Supplemental Disclosure that staff anticipates presenting to the Board prior to the end of 2018.

In estimating the total amount of NOx emissions to be remediated, CARB only considered historical year-by-year LCFS-attributed biomass-based diesel NOx emissions that were greater than zero (i.e., historical LCFS-attributed biomass-based diesel NOx emissions less than zero were excluded)[143] and used the most conservative method of attributing biomass-based diesel use to the LCFS (i.e., Method III, which results in the highest cumulative LCFS NOx emissions).[144] CARB has estimated historical LCFS-attributed biomass-based diesel NOx emissions from 2007 through 2016. Biomass-based diesel usage data for California are not available for all of 2017. Following receipt of all 2017 biomass-based diesel volume data, CARB will update the total historical LCFS NOx emissions to include 2017 data, as appropriate.

[143] LCFS NOx emissions that were greater than zero represent NOx emissions increases due to LCFS-attributed biomass-based diesel relative to conventional diesel. LCFS NOx emissions that were less than zero represent NOx emissions decreases due to LCFS-attributed biomass-based diesel relative to conventional diesel.
[144] Methods for attributing biodiesel and renewable diesel use to the LCFS for the period 2005 – 2025 are discussed in Section C.

The substantial health benefits resulting from PM reductions associated with LCFS-attributed biodiesel use alone (116 to 247 total reduced premature deaths statewide over the period analyzed for Scenarios 1 and 2, respectively), could serve as overriding considerations related to potentially significant and unavoidable historical air quality impacts, due to LCFS-attributed biomass-based diesel NOx emissions, that cannot be mitigated to less-than-significant levels through implementation of feasible mitigation measures. In addition to the substantial health benefits associated with biodiesel use, CARB also notes the substantial environmental and other benefits resulting from GHG reductions associated with biodiesel. CARB acknowledges the important role that biodiesel plays in improving public health and believes that the use of biodiesel on its own is beneficial to California, regardless of whether that use is in conjunction with renewable diesel.

Although the Board could consider the substantial health benefits of PM associated with biodiesel an overriding consideration, should it so decide, NOx emissions reductions in California must continue. Accordingly, CARB has prioritized and will continue to prioritize NOx emissions reductions associated with California's increasingly diverse fuel pool. This is evidenced in CARB's development and adoption of the ADF regulation in 2015, as well as CARB's State Implementation Plan commitment to develop a regulation to reduce NOx and PM emissions from diesel fuels by 2020. One of the primary goals of the ADF regulation was to mitigate NOx emissions increases associated with biodiesel use relative to conventional diesel through in-use requirements (e.g., introduction of a NOx-reducing additive).

b. Description of Mitigation Measure to Mitigate Future NOx Emissions Increases due to LCFS-Attributed Biomass-Based Diesel

The current ADF regulation sunsets in-use requirements for biodiesel blends up to B20 when the vehicle miles travelled (VMT) by on-road NTDE heavy-duty vehicles in California reaches 90 percent of total VMT by the California on-road heavy-duty diesel vehicle fleet. The current sunset date does not account for adoption of NTDEs in the off-road sector, which is occurring at a slower rate than in the on-road sector.

Future volume scenarios for biomass-based diesel are based on a complex set of factors and are a projection based on CARB's best understanding at this time.[145] There is high uncertainty in these scenarios, and the complex market factors that affect fuel demand mean that CARB's estimates will almost certainly change with time as new information becomes available. As such, the actual biomass-based diesel volumes that will be used cannot be known with certainty and will likely vary from CARB's current illustrative scenarios. Therefore, if the in-use requirements of the ADF regulation sunset

[145] This is why staff continues to use the term "illustrative" to describe these scenarios.

as currently written, it is possible that biodiesel use attributable to the LCFS could significantly increase NOx emissions relative to the use of conventional diesel in the future, even for years that CARB assumed no NOx emissions increase in the scenarios discussed in this analysis.

CARB is proposing to mitigate projected future LCFS-attributed NOx emissions due to biomass-based diesel use through an amendment to the ADF regulation. This amendment would revise the sunset provision for the ADF regulation to indicate that the sunset of in-use requirements is based on penetration of NTDEs for both on-road vehicles and off-road vehicles and equipment. Specifically, in-use requirements would sunset when:

1. The vehicle miles traveled (VMT) by NTDE heavy-duty on-road diesel vehicles in California reaches 90 percent of total VMT by the California heavy-duty on-road fleet, based on the most current CARB mobile source emissions inventory; and

2. The hours of operation of NTDE off-road diesel engines in California reaches 90 percent of total hours of operation by the California heavy-duty off-road diesel engine fleet (exclusive of OGVs),[146] based on the most current CARB mobile source emissions inventory.

As a result of this amendment, the sunset of in-use requirements in the ADF regulation would likely occur no earlier than 2030. With the implementation of the proposed amendments to the ADF NOx mitigation measure, the potentially significant adverse impact to long-term air quality caused by LCFS-attributed biomass-based diesel use would be reduced to a less-than-significant level. Thus, with mitigation, LCFS-attributed biomass-based diesel NOx emissions would not result in a cumulatively-considerable contribution that adversely impacts long-term air quality.

c. LCFS-attributed Biomass-based Diesel NOx Emissions Impacts Following Historical Remediation and Future Mitigation

Following implementation of the remedial measure, cumulative historical LCFS-attributed biomass-based diesel NOx emissions will be remediated (i.e., reduced to or below the NOx emissions level associated with conventional diesel use) for all scenarios. Similarly, the change in the sunset provision to the ADF regulation described in Section D.4.b will mitigate future LCFS NOx emissions to below the NOx emissions level associated with conventional diesel use for all scenarios on a year-by-year basis. Comparisons of the statewide LCFS NOx emissions due to biomass-based diesel use with and without the implementation of the remedial measure and mitigation measure for Scenarios 1 and 2 are presented in **Figures 15** and **16**, respectively.

[146] Biomass-based diesel fuels have not historically been used, and are currently not used, in OGVs.

Figure 15: Comparison of Statewide LCFS-attributed Biomass-based Diesel NOx Emissions With and Without Implementation of Remedial and Mitigation Measures, 2007 – 2025, Scenario 1

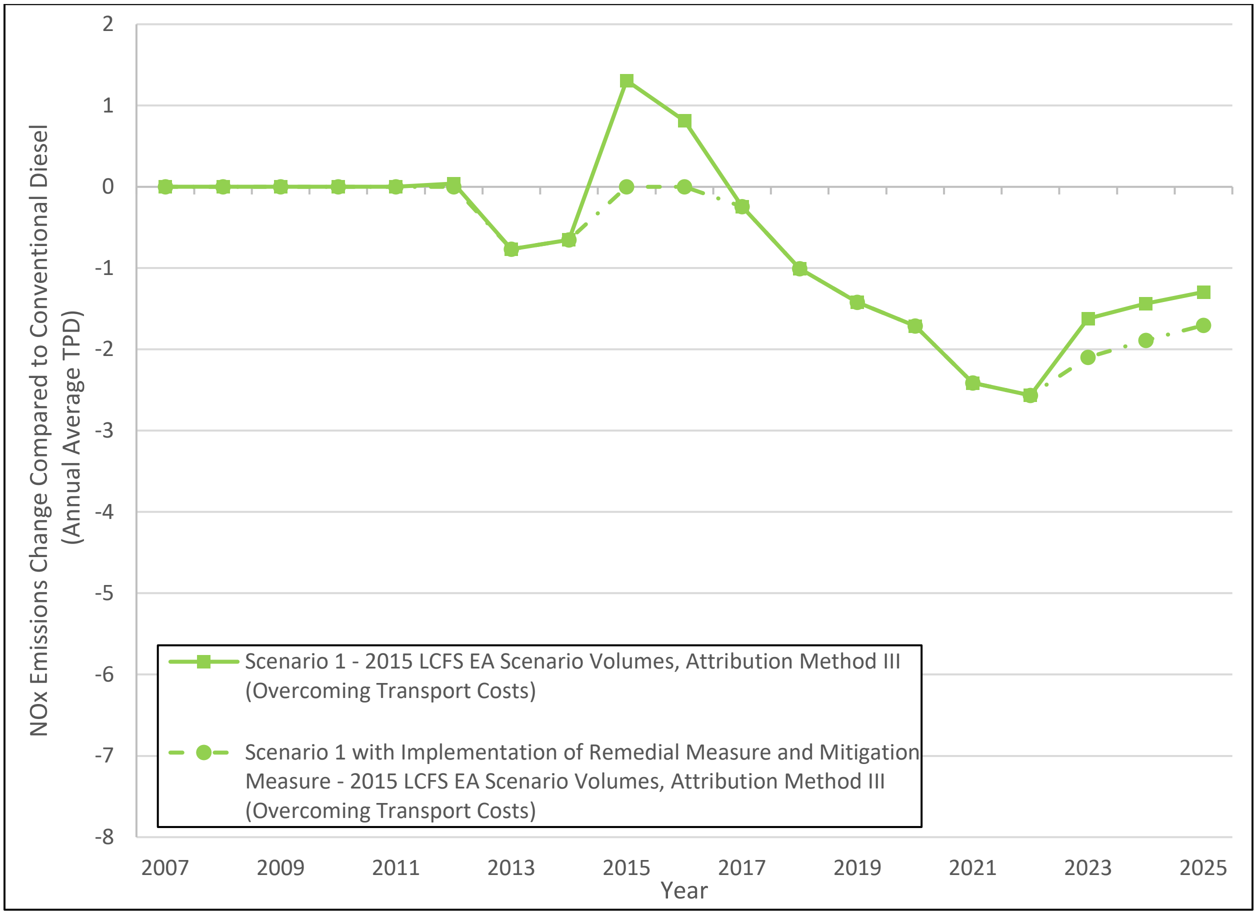
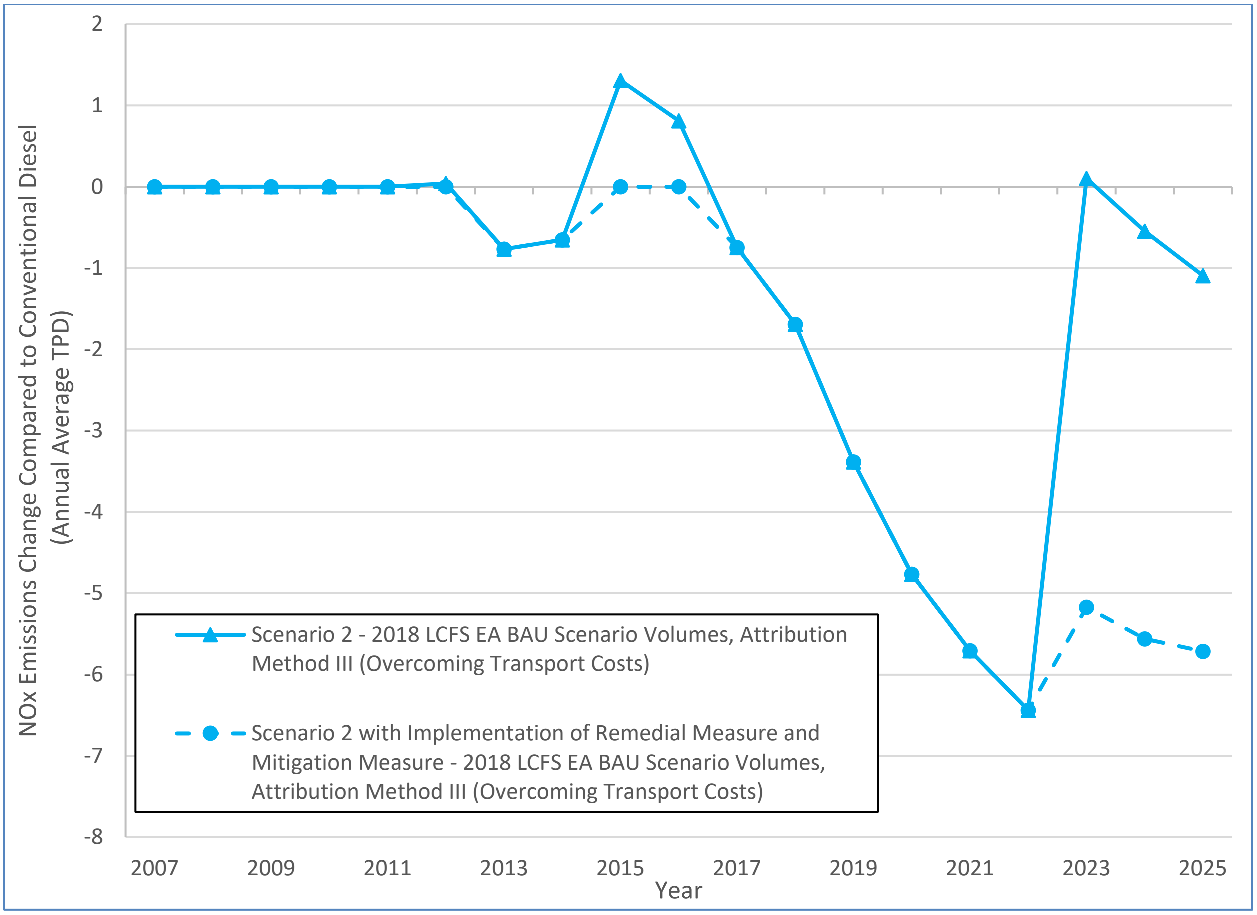


Figure 16: Comparison of Statewide LCFS-attributed Biomass-based Diesel NOx Emissions With and Without Implementation of Remedial and Mitigation Measures, 2007 – 2025, Scenario 2



d. LCFS-attributed Biomass-based Diesel PM Emissions Impacts Following Historical Remediation and Future Mitigation

Assuming that future usage of biomass-based diesel in California would not be impacted by the proposed mitigation measure (i.e., the revision to the in-use requirements of the ADF regulation would not reduce biodiesel sales), direct LCFS-attributed biomass-based diesel PM emissions would not be impacted by the remedial measure or the mitigation measure. However, decreased LCFS-attributed biomass-based diesel NOx emissions resulting from implementation of both the remedial measure and mitigation measure would result in reduced secondary $PM_{2.5}$ formation and corresponding reductions in associated health impacts.

E. HEALTH IMPACTS OF LCFS-ATTRIBUTED BIOMASS-BASED DIESEL NOX AND PM EMISSIONS

CARB estimated health impacts from the LCFS-attributed biomass-based diesel emissions described above. These estimates show that the LCFS-attributed biomass-based diesel produced positive public health benefits in every year of its operation (as did the overall trend in improving air quality, to which the LCFS contributes). Accordingly, this analysis looks at the net effect on health of the individual LCFS-attributed biomass-based diesel trends in PM and NOx. It also, for clarity, provides an estimate of the effects of these pollutants on a disaggregated basis, but the joint impact of both pollutants is ultimately the best measure of the health effects of the rule. That analysis shows that LCFS-attributed biomass-based diesel saved lives and improved health outcomes.

1. Background on Human Health Impacts of Diesel PM and NOx

The combustion of diesel, biodiesel, and renewable diesel in mobile and stationary sources emits a complex mixture of air pollutants, including both gaseous and solid material. The solid material in diesel exhaust is known as diesel particulate matter (PM). In 1998, CARB identified diesel PM as a toxic air contaminant based on published evidence of a relationship between diesel exhaust exposure and lung cancer and other adverse health effects. More than 90% of diesel PM is less than 1 micrometer (µm) in diameter and thus is a subset of particulate matter less than 2.5 µm in diameter ($PM_{2.5}$). $PM_{2.5}$ particles easily penetrate airways and lungs, where they can produce harmful health effects. These effects include premature death, hospitalizations and emergency department visits for exacerbated chronic heart and lung disease, including asthma, increased respiratory symptoms, and decreased lung function in children.[147]

Diesel exhaust also contains gaseous pollutants, including NOx. NOx emissions can undergo chemical reactions in the atmosphere leading to formation of ground level ozone and secondary $PM_{2.5}$. Health effects associated with ozone exposure above the ambient air quality standards include lung inflammation and tissue damage and impaired lung function.[148]

[147] CARB. 2016. Overview: Diesel Exhaust and Health. April. Available at: https://www.arb.ca.gov/research/diesel/diesel-health.htm. Accessed: August, 2017.
[148] CARB. 2015. Ozone and Ambient Air Quality Standards. October. Available at: https://www.arb.ca.gov/research/aaqs/caaqs/ozone/ozone.htm. Accessed: August, 2017.

2. Summary of Health Impacts Methodology

Staff quantified incremental health impacts resulting from changes in direct PM emissions and secondary PM formation from NOx emissions associated with LCFS-attributed biomass-based diesel use relative to conventional diesel use for Scenarios 1 and 2. Incremental health impacts, including mortality (i.e., premature death) and morbidity (i.e., hospital visits associated with cardiovascular or respiratory illness, and emergency room visits associated with respiratory illness or asthma) due to changes in PM emissions, including secondary PM formation from NOx emissions, were estimated based on CARB's incidents-per-ton (IPT) methodology.[149]

Methods to quantify the impacts of NOx emissions on ozone concentrations and health impacts are regional, complex, and uncertain.[150] Therefore, although LCFS-attributed biomass-based diesel NOx emissions were evaluated quantitatively, changes to ozone concentrations and associated health impacts attributed to LCFS-attributed biomass-based diesel NOx emissions were evaluated qualitatively. The specific methodology used to evaluate health impacts due to LCFS-attributed biomass-based diesel NOx and PM emissions are presented in **Appendix 6**.

The incremental health impacts resulting from changes in direct PM emissions and secondary PM formation from NOx emissions associated with LCFS-attributed biomass-based diesel use relative to conventional diesel use for Scenarios 1 and 2, based on Attribution Method III, are presented below.

3. Health Impacts of LCFS-attributed Biomass-based Diesel PM and NOx Emissions

a. Impact of LCFS-attributed Biomass-based Diesel PM Emissions on Mortality and Morbidity

Both biodiesel and renewable diesel blends reduce directly-emitted PM emissions compared to conventional diesel, resulting in health benefits.

Table 14 provides a summary of the 2007 health impacts (i.e., the health impacts at the time when the environmental analysis of the original LCFS regulations commenced),

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[149] Because the change in the number of incidences of emergency room visits due to respiratory illness was very small (i.e., between zero and one) for LCFS PM emissions and secondary PM2.5 formation from LCFS NOx emissions for Scenarios 1 and 2 in all years, this health impact was not reported in the results below.

[150] Estimation of ozone concentrations depends on several variables (e.g., concentrations of NOx and VOCs, solar radiation, temperature and wind speed) that vary based on time and location.

expressed as changes in the number of persons experiencing each health impact, due to reductions in direct PM emissions as a result of all biomass-based diesel use in California during year 2007 relative to conventional diesel use.[151] **Table 14** indicates that biomass-based diesel use in 2007 provided health benefits

Table 14 – 2007 Health Impacts Due to Reductions in Direct PM Emissions Resulting from All Biomass-Based Diesel Use[152]

Health Impact	Incidence in Year 2007 (Change in Number of Persons Experiencing Impact)
Mortality	-8
Hospital Admissions – Cardiovascular Illness	-1
Hospital Admissions – Respiratory Illness	-1
Emergency Room Visits - Asthma	-3

Figures 17 and **18** show the health impacts by year for Scenarios 1 and 2, respectively, expressed as a change in the number of persons experiencing each health impact, due to LCFS-attributed biomass-based diesel PM emissions for the period 2007 – 2025 relative to conventional diesel use.

[151] As shown in Table 9, there was no renewable diesel use in California in 2007.
[152] Ibid.

Figure 17 - Health Impacts by Year Due to LCFS-attributed Biomass-based Diesel PM Emissions, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)

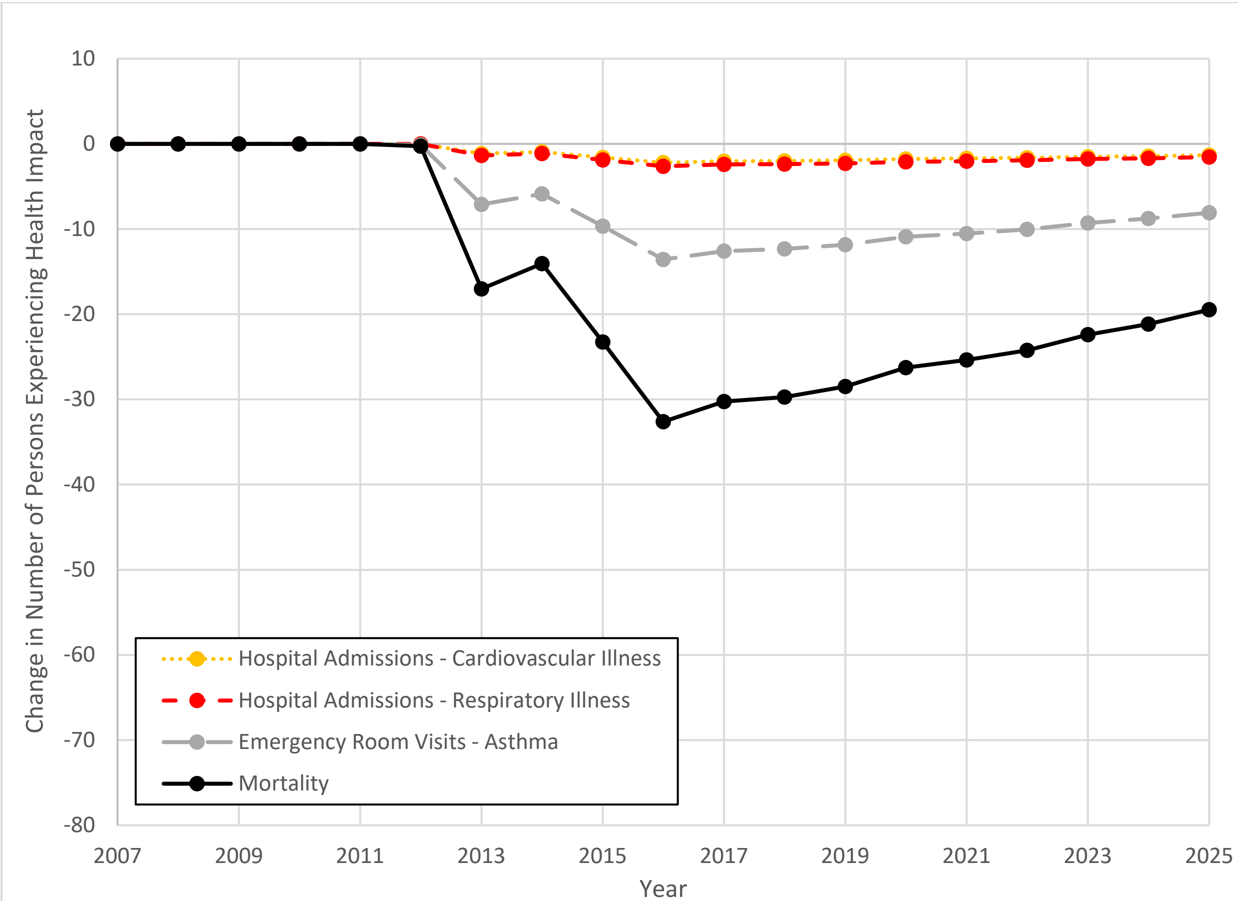
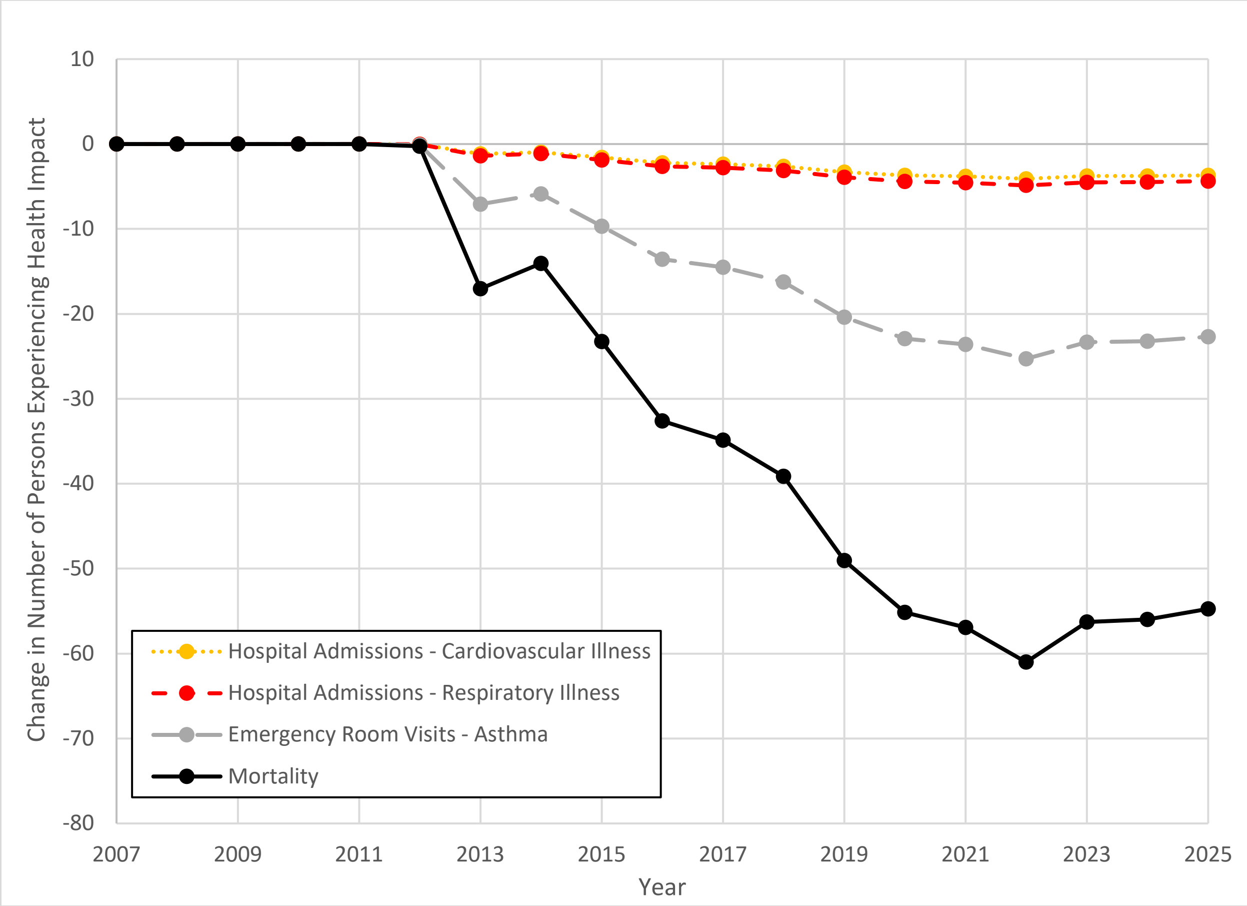


Figure 18 - Health Impacts by Year Due to LCFS-attributed Biomass-based Diesel PM Emissions, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)

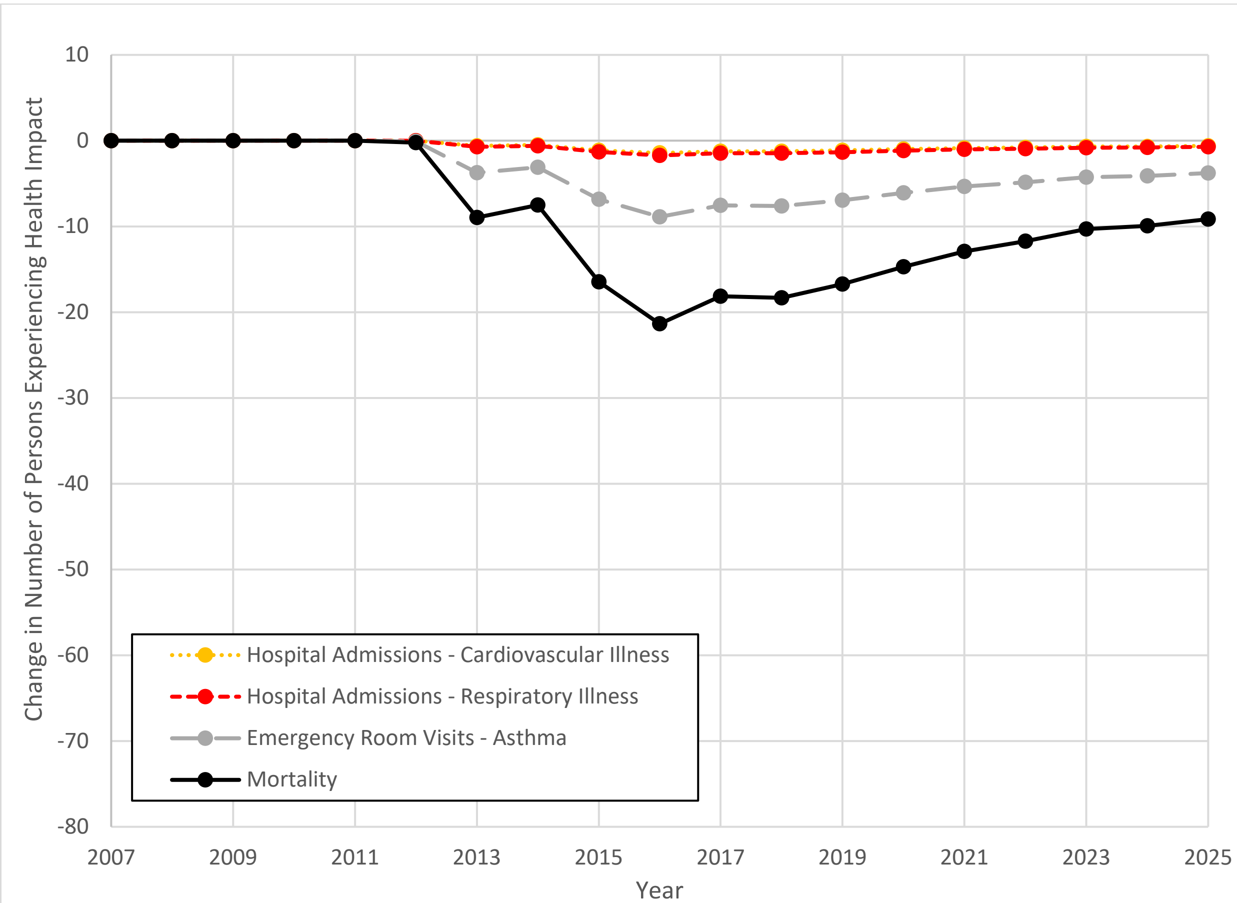


As described in **Appendix 1**, staff determined that no biodiesel or renewable diesel use was attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year. As a result, there were no changes in health impacts relative to conventional diesel use prior to 2012, as indicated in **Figures 17** and **18**. For each year from 2013 – 2025, health impacts associated with LCFS-attributed biomass-based diesel PM emissions are negative (i.e., result in health benefits relative to conventional diesel use) for both scenarios.[153]

153 For both scenarios, health impacts due to LCFS-attributed biomass-based diesel PM emissions in 2012 were very small, and were rounded to zero for this year.

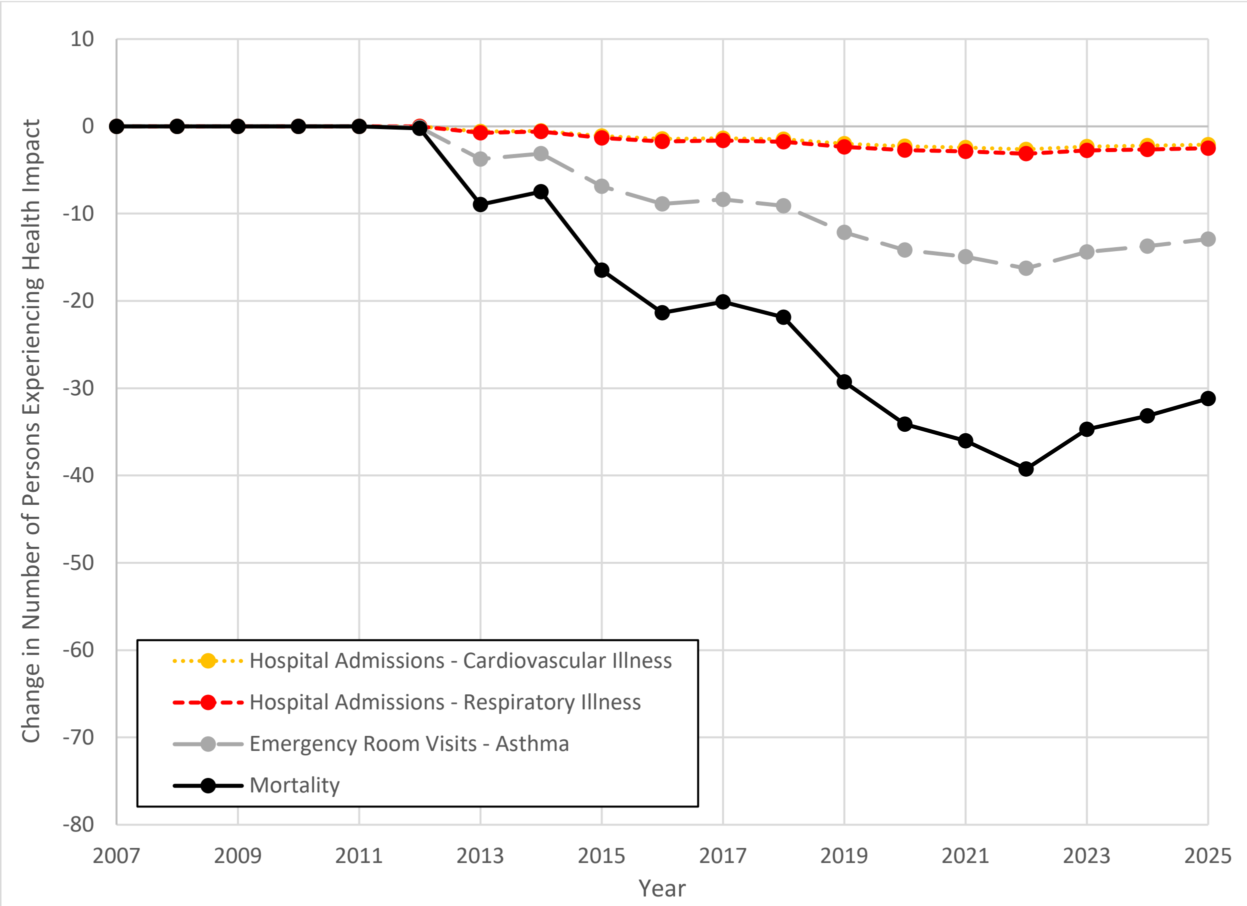
Staff also analyzed the health impacts of LCFS-attributed biodiesel use only for each year from 2007 – 2025 in comparison to conventional diesel use. As shown in **Figures 19** and **20**, LCFS PM emissions due to biodiesel result in health benefits for every year from 2013 – 2025 for Scenarios 1 and 2, respectively.[154]

Figure 19 - Health Impacts by Year Due to LCFS PM Emissions from Biodiesel Use Only, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)



[154] Staff determined that no biodiesel or renewable diesel use was attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year. As a result, there are no changes in health impacts relative to conventional diesel use prior to 2012. For both scenarios, health impacts due to LCFS PM emissions in 2012 were very small, and were rounded to zero for this year.

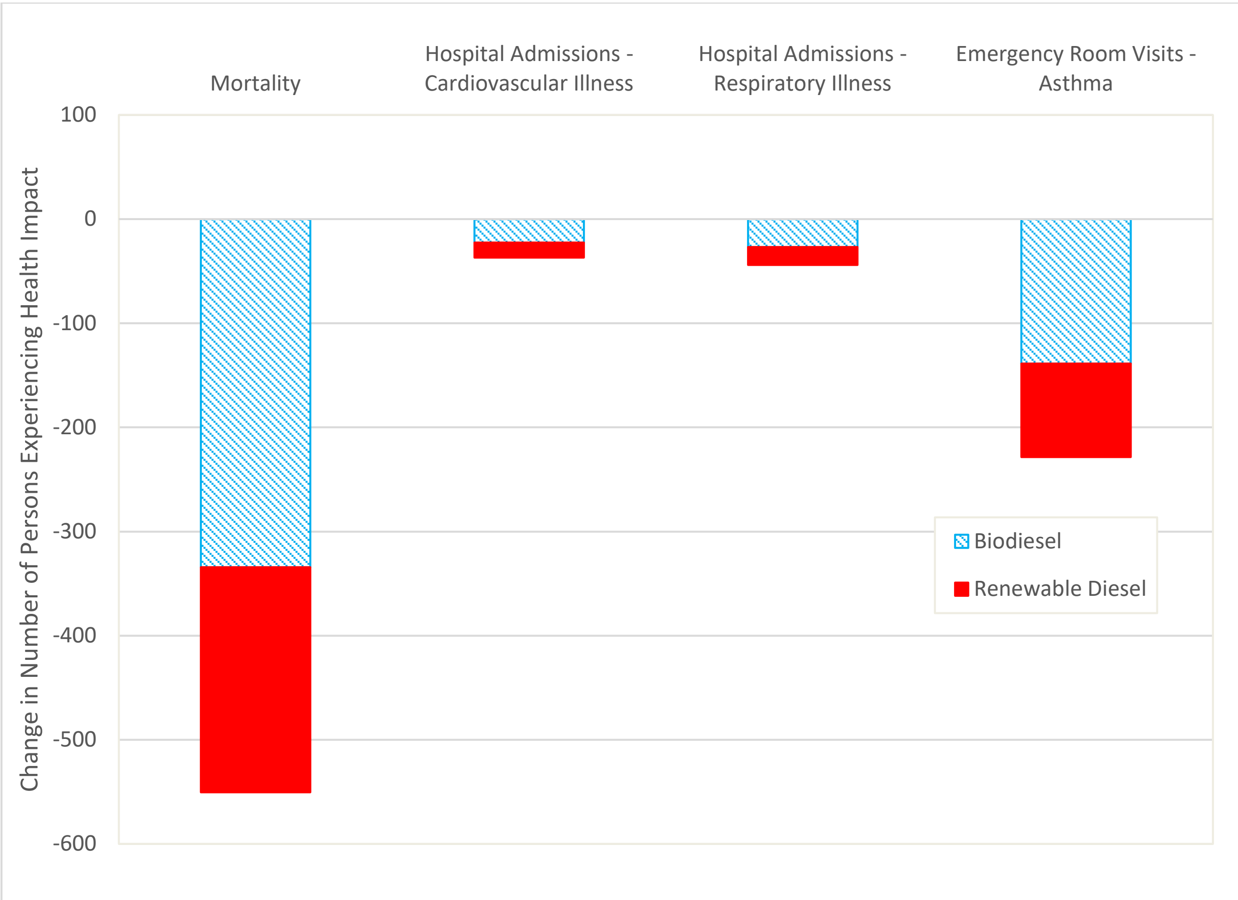
Figure 20 - Health Impacts by Year Due to LCFS-attributed Biomass-based Diesel PM Emissions from Biodiesel Use Only, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)



The health benefits due to reductions in LCFS-attributed biomass-based diesel PM emissions were summed for 2007 – 2025 for Scenarios 1 and 2, as shown in **Figures 21** and **22**, respectively. These cumulative health impacts indicate that both biodiesel and renewable diesel use attributed to the LCFS result in substantial health benefits associated with direct PM emissions reductions over the period 2007 – 2025 for Scenarios 1 and 2, respectively.

Figure 21 – Cumulative Health Benefits Due to LCFS-attributed Biomass-based Diesel PM Emissions, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)

Figure 22 – Cumulative Health Benefits Due to LCFS-attributed Biomass-based Diesel PM Emissions, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)



b. Impact of LCFS-attributed Biomass-based Diesel NOx Emissions on PM Mortality and Morbidity

As indicated in Section E.1.a, NOx emissions from diesel engines undergo chemical reactions in the atmosphere leading to formation of secondary $PM_{2.5}$. The use of biodiesel blends can increase NOx emissions compared to conventional diesel if used in non-NTDEs, resulting in increased formation of secondary $PM_{2.5}$ compared to conventional diesel. Conversely, the use of renewable diesel blends reduces NOx emissions compared to conventional diesel, resulting in decreased formation of secondary $PM_{2.5}$ compared to conventional diesel. The health impacts of biomass-based diesel use relative to conventional diesel use were estimated using the methods discussed in Section E.2.

Table 15 provides a summary of the 2007 health impacts due to increases in secondary $PM_{2.5}$ formation as a result of all biomass-based diesel use in California during year 2007 relative to conventional diesel use.[155]

Table 15 – 2007 Health Impacts Due to Increases in Secondary $PM_{2.5}$ Formation Resulting from All Biomass-Based Diesel Use[156]

Health Impact	Incidence in Year 2007 (Change in Number of Persons Experiencing Impact)
Mortality	2
Hospital Admissions – Cardiovascular Illness	0
Hospital Admissions – Respiratory Illness	0
Emergency Room Visits - Asthma	1

Figures 23 and **24** show the health impacts by year for Scenarios 1 and 2, respectively, due to changes in secondary $PM_{2.5}$ formation as a result of biomass-based diesel use attributed to the LCFS (hereafter referred to as "LCFS-attributed biomass-based diesel secondary $PM_{2.5}$ formation") for the period 2007 – 2025 relative to conventional diesel use.

[155] As shown in Table 9, there was no renewable diesel use in California in 2007.
[156] Ibid.

Figure 23 - Health Impacts by Year Due to LCFS-attributed Biomass-based Diesel Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)

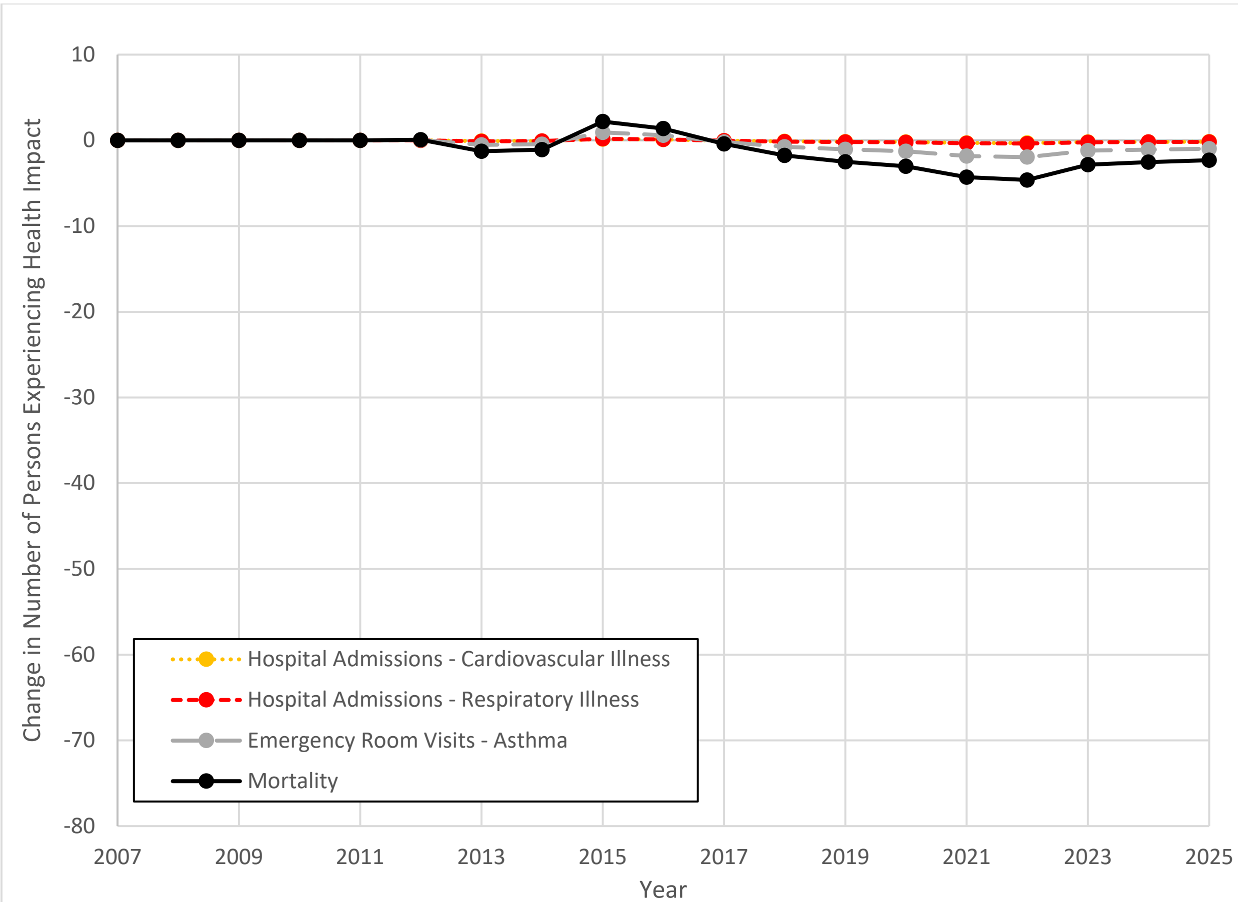
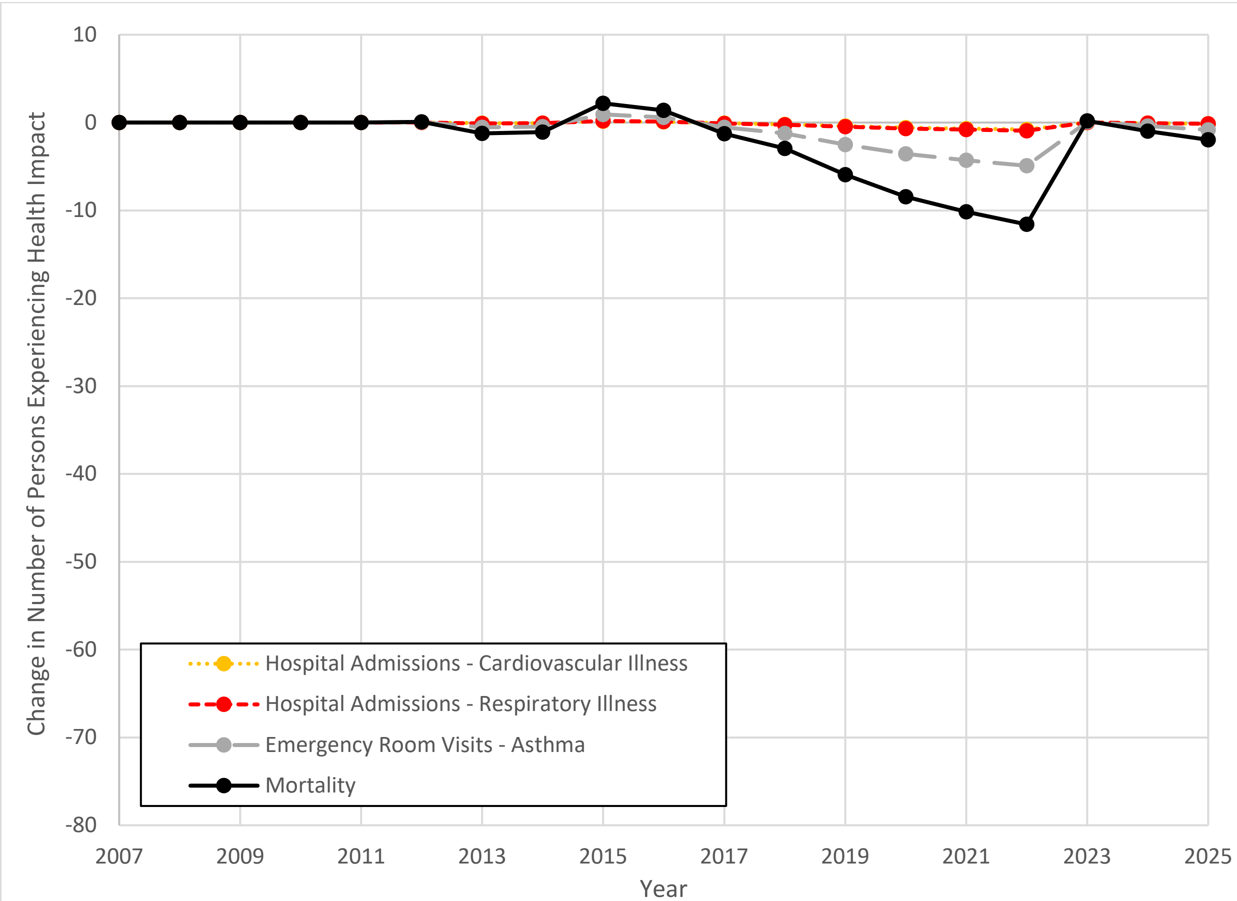


Figure 24 - Health Impacts by Year Due to LCFS-attributed Biomass-based Diesel Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)



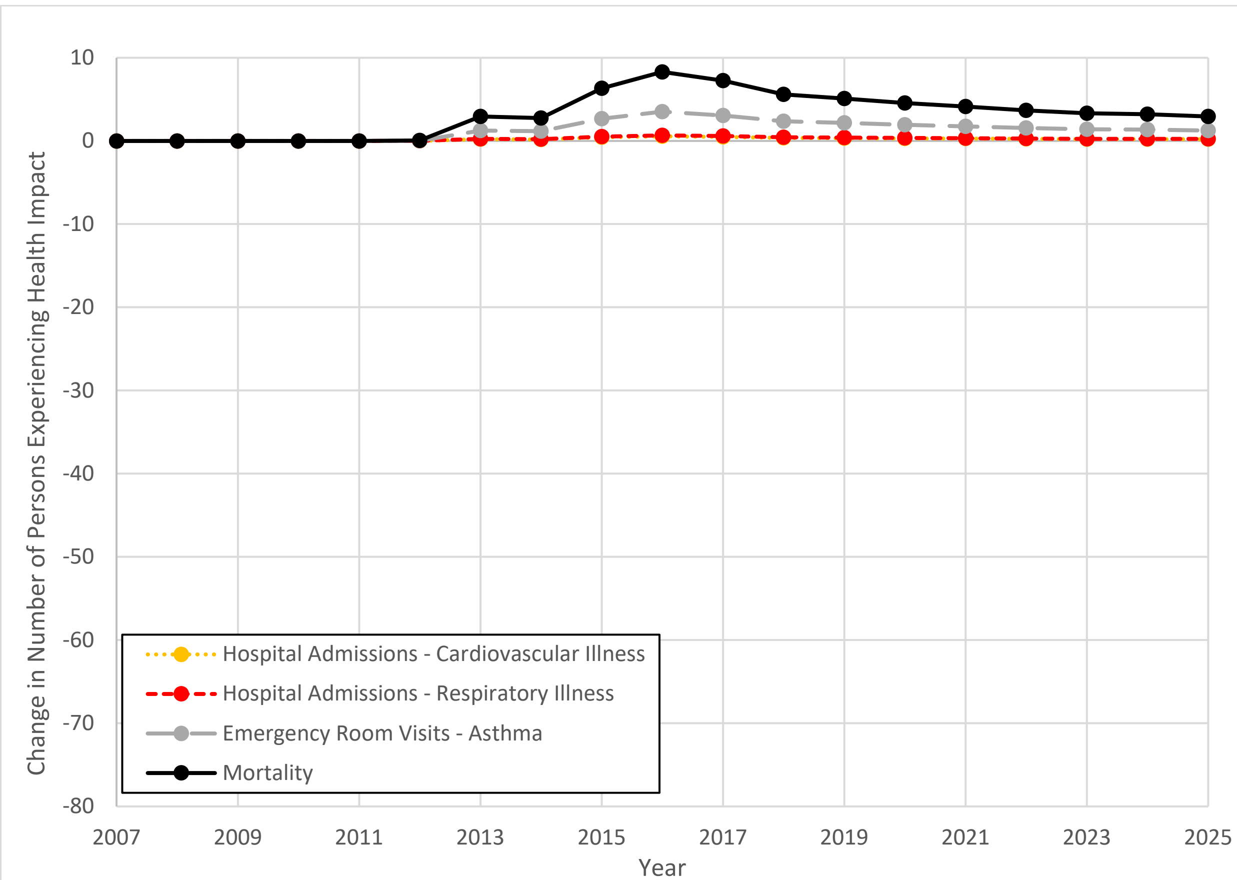
There were no health impacts due to LCFS-attributed biodiesel or renewable diesel use relative to conventional diesel use prior to 2012, as indicated in **Figures 23** and **24**.[157] From 2013 – 2025, health impacts due to LCFS-attributed biomass-based diesel secondary $PM_{2.5}$ formation fluctuate. For Scenario 1, LCFS-attributed biomass-based diesel secondary $PM_{2.5}$ formation results in adverse health impacts in 2015 and 2016 and beneficial health impacts in 2013 – 2014 and 2017 – 2025. [158] For Scenario 2, LCFS-attributed biomass-based diesel secondary $PM_{2.5}$ formation results in adverse

[157] Staff determined that no biodiesel or renewable diesel use was attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year.
[158] The health impacts due to LCFS secondary $PM_{2.5}$ formation in 2012 were very small, and were rounded to zero for this year.

health impacts in 2015, 2016, and 2023, and beneficial health impacts in 2013 – 2014, 2017 – 2022, and 2024 – 2025.[159]

Staff also analyzed the health impacts of LCFS-attributed biodiesel use only for each year from 2007 – 2025 in comparison to conventional diesel use. As shown in **Figures 25** and **26**, LCFS-attributed secondary $PM_{2.5}$ formation from biodiesel use results in adverse health impacts compared to conventional diesel use for every year for Scenarios 1 and 2, respectively.[160]

Figure 25 - Health Impacts by Year Due to LCFS-attributed Secondary $PM_{2.5}$ Formation Resulting from Biodiesel Use Only, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)



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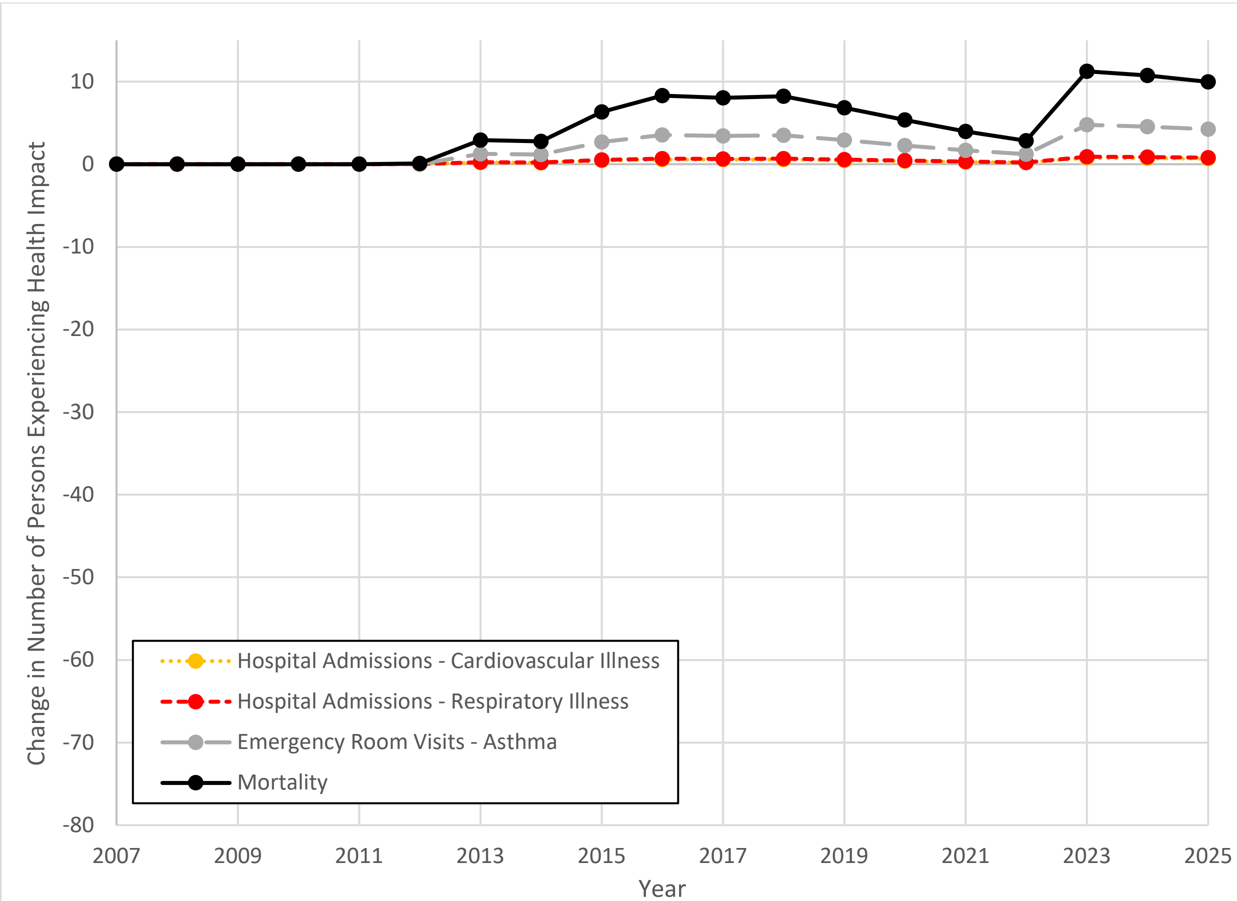
[159] The health impacts due to LCFS secondary $PM_{2.5}$ formation in 2012 were very small, and were rounded to zero for this year.

[160] Staff determined that no biodiesel or renewable diesel use was attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year. As a result, there were no changes in health impacts relative to conventional diesel use prior to 2012. For both scenarios, the health impacts due to LCFS secondary $PM_{2.5}$ formation in 2012 were very small, and were rounded to zero for this year.

Figure 26 - Health Impacts by Year Due to LCFS-attributed Secondary $PM_{2.5}$ Formation Resulting from Biodiesel Use Only, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)



The health impacts due to LCFS-attributed biomass-based diesel secondary $PM_{2.5}$ formation were summed for years 2007 - 2025 for Scenarios 1 and 2, as shown in **Figures 27** and **28**. These cumulative health impacts indicate that the adverse health impacts due to LCFS-attributed biomass-based diesel secondary $PM_{2.5}$ formation resulting from NOx emissions associated with LCFS-attributed biodiesel use are outweighed by the beneficial health impacts due reductions in secondary $PM_{2.5}$ formation associated with LCFS-attributed renewable diesel use, resulting in net health benefits associated with LCFS secondary $PM_{2.5}$ formation for both scenarios.

Figure 27 – Cumulative Health Impacts Due LCFS-attributed Biomass-based Diesel Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)

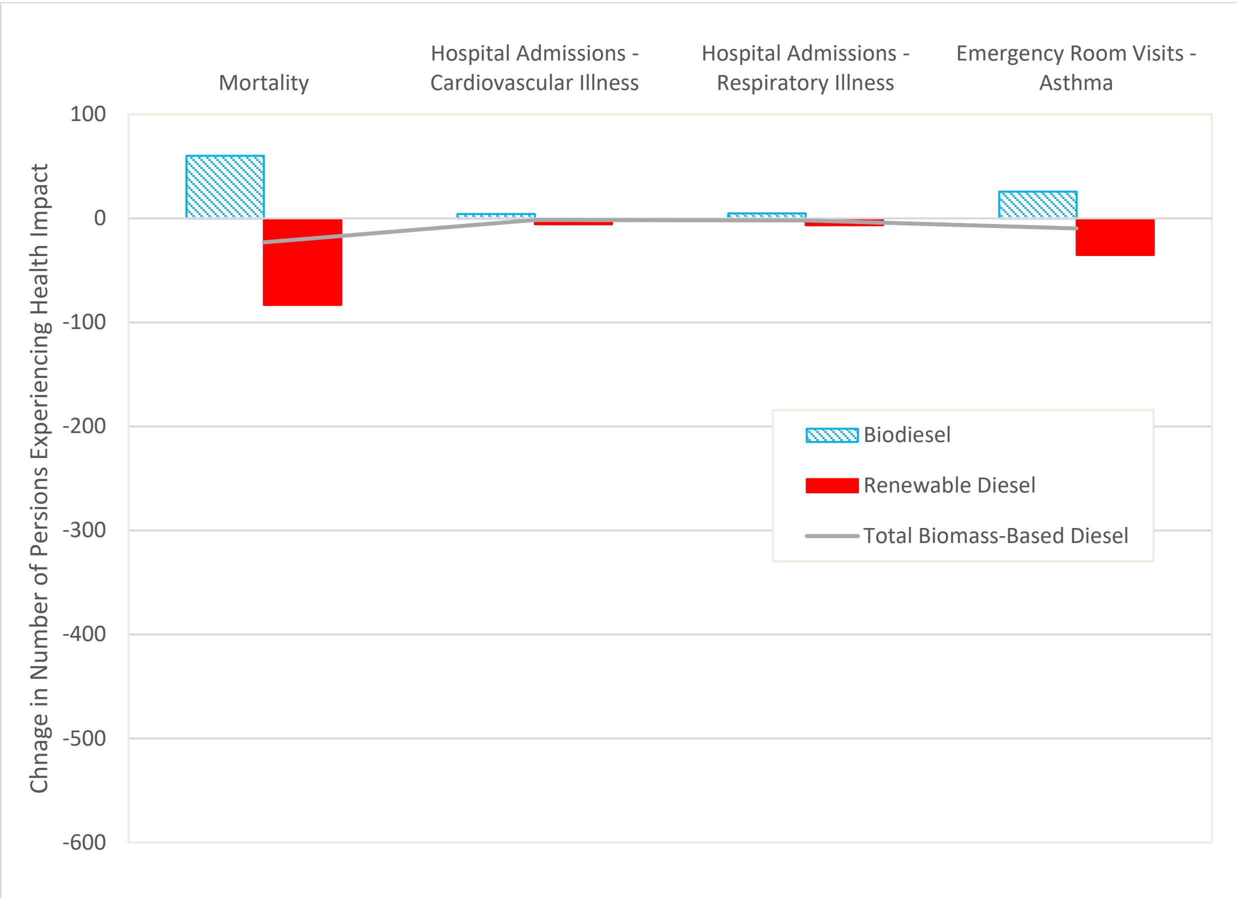
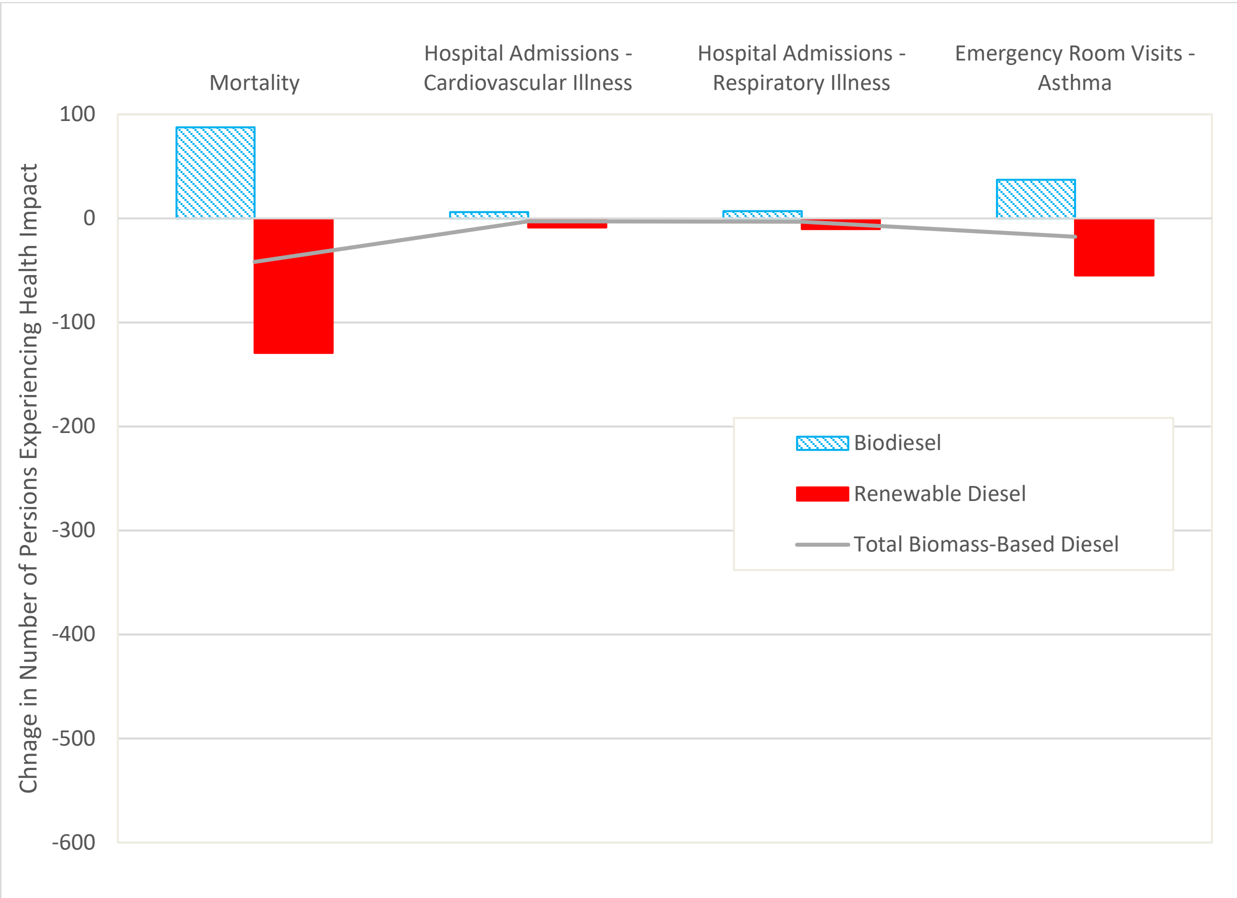


Figure 28 – Cumulative Health Impacts Due to LCFS-attributed Biomass-based Diesel Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)



c. Combined Impacts of LCFS-attributed Biomass-based Diesel NOx and PM Emissions on PM Mortality and Morbidity

The combined health impacts of LCFS-attributed biomass-based diesel NOx and PM emissions from 2007 - 2025 on PM mortality and morbidity were determined by summing the health impacts associated with reductions in PM emissions and secondary $PM_{2.5}$ formation.

Table 16 provides a summary of the 2007 health impacts related to PM mortality and morbidity due to the combined effect of direct PM emissions reductions and secondary

$PM_{2.5}$ formation because of all biomass-based diesel use in California during year 2007 relative to conventional diesel use.[161]

Table 16 – 2007 Combined Health Impacts Due to Reductions in Direct PM Emissions and Increases in Secondary $PM_{2.5}$ Formation Resulting from Biomass-Based Diesel Use [162]

Health Impact	Incidence in Year 2007 (Change in Number of Persons Experiencing Impact)
Mortality	-6
Hospital Admissions – Cardiovascular Illness	-1
Hospital Admissions – Respiratory Illness	-1
Emergency Room Visits - Asthma	-2

Figures 29 and **30** show the combined health impacts by year for Scenarios 1 and 2, respectively, due to LCFS-attributed biomass-based diesel PM and secondary $PM_{2.5}$ formation for the period 2007 – 2025.

[161] As shown in Table 9, there was no renewable diesel use in California in 2007.
[162] Ibid.

Figure 29 – Combined Health Impacts by Year Due to LCFS-attributed Biomass-Based Diesel PM Emissions and Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)

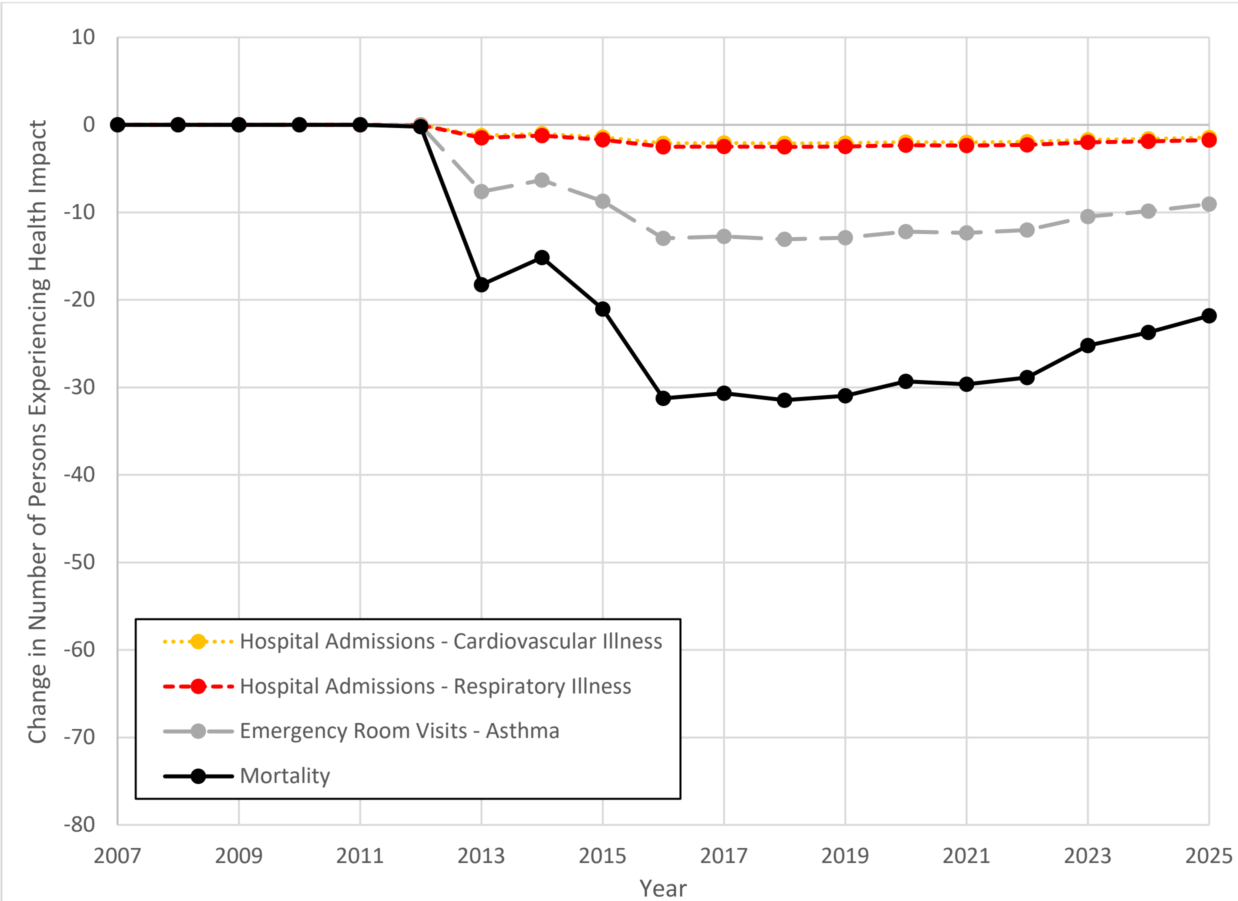
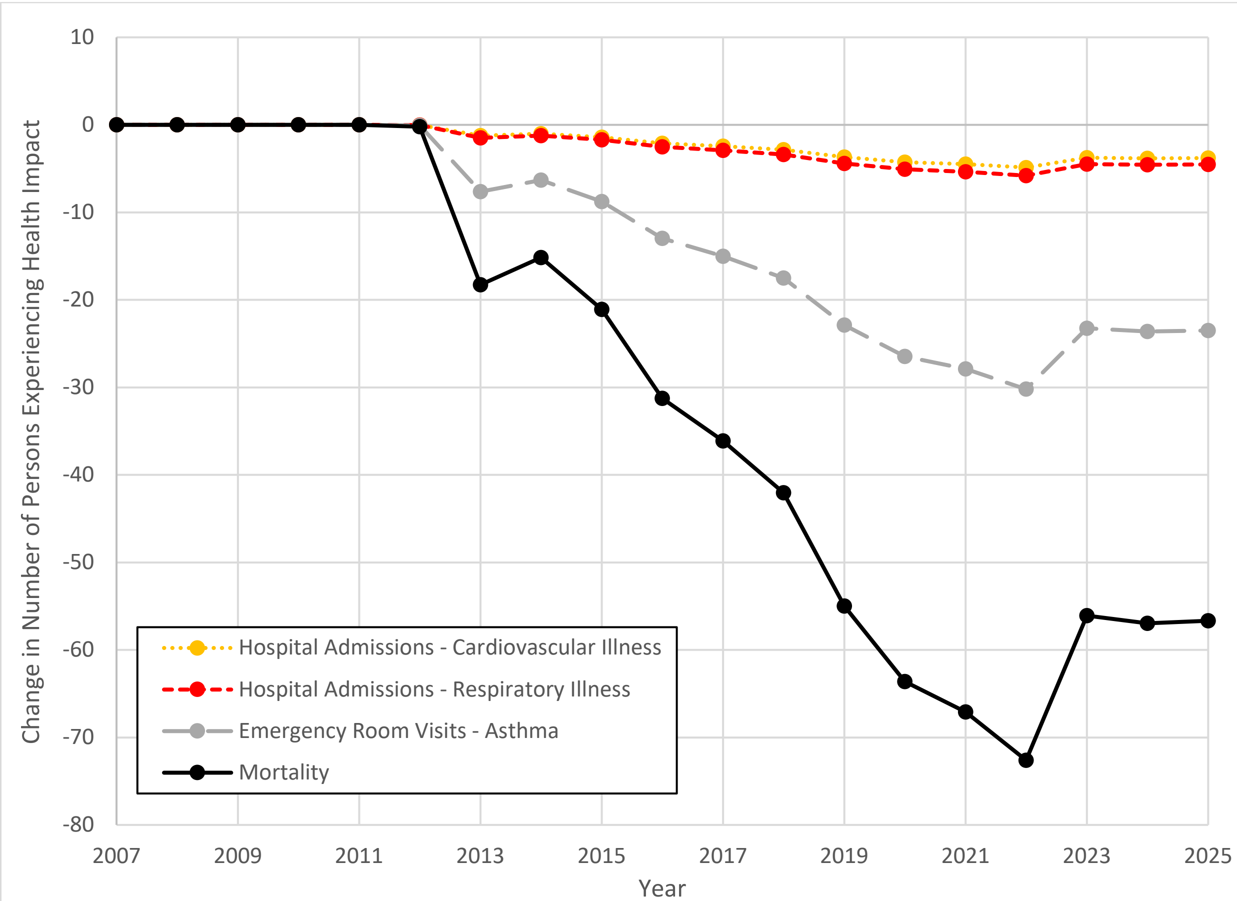


Figure 30 – Combined Health Impacts Due to LCFS-attributed Biomass-Based Diesel PM Emissions and Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)



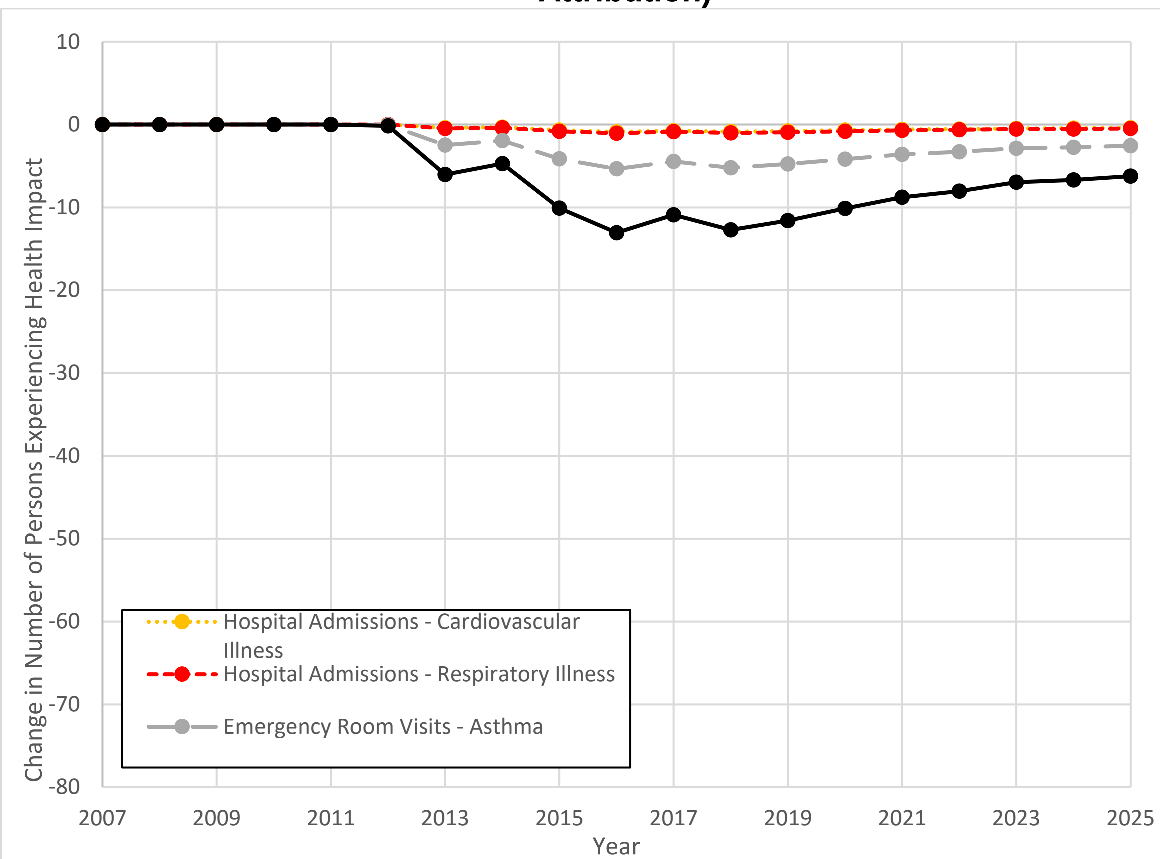
There were no health impacts due to LCFS-attributed biodiesel or renewable diesel use relative to conventional diesel use prior to 2012, as indicated in **Figures 36** and **37**.[163] For each year from 2013 – 2025, the combined health impacts associated with LCFS-attributed biomass-based diesel PM emissions and secondary $PM_{2.5}$ formation are negative (i.e., result in health benefits relative to conventional diesel use) for both scenarios.[164]

[163] Staff determined that no biodiesel or renewable diesel use was attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year. As a result, there were no changes in health impacts relative to conventional diesel use prior to 2012.

[164] For both scenarios, the combined health impacts due to LCFS PM emissions and LCFS secondary $PM_{2.5}$ formation in 2012 were very small, and were rounded to zero for this year.

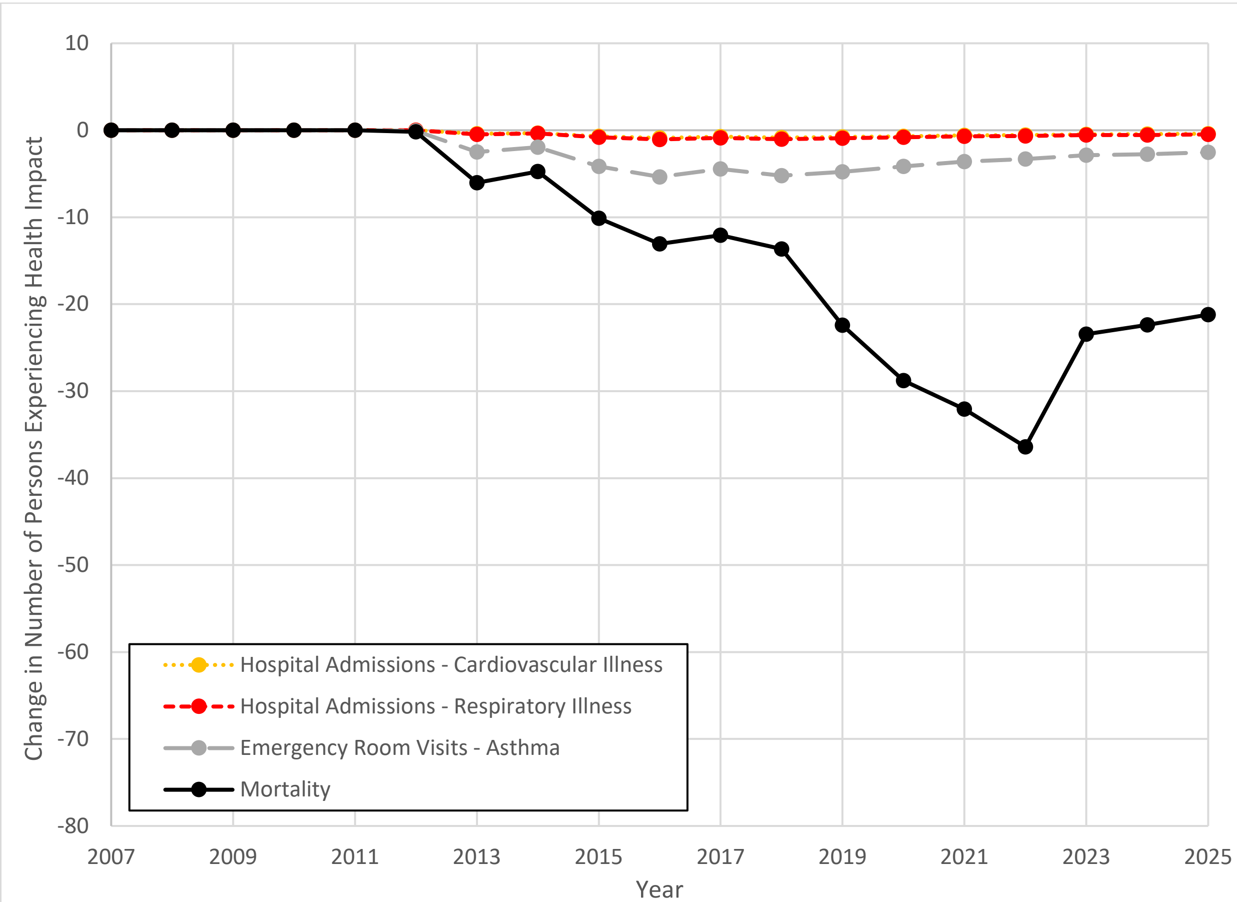
As described above, staff also analyzed the health impacts of LCFS-attributed biodiesel use only for each year from 2007 – 2025 in comparison to conventional diesel use. As shown in **Figures 31** and **32**, the combined health impacts due LCFS-attributed Biomass-Based Diesel PM emissions and secondary $PM_{2.5}$ formation results in net health benefits for every year for Scenarios 1 and 2, respectively.[165] Moreover, this result shows that for all biodiesel use, whether attributed to the LCFS or not, the health benefits of direct PM reductions outweigh the adverse health impacts of secondary $PM_{2.5}$ formation resulting from NOx emissions increases.

Figure 31 – Combined Health Impacts by Year Due to LCFS-attributed Biomass-Based Diesel PM Reductions and Secondary $PM_{2.5}$ Formation from Biodiesel Use Only, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)



[165] Staff determined that no biodiesel or renewable diesel use is attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year. As a result, there are no changes in health impacts relative to conventional diesel use prior to 2012. Also, for both scenarios, the combined health impacts due to LCFS PM emissions and LCFS secondary $PM_{2.5}$ formation for biodiesel use only in 2012 were very small, and were rounded to zero for this year.

Figure 32 – Combined Health Impacts Due to LCFS-attributed Biomass-Based Diesel PM Reductions and Secondary $PM_{2.5}$ Formation from Biodiesel Use Only, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)



The health impacts due to the combined reductions in LCFS-attributed biomass-based diesel PM emissions and secondary $PM_{2.5}$ formation were summed for years 2007 – 2025 for Scenarios 1 and 2, as shown in **Figures 33** and **34**. These cumulative health impacts indicate that, overall, there are substantial beneficial health impacts associated with the combined reductions in PM emissions and secondary $PM_{2.5}$ formation from 2007 – 2025 for both scenarios.

Figure 33 – Combined Cumulative Health Impacts Due to LCFS-attributed Biomass-Based Diesel PM Emissions and Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 1 (2015 LCFS EA Scenario Volumes, Method III Attribution)

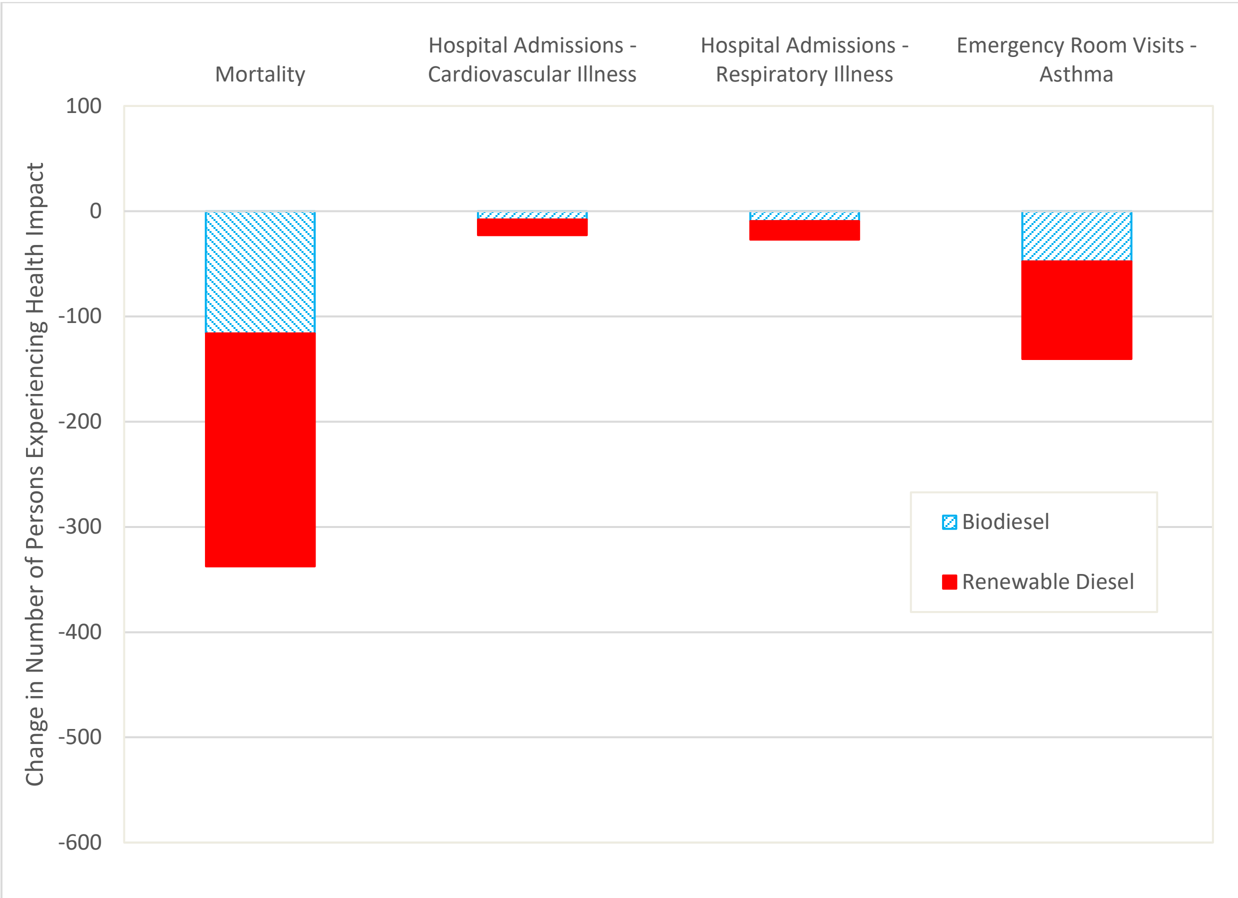
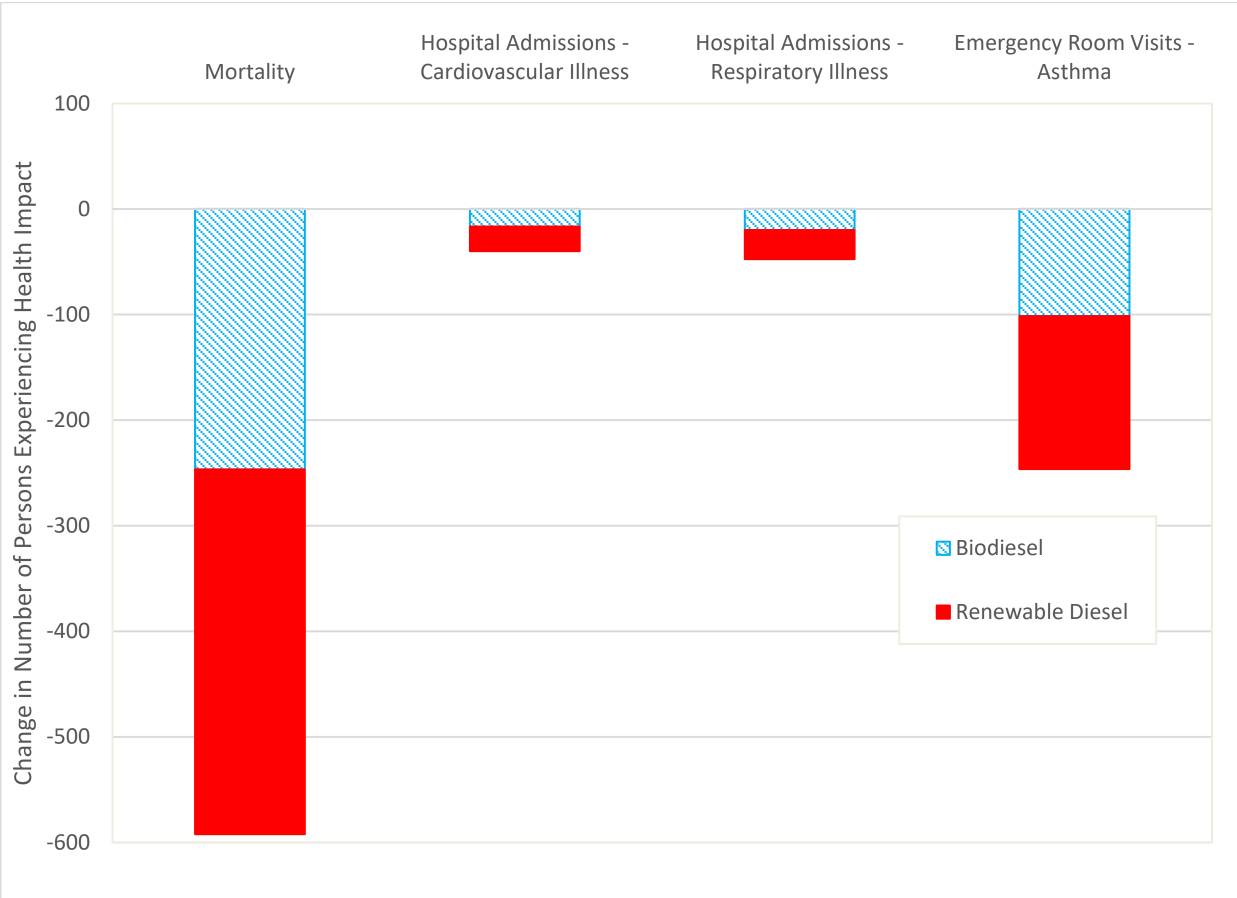


Figure 34 – Combined Cumulative Health Impacts Due to LCFS-attributed Biomass-Based Diesel PM Emissions and Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 2 (2018 LCFS EA BAU Scenario Volumes, Method III Attribution)



d. Impact of LCFS-attributed Biomass-Based Diesel NOx Emissions on Ozone Concentrations and Ozone-Related Health Impacts

As indicated in Section E.2, methods to quantify the impacts of NOx emissions on ozone concentrations and health impacts are regional, complex, and uncertain.[166] Therefore, staff qualitatively evaluated how changes in LCFS-attributed biomass-based diesel NOx emissions could affect ozone concentrations and ozone-related health impacts.

The potential impacts of LCFS-attributed NOx emissions due to biomass-based diesel use on ozone concentrations and ozone-related health impacts were evaluated by

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[166] Estimation of ozone concentrations depends on several variables (e.g., concentrations of NOx and VOCs, solar radiation, temperature and wind speed) that vary based on time and location.

comparing these NOx emissions to the statewide NOx emissions inventory. LCFS NOx emissions associated with use of biomass-based diesel were compared with total statewide NOx emissions and changes in statewide NOx emissions for the period of 2007 – 2025, as shown in **Figures 8** and **9**, respectively.

As discussed in Section D.3.a.i, **Figure 8** shows that maximum statewide LCFS-attributed biomass-based diesel NOx emissions are approximately 0.1 percent of total statewide NOx emissions for Scenarios 1 and 2. Assuming that changes in NO_2 and ozone concentrations are proportional to changes in NOx emissions,[167] staff estimated that statewide NO_2 and ozone concentrations could increase by as much as 0.1 percent statewide for both scenarios. **Figure 8** also shows LCFS-attributed biomass-based diesel NOx emissions that could result in statewide ozone concentration reductions under Scenarios 1 and 2 for a number of years.[168]

The State standard for ozone was last revised in 2005, and at that time it was estimated that exposures to ozone above the standard contributed to approximately 630 premature deaths annually.[169] Ozone concentrations have decreased in the last

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[167] The relationship between NOx emissions and ozone concentrations is complex, and depends on several other variables, including VOC concentrations, solar radiation, and temperature. For the purposes of this qualitative analysis, staff assumed that ozone concentrations would increase with NOx emissions increases, and would scale at less than a one-to-one ratio (e.g., ozone concentrations would increase at a lower rate than NOx emissions increases). Staff also notes that, under certain conditions (i.e., relatively low VOC/NOx ratios), ozone concentrations can increase with decreasing NOx emissions. See:

National Research Council. 1991. Rethinking the Ozone Problem in Urban and Regional Air Pollution. Washington, DC. The National Academies Press. pp. 163-168. Available at: https://www.nap.edu/catalog/1889/rethinking-the-ozone-problem-in-urban-and-regional-air-pollution. Accessed: September, 2017.

Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. pp. 14-16. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

[168] Under certain conditions (i.e., relatively low VOC to NOx concentration ratios), NOx emissions reductions result in increased ozone concentrations. See Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

[169] CARB. 2005. Staff Report: Initial Statement of Reasons for Review of the California Ambient Air Quality Standard for Ozone, Volume IV of IV, Appendices B-G, October 2005 Revision. October 27. Available at: https://www.arb.ca.gov/carbis/research/aaqs/ozone-rs/rev-staff/vol4.pdf Accessed: November, 2017.

decade,[170] and the annual number of premature deaths and other health impacts attributed to ozone exposure are expected to be lower in 2017 than they were in 2005. Since changes in ozone concentration are generally less than proportional to the corresponding emissions changes of a single ozone precursor,[171] changes in ozone concentrations would be expected to be less than the changes in NOx emissions. Therefore, increases in ozone concentrations resulting from LCFS-attributed biomass-based diesel NOx emissions from 2007 - 2025 would:

- Be very small on an absolute basis. Increases in ozone concentrations due to LCFS-attributed biomass-based diesel NOx emissions as a percent of total ozone concentrations would be less than LCFS NOx emissions as a percent of total statewide NOx emissions. Based on **Figure 8**, staff estimated that increases in ozone concentrations due to LCFS-attributed biomass-based diesel NOx emissions would be less than 0.1 percent of total ozone concentrations (i.e., less than the LCFS-attributed biomass-based diesel NOx emissions as a percent of statewide NOx emissions in the peak year). Assuming that changes in ozone health impacts are proportional to changes in ozone concentrations, and based on CARB's 2005 estimate of premature deaths due to ozone above the standard,[172] staff conservatively estimated a potential increase of less than one premature death per year due to increases in ozone concentrations resulting from LCFS-attributed biomass-based diesel NOx emissions due to biomass-based diesel use. This estimate is more than an order of magnitude less than the combined annual reductions in premature death due to LCFS-attributed biomass-based diesel PM emissions and secondary PM formation for Scenarios 1 and 2, as shown in **Figures 31** and **32**.

- Result in only a very small change in ongoing progress in reducing ozone exposures due to the substantial reductions in NOx emissions occurring between 2007 and 2025 due to implementation of other control programs (e.g., CARB

[170] Based on a review of national design values and state designation values for 1-hour observations and 8-hour averages for ozone from 2005 – 2016 for California air basins from CARB iADAM database. CARB. 2017. iADAM: Air Quality Data Statistics. Available at: https://www.arb.ca.gov/adam. Accessed: January, 2018.

[171] Hidy, George M. and Charles L. Blanchard. 2015. Precursor reductions and ground-level ozone in the Continental United States, Journal of the Air & Waste Management Association, 65:10, 1261-1282. Available at: http://www.tandfonline.com/doi/pdf/10.1080/10962247.2015.1079564. Accessed: January, 2018.

[172] As indicated above, ozone concentrations, and premature deaths due to ozone concentrations above the ozone standard, have decreased since 2005. Therefore, the use of CARB's 2005 estimate of annual premature deaths due to exposures to ozone above the State standard is conservative (i.e., overestimates health impacts due to ozone from LCFS-attributed NOx emissions from biomass-based diesel use).

Truck and Bus Regulation,[173] CARB In-Use Off-Road Diesel-Fueled Fleets Regulation[174], Carl Moyer Program,[175] Goods Movement Emissions Reduction Program,[176] and Lower-Emission School Bus Program[177]), as shown in **Figure 4**.

[173] CARB. 2014. Final Regulation Order. Title 13, California Code of Regulations (CCR), Section 2025. Regulation to Reduce Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use Heavy-Duty Diesel-Fueled Vehicles. December 31. Available at: https://www.arb.ca.gov/msprog/onrdiesel/documents/tbfinalreg.pdf. Accessed: September, 2017.
[174] CARB. 2011. Final Regulation Order. Title 13 California Code of Regulations (CCR), section 2449.Regulation for In-Use Off-Road Diesel Vehicles. Available at: https://www.arb.ca.gov/regact/2010/offroadlsi10/finaloffroadreg.pdf. Accessed: September, 2017.
[175] CARB. 2017. The Carl Moyer Program Guidelines, 2017 Revisions, Volume 1: Program Overview, Program Administration, and Project Criteria. May. Available at: https://www.arb.ca.gov/msprog/moyer/april2017_boarditem_proposedmoyerguidelines_vol1.pdf. Accessed: February, 2018.
[176] CARB. 2015. Proposition 1B: Movement Emission Reduction Program. Final 2015 Guidelines for Implementation. June. Available at: https://www.arb.ca.gov/bonds/gmbond/docs/prop_1b_goods_movement_2015_program_guidelines_for_implementation.pdf. Accessed: Febuary, 2018.
[177] CARB. 2008. Lower-Emission School Bus Program, 2008 Guidelines. April. Available at: https://www.arb.ca.gov/bonds/schoolbus/guidelines/2008lesbp.pdf. Accessed: February, 2018.

F. ALTERNATIVES ANALYSIS

This section satisfies CEQA Guidelines Section 15126.6, which addresses requirements related to alternatives for proposed projects. In this analysis, the project (i.e., the approval of the original and modified LCFS regulations, as described in Sections A.1 and B.2), is comprised of actions that occurred in the past. This supplemental disclosure analysis also proposes to mitigate potentially significant future air quality impacts due to NOx emissions increases associated with the future operation of the project previously adopted. This proposed action, an amendment to the ADF regulation that revises the sunset provision for biodiesel in-use requirements to mitigate potential NOx emissions increases associated with off-road engines, is part of the Proposed Amendments (i.e., the proposed amendments to the LCFS and ADF regulations) supported by the supplemental disclosure discussion contained in this Appendix G.[178]

As noted above, the purpose of a CEQA alternatives analysis is to evaluate alternatives that could reduce or avoid the project's significant environmental impacts.[179] While CEQA does not provide a clear framework for evaluating alternatives to address wholly past impacts (particularly air quality impacts which have already left the atmosphere), consistent with the most closely-applicable CEQA Guidelines[180] and with the writ of mandate, CARB has evaluated alternatives to the project (i.e., the original and modified LCFS regulations, as well as the ADF regulation) and to the Proposed Amendments (which includes mitigation through a proposed amendment to the ADF regulation) that address diesel fuel and its substitutes. Staff's alternatives analysis focused the evaluation of feasible alternatives (i.e., alternatives to the Proposed Amendments that could be implemented in the future). However, because the alternative analysis also discusses alternatives to actions that occurred in the past, staff also discuss potential impacts for each alternative based on historical implementation (i.e., implementation of each alternative in place of or as part of the project adopted in 2009).

The following discussion provides an overview of the steps taken to develop alternatives to the project and Proposed Amendments, the objectives associated with the project and Proposed Amendments, and an analysis of the alternatives' environmental effects and ability to meet the objectives of the project and Proposed Amendments.

[178] CARB. 2018. Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Proposed Amendments to the Low Carbon Fuel Standard and Alternative Diesel Fuels Regulations. March.
[179] Cal. Pub. Resources Code § 21002.
[180] See 14 CCR § 15126.6.

1. Approach to Alternatives Analysis

CARB's certified regulatory program requires that where a contemplated action may have a significant effect on the environment, a staff report shall be prepared in a manner consistent with the environmental protection purposes of CARB's regulatory program and with the goals and policies of CEQA.[181] Among other things, the staff report must address feasible alternatives to the proposed action that would substantially reduce any significant adverse impact identified.

The certified regulatory program provides general guidance that any action or proposal for which significant adverse environmental impacts have been identified during the review process shall not be approved or adopted as proposed if there are feasible mitigation measures or feasible alternatives available that would substantially reduce such adverse impact. For purposes of this section, "feasible" means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors, and consistent with the Board's legislatively mandated responsibilities and duties.[182]

While CARB, by virtue of its certified program, is exempt from Chapters 3 and 4 of CEQA and corresponding sections of the CEQA Guidelines, the Guidelines nevertheless provide useful information for preparation of a thorough and meaningful alternatives analysis. CEQA Guidelines section 15126.6(a) speaks to evaluation of "a range of reasonable alternatives to the proposed action, or the location of the proposed action, which would feasibly attain most of the basic objectives of the proposed action but would avoid or substantially lessen any of the significant effects, and evaluate the comparative merits of the alternatives."[183] The purpose of the alternatives analysis is to determine whether or not different approaches to or variations of the proposed action would reduce or eliminate significant impacts, within the basic framework of the objectives, a principle that is consistent with CARB's regulatory requirements.

The range of alternatives is governed by the "rule of reason," which requires evaluation of only those alternatives "necessary to permit a reasoned choice."[184] Further, an agency "need not consider an alternative whose effect cannot be reasonably ascertained and whose implementation is remote and speculative."[185] The analysis should focus on alternatives that are feasible and that take economic, environmental, social, and technological factors into account. Alternatives that are remote or speculative need not be discussed. Furthermore, the alternatives analyzed for a

[181] California Code of Regulations, Title 17, § 60000 – 60008.
[182] California Code of Regulations, Title 17, § 60006.
[183] California Code of Regulations, Title 14, § 15126.6(a).
[184] California Code of Regulations, Title 14, § 15126.6(f).
[185] California Code of Regulations, Title 14, § 15126.6(f)(3).

proposed action should focus on reducing or avoiding significant environmental impacts associated with the action as proposed.

2. Objectives of the Project and Proposed Amendments

The primary objectives of the project include:

1. Reduce the carbon intensity of transportation fuels in the California market by at least 10 percent of its 2010 level by 2020 to reduce GHG emissions from the State's transportation sector;

2. Diversify the State's fuel portfolio;

3. Reduce the State's dependence on petroleum;

4. Decrease the associated economic impacts of gasoline and diesel price spikes caused by volatile oil price changes;

5. Provide greater innovation and development of cleaner fuels, and support for California's ongoing efforts to improve ambient air quality.

6. Establish a comprehensive legal path to bring new or emerging diesel fuel substitutes to the commercial market in California as efficiently as possible while preserving or enhancing public health, the environment, and the emissions benefits of the state's existing motor vehicle diesel regulations; and

7. Establish specific rules governing the use of biodiesel fuel to ensure its use will meet the program goals of protecting public health and the environment.

The primary objectives of the Proposed Amendments are very similar to the project objectives, and include:

1. Improve California's long-term ability to support the consumption of increasingly lower-carbon intensity fuels and to improve the program's overall effectiveness;

2. Strengthen the carbon intensity reduction targets beyond 2020 in-line with California's 2030 GHG reduction requirement enacted through Senate Bill (SB) 32;[186]

3. Reduce the carbon intensity of transportation fuels in the California market by at least 20 percent of its 2010 level by 2030;

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[186] Senate Bill 32, Chapter 249, Statutes of 2016.

4. Provide greater diversification of the State's fuel portfolio;

5. Provide reduced dependence on petroleum;

6. Decrease the associated economic impacts of gasoline and diesel price spikes caused by volatile oil price changes;

7. Provide greater innovation and development of cleaner fuels, and support for California's ongoing efforts to improve ambient air quality;

8. Provide additional, cost-effective LCFS compliance options including carbon capture and sequestration (CCS) and alternative jet fuel; and

9. Mitigate potential NOx emissions increases relative to conventional diesel due to biodiesel use attributed to the LCFS.

3. Description of Alternatives

A detailed description of each alternative is presented below. The analysis that follows the descriptions of the alternatives includes a discussion of the degree to which each alternative meets the basic objectives of the project and Proposed Amendments, and the degree to which each alternative avoids potentially significant impacts identified in Section D.

CEQA requires that a No Project Alternative be considered (CEQA Guidelines Section 16126.6(e)). Typically, the purpose of describing and analyzing a no project alternative is to allow decision makers to compare the impacts of approving the proposed project with the impacts of not approving the proposed project. However, here the project (i.e., the original and modified LCFS regulations) has already been approved and adopted. Therefore, the No Project Alternative evaluates impacts projected to occur in the future, and that would have occurred in the past, without the project. As part of this alternative, staff also assumed that the currently proposed amendment to the ADF regulation would not be adopted.

As indicated above, this alternatives analysis evaluates alternatives to the project and Proposed Amendments that address diesel fuel and its substitutes. In addition to the No Project Alternative, staff evaluated the Exempt Biodiesel from the LCFS Alternative and the Require Mitigation for All Biodiesel Blends Alternative.

a. Alternative 1: No Project Alternative

i. Description

Under the No Project Alternative, the LCFS would be set aside and the Proposed Amendments would not be adopted. Staff evaluated a similar alternative (i.e., the setting aside of the project) as part of the alternatives analysis for the LCFS regulations adopted in 2015.[187] Staff also assessed the No Project Alternative assuming that the project had not been approved and adopted in 2009.

ii. Discussion

If the existing LCFS and ADF regulations are set aside and the Proposed Amendments are not adopted, other existing regulations relating to fuels including Cap-and-Trade, Advanced Clean Cars, the Federal Renewable Fuel Standard, CARB's Pavley Regulations, and the federal vehicle emissions standards would still drive GHG reductions in the State. However, without the additional incentives driven by the LCFS that would reduce the average carbon intensity value of fuels in California,[188] feedstocks and fuels would likely be different than under the existing LCFS regulations. While other programs, including the federal Renewable Fuel Standard, would likely reduce average carbon intensity in California to some extent, it would not do so as much as the combination of the RFS and LCFS programs. Indeed, EPA itself has recognized that multiple, reinforcing incentives are necessary to drive innovation and production in the clean fuels space. *See* 80 Fed. Reg. 33,101-33,102 (recognizing "real-world limitations" on renewable fuel development); 33,103 (noting "myriad" programs that complement RFS in attempting to reduce those limitations). Without implementation of LCFS there would be lesser or no incentives to maintain or reduce carbon intensity values of fuels, diversification of the State's fuel portfolio, development of commercialization pathways for biodiesel and other alternative diesel fuels, or specifications set to reduce NOx emissions from biodiesel. Thus, the basic project objectives would not be met.

Similarly, the objectives of the project would not have been met had the project not been adopted in 2009, for the reasons discussed above.

iii. Environmental Impacts

Assuming that compliance responses associated with the project would not occur under this alternative, California's fuel portfolio would not be likely to change substantially and average carbon intensity values of fuels would be much less likely to be reduced. Thus, potentially significant impacts due to compliance responses that could result in changes in shipment patterns, land use changes, additional infrastructure, and methods used to

[187] CARB. 2015. Appendix B – Final Environmental Analysis for the Low Carbon Fuel Standard and Alternative Diesel Fuel Regulations. September 21. pp. 155-158 Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/environmentalanalysis.pdf. Accessed: January, 2018.

[188] As indicated in Section C.1, the U.S. federal government provides incentives for biodiesel and renewable diesel production and blending.

obtain carbon intensity credits would be avoided. However, beneficial impacts related to GHG emissions and statewide air quality, including long-term reductions in PM associated with alternative diesel fuels such as biodiesel and renewable diesel, would not be realized.[189]

Similarly, if the project had not been approved and adopted, and compliance responses associated with the LCFS and ADF regulations had not occurred, California's fuel portfolio would not likely have changed substantially and the average carbon intensity values of fuels would not have been reduced. Consequently, potentially significant impacts related to compliance responses associated with the project would also not have occurred. However, as described above, beneficial impacts related to GHG emissions and air quality associated with alternative diesel fuels such as biodiesel and renewable diesel, would not have been achieved, and this impact would be considered significant.[190]

b. Alternative 2: Exempt Biodiesel from the LCFS Alternative

i. Description

Under Alternative 2, biodiesel would be exempted from the current LCFS regulations as part of the Proposed Amendments and, therefore, would not be able to generate LCFS credits once such amendments were adopted and took effect. This alternative would maintain all other provisions of the project and Proposed Amendments, except for the biodiesel in-use requirements in Section 2293.6(a) of the current ADF regulation, which might be removed or revised,[191] and the proposed amendment to the ADF regulation, which may not be adopted.[192] Both the biodiesel in-use requirements and the proposed

[189] CARB. 2015. Appendix B – Final Environmental Analysis for the Low Carbon Fuel Standard and Alternative Diesel Fuel Regulations. September 21. pp. 56–61 and 155-158 Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/environmentalanalysis.pdf. Accessed: January, 2018.
[190] CARB. 2015. Appendix B – Final Environmental Analysis for the Low Carbon Fuel Standard and Alternative Diesel Fuel Regulations. September 21. pp. 56–61 and 155-158 Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/environmentalanalysis.pdf. Accessed: January, 2018.
[191] The biodiesel in-use requirements in Section 2293.6(a) of the ADF regulation were designed to mitigate NOx emissions due to the use of biodiesel blends of B20 and lower attributed to the LCFS. If biodiesel is exempted from the LCFS, there would likely be no biodiesel use attributed to the LCFS, and therefore no NOx emissions due biodiesel use attributed to the LCFS requiring mitigation. CARB may still decide in-use requirements are necessary for other purposes but would need to conduct additional analysis; adoption and amendment would not be tied to the LCFS rulemaking.
[192] As described further in Section F.3.b.ii, this alternative would likely lead to a decrease in biodiesel consumption and an increase in renewable diesel use, resulting in a decrease in NOx emissions. This reduction in NOx emissions due to biomass-based diesel use may preclude the need for the proposed amendment to the ADF regulation, which was designed to reduce NOx emissions associated with biodiesel use in off-road engines.

ADF amendment would have to be further analyzed to determine the effects of exempting biodiesel from the LCFS. The ADF regulation and amendment may or may not be adopted depending on the result of that analysis. As part of the evaluation of this alternative, staff also analyzed the impacts of exempting biodiesel from the project as adopted in 2009.

ii. Discussion

The exemption of biodiesel from the LCFS as part of the Proposed Amendments would provide no additional incentive for biodiesel use in California beyond federal incentives,[193] and would likely result in a substantial decrease in the current level of biodiesel production and consumption in California relative to the future projections of likely LCFS compliance responses. Biodiesel is currently one of the cheapest LCFS compliance options. Because of this, increased production and consumption of other more expensive fuels, such as renewable diesel, and implementation of additional petroleum-based projects would be necessary to replace credits that would have been generated by biodiesel. This would make it more difficult and more expensive for the LCFS to achieve future carbon intensity reductions and associated GHG reduction benefits. Therefore, this alternative would fail to meet the objectives of the existing LCFS and Proposed Amendments, and would likely hinder the attainment of several other objectives of the LCFS as a whole and the Proposed Amendments by increasing the costs for regulated parties associated with achieving the objectives.

The exemption of biodiesel from the project, as adopted in 2009, would have caused changes similar to those described above. The removal of the additional incentive for biodiesel use in California beyond the federal incentives would have likely led to lower increases in historical biodiesel consumption. LCFS credits that were generated by biodiesel may have instead been generated by consumption of more expensive fuels or through increased implementation of petroleum-based projects. Therefore, the average carbon intensity reduction and GHG benefits achieved by the project may not have been achieved by this alternative, or would have been more expensive to achieve.

iii. Environmental Impacts

The use of biodiesel in place of conventional diesel can result in an increase in NOx emissions when used in older, heavy-duty engines, and a decrease in PM emissions. Therefore, reductions in LCFS-attributed biodiesel use associated with this alternative would likely result in a decrease in LCFS NOx emissions relative to the project and Proposed Amendments. Likely increases in renewable diesel use would further reduce NOx emissions relative to the project and Proposed Amendments. In addition, because production of biodiesel would not be incentivized by the LCFS, the number of biodiesel

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[193] As indicated in Section C.1, the U.S. federal government provided incentives for biodiesel production and blending.

production facilities constructed or modified to meet demand would be reduced, thus reducing the environmental impacts related to construction and operation of these new and modified facilities.

However, this alternative could result in the construction or modification of facilities to produce additional quantities of other fuels (e.g., renewable diesel), potentially increasing environmental impacts associated with construction and operation of these facilities. This alternative would also likely result in future NOx emissions increases associated with non-LCFS-attributed biodiesel that might not be mitigated as opposed to if such biodiesel had been mitigated through the NOx specifications for biodiesel in the current and amended ADF regulation. Most importantly, this alternative would likely result in increased PM emissions relative to the project and Proposed Amendments as biodiesel use results in more substantial PM emissions reductions compared to both conventional diesel and renewable diesel use. As indicated in Section E., changes in health impacts associated with biomass-based diesel use relative to conventional diesel use are driven by PM emissions reductions. Therefore, Alternative 2 would likely result in decreased overall health benefits compared to the project and Proposed Amendments.

The exemption of biodiesel from the project, as adopted in 2009, would have resulted in impacts similar to those projected for this alternative, as described above. Decreases in biodiesel use and increases in renewable diesel use relative to the project would have resulted in avoided LCFS NOx emissions. Also, avoided construction associated with new or modified biodiesel production facilities would have avoided construction- and operational-related impacts of these facilities. However, historical implementation of this alternative would have also resulted in increased PM emissions and reduced overall health benefits compared to the project, as well as likely increased construction and operational emissions from other types of alternative fuel facilities.

c. Alternative 3: Require Mitigation for all Biodiesel Blends

i. Description

The current ADF regulation requires NOx mitigation of biodiesel to the level of conventional diesel using NOx-reducing additives depending on biodiesel blend level and saturation level and the season of the year. Under the Require Mitigation for all Biodiesel Blends Alternative, the LCFS would require NOx mitigation to the level of conventional diesel for all biodiesel blends, regardless of biodiesel saturation level and season of the year. This alternative would maintain all other provisions of the project and Proposed Amendments except for the biodiesel in-use requirements in Section

2293.6(a) of the current ADF regulation, which would be removed,[194] and the proposed amendment to the ADF regulation, which would likely not be adopted.[195] As part of the evaluation of this alternative, staff also analyzed the impacts of requiring NOx mitigation of all biodiesel blends to the level of conventional diesel for the project as adopted in 2009. Staff analyzed a very similar alternative as part of the alternatives analysis for the LCFS regulations adopted in 2015.[196]

ii. Discussion

The future effects of requiring NOx mitigation of all biodiesel blends to the level of conventional diesel would be a likely increase in the use of additives, such as Di-tert-butyl peroxide or renewable diesel, to reduce NOx emissions associated with biodiesel use. This would increase the cost of biodiesel, which is currently one of the cheapest compliance options for the LCFS. The increased cost of biodiesel would likely reduce the incentive for its use, leading to a likely decrease in biodiesel consumption in California relative to projected levels for the project following the adoption of the Proposed Amendments. Because of this, greater quantities of other, more expensive fuels, including renewable diesel, would be necessary to replace credits that could otherwise be generated by biodiesel. Therefore, this alternative would make it more difficult and expensive to generate the average carbon intensity reductions and GHG benefits associated with the project following the adoption of the Proposed Amendments.

If NOx mitigation were required for all biodiesel blends as part of the LCFS, as adopted in 2009, it would have also likely led to increased use of biodiesel additives, resulting in higher costs for biodiesel use. The increased costs for biodiesel would likely have resulted in decreased biodiesel production relative to the project, and increased use of more expensive fuels such as renewable diesel, making it more expensive and difficult to achieve the average carbon intensity reductions and GHG benefits realized by the project.

iii. Environmental Impacts

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[194] The biodiesel in-use requirements in Section 2293.6(a) of the ADF regulation were designed to mitigate NOx emissions due use of biodiesel blends of B20 and lower attributed to the LCFS. If all biodiesel blends are NOx-mitigated to the level of conventional diesel under LCFS, this provision would not be required as it would be redundant.

[195] The proposed amendment to the ADF regulation was designed to reduce NOx emissions associated with biodiesel use in off-road engines. If all biodiesel blends are NOx-mitigated to the level of conventional diesel under LCFS, this proposed amendment would not be required.

[196] CARB. 2015. Appendix B – Final Environmental Analysis for the Low Carbon Fuel Standard and Alternative Diesel Fuel Regulations. September 21. pp. 155-158 Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/environmentalanalysis.pdf. Accessed: January, 2018.

The requirement to mitigate NOx emissions associated with all biodiesel blends under this alternative would result in avoided NOx emissions relative to project following adoption of the Proposed Amendments. Potential increases in renewable diesel use would also result in avoided NOx emissions. In addition, because production of biodiesel would not be as incentivized by the LCFS, the number of biodiesel production facilities constructed or modified to meet demand would be reduced, thus reducing the environmental impacts related to construction and operation of these new and modified facilities.

However, this alternative could result in the construction or modification of facilities to produce additional quantities of additives that would be necessary to mitigate biodiesel emissions, or quantities of other fuels (e.g., renewable diesel), potentially increasing environmental impacts associated with construction and operation of these facilities. More importantly, the alternative would also likely result in increased PM emissions as biodiesel use results in more substantial PM emissions reductions compared to both conventional diesel and renewable diesel use. As indicated in Section E, changes in health impacts associated with biomass-based diesel use relative to conventional diesel use are driven by PM emissions reductions. Therefore, Alternative 3 would likely result in decreased overall health benefits compared to the currently operative LCFS and Proposed Amendments. This is underscored by the fact that the project, and the Proposed Amendments, mitigate the NOx impacts of the project, which eliminates any comparative benefit from this alternative.

If adopted in 2009 along with the original LCFS, a requirement to mitigate NOx emissions from all biodiesel blends would likely have had similar environmental impacts to those described above relative to the regulatory scheme that was historically in effect. Decreased biodiesel use and increased renewable diesel use would have resulted in avoided NOx emissions relative to the observed project implementation scenario, and decreased biodiesel production would have also resulted in reduced associated environmental impacts. However, increased production of additives and replacement fuels could have resulted in increased environmental impacts, and increased PM emissions associated with lower biodiesel use would likely have resulted in decreased overall health benefits.

APPENDIX 1

METHODS FOR ATTRIBUTION OF BIOMASS-BASED DIESEL VOLUMES TO THE LCFS

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Appendix 1: Methods for Attribution of Biomass-Based Diesel Volumes to LCFS

A. Method I. Testing for Correlation using Statistical Models

Staff attempted to assess the effect that the LCFS had on biomass-based diesel volumes by comparing California trends to trends that have occurred in other regions of the United States that do not have an LCFS in place. Specifically, staff completed broad statistical evaluations using multiple regression analysis, testing a wide variety of possible independent variables, including LCFS credit prices, to attempt to understand what drove the increased use of biomass-based diesel over the relevant historical period.

The purpose of this exercise was to attempt to determine how well-correlated the volumes of biomass-based diesel consumed in California were with LCFS program implementation and the value provided by LCFS credits over the historical period for which data are available. Proving statistical correlation at a high degree of confidence is usually necessary before any definitive statements regarding historical causation can be considered[197]. Because the LCFS targets and credit price have changed over time, there is not only a geospatial aspect, but also a temporal aspect to this analysis.
To better understand what impact the LCFS may have had on biodiesel consumption in California, staff compiled and reviewed the dataset indicated in **Table 1**.

[197] Antonakis, John, et al. "Causality and endogeneity: Problems and solutions." *The Oxford handbook of leadership and organizations* 1 (2014): 93-117.

Table 1 - Data Sources and Types used for Method I Analysis

Item	Data Source	Granularity of Time Series	Timeframe	Geography	Data Type
California Diesel Prices	U.S. EIA[198]	Monthly	2009-2016	CA	Price
LCFS Credit Prices	CARB – LRT Data[199]	Daily	2012-2016*	CA	Price
CA Biodiesel Use	CARB – LRT Data	Quarterly	2010-2016	CA	Quantity
California Diesel Use	CARB – LRT Data[200]	Quarterly	2010-2016	CA	Quantity
Biodiesel Production	U.S. EIA[201]	Monthly	2009-2016	PADD region	Quantity
Biomass-based Diesel Receipts	U.S. EIA[202]	Monthly	2009-2016	PADD region	Quantity
Biomass-based Diesel Stock	U.S. EIA[203]	Monthly	2009-2016	PADD region	Quantity
Biomass-based Diesel Imports	U.S. EIA[204]	Monthly	2009-2016	PADD region	Quantity
Biomass-based Diesel Exports	U.S. EIA [205]	Monthly	2009-2016	PADD region	Quantity
RFS Mandate Volumes	U.S. EPA[206]	Yearly	2009-2016	US	Quantity
Diesel consumption	U.S. EIA [207]	Monthly	2009-2016	PADD	Quantity

***** No LCFS credits existed in 2010, because it was a reporting year, and no trades were reported to CARB in 2011, so prices were zero for those years.

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[198] U.S. EIA. 2017a. Weekly Retail Gasoline and Diesel Prices. September. Available at: https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_sca_w.htm. Accessed: September, 2017 (EMD_EPD2DXL0_PTE_SCA_DPGm.xls).

[199] CARB. 2017a. Weekly Credit Transfer Activity. Low Carbon Fuel Standard. September. https://lcfsint.arb.ca.gov/LCFSRT/. Accessed: September, 2017.

[200] CARB. 2017b. Low Carbon Fuel Standard Reporting Tool Quarterly Summaries. Low Carbon Fuel Standard. April. Available at: https://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm. Accessed: May, 2017

[201] U.S. EIA. 2017b. Monthly Biodiesel Production Report." April, 2017, https://www.eia.gov/biofuels/biodiesel/production/. Accessed: May, 2017

[202] U.S. EIA. 2017c. Net receipts of crude oil and petroleum products by pipeline, tanker, barge, and rail. Petroleum and Other Liquids. February, 2017. https://www.eia.gov/dnav/pet/pet_move_netr_d_r10-z0p_VNR_mbbl_m.htm. Accessed: May, 2017

[203]U.S. EIA. 2017d. Stocks by Type. Petroleum and Other Liquids. February. https://www.eia.gov/dnav/pet/pet_stoc_typ_d_nus_SAE_mbbl_m.htm. Accessed: May, 2017

As indicted above, some data are available only for California or only for each Petroleum Administration for Defense District (PADD). PADDs divide the United States into five regions. Region 5 is the West Coast, which includes California, Oregon, Washington, Nevada, Alaska, Hawaii, and Arizona. For biodiesel data, U.S. EIA only started collecting data part way through 2009, and the LCFS program similarly only has California consumption data starting in 2010, with credit price data starting in 2012. Given that statistical analysis is more robust for larger time series, staff has used the earliest recorded data available for each data set. The largest dataset available is at the PADD-level without explicit LCFS prices.

U.S. EIA tracks biodiesel production and consumption across different PADDs for different time intervals, but it does not track renewable diesel production and consumption. Accordingly, the statistical analysis to assess renewable diesel volumes is limited to a much smaller, California-specific, dataset.

The PADD data, which includes regions outside of California, is recorded at monthly intervals for production, stocks, and volume flows. Biodiesel consumption is not directly broken down by PADD at a monthly level, and so must be estimated. Using U.S. EIA data, biodiesel consumption in each PADD was estimated as being the unaccounted difference in biodiesel volumes when accounting for biodiesel production, biodiesel imports, biodiesel exports, change in existing stock, and volume transfers between PADDs (Net Receipts).

$$BD\ Consumption = BDProduction + BD\ NetImports + NetReceipts - \Delta(BDStock)$$

U.S. EIA defines Net Receipts as “the difference between total movements into and total movements out of each PADD district by pipeline, tanker, and barge.” BD Net Imports accounts for imports from and exports to non-PADD regions (regions outside the U.S.). Given the monthly PADD data for each of the five PADDs, the largest dataset available for analysis consists of 450 data points. As this PADD-specific dataset is the largest, models made using this dataset are likely to be more robust, and provide more meaningful statistical interpretations than for smaller data series. Using this larger PADD dataset, staff created models to predict Biodiesel Consumption as a function of key explanatory variables. Given the limited time-scale resolution for some possible

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[204] U.S. Energy Information Administration. “PAD District Imports by Country of Origin.” *Petroleum and Other Liquids*. February, 2017. <https://www.eia.gov/dnav/pet/pet_move_impcp_a2_r10_EPOORDB_im0_mbbl_m.htm>. Accessed: May, 2017

[205] U.S. Energy Information Administration. “Exports.” *Petroleum and Other Liquids*. February, 2017. < https://www.eia.gov/dnav/pet/pet_move_exp_dc_R10-Z00_mbbl_m.htm >. Accessed: May, 2017

[206] U.S. Environmental Protection Agency. “Final Renewable Fuel Standards for 2017, and the Biomass-Based Diesel Volume for 2018”. <https://www.epa.gov/renewable-fuel-standard-program/final-renewable-fuel-standards-2017-and-biomass-based-diesel-volume>. Accessed: September 2017

[207] U.S. Energy Information Administration. “Product Supplied.” *Petroleum and Other Liquids.* February, 2017. <https://www.eia.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_m.htm>. Accessed: May, 2017

explanatory variables (for instance, CARB only has quarterly data for biodiesel consumption in California), only a small subset of possible explanatory variables could be used. One model considered was a simple, quantity-based model that excluded price effects to determine whether having an LCFS policy in a specific PADD was a major predictor of biodiesel consumption volumes. This model included an LCFS "dummy" variable for whether LCFS policy had been enacted in a given region (which takes the value of 1 for PADD 5 and 0 otherwise), the RFS Volume Mandate, and total Diesel Consumption in each PADD. The biodiesel blender's tax credit was in place and did not change in value for all years considered, and thus appears only as part of the regression constant for all models.

$$\begin{aligned} BD\ Consumption \\ &= Diesel\ Consumption + LCFS\ Region + RFS \\ &+ Lagged\ BD\ Consumpton \end{aligned}$$

Although it is possible to analyze each month in the time series as an independent observation, this is likely to create incorrect model outcomes. For regression analysis to provide good estimates, the error from modeling must be uncorrelated. As changes from one month to the next; however, are likely to be related (e.g. seasonality changes, there is unlikely to be a sudden and dramatic change in travel behaviors), it is important to consider time trend, or "autocorrelation" effects. As such, models that do not include a "lag" variable, a variable that considers what biodiesel consumption had been at a previous time interval, are unlikely to yield correct results.[208] With and without the autoregressive term included, however, the PADD-level model (the model made using the largest data set), indicates that having an LCFS policy in place within the PADD region does not improve model fit, and so is not a strong driver of biodiesel consumption. These model results are detailed in **Appendix 2** (Models M4 and M5).

Although there is no discernable LCFS effect compared to other explanatory variables at the PADD level, it is worth noting that other regions grouped into the PADD could mask the LCFS effect. As such, staff have looked to further disaggregate the data by breaking out California from PADD 5 (CA-PADD Model). Given that California data are only available at quarterly intervals, the number of data points for California analysis further decreases from 450 at the PADD-level to only 114 (4 Quarters for 2012-2015, 3 Quarters for 2016, and 5 PADD regions + California). Although CARB has biomass-based diesel consumption data prior to 2012, LCFS credit transactions, and therefore LCFS credit prices, only came into effect in 2012. Consequently, staff believe that no biodiesel or renewable diesel use is attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year.

[208] Simonoff, JF. "Ordinary least squares estimation and time series." *Regression and Multivariate Data Analysis.* August, 2016. <http://people.stern.nyu.edu/jsimonof/classes/2301/pdf/regtime.pdf>. Accessed: September, 2017

Given that these datasets are still quite small, it is important to limit the number of variables being tested in the model, or model over-fit may occur. Although there are many variables worth considering, staff believes that the more important variables for consideration are diesel consumption, biodiesel production, the RFS mandate, and the LCFS incentive as measured by the credit price translated to a fuel “subsidy”. Diesel prices and biodiesel prices are mostly the result of balancing supply and demand, so would not necessarily be considered independent variables from diesel consumption (demand) and biodiesel production (supply). Furthermore, the RFS credit price is a result of fuel prices and the stringency of the RFS volume mandate.

A similar argument can be made for using LCFS targets versus prices. However, the LCFS target is based on carbon emissions rather than fuel volumes, and so does not directly translate to fuel supply (it translates to supply of carbon). The LCFS credit price can better more easily aligned with biodiesel fuel quantities, rather than carbon, by converting it to a price impact per gallon of fuel. This measurement of biodiesel incentive is likely to be a more direct way to compare biodiesel quantities than to simply specify the annual carbon intensity target for the LCFS program.

This CA-PADD model is discussed in more detail in **Appendix 2** (Models M1 and M2). Even when breaking out the California region from PADD5, the regression analysis again indicates that the LCFS is not a strong determinant of model fit, and that biodiesel consumption is better explained by other variables.

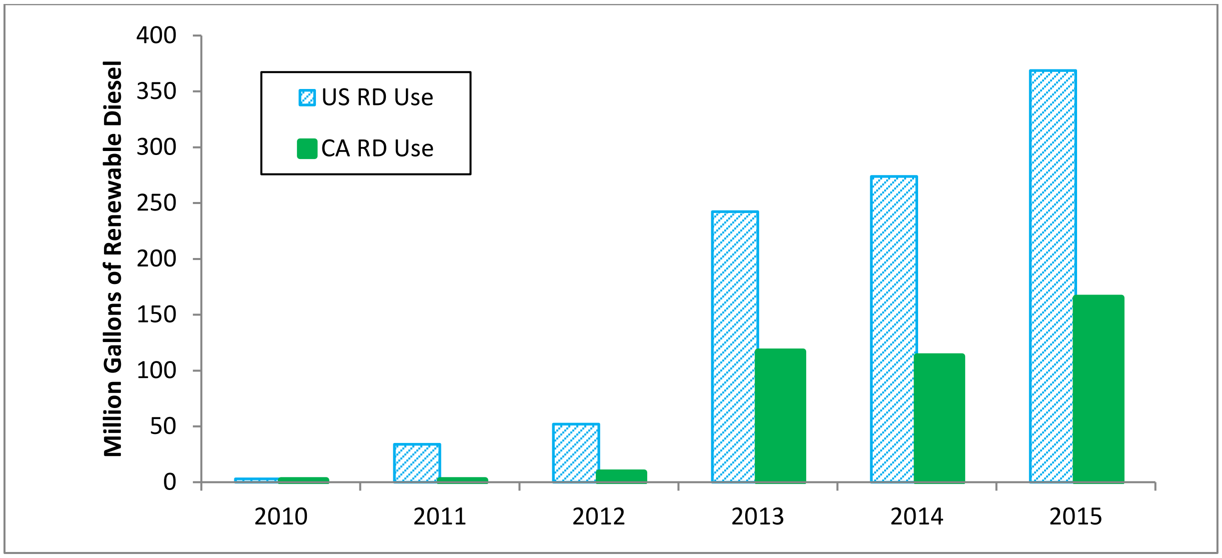
Staff analyzed the California-specific data in a similar fashion to the PADD data (Models M6 – M8). For California-specific data, the time series is given in quarterly intervals (four quarters per year). Due to the limited data available for this California-specific assessment, only 28 points were available for analysis within California. The small number of observations in the quarterly California-specific data makes it inherently more challenging to find statistically robust and significant results, supporting staff’s original assertion that showing correlation, much less causation, may be impossible for the historical period.

In Model M6, staff modeled biodiesel use in California as a function of California diesel price, the RFS Volume Mandate, and the monetary LCFS incentive provided to biodiesel in each quarter ($/gallon). The total diesel amount consumed in California (Model M7), as well as the quantity of biodiesel produced nationally (Model M8) were also considered.

Modeling results indicate that the amount of biodiesel used in California depends strongly on the RFS volume obligation, as well as the price of diesel. Results suggest that the biodiesel fuel incentive created by the LCFS was not a strong predictor for biodiesel used in California at the low LCFS prices observed for most of this historical period.

Although the LCFS was not shown to have a statistically significant effect on biodiesel consumption during the historical period in question, similar statistical approaches indicate that the LCFS may have had a statistically significant, positive effect on renewable diesel use. The United States Department of Agriculture (USDA) has estimated total renewable diesel consumption in the U.S. through 2015.[209] **Figure 1** below shows the amount of renewable diesel that has been used in California relative to total national consumption.

Figure 1. Renewable Diesel Use in California and the United States



There are limited renewable diesel volume data both at a geographic and temporal level. Without other regions as a comparison point, it is difficult to have confidence in any statistical results associated with California renewable diesel consumption.

Building on the biodiesel models, specifically Model 6, staff used a statistical model with a limited number of terms to evaluate renewable diesel consumption in California as it may relate to the price of diesel fuel, the monetary LCFS incentive for renewable diesel, and the RFS mandate (Model M9).

As previously discussed, regression results will be inaccurate if autocorrelation is not considered in the model, so an autoregressive term was also used. From this regression analysis, staff found that the LCFS price incentive was a statistically significant variable, while the RFS volume mandate did not affect renewable diesel consumption. However, because the time series is small, and staff is unable to readily compare renewable diesel use in California to use in other regions, renewable diesel model results should be interpreted with caution.

[209] Carter, Ernest. "U.S. Biodiesel/Renewable Diesel Market." U.S. Department of Agriculture. Office of Global Analysis. May 2016. <https://www.usda.gov/oce/energy/files/US_Biodiesel_RD_MarketJul2016.pdf>. Accessed: May 2017

Since the statistical models that staff attempted did not yield statistically significant results for biodiesel, staff could not find a correlation between biodiesel and LCFS credit prices through statistical modeling for the historical period. However, staff's opinion is that most biomass-based diesel fuel producers believe the LCFS is intended to incent the use of both biomass-based diesels and the program is likely to do so when LCFS prices are high. This relationship is likely to be observed more easily once additional data become available.

In the interim, staff explored other methods to attribute biomass-based diesel volumes to the LCFS in the interest of disclosing to the public the full range of *possible* impacts. Staff emphasizes that these are conceptual methods for attribution (rather than statistically observable correlations that can be used as a starting point to make definitive causal arguments). The two approaches considered (labeled Method II and Method III) are both based on basic economic reasoning and the mechanics that underlie the LCFS program. CARB staff took a conservative approach in the choice of these mechanisms (i.e., attributed higher amounts of biodiesel to the LCFS).

B. Method II. Attribution Based on the Magnitude of Various Biomass-Based Diesel Incentives

In Method II, staff attributes the increase in use of biomass-based diesel to federal and State programs, respectively, based on the relative increases in value of biomass-based diesel from federal and state incentives. **Tables 2** and **3** provide a summary of how, over time, oil prices, the RFS, the LCFS, and federal tax credits affected potential revenue from sales of biodiesel and renewable diesel, respectively, in California.[210]

[210] In a brief submitted to the Court of Appeal on February 24th, 2017, the Natural Resources Defense Council outlined a similar set of variables that may have influenced and contributed to biodiesel uptake in California. The NRDC brief included factors such as fuel prices, federal fuel incentives (such as the Renewable Fuel Standard and the biodiesel blender tax credit), and California fuel incentives (LCFS). In addition to these factors, other factors influencing biodiesel use in California could include total biodiesel produced, the total amount of diesel fuel used, seasonal or time-dependent effects, feedstock availability and prices, infrastructure constraints, carbon intensity values and standards, anticipated state policies, etc.

Table 2 - Revenue Components for Biodiesel in California

Year	Energy Value as Diesel Fuel[211]	Federal Tax Incentive[212]	D4 RIN Value [213]	LCFS Credit Value[214]	Effective Value of Biodiesel	Percent of Policy-derived Value (excluding the energy value) derived from:	
	$'s / gal.	$'s / gal.	$'s / gal.	$'s / gal.	$'s / gal.	Federal Policies	LCFS Credits
2007 – Pre LCFS	$2.92[215]	$1.00	$0.00	$0.00	$3.92	100%	0%
2011	$3.84	$1.00	$1.98	$0.00	$6.82	100%	0%
2012	$3.97	$1.00	$1.64	$0.11	$6.72	96%	4%
2013	$3.87	$1.00	$1.12	$0.46	$6.45	82%	18%
2014	$3.76	$1.00	$0.84	$0.35	$5.95	84%	16%
2015	$2.83	$1.00	$1.12	$0.41	$5.36	84%	16%
2016	$2.49	$1.00	$1.37	$1.08	$5.94	69%	31%
Avg. 2011-16	$3.46	$1.00	$1.35	$0.40	$6.21	85%	15%

[211] U.S. Department of Energy. "California No. 2 Diesel Ultra Low Sulfur (0-15 ppm) Retail prices." *Petroleum and Other Liquids.* May, 2017. <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMD_EPD2DXL0_PTE_SCA_DPG&f=A>. Accessed: May, 26th, 2017. Prices are adjusted to reflect biodiesel's energy content by multiplying by the price of diesel by 126.13/134.47, the relative energy density of a gallon of biodiesel to a gallon of diesel according to CA-GREET 2.0.

[212] Public Law 114-113 and 26 U.S. Code 6426. In some years, the federal Biodiesel Mixture Excise Tax Credit was signed into law for the full years, while in the following years: 2010, 2012, 2014 and 2015, the tax credit was applied retroactively. Sources: Scott Irwin, "*Why Do Blenders Share Retroactively Reinstated Tax Credits with Biodiesel Producers?".* (2015).< http://farmdocdaily.illinois.edu/2015/07/why-blenders-share-retroactively-reinstated-tax.html> Accessed: June, 1st, 2017. Ron Kotrba, "*Biodiesel blenders tax credit passes US House, Senate"* (2015). <http://www.biodieselmagazine.com/articles/646582/biodiesel-blenders-tax-credit-passes-us-house-senate> Accessed: June, 1st, 2017.

[213] Lade, Gabriel, C-Y. Cynthia Lin Lawell, and Aaron Smith. "*Ex post costs and renewable identification number (RIN) prices under the Renewable Fuel Standard*." (2015). Data for 2014 onward came from Argus Media RIN prices. RIN values are obtained by multiplying D4 prices by 1.5 to reflect EPA's rules, which award each gallon of biodiesel 1.5 RINs, due to biodiesel's higher energy content in comparison to ethanol.

[214] The average LCFS credit value for biodiesel for each year was calculated using the following standard formula: $(Diesel\ CI\ Standard\ in\ Year\ t - Biodiesel\ Average\ CI\ in\ Year\ t) \times Average\ LCFS\ Credit\ Price\ in\ Year\ t \times 126.13 \frac{MJ}{gallon} \div 1{,}000{,}000$.

[215] Data for diesel prices did not include the monthly price for Jan. 2007; the number reported for 2007 is the average for Feb. – Dec. 2007.

Table 3 - Revenue Components for Renewable Diesel in California

Year	Energy Value as Diesel Fuel[216]	Federal Tax Incentive[217]	RIN Value [218]	LCFS Credit Value[219]	Effective Value of Renewable Diesel	Percent of Policy-derived Value (excluding the energy value) derived from:	
	$'s / gal.	$'s / gal.	$'s / gal.	$'s / gal.	$'s / gal.	Federal Policies	LCFS Credits
2007 – Pre LCFS	$3.01[220]	$1.00	$0.00	$0.00	$4.01	100%	0%
2011	$3.94	$1.00	$2.24	$0.00	$7.19	100%	0%
2012	$4.08	$1.00	$1.86	$0.13	$7.07	96%	4%
2013	$3.98	$1.00	$1.27	$0.37	$6.62	86%	14%
2014	$3.87	$1.00	$0.95	$0.28	$6.10	87%	13%
2015	$2.91	$1.00	$1.27	$0.30	$5.48	88%	12%
2016	$2.56	$1.00	$1.55	$0.83	$5.94	75%	25%
Avg. 2011-16	$3.56	$1.00	$1.52	$0.32	$6.40	89%	11%

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[216] U.S. Department of Energy. "California No. 2 Diesel Ultra Low Sulfur (0-15 ppm) Retail prices." *Petroleum and Other Liquids.* May, 2017. <https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=EMD_EPD2DXL0_PTE_SCA_DPG&f=A>. Accessed: May, 26th, 2017. Prices are adjusted to reflect renewable diesel's energy content by multiplying by the price of diesel by 129.65/134.47, the relative energy density of a gallon of renewable diesel to a gallon of diesel according to CA-GREET 2.0.

[217] Public Law 114-113 and 26 U.S. Code 6426. For the years 2010, 2012, 2014 and 2015, the tax credit was applied retroactively (see footnote 28).

[218] Lade, Gabriel, C-Y. Cynthia Lin Lawell, and Aaron Smith. "Ex post costs and renewable identification number (RIN) prices under the Renewable Fuel Standard." (2015). Data for 2014 onward came from Argus Media RIN prices. RIN values are obtained by multiplying D4 prices by 1.7 to reflect EPA's rules, which award each gallon of renewable diesel 1.7 RINs, due to renewable diesel's higher energy content in comparison to ethanol.

[219] The average LCFS credit value for biodiesel for each year was calculated using the following standard formula: $(Diesel\ CI\ Standard\ in\ Year\ t - Renewable\ diesel\ Average\ CI\ in\ Year\ t) \times Average\ LCFS\ Credit\ Price\ in\ Year\ t \times 129.65 \frac{MJ}{gallon} \div 1{,}000{,}000.$

[220] Data for diesel prices did not include the monthly price for Jan. 2007; the number reported for 2007 is the average for Feb. – Dec. 2007.

The LCFS incentives in **Tables 2** and **3** were calculated using the average credit price, the annual LCFS carbon intensity standard, and the average biodiesel or renewable diesel carbon intensity value reported. [221]

On average, from the start of LCFS compliance in 2011 through 2016, the revenue that could be generated by a gallon of biomass-based diesel increased about 60% from that in 2007. Nationally, biodiesel use increased from about 354[222] million gallons in 2007 to roughly 2.1 billion gallons in 2016, a change of more than 490%. California biodiesel use went from about 17[223] million gallons in 2007 to roughly 163 million gallons in 2016, an increase of more than 860%.

Also, as the data in **Table 2** illustrate, the magnitudes of the different factors driving the increase in value to biodiesel are not equal. The incentives per gallon of biodiesel from federal programs increased from $1.00/gallon in 2007 to an average $2.35/gallon in 2011 to 2016. In the same period, the LCFS program contributed an average of $0.40/gallon of biodiesel. Thus, for the period 2011 - 2016, federal program incentives accounted for an average of 85% of the policy-derived value for biodiesel, while the LCFS program accounted for an average of 15% of the policy-derived value.

Table 3 illustrates that the size of the federal and California monetary incentives for renewable diesel, which are similar to those of biodiesel, as both fuels are eligible for the same programs. The incentives per gallon of renewable diesel from federal programs increased from $1.00/gallon in 2007 to an average $2.52/gallon for the period 2011 - 2016. In the same period, the LCFS program contributed an average of $0.32/gallon of renewable diesel. Thus, for the period 2011 - 2016, federal programs incentives accounted for an average of 89% of the policy-derived value for renewable diesel, while the LCFS program accounted for an average of 11% of the policy-derived value.

Figures 2 and **3** summarize the attribution estimates using Method II for biodiesel and renewable diesel, respectively.

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[221] LCFS Reporting Tool Quarterly Summaries. https://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm. Accessed September 26th, 2017.
[222] U.S. Department of Energy. " Monthly Biodiesel Consumption" *Monthly Energy Review.* June, 2017. <https://www.eia.gov/totalenergy/data/monthly/#renewable> Accessed June 1st, 2017.
[223] California Energy Commission Fuel Consumption Data 2003 – 2015.

Figure 2: Biodiesel Attribution to LCFS using Method II

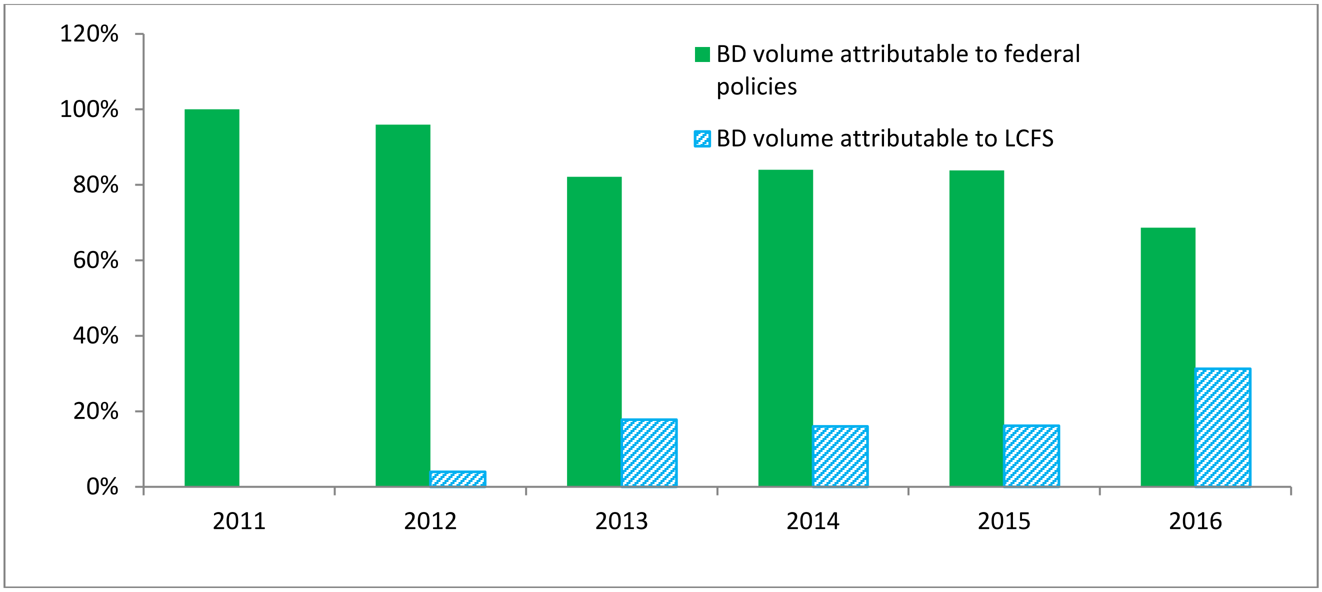
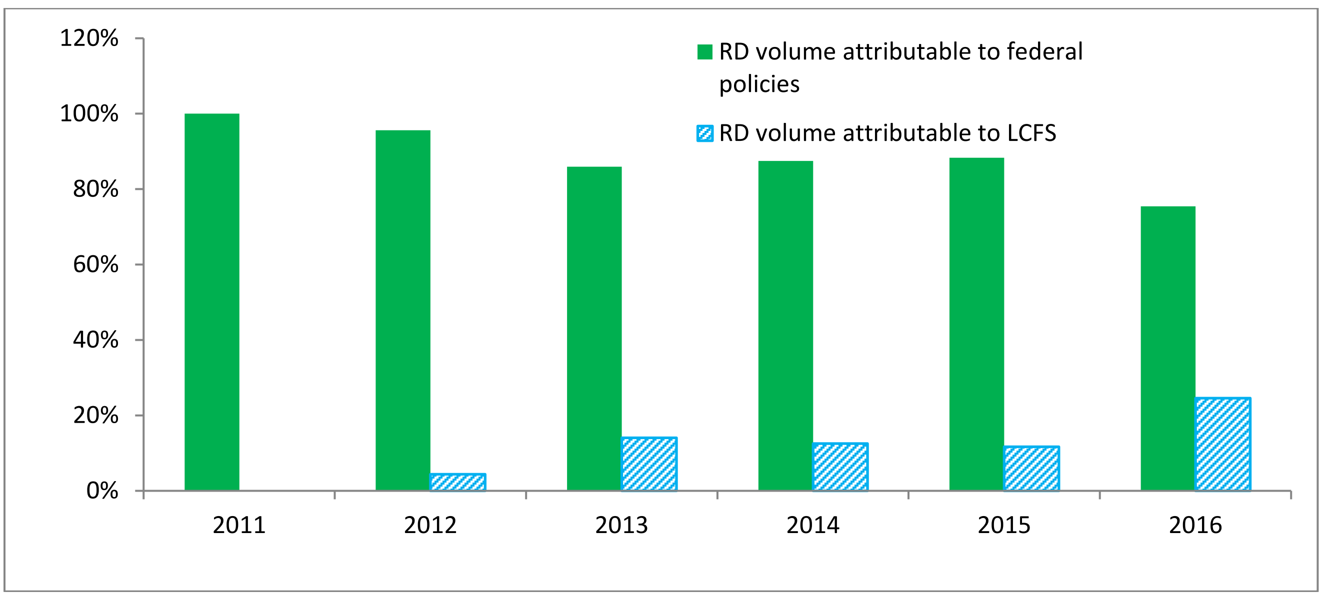


Figure 3: Renewable Diesel Attribution to LCFS using Method II



C. Method III. Attribution Based on Analysis of Domestic Production and Imports

In Method III, staff broke down the use of biodiesel and renewable diesel by geographic source (imported versus in-state produced) and CI category. The LCFS awards low CI fuels—including most biodiesels and renewable diesels—with a larger credit per gallon than their high CI counterparts. Imported biodiesel and renewable diesel that receives LCFS credit value greater than the cost of transportation to California is assumed, for Method III, to be attributed to the LCFS program. Staff estimated the average cost of transporting biodiesel by rail to be $0.25/gallon, and the cost of transporting renewable diesel by ocean going vessels to be $0.15/gallon.[224] If the LCFS credit is smaller than the cost of transportation, either because the fuel had a high CI or the value of the LCFS incentive was low in a certain period, then that volume is not attributed to the LCFS program for this method. For domestic (in-state) biodiesel and renewable diesel production, staff assumes that these volumes were consumed in California where there is sufficient diesel volume to make low-level blends without adding costs to export the fuel to other states. Due to California's more-stringent environmental standards, production costs for these fuels are likely to be higher than production in states with less stringent environmental regulation in place. As such, for in-state production, staff attributes these volumes to the LCFS program and federal programs based on the relative size of the financial incentives provided by the LCFS and federal programs, as staff did for Method II described above.

In the following analysis, staff aggregated biodiesel and renewable diesel volumes into four categories: less than 20 gCO_2/MJ, 20 - 40 gCO_2/MJ, 41-80 gCO_2/MJ, and greater than 80 gCO_2/MJ. Staff then calculated the value of the LCFS incentive for each category, and compared it to the value of the federal credits and the cost of transporting the fuel to California.

To conduct this analysis a dataset was prepared which contains quarterly data on:

- The biodiesel and renewable diesel volumes by CI for each year; and
- For each CI, the volumes produced in, and imported to, California.

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[224] Most of the renewable diesel imported to California during this period is sourced from Singapore, while most biodiesel imported to California during this period is imported from Midwestern states and was transported using rail.
Transportation cost of rail is calculated using estimates from a 2008 study done by UC Davis for the Western Governors' Association titled *"Strategic Assessment of Bioenergy Development in the West Spatial Analysis and Supply Curve Development"*. The cost of loading/unloading is $0.015/gallon, the fixed cost is $8.80/100 gallons, and the distance dependent cost is $0.0075/mile/100 gallons. Assuming an average distance of 2000 miles, these costs add up to $0.25/gallon. Additionally, the Association of American Railroads estimates that the average U.S. freight rail rate was about 4 cents per ton-mile; assuming an average distance of 2000 miles and a density of 7.4 lb/gal, this estimate translates to a cost of $0.30gallon. https://www.aar.org/Pages/Average-US-Freight-Rail-Rates-Chart.aspx. Accessed Nov. 30th, 2017.
Transportation cost of ocean going vessels was estimated to be $0.15/gallon based on conversations with CEC staff that estimated the average cost of transportation by ocean going vessels to be within $0.10 - $0.20 a gallon range.

Because this information is considered to be confidential business information,[225] the data were further aggregated to a non-confidential data set that includes:

- The yearly biodiesel and renewable diesel volumes by the four CI ranges; and
- For each CI range, the volumes produced in, and imported to, California.

The data set also includes the annual average price incentives (on an annual average $/gal basis) for the federal tax credit, RFS RINs, and LCFS credits for each year from 2011 to 2016. Together this information enables a calculation of the relative role each program had in adding monetary value to biodiesel and renewable diesel use in California, similar to the data included in **Tables 2** and **3**.

Figure 4 shows the result of this analysis for California's biodiesel use. In 2011 and 2012, LCFS credits were marginal (less than $0.25/gallon) for all CI categories. For Method III, staff concluded that LCFS provided no incentive to import or increase the production of biodiesel in California in 2011 and 2012. In 2013 to 2016 the value of the LCFS credit increased, and the LCFS value exceeded the cost of transportation for all categories except the >80+ gCO_2/MJ category (in 2013 to 2016) and the 41-80 gCO_2-/MJ category (in 2014).

The federal incentives, which added an average value of $2.35/gal, were likely high enough to incent a large majority of higher biodiesel production at domestic California plants that was observed in the 2011 to 2016 period. (This observation is underscored by the fact that production increased nationwide in this period from 967 million gallons to almost 1.6 billion gallons.) However, although LCFS credit values were less than the monetary value of the federal incentives, the LCFS credit value was also likely sufficient to motivate some production of lower CI biodiesel in California, especially in the periods between 2013 and 2016 when LCFS credit prices were elevated, often adding greater than $1.00 per gallon value to less than 20 gCO_2/MJ category biodiesel. (Notably, the federal tax credit was $1.00/gallon and the U.S. Energy Information Agency credits that tax credit, along with the RFS, as a cause of the increased production and use of biodiesel.[226])

Figure 5 shows the result of this analysis for California's renewable diesel use. In 2011 and 2012, LCFS credits were marginal (less than $0.15/gallon) for all CI categories. For Method III, the LCFS provided no incentive to import or increase the production of renewable diesel in California in 2011 and 2012. In 2013 to 2016 the value of the LCFS credit increased, and the LCFS value exceeded the cost of transportation (assumed to

[225] The individual CIs could enable the identification of the specific production data from individual biodiesel facilities
[226] https://www.eia.gov/energyexplained/index.cfm?page=biofuel_biodiesel_use

be $0.15/gallon) for all categories except the less than 80 gCO_2/MJ category for all years and the 41 - 80 gCO_2/MJ category in 2014. Under Method III, the federal incentives, which added an average value of $2.53/gal, were likely high enough to incent a large majority of higher renewable diesel production at domestic California plants that was observed in the 2011 to 2016 period.

Figure 4: Biodiesel Attribution to LCFS using Method III

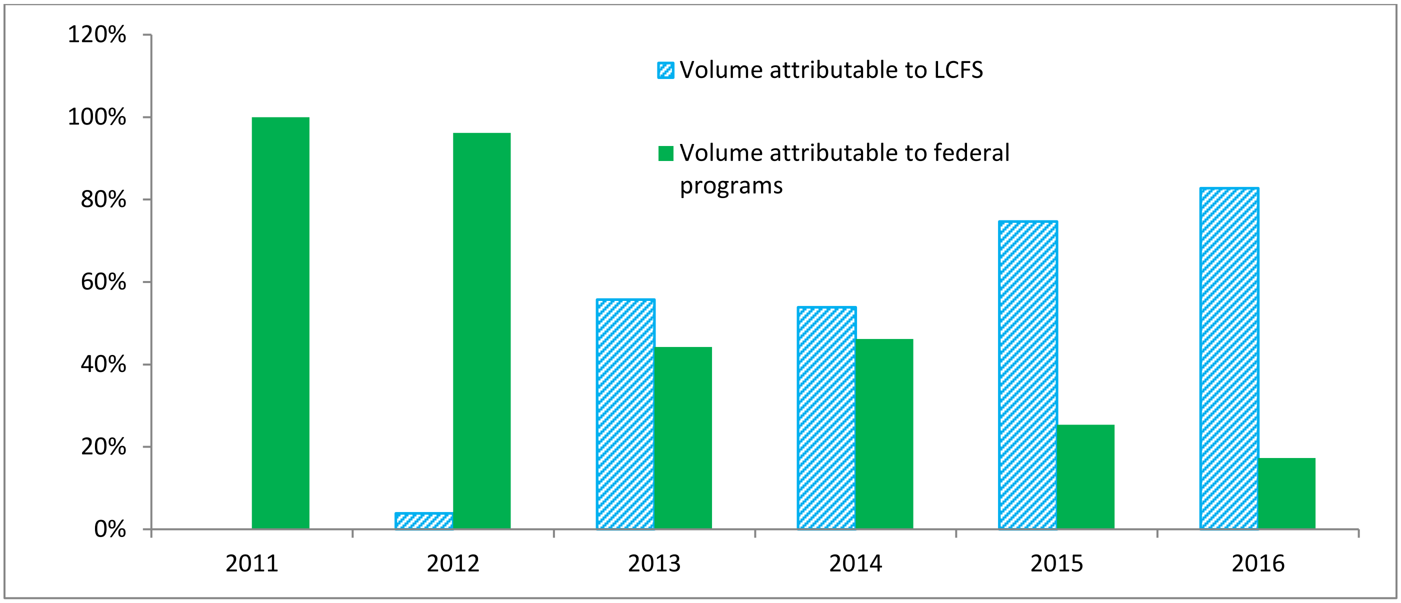
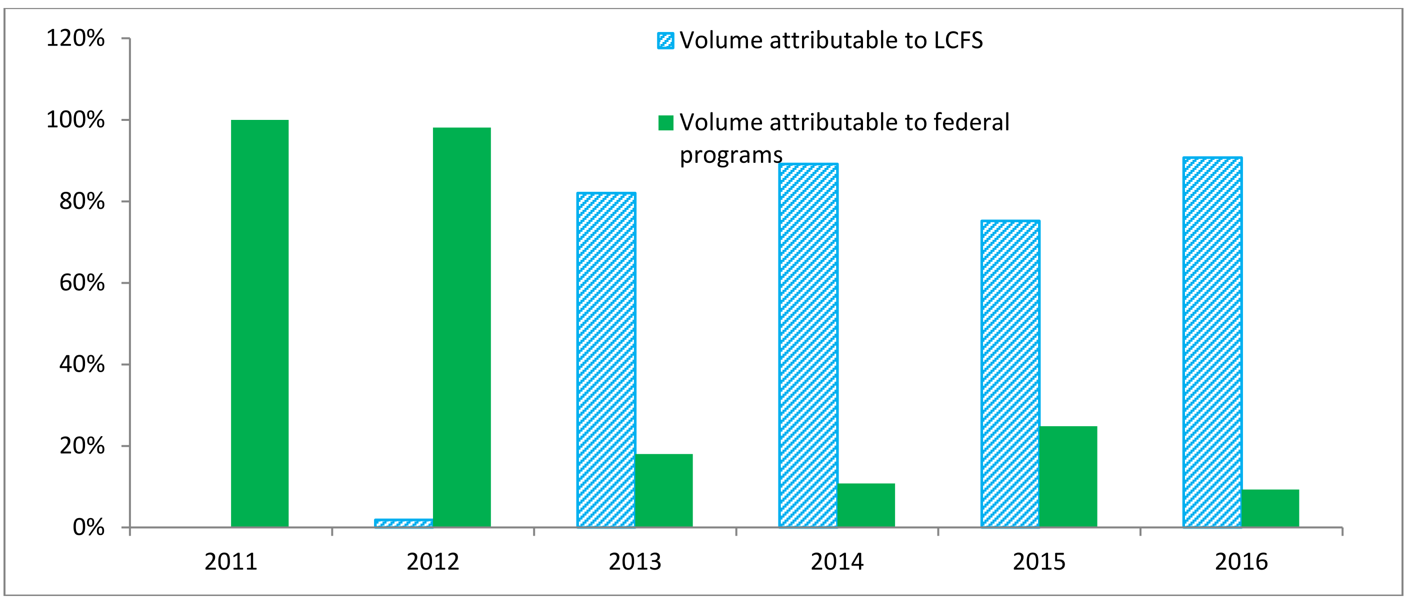


Figure 5: Renewable Diesel Attribution to LCFS using Method III



D. Other Literature Estimates

CARB is not aware of any literature that directly measures the effect of the LCFS on California's biodiesel or renewable diesel use. However, it is widely accepted that the RFS is a key driver of the rapid increase in biofuel production in the United States.[227]

[227] For example, see: Chen, Xiaoguang, and Madhu Khanna. "Food vs. fuel: the effect of biofuel policies." American Journal of Agricultural Economics (2012): aas039. Carter, Colin A., Gordon C. Rausser, and Aaron Smith. "Commodity storage and the market effects of biofuel policies." American Journal of Agricultural Economics (2016): aaw010. Cui, J., Lapan, H., Moschini, G., & Cooper, J. (2011). Welfare impacts of alternative biofuel and energy policies. American Journal of Agricultural Economics, aar053.

APPENDIX 2

STATISTICAL ANALYSIS METHODS AND RESULTS

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Appendix 2 - Statistical Analysis Methods and Results

To evaluate the effect that the LCFS has had on biodiesel and renewable diesel consumption, a variety of statistical tests were performed. These tests considered time series effects alongside robust standard errors and a variety of explanatory variables.

The first test made use of the PADD dataset that staff created. The PADD data consists of consumption and production data for diesel and biodiesel for each US Petroleum Administration for Defense District (PADD). PADD 5 – the west coast PADD – contains California. Because ARB also has production and consumption data for California, these values were added to the PADD data to create a California region, and PADD 5 data were corrected to exclude California.

The first test performed on the PADD dataset was a fixed-effect regression analysis on the panel data. This model took the form:

$$D_{i,t}^{BD} = \alpha_i + \beta_1 R_t + \beta_2 D_{i,t}^{D} + \beta_3 S_{i,t}^{BD} + \beta_4 P_{i,t}^{LCFS} \qquad \text{(M.1)}$$

where α_i was the fixed effect coefficient corresponding to each PADD, i, R was the annual RFS volume mandate associated with a given quarter, t, $D_{i,t}^{BD}$was the biodiesel consumed in PADD i for a given quarter from 2012 through 2016, $D_{i,t}^{D}$ was the amount of diesel consumed, $S_{i,t}^{BD}$was the amount of biodiesel produced in PADD i, and $P_{i,t}^{LCFS}$was the average LCFS credit price for a given PADD for each quarter. For non-California PADDs, the LCFS credit price was $0, as no LCFS was in place.

Important to note is that M.1 does not contain a time trend, and so results do not accurately reflect time effects and autoregressive tendencies. To correct for this concern, a different model was setup to take into account autoregressive effects with a 1-quarter time-lag effect. The model took on the form:

$$D_{i,t}^{BD} = \alpha_i + \beta_1 R_t + \beta_2 D_{i,t}^{D} + \beta_3 S_{i,t}^{BD} + \beta_4 P_{i,t}^{LCFS} + \beta_5 D_{i,t-1}^{BD} \qquad \text{(M.2)}$$

As seen in table 1, the LCFS price was not shown to be a significant predictor of biodiesel consumption when accounting for the time-series effects.

To increase the number of observations for statistical analysis, a larger panel dataset was used containing monthly production and consumption data (t) for each of the 5 PADDs. However, ARB only has quarterly consumption data, so California was not isolated from PADD 5. To ascertain the LCFS effects on biodiesel consumption, models were used to see if the LCFS price was had a significant effect on PADD 5 biodiesel consumption:

$$D_{i,t}^{BD} = \alpha_i + \beta_1 R_t + \beta_2 D_{i,t}^{D} + \beta_3 S_{i,t}^{BD} + \beta_4 P_{i,t}^{LCFS} \qquad \text{(M.3)}$$

where $P_{i,t}^{LCFS}$ was $0 for PADD regions without LCFS policy in place, and the monthly average California LCFS credit price for PADD 5. The LCFS price variable was not shown to have a significant effect, whereas biodiesel production and the diesel consumption within a PADD have significant effects. A pooled model was also utilized, in which an LCFS dummy value was used to distinguish PADD 5 from the rest of the observations. Because LCFS prices were not used in this model, data from 2009 through 2011 could also be used to extend the model, compared to only using data from 2012 onward (the point at which CARB recorded LCFS credit prices). The biodiesel production variable for each PADD was removed from the model as biofuel policy may also be a strong predictor of production volumes.

$$D_t^{BD} = \alpha + \beta_1 R_t + \beta_2 D_t^D + \beta_3\{LCFS\} \qquad \text{(M.4)}$$

In M.4, the LCFS region coefficient was negative and shows no significant effect, and the RFS mandate (which changes each year) alongside diesel consumption within the region explains 68% of the data. However, biodiesel consumption across PADDs may be a hetereoskedastic variable because the variability in biodiesel consumption in a PADD likely increases as more diesel is consumed. This may be the case because blending can be increased or decreased with less impact on the overall quality of the diesel fuel pool in a region.

Checking M.4 for hetereoskedasticity revealed that the model was heteroskedastic. Correcting for this effect did not substantially change results.

Additionally, staff checked M.4 for autocorrelation using a Durbin-Watson test, as time effects are likely an important factor in explaining biodiesel consumption. Autocorrelation was shown to be significant, so a model was created to account for this effect.

$$D_t^{BD} = \alpha + \beta_1 R_t + \beta_2 D_t^D + \beta_3\{LCFS\} + \beta_4 D_{t-1}^{BD} \qquad \text{(M.5)}$$

In M.5, the PADD5 region did not differ from other PADDs in terms of biodiesel consumption.

To further ascertain the effect of the LCFS on biodiesel consumption in California, staff looked at a California-only dataset for consumption, rather than the larger panel data. For quarterly consumption data, M.6 was used to assess the effect that the LCFS credit price, the RFS volume mandate, and the price of diesel in California had on biodiesel consumption when including an auto-regressive term.

$$D_t^{BD} = \alpha + \beta_1 R_t + \beta_2 P_t^D + \beta_3 P_t^{LCFS} + \beta_4 D_{t-1}^{BD} \qquad \text{(M.6)}$$

M.6 indicates that the LCFS credit price was not a significant predictor of biodiesel consumption for the California-only dataset, whereas diesel prices and the RFS volume mandate are. Additionally, staff looked at a model where the total consumption of diesel in the state was used instead of the diesel price:

$$D_t^{BD} = \alpha + \beta_1 R_t + \beta_2 D_t^D + \beta_3 P_t^{LCFS} + \beta_4 D_{t-1}^{BD} \qquad \text{(M.7)}$$

In M.7, the only significant effect was the autoregressive term.

The last set of models used to assess the effect of the LCFS on biodiesel consumption analyzed how California's percent share of total US-produced biodiesel (percent utilization) changed as a function of the RFS, the LCFS, and the price for diesel fuel in California.

$$\frac{D_t^{BD}}{S_t^{BD}} = \alpha + \beta_1 R_t + \beta_2 P_t^D + \beta_3 P_t^{LCFS} + \beta_4 D_{t-1}^{BD} \qquad \text{(M.8)}$$

In M.8, the LCFS credit price does not have an effect on the percent utilization of biodiesel in California, yet the price of diesel and the RFS volume mandate were shown to be significant.

A similar modeling approach was used to ascertain the effect of the LCFS credit price on renewable diesel. Unlike with biodiesel, however, data for production and consumption of renewable diesel are limited. The EIA does not readily track renewable diesel consumption and production for different PADDs. ARB, however, has renewable diesel consumption data for California. To look at the effect of LCFS credit prices on renewable diesel, the following model was used:

$$D_t^{RD} = \alpha + \beta_1 R_t + \beta_2 P_t^D + \beta_3 P_t^{LCFS} + \beta_4 D_{t-1}^{RD} \qquad \text{(M.9)}$$

Unlike model M.6, which did not show LCFS credit prices as being a significant predictor of biodiesel consumption, M.9 does indicate that LCFS credit prices are a significant, positive predictor for renewable diesel consumption.

Taken together, these statistical analyses indicate that it is currently not possible to detect if the LCFS has had an effect on biodiesel consumption in California. However, at this time, we find support from statistical models indicating that the LCFS has likely increased consumption of renewable diesel in the state.

Table 1 Results from Statistical Models

	M.1	M.2	M.3	M.4	M.4_CORRECTED	M.5	M.6	M.7	M.8	M.9
DATASET	PADD data + CA	PADD data + CA	PADD data	PADD data	PADD data	PADD data	California	California	California	California
DATASIZE (N)	114	114	300	450	450	450	28	28	28	28
DEPENDENT VARIABLE	BD Consumption	BD Consumption	BD Consumption	BD Consumption	BD Consumption	BD Consumption	BD Consumption	BD Consumption	Pct. Utilization	RD Consumption
AUTOREGRESSIVE TERM INCLUDED	No	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes
RFS	0.441 *** (1.98e-3)	0.102 (.259)	0.213 (0.136)	0.237 *** (.020)	0.224 *** (.020)	- 0.140 (.080)	1.33e4 ** (4.18e3)	-3.29e3 (6.58e3)	0.004 *** (0.001)	0.011 * (0.006)
DIESEL CONSUMPTION	0.005 *** (2.80e-5)	-0.001 (.008)	0.005 * (0.002)	0.032*** (.001)	0.032*** (.001)	0.009 . (.004)	---	8.65e3 (8.83e3)	---	---
BIODIESEL PRODUCTION	0.980 *** (1.55e-4)	1.21 *** (.092)	0.986 *** (0.031)	---	---	---	---	---	---	---
LCFS PRICE	224 *** (1.32)	44.72 (445.55)	0.468 (0.294)	---	---	---	7.39e6 (7.81e6)	7.20e5 (7.96e6)	0.250 (1.64)	45.94 ** (13.17)
CA DIESEL PRICE	---	---	---	---	---	---	- 9.06e6 * (3.58e6)	---	-2.71 ** (0.747)	-6.89 (4.84)
LCFS POLICY IN REGION	---	---	---	- 21.92 (35.14)	- 21.92 . (19.28)	- 243.41 (266.59)	---	---	---	---

Standard Error is shown in parentheses∑

Signif. codes: 0 ‘***’, 0.001 ‘**’, 0.01 ‘*’, 0.05 ‘.’

Attached R-Code and Results

BD_Incentive_Writeup.R

jkessler

Wed Sep 27 14:58:58 2017

```
# load necessary packages for importing the function

library(RCurl)

## Loading required package: bitops

library(sandwich)
library(dynlm)

## Loading required package: zoo

##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric

library(lmtest)

##
## Attaching package: 'lmtest'

## The following object is masked from 'package:RCurl':
##
##     reset

library(plm)

## Loading required package: Formula

library(car)
library(nlme)
library(ggplot2)


#Package that allows for robust standard errors

url_robust <- "https://raw.githubusercontent.com/IsidoreBeautrelet/economictheoryblog/master/robust_summary.R"
eval(parse(text = getURL(url_robust, ssl.verifypeer = FALSE)),
     envir=.GlobalEnv)
```

```r
# Read Data
ca_data<-read.csv("s:/Alternative Fuels Section 2.0/Jeff/Biodiesel Case/BD Pr
ice Incentive.csv")
panel_data<-read.csv("s:/Alternative Fuels Section 2.0/Jeff/Biodiesel Case/bd
_panel.csv")
PADD_CA<-read.csv("s:/Alternative Fuels Section 2.0/Jeff/Biodiesel Case/BD_PA
DD_CA_panel.csv")
summary(PADD_CA)
```

```
##   PADD         Time      Diesel.Consumption   BDProduction     BDConsumption
##   1 :19    2012Q1 : 6    Min.    : 15352     Min.    :   0.0    Min.    : -24.0
##   2 :19    2012Q2 : 6    1st Qu.: 21123      1st Qu.: 152.1    1st Qu.: 219.1
##   3 :19    2012Q3 : 6    Median : 45019      Median : 381.0    Median : 858.1
##   4 :19    2012Q4 : 6    Mean   : 55462      Mean   :1256.7    Mean   :1397.3
##   5*:19    2013Q1 : 6    3rd Qu.: 89238      3rd Qu.:1363.1    3rd Qu.:2294.9
##   CA:19    2013Q2 : 6    Max.   :119578      Max.   :6714.3    Max.   :5584.6
##            (Other):78
##     RFSMandate      LCFS_Price
##   Min.   :1000    Min.   :0.00000
##   1st Qu.:1280    1st Qu.:0.00000
##   Median :1630    Median :0.00000
##   Mean   :1487    Mean   :0.07623
##   3rd Qu.:1730    3rd Qu.:0.00000
##   Max.   :1900    Max.   :1.27000
##
```

```r
summary(panel_data)
```

```
##       Padd          Date        Net.Receipts..Thousand.Barrels.
##   Min.   :1    1/1/2010:  5    Min.    :-734.0000
##   1st Qu.:2    1/1/2011:  5    1st Qu.: -18.2500
##   Median :3    1/1/2012:  5    Median :  43.0000
##   Mean   :3    1/1/2013:  5    Mean   :  -0.0267
##   3rd Qu.:4    1/1/2014:  5    3rd Qu.: 126.0000
##   Max.   :5    1/1/2015:  5    Max.   : 445.0000
##                (Other) :420
##       Stock          Stock.Change_est    BDProduction        Imports
##   Min.   :   0.0   Min.   :-271.51    Min.   :   0.00    Min.   :   0.00
##   1st Qu.: 119.2   1st Qu.: -33.48    1st Qu.:  47.62    1st Qu.:   0.00
##   Median : 493.5   Median :   0.00    Median : 142.86    Median :   1.00
##   Mean   : 561.7   Mean   :  12.53    Mean   : 427.25    Mean   :  87.17
##   3rd Qu.: 878.2   3rd Qu.:  40.92    3rd Qu.: 476.19    3rd Qu.:  61.75
##   Max.   :2825.0   Max.   : 606.28    Max.   :2309.52    Max.   :1427.00
##
##     Exports         Consumption.Estimate      Lookup      Stock.Estimate
##   Min.   :  0.00   Min.   :-400.38       1|1-2010:  1    Min.   :   0.0
##   1st Qu.:  0.00   1st Qu.:  56.25       1|1-2011:  1    1st Qu.: 119.2
##   Median :  2.00   Median : 310.14       1|1-2012:  1    Median : 470.5
```

```
##  Mean   : 34.74   Mean   : 467.13      1|1-2013:  1   Mean   : 505.0
##  3rd Qu.: 40.75   3rd Qu.: 753.62      1|1-2014:  1   3rd Qu.: 780.1
##  Max.   :285.00   Max.   :1941.54      1|1-2015:  1   Max.   :2395.0
##                                        (Other) :444
##  Diesel.Consumption      RFS        LCFS_Region       Year      Quarter
##  Min.   : 4216      Min.   :   0   Min.   :0.0   Min.   :2009   Q1:105
##  1st Qu.:13946      1st Qu.: 800   1st Qu.:0.0   1st Qu.:2011   Q2:105
##  Median :22308      Median :1280   Median :0.0   Median :2013   Q3:120
##  Mean   :21436      Mean   :1112   Mean   :0.2   Mean   :2013   Q4:120
##  3rd Qu.:29879      3rd Qu.:1730   3rd Qu.:0.0   3rd Qu.:2015
##  Max.   :43901      Max.   :1900   Max.   :1.0   Max.   :2016
##
##    LCFSCPrice
##  Min.   :  0.000
##  1st Qu.:  0.000
##  Median :  0.000
##  Mean   :  9.747
##  3rd Qu.:  0.000
##  Max.   :122.290
##  NA's   :150
```

```
# Check to see how California BD Consumption compares to other regions
M.1<-pggls(BDConsumption~RFSMandate+Diesel.Consumption+BDProduction+LCFS_Pric
e,data=PADD_CA,model=c("within"))
dwtest(BDConsumption~RFSMandate+Diesel.Consumption+BDProduction+LCFS_Price+as
.factor(PADD),data=PADD_CA)
```

```
##
##  Durbin-Watson test
##
## data:  BDConsumption ~ RFSMandate + Diesel.Consumption + BDProduction +
LCFS_Price + as.factor(PADD)
## DW = 1.2776, p-value = 1.823e-06
## alternative hypothesis: true autocorrelation is greater than 0
```

```
M.2<-gls(BDConsumption~as.factor(PADD)+RFSMandate+Diesel.Consumption+BDProduc
tion+
           LCFS_Price,data=PADD_CA,correlation = corAR1(form=~"Time"|"PADD"))
summary(M.1)
```

```
##  Within model
##
## Call:
## pggls(formula = BDConsumption ~ RFSMandate + Diesel.Consumption +
##     BDProduction + LCFS_Price, data = PADD_CA, model = c("within"))
##
## Balanced Panel: n=6, T=19, N=114
##
## Residuals
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
```

```
## -1283.00  -189.90   -15.71     0.00   148.20  1362.00
##
## Coefficients
##                      Estimate Std. Error z-value  Pr(>|z|)
## RFSMandate         4.4143e-01 1.9784e-03  223.12 < 2.2e-16 ***
## Diesel.Consumption 5.1401e-03 2.8022e-05  183.43 < 2.2e-16 ***
## BDProduction       9.7967e-01 1.5471e-04 6332.22 < 2.2e-16 ***
## LCFS_Price         2.2439e+02 1.3222e+00  169.71 < 2.2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## Total Sum of Squares: 227690000
## Residual Sum of Squares: 16116000
## Multiple R-squared: 0.92922
```

```
summary(M.2)
```

```
## Generalized least squares fit by REML
##   Model: BDConsumption ~ as.factor(PADD) + RFSMandate + Diesel.Consumption
+      BDProduction + LCFS_Price
##   Data: PADD_CA
##        AIC      BIC    logLik
##   1603.893 1635.626 -789.9464
##
## Correlation Structure: AR(1)
##  Formula: ~"Time" | "PADD"
##  Parameter estimate(s):
##       Phi
## 0.7976413
##
## Coefficients:
##                         Value Std.Error   t-value p-value
## (Intercept)          1187.556  821.2257  1.446078  0.1512
## as.factor(PADD)2    -3692.445  651.3820 -5.668632  0.0000
## as.factor(PADD)3     -958.116  526.1559 -1.820973  0.0715
## as.factor(PADD)4    -1260.874  722.6738 -1.744735  0.0840
## as.factor(PADD)5*   -1262.804  689.5744 -1.831280  0.0699
## as.factor(PADD)CA   -1024.694  721.8941 -1.419452  0.1588
## RFSMandate              0.102    0.2588  0.392986  0.6951
## Diesel.Consumption     -0.001    0.0077 -0.097807  0.9223
## BDProduction            1.205    0.0915 13.161607  0.0000
## LCFS_Price             44.720  446.5453  0.100147  0.9204
##
##  Correlation:
##                     (Intr) a.(PADD)2 a.(PADD)3 a.(PADD)4 a.(PADD)5
## as.factor(PADD)2   -0.118
## as.factor(PADD)3   -0.520  0.435
## as.factor(PADD)4   -0.776  0.173     0.550
## as.factor(PADD)5*  -0.759  0.213     0.561     0.759
## as.factor(PADD)CA  -0.749  0.185     0.533     0.730     0.719
## RFSMandate         -0.418 -0.050    -0.035    -0.043    -0.044
```

```
## Diesel.Consumption -0.776 -0.065     0.332     0.735     0.705
## BDProduction        0.148 -0.610    -0.255    -0.168    -0.197
## LCFS_Price          0.030  0.014     0.019     0.031     0.031
##                    a.(PADD)C RFSMnd Dsl.Cn BDPrdc
## as.factor(PADD)2
## as.factor(PADD)3
## as.factor(PADD)4
## as.factor(PADD)5*
## as.factor(PADD)CA
## RFSMandate         -0.002
## Diesel.Consumption  0.679    -0.064
## BDProduction       -0.163     0.098 -0.293
## LCFS_Price         -0.253    -0.138  0.044 -0.038
##
## Standardized residuals:
##         Min          Q1         Med          Q3         Max
## -2.29169512 -0.41406807 -0.07600737  0.14343816  2.25319290
##
## Residual standard error: 601.2321
## Degrees of freedom: 114 total; 104 residual
```

```
# LCFS is not shown to be a significant predictor in the autocorrelation-corr
ected model


# Let's do a different panel regression
M.3 <- pggls(Consumption.Estimate~Diesel.Consumption+BDProduction+LCFSCPrice+
RFS, data=panel_data, model=c("within"))
summary(M.3)
```

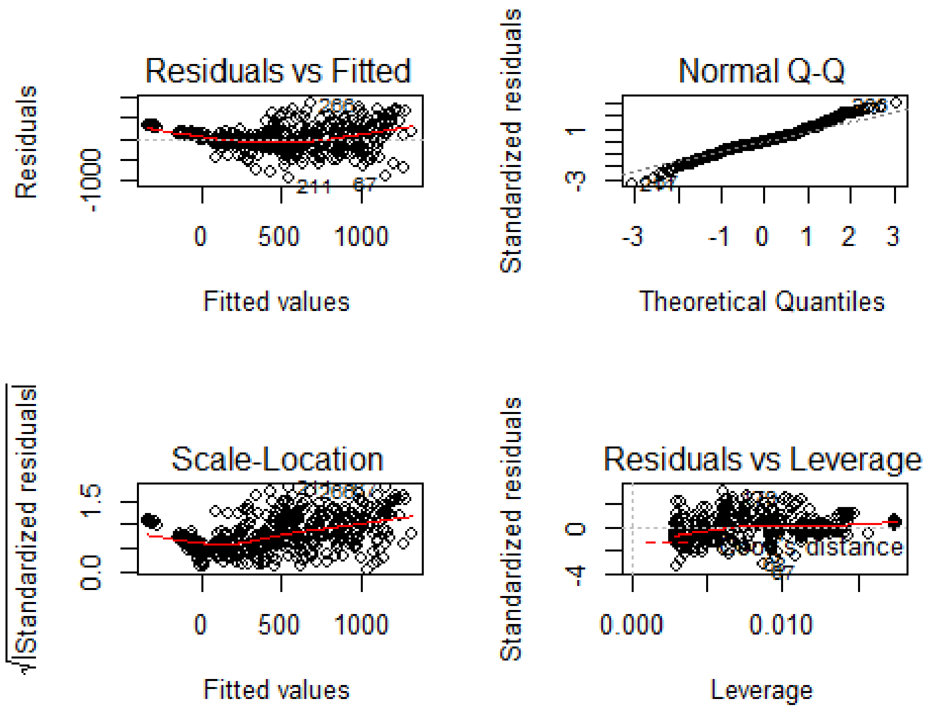
```
##  Within model
##
## Call:
## pggls(formula = Consumption.Estimate ~ Diesel.Consumption + BDProduction +
##     LCFSCPrice + RFS, data = panel_data, model = c("within"))
##
## Balanced Panel: n=5, T=60, N=300
##
## Residuals
##     Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
## -872.300 -101.000   -3.801    0.000   88.880  634.200
##
## Coefficients
##                     Estimate Std. Error z-value Pr(>|z|)
## Diesel.Consumption 0.0052669  0.0023428  2.2481  0.02457 *
## BDProduction       0.9860276  0.0306778 32.1414  < 2e-16 ***
## LCFSCPrice         0.4679110  0.2939099  1.5920  0.11138
## RFS                0.2134726  0.1361486  1.5679  0.11690
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
## Total Sum of Squares: 76900000
## Residual Sum of Squares: 9982100
## Multiple R-squared: 0.87019
```

```r
# Let's use an LCFS dummy variable for Padd5 (is PADD 5 different from other PADDs?)
M.4<-lm(Consumption.Estimate~Diesel.Consumption+LCFS_Region+RFS,data=panel_data)
summary(M.4)
```

```
##
## Call:
## lm(formula = Consumption.Estimate ~ Diesel.Consumption + LCFS_Region +
##     RFS, data = panel_data)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -935.89 -153.39   -9.09  138.15  836.21
##
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)
## (Intercept)        -4.674e+02  3.820e+01 -12.234   <2e-16 ***
## Diesel.Consumption  3.219e-02  1.305e-03  24.666   <2e-16 ***
## LCFS_Region        -2.192e+01  3.514e+01  -0.624    0.533
## RFS                 2.237e-01  2.047e-02  10.928   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 283.7 on 446 degrees of freedom
## Multiple R-squared:  0.6669, Adjusted R-squared:  0.6646
## F-statistic: 297.6 on 3 and 446 DF,  p-value: < 2.2e-16
```

```r
#Check for Hetereoskedacity
par(mfrow=c(2,2))
plot(M.4)
```




```
# Correct for Hetereoskedasticity
coeftest(M.4,vcov=hccm(M.4))

##
## t test of coefficients:
##
##                       Estimate  Std. Error  t value Pr(>|t|)
## (Intercept)        -4.6740e+02  3.6034e+01 -12.9710   <2e-16 ***
## Diesel.Consumption  3.2194e-02  1.2524e-03  25.7057   <2e-16 ***
## LCFS_Region        -2.1923e+01  1.9277e+01  -1.1372   0.2561
## RFS                 2.2374e-01  1.9487e-02  11.4815   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

# Check for Autocorrelation
dwtest(Consumption.Estimate~Diesel.Consumption+LCFS_Region+RFS,data=panel_dat
a)

##
##  Durbin-Watson test
##
## data:  Consumption.Estimate ~ Diesel.Consumption + LCFS_Region + RFS
## DW = 0.59412, p-value < 2.2e-16
## alternative hypothesis: true autocorrelation is greater than 0

# Correct for AutoCorrelation
M.5<-gls(Consumption.Estimate~Diesel.Consumption+LCFS_Region+RFS,data=panel_d
```

```
ata,correlation = corAR1(form=~"Date"|"Padd"))
summary(M.5)

## Generalized least squares fit by REML
##   Model: Consumption.Estimate ~ Diesel.Consumption + LCFS_Region + RFS
##   Data: panel_data
##        AIC      BIC    logLik
##   6040.227 6064.828 -3014.113
##
## Correlation Structure: AR(1)
##  Formula: ~"Date" | "Padd"
##  Parameter estimate(s):
##       Phi
## 0.9216148
##
## Coefficients:
##                         Value Std.Error    t-value p-value
## (Intercept)          510.8653 172.14052  2.9677228  0.0032
## Diesel.Consumption     0.0086   0.00407  2.1060252  0.0358
## LCFS_Region         -243.4057 266.58738 -0.9130427  0.3617
## RFS                   -0.1404   0.07997 -1.7554863  0.0799
##
##  Correlation:
##                     (Intr) Dsl.Cn LCFS_R
## Diesel.Consumption -0.526
## LCFS_Region        -0.371  0.125
## RFS                -0.485 -0.030 -0.004
##
## Standardized residuals:
##        Min         Q1        Med         Q3        Max
## -2.2121140 -0.7205563 -0.2388165  0.5183572  2.6779293
##
## Residual standard error: 509.0625
## Degrees of freedom: 450 total; 446 residual

# We see that the LCFS Region (Padd 5)
# Is not significantly different from other regions

# Let's assess California-specific Data (small time-series)
# Data is autoregressive
M.6<-gls(BD~Pdiesel+RFS_Mandate+LCFS, data=ca_data, correlation = corAR1(form
=~1))
summary(M.6)

## Generalized least squares fit by REML
##   Model: BD ~ Pdiesel + RFS_Mandate + LCFS
##   Data: ca_data
##        AIC      BIC    logLik
##   850.4425 857.5109 -419.2213
##
```

```
## Correlation Structure: AR(1)
##  Formula: ~1
##  Parameter estimate(s):
##       Phi
## 0.4249462
##
## Coefficients:
##                  Value Std.Error   t-value p-value
## (Intercept) 28559270  12844736  2.223422  0.0359
## Pdiesel     -9061731   3577025 -2.533315  0.0182
## RFS_Mandate    13299      4183  3.178880  0.0040
## LCFS         7391779   7809457  0.946516  0.3533
##
##  Correlation:
##             (Intr) Pdiesl RFS_Mn
## Pdiesel     -0.945
## RFS_Mandate  0.009 -0.268
## LCFS        -0.477  0.563 -0.674
##
## Standardized residuals:
##        Min         Q1        Med         Q3        Max
## -2.1258734 -0.3498671 -0.1108658  0.1128439  2.1337480
##
## Residual standard error: 6960814
## Degrees of freedom: 28 total; 24 residual

# We see that the LCFS price effect on Biodiesel in California
# is not significant
# a substantial increase in LCFS price might have a positive
# effect on Biodiesel usage

# Testing supply model
M.7<-gls(BD~CADTot+RFS_Mandate+LCFS, data=ca_data, correlation = corAR1(form=
~1))
summary(M.7)

## Generalized least squares fit by REML
##   Model: BD ~ CADTot + RFS_Mandate + LCFS
##   Data: ca_data
##        AIC      BIC    logLik
##   857.8433 864.9117 -422.9217
##
## Correlation Structure: AR(1)
##  Formula: ~1
##  Parameter estimate(s):
## Phi
##   1
##
## Coefficients:
##                  Value   Std.Error    t-value p-value
```

```
## (Intercept) 24390668 80783963575  0.0003019  0.9998
## CADTot           8649        8829  0.9797026  0.3370
## RFS_Mandate     -3286        6579 -0.4994664  0.6220
## LCFS           719709     7959042  0.0904266  0.9287
##
##  Correlation:
##             (Intr) CADTot RFS_Mn
## CADTot       0.000
## RFS_Mandate  0.000  0.087
## LCFS         0.000  0.180 -0.037
##
## Standardized residuals:
##           Min            Q1           Med            Q3           Max
## -3.926774e-04 -3.177485e-04 -1.800601e-04 -1.159777e-05  3.341061e-04
##
## Residual standard error: 80783964637
## Degrees of freedom: 28 total; 24 residual
```

```
# It is important to note that the autoregressive characteristic
# is the only thing that matters in this model


# Testing LCFS, Diesel Prices, and the RFS mandate on percent utilization
M.8<-gls(PctUtilization~Pdiesel+RFS_Mandate+LCFS, data=ca_data, correlation =
corAR1(form=~1))
summary(M.8)
```

```
## Generalized least squares fit by REML
##   Model: PctUtilization ~ Pdiesel + RFS_Mandate + LCFS
##   Data: ca_data
##        AIC      BIC    logLik
##   113.0254 120.0937 -50.51268
##
## Correlation Structure: AR(1)
##  Formula: ~1
##  Parameter estimate(s):
##       Phi
## 0.4097172
##
## Coefficients:
##                 Value Std.Error   t-value p-value
## (Intercept)  8.995519 2.6836380  3.351987  0.0027
## Pdiesel     -2.712591 0.7472392 -3.630150  0.0013
## RFS_Mandate  0.004125 0.0008777  4.699206  0.0001
## LCFS         0.249931 1.6445162  0.151978  0.8805
##
##  Correlation:
##             (Intr) Pdiesl RFS_Mn
## Pdiesel     -0.945
## RFS_Mandate  0.012 -0.271
```

```
## LCFS        -0.478  0.566 -0.679
##
## Standardized residuals:
##        Min         Q1        Med         Q3        Max
## -1.8775717 -0.4339408 -0.1397109  0.1847372  2.0793743
##
## Residual standard error: 1.466175
## Degrees of freedom: 28 total; 24 residual
```

```
# Here we see that the percent of BD utilized in CA
# relative to total BD produced depends on diesel price and RFS mandate

# Looking at Renewable Diesel for autocorrelation
dwtest(Rdiesel~Pdiesel+RFS_Mandate+LCFS,data=ca_data)
```

```
##
##  Durbin-Watson test
##
## data:  Rdiesel ~ Pdiesel + RFS_Mandate + LCFS
## DW = 1.564, p-value = 0.03603
## alternative hypothesis: true autocorrelation is greater than 0
```

```
# Testing LCFS, Diesel Prices, and the RFS Mandate on RD utilization, control
ing for autocorrelation
M.9<-gls(Rdiesel~Pdiesel+LCFS_RD+RFS_Mandate, data=ca_data, correlation = cor
AR1(form=~1))
summary(M.9)
```

```
## Generalized least squares fit by REML
##   Model: Rdiesel ~ Pdiesel + LCFS_RD + RFS_Mandate
##   Data: ca_data
##        AIC      BIC    logLik
##   200.8658 207.9341 -94.43291
##
## Correlation Structure: AR(1)
##  Formula: ~1
##  Parameter estimate(s):
##       Phi
## 0.4855051
##
## Coefficients:
##                Value Std.Error   t-value p-value
## (Intercept) 21.50102 17.628853  1.219649  0.2344
## Pdiesel     -6.88886  4.844029 -1.422134  0.1679
## LCFS_RD     45.93576 13.171069  3.487625  0.0019
## RFS_Mandate  0.01071  0.005837  1.835534  0.0788
##
##  Correlation:
##             (Intr) Pdiesl LCFS_R
## Pdiesel     -0.938
```

```
## LCFS_RD     -0.378  0.456
## RFS_Mandate -0.090 -0.182 -0.638
##
## Standardized residuals:
##        Min         Q1        Med         Q3        Max
## -1.6365476 -0.3632692 -0.1183280  0.2449089  1.8069600
##
## Residual standard error: 9.740743
## Degrees of freedom: 28 total; 24 residual
```

APPENDIX 3

BIOMASS-BASED DIESEL VOLUMES AND EMISSIONS AND HEALTH IMPACTS FOR SCENARIOS 3 AND 4

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Appendix 3: Biomass-Based Diesel Volumes and Emissions and Health Impacts for Scenarios 3 and 4

This appendix presents the LCFS-attributed biomass-based diesel volumes and the corresponding LCFS NOx and PM emissions and health impacts associated with Scenarios 3 and 4 during the time period from 2007 to 2025.

A. LCFS-ATTRIBUTED BIOMASS-BASED DIESEL VOLUMES

1. Attribution Analysis Results

Based on the attribution analysis methods detailed in **Appendix 1**, **Table 3-1** summarizes the results of Method II, used to estimate the percentages of biomass-based diesel attributed to the LCFS for 2010 - 2016. Post-2016, staff conservatively assumed that the LCFS program is responsible for any increase in the use of biomass-based diesel volumes in California beyond the 2016 volumes attributed to non-LCFS programs.[228]

[228] This conservative, forward-looking assumption was made for the purposes of this analysis and it is specific to estimating the NOx and PM impacts of the two liquid diesel substitutes. For comparison, the Final Environmental Analysis from the 2015 LCFS rulemaking reduced expected GHG benefits due to the federal RFS program (see Table 4-3 of the 2015 LCFS Final EA). This assumption remains conservative with respect to estimating the GHG benefits of the LCFS, given where the federal program appears to be headed.

Table 3-1 - Summary of Estimates of LCFS's Attribution to Biodiesel and Renewable Diesel Use for Method II

Year	Biodiesel Volume Percent Attributed to LCFS for Method II[229]	
	Biodiesel	Renewable Diesel
2010	0%	0%
2011	0%	0%
2012	4%	4%
2013	18%	14%
2014	16%	13%
2015	16%	12%
2016	31%	25%
Post-2016	All but 112 million gallons[230]	All but 186 million gallons[231]

a. Estimation of LCFS-Attributed Biomass-Based Diesel Volumes

Based on the results of the attribution analysis discussed in Appendix G, staff estimated biomass-based diesel volumes attributed to the LCFS for four scenarios. These four scenarios, summarized in **Table 3-2**, all use actual data for historical periods but represent a range of projected future total biomass-based diesel usage volumes and the percentages of those volumes attributed to the LCFS based on Attribution Methods II and III.

[229] Attribution volume percentages of biomass-based diesel vary based on the projected future volumes. As discussed in Appendix G, staff evaluated two sets of projected future volumes. Therefore, for simplicity, Table 3-1 presents attribution of biodiesel to the LCFS for future years in units of volume.
[230] Based on 2016 biodiesel use attributed to federal programs, which consists of 69% of total California use of biodiesel or 112 million gallons.
[231] Based on 2016 renewable diesel use attributed to federal programs, which consists of 75% of total California renewable diesel use or 186 million gallons.

Table 3-2 - Summary of Biomass-Based Diesel Volume Scenarios Evaluated

Scenario	Basis for Total Biomass-Based Diesel and Conventional Diesel Volumes		Method of Attribution of Total Biomass-based diesel Volumes to the LCFS
	Historical (2007 – 2016)	Projected Future (2017 – 2025)[232]	
1	Reported actual	2015 LCFS EA – Illustrative Compliance Scenario	Method III (Overcoming transport costs)
2	Reported actual	2018 LCFS EA BAU Scenario	Method III (Overcoming transport costs)
3	Reported actual	2015 LCFS EA – Illustrative Compliance Scenario	Method II (Policy-based attribution)
4	Reported actual	2018 LCFS EA BAU Scenario	Method II (Policy-based attribution)

LCFS-attributed biomass-based diesel volumes for Scenarios 1 and 2, which are based on the more conservative attribution method (Method III), were presented in **Appendix G**. LCFS-attributed biomass-based diesel volumes for Scenarios 3 and 4, which are based on the less conservative attribution method (Method II),[233] are presented in this appendix.

As indicated in **Table 3-3**, total historical biodiesel, renewable diesel, and conventional diesel volumes and total diesel demand[234] for all scenarios are based on reported volume data. Prior to 2011, total biomass-based diesel and conventional diesel volumes are from the Board of Equalization (BOE) and reported in the LCFS 2011

[232] Biomass-based diesel consumption data for California are not available for the entire year in 2017, and total annual biomass-based diesel volumes for 2017 are projected. Therefore 2017 is considered a future year for the purposes of this analysis.
[233] Estimated LCFS NOx emissions using Attribution Method II result in cumulative LCFS NOx emissions that are less than using Attribution Method III.
[234] Total diesel demand represents the sum of biodiesel, renewable diesel, and conventional diesel volumes.

Program Review Report (pre-2011).[235] For 2011 and later, total biomass-based diesel and conventional diesel volumes were reported to CARB through the LCFS Reporting Tool (LRT).[236] The total historical volumes of biodiesel, renewable diesel, and conventional diesel used in California from 2007 – 2016, in millions of gallons per year (MGPY), are provided in **Table 3-3**.

Table 3-3 – Historical Total Biomass-Based Diesel and Conventional Diesel Volumes Used in California, 2007 to 2016 (for all Scenarios)

Fuel	Historical Total Volumes by Year (MGPY)									
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Biodiesel	17	12	6.9	5.4	13	20	60	67	126	163
Renewable Diesel	0	0	0	0	1.8	8.8	117	113	165	248
Conventional Diesel	3,805	3,429	3,200	3,295	3,470	3,578	3,405	3,444	3,475	3,421
Total Diesel Demand[237]	3,822	3,441	3,207	3,300	3,485	3,607	3,582	3,624	3,767	3,832

Projected future total biodiesel, renewable diesel, and conventional diesel use in California for years 2017 - 2025 for Scenarios 3 and 4 were based on two sets of volume estimates:

1. Scenario 3: Based on the 15-day changes to the Illustrative Compliance Scenario in the 2015 LCFS staff report (2015 LCFS EA scenario);[238] and

2. Scenario 4: Based on the business-as-usual (BAU) scenario evaluated as part of the environmental analysis for the 2018 LCFS Amendments (2018 LCFS EA

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[235] CARB. 2011. Low Carbon Fuel Standard 2011 Program Review Report. December 8. Available at: https://www.arb.ca.gov/fuels/lcfs/workgroups/advisorypanel/20111208_LCFS%20program%20review%20report_final.pdf. Accessed: August, 2017.
[236] CARB. 2017. Low Carbon Fuel Standard Reporting Tool Quarterly Summaries. August 2. Available at: https://www.arb.ca.gov/fuels/lcfs/lrtqsummaries.htm. Accessed: September, 2017.
[237] Total diesel demand represents the sum of biodiesel, renewable diesel, and conventional diesel volumes.
[238] CARB. 2014. Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Proposed Re-Adoption of the Low Carbon Fuel Standard, Appendix B: Development of Illustrative Compliance Scenarios and Evaluation of Potential Compliance Curves. Available at: https://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15appb.pdf. Accessed: July, 2017.

BAU scenario).[239] These biodiesel, renewable diesel, and conventional diesel volumes were included to represent an updated projection of possible biomass-based diesel and conventional diesel volumes assuming a LCFS program that remains at 10 percent carbon intensity reduction post 2020.[240]

Future total biodiesel, renewable diesel, and conventional diesel volumes projected to be used in California from 2017 – 2025 for Scenarios 3 and 4 are shown in **Tables 3-4** and **3-5**, respectively.

Table 3-4 – Projected Future Total Biomass-Based Diesel and Conventional Diesel Volumes to be Used in California, 2017 to 2025, Scenario 3 (Based on 2015 LCFS EA Scenario Volumes)

Fuel	Projected Future Total Volumes by Year, Scenario 3 - Based on 2015 LCFS EA Scenario Volumes (MGPY)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biodiesel	160	180	180	180	185	185	185	190	190
Renewable Diesel	300	320	360	400	500	550	600	600	600
Conventional Diesel	3,443	3,461	3,481	3,501	3,457	3,469	3,482	3,541	3,606
Total Diesel Demand[241]	3,903	3,961	4,021	4,081	4,142	4,204	4,267	4,331	4,396

[239] CARB. 2018. Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Proposed Amendments to the Low Carbon Fuel Standard, Appendix D: Environmental Analysis. March.

[240] The primary differences in biodiesel and renewable diesel projections from the 2015 LCFS EA scenario to the 2018 LCFS EA BAU scenario include increased biodiesel production due to CARB's knowledge of the introduction of a more cost-effective NOx reducing additive for ADF compliance and general updates to our expectations about the possible future supply of all fuels. Similar to the 2015 Illustrative Scenario, it is not a forecast of the only possible response to the regulation, but it is a plausible scenario by which compliance with the 2015 LCFS could be achieved. CARB believes the analysis presented below reflects a best estimate approach to future projections, given these uncertainties. Any uncertainties in compliance response would not alter the fundamental conclusions of this document because the proposed amendments to the ADF regulation work to produce full mitigation regardless of the particular compliance scenario in future, and the conservative upper-bound attribution methodology continues to operate for past emissions to ensure remediation.

[241] Total diesel demand represents the sum of biodiesel, renewable diesel, and conventional diesel volumes.

Table 3-5 – Projected Future Total Biomass-Based Diesel and Conventional Diesel Volumes to be Used in California, 2017 to 2025, Scenario 4 (Based on 2018 LCFS EA BAU Scenario Volumes)

Fuel	Projected Future Total Volumes by Year, Scenario 4 - Based on 2018 LCFS EA BAU Scenario Volumes (MGPY)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biodiesel	170	200	275	350	425	500	500	500	500
Renewable Diesel	350	450	550	650	750	850	950	1,050	1,150
Conventional Diesel	3,268	3,110	2,916	2,737	2,592	2,446	2,383	2,244	2,123
Total Diesel Demand[242]	3,788	3,760	3,741	3,737	3,767	3,796	3,833	3,794	3,773

Staff estimated the LCFS-attributed volumes of biodiesel and renewable diesel for Scenarios 3 and 4 by multiplying the total volumes of biodiesel and renewable diesel used in California by the percentages of biodiesel and renewable diesel attributed to the LCFS, as shown in **Equations A4-1** and **A4-2**, respectively, in **Appendix 4**. The total volumes of biodiesel and renewable diesel used in California during the historical and future periods are provided in **Tables 3-3 – 3-5**. The percentages of biodiesel and renewable diesel attributed to the LCFS for Scenarios 3 and 4 (based on Attribution Method II) in years 2007 - 2016 are provided in **Table 3-1**. For years 2017 - 2025, the percentages of biodiesel and renewable diesel attributed to the LCFS were estimated based on the conservative assumption that the LCFS program is responsible for any increase in the use of biomass-based diesel volumes in California beyond the 2016 volumes attributed to federal programs, as discussed in Section C.3 and shown in **Equations A4-3** and **A4-4**, respectively, in **Appendix 4**.[243]

Table 3-6 presents the LCFS-attributed volumes of biomass-based diesel for Scenarios 3 and 4 during the historical period (2007 – 2016),[244] and **Tables 3-7** and **3-8** present the LCFS-attributed volumes of biomass-based diesel for Scenarios 3 and 4, respectively, during the future period (2017 – 2025). LCFS-attributed values are

[242] Total diesel demand represents the sum of biodiesel, renewable diesel, and conventional diesel volumes.
[243] The estimation of the percentages of biodiesel and renewable attributed to the LCFS for Scenarios 3 and 4 from 2017 - 2025 rely on the volumes of biodiesel and renewable diesel attributed to non-LCFS programs in 2016 for Method II, provided in Table 3-1.
[244] Historical LCFS-attributed volumes are the same for Scenarios 3 and 4 because these scenarios are based on the same attribution method (Method III) and historical biomass-based diesel volumes.

presented as annual biomass-based diesel volumes used in California attributed to the LCFS, in MGPY, and as percentages of the total annual biomass-based diesel volumes used in California.

Table 3-6 – Historical LCFS-Attributed Biomass-Based Diesel Volumes and Percentages of Total Volumes, 2007 to 2016,[245] Scenarios 3 and 4

Fuel	Historical LCFS-Attributed Volumes and Percentages of Total Volumes by Year									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Biodiesel (MGPY)	0	0	0	0	0	0.80	11	11	20	51
% of Total Biodiesel	0%	0%	0%	0%	0%	4%	18%	16%	16%	31%
Renewable Diesel (MGPY)	0	0	0	0	0	0.35	16	15	20	62
% of Total Renewable Diesel	0%	0%	0%	0%	0%	4%	14%	13%	12%	25%

Table 3-7 – Projected Future LCFS-Attributed Biomass-Based Diesel Volumes and Percentages of Total Volumes, 2017 to 2025, Scenario 3

Fuel	Projected Future LCFS-Attributed Volumes and Percentages of Total Volumes by Year								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biodiesel (MGPY)	48	68	68	68	73	73	73	78	78
% of Total Biodiesel	30%	38%	38%	38%	39%	39%	39%	41%	41%
Renewable Diesel (MGPY)	114	134	174	214	314	364	414	414	414
% of Total Renewable Diesel	38%	42%	48%	54%	63%	66%	69%	69%	69%

245 As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel and renewable diesel usage in California attributed to the LCFS prior to 2012.

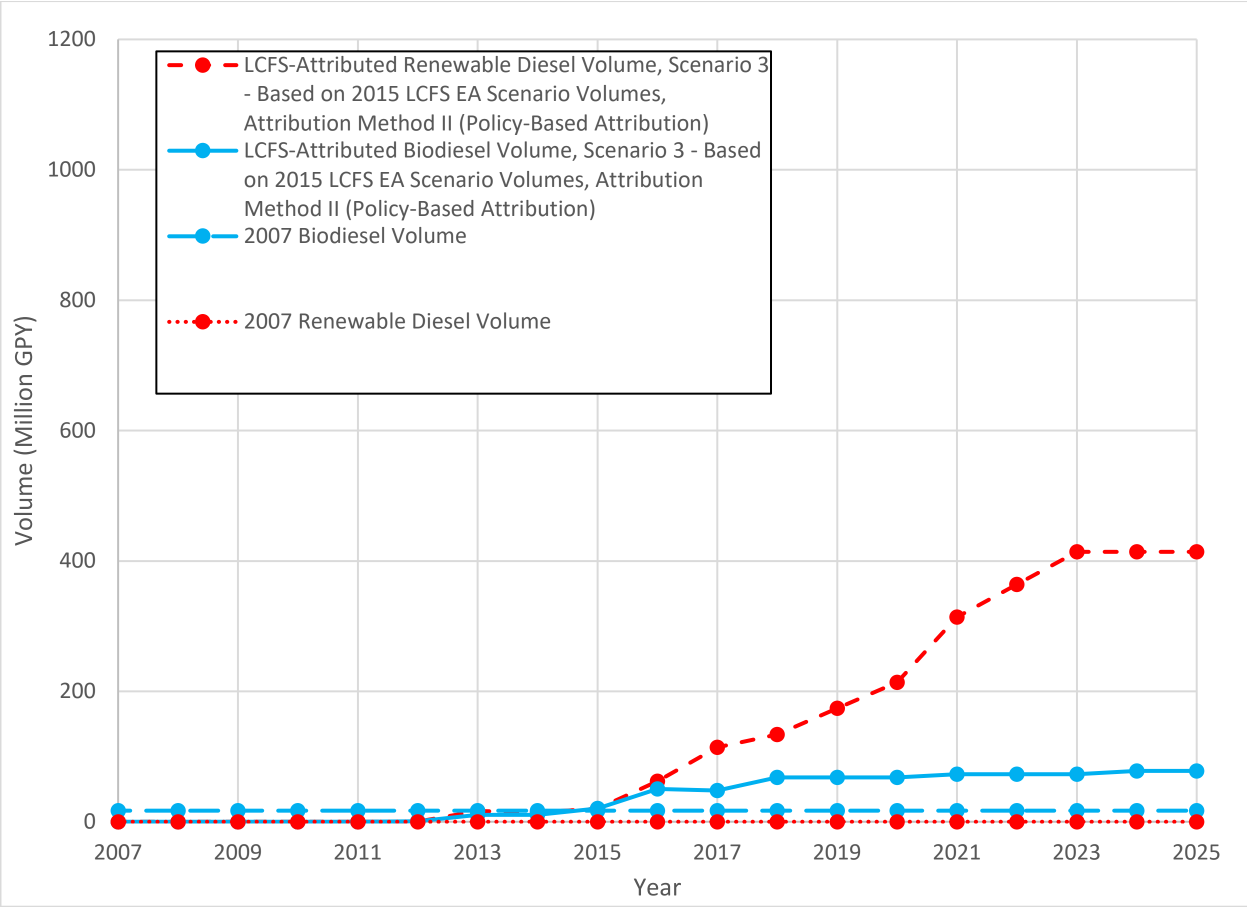
Table 3-8 – Projected Future LCFS-Attributed Biomass-Based Diesel Volumes and Percentages of Total Volumes, 2017 to 2025, Scenario 4

Fuel	Projected Future LCFS-Attributed Volumes and Percentages of Total Volumes by Year								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
Biodiesel (MGPY)	58	88	163	238	313	388	388	388	388
% of Total Biodiesel	34%	44%	59%	68%	74%	78%	78%	78%	78%
Renewable Diesel (MGPY)	164	264	364	464	564	664	764	864	964
% of Total Renewable Diesel	47%	59%	66%	71%	75%	75%	78%	80%	82%

b. Comparison of LCFS-Attributed Biomass-Based Diesel Volumes

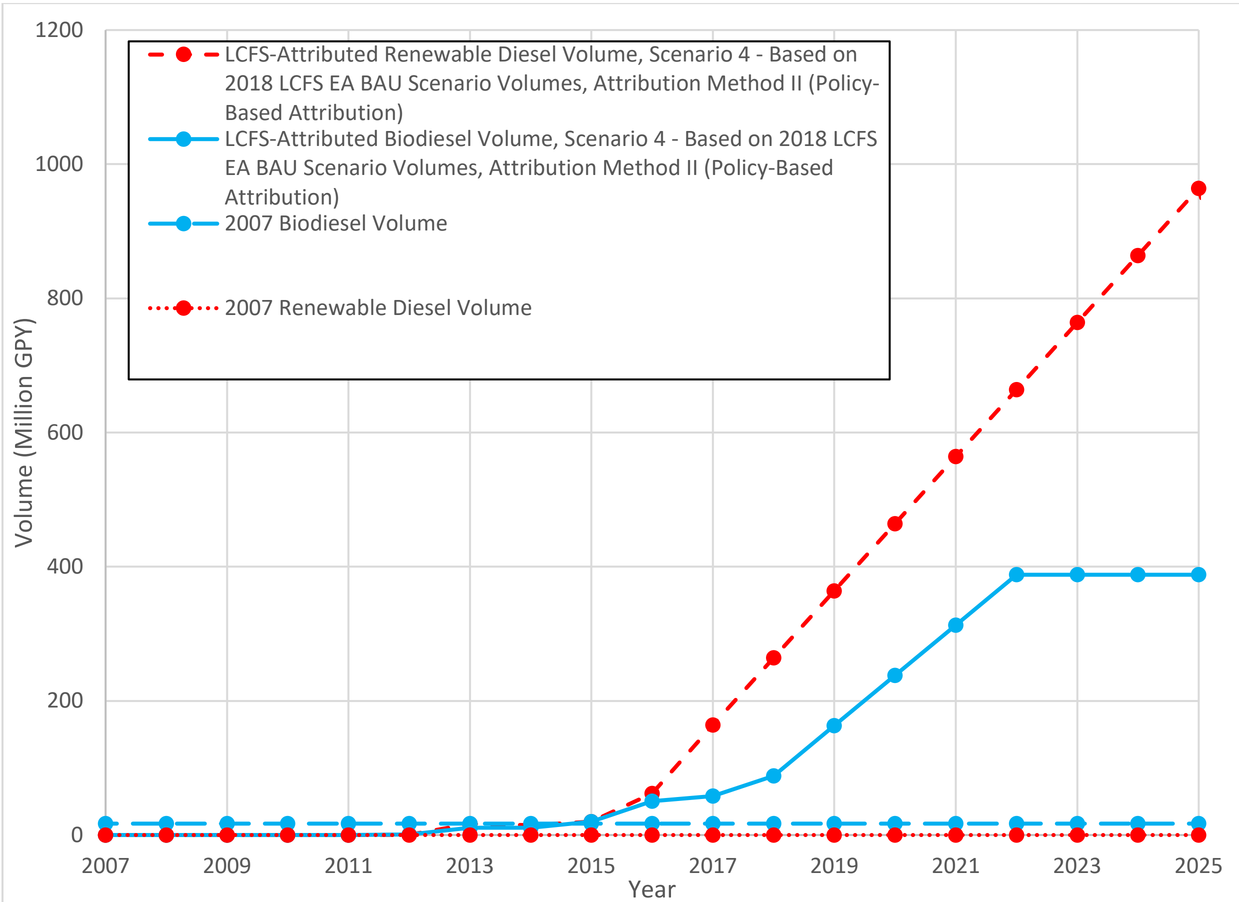
The LCFS-attributed biomass-based diesel volumes from 2007 to 2025 for Scenarios 3 and 4 are shown in **Figures 3-1** and **3-2**, respectively. **Figures 3-1** and **3-2** also show the total biodiesel and renewable volumes for 2007 as a comparison. **Figures 3-1** and **3-2** indicate that the LCFS-attributed biomass-based diesel volume trends are somewhat different for Scenarios 3 and 4. For instance, **Figure 3-1** (Scenario 3) indicates that the LCFS-attributed renewable diesel usage increases steadily over the time period from 2012 - 2023 and then levels off. LCFS-attributed biodiesel usage also increases steadily, but only from 2012 - 2016, after which it levels off and remains constant through 2025. **Figure 3-2** (Scenario 4) shows that LCFS-attributed renewable diesel usage increases steadily over the time period from 2012 – 2025, and at a much higher rate than in Scenario 3. **Figure 3-2** also shows that LCFS-attributed biodiesel usage in Scenario 4 increases at a much higher rate than in Scenario 3 from 2015 - 2022 and levels off after 2022.

Figure 3-1 – LCFS-Attributed Biomass-Based Diesel Volumes for Scenario 3[246]



[246] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012.

Figure 3-2 – LCFS-Attributed Biomass-Based Diesel Volumes for Scenario 4[247]



[247] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012.

B. LCFS NOX AND PM EMISSIONS IMPACTS

Staff estimated LCFS NOx and PM emissions on a year-by-year basis for Scenarios 3 and 4 using the methodology described in **Appendix 5**. Staff compared LCFS NOx and PM emissions for Scenarios 3 and 4 to a baseline that reflects conditions existing at the time environmental analysis of the original LCFS regulation was commenced.

Staff evaluated the impacts of LCFS NOx and PM emissions due to biomass-based diesel use for Scenarios 3 and 4 based on based on the significance criteria in Appendix G of the CEQA Guidelines.[248] The results of this evaluation are presented below.

1. LCFS NOx Emissions Impacts

Figures 3-3 and **3-4** show LCFS NOx emissions for biodiesel and renewable diesel separately as well as the net LCFS NOx emissions for biomass-based diesel for each year from 2007 - 2025 for Scenarios 3 and 4, respectively.[249] **Figures 3-3** and **3-4** indicate that historical biomass-based diesel use attributed to the LCFS for both scenarios resulted in five years (2012 - 2016) when NOx emissions increased relative to use of conventional diesel. For Scenario 3 (based on 2015 LCFS EA scenario volumes), **Figure 3-3** shows that LCFS NOx emissions due to renewable diesel more than offset LCFS NOx emissions due to biodiesel for all other years (2017 - 2025), providing a NOx emissions benefit during these years.

For Scenario 4 (based on 2018 LCFS EA BAU Scenario volumes), **Figure 3-4** shows that LCFS NOx emissions due to renewable diesel are not sufficient to offset LCFS NOx emissions due to biodiesel for all future years when the ADF regulation in-use requirements are not in effect, resulting in a net NOx emissions increase for one additional year (2023).[250] However, cumulative LCFS NOx emissions over the period 2007 – 2025 show a NOx emissions reduction for both scenarios (3,700 tons reduction for Scenario 3 and 6,500 tons reduction for Scenario 4). LCFS NOx emissions are also less than the 2007 NOx emissions increase from biomass-based diesel use for both scenarios.

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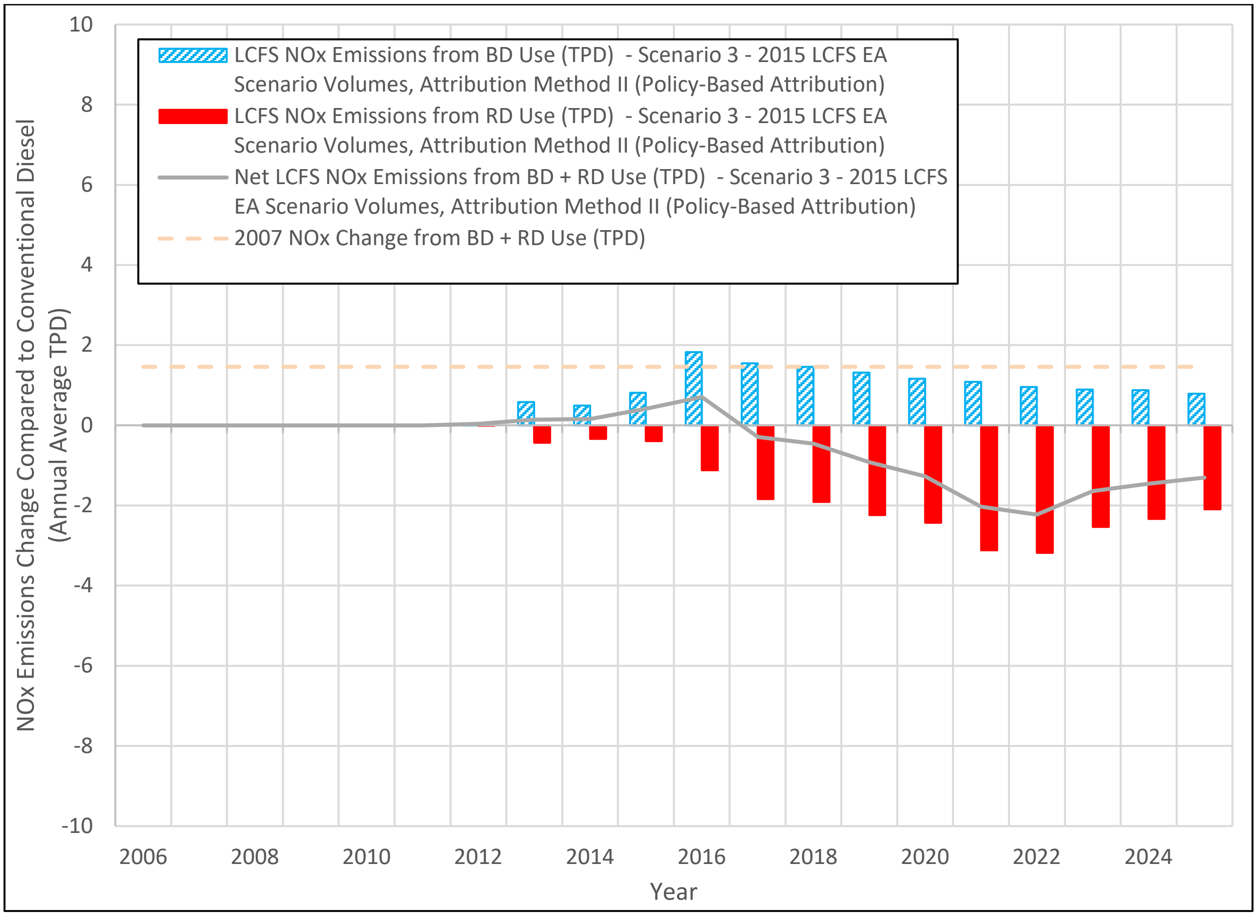
[248] California Code of Regulations (CCR). 2017. Title 14, Appendix G. Environmental Checklist Form. https://govt.westlaw.com/calregs/Document/I1D6750F63775483A8F7861C335CD6854?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)

[249] LCFS NOx emissions from biodiesel are inclusive of other offsetting factors, including adoption of NTDE vehicles and ADF regulation in-use requirements.

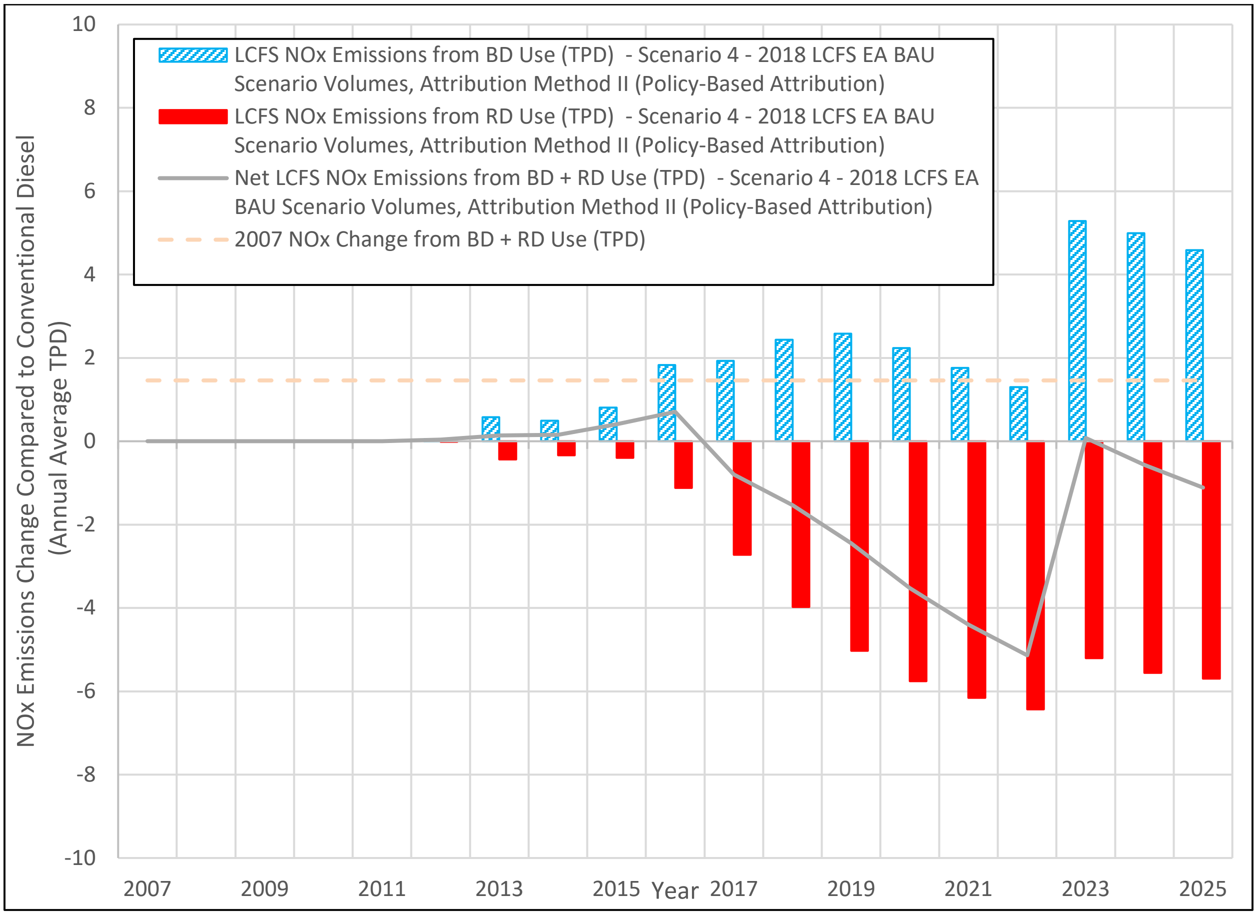
[250] CARB's analysis of projected biodiesel and renewable diesel consumption in California indicated LCFS NOx emissions beyond 2025 that could result in a potentially significant air quality impact. These LCFS NOx emissions, which were analyzed through 2030, would be mitigated by the proposed amendment to the ADF regulation described in Appendix G.

Figure 3-3 – LCFS NOx Emissions for Scenario 3 (2015 LCFS EA Scenario Volumes, Attribution Method II (Policy-Based Attribution)[251]



[251] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in NOx emissions from biomass-based diesel use to the LCFS prior to 2012.

Figure 3-4 – LCFS NOx Emissions for Scenario 4 (2018 LCFS EA BAU Scenario Volumes, Attribution Method II (Policy-Based Attribution)[252]



Staff evaluated the impacts of LCFS NOx emissions based on the significance criteria in Appendix G of the CEQA Guidelines.[253] Based on these criteria, LCFS NOx emissions would have a significant impact if they:

1. Violate any air quality standard or contribute substantially to an existing or projected air quality violation;

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[252] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in NOx emissions from biomass-based diesel use to the LCFS prior to 2012.
[253] California Code of Regulations (CCR). 2017. Title 14, Appendix G. Environmental Checklist Form. https://govt.westlaw.com/calregs/Document/I1D6750F63775483A8F7861C335CD6854?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default)

2. Conflict with or obstruct implementation of the applicable air quality plan;

3. Result in a cumulatively considerable net increase of any criteria air pollutant for which the project region is non-attainment under an applicable national or California ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors);[254] or

4. Expose sensitive receptors to substantial pollutant concentrations.[255]

Out of an abundance of caution, staff utilized a conservative analytical approach that likely overestimates LCFS attributable impacts, concluding that potential increases in NOx emissions from biomass-based diesel attributed to LCFS, considered in isolation from the overall air quality impacts of biodiesel use, may have had a significant adverse effect on the environment in 2012 – 2016, and could cause significant adverse environmental impacts from 2023 onward, again considered independently of the PM reductions they deliver, if the ADF regulation is not modified.

a. Impact of LCFS NOx Emissions on Meeting Air Quality Standards

NOx is regulated as an ozone precursor, and a subset of NOx (NO_2) is regulated as a criteria pollutant. Both CARB and U.S. EPA have set ambient air quality standards for ozone and NO_2 concentrations.[256] Many areas of California are currently designated as State and federal ozone non-attainment areas, and are subject to emissions reduction strategies for ozone, outlined in the California State Implementation Plan (SIP).[257] Currently, there are no State- or federally-designated NO_2 non-attainment areas in California.[258,259]

Staff evaluated the potential for LCFS NOx emissions to cause or substantially contribute to a potential violation of the State or Federal NO_2 or ozone standards by comparing LCFS NOx emissions to total statewide NOx emissions for the period from

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[254] NOx is an ozone precursor. Most air districts in California have set quantitative CEQA thresholds for ozone precursors, including NOx emissions, to evaluate significance of emissions.
[255] Health impacts of LCFS-attributed biomass-based diesel use are discussed in Section C.
[256] CARB. 2016. Ambient Air Quality Standards. May. Available at: https://www.arb.ca.gov/research/aaqs/aaqs2.pdf. Accessed: September, 2017.
[257] CARB. 2017. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf. Accessed: September, 2017.
[258] CARB. 2017. Area Designations for State Ambient Air Quality Standards – Nitrogen Dioxide. Available at: https://www.arb.ca.gov/desig/adm/2015/state_no2.pdf. Accessed: September, 2017.
[259] CARB. 2015. Area Designations for National Ambient Air Quality Standards – Nitrogen Dioxide. Available at: https://www.arb.ca.gov/desig/adm/2015/fed_no2.pdf. Accessed: September, 2017.

2007 - 2025,[260] as shown in **Figure 3-5**. **Figure 3-5** shows that maximum LCFS NOx emissions are less than 0.1 percent of total statewide NOx emissions for both scenarios. Assuming that NO_2 and ozone concentrations are proportional to NOx emissions,[261] staff estimated that statewide NO_2 and ozone concentrations would increase by less than 0.1 percent statewide for both scenarios in any given year. **Figure 3-5** also shows LCFS NOx emissions that could result in statewide ozone concentration reductions under Scenarios 3 and 4 for a number of years.[262]

Due to the likely broad geographical distribution of LCFS NOx emissions, staff anticipates that potential changes in NO_2 and ozone concentrations due to LCFS NOx emissions would likely occur over large geographical areas instead of spiking in certain areas.

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[260] Total statewide annual average daily NOx emissions data are from CARB's CEPAM emissions inventory. Available at: https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php. Statewide total NOx emissions are shown in Figure 9 of Appendix G.

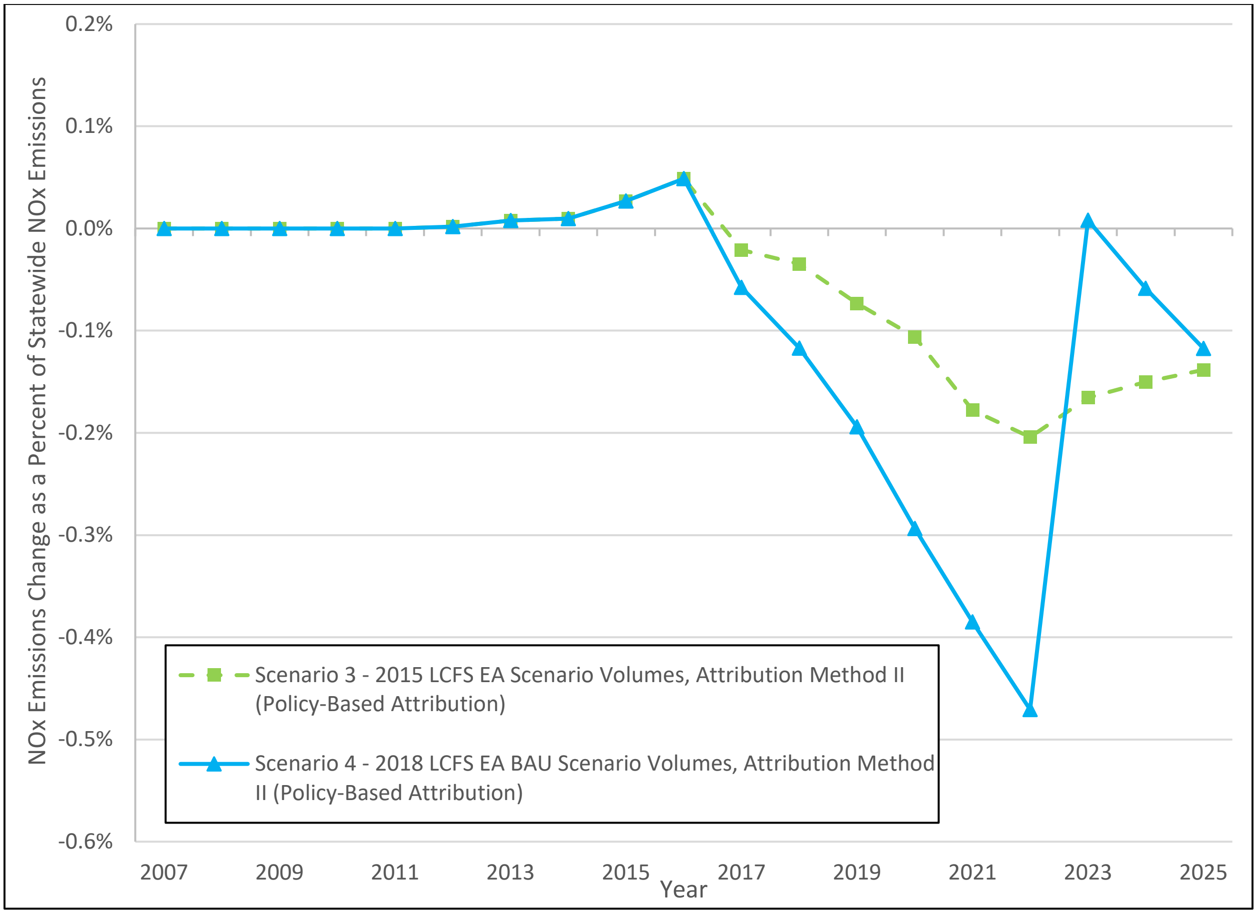
[261] The relationship between NOx emissions and ozone concentrations is complex, and depends on several other variables, including VOC concentrations, solar radiation, and temperature. For the purposes of this qualitative analysis, staff assumed that ozone concentrations would increase with NOx emissions increases, and would scale at less than a one-to-one ratio (e.g., ozone concentrations would increase at a lower rate than NOx emissions increases). Staff also notes that, under certain conditions (i.e., relatively low VOC/NOx ratios), ozone concentrations can increase with decreasing NOx emissions. See:

National Research Council. 1991. Rethinking the Ozone Problem in Urban and Regional Air Pollution. Washington, DC. The National Academies Press. pp. 163-168. Available at: https://www.nap.edu/catalog/1889/rethinking-the-ozone-problem-in-urban-and-regional-air-pollution. Accessed: September, 2017.

Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. pp. 14-16. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

[262] Under certain conditions (i.e., relatively low VOC to NOx concentration ratios), NOx emissions reductions result in increased ozone concentrations. See Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

Figure 3-5 – LCFS NOx Emissions as a Percent of Total Statewide NOx Emissions, Scenarios 3 and 4[263]



b. Impact of LCFS NOx Emissions on Implementation of the Applicable Air Quality Plan

Assuming that ozone concentrations are proportional to NOx emissions,[264] staff evaluated the potential for LCFS NOx emissions to obstruct or delay attainment of the

[263] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in NOx emissions from biomass-based diesel use to the LCFS prior to 2012.
[264] The relationship between NOx emissions and ozone concentrations is complex, and depends on several other variables, including VOC concentrations, solar radiation, and temperature. For the purposes of this qualitative analysis, staff assumed that ozone concentrations would increase with NOx

State and federal ozone standards by comparing LCFS NOx emissions to statewide NOx emissions reductions.[265] As indicated in **Figure 3-6**, LCFS NOx emissions could reduce statewide NOx emissions reductions in certain years, up to a maximum of approximately one percent of statewide NOx emissions reductions for both Scenarios 3 and 4. However, **Figure 3-6** also indicates that LCFS NOx emissions would further increase statewide NOx emissions reductions in other years, up to four to 10 percent of statewide NOx emissions reductions for Scenarios 3 and 4, respectively. [266]

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emissions increases, and would scale at less than a one-to-one ratio (e.g., ozone concentrations would increase at a lower rate than NOx emissions increases). Staff also notes that, under certain conditions (i.e., relatively low VOC/NOx concentration ratios), ozone concentrations can increase with decreasing NOx emissions. See:

National Research Council. 1991. Rethinking the Ozone Problem in Urban and Regional Air Pollution. Washington, DC. The National Academies Press. pp. 163-168. Available at: https://www.nap.edu/catalog/1889/rethinking-the-ozone-problem-in-urban-and-regional-air-pollution. Accessed: September, 2017.

Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. pp. 14-16. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

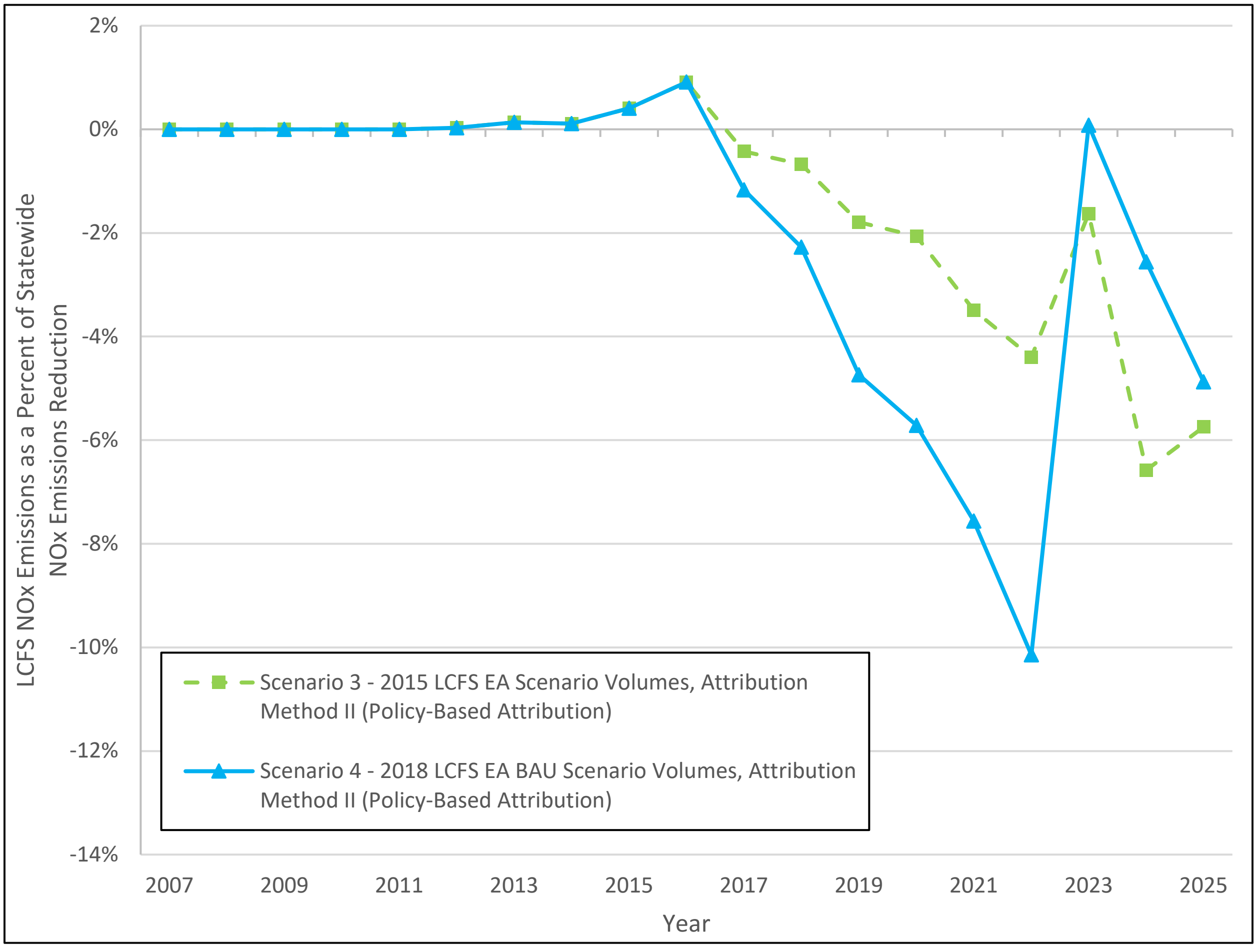
[265] Total statewide annual average daily NOx emissions reductions were estimated as the difference between statewide annual average daily NOx emissions for consecutive years.

[266] Staff notes that, under certain conditions (i.e., relatively low VOC/NOx concentration ratios), ozone concentrations can increase with decreasing NOx emissions. See:

National Research Council. 1991. Rethinking the Ozone Problem in Urban and Regional Air Pollution. Washington, DC. The National Academies Press. pp. 163-168. Available at: https://www.nap.edu/catalog/1889/rethinking-the-ozone-problem-in-urban-and-regional-air-pollution. Accessed: September, 2017.

Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. pp. 14-16. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

Figure 3-6 – LCFS NOx Emissions as a Percent of Total Statewide NOx Emissions Reductions, Scenarios 3 and 4[267]



Because non-attainment areas are defined over much smaller geographical areas (i.e., by air basin or partial air basin as opposed to by state), staff also evaluated the potential impacts of LCFS NOx emissions by air basin. CARB's Revised

Proposed 2016 Strategy for the State Implementation Plan provides ozone attainment dates for each non-attainment area ranging from 2015 to 2031, depending on the specific non-attainment area.[268] Cumulative LCFS NOx emissions over the period 2007 – 2025 show a NOx emissions reduction for both scenarios (3,700 tons reduction for Scenario 3 and 6,500 tons reduction for Scenario 4). Therefore, LCFS NOx emissions

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[267] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in NOx emissions from biomass-based diesel use to the LCFS prior to 2012.
[268] CARB. 2016. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf. Accessed: July, 2017.

would likely not contribute to obstruction or delay in meeting ozone standards for non-attainment areas with compliance dates closer to 2031 for either scenario.

For non-attainment areas with attainment dates prior to 2031, staff evaluated the potential for LCFS NOx emissions to obstruct or delay attainment of the State and federal ozone standards by estimating LCFS NOx emissions within each air basin as a percent of air basin-wide NOx emissions for years when LCFS NOx emissions were greater than zero (i.e., when there were NOx emissions increases due to LCFS-attributed biomass-based diesel use relative to conventional diesel use). These values represent the percentage of the total NOx emissions reduction occurring in each air basin that would be reduced by LCFS NOx emissions within each air basin in a given year. The results of this analysis are presented in **Tables 3-9** and **3-10** for Scenarios 3 and 4, respectively. **Tables 3-9** and **3-10** indicate that increases in air basin LCFS NOx emissions are three percent or less of the total NOx emissions reduction in the given air basin for any individual year. **Tables 3-9** and **3-10** do not reflect LCFS NOx emissions less than zero (i.e., LCFS NOx emissions that result in a NOx emissions decrease relative to conventional diesel) that occur in all other years during the period 2012 – 2025. These LCFS NOx emissions would further reduce total NOx emissions within each air basin.

Table 3-9 – LCFS NOx Emissions for Scenario 3 as a Percent of Total NOx Emissions Reductions in each Air Basin – 2012 - 2016[269]

Air Basin	Federal 8-hr Ozone Non-Attainment Area(s)[270]	Attain-ment Dates[271, 272]	LCFS NOx Emissions as a Percent of Total NOx Emissions Reduction (%)				
			2012	2013	2014	2015	2016
Great Basin Valleys	None	-	>0%	>0%	>0%	>0%	1%
Lake County	None	-	>0%	>0%	>0%	1%	1%
Lake Tahoe	None	-	>0%	>0%	>0%	>0%	1%
Mojave Desert	Eastern Kern, Western Mojave Desert	2017, 2026	>0%	>0%	>0%	1%	2%
Mountain Counties	Mariposa, Western Nevada County	2017	>0%	>0%	>0%	1%	1%
North Central Coast	None	-	>0%	>0%	>0%	>0%	1%
North Coast	None	-	>0%	>0%	>0%	>0%	1%
Northeast Plateau	None	-	>0%	>0%	>0%	1%	1%
Sacramento Valley	Butte County, Sacramento Metro	2015, 2026	>0%	>0%	>0%	>0%	1%
Salton Sea	Imperial County, Coachella Valley	2017, 2026	>0%	>0%	>0%	1%	1%
San Diego	San Diego County	2017	>0%	>0%	>0%	>0%	1%
San Francisco Bay Area	San Francisco Bay Area	2015	>0%	>0%	>0%	>0%	1%
San Joaquin Valley	San Joaquin Valley	2031	>0%	>0%	>0%	>0%	1%

[269] LCFS NOx emissions as a percent of total NOx emissions reductions in each air basin for Scenario 3 provided for years when NOx emissions due to biodiesel and renewable diesel use attributed to the LCFS increase relative to conventional diesel use (years 2012-2016).
[270] CARB. 2015. Area Designations for National Ambient Air Quality Standards – 8-hour Ozone. December. Available at: https://www.arb.ca.gov/desig/adm/2015/fed_o3.pdf. Accessed: July, 2017.
[271] Attainment dates provided for ozone non-attainment areas within each air basin based on the federal 8-hour ozone standard. CARB. 2016. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf (p. 21).
[272] Non-attainment areas with a 2015 attainment date are considered marginal non-attainment areas. These areas have already met the 75 ppb 8-hour ozone standard and have no further SIP requirements.

South Central Coast	Eastern San Luis Obispo, Ventura County	2015, 2020	>0%	>0%	>0%	>0%	1%
South Coast	South Coast Air Basin	2031	>0%	>0%	>0%	>0%	1%

Table 3-10 – LCFS NOx Emissions for Scenario 4 as a Percent of Total NOx Emissions Reductions in each Air Basin – 2012 - 2016 and 2023[273]

Air Basin	Federal 8-hr Ozone Non-Attainment Area(s)[274]	Attain-ment Dates[275, 276]	LCFS NOx Emissions as a Percent of Total NOx Emissions Reduction (%)					
			2012	2013	2014	2015	2016	2023
Great Basin Valleys	None	-	>0%	>0%	>0%	>0%	1%	>0%
Lake County	None	-	>0%	>0%	>0%	1%	1%	>0%
Lake Tahoe	None	-	>0%	>0%	>0%	>0%	1%	>0%
Mojave Desert	Eastern Kern, Western Mojave Desert	2017, 2026	>0%	>0%	>0%	1%	2%	>0%
Mountain Counties	Mariposa, Western Nevada County	2017	>0%	>0%	>0%	1%	1%	>0%
North Central Coast	None	-	>0%	>0%	>0%	>0%	1%	>0%
North Coast	None	-	>0%	>0%	>0%	>0%	1%	>0%
Northeast Plateau	None	-	>0%	>0%	>0%	1%	1%	>0%
Sacramento Valley	Butte County, Sacramento Metro	2015, 2026	>0%	>0%	>0%	>0%	1%	>0%
Salton Sea	Imperial County, Coachella Valley	2017, 2026	>0%	>0%	>0%	1%	1%	>0%

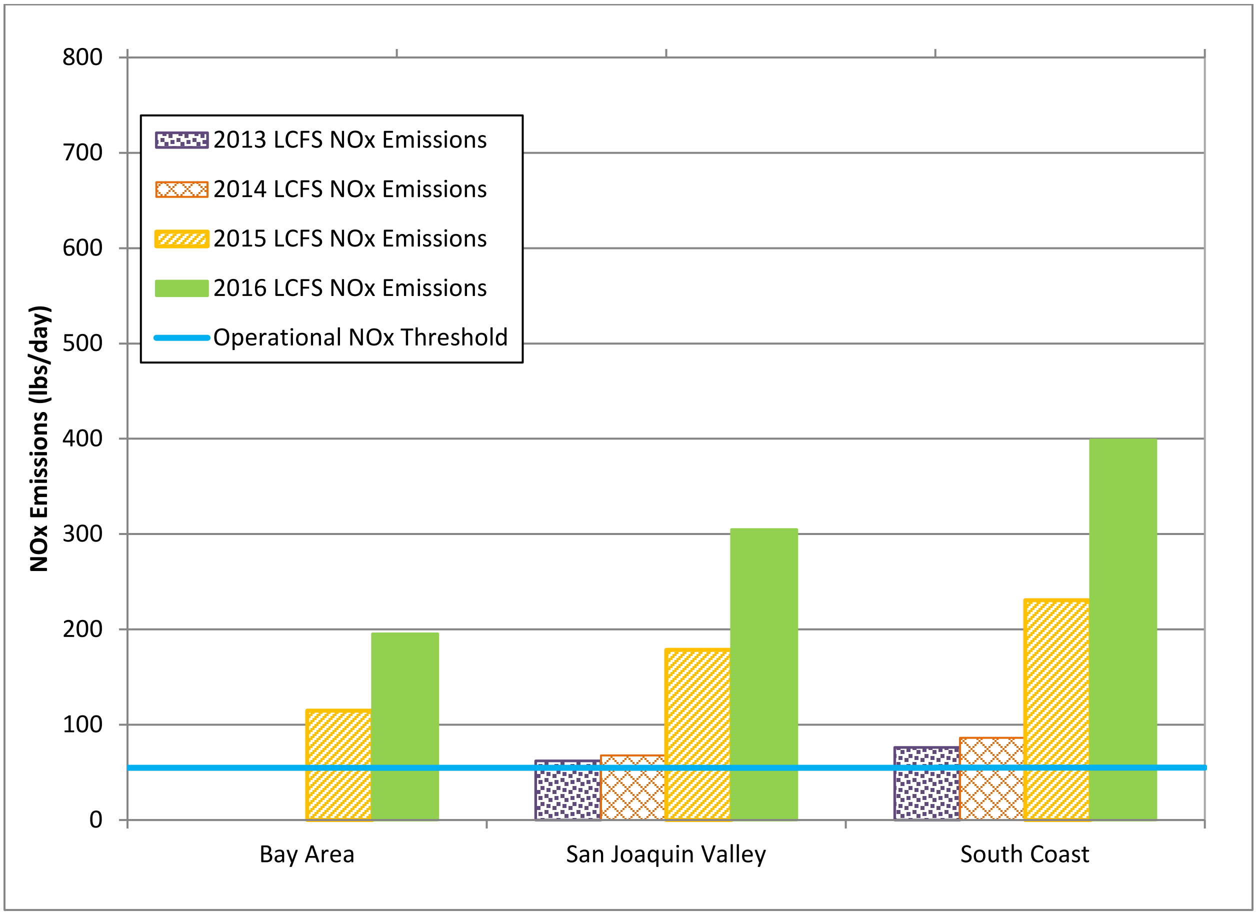
[273] LCFS NOx emissions as a percent of total NOx emissions reductions in each air basin for Scenario 4 provided for years when NOx emissions due to biodiesel and renewable diesel use attributed to the LCFS increase relative to conventional diesel use (years 2012-2016 and 2023).
[274] CARB. 2015. Area Designations for National Ambient Air Quality Standards – 8-hour Ozone. December. Available at: https://www.arb.ca.gov/desig/adm/2015/fed_o3.pdf. Accessed: July, 2017.
[275] Attainment dates provided for ozone non-attainment areas within each air basin based on the federal 8-hour ozone standard. CARB. 2016. Revised Proposed 2016 State Strategy for the State Implementation Plan. March 7. Available at: https://www.arb.ca.gov/planning/sip/2016sip/rev2016statesip.pdf (p. 21).
[276] Non-attainment areas with a 2015 attainment date are considered marginal non-attainment areas. These areas have already met the 75 ppb 8-hour ozone standard and have no further SIP requirements.

San Diego	San Diego County	2017	>0%	>0%	>0%	>0%	1%	>0%
San Francisco Bay Area	San Francisco Bay Area	2015	>0%	>0%	>0%	>0%	1%	>0%
San Joaquin Valley	San Joaquin Valley	2031	>0%	>0%	>0%	>0%	1%	>0%
South Central Coast	Eastern San Luis Obispo, Ventura County	2015, 2020	>0%	>0%	>0%	>0%	1%	>0%
South Coast	South Coast Air Basin	2031	>0%	>0%	>0%	>0%	1%	>0%

c. Comparison of LCFS NOx Emissions to Quantitative Emissions Thresholds

CEQA was designed to evaluate local impacts of land use projects that extend over limited geographical areas (e.g., construction of a multi-unit residential complex or construction or modification of an industrial facility). Most California Air Pollution Control Districts and Air Quality Management Districts, collectively referred to as “air districts”, have published quantitative thresholds for evaluation of criteria pollutant emissions, including NOx emissions, for projects subject to CEQA. However, CEQA was not designed to evaluate impacts of statewide projects, and there are no quantitative thresholds available to evaluate criteria pollutant emissions from statewide projects, including statewide LCFS NOx emissions. In order to further evaluate the statewide LCFS NOx emissions shown in **Figures 3-3** and **3-4**, staff estimated the LCFS NOx emissions in each air district for Scenarios 3 and 4 and compared them to air district-specific CEQA significance thresholds for operational NOx emissions. Although CARB does not believe that the comparison of LCFS NOx emissions in each air district to air district-specific operational NOx emissions thresholds is an appropriate metric for determining significance of a statewide program, staff considered these comparisons in the significance evaluation for LCFS NOx emissions. **Figure 3-7** shows the LCFS NOx emissions for each air district where LCFS NOx emissions exceeded the air district-specific operational NOx emissions threshold for Scenarios 3 and 4. This figure indicates that LCFS NOx emissions exceed air district operational NOx thresholds in multiple air districts for multiple years in both scenarios.

Figure 3-7 – Comparison of LCFS NOx Emissions to Air District CEQA Operational NOx Thresholds, Scenarios 3 and 4[277]



d. Cumulative Impact of LCFS NOx Emissions

CEQA Guidelines section 15355(b) requires an analysis of "other closely related past, present, and reasonably foreseeable probable future projects." However, due to the

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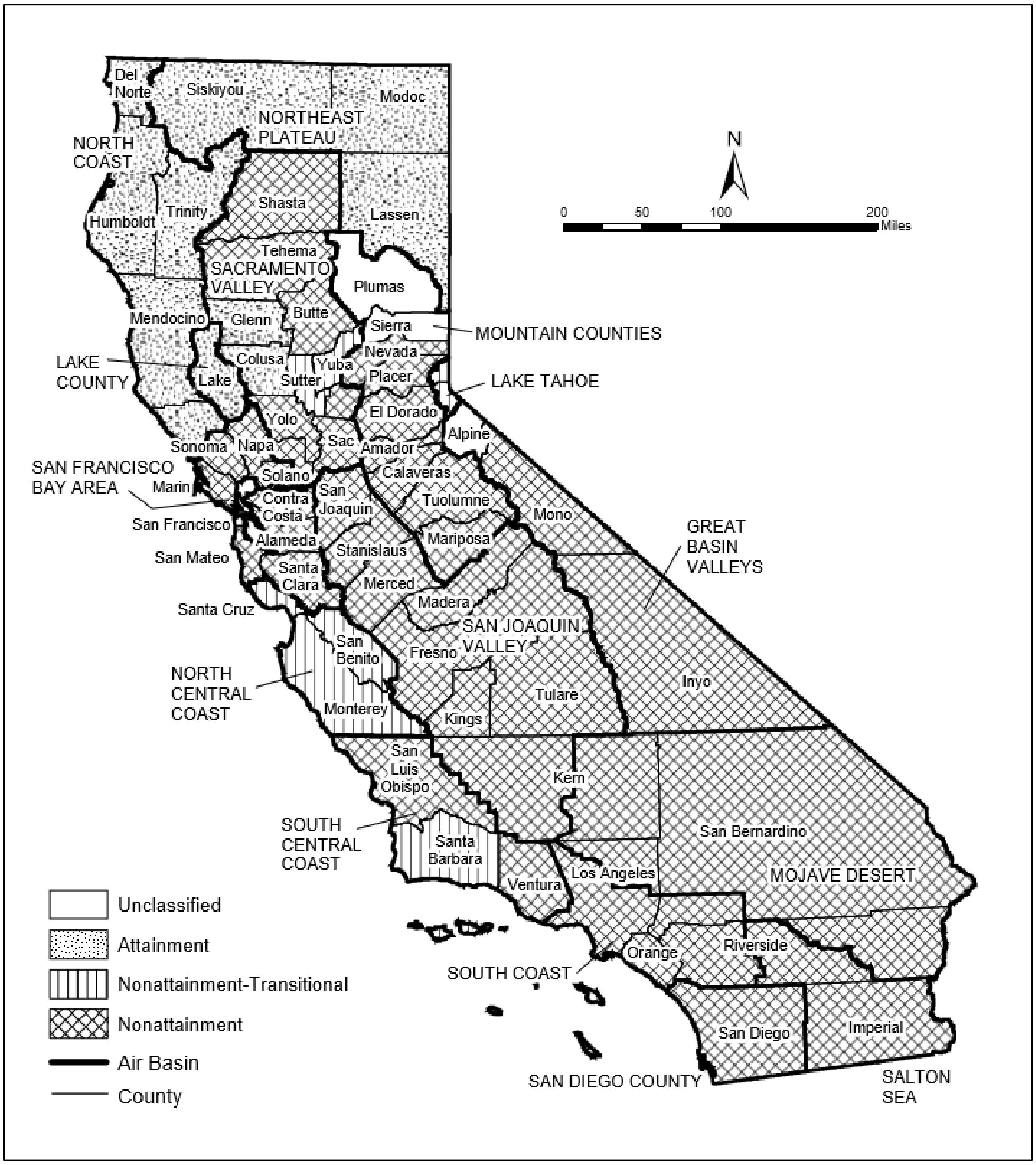
[277] Operational NOx emissions significance thresholds are based on the following sources:
Bay Area Air Quality Management District. 2017. California Environmental Quality Act Air Quality Guidelines. May. Available at: http://www.baaqmd.gov/~/media/files/planning-and-research/ceqa/ceqa_guidelines_may2017-pdf.pdf?la=en. Accessed: August, 2017.
San Joaquin Valley Air Pollution Control District. 2015. Air Quality Thresholds of Significance – Criteria Pollutants. Available at: http://www.valleyair.org/transportation/0714-GAMAQI-Criteria-Pollutant-Thresholds-of-Significance.pdf. Accessed: August, 2017.
South Coast Air Quality Management District. 2015. SCAQMD Air Quality Significance Thresholds. March. Available at: http://www.aqmd.gov/docs/default-source/ceqa/handbook/scaqmd-air-quality-significance-thresholds.pdf?sfvrsn=2. Accessed: August, 2015.

programmatic nature of the NOx emissions impact analysis for LCFS-attributed biomass-based diesel, the statewide reach of the LCFS regulation, and the regional impacts of LCFS NOx emissions, the NOx emissions impact analysis for LCFS-attributed biomass-based diesel use is inherently cumulative in nature.

As indicated in **Figures 3-8** and **3-9**, many areas in California are located in State- and federally-designated ozone non-attainment areas, respectively. Thus, there is an existing, long-term significant air quality impact in these areas due to ozone.[278] Therefore, staff determined that the potentially significant impact of emissions due to biomass-based diesel use in historical and future years could result in a cumulatively considerable contribution to a significant adverse long-term air quality impact.

[278] NOx is an ozone precursor. See CARB. 2015. Ozone and Ambient Air Quality Standards. October. Available at: https://www.arb.ca.gov/research/aaqs/caaqs/ozone/ozone.htm. Accessed: August, 2017.

Figure 3-8 – Area Designations for State Ozone Standards[279]



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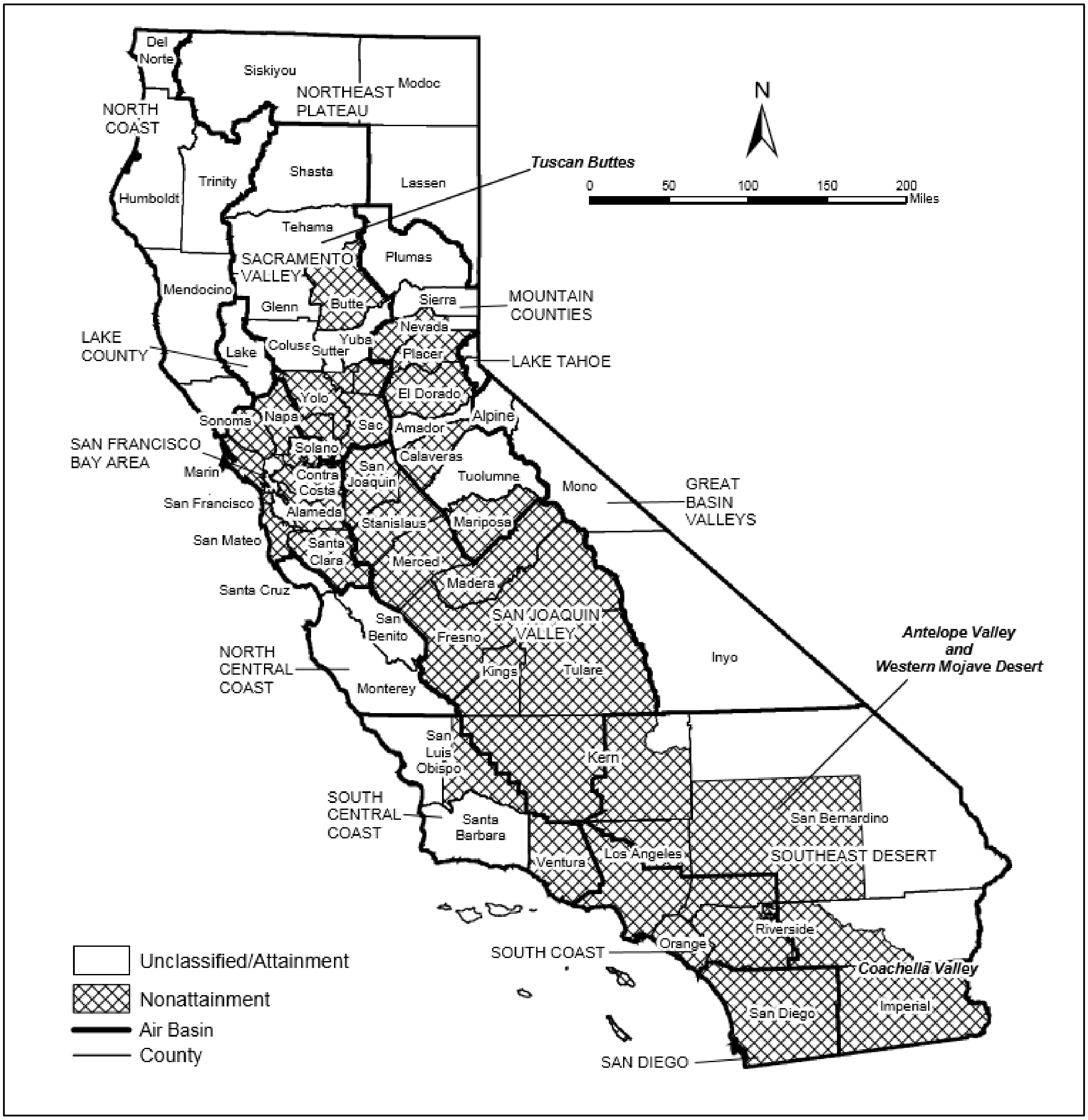
279 CARB. 2017. Area Designations for State Ambient Air Quality Standards - Ozone. Available at: https://www.arb.ca.gov/desig/adm/2016/state_o3.pdf. Accessed: September, 2017.

Figure 3-9 – Area Designations for Federal 8-Hour Ozone Standard[280]



2. LCFS PM Emissions Impacts

Figures 3-10 and **11** show LCFS PM emissions for biodiesel and renewable diesel separately as well as the net LCFS PM emissions for biomass-based diesel for each

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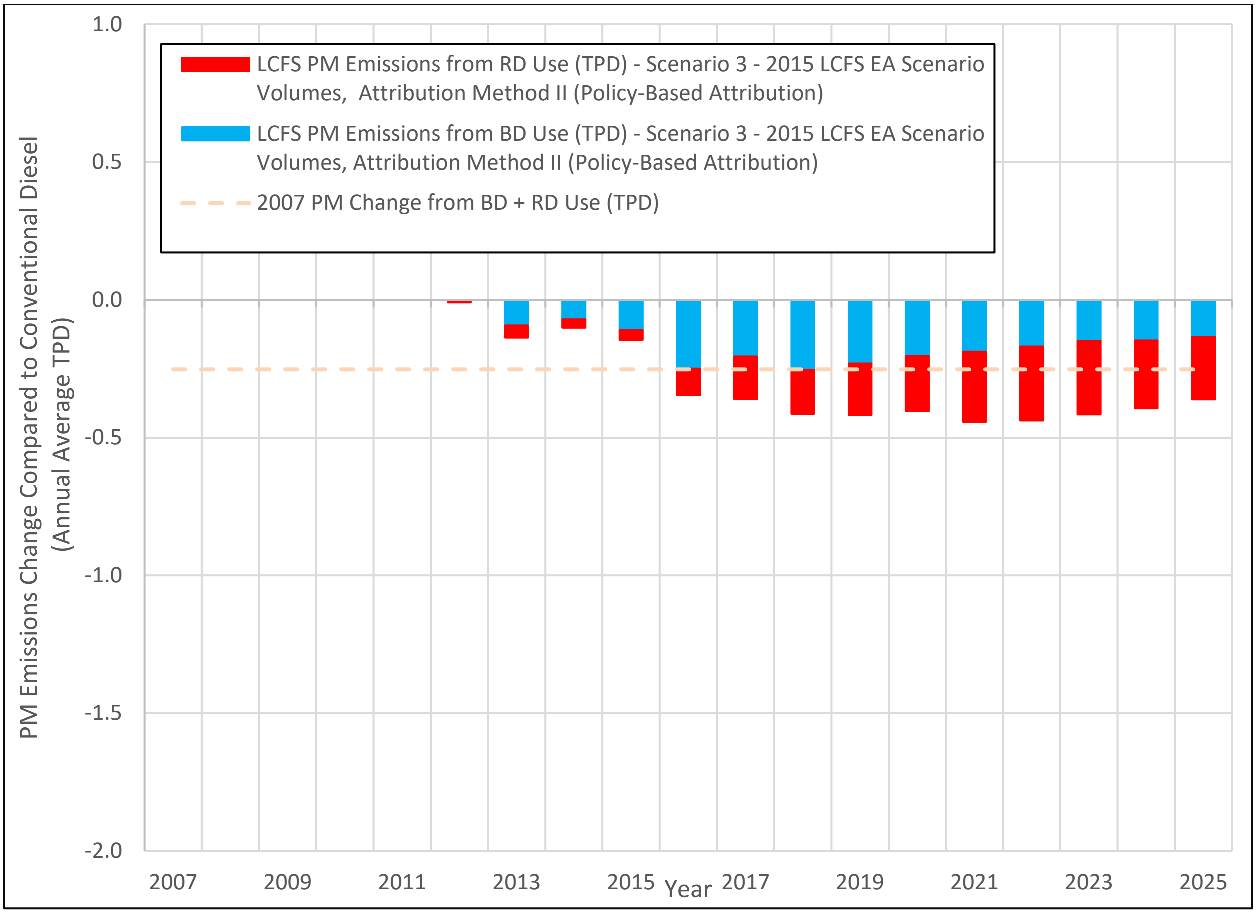
[280] CARB. 2015. Area Designations for National Ambient Air Quality Standards – 8-Hour Ozone. Available at: https://www.arb.ca.gov/desig/adm/2015/fed_o3.pdf. Accessed: September, 2017.

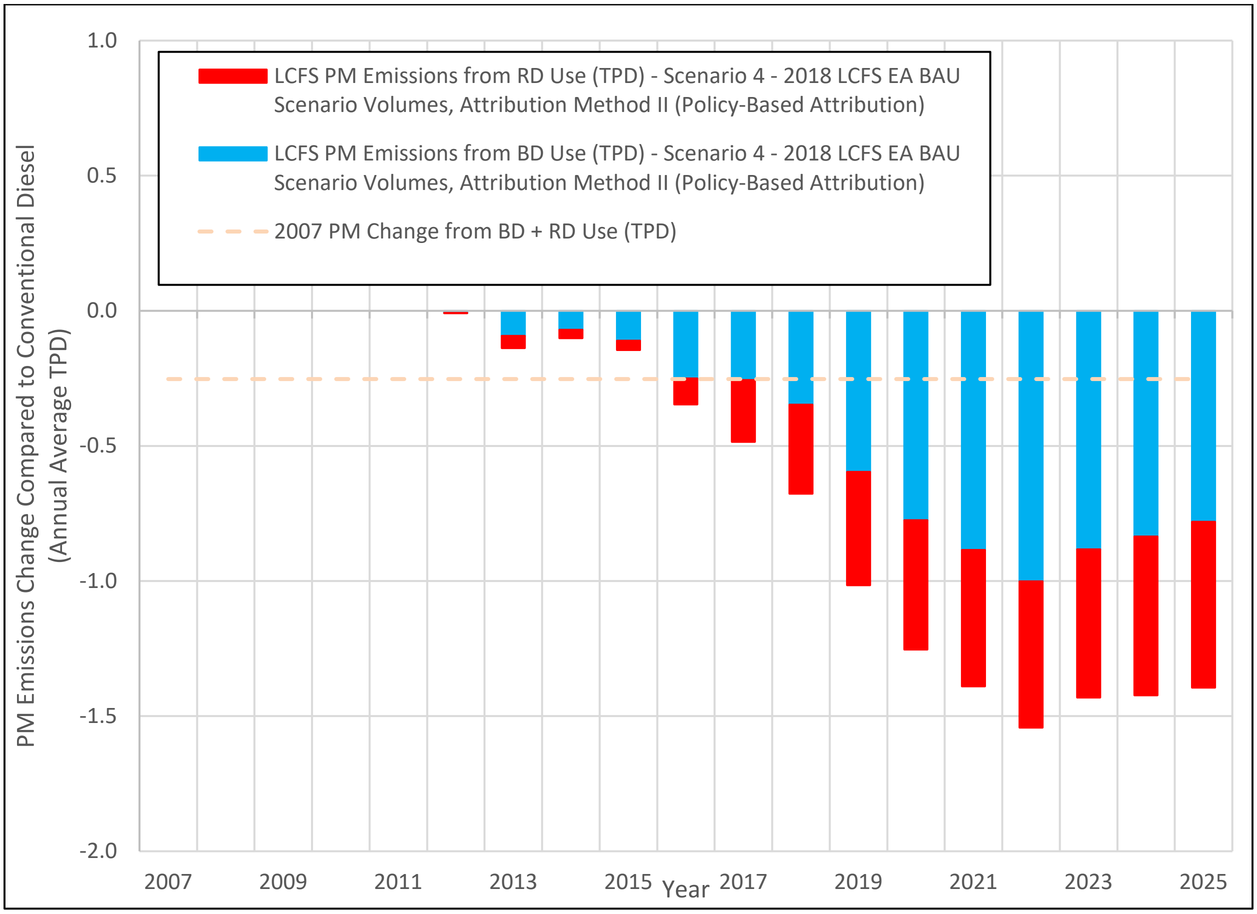
year from 2007 - 2025 for Scenarios 3 and 4, respectively. **Figures 3-10** and **3-11** indicate that LCFS PM emissions are zero or negative (i.e., provide a PM emissions benefit) for both scenarios for all years considered (i.e., 2007 - 2025). For both scenarios, LCFS PM emissions are lower than the 2007 PM emissions change due to biomass-based diesel use relative to conventional diesel. Based on the analysis above, staff determined that LCFS PM emissions resulted in environmentally beneficial impacts for Scenarios 3 and 4 for all historical years (i.e., from 2012 - 2016), and are also anticipated to result in environmentally beneficial PM impacts for Scenarios 3 and 4 for all future years (i.e., from 2017 - 2025).

Figure 3-10 – LCFS PM Emissions for Scenario 3 (2015 LCFS EA Scenario Volumes, Attribution Method II (Policy-Based Attribution)[281]



[281] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in PM emissions from biomass-based diesel use to the LCFS prior to 2012.

Figure 3-11 – LCFS PM Emissions for Scenario 4 (2018 LCFS EA BAU Scenario Volumes, Attribution Method II (Policy-Based Attribution)[282]



3. LCFS NOx and PM Emissions Impacts Following Historical Remediation and Future Mitigation

a. LCFS NOx Emissions Impacts Following Historical Remediation and Future Mitigation

Following implementation of the remedial measure, staff anticipates that cumulative historical LCFS NOx emissions will be fully offset (i.e., reduced to or below the NOx emissions level associated with conventional diesel use) for all scenarios.[283] Similarly,

[282] As described in Appendix 1, staff's attribution analysis indicated that there was no biodiesel or renewable diesel usage in California attributed to the LCFS prior to 2012. Therefore, staff did not attribute any changes in PM emissions from biomass-based diesel use to the LCFS prior to 2012.
[283] As indicated in Appendix G, historical LCFS NOx emissions occurred in the past, and cannot now be directly mitigated in a traditional CEQA sense because of the time-sensitive nature of NOx emissions. Therefore, CARB is proposing to offset the cumulative historical LCFS NOx emissions for the most conservative scenario evaluated.

staff projects that projected future LCFS NOx emissions will be mitigated to below the NOx emissions level associated with conventional diesel use for all scenarios on a year-by-year basis following implementation of feasible the change in the sunset provision to the ADF regulation described in Section D.4.b. Comparisons of the statewide LCFS NOx emissions due to biomass-based diesel use with and without the implementation of the remedial measure and mitigation measure for Scenarios 3 and 4 are presented in **Figures 3-12** and **3-13**, respectively.

Figure 3-12: Comparison of Statewide LCFS NOx Emissions With and Without Implementation of Remedial and Mitigation Measures, 2007 – 2025, Scenario 3

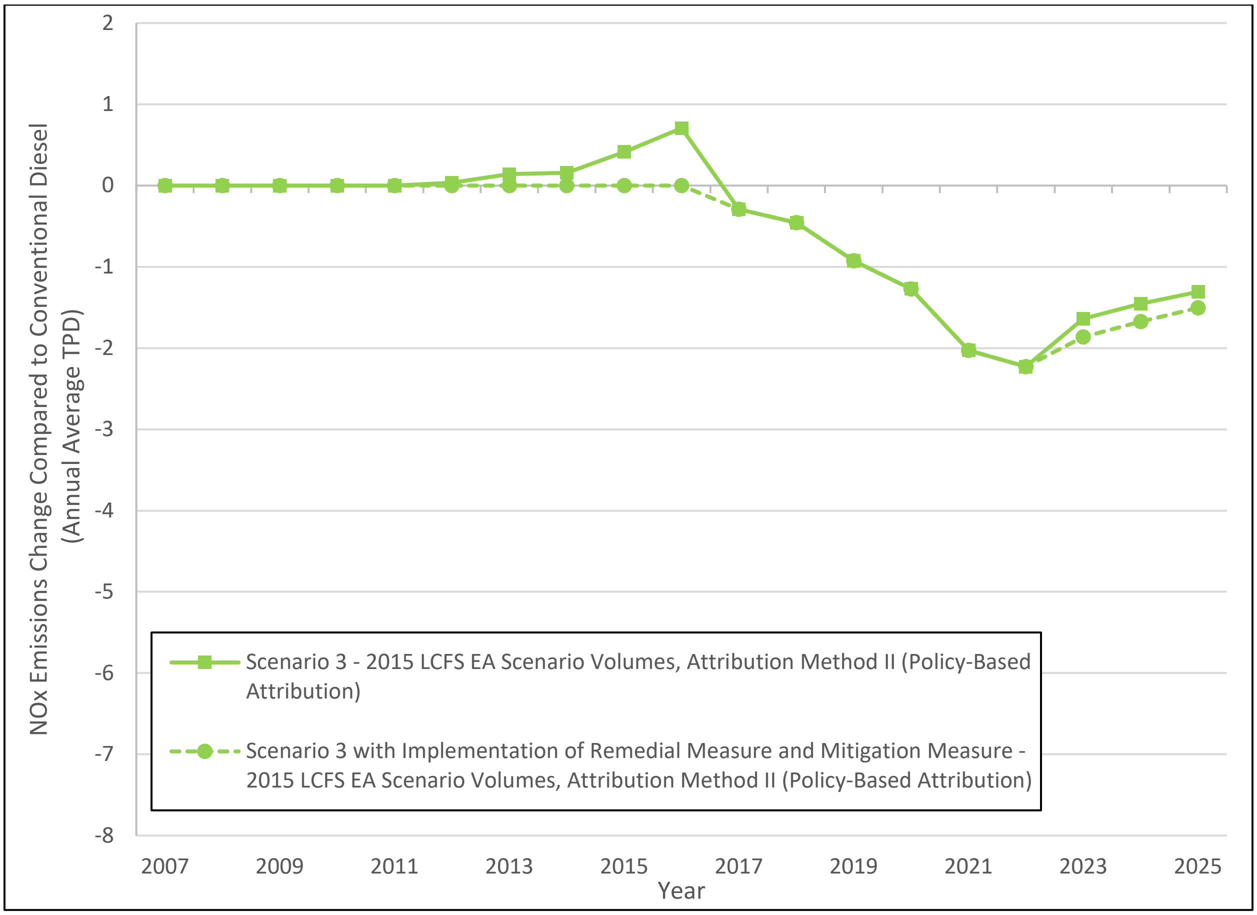
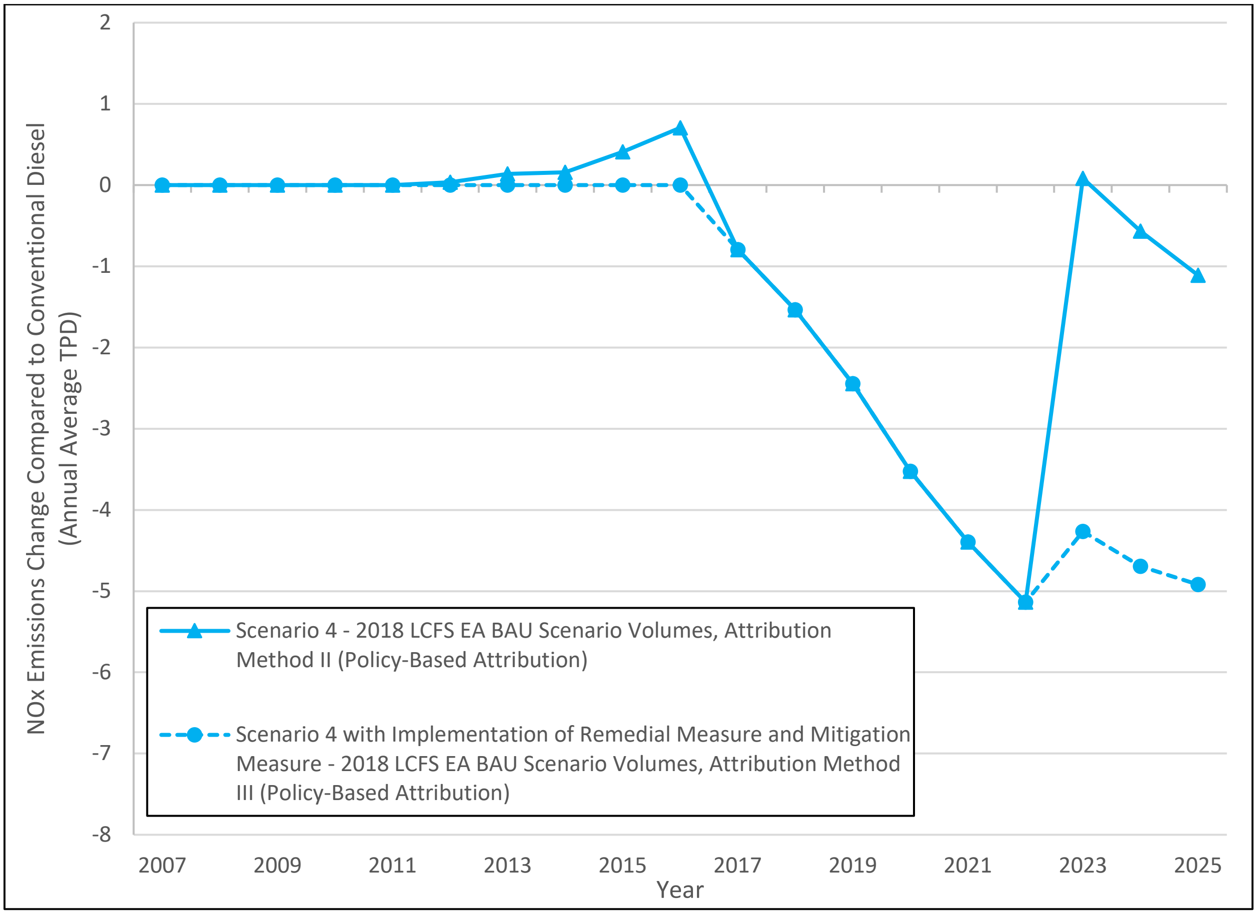


Figure 3-13: Comparison of Statewide LCFS NOx Emissions With and Without Implementation of Remedial and Mitigation Measures, 2007 – 2025, Scenario 4



b. LCFS PM Emissions Impacts Following Historical Remediation and Future Mitigation

Assuming that future usage of biomass-based diesel in California would not be impacted by the proposed mitigation measure (i.e., the revision to the in-use requirements of the ADF regulation), direct LCFS PM emissions would not be impacted by the remedial measure or the mitigation measure. However, decreased LCFS NOx emissions resulting from implementation of both the remedial measure and mitigation measure would result in reduced secondary $PM_{2.5}$ formation and corresponding reductions in associated health impacts.

C. HEALTH IMPACTS OF LCFS NOX AND PM EMISSIONS

Staff quantified incremental health impacts resulting from changes in direct PM emissions and secondary PM formation from NOx emissions associated with LCFS-attributed biomass-based diesel use relative to conventional diesel use for Scenarios 3 and 4 based on the methodology presented in **Appendix 6**. Staff's quantification of incremental health impacts included mortality (i.e., premature death) and morbidity (i.e., hospital visits associated with cardiovascular or respiratory illness, and emergency room visits associated with respiratory illness or asthma).[284]

Methods to quantify the impacts of NOx emissions on ozone concentrations and health impacts are regional, complex, and uncertain.[285] Therefore, although LCFS NOx emissions were evaluated quantitatively, changes to ozone concentrations and associated health impacts attributed to LCFS NOx emissions were evaluated qualitatively.

1. Impact of LCFS PM Emissions on Mortality and Morbidity

Both biodiesel and renewable diesel blends reduce directly-emitted PM emissions compared to conventional diesel, resulting in health benefits.

Table 3-11 provides a summary of the 2007 health impacts, expressed as changes in the number of persons experiencing each health impact, due to reductions in direct PM emissions as a result of all biomass-based diesel use in California during year 2007 relative to conventional diesel use.[286,287] **Table 3-11** indicates that biomass-based diesel use in 2007 provided health benefits

[284] Because the change in the number of incidences of emergency room visits due to respiratory illness was very small (i.e., between zero and one) for LCFS PM emissions and secondary PM2.5 formation from LCFS NOx emissions for Scenarios 3 and 4 in all years, this health impact was not reported in the results below.
[285] Estimation of ozone concentrations depends on several variables (i.e., concentrations of NOx and VOCs, solar radiation, temperature and wind speed) that vary based on time and location.
[286] Table 3-11 is equivalent to Table 14 in Appendix G.
[287] As shown in Table 3-3, there was no renewable diesel use in California in 2007.

Table 3-11 – 2007 Health Impacts Due to Reductions in Direct PM Emissions Resulting from All Biomass-Based Diesel Use[288]

Health Impact	Incidence in Year 2007 (Change in Number of Persons Experiencing Impact)
Mortality	-8
Hospital Admissions – Cardiovascular Illness	-1
Hospital Admissions – Respiratory Illness	-1
Emergency Room Visits - Asthma	-3

Figures 3-14 and **3-15** show the health impacts by year for Scenarios 3 and 4, respectively, expressed as a change in the number of persons experiencing each health impact, due to LCFS PM emissions for the period 2007 – 2025 relative to conventional diesel use.

[288] Ibid.

Figure 3-14 - Health Impacts by Year Due to LCFS PM Emissions, 2007 – 2025, Scenario 3 (2015 LCFS EA Scenario Volumes, Method II Attribution)

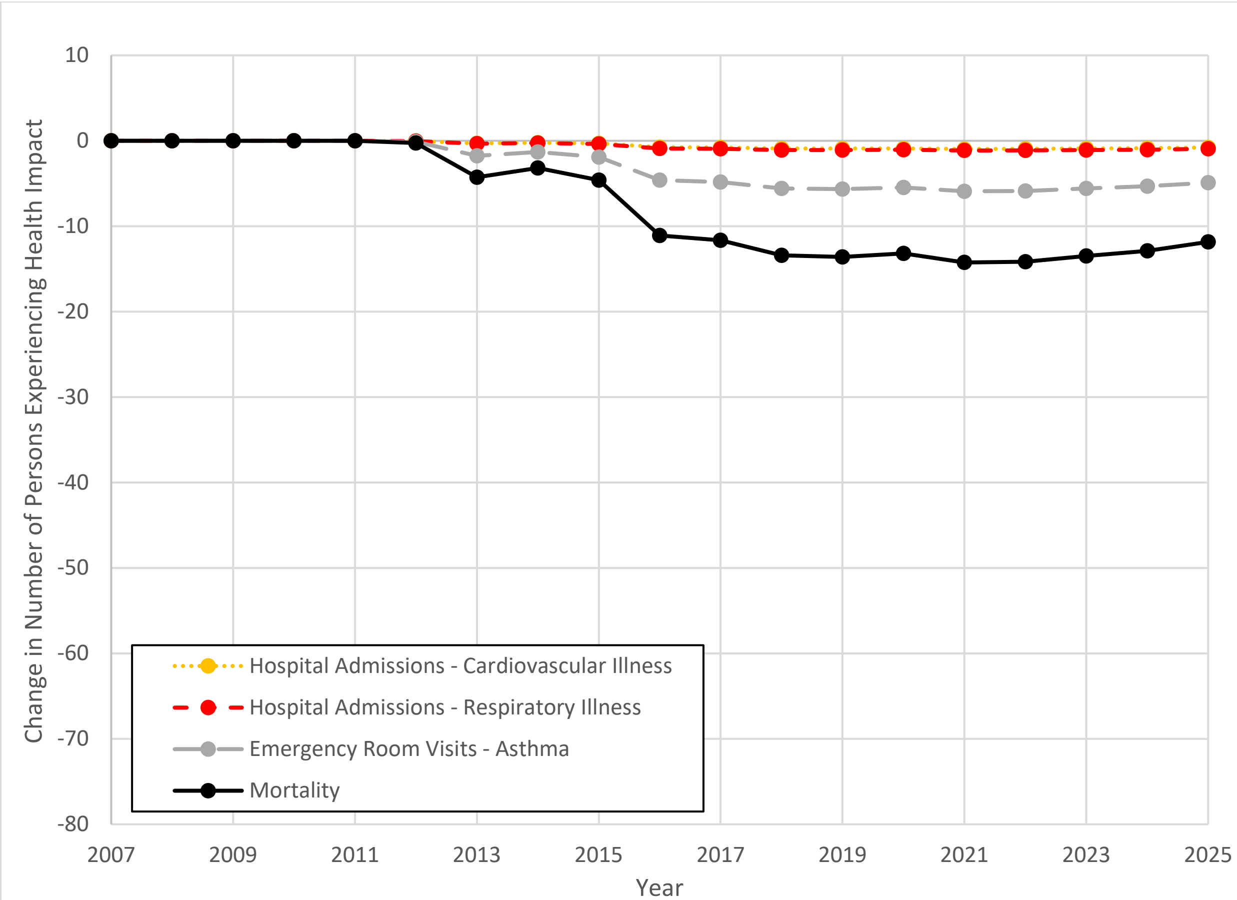
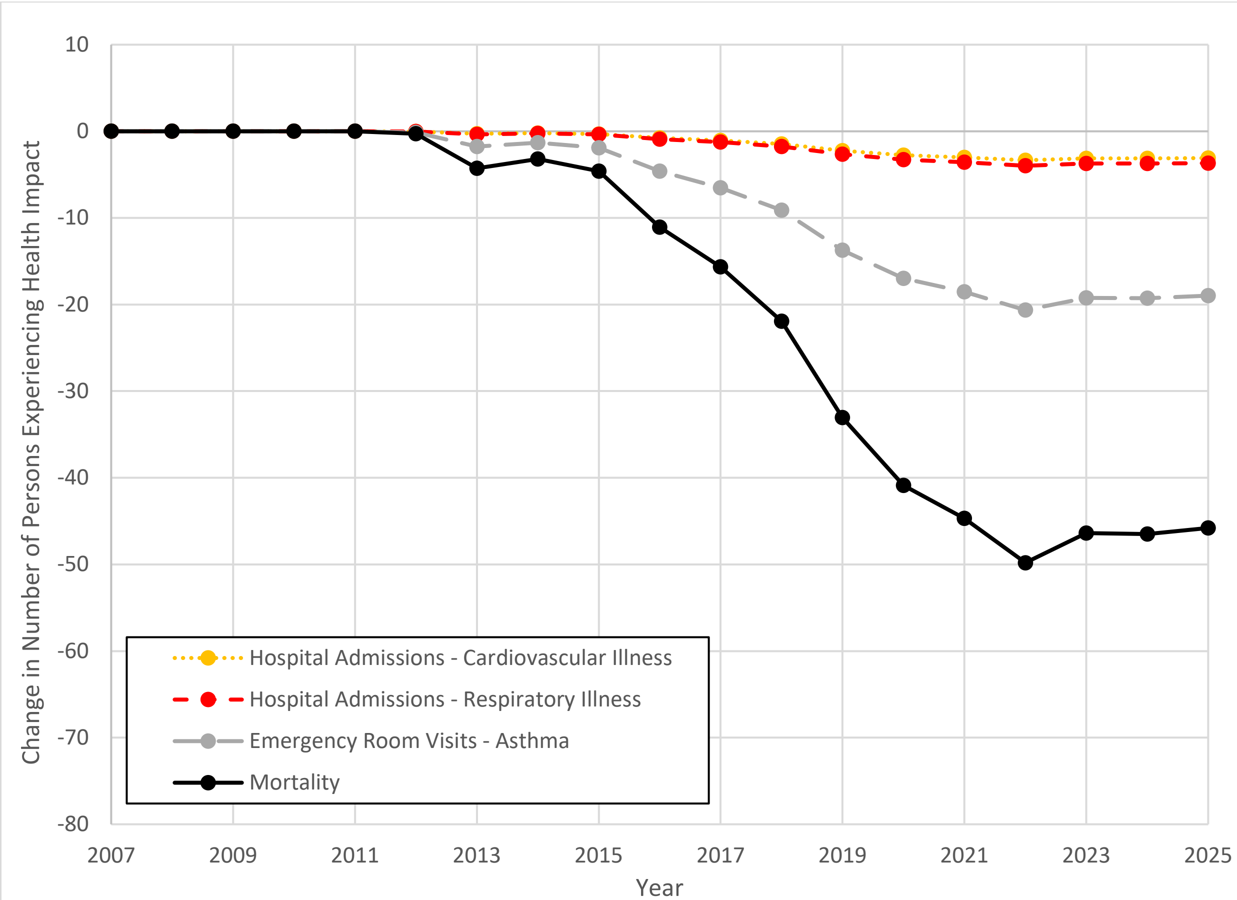


Figure 3-15 - Health Impacts by Year Due to LCFS PM Emissions, 2007 – 2025, Scenario 4 (2018 LCFS EA BAU Scenario Volumes, Method II Attribution)



As described in **Appendix 1**, staff determined that no biodiesel or renewable diesel use was attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year. As a result, there were no changes in health impacts relative to conventional diesel use prior to 2012, as indicated in **Figures 3-14** and **3-15**. For each year from 2013 – 2025, health impacts associated with LCFS PM emissions are negative (i.e., result in health benefits relative to conventional diesel use) for both scenarios.[289]

The health benefits due to LCFS PM emissions were summed for 2007 – 2025 for Scenarios 3 and 4, as shown in **Figures 3-16** and **3-17**, respectively. These cumulative health impacts indicate that both biodiesel and renewable diesel use attributed to the LCFS result in substantial health benefits associated with direct PM emissions reductions over the period 2007 – 2025 for Scenarios 3 and 4, respectively.

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[289] For both scenarios, health impacts due to LCFS PM emissions in 2012 were very small, and were rounded to zero for this year.

Figure 3-16 – Cumulative Health Benefits Due to LCFS PM Emissions, 2007 – 2025, Scenario 3 (2015 LCFS EA Scenario Volumes, Method II Attribution)

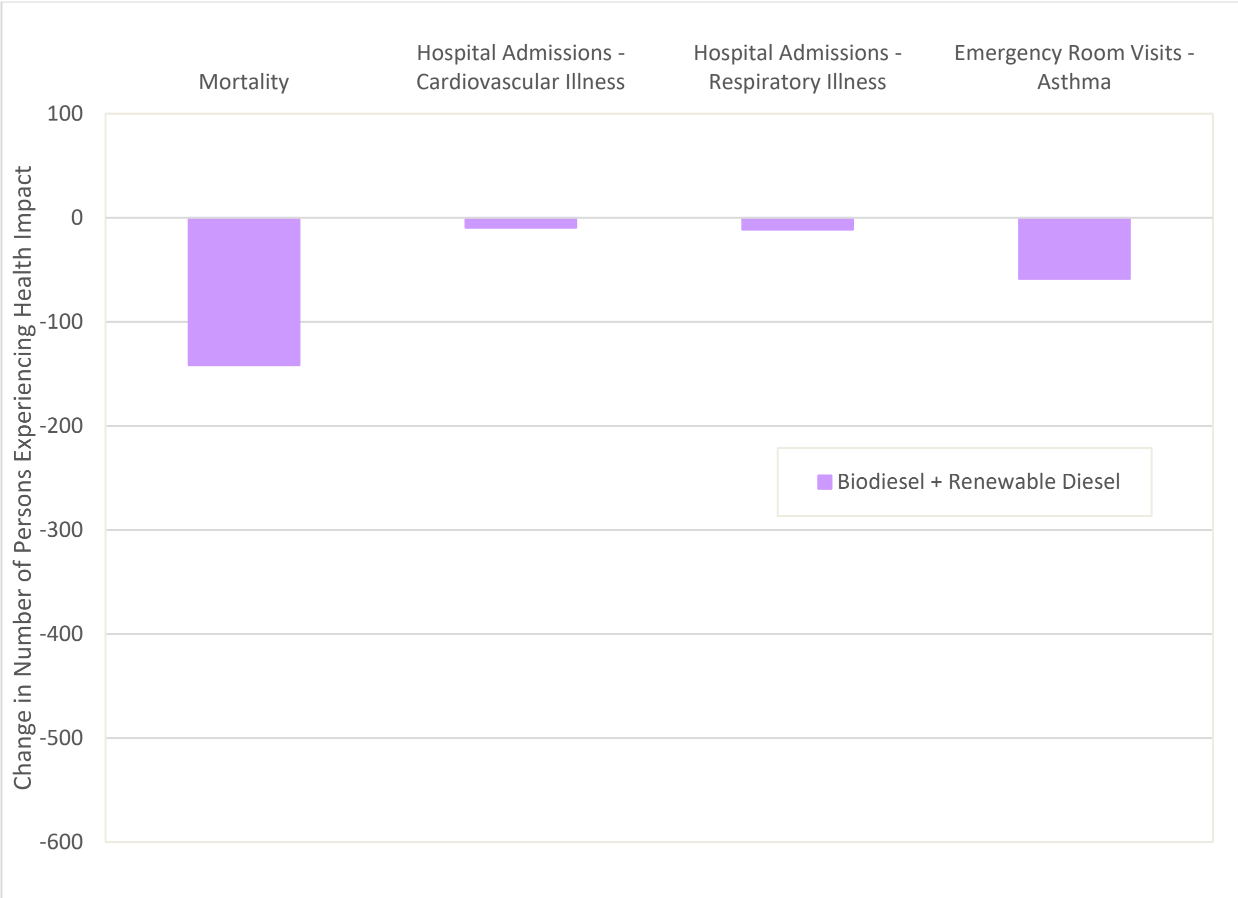
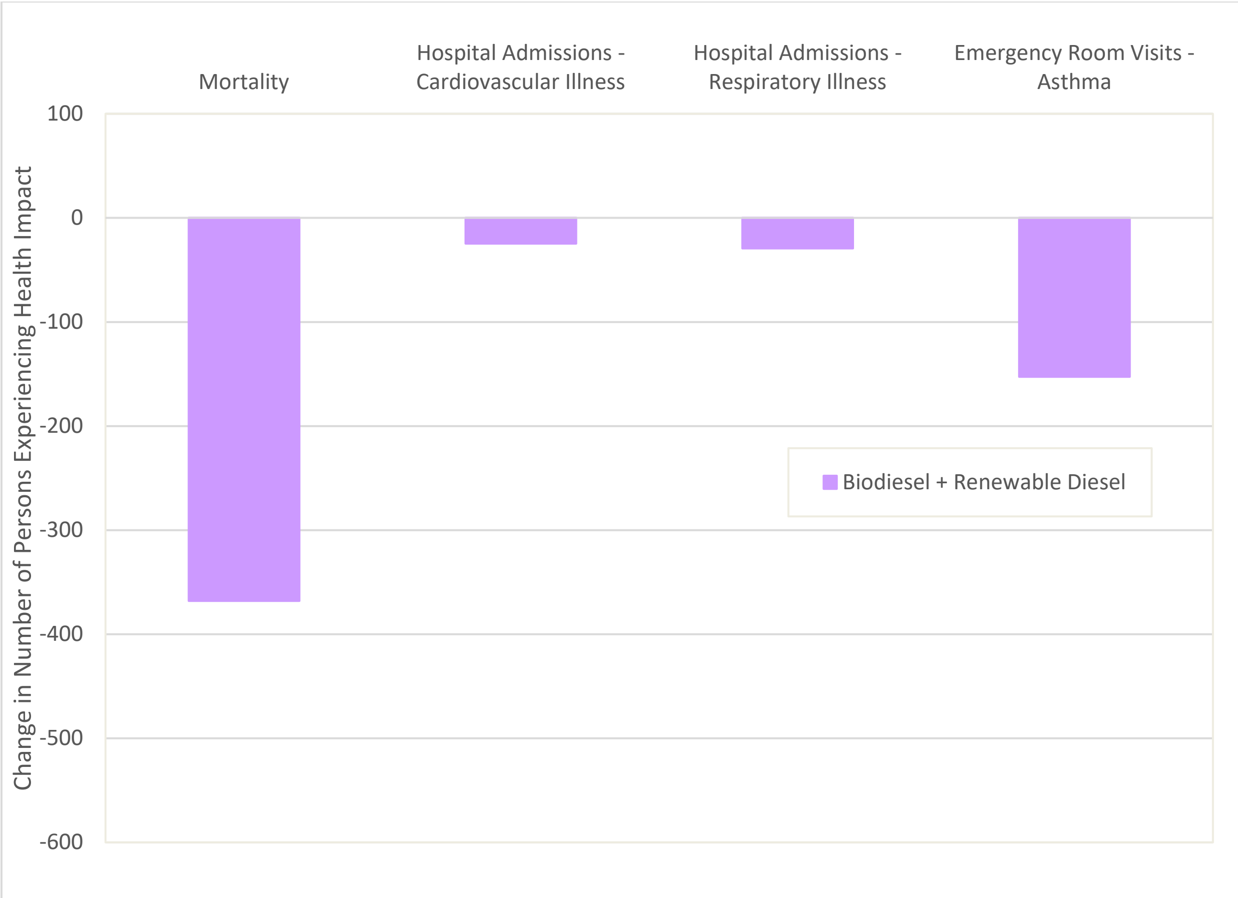


Figure 3-17 – Cumulative Health Benefits Due to LCFS PM Emissions, 2007 – 2025, Scenario 4 (2018 LCFS EA BAU Scenario Volumes, Method II Attribution)



2. Impact of LCFS NOx Emissions on PM Mortality and Morbidity

As indicated in Section E.1.a, NOx emissions from diesel engines undergo chemical reactions in the atmosphere leading to formation of secondary $PM_{2.5}$. The use of biodiesel blends increases NOx emissions compared to conventional diesel, resulting in increased formation of secondary $PM_{2.5}$ compared to conventional diesel. Conversely, the use of renewable diesel blends reduces NOx emissions compared to conventional diesel, resulting in decreased formation of secondary $PM_{2.5}$ compared to conventional diesel. The health impacts of biomass-based diesel use relative to conventional diesel use were estimated using the methods discussed in **Appendix 6**.

Table 3-12 provides a summary of the 2007 health impacts due to increases in secondary $PM_{2.5}$ formation as a result of all biomass-based diesel use in California during year 2007 relative to conventional diesel use. [290,291]

Table 3-12 – 2007 Health Impacts Due to Increases in Secondary $PM_{2.5}$ Formation Resulting from All Biomass-Based Diesel Use[292]

Health Impact	Incidence in Year 2007 (Change in Number of Persons Experiencing Impact)
Mortality	2
Hospital Admissions – Cardiovascular Illness	0
Hospital Admissions – Respiratory Illness	0
Emergency Room Visits - Asthma	1

Figures 3-18 and **3-19** show the health impacts by year for Scenarios 3 and 4, respectively, due to changes in secondary $PM_{2.5}$ formation as a result of biomass-based diesel use attributed to the LCFS (hereafter referred to as “LCFS secondary $PM_{2.5}$ formation”) for the period 2007 – 2025 relative to conventional diesel use.

[290] Table 3-12 is equivalent to Table 15 in Appendix G.
[291] As shown in Table 3-3, there was no renewable diesel use in California in 2007.
[292] Ibid.

Figure 3-18 - Health Impacts by Year Due to LCFS Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 3 (2015 LCFS EA Scenario Volumes, Method II Attribution)

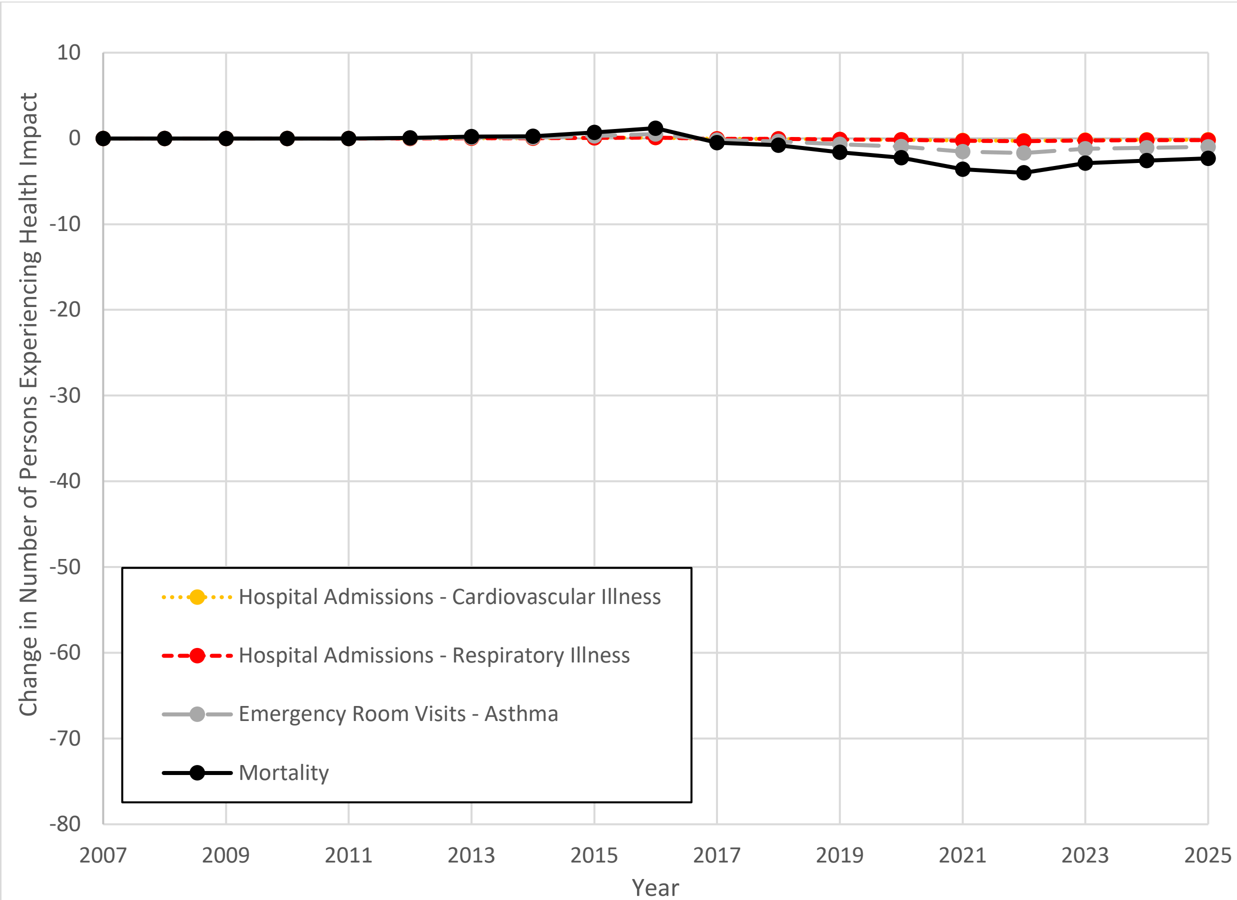
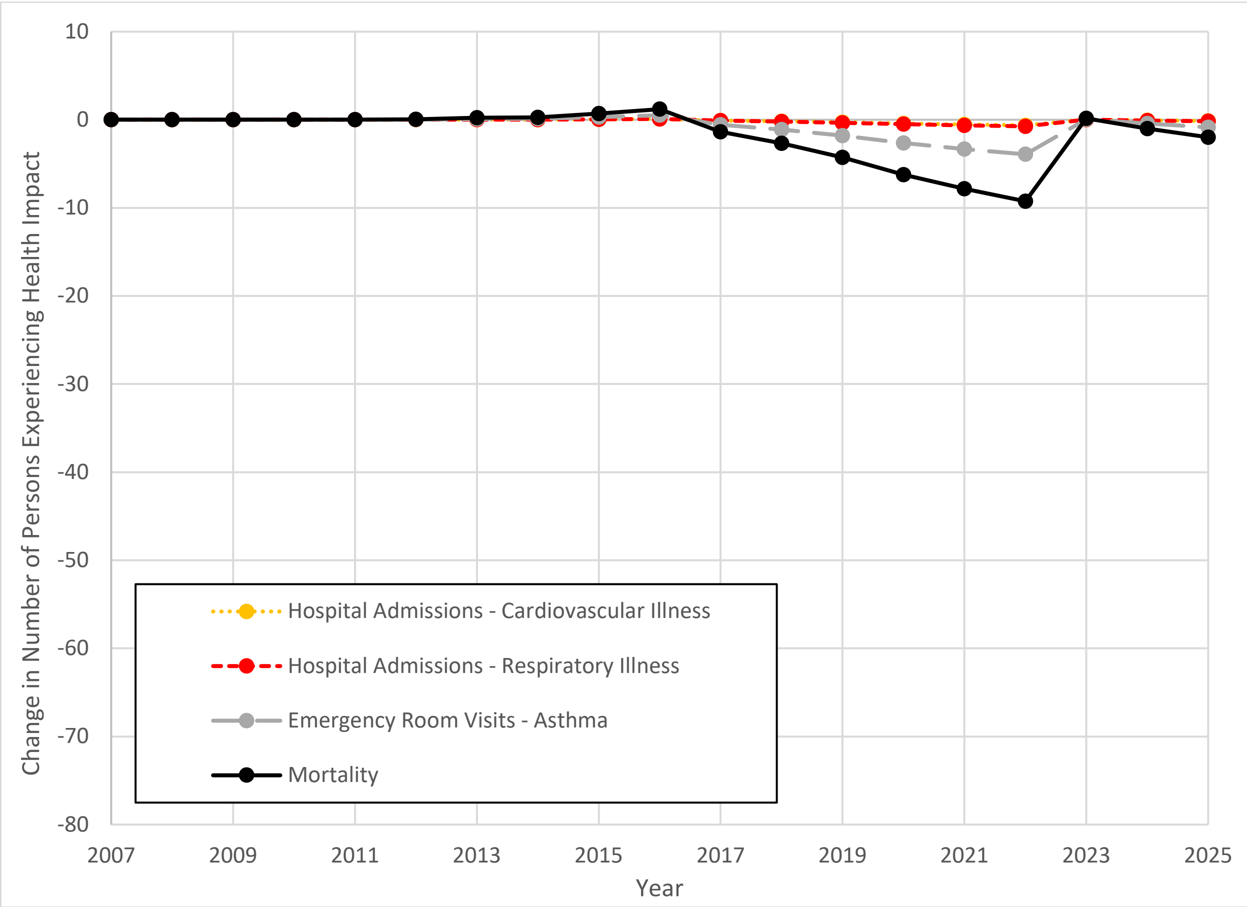


Figure 3-19 - Health Impacts by Year Due to LCFS Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 4 (2018 LCFS EA BAU Scenario Volumes, Method II Attribution)



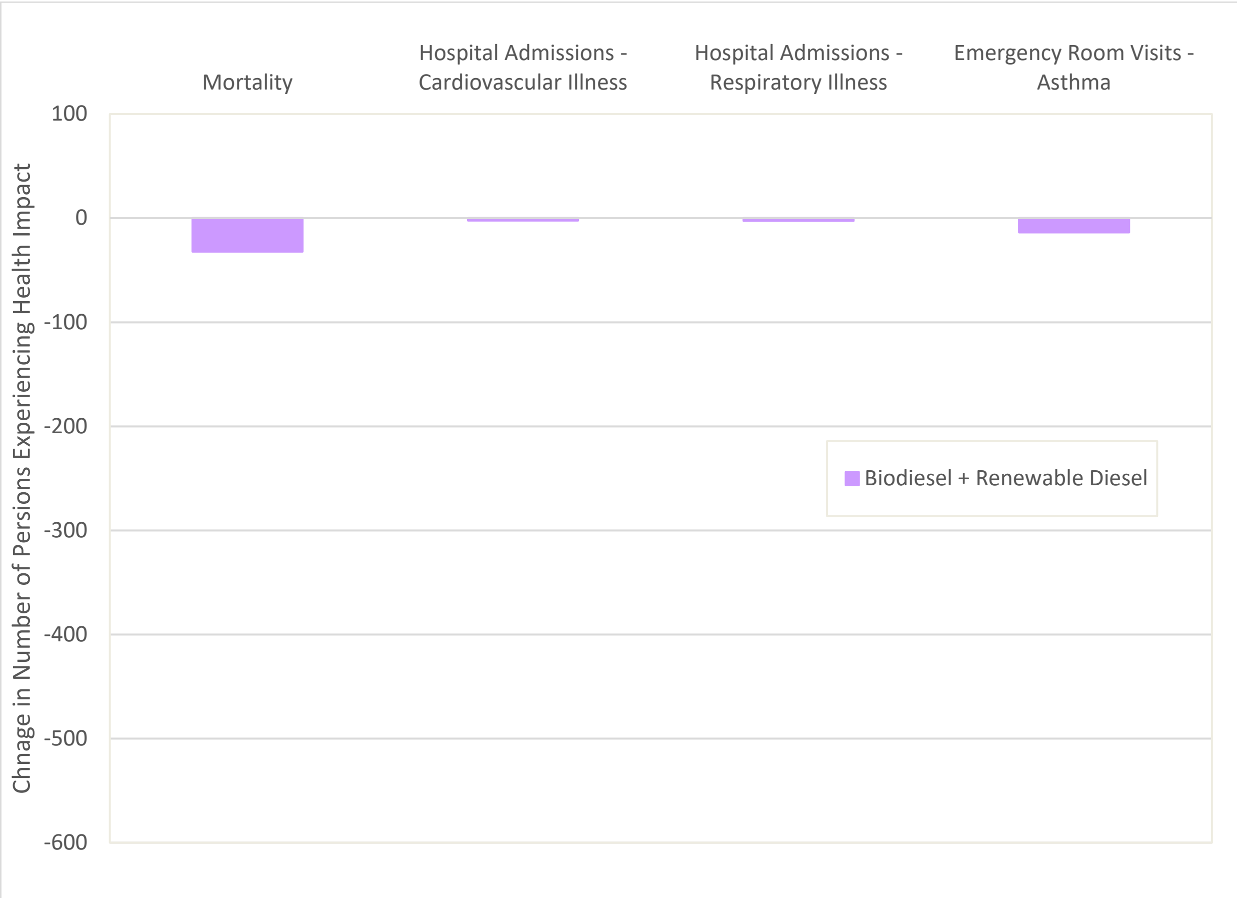
There were no health impacts due to LCFS-attributed biodiesel or renewable diesel use relative to conventional diesel use prior to 2012, as indicated in **Figures 3-18** and **3-19**.[293] From 2013 – 2025, health impacts due to LCFS secondary $PM_{2.5}$ formation fluctuate. For Scenario 3, LCFS secondary $PM_{2.5}$ formation results in adverse health impacts in 2012 - 2016 and beneficial health impacts in 2017 – 2025.[294] For Scenario 4, LCFS secondary $PM_{2.5}$ formation results in adverse health impacts in 2015, 2016, and 2023, and beneficial health impacts in 2013 – 2014, 2017 – 2022, and 2024 – 2025.[295]

[293] Staff determined that no biodiesel or renewable diesel use was attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year.
[294] The health impacts due to LCFS secondary $PM_{2.5}$ formation in 2012 were very small, and were rounded to zero for this year.
[295] The health impacts due to LCFS secondary $PM_{2.5}$ formation in 2012 were very small, and were rounded to zero for this year.

The health impacts due to LCFS secondary $PM_{2.5}$ formation were summed for years 2007 - 2025 for Scenarios 3 and 4, as shown in **Figures 3-20** and **3-21**. These cumulative health impacts indicate that the adverse health impacts due to LCFS secondary $PM_{2.5}$ formation resulting from LCFS NOx emissions associated with LCFS-attributed biodiesel use are outweighed by the beneficial health impacts due LCFS secondary $PM_{2.5}$ formation associated with LCFS-attributed renewable diesel use, resulting in net health benefits associated with LCFS secondary $PM_{2.5}$ formation for both scenarios.

Figure 3-20 – Cumulative Health Impacts Due LCFS Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 3 (2015 LCFS EA Scenario Volumes, Method II Attribution)

Figure 3-21 – Cumulative Health Impacts Due to LCFS Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 4 (2018 LCFS EA BAU Scenario Volumes, Method II Attribution)



3. Combined Impacts of LCFS NOx and PM Emissions on PM Mortality and Morbidity

The combined health impacts of LCFS NOx and PM emissions from 2007 - 2025 on PM mortality and morbidity were determined by summing the health impacts associated with reductions in LCFS PM emissions and LCFS secondary $PM_{2.5}$ formation.

Table 3-13 provides a summary of the 2007 health impacts related to PM mortality and morbidity due to the combined effect of direct PM emissions reductions and secondary

$PM_{2.5}$ formation because of all biomass-based diesel use in California during year 2007 relative to conventional diesel use. [296,297]

Table 3-13 – 2007 Combined Health Impacts Due to Reductions in Direct PM Emissions and Increases in Secondary $PM_{2.5}$ Formation Resulting from Biomass-Based Diesel Use [298]

Health Impact	Incidence in Year 2007 (Change in Number of Persons Experiencing Impact)
Mortality	-6
Hospital Admissions – Cardiovascular Illness	-1
Hospital Admissions – Respiratory Illness	-1
Emergency Room Visits - Asthma	-2

Figures 3-22 and **3-23** show the combined health impacts by year for Scenarios 3 and 4, respectively, due LCFS PM emissions and LCFS secondary $PM_{2.5}$ formation for the period 2007 – 2025.

[296] Table 3-13 is equivalent to Table 16 in Appendix G.
[297] As shown in Table 3-3, there was no renewable diesel use in California in 2007.
[298] Ibid.

Figure 3-22 – Combined Health Impacts by Year Due to LCFS PM Emissions and LCFS Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 3 (2015 LCFS EA Scenario Volumes, Method II Attribution)

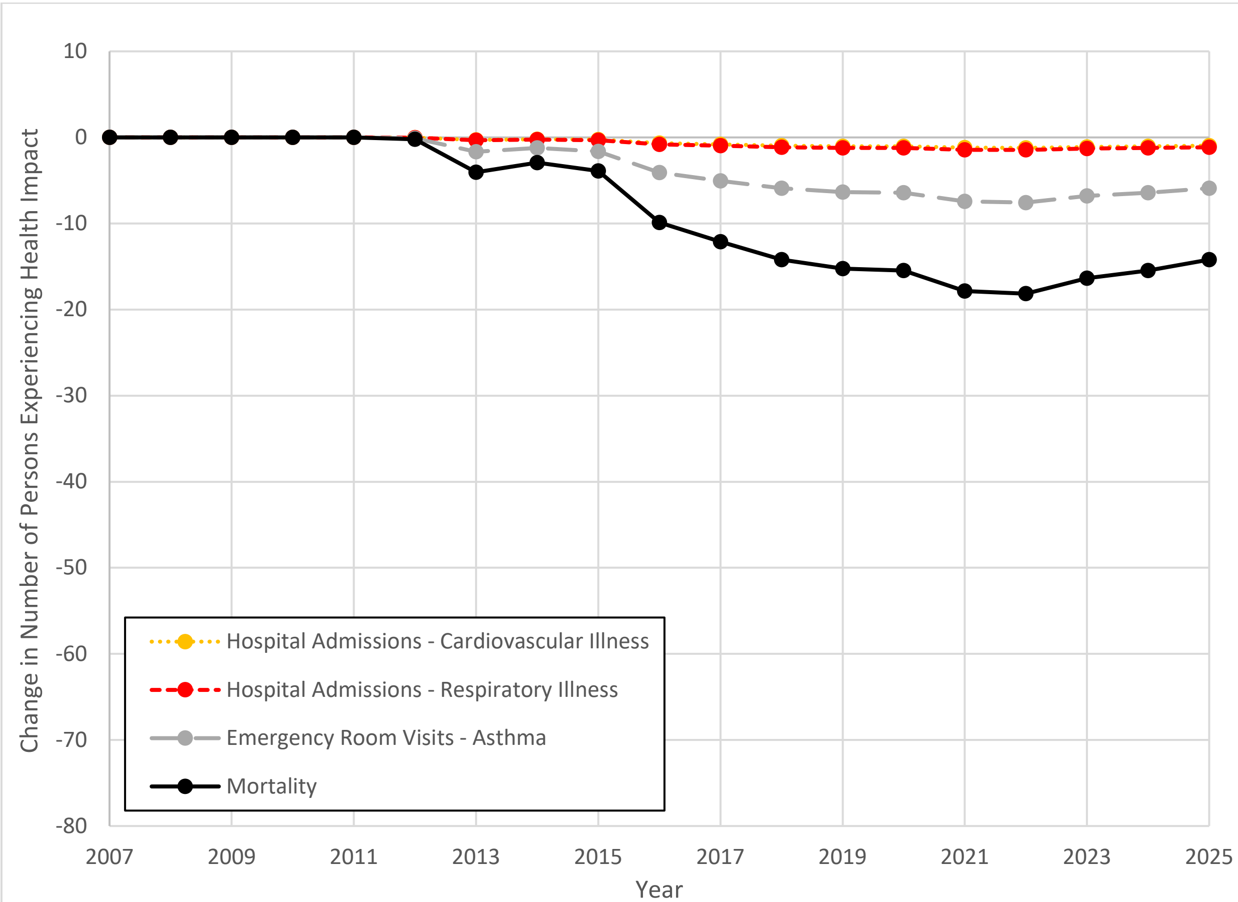
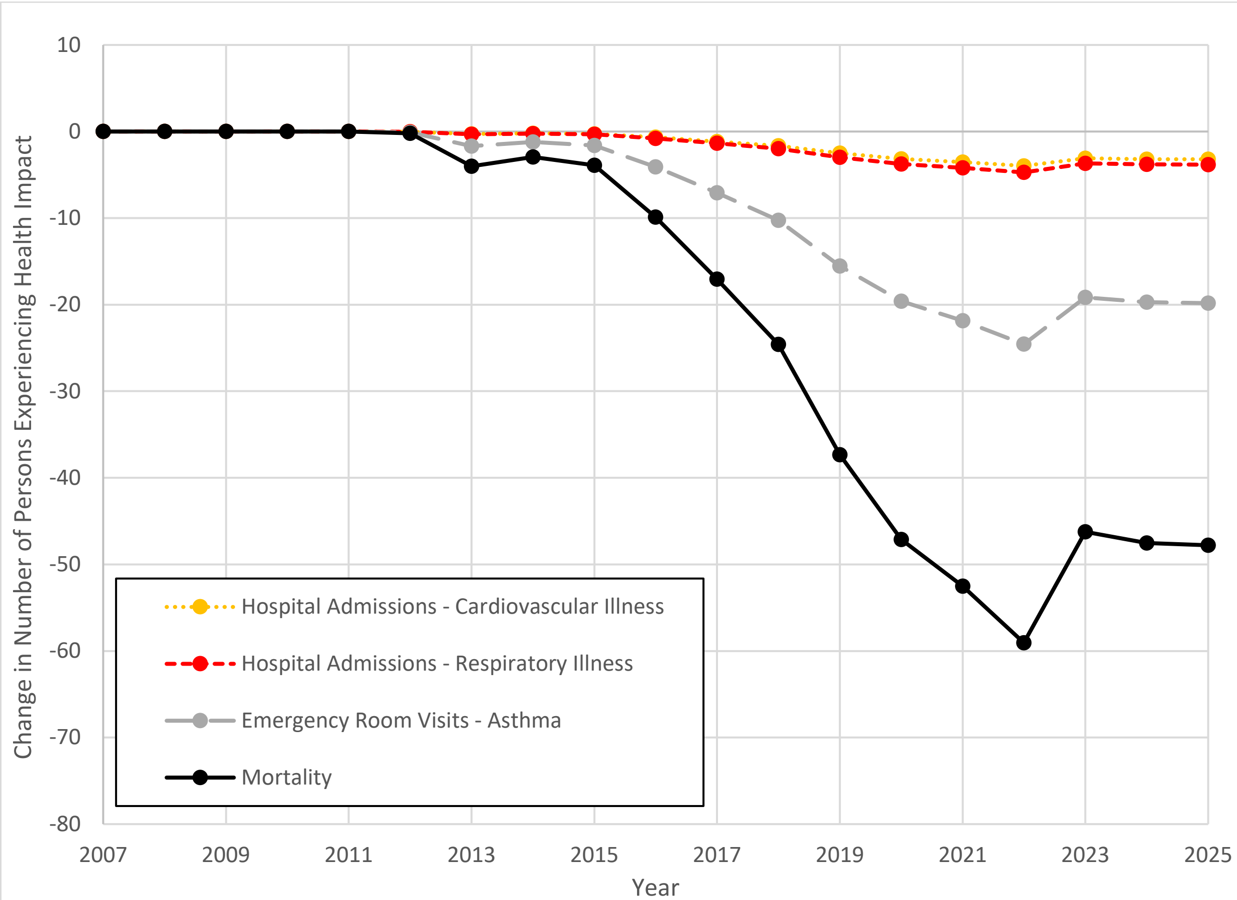


Figure 3-23 – Combined Health Impacts Due to LCFS PM Emissions and LCFS Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 4 (2018 LCFS EA BAU Scenario Volumes, Method II Attribution)



There were no health impacts due to LCFS-attributed biodiesel or renewable diesel use relative to conventional diesel use prior to 2012, as indicated in **Figures 3-22** and **3-23**.[299] For each year from 2013 – 2025, the combined health impacts associated with LCFS PM emissions and LCFS secondary $PM_{2.5}$ formation are negative (i.e., result in health benefits relative to conventional diesel use) for both scenarios.[300]

The health impacts due to the combined reductions in LCFS PM emissions and LCFS secondary $PM_{2.5}$ formation were summed for years 2007 – 2025 for Scenarios 3 and 4,

[299] Staff determined that no biodiesel or renewable diesel use was attributed to the LCFS prior to 2012 due to the lack of any value of LCFS credits prior to that year. As a result, there were no changes in health impacts relative to conventional diesel use prior to 2012.
[300] For both scenarios, the combined health impacts due to LCFS PM emissions and LCFS secondary $PM_{2.5}$ formation in 2012 were very small, and were rounded to zero for this year.

as shown in **Figures 3-24** and **3-25**. These cumulative health impacts indicate that, overall, there are substantial beneficial health impacts associated with the combined reductions in LCFS PM emissions and LCFS secondary $PM_{2.5}$ formation from 2007 – 2025 for both scenarios.

Figure 3-24 – Combined Cumulative Health Impacts Due to LCFS PM Emissions and LCFS Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 3 (2015 LCFS EA Scenario Volumes, Method II Attribution)

Figure 3-25 – Combined Cumulative Health Impacts Due to LCFS PM Emissions and LCFS Secondary $PM_{2.5}$ Formation, 2007 – 2025, Scenario 4 (2018 LCFS EA BAU Scenario Volumes, Method II Attribution)

4. Impact of LCFS NOx Emissions on Ozone Concentrations and Ozone-Related Health Impacts

As indicated in **Appendix G**, methods to quantify the impacts of NOx emissions on ozone concentrations and health impacts are regional, complex, and uncertain.[301] Therefore, staff qualitatively evaluated how changes in LCFS NOx emissions could affect ozone concentrations and ozone-related health impacts.

The potential impacts of LCFS NOx emissions due to biomass-based diesel use on ozone concentrations and ozone-related health impacts were evaluated by comparing LCFS-attributed NOx emissions to the statewide NOx emissions inventory. LCFS NOx emissions associated with use of biomass-based diesel were compared with total

[301] Estimation of ozone concentrations depends on several variables (i.e., concentrations of NOx and VOCs, solar radiation, temperature and wind speed) that vary based on time and location.

statewide NOx emissions and changes in statewide NOx emissions for the period 2007 – 2025, as shown in **Figures 3-5** and **3-6**, respectively.

As discussed in Section B.1.a, **Figure 3-5** shows that maximum statewide LCFS NOx emissions are less than 0.1 percent of total statewide NOx emissions for Scenarios 3 and 4. Assuming that changes in NO_2 and ozone concentrations are proportional to changes in NOx emissions,[302] staff estimated that statewide NO_2 and ozone concentrations could increase by no more than 0.1 percent statewide for both scenarios. **Figure 3-5** also shows LCFS NOx emissions that could result in statewide ozone concentration reductions under Scenarios 3 and 4 for a number of years.[303]

The State standard for ozone was last revised in 2005, and at that time it was estimated that exposures to ozone above the standard contributed to approximately 630 premature deaths annually.[304] Ozone concentrations have decreased in the decade since 2005,[305] and the annual number of premature deaths and other health impacts

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[302] The relationship between NOx emissions and ozone concentrations is complex, and depends on several other variables, including VOC concentrations, solar radiation, and temperature. For the purposes of this qualitative analysis, staff assumed that ozone concentrations would increase with NOx emissions increases, and would scale at less than a one-to-one ratio (e.g., ozone concentrations would increase at a lower rate than NOx emissions increases). Staff also notes that, under certain conditions (i.e., relatively low VOC/NOx ratios), ozone concentrations can increase with decreasing NOx emissions. See:

National Research Council. 1991. Rethinking the Ozone Problem in Urban and Regional Air Pollution. Washington, DC. The National Academies Press. pp. 163-168. Available at: https://www.nap.edu/catalog/1889/rethinking-the-ozone-problem-in-urban-and-regional-air-pollution. Accessed: September, 2017.

Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. pp. 14-16. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

[303] Under certain conditions (i.e., relatively low VOC to NOx concentration ratios), NOx emissions reductions result in increased ozone concentrations. See Fujita, Eric M., William R. Stockwell, David E. Campbell, Lyle R. Chinkin, Hilary H. Main, and Paul T. Roberts. 2002. Weekend/Weekday Ozone Observations in the South Coast Air Basin: Volume I – Executive Summary, Final Report. Available at: https://www.arb.ca.gov/research/weekendeffect/final_wknd_7_1/nrelp3v1f.pdf Accessed: January, 2018.

[304] CARB. 2005. Staff Report: Initial Statement of Reasons for Review of the California Ambient Air Quality Standard for Ozone, Volume IV of IV, Appendices B-G, October 2005 Revision. October 27. Available at: https://www.arb.ca.gov/carbis/research/aaqs/ozone-rs/rev-staff/vol4.pdf Accessed: November, 2017.

[305] Based on a review of national design values and state designation values for 1-hour observations and 8-hour averages for ozone from 2005 – 2016 for California air basins from CARB iADAM database. CARB. 2017. iADAM: Air Quality Data Statistics. Available at: https://www.arb.ca.gov/adam. Accessed: January, 2018.

attributed to ozone exposure are expected to be lower in 2017 than they were in 2005. Since changes in ozone concentration are generally less than proportional to the corresponding emissions changes of a single ozone precursor, [306] changes in ozone concentrations would be expected to be less than the changes in NOx emissions. Therefore, increases in ozone concentrations resulting from LCFS NOx emissions from 2007 - 2025 would:

- Be very small on an absolute basis. Increases in ozone concentrations due to LCFS NOx emissions as a percent of total ozone concentrations would be less than LCFS NOx emissions as a percent of total statewide NOx emissions. Based on **Figure 3-5**, staff estimated that increases in ozone concentrations due to LCFS NOx emissions would be less than 0.1 percent of total ozone concentrations (i.e., less than the LCFS NOx emissions as a percent of statewide NOx emissions in the peak year). Assuming that changes in ozone health impacts are proportional to changes in ozone concentrations, and based on CARB's 2005 estimate of premature deaths due to ozone above the standard,[307] staff conservatively estimated a potential increase of less than one premature death per year due to increases in ozone concentrations resulting from LCFS NOx emissions due to biomass-based diesel use. This estimate is more than an order of magnitude less than the combined annual reductions in premature death due to LCFS PM emissions and LCFS secondary PM formation for Scenarios 3 and 4, as shown in **Figures 3-24** and **3-25**.

- Result in only a very small change in ongoing progress in reducing ozone exposures due to the substantial reductions in NOx emissions occurring between 2007 and 2025 due to implementation of other control programs (e.g., CARB Truck and Bus Regulation[308], CARB In-Use Off-Road Diesel-Fueled Fleets

[306] Hidy, George M. and Charles L. Blanchard. 2015. Precursor reductions and ground-level ozone in the Continental United States, Journal of the Air & Waste Management Association, 65:10, 1261-1282. Available at: http://www.tandfonline.com/doi/pdf/10.1080/10962247.2015.1079564. Accessed: January, 2018.

[307] As indicated above, ozone concentrations, and premature deaths due to ozone concentrations above the ozone standard, have decreased since 2005. Therefore, the use of CARB's 2005 estimate of annual premature deaths due to exposures to ozone above the State standard is conservative (i.e., overestimates health impacts due to ozone from LCFS-attributed NOx emissions from biomass-based diesel use).

[308] CARB. 2014. Final Regulation Order. Title 13, California Code of Regulations (CCR), Section 2025. Regulation to Reduce Emissions of Diesel Particulate Matter, Oxides of Nitrogen and Other Criteria Pollutants from In-Use Heavy-Duty Diesel-Fueled Vehicles. December 31. Available at: https://www.arb.ca.gov/msprog/onrdiesel/documents/tbfinalreg.pdf. Accessed: September, 2017.

Regulation[309], Carl Moyer Program,[310] Goods Movement Emissions Reduction Program,[311] and Lower-Emission School Bus Program[312]), as shown in **Figure 4 in Appendix G**.

[309] CARB. 2011. Final Regulation Order. Title 13 California Code of Regulations (CCR), section 2449.Regulation for In-Use Off-Road Diesel Vehicles. Available at: https://www.arb.ca.gov/regact/2010/offroadlsi10/finaloffroadreg.pdf. Accessed: September, 2017.

[310] CARB. 2017. The Carl Moyer Program Guidelines, 2017 Revisions, Volume 1: Program Overview, Program Administration, and Project Criteria. May. Available at: https://www.arb.ca.gov/msprog/moyer/april2017_boarditem_proposedmoyerguidelines_vol1.pdf. Accessed: February, 2018.

[311] CARB. 2015. Proposition 1B: Movement Emission Reduction Program. Final 2015 Guidelines for Implementation. June. Available at: https://www.arb.ca.gov/bonds/gmbond/docs/prop_1b_goods_movement_2015_program_guidelines_for_implementation.pdf. Accessed: Febuary, 2018.

[312] CARB. 2008. Lower-Emission School Bus Program, 2008 Guidelines. April. Available at: https://www.arb.ca.gov/bonds/schoolbus/guidelines/2008lesbp.pdf. Accessed: February, 2018.

APPENDIX 4

BIOMASS-BASED DIESEL VOLUME AND EMISSIONS ANALYSIS EQUATIONS

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Appendix 4: Biomass-Based Diesel Volume and Emissions Analysis Equations

This appendix provides the equations used to estimate LCFS-attributed biomass-based diesel volumes and LCFS NOx and PM emissions.

Equation A4-1 – Biodiesel Volume Attributed to the LCFS (2007 – 2025)

$$BD\ Vol_{LCFS,i} = BD\ Vol_{total,i} \times BD\ \%_{LCFS,i}$$

Where,

$BD\ Vol_{LCFS,i}$	=	Biodiesel volume attributed to the LCFS in year i (2007 – 2025), (million gallons per year, MGPY)
$BD\ Vol_{total,i}$	=	Total biodiesel volume used in California in year i (2007 to 2025), (MGPY)
$BD\ \%_{LCFS,i}$	=	Percent of biodiesel consumption attributed to the LCFS in year i (2007 – 2025), (%)

Equation A4-2 – Renewable Diesel Volume Attributed to the LCFS (2007 – 2025)

$$RD\ Vol_{LCFS,i} = RD\ Vol_{total,i} \times RD\ \%_{LCFS,i}$$

Where,

$RD\ Vol_{LCFS,i}$	=	Renewable diesel volume attributed to the LCFS in year i (2007 – 2025), (million gallons per year, MGPY)
$RD\ Vol_{total,i}$	=	Total renewable diesel volume used in California in year i (2007 to 2025), (MGPY)
$RD\ \%_{LCFS,i}$	=	Percent of renewable diesel consumption attributed to the LCFS in year i (2007 – 2025), (%)

Equation A4-3 – Percent Biodiesel Attributed to the LCFS (2017 – 2025)

$$BD\ \%_{LCFS,i} = \frac{BD\ Vol_{total,i} - BD\ Vol_{non-LCFS,2016}}{BD\ Vol_{total,i}}$$

Where,

$BD\ \%_{LCFS,i}$	=	Percent of biodiesel that is attributed to the LCFS in year i (2017 – 2025), (%)
$BD\ Vol_{total,i}$	=	Total volume of biodiesel used in California in year i (2017 – 2025), (MGPY)
$BD\ Vol_{non-LCFS,2016}$	=	Volume of biodiesel that is attributed to non-LCFS programs in 2016, (MGPY)

Equation A4-4 – Percent Renewable Diesel Attributed to the LCFS (2017 – 2025)

$$RD\ \%_{LCFS,i} = \frac{RD\ Vol_{total,i} - RD\ Vol_{non-LCFS,2016}}{RD\ Vol_{total,i}}$$

Where,

$RD\ \%_{LCFS,i}$	=	Percent of renewable diesel that is attributed to the LCFS in year i (2017 – 2025), (%)
$RD\ Vol_{total,i}$	=	Total volume of renewable diesel used in California in year i (2017 – 2025), (MGPY)
$RD\ Vol_{non-LCFS,2016}$	=	Volume of renewable diesel that is attributed to non-LCFS programs in 2016, (MGPY)

Equation A4-5 – Total Biodiesel Volume (for use in estimation of biodiesel mitigation percentage associated with ADF regulation in-use requirements, 2018 – 2022)

$$BD\,Vol_{total,i} = 0.05 \times BD\,Vol_{5\%,i} \times 0.2 \times BD\,Vol_{20\%,i}$$

Where,

$BD\,Vol_{total,i}$	=	Total volume of biodiesel used in California in year i (2018 – 2022), (MGPY)
$BD\,Vol_{5\%,i}$	=	Biodiesel volume as a 5 percent blend used in California in year i (2018 to 2022), (MGPY)
$BD\,Vol_{20\%,i}$	=	Biodiesel volume as a 20 percent blend used in California in year i (2018 – 2022), (MGPY)

Equation A4-6 – Total Diesel Demand Volume (used in estimation of biodiesel mitigation percentage associated with ADF regulation in-use requirements, 2018 - 2022)

$$BD\,Vol_{5\%,i} + BD\,Vol_{20\%,i} = D\,Vol_{total,i} + RD\,Vol_{total,i} + BD\,Vol_{total,i}$$

Where,

$BD\,Vol_{5\%,i}$	=	Biodiesel volume as a 5 percent blend used in California in year i (2018 to 2022), (MGPY)
$BD\,Vol_{20\%,i}$	=	Biodiesel volume as a 20 percent blend used in California in year i (2018 – 2022), (MGPY)
$D\,Vol_{total,i}$	=	Total volume of conventional diesel used in California in year i (2018 – 2022), (MGPY)
$RD\,Vol_{total,i}$	=	Total volume of renewable diesel used in California in year i (2018 – 2022), (MGPY)
$BD\,Vol_{total,i}$	=	Total volume of biodiesel used in California in year i (2018 – 2022), (MGPY)

Equation A4-7 – Biodiesel Volume as a Five Percent Blend (used in estimation of biodiesel mitigation percentage associated with ADF regulation in-use requirements, 2018 - 2022)

$$BD\,Vol_{5\%,i} = \frac{\left(D\,Vol_{total,i} + RD\,Vol_{total,i} - 4 \times BD\,Vol_{total,i}\right)}{0.75}$$

Where,

$BD\,Vol_{5\%,i}$	=	Biodiesel volume as a 5 percent blend used in California in year i (2018 to 2022), (MGPY)
$D\,Vol_{total,i}$	=	Total volume of conventional diesel used in California in year i (2018 – 2022), (MGPY)
$RD\,Vol_{total,i}$	=	Total volume of renewable diesel used in California in year i (2018 – 2022), (MGPY)
$BD\,Vol_{total,i}$	=	Total volume of biodiesel used in California in year i (2018 – 2022), (MGPY)

Equation A4-8 – Biodiesel Volume as a 20 Percent Blend (used in estimation of biodiesel mitigation percentage associated with ADF regulation in-use requirements, 2018 - 2022)

$$BD\,Vol_{20\%,i} = \left(D\,Vol_{total,i} + RD\,Vol_{total,i} + BD\,Vol_{total,i}\right) - BD\,Vol_{5\%,i}$$

Where,

$BD\,Vol_{20\%,i}$	=	Biodiesel volume as a 20 percent blend used in California in year i (2018 to 2022), (MGPY)
$D\,Vol_{total,i}$	=	Total volume of conventional diesel used in California in year i (2018 – 2022), (MGPY)
$RD\,Vol_{total,i}$	=	Total volume of renewable diesel used in California in year i (2018 – 2022), (MGPY)
$BD\,Vol_{total,i}$	=	Total volume of biodiesel used in California in year i (2018 – 2022), (MGPY)
$BD\,Vol_{5\%,i}$	=	Biodiesel volume as a 5 percent blend used in California in year i (2018 to 2022), (MGPY)

Equation A4-9 – Percentage of Biodiesel Volume Mitigated Through ADF Regulation In-Use Requirements (Based on 2018 LCFS EA BAU Volumes, 2018 - 2022)

$$BD\ \%\ Mit_i = \frac{\left(BD\ Vol_{20\%,i} \times 0.2\right)}{BD\ Vol_{total,i}}$$

Where,

$BD\ \%\ Mit_i$	=	Percent of total biodiesel volume (as B100) mitigated through ADF regulation in-use requirements in year i (2018 to 2022), (MGPY)
$BD\ Vol_{20\%,i}$	=	Biodiesel volume as a 20 percent blend used in California in year i (2018 to 2022), (MGPY)
$BD\ Vol_{total,i}$	=	Total volume of biodiesel used in California in year i (2018 – 2022), (MGPY)

Equation A4-10 – Total Biodiesel Volume Mitigated (2018 – 2022)

$$BD\ Vol_{mitigated,i} = BD\ \%\ Mit_i \times BD\ Vol_{total,i}$$

Where,

$BD\ Vol_{mitigated,i}$	=	Total volume of biodiesel mitigated as a result of in-use requirements in year i (2018 – 2022), (million gallons per year, MGPY)
$BD\ \%\ Mit_i$	=	Percent of total biodiesel volume mitigated as a result of in-use requirements in year i (2018 to 2022), (%)
$BD\ Vol_{total,i}$	=	Total biodiesel volume used in California in year i (2018 – 2022), (MGPY)

Equation A4-11 – LCFS-Attributed Biodiesel Volume Percentage Causing a NOx Increase (2007 – 2025)

$$BD\ Vol\ \%_{LCFS,NOx,i} = \frac{(BD\ Vol_{total,i} - BD\ Vol_{mitigated,i})(BD\ \%_{LCFS,i})}{Diesel\ Demand_i}$$

Where,

$BD\ Vol\ \%_{,NOx,i}$	=	LCFS-attributed biodiesel volume percentage causing a NOx emissions increase in year i (2007 – 2025), (%)
$BD\ Vol_{total,i}$	=	Total volume of biodiesel used in California in year i (2007 - 2025), (MGPY)
$BD\ Vol_{mitigated,i}$	=	Total volume of biodiesel mitigated in California in year i (2007), (MGPY)
$BD\ \%_{LCFS,i}$	=	Percent of biodiesel that is attributed to the LCFS in year i (2007 – 2025), (%)
$Diesel\ Demand_i$	=	Total volume of conventional diesel, biodiesel and renewable diesel consumed in California in year i (2007 – 2025), (MGPY)

Equation A4-12 – Annual Off-Road Non-NTDE NOx Emissions by Air Basin (2007 – 2025)

$$NOx_{off-road,non-NTDE,i,j} = NOx_{off-road,i,j} \times (1 - NOx\ Fraction_{NTDE,i})$$

Where,

$NOx_{off-road,non-NTDE,i,j}$	=	Off-road NOx emissions from non-NTDE vehicles and equipment in year i (2007 – 2025) in air basin j, (tons per day, TPD)
$NOx_{off-road,i,j}$	=	Off-road NOx emissions in year i (2007 - 2025) and air basin j, (TPD)
$NOx\ Fraction_{NTDE,i}$	=	Fleet-average[313] fraction of NOx emissions from NTDEs (i.e., controlled by SCR) in year I (2007 – 2025), (unitless)

[313] Fleet-average refers to the average across all vehicles of the specified type in California.

Equation A4-13 – Annual Statewide Non-NTDE NOx Emissions from Diesel-Fueled Mobile Sources, Exclusive of OGVs (2007 – 2025)[314]

$$NOx_{non-NTDE,state,i} = \sum_{j=1}^{15} NOx_{on-road,non-NTDE,i,j} + \sum_{j=1}^{15} NOx_{off-road,non-NTDE,i,j}$$

Where,

$NOx_{non-NTDE,state,i}$	=	Statewide non-NTDE NOx emissions from diesel-fueled mobile sources exclusive of OGVs in year i (2007 – 2025), (TPD)
$NOx_{on-road,non-NTDE,i,j}$	=	On-road non-NTDE NOx emissions from diesel-fueled mobile sources in year i (2007 – 2025) in air basin j (Great Basin Valleys to South Coast), (TPD)
$NOx_{off-road,non-NTDE,i,j}$	=	Off-road non-NTDE NOx emissions from diesel-fueled mobile sources, exclusive of OGVs in year i (2007 – 2025) in air basin j (Great Basin Valleys to South Coast), (TPD)

Equation A4-14 – LCFS NOx Emissions Due to Biodiesel Use (2007 – 2025)

$$NOx_{LCFS,BD,i} = \%\ NOx\ Change_{BD} \times BD\ Vol\ \%_{LCFS,NOx,i} \times NOx_{non-NTDE,state,i}$$

Where,

$NOx_{LCFS,BD,i}$	=	LCFS NOx emissions due to use of biodiesel in year i (2007 – 2025), (TPD)
$\%\ NOx\ Change_{BD}$	=	Percent NOx emissions change due to use of pure biodiesel relative to use of conventional diesel, (%)
$BD\ Vol\ \%_{LCFS,NOx,i}$	=	LCFS-attributed biodiesel volume percentage causing a NOx emissions increase in year i (2007 – 2025), (%)
$NOx_{non-NTDE,state,i}$	=	Statewide non-NTDE NOx emissions from diesel-fueled mobile sources in year i (2007 – 2025), (TPD)

[314] Mobile source non-NTDE NOx emissions summed across the 15 air basins in California.

Equation A4-15 – LCFS-Attributed Renewable Volume Percentage (2007 – 2025)

$$RD\ Vol\ \%_{LCFS,i} = \frac{RD\ Vol_{total,i} \times RD\ \%_{LCFS,i}}{Diesel\ Demand_i}$$

Where,

$RD\ Vol\ \%_{LCFS,i}$	=	LCFS-attributed renewable diesel volume percentage in year i (2007 – 2025), (%)
$RD\ Vol_{total,i}$	=	Total volume of renewable diesel used in California in year i (2007 - 2025), (MGPY)
$RD\ \%_{LCFS,i}$	=	Percent of renewable diesel that is attributed to the LCFS in year i (2007 – 2025), (%)
$Diesel\ Demand_i$	=	Total volume of conventional diesel, biodiesel and renewable diesel used in California in year i (2007 – 2025), (MGPY)

Equation A4-16 – LCFS NOx Emissions Due to Renewable Diesel Use (2007 – 2025)

$$NOx_{LCFS,RD,i} = \%\ NOx\ Change_{RD} \times RD\ Vol\ \%_{LCFS,NOx,i} \times NOx_{non-NTDE,state,i}$$

Where,

$NOx_{LCFS,RD,i}$	=	LCFS NOx emissions due to use of renewable diesel in year i (2007 – 2025), (TPD)
$\%\ NOx\ Change_{RD}$	=	Percent NOx emissions change due to use of pure renewable diesel relative to use of conventional diesel (%)
$RD\ Vol\ \%_{LCFS,NOx,i}$	=	LCFS-attributed renewable diesel volume percentage causing a NOx emissions decrease in year i (2007 – 2025), (%)
$NOx_{non-NTDE,state,i}$	=	Statewide non-NTDE NOx emissions from diesel-fueled mobile sources exclusive of OGVs in year i (2007 – 2025), (TPD)

Equation A4-17 – Total LCFS NOx Emissions Due to Biodiesel and Renewable Diesel Use (2007 – 2025)

$$NOx_{LCFS,total,i} = NOx_{LCFS,BD,i} + NOx_{LCFS,RD,i}$$

Where,

$NOx_{LCFS,total,i}$	=	Total LCFS NOx emissions due to use of biodiesel and renewable diesel in year i (2007 – 2025), (TPD)
$NOx_{LCFS,BD,i}$	=	LCFS NOx emissions due to use of biodiesel in year i (2007 – 2025), (TPD)
$NOx_{LCFS,RD,i}$	=	LCFS NOx emissions due to use of renewable diesel in year i (2007 – 2025), (TPD)

Equation A4-18 – LCFS-Attributed Biodiesel Volume Percentage (2007 – 2025)

$$BD\ Vol\ \%_{LCFS,i} = \frac{BD\ Vol_{total,i} \times BD\ \%_{LCFS,i}}{Diesel\ Demand_i}$$

Where,

$BD\ Vol\ \%_{LCFS,i}$	=	Average LCFS-attributed biodiesel volume percentage in year i (2007 – 2025), (%)
$BD\ Vol_{total,i}$	=	Total volume of biodiesel used in California in year i (2007 - 2025), (MGPY)
$BD\ \%_{LCFS,i}$	=	Percent of biodiesel that is attributed to the LCFS in year i (2007 – 2025), (%)
$Diesel\ Demand_i$	=	Total volume of conventional diesel, biodiesel and renewable diesel used in California in year i (2007 – 2025), (MGPY)

Equation A4-19 – Annual Statewide Mobile Source diesel PM Emissions (2007 – 2025)[315]

$$PM_{state,i} = \sum_{j=1}^{15} PM_{on-road,i,j} + \sum_{j=1}^{15} PM_{off-road,i,j}$$

Where,

$PM_{state,i}$	=	Statewide mobile source diesel PM emissions exclusive of OGVs in year i (2007 – 2025), (TPD)
$PM_{on-road,i,j}$	=	On-road diesel PM emissions in year i (2007 – 2025) in air basin j (Great Basin Valleys to South Coast), (TPD)
$PM_{off-road,i,j}$	=	Off-road diesel PM emissions exclusive of OGVs in year i (2007 – 2025) in air basin j (Great Basin Valleys to South Coast), (TPD)

Equation A4-20 – LCFS PM Emissions Due to Biodiesel Use (2007 – 2025)

$$PM_{LCFS,BD,i} = \%\, PM\ Change_{BD} \times BD\ Vol\ \%_{LCFS,i} \times PM_{state,i}$$

Where,

$PM_{LCFS,BD,i}$	=	LCFS PM emissions due to use of biodiesel in year i (2007 – 2025), (TPD)
$\%\, PM\ Decrease_{BD}$	=	Percent PM emissions change due to use of pure biodiesel relative to use of conventional diesel, (%)
$BD\ Vol\ \%_{LCFS,i}$	=	LCFS biodiesel volume percentage in year i (2007 – 2025), (%)
$PM_{state,i}$	=	Statewide diesel PM emissions from mobile sources exclusive of OGVs in year i (2007 – 2025), (TPD)

[315] Mobile source PM emissions summed across the 15 air basins in California.

Equation A4-21 – LCFS PM Emissions Due to Renewable Diesel Use (2007 – 2025)

$$PM_{LCFS,RD,i} = \%\,PM\,Change_{RD} \times RD\,Vol\,\%_{LCFS,i} \times PM_{state,i}$$

Where,

$PM_{LCFS,RD,i}$	=	LCFS NOx emissions due to use of renewable diesel in year i (2007 – 2025), (TPD)
$\%\,PM\,Change_{RD}$	=	Percent PM emissions change due to use of pure renewable diesel relative to use of conventional diesel (%)
$RD\,Vol\,\%_{LCFS,i}$	=	LCFS-attributed renewable diesel volume percentage in year i (2007 – 2025), (%)
$PM_{state,i}$	=	Statewide diesel PM emissions from mobile sources exclusive of OGVs in year i (2007 – 2025), (TPD)

Equation A4-22 – Total LCFS PM Emissions Due to Biodiesel and Renewable Diesel Use (2007 – 2025)

$$PM_{LCFS,total,i} = PM_{LCFS,BD,i} + PM_{LCFS,RD,i}$$

Where,

$PM_{LCFS,total,i}$	=	LCFS PM emissions due to use of biomass-based diesel in year i (2007 – 2025), (TPD)
$PM_{LCFS,BD,i}$	=	LCFS PM emissions due to use of biodiesel in year i (2007 – 2025), (TPD)
$PM_{LCFS,RD,i}$	=	LCFS PM emissions due to use of renewable diesel in year i (2007 – 2025), (TPD)

APPENDIX 5

LCFS NOX AND PM EMISSIONS METHODOLOGY

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Appendix 5: LCFS NOx and PM Emissions Methodology

This appendix describes the methodology staff used to estimate LCFS NOx and PM emissions.

A. LCFS NOx Emissions Methodology

Potential changes in NOx emissions resulting from the use of biodiesel relative to conventional diesel depend on engine type. For example, there are no changes in NOx emissions due to biodiesel use (compared to conventional diesel use) in light-duty vehicles and NTDE vehicles,[316,317] but there is a NOx emissions increase associated with biodiesel use in on-road heavy-duty non-NTDE and off-road non-NTDE vehicles.[318,319] Similarly, the use of renewable diesel results in NOx emissions decreases in non-NTDE vehicles.[320]

Staff estimated LCFS NOx emissions due to biomass-based diesel use in non-NTDEs based on:

1. The LCFS-attributed volumes of biodiesel and renewable diesel, as percentages of the total diesel demand, that would result in changes in NOx emissions relative to use of conventional diesel in non-NTDE vehicles;

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[316] The use of biodiesel (any blend level) in light- and medium-duty on-road vehicles does not result in NOx emissions changes. See CARB. 2015. Staff Report: Initial Statement of Reasons for Proposed Regulation on the Commercialization of Alternative Diesel Fuels. January 2. pp. 44-45. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf. Accessed: July, 2017.

[317] There are no detrimental NOx impacts in NTDEs for blends of B20 and below. See CARB. 2015. Staff Report: Initial Statement of Reasons for Proposed Regulation on the Commercialization of Alternative Diesel Fuels. January 2. pp. 44-45. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf. Accessed: July, 2017.

[318] CARB. 2015. Staff Report: Initial Statement of Reasons for Proposed Regulation on the Commercialization of Alternative Diesel Fuels. January 2. pp. 44-45. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf. Accessed: July, 2017.

[319] An approved emissions equivalent additive, such as Di-tert-butyl peroxide (DTBP), can be added to biodiesel to mitigate NOx increases due to biodiesel use in non-NTDE vehicles and equipment.

[320] Test data for renewable diesel in NTDEs were not available. Based on test data for biodiesel, staff conservatively assumed use of renewable diesel in NTDEs results in no change in NOx emissions relative to conventional diesel. See Durbin, et al. 2011. CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California, “Biodiesel Characterization and NOx Mitigation Study,” Final Report. October. Available at: https://www.arb.ca.gov/fuels/diesel/altdiesel/20111013_CARB%20Final%20Biodiesel%20Report.pdf. Accessed: August, 2017.

2. The NOx emissions changes due to use of 100 percent biodiesel and 100 percent renewable diesel relative to use of conventional diesel;[321] and

3. The annual-average daily NOx emissions from diesel-fueled non-NTDE mobile sources in each California air basin, exclusive of OGVs.[322]

The specific methodologies used to quantify annual-average daily LCFS NOx emissions are presented below. The LCFS NOx emissions and the impacts of those emissions for Scenarios 1 and 2 are also discussed below.

1. LCFS NOx Emissions Due to Biodiesel Use

Beginning on January 1, 2018, producers, importers, and blenders of biodiesel in California will be subject to pollutant control levels based on feedstock saturation and time of year under the ADF regulation. The ADF regulation requires biodiesel blends above the pollutant control level for NOx emissions to employ in-use requirements (i.e., use of an approved additive to mitigate NOx emissions above the level of conventional diesel or demonstration of emissions equivalence with conventional diesel), unless the use of biodiesel qualifies for an exemption based on its use in fleets comprised of vehicles or equipment with NTDEs.[323] Biodiesel blends that meet in-use requirements or are used in NTDE vehicles or equipment do not result in NOx emissions increases compared to conventional diesel. Based on a projection of the level of penetration of NTDEs in on-road vehicles during the development of the ADF regulation, staff estimated that in-use requirements would sunset at the beginning of 2023.[324]

The first step in the calculation of LCFS NOx emissions due to biodiesel use was the estimation of the volume of biodiesel use attributed to the LCFS as a percentage of the total diesel demand causing a NOx increase relative conventional diesel ("LCFS-attributed biodiesel volume percentage causing a NOx increase") for Scenarios 1 and 2

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[321] NOx emissions from biodiesel and renewable diesel have been shown to have a relatively linear relationship with blend level, so the NOx emission factors for 100 percent biodiesel and 100 percent renewable diesel were used for the NOx analysis.
[322] Biomass-based diesel fuels have not historically been used, and are currently not used, in OGVs.
[323] CARB. 2015. Final Regulation Order: Regulation on Commercialization of Alternative Diesel Fuels. November 15. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adffinalregorder.pdf. Accessed: July, 2017.
[324] For these scenarios, the ADF regulation in-use requirements for biodiesel were assumed to sunset in 2023 because CARB's current version of the EMFAC model (EMFAC2014) predicts vehicle miles travelled (VMT) by NTDE heavy-duty vehicles in California reaches 90 percent of total VMT by the California heavy-duty diesel vehicle fleet in that year. This would trigger the sunset provision found in section 2293.6(a)(4) of the ADF regulation. See CARB. 2015. Staff Report: Initial Statement of Reasons for the Proposed Regulation on the Commercialization of Alternative Diesel Fuels. January 2. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf. Accessed: July, 2017.

for each year. Because this percentage is estimated based on the volume of biodiesel that would result in an increase in NOx emissions relative to use of conventional diesel in non-NTDE vehicles, staff first determined the total annual volume of biodiesel that was mitigated (i.e., the volume of biodiesel that caused no NOx increase in non-NTDE vehicles) for the given year and scenario.

In estimating the total annual volumes of biodiesel that were mitigated for Scenarios 1 and 2, staff assumed that mitigation would occur during the period when in-use requirements of the ADF regulation are currently required (i.e., from January 1, 2018 - December 31, 2022),[325] and that no mitigation would occur outside of this period. For Scenario 1, the total volumes of biodiesel were relatively low compared to the total diesel demand, and biodiesel volumes could be blended to B5 or lower for all years. However, 2016 biodiesel reporting data indicated that approximately 25 percent of biodiesel was blended to a level greater than B5.[326] Staff estimated the percent mitigation based on volumes and blend levels of biodiesel reported in 2016 biodiesel,[327] assuming that any volume of biodiesel above a blend level of B5 would be mitigated to the NOx emissions level of conventional diesel. Staff assumed that this estimated level of mitigation (25 percent) would remain constant from 2018 – 2022 for Scenario 1.

For Scenario 2, the volumes of biodiesel were relatively high compared to the total diesel demand. These biodiesel volumes could not be blended to B5 or lower, requiring the use biodiesel blends above B5 for all years. For the purposes of estimating the biodiesel mitigation level for each year, staff assumed that biodiesel would be used as blends of B5 and B20 only, and that the volume of B5 would be maximized.[328] Staff then estimated the annual volumes of B5 and B20 based on relationships between these volumes and the total biodiesel volume, total renewable diesel volume, and total conventional diesel volume, as shown in **Equations A4-5** and **A4-6 in Appendix 4**. Staff solved these equations for the volumes of B5 and B20, as indicated in **Equations A2-7** and **A2-8**. The volumes of B5 and B20 were estimated using **Equations A4-7** and **A4-8** for the period 2018 – 2022 for Scenario 2 based on the volumes of conventional

[325] Staff found that offsetting factors in the form of renewable diesel usage and NTDEs would be 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 did not increase NOx emissions, the ADF regulation imposed control levels above which per gallon in-use requirements (e.g., addition of a NOx-reducing additive) were instituted.
[326] CARB. 2017. Alternative Diesel Fuels Regulation Reporting Summary – 2016. August. Available at: https://www.arb.ca.gov/fuels/diesel/altdiesel/20170810ADF2016ReportingSummary.pdf. Accessed: October, 2017.
[327] CARB. 2017. Alternative Diesel Fuels Regulation Reporting Summary – 2016. August. Available at: https://www.arb.ca.gov/fuels/diesel/altdiesel/20170810ADF2016ReportingSummary.pdf. Accessed: October, 2017.
[328] Maximizing the volume of biodiesel blended to B5 results in a conservative estimate of the biodiesel mitigation level and LCFS NOx emissions for each year.

diesel, biodiesel (as B100), renewable diesel (as R100), and total diesel demand provided in **Table 6** in **Appendix G**. The estimated volumes of B5 and B20 for Scenario 2 are presented in **Table 5-1**.

Table 5-1 – Estimated Total Volumes of Biodiesel (as B5 and B20) Used in California, 2018 – 2022, Scenario 2[329,330]

Fuel	Volume (MGPY)				
	2018	2019	2020	2021	2022
Biodiesel (B5)	3,679	3,155	2,650	2,189	1,728
Biodiesel (B20)	80	586	1,088	1,578	2,068

Staff then estimated the percent of the total biodiesel volume (as 100 percent biodiesel) that would be mitigated each year for Scenario 2, assuming that all B20 would be mitigated to the NOx emissions level of conventional diesel, as shown in **Equation A4-9**. The percentages of biodiesel mitigated for Scenarios 1 and 2 for each year from 2018 - 2022 are presented in **Table 5-2**.

Table 5-2 – Biodiesel Mitigation Percentages for Scenarios 1 and 2 During Period When ADF Regulation In-Use Requirements are in Effect

Scenario	Percent Mitigation (Based on 100 Percent Biodiesel)				
	2018	2019	2020	2021	2022
Scenario 1	25%	25%	25%	25%	25%
Scenario 2	8%	43%	62%	74%	83%

The total volume of biodiesel that was mitigated for a given year and scenario was estimated by multiplying the biodiesel mitigation percentage for the given year and scenario, provided in **Table 5-2**, by the total biodiesel volume for the given year and scenario, provided in **Tables 5** and **6**, as shown in **Equation A4-10** in **Appendix 4**. The total volume of biodiesel mitigated for each year from 2018 through 2022 for Scenarios 1 and 2 are shown in shown in **Table 5-3**.

[329] Estimated total volumes of biodiesel (B100) and renewable diesel (R100) correspond to the 2018 LCFS EA BAU scenario volumes previously presented in Table 11.
[330] Total diesel demand represents the sum of conventional diesel, biodiesel, and renewable diesel volumes.

Table 5-3 – Biodiesel Volume (as B100) Mitigated for Scenarios 1 and 2 During Period When ADF Regulation In-Use Requirements are in Effect

Scenario	Biodiesel Volume Mitigated (MGPY)				
	2018	2019	2020	2021	2022
Scenario 1	45	45	45	46	46
Scenario 2	16	117	218	316	414

The LCFS-attributed biodiesel volume percentage causing a NOx increase for a given year and scenario was then estimated by calculating the difference between the total biodiesel volume, provided in **Tables 4 – 6** in **Appendix G**, and the mitigated biodiesel volume, provided in **Table 5-3**, for the given year and scenario and multiplying this difference by the percentage of biodiesel consumption attributed to the LCFS for the given year and scenario, provided in **Tables 7 – 9** in **Appendix G**, and dividing by the total diesel demand for the given year and scenario, provided in **Tables 4 – 6** in **Appendix G**, as shown in **Equation A4-11** in **Appendix 4**. The LCFS-attributed biodiesel volume percentage causing a NOx increase for Scenarios 1 and 2 for historical and future years are presented in **Tables 5-4** and **5-5**, respectively.

Table 5-4 – Historical LCFS-Attributed Biodiesel Volume Percentage Causing a NOx Increase, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS-Attributed Biodiesel Volume Percentage Causing a NOx Increase (%)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0%	0%	0%	0%	0%	>0%	1%	1%	3%	4%

Table 5-5 – Projected Future LCFS-Attributed Biodiesel Volume Percentage Causing a NOx Increase, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS-Attributed Biodiesel Volume Percentage Causing a NOx Increase (%)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	3%	3%	3%	3%	3%	3%	4%	4%	4%
2	4%	4%	4%	3%	3%	2%	12%	12%	12%

The second step in the calculation of LCFS NOx emissions due to biodiesel use was the estimation of the percentage change in NOx emissions due to use of biodiesel relative to use of conventional diesel ("biodiesel percentage NOx change"). As noted above, biodiesel use in NTDEs does not result in a change in NOx emissions compared to the use of conventional diesel, regardless of biodiesel blend level. The use of 100 percent biodiesel in non-NTDEs, on the other hand, results in a NOx emissions increase of approximately 20 percent relative to conventional diesel.[331,332] Because LCFS NOx emissions due to biodiesel were estimated based on NOx emissions from diesel-fueled non-NTDEs, staff estimated the biodiesel percentage NOx change as 20 percent.

The third step in the calculation of LCFS NOx emissions due to biodiesel use was the estimation of annual-average daily NOx emissions from diesel-fueled non-NTDE vehicles and equipment. Staff compiled annual average daily NOx emissions inventory data for non-NTDE diesel-fueled mobile sources (exclusive of OGVs)[333] by air basin for the period 2007 - 2025.[334] For on-road vehicles, staff estimated annual NOx emissions for diesel-fueled non-NTDE vehicles by assuming that all vehicles 2010 and older are equipped with non-NTDEs, and that all vehicles 2011 and newer are equipped with NTDEs.[335] For off-road vehicles and equipment, staff estimated NOx emissions for diesel-fueled non-NTDEs based on a review of engine emission control phase-in requirements by vehicle type and equipment class. Based on this review, staff developed an annual fleet-average fraction of NOx emissions that are controlled by SCR. This fraction was multiplied by the total off-road NOx emissions by air basin to estimate the annual off-road diesel-fueled non-NTDE NOx emissions by air basin, as indicated in **Equation A4-12**. On-road and off-road diesel-fueled non-NTDE NOx emissions data provided by air basin were aggregated to a single annual-average daily statewide value for all diesel-fueled mobile sources for each year from 2007 - 2025, as shown in **Equation A4-13**. Historical and projected future annual average statewide non-NTDE NOx emissions for diesel-fueled on-road vehicles, off-road vehicles and equipment, and for all mobile sources (i.e., on-road vehicles plus off-road vehicles and equipment) are summarized in **Tables 5-6** and **5-7**, respectively.

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331 Staff estimated a 20 percent increase in NOx emissions due to 100 percent biodiesel relative to conventional diesel based on the percent increase in NOx emissions for a low saturation 20 percent biodiesel blend (4 percent increase from **Table 10** in **Appendix G**) and assuming a linear relationship between biodiesel blend levels and percent increase in NOx emissions.
332 ARB. 2015. Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons. January 2. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf, p. 42).
333 Biomass-based diesel fuels have not historically been used, and are currently not used, in OGVs.
334 Annual average daily NOx emissions data for on-road and off-road diesel-fueled mobile sources are from CARB's CEPAM emissions inventory. Available at: https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php
335 U.S. EPA's Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements rule required heavy-duty vehicles to use SCR-equipped engines by 2010.

Table 5-6 – Historical Annual Average Daily Statewide NOx Emissions from Diesel-Fueled Non-NTDE Mobile Sources (Exclusive of OGVs), 2007 to 2016

Source Type	Statewide NOx Emissions by Year (TPD)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
On-Road Vehicles	1145	984	869	828	784	686	610	503	440	395
Off-Road Vehicles and Equipment	496	451	392	376	368	360	348	334	315	298
Mobile Sources Total	1641	1436	1260	1204	1153	1046	957	837	755	693

Table 5-7 – Projected Future Annual Average Daily Statewide NOx Emissions from Diesel-Fueled Non-NTDE Mobile Sources (Exclusive of OGVs), 2017 to 2025

Source Type	Statewide NOx Emissions by Year (TPD)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
On-Road Vehicles	345	304	273	233	193	165	69	61	54
Off-Road Vehicles and Equipment	284	262	244	231	218	203	192	182	169
Mobile Sources Total	629	566	517	464	411	368	261	244	223

Finally, the LCFS NOx emissions due to biodiesel use for Scenarios 1 and 2 were estimated for each year from 2007 - 2025 by multiplying the LCFS-attributed biodiesel volume percentage causing a NOx increase for a given year and scenario, provided in **Tables 5-4** and **5-5**, the biodiesel percentage NOx change (20 percent), and the statewide non-NTDE mobile source NOx emissions for the given year, provided in **Tables 5-6** and **5-7**, as shown in **Equation A4-14**.

The LCFS NOx emissions due to biodiesel use for Scenarios 1 and 2 for historical and future years are shown in **Tables 5-8** and **5-9**, respectively.

Table 5-8 – Historical LCFS NOx Emissions Due to Biodiesel, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS NOx Emissions Due to Biodiesel (TPD)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0	0	0	0	0	>0	2	2	4	5

Table 5-9 – Projected Future LCFS NOx Emissions Due to Biodiesel, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS NOx Emissions Due to Biodiesel (TPD)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	4	3	3	3	2	2	2	2	2
2	5	5	4	3	2	2	6	6	6

2. LCFS NOx Emissions Due to Renewable Diesel Use

Renewable diesel use in non-NTDEs results in decreased NOx emissions compared to conventional diesel,[336] and therefore, does not necessitate any pollutant control limits or in-use requirements similar to those for biodiesel. Renewable diesel that is blended in a refinery to be used as blendstock has the potential to be blended in a way that negates a portion of the NOx emissions decreases. However, a recent CARB survey of California refiners indicated that California refineries that blend renewable diesel do not do so in a way that would negate the NOx emissions decreases.[337] Therefore staff assumed that all renewable diesel used in non-NTDEs in California results in NOx emissions reductions.

The calculation of LCFS NOx emissions due to renewable diesel use followed a methodology similar to that used for calculation of LCFS NOx emissions due to biodiesel use. First, the volume of renewable diesel attributed to the LCFS as a percentage of the total diesel demand ("LCFS-attributed renewable diesel volume percentage") was estimated for Scenarios 1 and 2. For Scenarios 1 and 2, the LCFS-attributed renewable diesel volume percentage for a given year and scenario was determined by multiplying the total volume of renewable diesel consumed in California

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[336] CARB. 2015. Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons. January 2. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf, p. 44.
[337] CARB. 2017. ARB Survey of California Refiners Regarding Renewable Diesel Blending Practices. June.

for the given year and scenario, provided in **Tables 4 – 6** in **Appendix G**, by the percentage of renewable diesel consumption attributed to the LCFS for the given year, provided in **Tables 7 – 9** in **Appendix G**, and scenario and dividing by the total diesel demand for the given year and scenario, provided in **Tables 4 – 6** in **Appendix G**, as shown in **Equation A4-15**. The LCFS-attributed renewable diesel volume percentages for Scenarios 1 and 2 for historical and future years are presented in **Tables 5-10** and **5-11**, respectively.

Table 5-10 – Historical LCFS-Attributed Renewable Diesel Volume Percentage, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS-Attributed Renewable Diesel Volume Percentage (%)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0%	0%	0%	0%	0%	>0%	3%	3%	3%	6%

Table 5-11 – Project Future LCFS-Attributed Renewable Diesel Volume Percentage, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS-Attributed Renewable Diesel Volume Percentage (%)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	7%	7%	8%	9%	12%	13%	14%	13%	13%
2	9%	11%	14%	17%	19%	22%	24%	27%	30%

Next, the percentage change in NOx emissions due to use of renewable diesel relative to use of conventional diesel ("renewable diesel percentage NOx change") was determined. Testing data showing the relationship between renewable diesel blend level and NOx emissions changes for renewable diesel use in NTDE vehicles and equipment were not available. Therefore, based on testing data available for biodiesel use in NTDE vehicles and equipment,[338] staff conservatively assumed that the use of renewable diesel in NTDE vehicles or equipment does not result in decreases in NOx emissions compared to conventional diesel, regardless of renewable diesel blend level. The use of 100 percent renewable diesel in non-NTDE vehicles, on the other hand, results in a NOx emissions decrease of approximately 10 percent below conventional diesel, as shown in **Table 11** in **Appendix G**.[339] Because LCFS NOx emissions due to

[338] CARB. 2015. Proposed Regulation on the Commercialization of Alternative Diesel Fuels – Staff Report: Initial Statement of Reasons. January 2. Available at: https://www.arb.ca.gov/regact/2015/adf2015/adf15isor.pdf, p. 44.
[339] CARB. 2015. Staff Report – Multimedia Evaluation of Renewable Diesel. May. Available at: https://www.arb.ca.gov/fuels/diesel/altdiesel/20150521RD_StaffReport.pdf. Accessed: July, 2017. (p. 8).

renewable diesel were estimated based on NOx emissions from diesel-fueled non-NTDEs, staff estimated the renewable diesel percentage NOx change as -10 percent.

The statewide non-NTDE NOx emissions from diesel-fueled mobile sources were estimated as described in Section A.1. These emissions are provided in **Tables 5-6** and **5-7**.

Finally, the LCFS NOx emissions due to renewable diesel use for Scenarios 1 and 2 were estimated for a given year by multiplying the renewable diesel volume percentage for the given year and scenario, provided in **Tables 5-10** and **5-11**, the renewable diesel percentage NOx change (-10 percent), and the total statewide diesel-fueled non-NTDE NOx emissions for the given year, provided in **Tables 5-6** and **5-7**, as shown in **Equation A2-16**.

The LCFS NOx emissions due to renewable diesel use for Scenarios 1 and 2 for historical and future years are shown in **Tables 5-12** and **5-13**, respectively.

Table 5-12 – Historical LCFS NOx Emissions Due to Renewable Diesel, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS NOx Emissions Due to Renewable Diesel Use (TPD)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0	0	0	0	0	<0	-3	-2	-2	-4

Table 5-13 – Projected Future LCFS NOx Emissions Due to Renewable Diesel, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS NOx Emissions Due to Renewable Diesel Use (TPD)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	-4	-3	-3	-3	-2	-2	-2	-2	-2
2	-5	-5	-4	-3	-2	-2	-6	-6	-6

3. LCFS NOx Emissions Due to Biomass-Based Diesel Use

For Scenarios 1 and 2, LCFS NOx emissions due to biomass-based diesel use for a given year and scenario were estimated by summing the LCFS NOx emissions due to biodiesel use during the given year and scenario, provided in **Tables 5-8** and **5-9** and the LCFS NOx emissions due to renewable diesel use during the given year and scenario, provided in **Tables 5-12** and **5-13,** as shown in **Equation A2-17**.

The LCFS NOx emissions due to biomass-based diesel use for Scenarios 1 and 2 for historical and future years are shown in **Tables 5-14** and **5-15**, respectively.

Table 5-14 – Historical LCFS NOx Emissions Due to Biomass-Based Diesel Use, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS NOx Emissions Due to Biomass-Based Diesel Use (TPD)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0	0	0	0	0	>0	-1	-1	1	1

Table 5-15 – Projected Future LCFS NOx Emissions Due to Biomass-Based Diesel Use, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS NOx Emissions Biomass-Based Diesel Use (TPD)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	<0	-1	-1	-2	-2	-3	-2	-1	-1
2	-1	-2	-3	-5	-6	-6	>0	-1	-1

B. LCFS PM Emissions Methodology

In contrast to NOx emissions, direct PM emissions decrease with increased use of biomass-based diesel[340]. Biomass-based diesel use results in reductions in direct PM emissions in both NTDE and non-NTDE engines. Staff estimated LCFS PM emissions due to biomass-based diesel use as described below based on:

a. The LCFS-attributed volumes of biodiesel and renewable diesel, as percentages of the total diesel demand;

[340] As discussed further in Section E, health effects due to diesel PM are associated with exposure to $PM_{2.5}$. Because mobile source diesel PM emissions in California are approximately 95% $PM_{2.5}$ during the period analyzed, staff estimated health effects by treating diesel PM emissions as $PM_{2.5}$.

b. The PM emissions changes due to use of biodiesel[341] and renewable diesel[342] relative to the use of conventional diesel; and

c. The annual-average daily diesel PM emissions from mobile sources in each California air basin, exclusive of OGVs.[343].

The specific methodologies used to quantify the LCFS-attributed PM emissions associated with the use of biomass-based diesel are presented below.

1. LCFS PM Emissions Due to Biodiesel Use

The calculation of LCFS PM emissions associated due to biodiesel use followed a methodology similar to that used for the calculation of LCFS NOx emissions due to biodiesel use. First, staff estimated the volume of biodiesel attributed to the LCFS as a percentage of the total diesel demand ("LCFS-attributed biodiesel volume percentage") for Scenarios 1 and 2. The total volume of biodiesel consumed in California for a given year and scenario, provided in **Tables 4 – 6** in **Appendix G**, was multiplied by the percentage of biodiesel consumption attributed to the LCFS for the given year and scenario, provided in **Tables 7 – 9** in **Appendix G**. The result was divided by the total diesel demand for the given year and scenario, provided in **Tables 4 – 6** in **Appendix G**, to determine the LCFS-attributed biodiesel volume percentage for the given year and scenario, as shown in **Equation A2-18**.

The LCFS-attributed biodiesel volume percentages for Scenarios 1 and 2 for historical and future years are presented in **Tables 5-16** and **5-17**, respectively.

[341] PM emissions do not decrease linearly with increasing biodiesel blend level above a blend level of B20. However, biodiesel is used at a blend level of 20 percent biodiesel or less in California. Therefore, staff estimated the percentage of PM emissions reduction for 100 percent biodiesel assuming a linear relationship between PM emissions reductions and biodiesel blend level based on the percentage PM decrease associated with a 20 percent biodiesel blend, as discussed in Section C.4.a.
[342] PM emissions decrease linearly with increasing renewable diesel blend level across all blend levels. Therefore, staff used the reported PM emissions reduction percentage for 100 percent renewable diesel (30 percent) from the CARB Multimedia Evaluation of Renewable Diesel.
[343] Biomass-based diesel fuels have not historically been used, and are currently not used, in OGVs.

Table 5-16 – Historical LCFS-Attributed Biodiesel Volume Percentage, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS-Attributed Biodiesel Volume Percentage (%)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0%	0%	0%	0%	0%	>0%	1%	1%	3	4%

Table 5-17 – Projected Future LCFS-Attributed Biodiesel Volume Percentage, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS-Attributed Biodiesel Volume Percentage (%)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	3%	4%	4%	4%	4%	4%	4%	4%	4%
2	4%	5%	7%	9%	11%	12%	12%	12%	12%

Next, the percentage change in PM emissions due to use of biodiesel relative to use of conventional diesel ("biodiesel percentage PM change") was determined. PM emissions reductions vary approximately linearly with biodiesel blend level over the range of biodiesel blends used in California (i.e., blend levels of 5 percent to 20 percent biodiesel), as shown in **Table 10** in **Appendix G**. However, above a blend level of 20 percent biodiesel, PM emissions reductions increase at a lower rate than the rate observed for blend levels of 20 percent biodiesel or less. Because all biodiesel is used at a blend level of 20 percent biodiesel or lower in California, staff extrapolated an emission factor for PM decreases associated with 100 percent biodiesel assuming a linear increase in PM emissions reductions with biodiesel blend level based on the percentage PM decrease associated with a 20 percent biodiesel blend (19 percent PM reduction, as indicated in **Table 10** in **Appendix G**). This resulted in an estimated 95 percent PM decrease for 100 percent biodiesel. Therefore, staff estimated biodiesel percentage PM change as -95 percent.

Staff then compiled annual average daily PM emissions inventory data for diesel-fueled mobile sources (exclusive of OGVs)[344] by air basin for the period 2007 - 2025.[345] Diesel PM emissions inventory data provided by air basin were aggregated to a statewide annual-average daily value for each year from 2007 - 2025), as shown in **Equation A2-19**. Historical and projected annual-average statewide diesel PM emissions for on-road

[344] Biomass-based diesel fuels have not historically been used, and are currently not used, in OGVs.
[345] Annual average daily PM emissions data for on-road and off-road diesel-fueled mobile sources are from CARB's CEPAM emissions inventory. Available at: https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php

vehicles, off-road vehicles and equipment, and for all mobile sources, exclusive of OGVs, for 2007 - 2016 and 2017 - 2025 are summarized in **Tables 5-18** and **5-19**, respectively.

Table 5-18 – Historical Annual Average Daily Statewide Diesel PM Emissions from Mobile Sources, 2007 to 2016

Source Type	Statewide PM Emissions by Year (TPD)									
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
On-Road Vehicles	35	31	27	26	25	20	17	10	7.7	6.6
Off-Road Vehicles and Equipment	24	22	19	18	18	17	16	15	14	13
Mobile Sources Total	60	54	47	44	43	38	32	25	22	20

Table 5-19 – Projected Future Annual Average Daily Statewide Diesel PM Emissions from Mobile Sources, 2017 to 2025

Source Type	Statewide PM Emissions by Year (TPD)								
	2017	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
On-Road Vehicles (TPD)	5.1	4.2	3.7	2.9	1.9	1.7	1.1	1.1	1.0
Off-Road Vehicles and Equipment (TPD)	12	11	11	10	9.3	8.6	8.0	7.6	7.0
Mobile Sources Total (TPD)	18	16	14	13	11	10	9.2	8.6	8.0

Finally, the LCFS PM emissions due to biodiesel use were estimated for Scenarios 1 and 2 for each year from 2007 - 2025 by multiplying the LCFS-attributed biodiesel volume percentage for the given year and scenario, provided in **Tables 5-16** and **5-17**, the biodiesel percentage PM change (-95 percent), and the statewide mobile source diesel PM emissions for the given year, provided in **Tables 5-18 and 5-19**, as shown in **Equation A2-20**.

The LCFS PM emissions due to biodiesel use for Scenarios 1 and 2 for historical and future years are shown in **Tables 5-20** and **5-21**, respectively.

Table 5-20 – Historical LCFS PM Emissions Due to Biodiesel, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS PM Emissions Due to Biodiesel (TPD)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0	0	0	0	0	<0	<0	<0	-1	-1

Table 5-21 – Projected Future LCFS PM Emissions Due to Biodiesel, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS PM Emissions Due to Biodiesel (TPD)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	-1	-1	-1	<0	<0	<0	<0	<0	<0
2	-1	-1	-1	-1	-1	-1	-1	-1	-1

2. LCFS PM Emissions Due to Renewable Diesel Use

Renewable diesel use results in decreased PM emissions compared to conventional diesel. Renewable diesel that is blended in a refinery to be used as blendstock has the potential to be blended in a way that negates a portion of the PM emissions decreases. However, a CARB survey of California refiners conducted for this analysis indicated that California refineries that blend renewable diesel do not do so in a way that would reduce or negate the PM emissions decreases.[346] Therefore, staff assumed that all renewable diesel used in California results in PM emissions reductions.

The calculation of LCFS PM emissions due to renewable diesel use followed a methodology similar to that used for calculation of LCFS PM emissions associated with the use of biodiesel. First, the volume of renewable diesel attributed to the LCFS as a percentage of the total diesel demand ("LCFS-attributed renewable diesel volume percentage") was estimated for Scenarios 1 and 2. The LCFS-attributed renewable diesel volume percentages for Scenarios 1 and 2 for historical and future years were estimated based on the methodology described in Section A.2 and are presented in **Tables 5-10** and **5-11**, respectively.

[346] CARB. 2017. CARB Survey of California Refiners Regarding Renewable Diesel Blending Practices. June.

Next, the percentage change in PM emissions due to use of renewable diesel relative to use of conventional diesel (“renewable diesel percentage PM change”) was determined. Because PM emissions reductions increase linearly with increasing renewable diesel blend level across all blend levels, staff estimated the renewable diesel percentage PM change as -30 percent, based on the PM reduction for 100 percent renewable diesel shown in **Table 11** in **Appendix G**.[347]

The statewide mobile source diesel PM emissions were estimated based on the methodology described in Section B.1 and are presented in **Tables 5-18** and **5-19**.

Finally, the LCFS-attributed PM emissions decreases due to renewable diesel use were estimated for Scenarios 1 and 2 for each year from 2007 - 2025 by multiplying the LCFS-attributed renewable diesel volume percentage for the given year and scenario, provided in **Tables 5-10 and 5-11**, the renewable diesel percentage PM change (-30 percent), provided in **Table 11** in **Appendix G**, and the statewide mobile source diesel PM emissions for the given year, provided in **Tables 5-18** and **5-19**, as shown in **Equation A2-21**.

The LCFS PM emissions due to renewable diesel use for Scenarios 1 and 2 for historical and future years are shown in **Tables 5-22** and **5-23**, respectively.

Table 5-22 – Historical LCFS PM Emissions Due to Renewable Diesel, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS PM Emissions Due to Renewable Diesel (TPD)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0	0	0	0	0.0	<0	<0	<0	<0	<0

Table 5-23 – Projected Future LCFS PM Emissions Due to Renewable Diesel, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS PM Emissions Due to Renewable Diesel (TPD)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	<0	<0	<0	<0	<0	<0	<0	<0	<0
2	<0	-1	-1	-1	-1	-1	-1	-1	-1

[347] CARB. 2015. Staff Report – Multimedia Evaluation of Renewable Diesel. May. Available at: https://www.arb.ca.gov/fuels/diesel/altdiesel/20150521RD_StaffReport.pdf (p. 8). Accessed: July, 2017.

3. LCFS PM Emissions Due to Biomass-Based Diesel Use

For Scenarios 1 and 2, LCFS PM emissions due to biomass-based diesel for a given year and scenario were estimated by summing the LCFS PM emissions due to biodiesel use during the given year and scenario, provided in **Tables 5-20** and **5-21** and the LCFS PM emissions due to renewable diesel use during the given year and scenario, provided in **Tables 5-22** and **5-23,** as shown in **Equation A2-22**.

The LCFS PM emissions due to biomass-based diesel use for Scenarios 1 and 2 for historical and future years are shown in **Tables 5-24** and **5-25**, respectively.

Table 5-24 – Historical LCFS PM Emissions Due to Biomass-Based Diesel Use, Scenarios 1 and 2, 2007 to 2016

Scenario	Historical LCFS PM Emissions Due to Biomass-Based Diesel Use (TPD)									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1 and 2	0	0	0	0	0	<0	-1	<0	-1	-1

Table 5-25 – Projected Future LCFS PM Emissions Due to Biomass-Based Diesel Use, Scenarios 1 and 2, 2017 to 2025

Scenario	Projected Future LCFS PM Emissions Due to Biomass-Based Diesel Use (TPD)								
	2017	2018	2019	2020	2021	2022	2023	2024	2025
1	-1	-1	-1	-1	-1	-1	-1	-1	-1
2	-1	-1	-2	-2	-2	-2	-2	-2	-2

The results of staff's NOx and PM emissions analysis for LCFS-attributed biomass-based diesel use are summarized above and presented in more detail in Sections D.3 and D.4 of this Appendix G (for Scenarios 1 and 2) and Appendix 3 (for Scenarios 3 and 4).[348]

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[348] CARB. "Statewide LCFS NOx Analysis using 2015 EA Volumes (March 6, 2018)." Excel Workbook. CARB. "Air Basin LCFS NOx Analysis using 2015 LCFS EA Volumes (March 6, 2018)." Excel Workbook.

CARB. “Air District LCFS NOx Analysis using 2015 LCFS EA Volumes (March 6, 2018).” Excel Workbook.
CARB. “Statewide LCFS NOx Analysis using 2018 LCFS EA BAU Volumes (March 6, 2018).” Excel Workbook.
CARB. “Air Basin LCFS NOx Analysis using 2018 LCFS EA BAU Volumes (March 6, 2018).” Excel Workbook.
CARB. “Air District LCFS NOx Analysis using 2018 LCFS EA BAU Volumes (March 6, 2018).” Excel Workbook.
CARB. “Mobile Source NOx Emissions by Air Basin (March 6, 2018).” Excel Workbook.
CARB. “Mobile Source NOx Emissions by Air District (March 6, 2018).” Excel Workbook.
CARB. “Statewide LCFS PM Analysis using 2015 LCFS EA Volumes (March 6, 2018).” Excel Workbook.
CARB. “Air Basin LCFS PM Analysis using 2015 LCFS EA Volumes (March 6, 2018).” Excel Workbook.
CARB. “Statewide LCFS PM Analysis using 2018 LCFS EA BAU Volumes (March 6, 2018).” Excel Workbook.
CARB. “Air Basin LCFS PM Analysis using 2018 LCFS EA BAU Volumes (March 6, 2018).” Excel Workbook.

APPENDIX 6

HEALTH IMPACTS METHODOLOGY

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Appendix 6: Health Impacts Methodology

A. Incidents-Per-Ton Factors

To estimate the health impacts due to LCFS-attributed NOx and PM emissions changes resulting from use of bio-mass based biodiesel in mobile sources in California, staff used CARB's IPT methodology. This methodology is used to quantify the health impacts of changes in directly emitted (primary) and secondary PM due to regulatory controls. This method, which was peer reviewed in 2006,[349] yields results similar to those of a more sophisticated modeling analysis, but can be used more efficiently. It is similar to the methodology developed by the U.S. EPA for such estimations. [350] Details on the methodology used to calculate these estimates can be found in Appendix A of the Emission Reduction Plan for Ports and Goods Movement in California. [351]

The basis of the IPT methodology is the approximately linear relationship which holds between changes in emissions and estimated changes in health outcomes. This is a consequence of the following observations:

1. Across the range of ambient $PM_{2.5}$ concentrations encountered in California, modeled changes in premature health outcomes are approximately proportional to changes in ambient pollutant concentrations.

2. For primary pollutants such as diesel particulate matter, changes in ambient concentrations are approximately proportional to changes in emissions.

3. For secondary pollutants such as ammonium nitrate aerosol, a linear relationship may be used as a first-order approximation to the relationship between ambient concentration and emissions of NOx. There may be cases where the relationship between emission of NOx and ammonium nitrate aerosol is greater than or less than linear.

[349] CARB. 2006. Emission Reduction Plan for Ports and Goods Movement in California, Appendix A: Quantification of the Health Impacts and Economic Valuation of Air Pollution from Ports and Goods Movement in California. March 21. Available at: https://www.arb.ca.gov/planning/gmerp/plan/appendix_a.pdf. Accessed: August, 2017.
[350] Fann, Neal, Charles M. Fulcher, and Bryan J. Hubbell. 2009. The influence of location, source, and emission type in estimates of the human health benefits of reducing a ton of air pollution. Air Qual Atmos Health. 2009 Sep; 2(3): 169-176. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2770129/pdf/11869_2009_Article_44.pdf. Accessed: August, 2017.
[351] CARB. 2006. Emission Reduction Plan for Ports and Goods Movement in California, Appendix A: Quantification of the Health Impacts and Economic Valuation of Air Pollution from Ports and Goods Movement in California. March 21. Available at: https://www.arb.ca.gov/planning/gmerp/plan/appendix_a.pdf. Accessed: August, 2017.

Therefore, health outcomes are approximately proportional to emissions, and can be estimated by multiplying emissions by a scaling factor, the IPT factor. IPT factors are derived by calculating the incidence of mortality and morbidity associated with a $PM_{2.5}$ source in an air basin, and dividing by the emissions of that $PM_{2.5}$ source. The emission inventories for NOx were developed for 2007 – 2025, adjusted to account for changes due to the recession, updates to the trucks/buses, locomotives, and construction equipment models. Separate IPT factors are used for each air basin and for each pollutant. Since the total incidence of health outcomes is proportional to population, the result is adjusted by the ratio of the population in the target year to the population in the base year for which the IPT factors were developed.

B. Mortality and Morbidity Incidence

4. Background

For estimating the health impacts of NOx and PM emission reductions changes brought about by biomass-based diesel use attributed to the LCFS, CARB applied the methodology used by U.S. EPA in the 2010 Quantitative Health Risk Assessment[352] that was developed to estimate health outcomes associated with $PM_{2.5}$ exposure. In this assessment of premature mortality, CARB calculated estimates for cardiopulmonary mortality. CARB is emphasizing cardiopulmonary deaths because they are the most frequent causes of death, and category of deaths most strongly related to $PM_{2.5}$ exposure.[353]

Calculation of the mortality and morbidity incidence associated with $PM_{2.5}$ exposure requires baseline incidence rates, population data, ambient concentration of $PM_{2.5}$, and a concentration-response function relating changes in $PM_{2.5}$ exposure to changes in mortality incidence. Calculations were made based on both primary and secondary $PM_{2.5}$ exposure. The sources and derivation of these parameters are described in Sections C - F.

5. Estimating Population Exposure to $PM_{2.5}$

Estimation of the $PM_{2.5}$ exposure is a several step process, involving estimation of the annual-average concentration at each $PM_{2.5}$ monitor in the state, and interpolation of concentrations between monitors to estimate exposure for each census tract. Since diesel engines emit particles directly (primary particles), as well as gases that convert to

[352] U.S. EPA. 2010. Quantitative Health Risk Assessment for Particulate Matter. EPA-452/R-10-005. June. Available at: http://www.epa.gov/ttn/naaqs/standards/pm/data/PM_RA_FINAL_June_2010.pdf. Accessed: August, 2017.
[353] Ibid.

$PM_{2.5}$ through atmospheric chemical reactions (secondary particles), exposure estimates are made for both, in order to capture the full impact of diesel engines on mortality and morbidity.

Population-weighed exposure to primary and secondary $PM_{2.5}$ was estimated based on monitor-specific concentrations. Even with an extensive air quality monitoring network, the quantification method requires estimation of exposure between monitors across a geographic area. CARB uses a standard spatial interpolation method known as inverse distance-squared weighting which was peer reviewed in 2007.[354,355] This method yields reasonable accuracy in estimating pollutant concentrations near monitoring stations, although when distance from the monitoring station increases, the uncertainty in the interpolated concentration also increases. This method gives more accurate estimates of concentration in areas with a large number of monitors with good spatial coverage and low variability in concentration. When data are abundant, most simple interpolation techniques give similar results.[356] When data are sparse, however, the assumption made about the underlying variation in $PM_{2.5}$ concentration, along with the choice of interpolation method and its parameters can be critical to avoid misleading results.

6. Aggregating Results to County, Air Basin and State

To aggregate results from census tracts to larger geographical subdivisions such as counties or air basins, we used a GIS technique called areal interpolation. Areal interpolation is a procedure for translating spatial data from one set of geographical subdivisions to another when the boundaries do not exactly overlap. Numerous variants of the technique exist, but for the purpose of this analysis the simplest form, which uses area of polygon intersection, was employed.[357,358]

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[354] Shepard, Donald. 1968. A two-dimensional interpolation function for irregularly-spaced data. Proceedings of the 1968 ACM National Conference. Pp. 517–524. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.154.6880&rep=rep1&type=pdf. Accessed: September, 2017.

[355] Goodin, William R., Gregory J. McRae, and John H. Seinfeld. 1979. A Comparison of Interpolation Methods for Sparse Data: Application to Wind and Concentration Fields. J Applied Meteor. 18:761-771. Available at: http://journals.ametsoc.org/doi/pdf/10.1175/1520-0450(1979)018%3C0761:ACOIMF%3E2.0.CO%3B2. Accessed: August, 2017.

[356] Jarvis, Claire H. and Neil Stuart. 2001. A Comparison among Strategies for Interpolating Maximum and Minimum Daily Air Temperatures. Part II: The Interaction between Number of Guiding Variables and the Type of Interpolation Method. Journal of Applied Meteorology. 40, 1075-1084. Available at: http://journals.ametsoc.org/doi/full/10.1175/1520-0450%282001%29040%3C1075%3AACASFI%3E2.0.CO%3B2. Accessed: August, 2017.

[357] Goodchild Michael F. and Nina Siu-Ngan Lam. 1980. Areal Interpolation: A Variant of the Traditional Spatial Problem. Geo-Processing, 1: 297-312. Available at: http://www.geog.ucsb.edu/~good/papers/46.pdf. Accessed: August, 2017.

[358] Flowerdew, Robin and Mick Green. 1994. Areal interpolation and types of data. Chapter 7 in: Fotheringham, Stewart and Peter Rogerson, editors. 1994. Spatial Analysis and GIS. London. Taylor and

The precision of areal interpolation based on area of intersection depends on the relative size of the geographical subdivisions, and the homogeneity of the spatial distribution of the quantity being apportioned. In urban areas, where census tracts are small and population is distributed more evenly, areal interpolation to larger subdivisions such as air basins yields relatively precise estimates. In rural areas where the population is distributed unevenly over large census tracts, estimates are less precise.

C. Population at the Census Tract Level

Age-resolved population data at the census tract level, for the 2010 Census, were obtained from the United States Census Bureau.[359] These data were projected to 2007-2025 using age-resolved county population projections from the California Department of Finance (CDOF).[360]

Age-specific growth factors for each county, for each year, were computed from the CDOF projections by dividing each county population for the target year by the county population for the year 2000. Since each census tract lies entirely in a county, these growth factors were applied to each census tract in the county, each age group separately. Population was projected for ten-year age groups 25-34 through 75-84, and for age 85 and older.

This method of projection reflects growth in overall county population, but does not model changes in population distribution within counties, such as expansion of urban areas into surrounding rural land.

D. Baseline Incidence Rates

Baseline incidence rates for mortality and morbidity were taken from the CDC Wonder database.[361] They vary by age: incidence rates for five-year age groups from 0 to 84,

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Francis. Available at: https://www.researchgate.net/profile/Alexander_Fotheringham/publication/246324467_GIS_and_spatial_analysis_introduction_and_overview/links/0f31753876e56698a7000000/GIS-and-spatial-analysis-introduction-and-overview.pdf. Accessed: August, 2017.

[359] U.S. Census Bureau. 2017. American Fact Finder. Available at: https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml. Accessed: August, 2017.

[360] California Department of Finance (CDOF). 2017. E-1 Population Estimates for Cities, Counties, and the State – January 1, 2016 and 2017. May. Available at: http://www.dof.ca.gov/Forecasting/Demographics/Estimates/E-1/. Accessed: September, 2017.

[361] Centers for Disease Control and Prevention (CDC). 2017. Wide-Ranging On-Line Data for Epidemiologic Research (WONDER) Database. Available at: https://wonder.cdc.gov/ucd-icd10.html. Accessed: August, 2017.

and an age 85 and over group, were used. Baseline mortality rates are subject to uncertainty. For example, the baseline incidence level is treated as uniform throughout the county of interest. In addition, baseline incidence rates can change over time as lifestyles, health care, income, and other factors evolve.

E. Annual Diesel PM Concentrations

No definitive measurement technique is available for monitoring ambient diesel PM concentrations. Therefore, diesel PM concentrations were estimated indirectly. Analysis previously published by CARB has demonstrated that ambient diesel PM concentrations are approximately proportional to ambient NOx concentrations.[362,363] Following the methodology described in that analysis, annual average diesel PM concentrations were estimated by multiplying annual average NOx concentrations by a conversion factor. Annual average NOX concentrations for the baseline air quality years of 2009-2011 were retrieved from CARB's air quality database (CARB ADAM).[364]

F. Annual PM2.5 Ammonium Nitrate Concentrations

In addition to directly emitted PM, diesel exhaust contains NOX, which is the precursor to nitrates, secondary diesel-related PM formed in the atmosphere. Secondary PM can lead to additional health impacts beyond those associated with directly emitted diesel PM. To quantify such impacts, staff developed annual average ammonium nitrate concentrations for 2007-2025. The concentrations were computed from ambient nitrate ion concentrations, using PM_{10} data combined from two sources: the regular air quality monitoring network and the IMPROVE Visibility Network.

CARB and air pollution control districts operate a network of PM_{10} monitors around the state, mostly in urban areas (CARB AQMN). PM_{10} samples are collected as 24-hour filter samples, once every six days, using size-selective inlet (SSI) sampler. Samples from some monitors are further analyzed to determine the concentration of nitrate and

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[362] CARB. 2010. Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Proposed Amendments to the Truck and Bus Regulation, the Drayage Truck Regulation and the Tractor-Trailer Greenhouse Gas Regulation, Appendix J: Methodology for Estimating Ambient Concentration of Particulate Matter from Diesel-Fueled Engine Emissions and Health Benefits Associated with Reductions in Diesel PM Emissions from In-Use On-Road Heavy-Duty Diesel-Fueled Vehicles. October. Available at: https://www.arb.ca.gov/regact/2010/truckbus10/correctedappj.pdf. Accessed: August, 2017.

[363] Proper, Ralph, Patrick Wong, Son Bui, Jeff Austin, William Vance, Álvaro Alvarado, Bart Croes, and Dongmin Luo. 2015. (2015). Ambient and Emission Trends of Toxic Air Contaminants in California. Environ. Sci. Technol., 2015, 49 (19), pp 11329–11339). Available at: http://pubs.acs.org/doi/pdf/10.1021/acs.est.5b02766. Accessed: August, 2017.

[364] CARB. 2013. California Air Quality Data Available on DVD-ROM (1980-2011). September. Available at: https://www.arb.ca.gov/aqd/aqdcd/aqdcd.htm. Accessed: August, 2017.

other constituents. During the baseline air quality years of 2009-2011, nitrate data were available from 37 monitors. Since nitrate particles form a fine aerosol, essentially all of the nitrate mass falls into the $PM_{2.5}$ fraction, so the PM_{10} nitrate concentration may be regarded as equivalent to $PM_{2.5}$ nitrate concentration. SSI data were retrieved from CARB's ADAM air quality database.[365]

In addition to urban PM_{10} nitrate monitoring, the national IMPROVE Visibility Network operated 18 $PM_{2.5}$ nitrate monitors, mainly in national parks and other remote locations. These instruments collect one sample every three days. The IMPROVE samplers are more efficient than the SSI samplers, and tend to recover a higher fraction of ambient ammonium nitrate than the SSI samplers. However, since the IMPROVE samplers are located at remote locations where $PM_{2.5}$ concentrations are close to natural background levels, the effect of instrument bias is considered negligible, and the data were treated as equivalent to the SSI data. IMPROVE data were retrieved from the IMPROVE Visibility Network web site.

Daily samples were aggregated by monitor to obtain annual averages. In order to avoid potential seasonal bias due to missed samples, the samples were aggregated into quarterly means, and the four-quarterly means were averaged to obtain annual means. For a quarterly average to be considered valid, the data were required to be at least 75% complete. For a year to be considered valid, all four valid quarters were required.

To convert from nitrate ion concentration to ammonium nitrate (NH4NO3) concentration, the annual averages were multiplied by the ratio of the molecular weight of ammonium nitrate to that of the nitrate ion, 1.29.

[365] *Id.*