State of California
California Environmental Protection Agency

STAFF REPORT
Multimedia Evaluation of Renewable Diesel



Prepared by the
Multimedia Working Group

May 2015

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Acknowledgements

Staff acknowledges the invaluable contributions from the University of California researchers who conducted the multimedia evaluation. This report was prepared by the Multimedia Working Group with the assistance and support from other individuals within the California Environmental Protection Agency and academia.

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GLOSSARY

AA	Acetaldehyde
ADF	Alternative Diesel Fuel
ARB	Air Resources Board
Cal/EPA	California Environmental Protection Agency
CEPC	California Environmental Policy Council
DTSC	Department of Toxic Substances Control
CARB	California Air Resources Board
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DOC	Diesel Oxidation Catalyst
DPR	Department of Pesticide Regulation
FA	Formaldehyde
FTP	Federal Test Procedure
GHG	Greenhouse Gas
H&SC	Health and Safety Code
HVORD	Hydrotreated Vegetable Oil Renewable Diesel
MMWG	Multimedia Working Group
NOx	Oxides of Nitrogen
OEHHA	Office of Environmental Health Hazard Assessment
PAH	Polycyclic Aromatic Hydrocarbon
POC	Particulate Oxidation Catalyst
PM	Particulate Matter
ROS	Reactive Oxygen Species
SWRCB	State Water Resources Control Board
TAC	Toxic Air Contaminant
THC	Total Hydrocarbons
UDDS	Urban Dynamometer Driving Schedule
VOC	Volatile Organic Compounds

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I. Introduction

The staff of the Air Resources Board (ARB or Board) intends to establish new motor vehicle fuel specifications and in-use requirements for biodiesel, which includes the use of renewable diesel as part of the proposed ADF regulation.[1] The ADF regulation is intended to provide a framework for low carbon diesel fuel substitutes to enter the commercial market in California, while mitigating any potential environmental or public health impacts. The proposed regulation order is provided in Appendix A.

Before new fuel specifications are established, California Health and Safety Code (HSC) section 43830.8 requires a multimedia evaluation to be conducted and reviewed by the California Environmental Policy Council (CEPC). The CEPC must determine if the proposed regulation poses a significant adverse impact on public health or the environment.[2] As part of the proposed ADF regulation, a multimedia evaluation of renewable diesel was conducted pursuant to HSC section 43830.8.

The purpose and scope of the multimedia evaluation is to inform the rulemaking process and provide the information needed for the development of fuel regulations. The Multimedia Working Group (MMWG) was established to oversee the multimedia evaluation process and make recommendations to the CEPC regarding the acceptability of new fuel formulations proposed for use in the State.

For the multimedia evaluation of renewable diesel, the MMWG prepared this staff report for submittal to the CEPC. The purpose of this report is to provide a summary of the multimedia evaluation and the MMWG's conclusions and recommendations to the CEPC.

A. Fuels Multimedia Evaluation

"Multimedia evaluation" is the identification and evaluation of any significant adverse impact on public health or the environment, including air, water, and soil, that may result from the production, use, or disposal of the motor vehicle fuel that may be used to meet the state board's motor vehicle fuel specifications.[3]

At a minimum, the evaluation should address impacts associated with the following:

- Emissions of air pollutants, including ozone forming compounds, particulate matter, toxic air contaminants, and greenhouse gases.
- Contamination of surface water, ground water, and soil.

[1] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*, October 23, 2013. ES-1.
[2] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8.
[3] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(b).

- Disposal or use of the byproducts and waste materials from the production of the fuel.

As specified in HSC 43830.8, a multimedia evaluation must be based on the best available scientific data, written comments, and any information collected by the Board in preparation for the proposed rulemaking. After an evaluation has been completed, the MMWG must prepare a written summary report, including the MMWG's conclusions and recommendations to the CEPC, and submit it for peer review pursuant to HSC section 57004. The staff report and results of the peer review will then be submitted to the CEPC for final review and approval.

1. Multimedia Working Group

The California Environmental Protection Agency (Cal/EPA) formed the inter-agency MMWG to oversee the multimedia evaluation process and make recommendations to the CEPC. The MMWG includes representatives from the ARB, State Water Resources Control Board (SWRCB), Office of Environmental Health Hazard Assessment (OEHHA), Department of Toxic Substances Control (DTSC), and Office of the State Fire Marshal (OSFM). The MMWG may also consult with other agencies and experts, as needed. The complete list of all members of the MMWG is provided in Appendix B.

The renewable diesel multimedia evaluation includes an assessment of potential impacts on public health and the environment, including air, water, and soil, that may result from the production, use, and disposal of the fuel. In this evaluation, ARB staff was responsible for the air quality impact assessment and the overall coordination of the evaluation process. OEHHA staff was responsible for evaluating potential public health impacts, SWRCB staff was responsible for evaluating potential surface water and groundwater quality impacts, and DTSC staff was responsible for evaluating potential hazardous waste and soil impacts.

2. California Environmental Policy Council

Pursuant to Public Resources Code section 71017(b), the CEPC was established as a seven-member body comprised of the Secretary for Environmental Protection; the Chairpersons of ARB and SWRCB; and the Directors of OEHHA, DTSC, Department of Pesticide Regulation (DPR), and Department of Resources Recycling and Recovery (CalRecycle).

As previously stated, the CEPC must determine if the regulation poses a significant adverse impact on public health or the environment. In making its determination, the CEPC must consider the following:

- Emissions of air pollutants.
- Contamination of surface water, groundwater, and soil.
- Disposal of waste materials.

- MMWG recommendations contained in the staff report and peer review comments.

According to HSC section 43830.8(e), the CEPC shall complete its review of the evaluation within 90 calendar days following notice that the ARB intends to adopt a new regulation. If the CEPC determines that the regulation will cause a significant adverse impact on public health or the environment, or that alternatives exist that would be less adverse, the CEPC shall recommend alternative or mitigating measures to reduce the adverse impact on public health or the environment.

3. Overview of the Multimedia Evaluation Process

A multimedia evaluation consists of three tiers. Tier I begins with a summary of what is known about the fuel and the information needed for the multimedia risk assessment. The Tier I Report, or Work Plan, identifies key knowledge gaps about the fuel, if any, and establishes the overall scope of the evaluation. Tier II is the development of the Tier II Report, or Risk Assessment Protocol, to fill in any knowledge gaps identified during Tier I. If key knowledge gaps are not identified in Tier I, no further Tier II testing or information are needed and the multimedia evaluation would then proceed directly to Tier III. Tier III is the implementation of the risk assessment, resulting in a final report of any significant adverse impacts on public health or the environment. The multimedia evaluation process is summarized in Table 1.[4]

Table 1. Summary of the Multimedia Evaluation Process

	Fuel Applicant	**Multimedia Work Group Review**	**MMWG Consultation and Peer Review**
Tier I	Fuel Background Summary Report: • Chemistry • Release scenarios • Environmental behavior	Screens applicant and establishes key assessment elements and issues	Technical consultation during development of Tier I Work Plan including identification of key risk assessment elements and issues
	Mutually-agreed upon Tier I Work Plan		
Tier II	Risk Assessment Protocol Report	Comment on Risk Assessment Protocol	Technical consultation on Risk Assessment Design
Tier III	Execution of Risk Assessment and preparation of Multimedia Risk Assessment Report	Prepare recommendations to the Environmental Policy Council based on Multimedia Risk Assessment Report	Independent external peer review of the Multimedia Risk Assessment Report and Multimedia Working Group recommendations

[4] U.C. Berkeley, U.C. Davis, and Lawrence Livermore National Laboratory. *Guidance Document and Recommendations on the Types of Scientific Information Submitted by Applicants for California Fuels Environmental Multimedia Evaluations*. June 2008, 9-10.

Each tier of the multimedia evaluation process is designed to provide input for the next stage of the decision-making process. After Tier III is complete, the MMWG prepares a summary of the multimedia evaluation and their conclusions and recommendations in a staff report to the CEPC.

4. External Scientific Peer Review

Under HSC section 43830.8(d), an external scientific peer review of the multimedia evaluation must be conducted pursuant to HSC section 57004. The purpose of the peer review is to determine whether the scientific portions of the MMWG staff report are based upon "sound scientific knowledge, methods, and practices." [5]

The peer review process is initiated by submittal of a request memorandum to the manager of the Cal/EPA Scientific Peer Review Program. The memorandum is prepared by the ARB as the leading agency of the MMWG and includes a summary of the nature and scope of the requested review, descriptions of the scientific conclusions to be addressed, and list of recommended areas of expertise. The request memorandum for peer review is appended as Appendix H.

In November 2013, ARB requested peer review of the MMWG's assessment of the renewable diesel multimedia evaluation and the proposed ADF regulation. The review was completed in February 2014. The written reviews submitted by the peer reviewers are provided in Appendix I. Overall, the reviewers determined that the MMWG's conclusions were based on sound scientific knowledge, methods, and practices. The MMWG reviewed all peer review comments, addressed each comment in a written response, and have, where appropriate, made revisions to the staff report. The MMWG's response to peer review comments are provided in Appendix J.

C. <u>Renewable Diesel Background Information</u>

Renewable diesel is produced from non-petroleum renewable resources but is not a mono-alkyl ester. Renewable diesel consists solely of hydrocarbons and meets ARB motor vehicle fuel specifications under title 13, California Code of Regulations (CCR), section 2281 et seq. In fact, renewable diesel meets specified aromatic, sulfur, and lubricity standards, as well as ASTM International standard specification, ASTM D975-12a.[6]

The proposed ADF Regulation defines renewable diesel as follows:

(22) "Non-ester renewable diesel" means a diesel fuel that is produced from nonpetroleum renewable resources but is not a mono-alkyl ester and which is

[5] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 57004(d)(2).
[6] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*. October 23, 2013, 18, 20.

registered as a motor vehicle fuel or fuel additive under 40 CFR Part 79, as amended by Pub. L. 91-604.

(23) "Non-ester renewable diesel blend" means non-ester renewable diesel blended with petroleum-based diesel fuel.

(24) "Non-petroleum renewable resources" means non-fossil fuel resources including but not limited to biomass, waste materials, and renewable crude.

There are several different chemical approaches to producing renewable diesel. One is based on hydrotreating vegetable oils or animal fats. Hydrotreating frequently takes place in conventional refineries to reduce sulfur or aromatic hydrocarbon content in CARB diesel. A second method involves synthesis of hydrocarbons through enzymatic reactions. A third method involves partially combusting a biomass source to produce carbon monoxide and hydrogen (syngas) and utilizing the Fischer-Tropsch reaction to produce complex hydrocarbons. Compared to biodiesel, renewable diesel uses similar feedstocks but has different processing methods and can include chemically different components. [7]

Renewable diesel is typically produced by hydrotreating animal fats and vegetable oils, as well as refining similar to petroleum refining. Existing hydrotreatment processing equipment are typically used and results in a fuel containing pure hydrocarbons, paraffinic compounds, and nearly no aromatics.

In this report, CARB diesel fuel blended with 20 vol% or 50 vol% renewable diesel is denoted as R20 and R50, respectively. Pure or 100 vol% renewable diesel is denoted as R100.

D. <u>Multimedia Evaluation of Renewable Diesel</u>

Pursuant to HSC section 43830.8, researchers from UC Berkeley and UC Davis conducted the multimedia evaluation of renewable diesel. The evaluation is a relative comparison between hydrotreated renewable diesel and diesel fuel that meets ARB motor vehicle diesel fuel specifications (CARB diesel). The proposed ADF regulation defines "CARB diesel fuel" as a light or middle distillate fuel which may be comingled with up to five (5) volume percent biodiesel, and meeting the definition and requirements for "diesel fuel" or "California non-vehicular diesel fuel" as specified in 13 CCR 2281 et seq.[8]

As previously described, a multimedia evaluation may consist of a total of three tiers. Due to the specific fuel properties and indistinguishable chemical compositions of renewable diesel and CARB diesel, the UC researchers and the MMWG found no significant data needs and, therefore, no additional Tier II experiments were needed.

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[7] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier III Report*. Apr 2012, 5.
[8] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*. October 23, 2013, 5.

Consequently, after Tier I, the UC researchers proceeded directly to Tier III of the evaluation. The researchers submitted a Tier I and Tier III report, and finalized them with the MMWG. The final reports are listed below:

- California Renewable Diesel Multimedia Evaluation Final Tier I Report (Final Tier I Report)[9]
- California Renewable Diesel Multimedia Evaluation Final Tier III Report (Final Tier III Report or Renewable Diesel Final Report)[10]

The Renewable Diesel Final Report is provided in Appendix G and includes the Final Tier I Report as an attachment.

Based on the renewable diesel multimedia evaluation and the information provided in the Final Tier I and Tier III reports, the MMWG determined that the use of renewable diesel, as specified in this multimedia evaluation and the proposed ADF regulation, does not pose a significant adverse impact on public health or the environment compared to CARB diesel fuel.

[9] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier I Report*, Sept 2011.
[10] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier III Report*, Apr 2012.

II. Evaluation Summaries

This section provides the multimedia evaluation summaries prepared by ARB, SWRCB, OEHHA, and DTSC. The evaluations are based on the relative differences between renewable diesel and CARB diesel. The MMWG evaluated potential environmental and public health impacts from changes to air emissions, water quality, soil quality, and hazardous waste generation. The complete evaluations and supporting documentation are provided in the appendices of this report.

A. Air Resources Board Evaluation

ARB staff completed an air quality assessment of renewable diesel fuel. The evaluation includes a description of the emissions test program and impact analysis on air emissions, including toxic air contaminants and ozone precursors. The complete evaluation report is provided in Appendix C.

Staff's assessment is based on the data and information provided for the renewable diesel multimedia evaluation, including the UC researchers' multimedia reports (Final Tier I, Tier II, and Tier III reports) and the "*CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California*" (ARB Emissions Study)[11] by UC Riverside from emissions testing conducted at the College of Engineering – Center for Environmental Research and Technology (CE-CERT) and ARB emissions test facilities in Stockton and El Monte, California

Emissions testing was conducted on pure renewable diesel (R100) and two renewable diesel blends (R20 and R50) with CARB diesel as the baseline fuel. The test program includes both engine testing and chassis testing of renewable diesel and renewable diesel blends. Generally at least six repetitions were conducted on each fuel blend. The results of the testing were straight averages of the difference between renewable diesel and CARB diesel emissions.

Engine testing was performed on a 2006 Cummins ISM engine. Chassis testing was performed on a 2000 Caterpillar C-15 engine. Toxic emissions testing was completed on the Caterpillar C-15 engine.

1. Health-Relevant Air Emissions

Engine testing conducted as part of the ARB Emissions Study focused primarily on regulated emissions, including particulate matter (PM), nitrogen oxides (NOx), total hydrocarbons (THC), and carbon monoxide (CO). More extensive testing, including toxics analyses, was completed for chassis testing.

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[11] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

For R100, PM emissions results showed an average decrease of about 30%. NOx emissions results showed a decrease of about a 10%. THC and CO generally decreased by about 5% and 10%, respectively.
ARB identified diesel PM as a toxic air contaminant in 1998, and determined that diesel PM accounts for about 70% of the toxic risk from all identified toxic air contaminants.[12] Test results show that the use of renewable diesel reduces PM emissions by about 30%.[13]

Other toxic emissions tests were conducted for various carbonyls, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs). Overall, toxics test results show decreases in most PAHs and VOCs. Carbonyl emissions were not significantly different between renewable diesel and CARB diesel. Genotoxicity assays were also performed and in all cases renewable diesel showed either reduced toxicity compared to CARB diesel or no difference in toxicity.[14]

2. Climate-Relevant Air Emissions

Gases that trap heat in the atmosphere are called greenhouse gases (GHGs). GHG emissions are primarily CO_2, methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons.[15] Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years.[16] GHG emissions from the use of fuels are primarily CO_2.[17] Average CO_2 emissions results from the ARB Emissions Study showed a general decreased by about 3%.

Life cycle GHG emissions include emissions associated with the production, transportation, and use of a fuel in a motor vehicle. The life cycle analysis (LCA) of a fuel includes direct emissions from producing, transporting, and using the fuel, as well as indirect effects, including land use change. Depending on the fuel, GHG emissions from each step of the life cycle can include CO_2, CH_4, N_2O, and other GHG contributors. The "carbon intensity" of a fuel represents the equivalent amount of CO_2 emitted from each stage of the fuel's life cycle and is expressed in terms of grams of CO_2 equivalent per megajoule (gCO_2e/MJ).[18]

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[12] Air Resources Board. *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles.* October 2000. Page 1.
[13] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* Oct 2011, Table ES-6, xxxvii.
[14] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011, 148,164.
[15] Air Resources Board. *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles*. August 6, 2004, i.
[16] United States Environmental Protection Agency. *Overview of Greenhouse Gases* website. http://www.epa.gov/climatechange/ghgemissions/gases.html. Accessed April 29, 2015.
[17] Air Resources Board. *Proposed Re-Adoption of the Low Carbon Fuel Standard*. *Staff Report: Initial Statement of Reasons*. December 2014, ES-2.
[18] Air Resources Board. *Proposed Re-Adoption of the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons.* December 2014.

In contrast, end-of-pipe or tailpipe emissions only include exhaust emissions associated with the use of a fuel in an internal combustion engine.[19] Tailpipe CO_2 emissions are only one component in determining a fuel's life cycle carbon emissions. As previously stated, the measured increase in CO_2 emissions may not necessarily lead to an overall increase in carbon emissions. An increase in CO_2 reflects more complete combustion, and is an expected result of decreased THC and CO emissions.

Based on the results from the ARB Emissions Study, renewable diesel increased BSFC by about 5%. However, as with any alternative fuel, determination of GHG emissions impact is the result of a full LCA of the fuel. For renewable diesel, the outcome of the analysis is greatly dependent on the feedstock source. The LCA of renewable diesel under the Low Carbon Fuel Standard showed reductions in GHGs of about 15% to 80% depending on feedstock source.[20]

3. Secondary Air Pollutants

Secondary pollutants form in the atmosphere through chemical and photochemical reactions from other primary pollutants. An example includes ozone, which is formed when hydrocarbons and NOx combine in the presence of light. Its precursor components are primarily the result of road traffic. Unlike many of the other GHGs, ozone is a short-lived gas that is found in regionally varying concentrations.

Both THC and NOx emissions determine ozone concentrations. As previously stated, test results show a decrease in NOx emissions and most VOCs. THC emissions also generally decreased by about 5% from CARB diesel emissions levels. Overall, it's expected that the use of renewable diesel would result in an improvement in ground level ozone compared to the use of CARB diesel fuel.[21]

B. State Water Resources Control Board Evaluation

SWRCB staff completed an evaluation of potential surface water and groundwater impacts from renewable diesel fuel. Staff based their assessment on the information provided in the UC multimedia evaluation reports (Final Tier I and Tier III Reports). The multimedia evaluation and SWRCB's assessment of environmental impacts is specific to the difference between renewable diesel and CARB diesel. Please refer to Appendix D for staff's complete evaluation.

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[19] Air Resources Board. *Proposed Regulation to Implement the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons.* March 2009, IV-12.

[20] California Air Resources Board, *LCFS Carbon Intensity Lookup Table*, December 2012. http://www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf (accessed October 15, 2013).

[21] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011, 89.

1. Water Impacts

Aquatic toxicity was considered by comparing renewable diesel and CARB diesel. SWRCB staff reviewed the data comparing the effects of renewable diesel and CARB diesel when exposed to a series of aquatic toxicity tests. No significant changes in aquatic toxicity were identified by the multimedia study.

2. Underground Storage Tank Material Compatibility and Leak Detection

California statutes require that the underground storage tank systems be compatible with the substance stored, and the leak detection equipment be able to function appropriately with the substance stored. The multimedia evaluation indicates that renewable diesel is chemically comparable to CARB diesel. Therefore, differences in compatibility and leak detection are not anticipated.

3. Biodegradability and Fate and Transport

UC Davis and UC Berkeley researchers provided data on the impacts of fate and transport properties of renewable diesel compared to CARB diesel. Fate and transport, as well as biodegradability, are not expected to be significantly different given the similar chemical composition of renewable diesel and CARB diesel.

4. Waste Discharge from Manufacturing

Chemicals used in, and byproducts created by, the production of the fuel are required to comply with hazardous waste laws and regulations. No significant areas of concern have been identified by staff when comparing the waste streams of renewable diesel to CARB diesel.

C. Office of Environmental Health Hazard Assessment Evaluation

OEHHA staff evaluated potential public health impacts from the use of renewable diesel compared to CARB diesel. Staff based their evaluation on their analysis of toxicity test data and combustion emissions results. Please refer to Appendix E for the complete report.

1. Combustion Emissions

Diesel engine emissions from combustion of hydrotreated vegetable oil renewable diesel (HVORD) and CARB diesel were quantified by CE-CERT at UC Riverside.[22] The renewable diesel fuel was produced by Neste Oil and denoted NExBTL fuel. The CARB fuel used was certified CARB diesel fuel.

PM, NOx, CO, and THC were measured in combustion emissions from a 2006 Cummins ISM engine and a 2000 Caterpillar C-15 engine. Emissions from the

[22] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

Caterpillar C-15 engine were determined for the Urban Dynamometer Driving Schedule (UDDS) and the 50 mph cruise simulation. Emissions from the 2006 Cummins ISM engine were determined for the UDDS test protocol, the 50 mph cruise protocol and the Federal Testing Procedure (FTP) protocol.

In tests using the 2006 Cummins ISM engine, there was a significant reduction in PM emissions from R50 and R100 combustion compared with emissions from CARB diesel combustion during the UDDS protocol and the 50 mph cruise simulation protocol. There was also a significant decrease in PM for R20, R50 and R100 during the FTP protocol. There was a significant decrease in NOx emissions during all three test protocols for R20, R50 and R100. There was a significant reduction in CO emissions using R20, R50 or R100 during the UDDS and FTP protocols. There was a small but significant increase in CO using R100 during the 50 mph cruise simulation protocol.[23]

In tests using the Caterpillar C-15 engine, there was a significant reduction in PM emissions using R50 or R100 during the UDDS protocol but no significant reductions during the 50 mph cruise simulation protocol. There were significant reductions of NOx using R20, R50 or R100 during the UDDS protocol but no significant reductions using the 50 mph cruise simulation protocol. CO emissions were reduced when R20, R50 or R100 were used but the reductions were significant only for R50 using the UDDS protocol and R100 using the 50 mph cruise simulation protocol. [24]

In tests using the 2000 Caterpillar C-15 engine operated with the UDDS cycle, emissions of benzene and ethylbenzene were significantly lower using HVORD than they were using CARB diesel. When the engine was operated using the 50 mph cruise simulation, emissions of both benzene and toluene were significantly lower using HVORD than they were using CARB diesel. Emissions of ethylbenzene were lower when HVORD was used, but the reduction in emissions was not statistically significant.[25]

PAHs were measured in emissions from a 2000 Caterpillar C-15 engine operated using the UDDS cycle. There was a consistent decreasing trend in PAH emissions with increasing concentrations of HVORD in CARB-renewable diesel blends (R20, R50 and R100).[26]

[23] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.
[24] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.
[25] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.
[26] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

Murtonen *et al.*[27] compared engine emissions from truck (Scania DT 12 11 420, Variant L01) and off-road (Sisudiesel 74 CTA-4V (SCR equipped)) diesel engines fueled with EN590 petroleum diesel (EN590) (< 10 ppm sulfur) or HVORD. The emissions testing for the engines described above was performed using an engine dynamometer. The Scania engine was tested using a Braunschweig cycle and the SisuDiesel engine was tested using a Nonroad Transient Cycle (NRTC) test cycle and an International Standards Organization (ISO) C1 steady-state test cycle. Both regulated and unregulated emission outputs were expressed in units of weight/distance (e.g. milligrams per kilometer [mg/km]).

In the absence of a Diesel Oxidation Catalyst (DOC)/Particulate Oxidation Catalyst (POC) catalytic converter, PM and PAH output from the Scania engine run on HVORD was substantially reduced (43% and 68%, respectively) compared to operation on EN590. A substantial decrease (68%) was also noted for mutagenicity in *Salmonella typhimurium* (strain TA98) treated with HVORD-fueled engine PM extract in the absence of metabolic activation compared to PM extract from a EN590-fueled engine. Moderate decreases (approximately 20%) were noted for CO, THC, formaldehyde (FA), acetaldehyde (AA) and other aldehydes/ketones, and no change was noted for NOx in the HVORD-fueled engine exhaust compared to the EN590-fueled engine.[28]

In the presence of a DOC/POC catalytic converter, PM and PAH output from the Scania engine run on HVORD was substantially reduced (39% and 67%, respectively) compared to operation on EN590. A slight increase was noted for NOx and no change was noted for CO in the HVORD-fueled engine exhaust compared to the EN590-fueled engine.[29]

No significant difference was noted for CO, THC, PAH, FA, AA or other aldehyde/ketone output from the HVORD-fueled Sisudiesel engine run on either the NRTC or ISO cycles compared to the EN590-fueled engine. PM output from the HVORD-fueled engine was moderately decreased (25-35%), as was NOx output (12-15%) compared to the EN590-fueled engine on both test cycles. [30]

Jalava *et al.*[31] compared exhaust toxicities from a small industrial diesel engine (Kubota D1105-T) fueled EN590 or HVORD with using an ISO C1 steady-state test cycle. PM

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[27] Murtonen T, Aakko-Saksa P, Kuronen M, Mikkonen S and Lehtoranta K. (2010). *Emissions with heavy-duty diesel engines and vehicles using FAME, HVO and GTL fuels with and without DOC+POC aftertreatment*. SAE International Journal of Fuels and Lubricants. 2:147-166.
[28] Murtonen T, Aakko-Saksa P, Kuronen M, Mikkonen S and Lehtoranta K. (2010). *Emissions with heavy-duty diesel engines and vehicles using FAME, HVO and GTL fuels with and without DOC+POC aftertreatment*. SAE International Journal of Fuels and Lubricants. 2:147-166.
[29] Murtonen T, Aakko-Saksa P, Kuronen M, Mikkonen S and Lehtoranta K. (2010). *Emissions with heavy-duty diesel engines and vehicles using FAME, HVO and GTL fuels with and without DOC+POC aftertreatment*. SAE International Journal of Fuels and Lubricants. 2:147-166.
[30] Murtonen T, Aakko-Saksa P, Kuronen M, Mikkonen S and Lehtoranta K. (2010). *Emissions with heavy-duty diesel engines and vehicles using FAME, HVO and GTL fuels with and without DOC+POC aftertreatment*. SAE International Journal of Fuels and Lubricants. 2:147-166.
[31] Jalava PI, Tapanainen M, Kuuspalo K, Markkanen A, Hakulinen P, Happo MS, Pennanen AS, Ihalainen M, Yli-Pirilä P, Makkonen U, Teinilä K, Mäki-Paakkanen J, Salonen RO, Jokiniemi J and Hirvonen MR.

output (mg/kW-hr) from the HVORD-fueled engine was 22% less compared to the EN590-fueled engine in the absence of a DOC/POC catalytic converter, but when a DOC/POC catalytic converter was used PM emissions from combustion of HVORD were 18% greater than emissions from combustion of EN50 fuel.

Particulate-phase total and genotoxic PAHs (WHO/IPCS 1998 definition) were substantially reduced in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust (54% and 57% decrease, respectively; expressed as ng/mg PM) in the absence of a DOC/POC catalytic converter. HVORD-fueled engine emissions demonstrated moderately reduced total particulate-phase PAH emissions (31%) and genotoxic particulate-phase PAH emissions (11%) compared to a EN590-fueled engine in the presence of a DOC/POC catalytic converter.

In the fuel type comparison described above, the authors normalized PAH emissions to PM output. If PAH emissions are expressed in terms of nanograms per kilowatt-hour (ng/kW-hr), total and genotoxic particulate-phase PAH emissions were substantially reduced (64% and 66%, respectively) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in the absence of a DOC/POC catalytic converter. In the presence of a DOC/POC catalytic converter, total PAHs were moderately reduced (18%) while genotoxic PAHs were slightly increased (6%) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust.

Heikkilä *et al*.[32] tested the comparative exhaust emissions of an off-road diesel engine operated on a steady-state cycle without a DOC/POC catalytic converter and fueled with either EN590 or HVORD. PM output with HVORD fuel was reduced approximately 28 – 43% depending on engine load compared to the EN590 fuel. NOx emissions were similar for both fuels. Use of HVORD fuel reduced total particulate-phase PAH emissions by approximately 50% at all engine loads compared to the baseline fuel. Aldehyde exhaust output, including formaldehyde and acetaldehyde, was similar for both EN590 and HVORD fuel.

Similar to the Jalava *et al*. study,[33] in the fuel type comparison described above, the authors normalized PAH emissions to PM output. If PAH emissions are expressed in terms of ng/kW-hr, total and genotoxic particulate-phase PAH emissions were substantially reduced (58 and 62%, respectively) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in the absence of a DOC/POC catalytic converter. In the presence of a DOC/POC, total PAHs were slightly increased (10%)

(2010). *Toxicological effects of emission particles from fossil- and biodiesel-fueled diesel engine with and without DOC/POC catalytic converter*. Inhalation Toxicology, 22 Suppl 2:48-58.

[32] Heikkilä J, Happonen M, Murtonen T, Lehto K, Sarjovaara T, Larmi M, Keskinen J, and Virtanen A. (2012). *Study of Miller timing on exhaust emissions of a hydrotreated vegetable oil (HVO)-fueled diesel engine.* Journal of the Air and Waste Management Association, 62: 1305-1312.

[33] Jalava PI, Tapanainen M, Kuuspalo K, Markkanen A, Hakulinen P, Happo MS, Pennanen AS, Ihalainen M, Yli-Pirilä P, Makkonen U, Teinilä K, Mäki-Paakkanen J, Salonen RO, Jokiniemi J and Hirvonen MR. (2010). *Toxicological effects of emission particles from fossil- and biodiesel-fueled diesel engine with and without DOC/POC catalytic converter*. Inhalation Toxicology, 22 Suppl 2:48-58.

while genotoxic PAHs were moderately increased (18%) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust (Heikkilä *et al*., 2012).[34]

2. Toxicity Testing of Combustion Emissions

In the combustion emissions study performed as part of the ARB Emissions Study,[35] *Salmonella typhimurium* test strains TA98 and TA100 were exposed to emissions samples from an engine run on either CARB fuel, or R20, R50, or R100 HVORD, respectively, in the presence or absence of metabolic activation provided by rat liver S9. Particulate-phase and vapor-phase exhaust mutagenicity generally decreased as the percentage of HVORD in the engine fuel increased in both test strains with or without S9.[36]

Human U937 monocytic cells were exposed to particulate phase engine exhaust extract under the conditions described above, and evaluated for induction of DNA damage using the COMET assay. No increase in DNA damage was induced by exhaust from an HVORD or HVORD blend-fueled engine.[37]

The release of interleukin 8 (IL-8; a cytokine mediator of inflammation) from a human U937 macrophage cell line or cyclooxygenase 2 (COX-2; an inflammation mediator) from a human NCI-H441 bronchiolar Clara cell line was not increased by exposure to HVORD or HVORD blend-fueled engine particulate phase exhaust extracts relative to exposure of the cells to particulate phase exhaust extract from a ULSD-fueled engine.[38]

Murtonen *et al*.[39] compared the mutagenicity of engine emissions from truck (Scania DT 12 11 420, Variant L01) and off-road (Sisudiesel 74 CTA-4V SCR-equipped) diesel engines fueled with EN590 petroleum diesel (EN590) that contains less than 10 ppm sulfur or HVORD. In tests using an engine that was not equipped with a DOC/POC catalytic converter, a substantial decrease (68%) was noted for mutagenicity in *Salmonella typhimurium* (strain TA98) treated with HVORD-fueled engine PM extract in the absence of metabolic activation compared to PM extract from an EN590-fueled engine. In tests using an engine equipped with a DOC/POC catalytic converter, no mutagenicity was noted in *Salmonella typhimurium* (strain TA98) treated with

[34] Heikkilä J, Happonen M, Murtonen T, Lehto K, Sarjovaara T, Larmi M, Keskinen J, and Virtanen A. (2012). *Study of Miller timing on exhaust emissions of a hydrotreated vegetable oil (HVO)-fueled diesel engine.* Journal of the Air and Waste Management Association, 62: 1305-1312.

[35] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

[36] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

[37] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

[38] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

[39] Murtonen T, Aakko-Saksa P, Kuronen M, Mikkonen S and Lehtoranta K. (2010). *Emissions with heavy-duty diesel engines and vehicles using FAME, HVO and GTL fuels with and without DOC+POC aftertreatment*. SAE International Journal of Fuels and Lubricants. 2:147-166.

HVORD-fueled engine PM extract in the absence of metabolic activation, and mutagenicity from PM extract from an EN590-fueled engine was described by the authors as "minor" (93% reduction compared to test results from an engine not equipped with a DOC/POC catalytic converter).

Jalava *et al*.[40] compared exhaust toxicities from a 2005 model year Scania heavy-duty diesel engine equipped with a DOC/POC catalytic converter and fueled with EN590 or HVORD using a Braunschweig test cycle.[41] The effects of engine exhaust PM extracts on cytotoxicity and apoptosis were tested *in vitro* using the mouse macrophage RAW264.7 cell line at exposure levels of 0, 50, 150 and 300 µg/ml. PM extract-induced cytotoxicity was measured by a 3-(4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazolium bromide test (MTT-test; measures metabolic activity). Apoptosis was determined by using a flow cytometry assay to evaluate propidium iodide (PI)-stained cells. No significant differences in either cytotoxicity or apoptosis were noted in the mouse macrophage cell line RAW264.7 when exposed *in vitro* to PM from the test engine fueled with HVORD compared to PM from the test engine fueled with EN590, with or without use of a DOC/POC catalytic converter.

The effects of HVORD- and EN590-fueled engine PM on MIP-2 and TNF-∝ (cytokines that mediate inflammation) release were studied using mouse macrophage RAW264.7 cells *in vitro*. Both MIP-2 and TNF-∝ release were slightly increased by HVORD-fueled engine PM compared to EN590-fueled engine PM in the absence of a DOC/POC catalytic converter. There was no significant difference in release of either cytokine between the fuel types when a DOC/POC catalytic converter was used.[42]

DNA damage (Comet assay) in mouse macrophage RAW264.7 cells treated *in vitro* with by HVORD-fueled engine PM was statistically significantly increased compared to cells treated with EN590-fueled engine PM in the absence of a DOC/POC catalytic converter. However, in the presence of a DOC/POC catalytic converter there was no significant difference in DNA damage between the two test groups. In the same study, there was no significant difference in reactive oxygen species (ROS) production between the two test groups in the presence or absence of a DOC/POC catalytic converter.[43]

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[40] Jalava PI, Aakko-Saksa P, Murtonen T, Happo MS, Markkanen A, Yli-Pirilä P, Hakulinen P, Hillamo R, Mäki-Paakkanen J, Salonen RO, Jokiniemi J and Hirvonen MR. (2012). *Toxicological properties of emission particles from heavy duty engines powered by conventional and bio-based diesel fuels and compressed natural gas*. Particle and Fibre Toxicology, 9:37-50.

[41] Murtonen T, Aakko-Saksa P, Kuronen M, Mikkonen S and Lehtoranta K. (2010). *Emissions with heavy-duty diesel engines and vehicles using FAME, HVO and GTL fuels with and without DOC+POC aftertreatment*. SAE International Journal of Fuels and Lubricants. 2:147-166.

[42] Jalava PI, Aakko-Saksa P, Murtonen T, Happo MS, Markkanen A, Yli-Pirilä P, Hakulinen P, Hillamo R, Mäki-Paakkanen J, Salonen RO, Jokiniemi J and Hirvonen MR. (2012). *Toxicological properties of emission particles from heavy duty engines powered by conventional and bio-based diesel fuels and compressed natural gas*. Particle and Fibre Toxicology, 9:37-50.

[43] Jalava PI, Aakko-Saksa P, Murtonen T, Happo MS, Markkanen A, Yli-Pirilä P, Hakulinen P, Hillamo R, Mäki-Paakkanen J, Salonen RO, Jokiniemi J and Hirvonen MR. (2012). *Toxicological properties of emission particles from heavy duty engines powered by conventional and bio-based diesel fuels and compressed natural gas*. Particle and Fibre Toxicology, 9:37-50.

No significant difference was noted between HVORD-fueled and EN590-fueled engine exhaust cytotoxicity measured using the MTT-test was noted in the presence or absence of a DOC/POC. EN590-fueled engine exhaust appeared to have greater cytotoxicity than HVORD-fueled engine exhaust at the higher exposure levels in the absence of a DOC/POC catalytic converter as measured by the PI exclusion test. However, no difference in exhaust-induced apoptosis was evident between the two fuel types in the presence of a DOC/POC catalytic converter.[44]

DNA damage (Comet assay) in mouse macrophage RAW264.7 cells treated *in vitro* with by HVORD-fueled engine PM was decreased compared to cells treated with EN590-fueled engine PM in the absence of a DOC/POC catalytic converter. In the same study, there was no significant difference in ROS production between the two test groups in the presence or absence of a DOC/POC catalytic converter.

D. Department of Toxics Substances Control Evaluation

DTSC staff assessed potential impacts to human health and the environment from the production and use of renewable diesel compared to CARB diesel. Staff's evaluation focused on: (1) hazardous waste generation during production, use, and storage of renewable diesel in California, and (2) cleanup of contaminated sites in cases of spills of renewable diesel. Please refer to Appendix F for DTSC's complete evaluation.

According to the multimedia evaluation Tier I and Tier III reports, three methods are typically used to produce renewable diesel: (1) Fatty Acids to Hydrocarbon process (hydrotreatment), (2) enzymatic synthesis of hydrocarbons, and (3) a partial combustion of biomass feedstock. All three processes use biomass as their major feedstock. However, the current DTSC evaluation focused on impacts of hydrotreated renewable diesel on human health and the environment. The Tier I evaluation showed that the use of renewable diesel decreases PM, NOx and CO emissions in exhaust compared to CARB diesel. It also showed that renewable diesel's chemical composition is very similar to CARB diesel and that renewable diesel has a lower aromatic hydrocarbon content relative to diesel.

Depending on the feedstock, oil extraction chemicals may be used to produce renewable diesel. According to the Tier I and III reports, oil extraction processes may generate new hazardous waste (n-hexane) and discharge waters that also maybe hazardous waste, during the production of renewable diesel, compared to CARB diesel production releases. Additionally, renewable diesel's releases to soil, groundwater, or surface waters of production chemicals are expected to occur due to rupture or leaks of above ground or below ground storage tanks, production (blending, mixing, and extraction, etc.) equipment, piping and/or transportation vehicles. Potential knowledge gaps associated with the impacts of additive use and the potential generation of hazardous waste during production, use, transportation, and storage of renewable

[44] Heikkilä J, Happonen M, Murtonen T, Lehto K, Sarjovaara T, Larmi M, Keskinen J, and Virtanen A. (2012). *Study of Miller timing on exhaust emissions of a hydrotreated vegetable oil (HVO)-fueled diesel engine.* Journal of the Air and Waste Management Association, 62: 1305-1312.

diesel may need to be addressed in future multimedia evaluations, if: (1) in-state production of renewable diesel increases, (2) transportation of plant derived oils and tallow increases, or (3) new or different additives are needed to ensure reliable performance during generation, storage and use of renewable diesel.

III. Conclusions

This section provides the conclusions of each of the evaluations conducted by ARB, SWRCB, OEHHA, and DTSC. The conclusions on the impacts of hydrotreated vegetable oil renewable diesel on public health and the environment are summarized below:

A. Conclusions on Air Emissions Impact

Based on a relative comparison between CARB diesel and hydrotreated vegetable oil renewable diesel, ARB staff concludes that renewable diesel, as specified in this multimedia evaluation and proposed regulation, does not pose a significant adverse impact on public health or the environment from potential air quality impacts.

ARB staff also makes the following general conclusions:

- Renewable diesel reduces PM emissions in diesel exhaust.
- Renewable diesel reduces emissions and health risk from PM in diesel exhaust, a toxic air contaminant identified by ARB.
- Renewable diesel reduces NOx emissions in diesel exhaust.
- Renewable diesel reduces CO emissions in diesel exhaust.
- The adverse effects of renewable diesel are expected to be less than or equal to diesel fuel complying with current ARB fuel regulations.

Compared to CARB diesel, emissions testing results for renewable diesel show reductions in PM, NOx, CO, and THC. Toxics test results also show reductions in most PAHs and VOCs.

B. Conclusions on Water Impacts

SWRCB staff concludes that given the information provided by the UC researchers, and the similarities of renewable diesel and CARB diesel, there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone. SWRCB staff supports the multimedia evaluation of renewable diesel that meets ASTM D975 and the finding of no significant adverse impacts on public health or the environment.

C. Conclusions on Public Health Impact

PM, benzene, ethyl benzene and toluene in combustion emissions from diesel engines using HVORD are significantly lower than they are in combustion emissions from engines using conventional diesel. CO and NOx emissions are significantly lower in some tests using HVORD fuel. PAH emissions from engines not equipped with a DOC/POC were lower in exhaust of engines burning HVORD. In some tests of engines equipped with a DOC/POC, PAH emissions were higher in exhaust from an engine using HVORD fuel. It should be noted that semi-volatile exhaust phase PAHs were only measured in the ARB Emissions Study. Variability between studies precluded drawing a conclusion as to differences in PAH exhaust output levels and PAH/PM exhaust ratios from engines equipped with a DOC/POC between the two fuel types.

HVORD-fueled engine exhaust did not significantly increase pulmonary cytokine production (an inflammation biomarker), cytotoxicity, apoptosis or ROS production in the presence or absence of a DOC/POC. Variability in assay types, engine and test cycle types, and emission control status precluded drawing a conclusion as to differences in exhaust-induced genotoxicity between the two fuel types.

OEHHA scientists conclude that use of renewable diesel fuel produced by hydrotreating fatty acids from vegetable oil may reduce the amount of PM and aromatic organic chemicals that is released into the atmosphere in diesel engine exhaust. OEHHA scientists do not find any evidence that these potential beneficial impacts are offset by adverse impacts on human health that might result from replacing CARB diesel with HVORD.

D. Conclusions on Soil and Hazardous Waste Impact

In comparing renewable diesel with CARB diesel, DTSC's review concludes that the chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel. Based on the current production, use, transportation, and storage of renewable diesel in California, renewable diesel will not increase the potential negative impacts to human health and the environment. Both Tier I and Tier III reports highlighted the need to address knowledge gaps associated with environmental impacts of additive use with renewable diesel. The relative environmental impact in case of a spill or leak of renewable diesel compared to a spill or leak from CARB diesel depends on the types, concentrations and use specifications of diesel additives used with renewable diesel, as well as the different production processes.

IV. Recommendations

The Multimedia Working Group recommends that the CEPC:

1. Find that the use of renewable diesel fuel in California, as specified in this multimedia evaluation and the proposed regulation, does not pose a significant adverse impact on public health or the environment compared to CARB diesel fuel.

2. Condition the finding on the following:

    a. Renewable diesel must meet the definition as described in the ADF regulation and California diesel fuel regulations under Title 13, California Code of Regulations, Sections 2281-2285.

    b. Any hazardous substances and hazardous waste used in production, storage, and transportation of biodiesel will be handled in compliance with applicable California laws and regulations.

    c. Fuel formulations and additives that were not included within the scope of this multimedia evaluation must be reviewed by the MMWG for consideration of appropriate action.

    d. In the event that any relevant available information indicates the potential for significant risks to public health or the environment, the specific use of renewable diesel will be reviewed by the MMWG for appropriate action.

IV. References

Note: References are listed according to the corresponding footnote in the staff report. For references available online, electronic links have been provided. References used more than once are indicated as a duplicate (e.g., "Same as Footnote 2"), excluding specific page numbers, and are listed to maintain the order and numbering of the footnotes in the report.

1. Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*, October 23, 2013. http://www.arb.ca.gov/regact/2013/adf2013/adf2013isor.pdf (accessed November 4, 2013).

2. California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8. http://www.arb.ca.gov/bluebook/bb11/hea/hea-43830_8.htm (accessed November 4, 2013).

3. Same as Footnote 2.

4. U.C. Berkeley, U.C. Davis, and Lawrence Livermore National Laboratory. *Guidance Document and Recommendations on the Types of Scientific Information Submitted by Applicants for California Fuels Environmental Multimedia Evaluations*, June 2008. http://www.arb.ca.gov/fuels/multimedia/guidancedoc.pdf (accessed November 4, 2013).

5. California Air Pollution Control Laws. Health and Safety Code, Division 37, Section 57004. http://www.arb.ca.gov/bluebook/bb11/hea/hea-57004.htm (accessed November 4, 2013).

6. Same as Footnote 1.

7. McKone, T.E. et al. California Renewable Diesel Multimedia Evaluation Final Tier III Report, April 2012, 2. http://www.arb.ca.gov/fuels/multimedia/meetings/RenewableDiesel_FinalReport_Apr2012_101113.pdf (accessed November 11, 2013).

8. Same as Footnote 1.

9. McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Final Tier I Report*, September 2011. http://www.arb.ca.gov/fuels/multimedia/meetings/RenewableDiesel_FinalTierIReport_Sep2011_110413.pdf (accessed November 4, 2013).

10. Same as Footnote 7.

11. Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011. http://www.arb.ca.gov/fuels/diesel/altdiesel/20111013_CARB%20Final%20Biodiesel%20Report.pdf (accessed November 4, 2013).

12. Air Resources Board. *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles*. October 2000. http://www.arb.ca.gov/diesel/documents/rrpFinal.pdf (accessed May 7, 2015).

13. Same as Footnote 11.

14. Same as Footnote 11.

15. Air Resources Board*. Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles*. August 6, 2004. http://www.arb.ca.gov/regact/grnhsgas/isor.pdf (accessed February 23, 2015).

16. United States Environmental Protection Agency. *Overview of Greenhouse Gases* website. http://www.epa.gov/climatechange/ghgemissions/gases.html. (accessed April 29, 2015).

17. Air Resources Board. *Proposed Re-Adoption of the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons*. December 2014. http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15isor.pdf (accessed February 23, 2015).

18. Same as Footnote 17.

19. Air Resources Board. *Proposed Regulation to Implement the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons.* March 2009, IV-12. http://www.arb.ca.gov/regact/2009/lcfs09/lcfsisor1.pdf http://www.arb.ca.gov/regact/2009/lcfs09/lcfsisor2.pdf (accessed May 8, 2015).

20. California Air Resources Board, *LCFS Carbon Intensity Lookup Table*, December 2012. http://www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf (accessed October 15, 2013).

21. Same as Footnote 11.

22. Same as Footnote 11.

23. Same as Footnote 11.

24. Same as Footnote 11.

25. Same as Footnote 11.

26. Same as Footnote 11.

27. Murtonen T, Aakko-Saksa P, Kuronen M, Mikkonen S and Lehtoranta K. (2010). *Emissions with heavy-duty diesel engines and vehicles using FAME, HVO and GTL fuels with and without DOC+POC aftertreatment*. SAE International Journal of Fuels and Lubricants. 2:147-166.

28. Same as Footnote 27.

29. Same as Footnote 27.

30. Same as Footnote 27.

31. Jalava PI, Tapanainen M, Kuuspalo K, Markkanen A, Hakulinen P, Happo MS, Pennanen AS, Ihalainen M, Yli-Pirilä P, Makkonen U, Teinilä K, Mäki-Paakkanen J, Salonen RO, Jokiniemi J and Hirvonen MR. (2010). *Toxicological effects of emission particles from fossil- and biodiesel-fueled diesel engine with and without DOC/POC catalytic converter*. Inhalation Toxicology, 22 Suppl 2:48-58.

32. Heikkilä J, Happonen M, Murtonen T, Lehto K, Sarjovaara T, Larmi M, Keskinen J, and Virtanen A. (2012). *Study of Miller timing on exhaust emissions of a hydrotreated vegetable oil (HVO)-fueled diesel engine.* Journal of the Air and Waste Management Association, 62: 1305-1312.

33. Same as Footnote 31.

34. Same as Footnote 32.

35. Same as Footnote 11.

36. Same as Footnote 11.

37. Same as Footnote 11.

38. Same as Footnote 11.

39. Same as Footnote 27.

40. Jalava PI, Aakko-Saksa P, Murtonen T, Happo MS, Markkanen A, Yli-Pirilä P, Hakulinen P, Hillamo R, Mäki-Paakkanen J, Salonen RO, Jokiniemi J and Hirvonen MR. (2012). *Toxicological properties of emission particles from heavy duty engines powered by conventional and bio-based diesel fuels and compressed natural gas*. Particle and Fibre Toxicology, 9:37-50.

41. Same as Footnote 27.

42. Same as Footnote 40.

43. Same as Footnote 40.

44. Same as Footnote 32.

APPENDIX A

Proposed Regulation on the Commercialization of Alternative Diesel Fuels

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APPENDIX A. PROPOSED REGULATION

REGULATION ON COMMERCIALIZATION OF ALTERNATIVE DIESEL FUELS

Amend sections 2290, 2291, and 2293; renumber sections 2293 and 2293.5; adopt new sections 2293, 2293.1, 2293.2, 2293.3, 2293.4, 2293.5, 2293.6, 2293.7, 2293.8, 2293.9, and Appendix 1; and create new subarticles 1, 2, and 3, in title 13, chapter 5, article 3, California Code of Regulations, to read as follows:

[Note: The entire text of sections 2293, 2293.1, 2293.2, 2293.3, 2293.4, 2293.5, 2293.6, 2293.7, 2293.8, 2293.9, and Appendix 1 is new language. Existing sections 2290, 2291, 2292.1, 2292.2, 2292.3, 2292.4, 2292.5, 2292.6, and 2292.7 would be grouped as indicated under new subarticle 1 (Specifications for Current Alternative Motor Vehicle Fuels) and sections 2290 and 2291 would be revised as indicated. Existing sections 2293 and 2293.5 would be revised as indicated, renumbered to 2294 and 2295, and grouped as indicated under new subarticle 3 (Ancillary Provisions). The proposed amendments to existing text are shown in underline to indicate addition and ~~strikeout~~ to show deletions. All other portions of the article remain unchanged and are indicated by the symbol ******.]

Chapter 5. Standards for Motor Vehicle Fuels

Article 3. Specifications for Alternative Motor Vehicle Fuels

Subarticle 1. Specifications for Alternative Motor Vehicle Fuels

§2290. Definitions.

(a) For the purposes of this ~~article~~subarticle, the following definitions apply:

(1) “Alternative fuel” means any fuel which is commonly or commercially known or sold as one of the following: M-100 fuel methanol, M-85 fuel methanol, E-100 fuel ethanol, E-85 fuel ethanol, compressed natural gas, liquefied petroleum gas, or hydrogen.
(2) “ASTM” means the American Society for Testing Materials.
(3) “Motor vehicle” has the same meaning as defined in section 415 of the Vehicle Code.
(4) “Supply” means to provide or transfer a product to a physically separate facility, vehicle, or transportation system.

Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2291. Basic Prohibitions.

(a) Starting January 1, 1993, no person shall sell, offer for sale or supply an alternative fuel intended for use in motor vehicles in California unless it conforms with the applicable specifications set forth in this ~~article 3~~subarticle.

(b) An alternative fuel shall be deemed to be intended for use in motor vehicles in California if it is:

(1) stored at a facility which is equipped and used to dispense that type of alternative fuel to motor vehicles, or

(2) delivered or intended for delivery to a facility which is equipped and used to dispense that type of alternative fuel to motor vehicles, or

(3) sold, offered for sale or supplied to a person engaged in the distribution of motor vehicle fuels to motor vehicle fueling facilities, unless the person selling, offering or supplying the fuel demonstrates that he or she has taken reasonably prudent precautions to assure that the fuel will not be used as a motor vehicle fuel in California.

(c) For the purposes of this section, each retail sale of alternative fuel for use in a motor vehicle, and each supply of alternative fuel into a motor vehicle fuel tank, shall also be deemed a sale or supply by any person who previously sold or supplied such alternative fuel in violation of this section.

Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2292.1 Fuels Specifications for M100 Fuel Methanol.

* * * * *

Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2292.2 Specifications for M-85 Fuel Methanol.

* * * * *

Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2292.3 Specifications for E-100 Fuel Ethanol.

* * * * *

Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2292.4 Specifications for E-85 Fuel Ethanol.

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Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2292.5 Specifications for Compressed Natural Gas.

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Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2292.6 Specifications for Liquefied Petroleum Gas.

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Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2292.7 Specifications for Hydrogen.

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Note: Authority cited: Sections 39600, 39601, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

Subarticle 2. Commercialization of Alternative Diesel Fuels

§2293. Purpose.

The purpose of this regulation is to establish a comprehensive, multi-stage process governing the commercialization of alternative diesel fuels (ADF) in California, ranging from the initial limited sales of an ADF while it undergoes a screening evaluation; through expanded sales governed by enhanced monitoring, testing, and multimedia evaluations; and ending with full-scale commercial sales as warranted. This regulation is intended to foster the introduction and use of innovative ADFs in California while preserving or enhancing public health, the environment and the emissions benefits of the existing motor vehicle diesel fuel regulations.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2293.1. Basic Prohibitions.

(a) Starting January 1, 2016, no person shall sell, offer for sale or supply an ADF for use in California unless that person is in compliance with this subarticle and with the terms of any approved and current Executive Order issued under section 2293.5 that is applicable to the person or the ADF.

(b) For the purposes of this subarticle, each retail sale of ADF for use in a motor vehicle and each supply of ADF into a motor vehicle fuel tank constitutes a separate sale or supply by each and every person who previously sold or supplied such ADF in violation of this subarticle.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 39515, 40000, 43000, 43016, 43018 and 43101, 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§ 2293.2. Definitions.

(a) For the purposes of this subarticle, the definitions in Health and Safety Code sections 39010 through 39060 shall apply, except as otherwise specified in this subarticle. The following definitions shall also apply to this subarticle:

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

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

(3) “Biodiesel Blend” means biodiesel blended with petroleum-based CARB diesel fuel or non-ester renewable diesel.

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

(5) “Blendstock” means a component that is either used alone or is blended with another component(s) to produce a finished fuel used in a motor vehicle. A blendstock that is used directly as a transportation fuel in a vehicle is considered a finished fuel.

(6) “B5” means a biodiesel blend containing no more than five percent biodiesel by volume.

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

(8) "Candidate ADF" means a fuel that is in the Stage 1 or Stage 2 evaluation process in this subarticle.

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

(10) "Criteria Pollutant" means any air pollutant for which a California ambient air quality standard (CAAQS) or a national ambient air quality standard (NAAQS) has been established.

(11) "Diesel Substitute" means any liquid fuel that is intended for use as a neat fuel, with CARB diesel or CARB diesel blends in a compression ignition engine. "Diesel substitute" includes, but is not limited to, non-ester renewable diesel; gas-to-liquid fuels; Fischer-Tropsch fuels; CARB diesel blended with additives specifically formulated to reduce emissions of one or more criteria or toxic air contaminants relative to reference CARB diesel; and CARB diesel specifically formulated to reduce emissions of one or more criteria or toxic air contaminants relative to reference CARB diesel.

(12) "Executive Officer" means the Executive Officer of the Air Resources Board, or his or her designee.

(13) "Executive Order" or "EO" means a document signed by the Executive Officer or his or her designee under this subarticle that: a) provides an exemption from in-use requirements, b) approves a formulation under the certification procedures as an equivalent CARB diesel formulation, or c) specifies the stage at which a regulated party(ies) for an ADF or candidate ADF is or will be operating under. An Executive Order includes any enforceable terms, conditions, and requirements that the regulated party(ies) must meet in order to sell, offer for sale, or supply that ADF or candidate ADF for use in California.

(14) "Finished Fuel" means a fuel that is used directly in a vehicle for transportation purposes without requiring additional chemical or physical processing.

(15) “Hydrocarbon” means any chemical or mixture that is composed solely of hydrogen and carbon.

(16) “Importer” has the same meaning as defined in the Low Carbon Fuel Standard regulation at California Code of Regulations, title 17, section 95481(a).

(17) “Multimedia Evaluation” has the same meaning as defined in Health and Safety Code section 43830.8(b).

(18) “Multimedia Evaluation Guidance Document” means the procedure described in chapter 5, 6 and 7, governing the Executive Officer’s multimedia evaluation conducted prior to establishing a motor vehicle fuel specification. The multimedia evaluation guidance document chapters 5, 6, and 7 (“Guidance Document and Recommendations on the Types of Scientific Information Submitted by Applicants for California Fuels Environmental Multimedia Evaluations”) are available at www.arb.ca.gov/fuels/multimedia/guidancedoc.pdf, June 2008, and are incorporated herein by reference.

(19) “New Technology Diesel Engine” or “NTDE” means a diesel engine that meets at least one of the following criteria:

(A) Meets 2010 ARB emission standards for on-road heavy duty diesel engines under section 1956.8.

(B) Meets Tier 4 emission standards for non-road compression ignition engines under sections 2421, 2423, 2424, 2425, 2425.1, 2426, and 2427.

(C) Is equipped with or employs a Diesel Emissions Control Strategy (DECS), verified by ARB pursuant to section 2700 et seq., which uses selective catalytic reduction to control Oxides of Nitrogen (NOx).

(20) “Non-ester renewable diesel” means a diesel fuel that is produced from nonpetroleum renewable resources but is not a mono-alkyl ester and which is registered as a motor vehicle fuel or fuel additive under 40 Code of Federal Regulations part 79.

(21) “Offsetting factors” means any factors in the commercial market that serve to offset the emissions of a pollutant from the use of an ADF. Offsetting factors may include, but are not limited to, the use of:

(A) Specific vehicle technologies such as NTDEs that have been proven to reduce emissions of the pollutant;

(B) Diesel substitutes that reduce emissions of the pollutant; and

(C) Feedstocks that have been shown to reduce or eliminate increases in the pollutant.

(22) "Person" has the same meaning as defined in Health and Safety Code section 39047 and includes, but is not limited to, ADF producers, importers, marketers and blenders. "Person" includes the plural when two or more persons are subject to an Executive Order executed or an interim or final fuel specification issued pursuant to the requirements of this subarticle.

(23) "Pollutant Control Level" means a blend level of an ADF above which per gallon in-use requirements have been established by regulation to ensure there will be no increases in one or more criteria pollutants when compared to emissions from Reference CARB Diesel.

(24) "Potential Adverse Emissions Impacts" means for any given ADF or ADF blend, any criteria pollutant for which testing during a multimedia evaluation results in statistically significant increases of that criteria pollutant above an appropriate baseline for that ADF.

(25) "Producer" has the same meaning as defined in the Low Carbon Fuel Standard regulation at California Code of Regulations, title 17, section 94581(a).

(26) "Reference CARB Diesel" has the same meaning as "reference fuel" as that term is defined in section 2282(g)(3).

(27) "Toxic Air Contaminant" means any substance identified or designated by the Air Resources Board as a toxic air contaminant pursuant to Health and Safety Code section 39657, or is designated as a hazardous air pollutant under section 112 of the federal Clean Air Act (42 U.S.C. § 7412).

(28) "Trade Secret" has the same meaning as defined in Government Code section 6254.7.

(b) List of Acronyms and Abbreviations

AAQS	Ambient Air Quality Standards
ADF	Alternative Diesel Fuel or Fuels
API	American Petroleum Institute
ARB or Board	California Air Resources Board
ASTM	ASTM International formerly known as American Society for Testing and Materials
CCR	California Code of Regulations

CI	Carbon Intensity
EO	Executive Order
EmFAC	ARB's Emission (Em) Factors (FAC) Model
FAME	Fatty Acid Methyl Esters
GVWR	Gross Vehicle Weight Rating
H&SC	California Health and Safety Code
LRT	Low Carbon Fuel Standard Reporting Tool
MMWG	Multimedia Working Group
NOx	Oxides of Nitrogen
NTDE	New technology diesel engines
PM	Particulate Matter
ppm	Parts per Million
U.S. EPA	U.S. Environmental Protection Agency

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 39515, 40000, 43000, 43016, 43018 and 43101, 43830.8, 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2293.3. Exemptions.

This subarticle does not apply to any of the following, as specified:

(a) Fuels that have a specification under subarticle 1 of this article (commencing with section 2292);

(b) CARB diesel blends comprised solely of CARB diesel and one or more diesel additives comprising in the aggregate no more than 1.0 percent by volume of the CARB diesel blend. This exemption does not apply to additives used pursuant to the in use requirements specified in Appendix 1;

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2293.4. General Requirements Applicable to All ADFs.

Starting January 1, 2016, any person who sells, offers for sale or supplies an ADF for use in motor vehicles in California must first meet the requirements in this subarticle and must also:

(a) Have the ADF registered with U.S. EPA under 40 Code of Federal Regulations part 79.

(b) Meet all applicable regulatory requirements of the California Department of Food and Agriculture (including, but not limited to, those in Cal. Code Regs., tit. 4, §§ 4140—4148, 4200, and 4202—4205).

(c) Meet all other applicable local, State, and federal requirements.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2293.5. Phase-In Requirements.

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

An ADF that has not been approved for commercialized sales under subsection (c) for Stage 3A fuels or subsection (d) for Stage 3B fuels may only be sold, offered for sale, or supplied for use in motor vehicles in California pursuant to an approved Executive Order (EO) for candidate ADF issued under subsection (a) for a Stage 1 pilot program or under subsection (b) for a Stage 2 ADF.

(a) Stage 1: Pilot Program.

[Note: The purpose of this stage is to allow limited, small fleet use of innovative fuels while requiring screening tests and assessments to quickly determine whether there will be unreasonable potential impacts on air quality, the environment and vehicular performance. Such data will help inform more extensive testing and analysis to be conducted in Stage 2. This Stage 1 is modeled after the existing ARB regulation that provides limited, fuel test program exemptions under 13 CCR 2259.]

(1) Stage 1 Application.

A person seeking a Stage 1 Executive Order (EO) for an ADF must submit an application to the Executive Officer that includes all the following information:

(A) Expected program duration, not to exceed one year except as provided in section 2293.5(a)(4)(B) below;

(B) An estimate of the maximum number of vehicles or engines involved in the program;

(C) The mileage duration per vehicle involved in this stage;

(D) The quantity of fuel expected to be used in the pilot program, not to exceed the energy equivalent of one million gallons of diesel fuel per year, per ADF total;

(E) The site(s) in which the testing during this stage will be conducted (including the street address, city, county, and zip code);

(F) The manner in which the distribution pumps will be labeled to ensure proper use of the test fuel;

(G) The name, address, telephone number, title of the person(s) and the name of the company or organization requesting entry into a Stage 1 pilot program; and

(H) If different from the information in (G) above, the name, address, telephone number and title of the person(s) and the name of the company or organization responsible for recording and making the information specified above available to the Executive Officer and the location in which such information will be maintained.

(I) Chemical and physical properties of the candidate ADF: complete chemical speciation, Chemical Abstract Services (CAS) numbers (if available), density, energy content, vapor pressure, oxidative potential, distillation curve, log K_{ow} (water-octanol partition coefficient), and Henry's law coefficient.

(J) Environmental information about the ADF: Material Safety Data Sheet(s) (MSDS) for all components of the candidate ADF, production process diagram, identification of potential human health effects, lifecycle flow diagram (including all stages of the process-raw material extraction, manufacturing, distribution, use and disposal including all intervening transportation steps), and potential release scenarios during production (including by-products), transportation and use.

(K) Identify whether the fuel is intended to be blended with diesel, whether it can be used as a neat fuel, or whether it can be used either way.

(L) Plan for commercialization under this regulation.

(M) Emissions testing completed on criteria pollutants.

(N) Attestation that the vehicles to be used in the pilot program are owned by the applicant or the applicant has received written consent from their owners.

(O) The vehicle identification number (VIN) of each vehicle participating in the pilot program.

(P) Affirmative statement that the owner(s) of all vehicles to be used in the applicant's pilot program are aware of any possible warranty issues that may arise from the use of the candidate ADF or candidate ADF/CARB diesel blend in their engines.

(Q) A declaration by the applicant that, either:

1. there is an existing fuel standard for the ADF as required by Business and Professions Code Chapter 14, sections 13400 to 13460; or if no such standard exist,

2. a copy of the developmental fuel variance the applicant has submitted to the California Department of Food and Agriculture pursuant to Business and Professions Code section 13405 and proof of its approval; and,

a. the requirements of Business and Profession Code Section 12001– 13800 other than fuel quality have been met; and,

b. the California Department of Food and Agriculture received a copy of the application required to be submitted under 13 CCR §2293.5.

(R) Proof that the candidate complies with the U.S. Environmental Protection Agency under 40 CFR 79.

It is the responsibility of the applicant to identify any specific portion of the information submitted above as trade secret. Any such trade secret information identified by the applicant shall be treated pursuant to 17 CCR 91000—91022 and the California Public Records Act (Government Code sec. 6250 et seq.).

(2) Stage 1 Application Completeness Determination.

(A) After receiving a pilot program application, the Executive Officer shall advise the applicant in writing within 30 business days either that the application is provisionally complete or that specified additional information is required to make it provisionally complete.

(B) After receiving the additional information required under (A), the Executive Officer shall advise the applicant in writing within 15 business days either that the application is now provisionally complete or that specified additional information is still required to make it complete.

(C) If additional information is required and not received within 60 days the application will be deemed incomplete.

(3) Public Comment and Final Action on a Stage 1 Application.

(A) After deeming an application provisionally complete, the Executive Officer shall post the application on ARB's internet web site for 15 business days for public comments. Only comments related to potential factual or methodological errors may be considered by the Executive Officer. Within 30 calendar days, the applicant shall either make revisions to its application and submit those revisions to the Executive Officer, or submit a detailed written response to the Executive Officer explaining why no revisions are necessary.

(B) Within 30 business days of receiving the applicant's response to the public comments under (A), the Executive Officer shall either approve or disapprove the pilot program. The Executive Officer shall notify the applicant of his/her decision in writing and provide, if the application is denied, the reasons for the denial.

(C) The Executive Officer shall disapprove a proposed pilot program if he/she determines the use of the candidate ADF, under the terms and conditions of the pilot program as proposed, poses an unacceptable risk to the community in which the pilot program is proposed to be conducted, or its risks substantially outweigh the putative benefits of using the candidate ADF.

(D) No approval of a pilot program shall be effective without an approved Executive Order (EO) executed between the Executive Officer and the applicant(s). The EO shall include terms and conditions that the applicant must meet in order to provide the candidate ADF fuel in California during the term of the EO. The terms and conditions shall be based on the information specified in (1)(A)--(R) above, as well as require the following:

1. any additional information the Executive Officer determines is necessary to fill in data gaps that may have been identified during the application process;

2. additional toxicity and other testing the Executive Officer determines is necessary and appropriate to better characterize any substance in the candidate ADF; and

3. evidence of substantial progress in working in good faith with the original equipment/engine manufacturers of the engines involved in the EO, consensus standards organizations (e.g., ASTM), regulatory agencies, and other interested parties toward developing a consensus set of fuel specifications for the candidate ADF.

4. The use of adequate controls to ensure appropriate fuel quality and performance in consideration of vehicle performance, impact on the environment and fuel production. Appropriate controls include but are not limited to the use of interim fuel specifications and consensus standards.

(4) Operation under a Stage 1 EO.

(A) For the duration of the EO, the applicant must meet all the terms and conditions specified therein;

(B) The Executive Officer may terminate or modify a EO, with 30 days written notice to the applicant(s), for failure of the applicant(s) to comply with any of the terms and conditions of the EO, failure to comply with any other applicable provision in this subarticle, or for good cause. Good cause includes, but is not limited to, a determination by the Executive Officer that the information submitted in the application was inaccurate or incomplete and that the use of the ADF, under the terms and conditions of the approved pilot program, may pose an unacceptable risk to the community in which the pilot program is being conducted, or its risks substantially outweigh the putative benefits of using the candidate ADF;

(C) The Executive Officer shall not revoke or modify an approved Stage 1 EO without first affording the applicant an opportunity for a hearing in accordance with 17 CCR 60040 et seq., but the Executive Officer may temporarily suspend an EO without a hearing and prior to revocation or modification if the Executive Officer determines that continued operations under the EO may adversely affect human health;

(D) In the event an applicant cannot complete an approved pilot program within the allotted time, the applicant(s) may request a six month extension, renewable up to three times; and

(E) Upon successful completion of the pilot program, the applicant(s) may submit an application for a Stage 2 EO, as specified in section 2293.5(b) below.

(b) Stage 2: Development of Fuel Specification.

[Note: The purpose of this stage is to allow limited but expanded fleet use of an ADF that has successfully undergone the Stage 1 pilot program. Stage 2 candidate ADFs undergo additional emissions and performance testing to better characterize potential impacts on air quality, the environment and vehicular performance. This testing and assessment will be conducted pursuant to a formal multimedia evaluation leading to the development of a fuel specification, as appropriate. Further, the multimedia evaluation will be the basis for determining whether the candidate ADF has potential adverse emissions impacts. The determination of potential adverse emissions impacts determines whether the candidate ADF can proceed to Stage 3A or Stage 3B.]

A person who has successfully completed a Phase 1 pilot program for a candidate ADF under subsection (a) may apply for a Stage 2 EO for that candidate ADF.

(1) Stage 2 Application.

An applicant for Stage 2 must submit an application to the Executive Officer that includes all the following information:

(A) Planned duration for this stage, not to exceed one year, renewable up to four times or as otherwise provided in section 2293.5(b)(4);

(B) An estimate of the maximum number of vehicles or engines involved in this stage along with a description of the emissions control technology;

(C) The mileage duration per vehicle involved in this stage;

(D) The quantity of the candidate ADF fuel expected to be used in this stage, not to exceed the energy equivalent of 30 million gallons of diesel fuel per year;

(E) The site(s) in which the testing during this stage will be conducted (including the street address, city, county, and zip code);

(F) Any changes or updates to the information submitted under 2293.5(a)(1)(F)—(S) to reflect the expanded scope of vehicles, locations, fuel volume, timeframe, and other aspects of operation under Stage 2. For each of these items, the applicant must specify whether there has been no change or update, or if there has been a change or update, what that change or update is; and

(G) Identification of the test lab and principal investigator, including his/her curriculum vitae, who will be conducting the multimedia evaluation for the candidate ADF.

It is the responsibility of the applicant to identify any specific portion of the information submitted above as trade secret. Any such trade secret information identified by the applicant shall be treated pursuant to 17 CCR 91000—91022 and the California Public Records Act (Government Code sec. 6250 et seq.).

(2) Stage 2 Application Completeness Determination

(A) After receiving a Stage 2 application, the Executive Officer shall advise the applicant in writing within 30 business days either that the application is provisionally complete or that specified additional information is required to make it provisionally complete;

(B) After receiving the additional information required under (A), the Executive Officer shall advise the applicant in writing within 15 business days either that the application is now provisionally complete or that specified additional information is still required to make it provisionally complete.

(3) Public Comment and Final Action on a Stage 2 Application

(A) After deeming an application provisionally complete, the Executive Officer shall post the application on ARB's internet web site for 30 calendar days for public comments. Only comments related to potential factual or methodological errors or information regarding vehicle performance may be considered by the Executive Officer. Within 30 days, the applicant shall either make revisions to its application and submit those revisions to the Executive Officer, or submit a detailed written response to the Executive Officer explaining why no revisions are necessary;

(B) Within 30 business days of receiving the applicant's response to the public comments under (A), the Executive Officer shall either approve or disapprove the Stage 2 application. The Executive Officer shall notify the applicant of his/her decision in writing and provide, if the application is denied, the reasons for the denial;

(C) The Executive Officer shall disapprove a proposed pilot program if he/she determines the use of the ADF, under the terms and conditions of the Stage 2 program as proposed, poses an unacceptable risk to the community(ies) in which the program is proposed to be conducted, or its risks substantially outweigh the putative benefits of using the ADF;

(D) No approval of a Stage 2 program shall be effective without an approved Executive Order (EO) executed between the Executive Officer and the applicant(s). The EO shall include terms and conditions that the applicant must meet in order to provide the ADF fuel in California during the term of the EO. The terms and conditions shall be based on the information specified in (1)(A)-(G) above, as well as require the following:

1. any additional information requested in writing by the Executive Officer to fill in data gaps that may have been identified during the application process;

2. additional toxicity and other testing the Executive Officer determines is necessary and appropriate to better characterize any substance in the ADF;

3. substantial progress in working in good faith with the original equipment/engine manufacturers of the engines involved in the EO, consensus standards organizations (e.g., ASTM), regulatory agencies, and other interested parties toward developing a consensus set of fuel specifications for the ADF. These efforts must culminate in adoption of consensus standards by the end of the Stage 2 EO.

(4) Operation under a Stage 2 EO

(A) For the duration of the EO, the applicant must meet all the terms and conditions specified therein;

(B) The Executive Officer may terminate or modify a EO, with 30 days written notice to the applicant(s), for failure of the applicant(s) to comply with any of the terms and conditions of the EO, failure to comply with any other applicable provision in this subarticle, or for good cause. Good cause includes, but is not limited to, a determination by the Executive Officer that the information submitted in the application was inaccurate or incomplete and that the use of the ADF, under the terms and conditions of the approved Stage 2 program, may pose an unacceptable risk to the community in which the Stage 2 program is being conducted, or its risks substantially outweigh the putative benefits of using the ADF;

(C) In the event an applicant cannot complete an approved Stage 2 program within the allotted time, the applicant(s) may request a 1 year extension, renewable up to four times. The Executive Officer may provide additional extensions due to delays in completion of a multimedia evaluation, adoption of the applicable consensus standards, or for other good cause;

(D) Upon successful completion of the Stage 2 program, the applicant(s) may sell, offer for sale, or supply an ADF intended for use in motor vehicles in California pursuant to either Stage 3A or 3B, whichever applies, as specified in section 2293.5(c) or (d) below.

(5) Multimedia Evaluation and Determination of Potential Adverse Emissions Impacts

(A) Pursuant to the approved Stage 2 EO, Health and Safety Code section 43830.8, and the Multimedia Evaluation Guidance Document, the applicant shall conduct the prescribed multimedia evaluation under direction from ARB staff;

(B) The multimedia evaluation shall identify and evaluate any significant adverse impact on public health or the environment, including air, water, or soil, that may result from the production, use, or disposal of the ADF, relative to an appropriate baseline identified by the multimedia working group, under Stage 2, 3A, and 3B;

(C) In addition to determining any significant impacts, the multimedia assessment shall also include an evaluation of potential strategies that may reduce or eliminate each of the significant impacts identified;

(D) Approval of a multimedia evaluation shall be subject to the provisions of Health and Safety Code section 43830.8;

If the findings from the multimedia evaluation indicates a statistically significant increase in any criteria, toxic, or other air pollutant from the use of an ADF in a motor vehicle, compared to the appropriate baseline, the Executive Officer shall determine whether there is a level below which the use of a candidate ADF or a candidate ADF blend would avoid a detrimental impact on ambient pollutant.

(6) Completion of Stage 2

A person operating under a Stage 2 EO may qualify for commercial sales of the ADF under subsection (c) for Stage 3A or subsection (d) for Stage 3B if the Executive Office determines in writing that the person has successfully completed the requirements of Stage 2. To successfully complete Stage 2, the applicant must meet all the following requirements:

(A) Comply with all requirements specified in the approved Stage 2 EO;

(B) Adopt consensus standards applicable to the ADF;

(C) Obtain approval of at least 75 percent of compression ignition engine original equipment manufacturers for which the ADF is expected or intended to be used. Such approval must represent approval of the ADF blend levels expected or intended to be used in those engines;

(D) Identify appropriate fuel specifications or in-use requirements for the ADF identified as part of the multimedia evaluation conducted according to the provisions of this article;

(E) Obtain a written determination by the Executive Officer that all the above requirements have been met.

In the event the Executive Officer makes a determination of potential adverse emissions impacts under (5)(E), the Executive Officer shall post notice on the ARB website of his/her intent to initiate an evaluation to determine if the use of an ADF or ADF blends would lead to adverse emissions impacts considering the existence of offsetting factors, and if so develop and establish appropriate fuel specifications and/or in-use requirements to be added to section 2293.6 or 2293.7 as appropriate. Upon completion of that evaluation, all persons subject to Stage 2 for an ADF shall be subject to the provisions of Stage 3A.

(c) Stage 3A: Commercial Sales Subject to In-use requirements

In the event the Executive Officer has determined that a candidate ADF or candidate ADF blend has potential adverse emissions impacts, the Executive Officer shall direct ARB staff to conduct an evaluation to consider the effects of offsetting factors and the resultant impact that the use of the candidate ADF will have on criteria, toxic, or other air pollutants and resultant effect on air quality:

(1) If the Executive Officer determines that no adverse emissions impact will occur as a result of the use of a candidate ADF or candidate ADF blend, in consideration of offsetting factors, the candidate ADF shall then be subject to the provisions of Stage 3B of this regulation.

(2) If the Executive Officer finds that after considering the use of offsetting factors, the use of a candidate ADF or candidate ADF blend would result in adverse emissions impacts, then the Executive Officer shall determine conditions of ADF use including, but not limited to appropriate fuel specifications and/or in-use requirements to preclude adverse emission impacts. Conditions of use may consider, but are not limited to, the effect of ADF feedstocks, the region of ADF use, or any seasonal effects relative to emissions impacts on air quality mandates;

(3) If the Executive Officer finds appropriate fuel specifications and/or in-use requirements that would eliminate or reduce the adverse air quality impacts found in 2293.5(c)(1), then the Executive Officer will direct staff to initiate a rulemaking process to establish those standards under this subarticle.

(d) Stage 3B: Commercial Sales Not Subject to In-use Requirements

If the Executive Officer has determined that there are no potential adverse emissions impacts in accordance with 2293.5(b)(5)(E), or that there would be no adverse emissions impacts in accordance with 2293.5(c)(1) for an ADF or ADF blend, no additional conditions or sales restrictions are required under this article for that ADF or ADF blend. For an ADF that is subject to this provision, the fuel provider shall report to the Executive Officer the following information on a quarterly basis for any such ADF or ADF blend the fuel provider sold, offered for sale, or supplied for use in California:

(1) The volume of ADF blendstock, if applicable;

(2) the volume of ADF neat fuel, if applicable;

(3) the volume of ADF/CARB diesel blend, if applicable; and

(4) any other appropriate information deemed appropriate.

For purposes of this provision, the fuel provider may use information submitted to the ARB through the Low Carbon Fuel Standard Reporting Tool (LRT), as appropriate.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 39515, 40000, 43000, 43016, 43018, 43026, 43101, 43830.8, and 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2293.6. In-use Requirements for Specific ADFs subject to Stage 3A.

ADFs which have been determined to have adverse emissions impacts after accounting for offsetting factors shall have a sub-section under this section listing appropriate in-use requirements including pollutant emissions control trigger levels.

(a) Biodiesel Provisions

This section includes specific provisions applicable to the use of biodiesel in the State

(1) Phase-in period for biodiesel

Starting January 1, 2016, any person who produces, imports, blends, sells, or offers for sale or supply any biodiesel, shall be subject to the reporting requirements of Stage 3A, pursuant to 2293.8(b).

Starting January 1, 2018 any person who produces, imports, blends, sells, or offers for sale or supply any biodiesel in California, shall be subject to pollutant control levels under sub section (a)(2) of this section.

(2) Pollutant Control Level

Table A.1 below shows fuel quality requirements for biodiesel blends depending on feedstock saturation and time of year. Biodiesel blends above the pollutant control level for NOx emissions are required to employ one of the in-use requirements for biodiesel listed in Appendix 1.

Table A.1. Pollutant Control Level for NOx

Feedstock Saturation	**Time of Year**	**NOx Control Level**
Low Saturation	Apr 1 to Oct 31	B5, 5 volume percent biodiesel
	Nov 1 to Mar 31	B10, 10 volume percent biodiesel
High Saturation	Jan 1 to Dec 31	B10, 10 volume percent biodiesel

(3) Biodiesel saturation level:

Table A.2 below shows the requirements for determination of saturation level for biodiesel feedstocks. The following documents are hereby incorporated by reference:

(A) ASTM D613-14, “Standard Test Method for Cetane Number of Diesel Fuel Oil (2010).”

(B) ASTM D6890-13be1, “Standard Test Method for Determination of Ignition Delay and Derived Cetane Number (DCN) of Diesel Fuel Oils by Combustion in a Constant Volume Chamber (2013).”

Table A.2 Biodiesel Saturation Level

Biodiesel Saturation Level	**Unadditized Cetane Number**	**Test Method**
Low Saturation	<56	ASTM D613-14; or ASTM D6890-13be1
High Saturation	≥56	ASTM D613-14; or ASTM D6890-13be1

(4) Sunset of Biodiesel Blend Fuel Quality for NOx Control

NOx Control requirements under 2293.6(a)(2) for biodiesel blends up to B20 will no longer be required *when the following conditions are met:*

(A) When the vehicle miles travelled (VMT) by NTDE heavy-duty vehicles in California reaches 90 percent of total VMTs by the California heavy-duty diesel vehicle fleet, the NOx Control requirements under 2293.6(a)(2) for biodiesel blends will no longer be required. The portion of VMTs in California represented by NTDEs shall be determined using the most current ARB mobile source emission inventory based on EmFAC.

(5) Exemption from In-Use Requirements

(A) Any person may request an in-use requirement exemption from section 2293.6(a)(2) by submitting an application to the Executive Officer containing all the information required under section 2293.6(a)(5)(C) and (D)

(B) For purposes of this subsection, "In-Use Requirement Exemption" means an exemption from fuel requirements described under the in-use requirements stipulated in section 2293.6(a)(2) up to B20 blends, for biodiesel use in fleets that do not result in increased NOx emissions relative to the same fleet operated with CARB diesel.

(C) Before an exemption can be granted, the following demonstrations must be made:

1. Fueling facility has a centralized, secure fueling area, or uses another secure method of fueling,

2. Subject vehicle fleet under exemption consist of at least 90 percent in aggregate of either: Light or Medium duty diesel vehicles (GVWR ≤14,500lbs), or Heavy duty diesel vehicles equipped with New Technology Diesel Engines (NTDEs). The aggregation of this provision shall be weighted according to each vehicle's rated maximum horsepower.

3. Subject fleet fueling facility has procedures or protocols in place to reasonably preclude mis-fueling from other vehicles which have not received an exemption in accordance with this subsection.

(D) In order for an exemption to be granted, the applicant must submit an application containing the following:

1. The name, title, address and telephone number of the person(s) requesting an exemption from whom further information may be requested; and

2. Type of exemption being sought, either NTDE exemption or Light/medium duty exemption; and

3. Type of facility being requested for exemption, either public retail refueling facility, private fueling facility; and

4. For public retail fueling facility, applicant must include information, data, surveys, or other proof, that demonstrates that the customer base being serviced under the exemption will consist in aggregate of 90 percent of Light or Medium duty diesel vehicles (GVWR ≤14,500lbs), in combination with Heavy duty diesel vehicles equipped with New Technology Diesel Engines (NTDE).

(E) Within 20 days upon receipt of an application for an application, the executive officer shall advise the applicant in writing either that the application is complete or that specified information is required to make it complete. Within 15 days of submittal of additional information, the executive officer shall advise the applicant in writing that the information submitted makes the application complete or that specified additional information is still required to make application complete. Within 20 days after an application has been deemed complete, the executive office shall grant or deny an application.

(F) An exemption shall be granted by the executive officer upon successful demonstration of subparagraph (5)(C). The exemption shall be granted in the form of an executive order which shall sunset in accordance with 2293.6(a)(4).

(6) In-Use Requirement Program Review

(A) On or before December 31, 2019, ARB staff will conduct a program review of biodiesel in-use requirements to determine the efficacy of in-use requirements under section 2293.6(a)(2). In conducting the program review, staff will consider the effects of offsetting factors, in addition to any other factors that may affect NOx emissions stemming from biodiesel use in motor vehicles.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 39515, 40000, 43000, 43016, 43018, 43026, 43101, and 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2293.7. Specifications for Alternative Diesel Fuels

Unless more stringent specifications are required for any ADF that is sold, offered for sale, supplied for use in California, produced, or imported into California must meet the following specifications:

(a) Specifications for Biodiesel.

(1) Biodiesel Blendstock or Neat Fuel (B100).

(A) The following documents are hereby incorporated by reference:

1. ASTM D287-12b, "Standard Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method) (2012)."

2. ASTM D5453-93, "Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence (1993)."

Table A.3. Fuel Specifications for B100

Property	**Value**	**Test Method**
Unadditized Cetane Number	≥47	ASTM D613-14 or ASTM D6890-13be1
API Gravity	≥27 degrees API	ASTM D287-12b
Sulfur	≤15 ppm	ASTM D5453-93

(2) *Biodiesel Blends.* The fuel specifications promulgated by the California Department of Food and Agriculture in 4 CCR sections 4140-4148, 4200, and 4202-4205 shall apply to any biodiesel blend.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018, 43026, 43101, 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2293.8. Reporting and Recordkeeping.

(a) Sampling

(1) For reporting of fuel properties as required by the EO, an applicable sampling methodology set forth in 13 CCR section 2293.5 shall be used.

(b) Reporting

(1) For Stages 1 and 2

A person operating under a Stage 1 or Stage 2 EO must submit quarterly reports to the Executive Officer throughout the term of the EO. Each report shall include the following:

(A) The volume of ADF and ADF blend offered, supplied, or sold during each quarter;

(B) Results of a specified number of representative samples, for fuel properties by test methods specified in the EO;

(C) Progress made toward completing the terms of the EO;

(D) Any changes or updates to information submitted during the application process regarding the beneficial or adverse impacts of the ADF in California.

(2) For Stage 3A

Except as provided in this paragraph, a person operating within Stage 3A must submit quarterly reports to the Executive Officer. Each report shall include the following:

(A) The volume of ADF and ADF blend offered, supplied, or sold during each month;

(B) Results of a specified number of representative samples, for fuel properties by test methods specified in the EO;

(C) The volume of other applicable quantity of the in use requirements used during each month; and

(D) The blend rate of in use requirements used during each month, if applicable.

(3) For Stage 3B

A person operating within Stage 3B must submit quarterly reports to the Executive Officer, with each report specifying the volume of ADF sold, supplied, or offered for sale in California during each month. In addition, the monthly reports shall contain results of a specified number of representative samples, for fuel properties by test methods as otherwise specified in the EO under 2293.5(b)(4)(A).

(c) Recordkeeping

(1) The ADF producer shall maintain, for two years from the date of each sampling, records showing the sample date, product sampled, container or other vessel sampled, final blend volume, and the results of the fuel properties by the proscribed test methods.

(2) The ADF importer shall maintain, for two years from the date of each sampling, records showing the sample date, product sampled, container or other vessel sampled, final blend volume, and the results of the fuel properties by the proscribed test methods.

(3) Biodiesel Recordkeeping Requirements on or after January 1, 2016

(A) Producers shall maintain records regarding:
- Volume of total monthly B100 production supplied to California by facility,
- Volume of biodiesel produced for California by feedstock,
- Volume of biodiesel blends sold,
- Product transfer documentation for B100 including volume sold, CI pathway,
- Transaction invoices provided to downstream customers, including direct sales to fleets
- Volume of biodiesel or biodiesel blends sold under exemption from in-use requirements pursuant to 2293.6(5)

(B) Importers shall maintain records regarding:
- Total volume of B100 or biodiesel blends imported into California by source
- Volume of biodiesel produced for California by feedstock
- Product transfer documentation for B100 including volume sold, CI pathway,
- Transaction invoices provided to downstream customers, including direct sales to fleets

(C) Blenders shall maintain records pertaining to:
- Volume of biodiesel blends by blend level, including but not limited to B5, B10, B20, B100
- Volume of each biodiesel blend level recorded as either high saturation or low saturation; any mix of both high and low saturation will be recorded as low saturation.
-Volume of B5 blend level include any blend between B1 to B5.
- Product transfer documentation provided to downstream customers

(D) Distributors shall maintain records pertaining to:
- Product transfer documentation which indicates volume sold, CI pathway,

(E) Retailers
- Product transfer documentation which indicates volume sold, CI pathway
- Copy of any exemptions provided pursuant to subparagraph 2293.6(a)(5)

(4) Biodiesel Recordkeeping Requirements on or after January 1, 2018

(A) Producers shall also maintain records regarding:
- Volume of B100 that has been produced in accordance with in-use requirements in Appendix 1, including method of NOx control

(B) Importers shall maintain records regarding:
- Total volume of B100 or biodiesel blends imported into California by source including volumes sold that have been treated for NOx control per in-use requirements in Appendix 1 (if applicable) and method of NOx control

(C) Blenders shall maintain records
- Statements on invoices indicating NOx control for each transaction of B100 or biodiesel blend as described in Appendix 1

(D) Distributors
- Statements on invoices indicating that B100 or biodiesel blend contains NOx control and the type of NOx control, as described in Appendix 1

(E) Retailers
- Statements on invoices indicating that B100 or biodiesel blend contains NOx control and the type of NOx control, as described in Appendix 1

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 39515, 40000, 43000, 43016, 43018, 43026, 43101, and 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§2293.9. Severability.

Each part of this subarticle shall be deemed severable, and in the event that any part of this subarticle is held to be invalid, the remainder of this subarticle shall continue in full force and effect.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018, 43101, and 43865, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

Subarticle 3. Ancillary Provisions

§~~2293~~2294. Equivalent Test Methods.

~~(a)~~ Whenever ~~sections 2292.1 thru 2292.7 provide for~~ this article requires the use of a specified test method, another test method may be used following a determination by the Executive Officer that the other test method produces results equivalent to the results obtained with the specified method.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

§~~2293.5~~2295. Exemptions for Alternative Motor Vehicle Fuel Used in Test Programs.

The E~~e~~xecutive ~~o~~Officer shall consider and grant test program exemptions from the requirements of this Article in accordance with section 2259.

Note: Authority cited: Sections 39600, 39601, 39667, 43013, 43018, and 43101, Health and Safety Code; and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975). Reference: Sections 39000, 39001, 39002, 39003, 39010, 39500, 40000, 43000, 43016, 43018 and 43101, Health and Safety Code: and *Western Oil and Gas Ass'n. v. Orange County Air Pollution Control District*, 14 Cal. 3d 411, 121 Cal.Rptr. 249 (1975).

Appendix 1. In-use Requirements for Pollutant Emissions Control

A person subject to the Stage 3A in use requirements (section 2293.5(c)) may meet the in-use requirements imposed above the Pollutant Control Trigger Level by implementing any of the following in-use requirements as applicable, either alone or in combination:

Additives approved for NOx emission control purposes, an ADF-CARB diesel blend certified as emissions equivalent to CARB diesel or better, a neat ADF finished fuel certified as emissions equivalent to CARB diesel or better, or other options certified by the Executive Officer for this purpose.

(a) Biodiesel:

(1) Approved Emissions Equivalent Additives:

The following list shows the additive and required amounts by saturation and blend level:

(A) Di-tert-butyl peroxide (DTBP): Biodiesel blends above the NOx emission control trigger level that contain DTBP by volume in the amounts specified in the table below meet the in-use requirements for biodiesel.

Table A.5: DTBP NOx Control Blend Level

Biodiesel Saturation Level	**Biodiesel Blend Level**	**Required level of DTBP (volume percent of blend)**
Low Saturation	>B5 to <B10	0.5 minimum
	B10 to <B15	0.75 minimum
	B15 to B20	1.0 minimum
High Saturation	B10 to <B15	0.25 minimum
	B15 to B20	0.5 minimum

(B) [Reserved]

(2) Certification of Alternative Diesel Fuels Resulting in Emissions Equivalence with Diesel

(A) The Executive Officer, upon application of any producer or importer, may certify alternative diesel fuel formulations or additives in accordance with (a)(2) of this appendix. The applicant shall initially submit a proposed test protocol to the Executive Officer. The proposed test protocol shall include: (A) the identity of the entity proposed to conduct the tests described in (a)(2)(F) of this appendix; (B) test procedures consistent with the requirements of (a)(2) of this appendix; (C) test data showing that the fuel to be used as the Reference CARB Diesel satisfies the specifications identified in (a)(2)(E) of this appendix; (D) reasonably adequate quality assurance and quality control procedures; and (E) notification of any outlier identification and exclusion procedure that will be used, and a demonstration that any such procedure meets generally accepted statistical principles.

Within 20 business days of receipt of a proposed test protocol, the Executive Officer shall advise the applicant in writing either that it is complete or that specified additional information is required to make it complete. Within 15 business days of submittal of additional information, the Executive Officer shall advise the applicant in writing either that the information submitted makes the proposed test protocol complete or that specified additional information is still required to make it complete. Within 20 business days after the proposed test protocol is deemed complete, the Executive Officer shall either approve the test protocol as consistent with this (a)(2) of this appendix or advise the applicant in writing of the changes necessary to make the test protocol consistent with (a)(3) of this appendix. Any notification of approval of the test protocol shall include the name, telephone number, and address of the Executive Officer's designee to receive notifications pursuant to (a)(2)(F) of this appendix. The tests shall not be conducted until the protocol is approved by the Executive Officer.

Upon completion of the tests, the applicant may submit an application for certification to the Executive Officer. The application shall include the approved test protocol, all of the test data, a copy of the complete test log prepared in accordance with (a)(2)(F) of this appendix, a demonstration that the candidate fuel meets the requirements for certification set forth in (a)(2)(C) of this appendix, and such other information as the Executive Officer may reasonably require.

Within 20 business days of receipt of an application, the Executive Officer shall advise the applicant in writing either that it is complete or that specified additional information is required to make it complete. Within 15 business days of submittal of additional information, the Executive Officer shall advise the applicant in writing either that the information submitted makes the application complete or that specified additional information is still required to make it complete. Within 20 business days after the application is deemed complete, the Executive Officer shall grant or deny the application. Any denial shall be accompanied by a written statement of the reasons for denial.

(B) The candidate fuel.

The candidate fuel to be used in the comparative testing described in (a)(2)(F) of this appendix shall be one of the following:

1. ADF formulation: The candidate fuel shall be the fuel blendstock or fuel blend that the applicant is attempting to certify. If the applicant is attempting to certify a fuel blend, that blend shall consist of the fuel blendstock blended to 20 percent with the Reference CARB Diesel. The applicant shall report all of the candidate fuel properties under (a)(3)(C) of this appendix for the candidate fuel.

2. Biodiesel additives: The candidate fuel shall be a mixture of the additive to be certified at the concentration specified by the applicant and the biodiesel additive certification fuel specified in (a)(3)(D) of this appendix. If the additive to be certified is meant to be used in B20 fuel blends, the candidate fuel shall be a mixture of the additive to be certified at the concentration specified by the applicant and the biodiesel additive certification fuel specified in (a)(3)(D) of this appendix blended to 20 volume percent biodiesel content with the Reference CARB Diesel. The applicant shall report all of the candidate fuel properties under (a)(3)(C) of this appendix for both the certification fuel without the additive, and the candidate fuel.

(C) Candidate fuel properties.

1. The applicant shall report all of the properties listed below for the candidate fuel. The candidate fuel shall be representative of the fuel that the applicant will produce commercially, and shall not contain streams or feedstocks that will not be used in the commercial fuel that the applicant intends to sell. If the executive officer determines that the candidate fuel contains streams or feedstocks that will not be used in the commercial fuel, this will be grounds for rejection of the application.

2. The following documents are incorporated by reference:

a. ASTM D5186-03, "Standard Test Method for Determination of the Aromatic Content and Polynuclear Aromatic Content of Diesel Fuels and Aviation Turbine Fuels By Supercritical Fluid Chromatography (2009)."

b. ASTM D4629-12, "Standard Test Method for Trace Nitrogen in Liquid Petroleum Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection (2012)."

c. ASTM D445-14e2, "Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity) (2012)."

d. ASTM D93-13e1, "Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester (2013)."

e. ASTM D86-12, "Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure (2012)."

f. EN 14103:2011, "Fat and oil derivatives. Fatty acid methyl esters (FAME). Determination of ester and linolenic acid methyl ester contents (2011)."

Table A.7: Candidate fuel properties

Property	Test Method
Sulfur Content	ASTM D5453-93
Aromatic Hydrocarbon Content, Volume %	ASTM D5186-03(2009)
Polycyclic Aromatic Content, Weight %	ASTM D5186-03(2009)
Nitrogen Content	ASTM D4629-12
Unadditized Cetane Number	ASTM D613-14 or ASTM D6890-13be1
API Gravity	ASTM D287-12b
Viscosity at 40°C, cSt	ASTM D445-14e2
Flash Point, °F, minimum	ASTM D93-13e1
Distillation, °F	ASTM D86-12
Initial Boiling Point	
10 % Recovered	
50 % Recovered	
90 % Recovered	
End Point	
FAME Content %	EN14103:2011

(D) *Biodiesel additive certification fuel.*

The biodiesel additive certification fuel shall be a biodiesel (fatty acid methyl ester) produced by transesterification of virgin soybean oil with the following properties.

Table A.8: Additive certification fuel blendstock properties

Property	Test Method	Fuel Specifications
Sulfur Content	ASTM D5453-93	15 ppm maximum
Nitrogen Content	ASTM D4629-12	10 ppm maximum
Unadditized Cetane Number	ASTM D613-14 or ASTM D6890-13be1	47-50
API Gravity	ASTM D287-12b	27 – 33
Viscosity at 40°C, cSt	ASTM D445-14e2	2.0 – 4.1
Flash Point, °F, minimum	ASTM D93-13e1	266
Distillation, °F	ASTM D86-12	
90 % Recovered		620-680
FAME Content %	EN 14103:2011	Report

(E) *The Reference CARB Diesel.*

The Reference CARB Diesel used in the comparative testing described in (a)(2)(F) of this appendix shall be produced from straight-run California diesel fuel by a hydrodearomatization process and shall have the characteristics set forth below under “Reference Fuel Specifications” (the listed ASTM methods are incorporated herein by reference):

Table A.9: Reference Fuel Specifications

Property	Test Method	Fuel Specifications
Sulfur Content	ASTM D5453-93	15 ppm maximum
Aromatic Hydrocarbon Content, Volume %	ASTM D5186-03(2009)	10 % maximum
Polycyclic Aromatic Content, Weight %	ASTM D5186-03(2009)	10 % maximum
Nitrogen Content	ASTM D4629-12	10 ppm maximum
Unadditized Cetane Number	ASTM D613-14 or ASTM D6890-13be1	48 minimum
API Gravity	ASTM D287-12b	33 – 39
Viscosity at 40°C, cSt	ASTM D445-14e2	2.0 – 4.1
Flash Point, °F, minimum	ASTM D93-13e1	130
Distillation, °F	ASTM D86-12	
Initial Boiling Point		340 – 420
10 % Recovered		400 – 490
50 % Recovered		470 – 560
90 % Recovered		550 – 610
End Point		580 – 660

(F) *Emissions testing.*

1. Exhaust emission tests using the candidate fuel and the reference fuel shall be conducted in accordance with the "California Exhaust Emission Standards and Test Procedures for 1985 and Subsequent Model Heavy-Duty Diesel-Powered Engines and Vehicles," as incorporated by reference in Title 13, California Code of Regulations, Section 1956.8(b). The tests shall be performed using a Detroit Diesel Corporation Series 60 engine, through December 31, 2017, or a 2004-2006 model-year, Cummins ISM370 engine having a nominal torque rating of 1450 ft-lb and a nominal power output of 360 to 380 hp, and produced between January 2004 and December 2006, inclusive, starting January 1, 2015, or, if the Executive Officer determines that the 2004-2006 Cummins ISM370 is no longer representative of the pre-2007 model-year, heavy duty diesel engine fleet, another engine found by the Executive Officer to be representative of such engines. A determination by the Executive Officer that an engine is no longer representative shall not affect the certification of a diesel fuel formulation based on prior tests using that engine pursuant to a protocol approved by the Executive Officer.

2. The comparative testing shall be conducted by a party or parties that are mutually agreed upon by the Executive Officer and the applicant. The applicant shall be responsible for all costs of the comparative testing.

3. The applicant shall use one of the following test sequences:

a. If both cold start and hot start exhaust emission tests are conducted, a minimum of five exhaust emission tests shall be performed on the engine with each fuel, using either of the following sequences, where "R" is the Reference CARB Diesel and "C" is the candidate fuel: RC RC RC RC RC (and continuing in the same order). or RC CR RC CR RC (and continuing in the same order).

   The engine mapping procedures and a conditioning transient cycle shall be conducted with the Reference CARB Diesel before each cold start procedure using the Reference CARB Diesel. The reference cycle used for the candidate fuel shall be the same cycle as that used for the fuel preceding it.

b. If only hot start exhaust emission tests are conducted, one of the following test sequences shall be used throughout the testing, where “R” is the Reference CARB Diesel and “C” is the candidate fuel:

   Alternative 1: RC CR RC CR (continuing in the same order for a given calendar day; a minimum of twenty individual exhaust emission tests must be completed with each fuel)

   Alternative 2: RR CC RR CC (continuing in the same order for a given calendar day; a minimum of twenty individual exhaust emission tests must be completed with each fuel)

   Alternative 3: RRR CCC RRR CCC (continuing in the same order for a given calendar day; a minimum of twenty-one individual exhaust emission tests must be completed with each fuel)

   For all alternatives, an equal number of tests shall be conducted using the Reference CARB Diesel and the candidate fuel on any given calendar day. At the beginning of each calendar day, the sequence of testing shall begin with the fuel that was tested at the end of the preceding day. The engine mapping procedures and a conditioning transient cycle shall be conducted after every fuel change and/or at the beginning of each day. The reference cycle generated from the Reference CARB Diesel for the first test shall be used for all subsequent tests.

For alternatives 2 and 3, each paired or triplicate series of individual tests shall be averaged to obtain a single value which would be used in the calculations conducted pursuant to (a)(3)(G) of this appendix.

4. The applicant shall submit a test schedule to the Executive Officer at least one week prior to commencement of the tests. The test schedule shall identify the days on which the tests will be conducted, and shall provide for conducting the test consecutively without substantial interruptions other than those resulting from the normal hours of operations at the test facility. The Executive Officer shall be permitted to observe any tests. The party conducting the testing shall maintain a test log which identifies all tests conducted, all engine mapping procedures, all physical modifications to or operational tests of the engine, all recalibrations or other changes to the test instruments, and all interruptions between tests and the reason for each such interruption. The party conducting the tests or the applicant shall notify the Executive Officer by telephone and in writing of any unscheduled interruption resulting in a test delay of 48 hours or more, and of the reason for such delay. Prior to restarting the test, the applicant or person conducting the tests shall provide the Executive Officer with a revised schedule for the remaining tests. All tests conducted in accordance with the test schedule, other than any tests rejected in accordance with an outlier identification and exclusion procedure included in the approved test protocol, shall be included in the comparison of emissions pursuant to (a)(3)(G) of this appendix.

5. In each test of a fuel, exhaust emissions of oxides of nitrogen (NOx) and particulate matter (PM) shall be measured.

(G)The average emissions during testing with the candidate fuel shall be compared to the average emissions during testing with the Reference CARB Diesel, applying one-sided Student's t statistics as set forth in Snedecor and Cochran, *Statistical Methods* (7^{th} ed.), page 91, Iowa State University Press, 1980, which is incorporated herein by reference. The Executive Officer shall issue a certification pursuant to this paragraph only if he or she makes all of the determinations set forth in (a)(3)(G) below, after applying the criteria of (a)(3)(G) of this appendix.

1. The average individual emissions of NOx and PM, respectively, during testing with the candidate fuel do not exceed the average individual emissions of NOx and PM, respectively, during testing with the Reference CARB Diesel.

2. Use of any additive identified pursuant to (a)(2)(B) of this appendix in heavy-duty engines will not increase emissions of noxious or toxic substances which would not be emitted by such engines operating without the additive. In addition, cellular tests on the particulate emissions from heavy-duty engines will not show greater harm for mutagenicity, inflammation, DNA damage, or oxidative stress with the use of any such additive than would occur with such engines operating without the additive.

3. In order for the determinations of (a)(2)(G) of this appendix to be made, for each referenced pollutant the candidate fuel shall satisfy the following relationship:

$$\overline{x_C} < \overline{x_R} + \delta - S_P \times \sqrt{\frac{2}{n}} \times t(a, 2n-2)$$

Where:

$\overline{X}_C$ =	Average emissions during testing with the candidate fuel
$\overline{X}_R$ =	Average emissions during testing with the Reference CARB Diesel
δ =	tolerance level equal to 1 percent of $\overline{X}_R$ NOx, 2 percent of $\overline{X}_R$ for PM.
S_p =	Pooled standard deviation
t (a, 2n-2) =	The one-sided upper percentage point of t distribution with a = 0.15 and 2n-2 degrees of freedom
n =	Number of tests of candidate fuel and Reference CARB Diesel

(H) If the Executive Officer finds that a candidate fuel has been properly tested in accordance with (a)(2)(F) of this appendix, and makes the determinations specified in (a)(2)(G) of this appendix, then he or she shall issue an Executive Order certifying the alternative diesel fuel or additive formulation represented by the candidate fuel. The Executive Order shall identify all of the characteristics of the candidate fuel determined pursuant to (a)(2)(C) of this appendix. The Executive Order shall provide that the certified alternative diesel fuel formulation has the following specifications: [1] a sulfur content, total aromatic hydrocarbon content, polycyclic aromatic hydrocarbon content, and nitrogen content not exceeding that of the candidate fuel, [2] a cetane number and API gravity not less than that of the candidate fuel, [3] any additional fuel specification required under (a)(3) of this appendix, and [4] presence of all additives that were contained in the candidate fuel, in a concentration not less than in the candidate fuel, except for an additive demonstrated by the applicant to have the sole effect of increasing cetane number. Additionally the Executive Order shall contain a table mirroring the table in Appendix 1 (a)(1)(A) listing the required concentration of additive at each 5 percent interval of blend level, if applicable. All such characteristics shall be determined in accordance with the test methods identified in (a)(2)(C) of this appendix. The Executive Order shall assign an identification name to the specific certified biodiesel fuel formulation.

(I) In-use testing.

1. If the executive officer determines that a commercially available biodiesel fuel blend meets all of the specifications of a certified biodiesel fuel formulation set forth in an Executive Order issued pursuant to (a)(2)(H) of this appendix, but does not meet the criteria of (a)(2)(G) of this appendix when tested in accordance with (a)(2)(F), the Executive Officer shall modify the Executive Order as is necessary to assure that biodiesel fuel blends sold commercially pursuant to the certification will meet the criteria set forth in (a)(2)(G). The modifications to the order may include additional specifications or conditions, or a provision making the order inapplicable to specified biodiesel fuel producers.

2. The Executive Officer shall not modify a prior Executive Order without the consent of the applicant and of the producer of the commercially available biodiesel fuel blend found not to meet the criteria, unless the applicant and producer are first afforded an opportunity for a hearing in accordance with Title 17, California Code of Regulations, Part III, Chapter 1, Subchapter 1, Article 4 (commencing with Section 60040). If the Executive Officer determines that a producer would be unable to comply with this regulation as a direct result of an order modification pursuant to this subsection, the Executive Officer may delay the effective date of such modification for such period of time as is necessary to permit the producer to come into compliance in the exercise of all reasonable diligence.

(b) [Reserved]

APPENDIX B

Members of the Multimedia Working Group

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Members of the Multimedia Working Group

May 2015

Air Resources Board

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APPENDIX C

Air Resources Board: Impact Assessment of Renewable Diesel on Exhaust Emissions from Compression Ignition Engines

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State of California
Air Resources Board

Impact Assessment of Renewable Diesel on Exhaust Emissions from Compression Ignition Engines

May 2015

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1. INTRODUCTION

The staff of the Air Resources Board (ARB or Board) intends to establish new motor vehicle fuel specifications and in-use requirements for biodiesel, which includes the use of renewable diesel as part of the proposed ADF regulation.[1] The ADF regulation is intended to provide a framework for low carbon diesel fuel substitutes to enter the commercial market in California, while mitigating any potential environmental or public health impacts.

California Health and Safety Code (HSC) section 43830.8 requires a multimedia evaluation to be conducted and reviewed by the California Environmental Policy Council (CEPC) before new fuel specifications are established. A "multimedia evaluation" is the identification and evaluation of any significant adverse impact on public health or the environment, including air, water, and soil, that may result from the production, use, or disposal of the motor vehicle fuel that may be used to meet the state board's motor vehicle fuel specifications.[2]

This report provides staff's assessment of the emissions data and air quality impact information obtained during the renewable diesel multimedia evaluation and ARB staff's overall conclusions and recommendations to the CEPC. Staff's assessment is based on the data and information provided for the renewable diesel evaluation, including the University of California (UC) researchers' multimedia reports (Final Tier I and Tier III Reports) and the "*CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California*" (ARB Emissions Study)[3] by UC Riverside from emissions testing conducted at the College of Engineering – Center for Environmental Research and Technology (CE-CERT) and ARB emissions test facilities in Stockton and El Monte, California.

A. Multimedia Evaluation of Renewable Diesel

Pursuant to HSC section 43830.8, researchers from UC Berkeley and UC Davis conducted the multimedia evaluation of renewable diesel fuel compared to diesel fuel that meets ARB motor vehicle fuel specifications (CARB diesel). Due to the specific fuel properties and indistinguishable chemical compositions of renewable diesel and CARB diesel, the UC researchers and the MMWG found no significant data needs and, therefore, no additional Tier II experiments were needed. Consequently, after Tier I, the UC researchers proceeded directly to Tier III of the evaluation. The researchers submitted a Tier I and Tier III report, and finalized them with the MMWG. The final reports are listed as follows:

[1] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*, October 23, 2013. ES-1.
[2] Health and Safety Code section 43830.8(b).
[3] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

- California Renewable Diesel Multimedia Evaluation Final Tier I Report (Final Tier I Report)[4]
- California Renewable Diesel Multimedia Evaluation Final Tier III Report (Final Tier III Report or Renewable Diesel Final Report)[5]

Based on the renewable diesel multimedia evaluation and the information provided in the Final Tier I and Tier III reports, the MMWG determined that the use of renewable diesel, as specified in this multimedia evaluation and the proposed ADF regulation, does not pose a significant adverse impact on public health or the environment compared to CARB diesel fuel.

B. ARB Emissions Testing Program

In order to better understand emissions from renewable diesel, ARB contracted with UC Riverside to conduct emissions testing, as well as in-house emissions testing (ARB Emissions Study).[6] Table 1 below summarizes the test matrix covered in the study.

Table 1. Summary of Testing Done by ARB and UC Riverside

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

In general, this study found that most emissions from renewable diesel are reduced from diesel fuel meeting ARB motor vehicle fuel specifications (CARB diesel), including particulate matter (PM), oxides of nitrogen (NOx), carbon monoxide (CO), carbon dioxide (CO_2), total hydrocarbons (THC), and most toxic species.

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[4] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier I Report*, Sept 2011.
[5] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier III Report*, Apr 2012.
[6] Durbin. T.D. et al, *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California, "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

2. RENEWABLE DIESEL

Renewable diesel is produced from non-petroleum renewable resources but is not a mono-alkyl ester. Renewable diesel consists solely of hydrocarbons and meets ARB motor vehicle fuel specifications under title 13, California Code of Regulations (CCR), section 2281 et seq. In fact, renewable diesel meets specified aromatic, sulfur, and lubricity standards, as well as ASTM International standard specification, ASTM D975-12a.[7] In this report, CARB diesel blended with 20 vol% or 50 vol% renewable diesel fuel is denoted as R20 or R50, respectively. Pure renewable diesel fuel is denoted as R100.

The Low Carbon Fuel Standard (LCFS) regulation, codified in 17 CCR 95480-95490, defines "renewable diesel" as "a motor vehicle fuel or fuel additive that is all of the following:

- (A) Registered as motor vehicle fuel or fuel additive under title 40, Code of Federal Regulations (CFR), part 79;
- (B) Not a mono-alkyl ester;
- (C) Intended for use in engines that are designed to run on conventional diesel fuel; and
- (D) Derived from non-petroleum renewable resources." [8]

Renewable diesel is chemically indistinguishable from conventional diesel fuel. Renewable diesel consists solely of hydrocarbons and is simply diesel made from renewable diesel feedstock.[9] As previously stated, renewable diesel meets the definition of "diesel fuel" in the California diesel fuel regulations (13 CCR 2281(b)(1)) and the ASTM International standard specification for diesel fuel oils (ASTM D975-12a).

A. Production

There are several different chemical approaches to producing renewable diesel. One is based on hydrotreating vegetable oils or animal fats. Hydrotreating can take place in the same facilities used to process petroleum-based diesel. A second method involves synthesis of hydrocarbons through enzymatic reactions. A third involves partially combusting a biomass source to produce carbon monoxide and hydrogen, or syngas, and then utilizing the Fischer-Tropsch reaction to produce complex hydrocarbons.

Since there are currently few plans to engage the Fischer-Tropsch process in California, the renewable diesel multimedia evaluation focused on the impacts of hydrotreated renewable diesel produced in existing refineries. Hydrotreating is a hydrodeoxygenation process used to remove oxygen and nitrogen containing compounds as well as metals from the fuel feedstock.

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[7] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*. October 23, 2013, 18, 20.
[8] *Low Carbon Fuel Standard.* Title 17, CCR, Sections 95480-95490,16.
[9] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011.

There are two general production strategies for hydrotreated renewable diesel production and distribution:

- Co-processing vegetable or animal triglycerides in a conventional petroleum production stream using a hydrotreating process. Currently, this results in diesel fuel that has a specified percentage of “green-derived” carbon, e.g., R20.
- Production of a pure hydrotreated renewable diesel (R100) in a dedicated hydrotreating facility that does not use conventional petroleum. The resulting fuel can be used as a 100% green fuel or blended with conventional CARB diesel fuel to any concentration.

The renewable diesel production process is designed to take advantage of the infrastructure of an existing refinery. Several of the renewable diesel products currently available meet the ASTM standard for conventional diesel.[10]

B. Feedstocks

Renewable diesel is derived from non-petroleum renewable resources, including, but not limited to, plant and algae oils, animal fats and wastes, municipal solid waste, sludge and oils derived from wastewater, and other wastes. As previously stated, renewable diesel uses similar feedstocks as biodiesel, but they have different processing methods, and can include chemically different components.

Soybeans are expected to be the main feedstock for renewable diesel in California. Oil is extracted from soy by crushing the beans and applying n-hexane as a solvent. Soy-based renewable diesel is sufficiently similar to the physical-chemical properties of CARB diesel that it can be readily used in a range of blending applications.

Palm trees used to produce palm oil are grown primarily in tropical or subtropical areas such as Malaysia and Indonesia. Palm oil is characterized by high concentrations of medium-chain saturated (palmitic acid) and mono-saturated (oleic acid) fatty acids. One of its greatest advantages as a biofuel feedstock is high oil yield.

Canola and rapeseed oils show promise as renewable diesel feedstock. These oils have properties similar to soy oil. The oil yield of canola, however, is much higher than soy; the seed contains 45% oil.

Animal tallow is a triglyceride material that is recovered by a rendering process, where the animal residues are cooked and the fat is recovered as it rises to the surface. Since it is a waste by-product, it is highly inexpensive, sustainable, and is available locally. Vegetable oil waste grease and brown trap grease can also be used to make renewable diesel.[8]

[10] McKone, T.E.et al. *California Renewable Diesel Multimedia Evaluation Final Tier III Report*. Apr 2012, 7-8.

C. Availability

Renewable diesel can be produced domestically and can be transported with the same methods used for conventional diesel, including pipelines, rail cars, tank trucks, and drums. The choice of transport vessel depends on the quantity of renewable diesel being transferred and the cold flow properties of the fuel.

There are several commercial renewable diesel ventures such as Amyris' Biotane, Global Energy Resources' renewable hydrocarbons, REEP Development's celluloisic diesel and Sierra Energy's biomass to liquid fuels.

Neste has developed a plant to process vegetable and animal fats into renewable diesel by the hydrotreatment process in Singapore with a production capacity of 240 million gallons per year.[11] Dynamic Fuels, a joint venture of Syntroleum and Tyson Foods, is currently producing renewable diesel and has a production capacity of 75 million gallons per year.[12] Diamond Green Diesel, a joint venture between Darling and Valero, is currently producing renewable diesel and has a production capacity of 137 million gallons per year.[13] Emerald Biofuels plans to build a renewable diesel facility using the Honeywell process, with a production capacity of 85 million gallons per year.[14]

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[11] Biofuels Digest, December 3, 2010, *Neste Oil becomes Chief Monster as renewable diesel becomes biofuels monster*, http://www.biofuelsdigest.com/bdigest/2010/12/03/neste-oil-becomes-chief-monster-as-renewable-diesel-becomes-biofuels-monster/ (accessed September 17, 2013).

[12] Dynamic Fuels, http://www.dynamicfuelsllc.com/about.aspx (accessed June 28, 2013).

[13] DAR PRO Diamond Green Diesel Renewable Fuel, *Thinking big: A partnership with Valero Energy Corporation for mass-scale green diesel production,* http://www.darpro.com/diamond-green-diesel (accessed June 28, 2013).

[14] Emerald Biofuels News, *Emerald Biofuels Plans Renewable Diesel Refinery in Plaquemine, Louisiana,* May 8, 2012, http://emeraldbiofuels.com/news.php (accessed June 28, 2013).

3. EXHAUST EMISSIONS

Engine emissions testing was performed to characterize regulated emissions, including PM, NOx, CO, and THC, and various unregulated toxic emissions.

A. Emissions Testing

Emissions testing was conducted on one engine and one vehicle. Engine dynamometer emissions testing was conducted at UC Riverside's College of Engineering – Center for Environmental Research and Technology (CE-CERT) Laboratory. Chassis dynamometer emissions testing was conducted at ARB's Heavy-Duty Engine Emissions Testing Laboratory (HDEETL) Laboratory in Los Angeles. [15]

i. Engine Dynamometer Testing

Renewable diesel was tested in a 2006 Cummins ISM in an engine dynamometer at UC Riverside. The engine specifications are listed in Table 2.

Table 2. Engine Dynamometer Engine Specifications

Engine Manufacturer	Cummins
Engine Model	ISM 370
Model Year	2006
Engine Type	In-line 6 cylinder 4 stroke
Displacement	10.8 liters
Power Rating	385 hp @ 1800 rpm
Fuel Type	Diesel
Induction	Turbocharger with charge air cooler

The following test cycles were used:

- U.S. EPA Heavy duty Federal Test Procedure (FTP)
- Urban Dynamometer Driving Schedule (UDDS) modified for engine dynamometer
- CARB Heavy Heavy-Duty Diesel Truck (HHDDT) 50 mph Cruise cycle modified for engine dynamometer

[15] Durbin. T.D. et al, *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California, "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

Engine dynamometer testing focused primarily on standard emissions, including THC, CO, NOx, PM, and CO_2. Renewable diesel blends (R20, R50 and R100) were tested against commercially available CARB diesel. Each fuel blend was tested seven times, and each test yielded THC, CO, NOx, PM, CO2 and brake specific fuel consumption (BSFC) measurements.

ii. Chassis Dynamometer Testing

Renewable diesel was tested in a 2000 Caterpillar C-15 in a chassis dynamometer in the Metropolitan Transit Authority facility in Los Angeles. The vehicle specifications are listed in Table 3.

Table 3. Chassis Dynamometer Engine Specifications

Engine Manufacturer	Caterpillar
Engine Model	C-15
Model Year	2000
Engine Type	In-line 6 cylinder 4 stroke
Displacement	14.6 liters
Power Rating	475 hp @ 2100 rpm
Fuel Type	Diesel
Induction	Turbocharged with aftercooler

The following test cycles were used:

- UDDS
- CARB HHDDT 50 mph Cruise cycle

Chassis dynamometer testing focused primarily on toxic pollutants. Renewable diesel blends of 20 vol%, 50 vol% and 100 vol% were compared against a commercially available CARB diesel. Each fuel blend was tested 6 times on the UDDS and 3 times on the 50 mph cruise cycle. Each test yielded measurements for the pollutants listed in Table 4.

Table 4. Chassis Dynamometer Emissions Measurements

Analyte	Collection Media	Analysis
THC	Modal, Bag	FID
NMHC	Modal, Bag	FID
NOx, NO_2	Modal, Bag	Chemiluminescence
CO, CO_2	Modal, Bag	NDIR
BTEX	Tedlar Bags	GC-FID
Carbonyls	2,4-DNPH cartridges	HPLC
PM Mass	Teflon 47mm (Teflo)	Gravimetric
Organic/Elemental Carbon	Quartz fiber filter 47mm	Thermo/Optical Carbon Analysis
Elements	Teflon filter	ICP-MS
PAH	Teflon Filter/PUF/XAD	GC-MS
N_2O	Tedlar Bags	FTIR

B. Results

Brake-specific emissions for regulated emissions, including PM, NOx, THC, and selected unregulated toxic emissions were obtained from the testing. All results below are from the CARB Emissions Study.[16]

Renewable diesel reduced the amount of criteria pollutants emitted from diesel fuel when tested both on engine and chassis dynamometer compared to CARB diesel. However, CO and THC emissions were essentially equivalent to CARB diesel for some of the test cycles. Tables 5, 6, and 7 show the criteria pollutant emissions for the engine dynamometer tests. The chassis dynamometer test results were comparable.

[16] Durbin. T.D. et al, *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California, "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

Table 5. Emissions Results on UDDS Cycle

	THC g/bhp-hr	ΔTHC %	CO g/bhp-hr	ΔCO %	NOx g/bhp-hr	ΔNOx %	PM g/bhp-hr	ΔPM %
CARB	0.769	*0.0%*	2.091	*0.0%*	5.891	*0.0%*	0.063	*0.0%*
R20	0.744	*-3.3%*	1.753	*-16.2%*	5.603	*-4.9%*	0.06	*-4.8%*
R50	0.726	*-5.6%*	1.612	*-22.9%*	5.289	*-10.2%*	0.055	*-12.7%*
R100	0.677	***-12.0%***	1.392	***-33.4%***	4.825	***-18.1%***	0.045	***-28.6%***

Table 6. Emissions Results on FTP Cycle

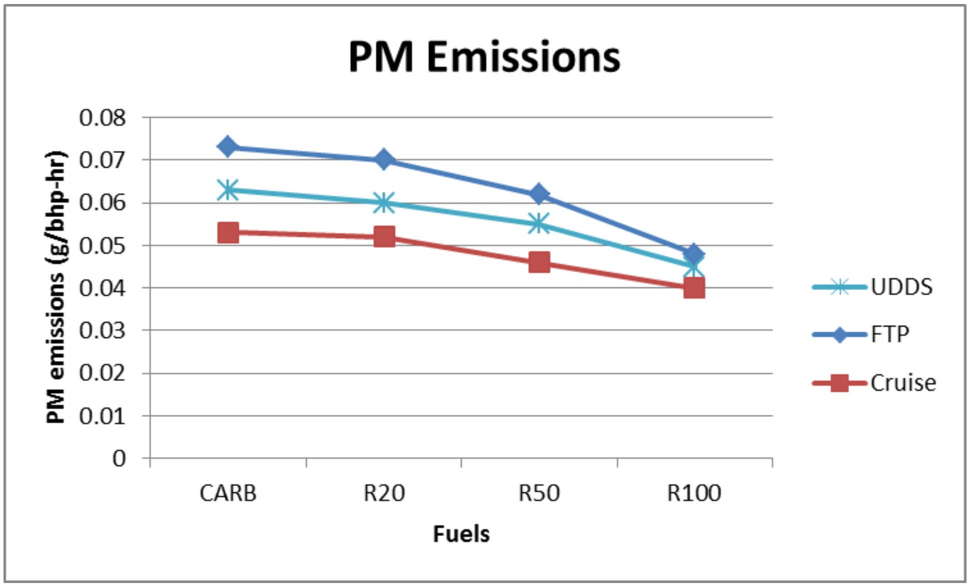
	THC g/bhp-hr	ΔTHC %	CO g/bhp-hr	ΔCO %	NOx g/bhp-hr	ΔNOx %	PM g/bhp-hr	ΔPM %
CARB	0.294	*0.0%*	0.701	*0.0%*	2.088	*0.0%*	0.073	*0.0%*
R20	0.296	*0.7%*	0.675	*-3.7%*	2.027	*-2.9%*	0.07	*-4.1%*
R50	0.293	*-0.3%*	0.643	*-8.3%*	1.975	*-5.4%*	0.062	*-15.1%*
R100	0.284	***-3.4%***	0.614	***-12.4%***	1.882	***-9.9%***	0.048	***-34.2%***

Table 7. Emissions Results on 50 mph Cruise Cycle

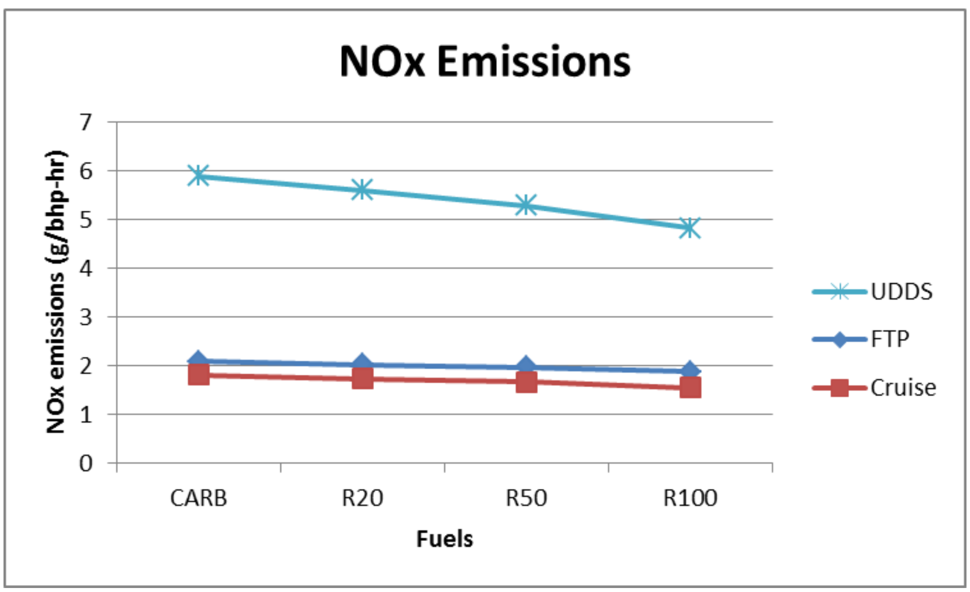
	THC g/bhp-hr	ΔTHC %	CO g/bhp-hr	ΔCO %	NOx g/bhp-hr	ΔNOx %	PM g/bhp-hr	ΔPM %
CARB	0.176	*0.0%*	0.452	*0.0%*	1.809	*0.0%*	0.053	*0.0%*
R20	0.18	*2.3%*	0.454	*0.4%*	1.74	*-3.8%*	0.052	*-1.9%*
R50	0.18	*2.3%*	0.459	*1.5%*	1.667	*-7.8%*	0.046	*-13.2%*
R100	0.174	***-1.1%***	0.467	***3.3%***	1.553	***-14.2%***	0.04	***-24.5%***

The following graphs show the criteria pollutant emissions in graphical form. These graphs are arranged such that one pollutant is shown in each graph with three different lines representing the emissions measured during each test cycle. Although the absolute emissions are not the same from cycle to cycle, the trends are generally the same, except for CO and THC. For CO, the UDDS show greater emissions reductions than the FTP and the 50 mph cruise show no emissions reductions. For THC, the UDDS show emissions reductions and the FTP and 50 mph cruise show no reductions. Graphs 1 through 4 show PM, NOx, CO, and THC emissions, respectively.

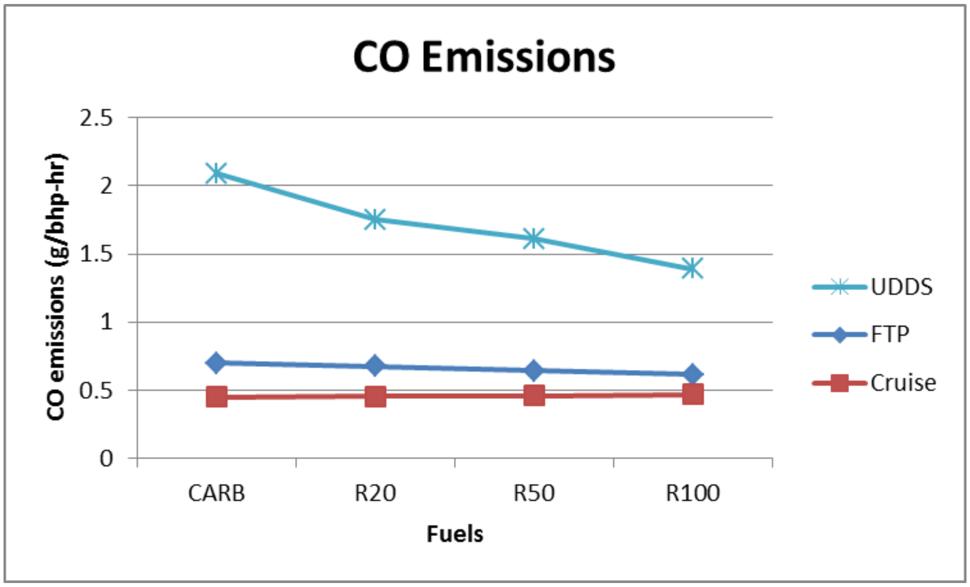
Graph 1. PM Emissions of R20, R50, R100 and CARB Diesel by Test Cycle



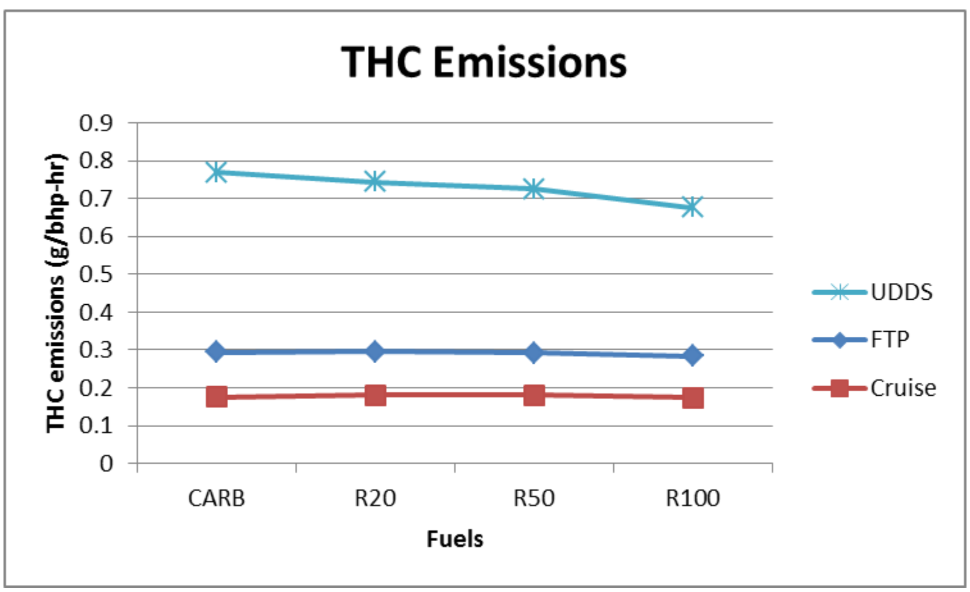
Graph 2. NOx Emissions of R20, R50, R100 and CARB Diesel by Test Cycle



Graph 3. CO Emissions of R20, R50, R100 and CARB Diesel by Test Cycle



Graph 4. THC Emissions of R20, R50, R100 and CARB Diesel by Test Cycle



Toxic pollutants including carbonyls, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs), were measured during chassis dynamometer testing. Various Genotoxicity measurements were also made. In general, renewable diesel either reduced or did not have an impact on toxic pollutant emissions.

Below is a summary of the differences between CARB diesel and renewable diesel with an emphasis on statistical significance:

- 1,3-butadiene emissions were not significantly different with renewable diesel
- Carbonyl emissions were not significantly different with renewable diesel
- PAH emissions were significantly reduced at R100 for almost all of the species measured, including nitro-PAHs and oxy-PAHs

In order to determine the greenhouse gas (GHG) impact of a fuel, that fuel must undergo a full fuel lifecycle analysis (LCA). The LCFS is the mechanism by which ARB conducts fuels LCA. LCA yields a carbon intensity (CI) value of a fuel. CI is the amount of GHG emissions per unit of energy contained within the fuel. The outcome of an LCA is heavily dependent upon the feedstock used to produce the fuel. For example, waste derived fuels tend to have significantly lower GHG emissions than crop derived fuels.

The LCFS currently has three LCA pathways that were developed for renewable diesel. Table 8 shows the CI values of diesel and renewable diesel in the LCFS.[17]

Table 8. Carbon Intensity Values for Renewable Diesel Compared to CARB Diesel

Fuel and Pathway Description	**Direct CI** (gCO_2e/MJ)	**Indirect CI** (gCO_2e/MJ)	**Total CI** (gCO_2e/MJ)
Diesel – ULSD based on the average crude oil supplied to CA refineries and average CA refinery efficiencies	98.03	0	98.03
Renewable Diesel – Conversion of tallow to renewable diesel using higher energy use for rendering	39.33	0	39.33
Renewable Diesel – Conversion of tallow to renewable diesel using lower energy use for rendering	19.65	0	19.65
Renewable Diesel – Conversion of Midwest soybeans to renewable diesel	20.16	62	82.16

The following two pathways were modeled for renewable diesel produced from tallow:

- Conversion of tallow to renewable diesel using higher energy use for rendering
- Conversion of tallow to renewable diesel using lower energy use for rendering

There two pathways were modeled because traditional plants need higher energy use but newer plants need lower energy use for the rendering of tallow. Complete details on the the pathways are provided in the *Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U.S. Sourced)*.[18]

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[17] California Air Resources Board, *LCFS Carbon Intensity Lookup Table*, December 2012.
[18] Air Resources Board. *Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U.S. Sourced).* September 23, 2009, Version 2.0.

Tallow is animal fat derived from waste at a meat processing plant. Rendering produces two types of tallow: edible and inedible tallow. Edible tallow is used by the food industry and most of the inedible tallow is currently used as a supplement in animal feed. New regulations under development by the Food and Drug Administration are likely to ban the use of tallow and other animal based waste products in animal feed (due to bovine spongiform encephalopathy and other similar diseases) and it is likely that use of inedible tallow as feed supplements will diminish in the future. Edible tallow that is generated from the rendering process is not considered a feedstock from renewable diesel production. Only inedible tallow is considered in the LCFS pathway analyses.

The transformation of tallow to renewable diesel includes transport of tallow produced in the Mid-Western United States to a California refinery via rail. The tallow is then co-processed with traditional crude in a refinery to produce renewable diesel.[19]

Compared to petroleum diesel, the soybean derived renewable diesel reduces GHG emissions by about 15% and the tallow derived renewable diesel using lower energy use for rendering reduces GHG emissions by about 80%.

[19] Air Resources Board. *Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U.S. Sourced).* September 23, 2009. Version 2.0, 2-3.

4. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In this chapter, staff provides the air quality assessment and emissions impact summary, conclusions, and recommendations.

A. Summary

ARB staff completed an air quality assessment of renewable diesel fuel. The evaluation includes a description of the emissions test program and impact analysis on air emissions, including toxic air contaminants and ozone precursors. The complete evaluation report is provided in Appendix C.

Staff's assessment is based on the data and information provided for the renewable diesel multimedia evaluation, including the UC researchers' multimedia reports (Final Tier I, Tier II, and Tier III reports) and the "*CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California*" (ARB Emissions Study)[20] by UC Riverside from emissions testing conducted at the College of Engineering – Center for Environmental Research and Technology (CE-CERT) and ARB emissions test facilities in Stockton and El Monte, California

Emissions testing was conducted on pure renewable diesel (R100) and two renewable diesel blends (R20 and R50) with CARB diesel as the baseline fuel. The test program includes both engine testing and chassis testing of renewable diesel and renewable diesel blends. Generally at least six repetitions were conducted on each fuel blend. The results of the testing were straight averages of the difference between renewable diesel and CARB diesel emissions.

Engine testing was performed on a 2006 Cummins ISM engine. Chassis testing was performed on a 2000 Caterpillar C-15 engine. Toxic emissions testing was completed on the Caterpillar C-15 engine.

1. Health-Relevant Air Emissions

Engine testing conducted as part of the ARB Emissions Study focused primarily on regulated emissions, including particulate matter (PM), nitrogen oxides (NOx), total hydrocarbons (THC), and carbon monoxide (CO). More extensive testing, including toxics analyses, was completed for chassis testing.

For R100, PM emissions results showed an average decrease of about 30%. NOx emissions results showed a decrease of about a 10%. THC and CO generally decreased by about 5% and 10%, respectively.

[20] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011.

ARB identified diesel PM as a toxic air contaminant in 1998, and determined that diesel PM accounts for about 70% of the toxic risk from all identified toxic air contaminants.[21] Test results show that the use of renewable diesel reduces PM emissions by about 30%.[22]

Other toxic emissions tests were conducted for various carbonyls, volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs). Overall, toxics test results show decreases in most PAHs and VOCs. Carbonyl emissions were not significantly different between renewable diesel and CARB diesel. Genotoxicity assays were also performed and in all cases renewable diesel showed either reduced toxicity compared to CARB diesel or no difference in toxicity.[23]

2. Climate-Relevant Air Emissions

Gases that trap heat in the atmosphere are called greenhouse gases (GHGs). GHG emissions are primarily CO_2, methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons.[24] Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years.[25] GHG emissions from the use of fuels are primarily CO_2.[26] Average CO_2 emissions results from the ARB Emissions Study showed a general decreased by about 3%.

Life cycle GHG emissions include emissions associated with the production, transportation, and use of a fuel in a motor vehicle. The life cycle analysis (LCA) of a fuel includes direct emissions from producing, transporting, and using the fuel, as well as indirect effects, including land use change. Depending on the fuel, GHG emissions from each step of the life cycle can include CO_2, CH_4, N_2O, and other GHG contributors. The "carbon intensity" of a fuel represents the equivalent amount of CO_2 emitted from each stage of the fuel's life cycle and is expressed in terms of grams of CO_2 equivalent per megajoule (gCO_2e/MJ).[27]

[21] Air Resources Board. *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles.* October 2000. Page 1.
[22] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* Oct 2011, Table ES-6, xxxvii.
[23] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011, 148,164.
[24] Air Resources Board. *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles*. August 6, 2004, i.
[25] United States Environmental Protection Agency. *Overview of Greenhouse Gases* website. http://www.epa.gov/climatechange/ghgemissions/gases.html. Accessed April 29, 2015.
[26] Air Resources Board. *Proposed Re-Adoption of the Low Carbon Fuel Standard*. *Staff Report: Initial Statement of Reasons*. December 2014, ES-2.
[27] Air Resources Board. *Proposed Re-Adoption of the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons.* December 2014.

In contrast, end-of-pipe or tailpipe emissions only include exhaust emissions associated with the use of a fuel in an internal combustion engine.[28] Tailpipe CO_2 emissions are only one component in determining a fuel's life cycle carbon emissions. As previously stated, the measured increase in CO_2 emissions may not necessarily lead to an overall increase in carbon emissions. An increase in CO_2 reflects more complete combustion, and is an expected result of decreased THC and CO emissions.

Based on the results from the ARB Emissions Study, renewable diesel increased BSFC by about 5%. However, as with any alternative fuel, determination of GHG emissions impact is the result of a full LCA of the fuel. For renewable diesel, the outcome of the analysis is greatly dependent on the feedstock source. The LCA of renewable diesel under the Low Carbon Fuel Standard showed reductions in GHGs of about 15% to 80% depending on feedstock source.[29]

3. Secondary Air Pollutants

Secondary pollutants form in the atmosphere through chemical and photochemical reactions from other primary pollutants. An example includes ozone, which is formed when hydrocarbons and NOx combine in the presence of light. Its precursor components are primarily the result of road traffic. Unlike many of the other GHGs, ozone is a short-lived gas that is found in regionally varying concentrations.

Both THC and NOx emissions determine ozone concentrations. As previously stated, test results show a decrease in NOx emissions and most VOCs. THC emissions also generally decreased by about 5% from CARB diesel emissions levels. Overall, it's expected that the use of renewable diesel would result in an improvement in ground level ozone compared to the use of CARB diesel fuel.[30]

B. Conclusions

Based on a relative comparison between CARB diesel and hydrotreated vegetable oil renewable diesel, ARB staff concludes that renewable diesel, as specified in this multimedia evaluation and proposed regulation, does not pose a significant adverse impact on public health or the environment from potential air quality impacts.

ARB staff also makes the following general conclusions:

- Renewable diesel reduces PM emissions in diesel exhaust.
- Renewable diesel reduces emissions and health risk from PM in diesel exhaust, a toxic air contaminant identified by ARB.

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[28] Air Resources Board. *Proposed Regulation to Implement the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons.* March 2009, IV-12.
[29] California Air Resources Board, *LCFS Carbon Intensity Lookup Table*, December 2012. http://www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf (accessed October 15, 2013).
[30] Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011, 89.

- Renewable diesel reduces NOx emissions in diesel exhaust.
- Renewable diesel reduces CO emissions in diesel exhaust.
- The adverse effects of renewable diesel are expected to be less than or equal to diesel fuel complying with current ARB fuel regulations.

Compared to CARB diesel, emissions testing results for renewable diesel show reductions in PM, NOx, CO, and THC. Toxics test results also show reductions in most PAHs and VOCs.

C. Recommendations

Based on the air quality assessment and evaluation of emissions impacts from the use of renewable diesel, ARB staff recommends that the CEPC find that the use of renewable diesel, as specified in the multimedia evaluation and the proposed regulation, does not pose a significant adverse impact on public health or the environment from potential air quality impacts, relative to CARB diesel fuel.

5. REFERENCES

Note: References are listed according to the corresponding footnote in the staff report. For references available online, electronic links have been provided. References used more than once are indicated as a duplicate (e.g., "Same as Footnote 2"), excluding specific page numbers, and are listed to maintain the order and numbering of the footnotes in the report.

1. Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*, October 23, 2013. http://www.arb.ca.gov/regact/2013/adf2013/adf2013isor.pdf (accessed November 4, 2013).

2. California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8. http://www.arb.ca.gov/bluebook/bb11/hea/hea-43830_8.htm (accessed November 4, 2013).

3. McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Final Tier I Report*, September 2011. http://www.arb.ca.gov/fuels/multimedia/meetings/RenewableDiesel_FinalTierIReport_Sep2011_110413.pdf (accessed November 4, 2013).

4. McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Final Tier III Report*, April 2012. http://www.arb.ca.gov/fuels/multimedia/meetings/RenewableDiesel_FinalReport_Apr2012_101113.pdf (accessed November 11, 2013).

5. Durbin, T.D. et al. *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California "Biodiesel Characterization and NOx Mitigation Study."* October 2011. http://www.arb.ca.gov/fuels/diesel/altdiesel/20111013_CARB%20Final%20Biodiesel%20Report.pdf (accessed November 4, 2103).

6. Same as Footnote 1.

7. Air Resources Board. *Low Carbon Fuel Standard.* Title 17, California Code of Regulations, Sections 95480-95490.

8. Same as Footnote 3.

9. Same as Footnote 4.

10. Biofuels Digest, December 3, 2010, *Neste Oil becomes Chief Monster as renewable diesel becomes biofuels monster*, http://www.biofuelsdigest.com/bdigest/2010/12/03/neste-oil-becomes-chief-monster-as-renewable-diesel-becomes-biofuels-monster/ (accessed September 17, 2013).

11. Dynamic Fuels, http://www.dynamicfuelsllc.com/about.aspx (accessed June 28, 2013).

12. DAR PRO Diamond Green Diesel Renewable Fuel, *Thinking big: A partnership with Valero Energy Corporation for mass-scale green diesel production,* http://www.darpro.com/diamond-green-diesel (accessed June 28, 2013).

13. Emerald Biofuels News, *Emerald Biofuels Plans Renewable Diesel Refinery in Plaquemine, Louisiana,* May 8, 2012, http://emeraldbiofuels.com/news.php (accessed June 28, 2013).

14. Same as Footnote 5.

15. Same as Footnote 5.

16. Air Resources Board. *LCFS Carbon Intensity Lookup Table*, December 2012. http://www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf (accessed October 15, 2013).

17. Air Resources Board. *Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U.S. Sourced).* September 23, 2009, Version 2.0. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_tallow_rd.pdf. (accessed May 8, 2015).

18. Same as Footnote 17.

19. Same as Footnote 5.

20. Air Resources Board. *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles*. October 2000. http://www.arb.ca.gov/diesel/documents/rrpFinal.pdf (accessed May 7, 2015).

21. Same as Footnote 5.

22. Same as Footnote 5.

23. Air Resources Board. *Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles*. August 6, 2004. http://www.arb.ca.gov/regact/grnhsgas/isor.pdf (accessed February 23, 2015).

24. United States Environmental Protection Agency. *Overview of Greenhouse Gases* website. http://www.epa.gov/climatechange/ghgemissions/gases.html. (accessed April 29, 2015).

25. Air Resources Board. *Proposed Re-Adoption of the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons*. December 2014. http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15isor.pdf (accessed February 23, 2015).

26. Same as Footnote 25.

27. Resources Board. *Proposed Regulation to Implement the Low Carbon Fuel Standard. Staff Report: Initial Statement of Reasons.* March 2009, IV-12. http://www.arb.ca.gov/regact/2009/lcfs09/lcfsisor1.pdf http://www.arb.ca.gov/regact/2009/lcfs09/lcfsisor2.pdf (accessed May 8, 2015).

28. Holloway, Tracey. *Review of "Staff Report: Multimedia Evaluation of Biodiesel."* February 2014.

29. Air Resources Board. *LCFS Carbon Intensity Lookup Table*, December 2012. http://www.arb.ca.gov/fuels/lcfs/lu_tables_11282012.pdf (accessed October 15, 2013).

30. Same as Footnote 5.

APPENDIX D

State Water Resources Control Board: Renewable Diesel Multimedia Evaluation

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CALIFORNIA
Water Boards

EDMUND G. BROWN JR.
GOVERNOR

MATTHEW RODRIQUEZ
SECRETARY FOR
ENVIRONMENTAL PROTECTION

State Water Resources Control Board

TO: Floyd Vergara
Chief, Alternative Fuels Branch
California Air Resources Board

FROM: Shahla Dargahi Farahnak, P.E.
Assistant Deputy Director
Division of Water Quality

DATE: August 26, 2013

SUBJECT: STAFF COMMENTS AND RECOMMENDATIONS ON BIODIESEL AND RENEWABLE DIESEL APPLICATION FOR MULTIMEDIA WORKING GROUP REVIEW

State Water Resources Control Board (State Water Board) staff have completed its review of the Biodiesel January 2009 Tier I Report, February 2012 Tier II Report and May 2013 Tier III Report. State Water Board staff have also completed its review of the Renewable Diesel September 2011 Tier I Report and April 2012 Tier III Report.

This memo transmits State Water Board staff comments and recommendations on the above mentioned Tier III reports.

If you have any questions regarding staff recommendations, please contact Laura Fisher, Chief of the UST Leak Prevention Unit at (916) 341- 5870 or laura.fisher@waterboards.ca.gov.

Attachments (2)

cc: Mr. Kevin L. Graves, Manager
UST and Site Cleanup Program
State Water Resources Control Board

Ms. Laura S. Fisher, Chief
UST Leak Prevention and
Office of Tank Tester Licensing
State Water Resources Control Board

Attachment #1

State Water Resources Control Board Staff Comments
Biodiesel Multimedia Evaluation

Below are comments on the California Biodiesel Multimedia Evaluation, May 2013, Tier III Report, prepared by the University of California, Davis, and the University of California, Berkeley.

Background

State Water Resources Control Board (State Water Board) staff has reviewed the University of California, Davis and the University of California, Berkeley, Tier I, Tier II, and Tier III Reports. The multimedia evaluation and review of environmental impacts is specific to the difference between biodiesel and to California Air Resources Board (CARB) diesel.

Biodiesel is an alternative diesel derived from biological sources. To create biodiesel a biological feedstock is reacted with alcohol and a catalyst to produce Fatty Acid Methyl Ester and the byproduct glycerin. Fatty Acid Methyl Ester also known as biodiesel can be blended with CARB diesel; B100 refers to pure biodiesel, B20 refers to a blend of 20% pure biodiesel and 80% CARB diesel, and so on.

Water Impacts

Based on a relative comparison between biodiesel and CARB diesel, as substantiated in the multimedia evaluation, State Water Board staff concludes:

- Aquatic toxicity screening with unadditized and additized biodiesel and biodiesel blends showed an increase in toxicity to subsets of screening species compared to CARB diesel.
- Water allocation and agricultural impacts associated with the growing of feedstocks used in the production of biodiesel were not considered as part of the multimedia evaluation. A supplemental multimedia review may need to be performed in the future to evaluate any agricultural and water resource impacts if feedstocks are to be grown in California.

UST Material Compatibility and Leak Detection

Material compatibility testing has demonstrated that biodiesel and biodiesel blends are incompatible with various products commonly used in California's existing underground storage tank (UST) infrastructure. Incompatibility increases the risk of unauthorized releases, therefore material selection in UST equipment and leak detection technology is important to prevent releases. Material compatibility and leak detection functionality with a stored substance is a requirement of the UST laws and regulations, and verified by the local permitting agency with the UST owner or operator. Recently revised UST regulations allow the storage of substances not certified as compatible by an independent testing organization, typically Underwriters Laboratories (UL), if the manufacturer of the components provides affirmative statements of compatibility. This option however is limited to double-walled UST's. UL's current certification status of biodiesel blends only includes blends up to B5. Therefore biodiesel blends up to B5 can be stored in both single or double-walled petroleum approved USTs. Blends above B5 may be stored in double-walled petroleum USTs when the manufacturer provides affirmative statements of compatibility.

Biodegradability and Fate/Transport

Multimedia evaluation identifies that unadditized biodiesel and biodiesel blends consistently show increased biodegradation as compared to CARB diesel, and that additized biodiesel and biodiesel blends can result in decreased biodegradation. These biodegradability scenarios are influenced by the additives used and biodiesel blend concentration.

Waste Discharge From Manufacturing

Chemicals used in the production and byproducts are required to comply with hazardous waste laws and regulations. No significant areas of concern have been identified by staff when comparing the waste streams of biodiesel to CARB diesel.

Conclusion and Recommendations

State Water Board staff concludes that given the information provided by University of California, Davis, and the University of California, Berkeley, there are minimal additional risks to beneficial uses of California waters posed by biodiesel than that posed by CARB diesel alone. State Water Board staff supports the multimedia evaluation of biodiesel which meets the ASTM fuel specifications and the finding of no significant adverse impacts on public health or the environment with the recommendations provided in the Biodiesel Multimedia Evaluation Staff Report.

As identified in the California Biodiesel Multimedia Evaluation Report, Tier III, the potential scope of any unanticipated impacts is difficult to determine due to the limited funding and time of the multimedia evaluation. Unanticipated risks and problems that may occur as full scale use of biodiesel becomes common will need to be addressed as they occur.

This recommendation is contingent upon biodiesel and biodiesel blends meeting the ASTM fuel specifications and using the same additives described in the California Biodiesel Diesel Multimedia Evaluation.

Attachment #2

State Water Resources Control Board Staff Comments
Renewable Diesel Multimedia Evaluation

Below are comments on the California Renewable Diesel Multimedia Evaluation, April 2012, Tier III Report, prepared by the University of California, Davis, and the University of California, Berkeley.

Background

State Water Resources Control Board (State Water Board) staff has reviewed the University of California, Davis and the University of California, Berkeley, Tier I and Tier III Reports. The multimedia evaluation and review of environmental impacts is specific to the difference between renewable diesel and California Air Resources Board (CARB) diesel.

Renewable diesel is an alternative diesel derived from non-petroleum sources. Renewable diesel is free of ester compounds and has a chemical composition that is almost identical to petroleum based diesel. To produce renewable diesel, a feedstock is converted into diesel fuel through a catalytic treatment that adds hydrogen. Hydrogenated-derived renewable diesel is then refined, typically at existing oil refineries. Renewable diesel can be blended with CARB diesel to create various renewable diesel blends.

Water Impacts

Aquatic toxicity was considered by comparing renewable diesel and CARB diesel. State Water Board staff reviewed the data comparing the effects of renewable diesel and CARB diesel when exposed to a series of aquatic toxicity tests. No significant changes in aquatic toxicity were identified by the multimedia study.

UST Material Compatibility and Leak Detection

California statutes require that underground storage tank (UST) systems be compatible with the substance stored, and that leak detection equipment be able to function appropriately with the substance stored. The multimedia evaluation indicates that renewable diesel is chemically comparable to CARB diesel, therefore differences in compatibility and leak detection are not anticipated.

Biodegradability and Fate/Transport

University of California, Davis, and University of California, Berkeley, provided data on the impacts of fate and transport properties of renewable diesel as compared to the CARB diesel. Fate and transport, as well as biodegradability, are not expected to be significantly different given the similar chemical composition of renewable diesel and CARB diesel.

State Water Resources Control Board Staff Comments
Renewable Diesel Multimedia Evaluation

Waste Discharge From Manufacturing

Chemicals used in, and byproducts created by, the production are required to comply with hazardous waste laws and regulations. No significant areas of concern have been identified when comparing the waste streams of renewable diesel to CARB diesel.

Conclusion and Recommendations

State Water Board staff concludes that given the information provided by University of California, Davis, and University of California, Berkeley, and the similarities of renewable diesel and CARB diesel, there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone. State Water Board staff supports the multimedia evaluation of ASTM D975 renewable diesel and a finding of no significant adverse impacts on public health or the environment with the recommendations provided in the Renewable Diesel Multimedia Evaluation Staff Report.

As identified in the California Renewable Diesel Multimedia Evaluation Report, Tier III, the potential scope of any unanticipated impacts is difficult to determine due to the limited funding and time of the multimedia evaluation. Unanticipated risks and problems that may occur as full scale use of renewable diesel becomes common will need to be addressed as they occur.

This recommendation is contingent upon renewable diesel meeting the ASTM D975 fuel specifications, being chemically indistinguishable from CARB diesel, and using the same additives described in the California Renewable Diesel Evaluation.

APPENDIX E

Office of Health Hazard Assessment: Staff Report on Health Impacts of Renewable Diesel Fuel

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Chemical Properties and Toxic Effects of Combustion Emissions from Diesel Engines Using Renewable Diesel Fuel Produced by Hydrotreating Fatty Acids from Plant Sources

April 2014

Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

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Introduction

Renewable diesel is a mixture of aliphatic hydrocarbons with physical properties similar to those of conventional diesel fuel. Hydrotreated vegetable oil is a renewable diesel fuel produced from fatty acids derived from plant sources. This report reviews studies comparing combustion emissions and their toxicity from an engine using hydrotreatred vegetable oil renewable diesel (HVORD) with those from the same engine using California Air Resources Board (CARB) ultra-low-sulfur diesel (ULSD) or other currently used diesel fuel.

Much of the information reviewed in this report was obtained by scientists at the University of California under contract with CARB. This information is contained in a document released by CARB (CARB, 2011) entitled *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, 2011.*[1] In addition, OEHHA staff also found peer-reviewed scientific articles on chemical properties and biological effects of renewable diesel combustion emissions and reviewed these articles.

In this report, information on the chemical composition and particulate matter (PM) content of combustion emissions is summarized first. This is followed by summaries of results of biological tests of the toxicity of substances found in combustion emissions. In every case the results obtained using renewable diesel are compared with results obtained using a petroleum-based diesel fuel.

Combustion Emissions of PM, NO_x and Toxic Organic Chemicals

Diesel engine emissions from combustion of HVORD and CARB ULSD were quantified by the Center for Environmental Research and Technology (CERT) at the University of California, Riverside (CARB, 2011). The renewable diesel fuel was produced by Neste Oil and denoted NExBTL fuel. In the following sections, CARB ULSD fuel blended with 20% or 50% NExBTL fuel is denoted R20 or R50, respectively, and pure NExBTL is denoted R100.

In the CERT study, PM, oxides of nitrogen (NO_x), carbon monoxide (CO), and total hydrocarbons (THC) were measured in combustion emissions from a 2006 Cummins ISM engine and a 2000 Caterpillar C-15 engine. Emissions from the Caterpillar C-15 engine were determined for the Urban Dynamometer Driving Schedule (UDDS) and the 50 mph cruise simulation. Emissions from the 2006

[1] CARB (2011) available online at: http://www.arb.ca.gov/fuels/diesel/altdiesel/20111013_CARB%20Final%20Biodiesel%20Report.pdf.

Cummins ISM engine were determined for the UDDS test protocol, the 50 mph cruise protocol and the Federal Testing Procedure (FTP) protocol (CARB, 2011).

In tests using the 2006 Cummins ISN engine, there was a significant reduction in PM emissions from R50 and R100 combustion compared with emissions from CARB ULSD combustion during the UDDS protocol and the 50 mph cruise simulation protocol, and there was a significant decrease in PM for R20, R50 and R100 during the FTP protocol. There was a significant decrease in NO_x emissions during all three test protocols for R20, R50 and R100. There was a significant reduction in CO emissions using R20, R50 or R100 during the UDDS and FTP protocols. There was a small but statistically significant increase in CO using R100 during the 50 mph cruise simulation protocol (CARB, 2011).

In tests using the Caterpillar C-15 engine, there was a significant reduction in PM emissions using R50 or R100 during the UDDS protocol but no significant reductions during the 50 mph cruise simulation protocol. There were significant reductions of NO_x using R20, R50 or R100 during the UDDS protocol but no significant reductions using the 50 mph cruise simulation protocol. CO emissions were reduced when R20, R50 or R100 were used but the reductions were significant only for R50 using the UDDS protocol and R100 using the 50 mph cruise simulation protocol (CARB, 2011).

In tests using the 2000 Caterpillar C-15 engine operated with the UDDS cycle, emissions of benzene and ethylbenzene were significantly lower using HVORD than they were using CARB diesel. When the engine was operated using the 50 mph cruise simulation, emissions of both benzene and toluene were significantly lower using HVORD than they were using CARB diesel. Emissions of ethylbenzene were lower when HVORD was used, but the reduction in emissions was not statistically significant (CARB, 2011).

Polycyclic aromatic hydrocarbons (PAHs) were measured in emissions from a 2000 Caterpillar C-15 engine operated using the UDDS cycle. There was a consistent decreasing trend in PAH emissions with increasing concentrations of HVORD in CARB-renewable diesel blends R20, R50 and R100 (CARB, 2011).

Murtonen *et al*. (2009) compared engine emissions from truck (Scania DT 12 11 420, Variant L01) and off-road (Sisudiesel 74 CTA-4V) SCR-equipped diesel engines fueled with EN590 petroleum diesel (EN590) that contains less than 10 parts per million (ppm) sulfur or HVORD. The emissions testing for the engines described above was performed using an engine dynamometer. The Scania engine was tested using a Braunschweig cycle, and the SisuDiesel engine was tested using an NRTC test cycle and an ISO C1 steady-state test cycle. Both regulated and unregulated emission outputs were expressed in units of weight/distance (e.g. milligrams per kilometer [mg/km]).

In the absence of a Diesel Oxidation Catalyst (DOC)/Particulate Oxidation Catalyst (POC) catalytic converter, PM and PAH output from the Scania engine run on HVORD was substantially reduced (43% and 68%, respectively) compared to operation on EN590. Moderate decreases (approximately 20%) were noted for carbon monoxide (CO), total hydrocarbons (THC), formaldehyde (FA), acetaldehyde (AA) and other aldehydes/ketones, and no change was noted for oxides of nitrogen (NO_x) in the HVORD-fueled engine exhaust compared to the EN590-fueled engine (Murtonen *et al*., 2009).

In the presence of a DOC/POC catalytic converter, PM and PAH output from the Scania engine run on HVORD was substantially reduced (39% and 67%, respectively) compared to operation on EN590. A slight increase was noted for NO_x, and no change was noted for CO in the HVORD-fueled engine exhaust compared to the EN590-fueled engine (Murtonen *et al*., 2009).

No significant difference was noted for CO, THC, PAH, FA, AA or other aldehyde/ketone output from the HVORD-fueled Sisudiesel engine run on either the NRTC or ISO cycles compared to the EN590-fueled engine. PM output from the HVORD-fueled engine was moderately decreased (25-35%), as was NO_x output (12-15%) compared to the EN590-fueled engine on both test cycles (Murtonen *et al*., 2009).

Jalava *et al*. (2010) compared exhaust toxicities from a small industrial diesel engine (Kubota D1105-T) fueled with EN590 or HVORD using an ISO C1 steady-state test cycle. PM output (mg/kW-hr) from the HVORD-fueled engine was 22% less compared to the EN590-fueled engine in the absence of a DOC/POC catalytic converter, but when a DOC/POC catalytic converter was used PM emissions from combustion of HVORD were 18% greater than emissions from combustion of EN50 fuel.

Particulate-phase total and genotoxic PAHs (WHO/IPCS 1998 definition) were substantially reduced in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust (54 and 57% decrease, respectively; expressed as ng/mg PM) in the absence of a DOC/POC catalytic converter. HVORD-fueled engine emissions demonstrated moderately reduced total particulate-phase PAH emissions (31%) and genotoxic particulate-phase PAH emissions (11%) compared to a EN590-fueled engine in the presence of a DOC/POC catalytic converter (Jalava *et al*., 2010).

In the fuel type comparison described above, the authors normalized PAH emissions to PM output. If PAH emissions are expressed in terms of nanograms per kilowatt-hour (ng/kW-hr), total and genotoxic particulate-phase PAH emissions were substantially reduced (64 and 66%, respectively) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in the absence of a DOC/POC catalytic converter. In the presence of a DOC/POC catalytic converter, total PAHs were moderately reduced (18%) while genotoxic PAHs were slightly increased (6%) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust (Jalava *et al*., 2010).

Heikkilä *et al*. (2012) tested the comparative exhaust emissions of an off-road diesel engine operated on a steady-state cycle without a DOC/POC catalytic converter and fueled with either EN590 or HVORD. PM output with HVORD fuel was reduced approximately 28 – 43% depending on engine load compared to the EN590 fuel. NO_x emissions were similar for both fuels. Use of HVORD fuel reduced total particulate-phase PAH emissions by approximately 50% at all engine loads compared to the baseline fuel. Aldehyde exhaust output, including formaldehyde and acetaldehyde, was similar for both EN590 and HVORD fuel.

Similar to the Jalava *et al*. (2010) study, in the fuel type comparison described above, the authors normalized PAH emissions to PM output. If PAH emissions are expressed in terms of ng/kW-hr, total and genotoxic particulate-phase PAH emissions were substantially reduced (58 and 62%, respectively) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in the absence of a DOC/POC catalytic converter. In the presence of a DOC/POC, total PAHs were slightly increased (10%) while genotoxic PAHs were moderately increased (18%) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust (Heikkilä *et al*., 2012).

Toxicity Testing of Combustion Emissions

In the combustion emissions study performed for CARB, *Salmonella typhimurium* test strains TA98 and TA100 were exposed to emissions samples from an engine run on either CARB ULSD fuel, or 20%, 50% or 100% HVORD (R20, R50 or R100, respectively) in the presence or absence of metabolic activation provided by rat liver S9. Particulate-phase and vapor-phase exhaust mutagenicity generally decreased as the percentage of HVORD in the engine fuel increased in both test strains with or without S9 (CARB, 2011).

Human U937 monocytic cells were exposed to particulate phase engine exhaust extract under the conditions described above, and evaluated for induction of DNA damage using the COMET assay. No increase in DNA damage was induced by exhaust from an HVORD or HVORD blend-fueled engine (CARB, 2011).

The release of interleukin 8 (IL-8; a cytokine mediator of inflammation) from a human U937 macrophage cell line or cyclooxygenase 2 (COX-2; an inflammation mediator) from a human NCI-H441 bronchiolar Clara cell line was not increased by exposure to HVORD or HVORD blend-fueled engine particulate phase exhaust extracts relative to exposure of the cells to particulate phase exhaust extract from a ULSD-fueled engine (CARB, 2011).

Murtonen *et al*. (2009) compared the mutagenicity of engine emissions from truck (Scania DT 12 11 420, Variant L01) and off-road (Sisudiesel 74 CTA-4V SCR-equipped) diesel engines fueled with EN590 petroleum diesel (EN590) that contains less than 10 ppm sulfur or HVORD. In tests using an engine that was not equipped with a DOC/POC catalytic converter, a substantial decrease (68%) was noted for mutagenicity in *Salmonella typhimurium* (strain TA98) treated with HVORD-fueled engine PM extract in the absence of metabolic activation compared to PM extract from an EN590-fueled engine. In tests using an engine equipped with a DOC/POC catalytic converter, no mutagenicity was noted in *Salmonella typhimurium* (strain TA98) treated with HVORD-fueled engine PM extract in the absence of metabolic activation, and mutagenicity from PM extract from an EN590-fueled engine was described by the authors as "minor" (93% reduction compared to test results from an engine not equipped with a DOC/POC catalytic converter).

Jalava *et al*. (2012) compared exhaust toxicities from a 2005 model year Scania heavy-duty diesel engine equipped with a DOC/POC catalytic converter and fueled with EN590 or HVORD using a Braunschweig test cycle (Murtonen *et al*., 2009). The effects of engine exhaust PM extracts on cytotoxicity and apoptosis were tested *in vitro* using the mouse macrophage RAW264.7 cell line at exposure levels of 0, 50, 150 and 300 µg/ml. PM extract-induced cytotoxicity was measured by a 3-(4,5-dimethylthiazolyl-2)-2,5-diphenyltetrazolium bromide test (MTT-test; measures metabolic activity). Apoptosis was determined by using a flow cytometry assay to evaluate propidium iodide (PI)-stained cells. No significant differences in either cytotoxicity or apoptosis were noted in the mouse macrophage cell line RAW264.7 when exposed *in vitro* to PM from the test engine fueled with HVORD compared to PM from the test engine fueled with EN590, with or without use of a DOC/POC catalytic converter.

The effects of HVORD- and EN590-fueled engine PM on MIP-2 and TNF-∝ (cytokines that mediate inflammation) release were studied using mouse macrophage RAW264.7 cells *in vitro*. Both MIP-2 and TNF-∝ release were slightly increased by HVORD-fueled engine PM compared to EN590-fueled engine PM in the absence of a DOC/POC catalytic converter. There was no significant difference in release of either cytokine between the fuel types when a DOC/POC catalytic converter was used (Jalava *et al*., 2012).

DNA damage (Comet assay) in mouse macrophage RAW264.7 cells treated *in vitro* with HVORD-fueled engine PM was statistically significantly increased compared to cells treated with EN590-fueled engine PM in the absence of a DOC/POC catalytic converter. However, in the presence of a DOC/POC catalytic converter there was no significant difference in DNA damage between the two test groups. In the same study, there was no significant difference in reactive oxygen species (ROS) production between the two test groups in the presence or absence of a DOC/POC catalytic converter (Jalava *et al*., 2012).

No significant difference was noted between HVORD-fueled and EN590-fueled engine exhaust cytotoxicity measured using the MTT-test in the presence or absence of a DOC/POC. EN590-fueled engine exhaust appeared to have greater cytotoxicity than HVORD-fueled engine exhaust at the higher exposure levels in the absence of a DOC/POC catalytic converter as measured by the PI exclusion test. However, no difference in exhaust-induced apoptosis was evident between the two fuel types in the presence of a DOC/POC catalytic converter (Heikkilä *et al*., 2012).

DNA damage (Comet assay) in mouse macrophage RAW264.7 cells treated *in vitro* with HVORD-fueled engine PM was decreased compared to cells treated with EN590-fueled engine PM in the absence of a DOC/POC catalytic converter. This result is in the opposite direction of that observed by Jalava et al, 2012. In the same study, there was no significant difference in reactive oxygen species (ROS) production between the two test groups in the presence or absence of a DOC/POC catalytic converter (Heikkilä *et al*., 2012).

Conclusions

PM, benzene, ethylbenzene and toluene in combustion emissions from diesel engines using HVORD are significantly lower than they are in combustion emissions from engines using conventional diesel. CO and NO_x emissions are significantly lower in some, but not all, tests using HVORD fuel. PAH emissions from engines not equipped with a DOC/POC were lower in exhaust of engines burning HVORD. In some tests of engines equipped with a DOC/POC, PAH emissions were higher in exhaust from an engine using HVORD fuel. It should be noted that semi-volatile exhaust phase PAHs were only measured in the CARB (2011) study. Variability between studies precluded drawing a conclusion as to differences in PAH exhaust output levels and PAH/PM exhaust ratios from engines equipped with a DOC/POC between the two fuel types.

HVORD-fueled engine exhaust did not significantly increase pulmonary cytokine production (an inflammation biomarker), cytotoxicity, apoptosis or ROS production in the presence or absence of a DOC/POC. Variability in assay types, engine and test cycle types and emission control status precluded drawing a conclusion as to differences in exhaust-induced genotoxicity between the two fuel types.

Office of Environmental Health Hazard Assessment (OEHHA) scientists conclude that use of renewable diesel fuel produced by hydrotreating fatty acids from vegetable oil may reduce the amount of PM and aromatic organic chemicals that are released into the atmosphere in diesel engine exhaust. OEHHA scientists do not find any evidence that these potential beneficial impacts are offset by adverse impacts on human health that might result from replacing CARB ULSD with HVORD.

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APPENDIX F

Department of Toxic Substances Control: Recommendation on Proposed Renewable Diesel

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Matthew Rodriquez
Secretary for
Environmental Protection

Department of Toxic Substances Control

Deborah O. Raphael, Director
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Edmund G. Brown Jr.
Governor

MEMORANDUM

DATE: May 9, 2013

TO: Multimedia Work Group
Air Resource Board

FROM: Donn Diebert, P.E. Chief,
Policy Implementation Unit
Hazardous Waste Management Program

SUBJECT: DTSC's Recommendation on Proposed Renewable Diesel

According to the renewable diesel application Tier I and Tier III reports, renewable diesel is a "green diesel fuel", which is produced from biomass, such as plant oil, animal fat/tallow, and other wastes in California. Air tests showed that renewable diesel can reduce air emissions in engine exhaust compared to California Air Resource Board (CARB) diesel. Typically, three methods are used to produce renewable diesel. This application is limited to the renewable diesel produced by hydrotreatment process.

Renewable diesel is chemically similar to CARB diesel and has a lower content of aromatic hydrocarbons than CARB diesel. These characteristics will potentially make the effects of a spill or release of renewable diesel into environment equally or less severe compared to the release of CARB diesel. However, the chemical composition from the production of the fuel and additives in the fuel may vary with different feedstock and production processes. Increased waste discharge from the process of extracting plant seed oils and releases of large volumes of raw triglycerides with tallow usage during the large-scale industrial operations may pose impacts to California's air and water. Additional research would be beneficial as large-scale operations are proposing to market in California.

Both Tier I and Tier III reports indicated that the knowledge gaps regarding the impact from releases of the associated additives should be of concern. The specific chemical components and amounts of any additives that may be used in renewable diesel by various producers have not been fully defined and described for the emerging industry in California. Different impacts to human health and the environment between CARB diesel and renewable diesel are more likely to be associated with additives than diesel fuels. Since little is known about the types, chemical nature and volume of the additives that are expected to be used with renewable diesel, DTSC considers that this is an area that deserves further in-depth investigation by the MMWG, in particular significant changes to surface soil and subsurface soil mobility of renewable diesel, changes in potential biodegradability of the diesel and contamination of soil, surface water, and groundwater from the additives.

Recommendations:

DTSC supports the renewable diesel application due to its green resources and air emission reduction under the following conditions:

1) The same additives used in conventional CARB diesel will be used in renewable diesel at approximately the same concentrations;

2) Any hazardous substances[1] used in production, storage, and transportation of renewable diesel will be handled in compliance with applicable California laws and regulations; and

3) No new hazardous wastes will be generated in the production, transportation, use, and disposal of renewable diesel.

DTSC recommends an additional MMWG evaluation be conducted if, in the future, the conditions under which renewable diesel is produced and used are found to be significantly different from the above assumptions. Each company proposing to produce and market renewable diesel within California should provide the CARB with a production, blending, additives, and distribution strategy that includes potential volumes to be stored and transported along with potential release scenarios. A comparative chemical analysis of the product they intend to market should be compared to conventional diesel currently in the market place.

cc: Li Tang, Ph. D., P.E.
Policy Implementation Unit
Hazardous Waste Management Program
Department of Toxic Substances Control

Adriana Ortegon
Policy Implementation Unit
Hazardous Waste Management Program
Department of Toxic Substances Control

[1] Renewable diesel is not a petroleum product and, therefore, it does not qualify for the exclusion of "petroleum" from the definition of a "hazardous substance," pursuant to subsection (a) of section 25317 of the Health and Safety Code.

Summary

DTSC staff assessed the potential impacts to human health and the environment from the production and use of renewable diesel as compared to CARB diesel in light of 1) hazardous waste generation during production, use and storage of renewable diesel in California; and 2) cleanup of contaminated sites in cases of spills of renewable diesel. According to the renewable diesel application Tier I and Tier III reports, three methods are typically used to produce renewable diesel: the Fatty Acids to Hydrocarbon process (hydrotreatment), enzymatic synthesis of hydrocarbons, and a partial combustion of biomass feedstock. All three processes use biomass as their major feedstock. However, the current DTSC evaluation focused on impacts of hydrotreated (HDRD/FAHC) renewable diesel on human health and the environment. The Tier I evaluation showed that the use of renewable diesel decreases PM, NOx and CO emissions in exhaust compared to CARB diesel. It also showed that renewable diesel's chemical composition is very similar to CARB diesel and that renewable diesel has a lower aromatic hydrocarbon content relative to diesel.

Depending on the feedstock, oil extraction chemicals may be used to produce renewable diesel. According to the Tier I and III Reports, oil extraction processes may generate new hazardous waste (n-hexane) and discharge waters that also maybe hazardous waste, during the production of renewable diesel, compared to CARB diesel production releases. Additionally, renewable diesel's releases to soil, groundwater, or surface waters of production chemicals are expected to occur due to rupture or leaks of above ground or below ground storage tanks, production (blending, mixing, and extraction etc.) equipment, piping and/or transportation vehicles. Potential knowledge gaps associated with the impacts of additive use and the potential generation of hazardous waste during production, use, transportation, and storage of renewable diesel may need to be addressed in future multimedia evaluations, if: 1) in-state production of renewable diesel increases, 2) transportation of plant derived oils and tallow increases, or 3) new or different additives are needed to ensure reliable performance during generation, storage and use of renewable diesel.

Conclusions

In comparing renewable diesel with CARB diesel, DTSC's review concludes renewable diesel is free of the ester compounds found in fatty acid methyl ester biodiesel (FAME), and has a lower aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel. Based on the current production, use, transportation and storage of renewable diesel in California will not increase the potential negative impacts to human health and the environment. Both Tier I and Tier III reports highlighted the need to address knowledge gaps associated with environmental impacts of additive use with renewable diesel. The relative environmental impact in case of a spill or leak of renewable diesel compared to a spill or leak from CARB diesel depends on the types, concentrations and use specifications of diesel additives used with renewable diesel, as well as the different production processes.

Since little is known about the types, chemical nature and volume of the additives that are expected to be used with renewable diesel, DTSC considers that this is an area that deserves further in-depth investigation by the MMWG, in particular, significant changes to surface soil and subsurface soil mobility of renewable diesel, changes in potential biodegradability of the diesel and contamination of soil, surface water, and groundwater from the additives.

Based on knowledge gaps identified in the Tier III report, DTSC assumes that the production and use of renewable diesel will meet the following conditions:

1) The same additives used in conventional CARB diesel will be used in renewable diesel at about the same concentrations;

2) Any hazardous substances used in production, storage, and transportation of renewable diesel will be handled in compliance with applicable California laws and regulations; and

3) No new hazardous wastes will be generated in the production, use, storage, transportation, and disposal of renewable diesel.

DTSC recommends an additional MMWG evaluation be conducted if, in the future, the conditions under which renewable diesel is produced and used are found to be significantly different from the above assumptions.

APPENDIX G

California Renewable Diesel Multimedia Evaluation
Final Tier III Report by UC Davis and UC Berkeley

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California Renewable Diesel Multimedia Evaluation

Final Tier III Report

Prepared By

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For the

California Environmental Protection Agency
Multimedia Working Group

FINAL

April 2012

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1. Introduction and Background

This report summarizes the results of Tier I and Tier II studies along with interpretations and conclusions from these studies regarding the suitability of Renewable Diesel as a motor-vehicle fuel in California. Because this is a summary report, the reader is referred to the 2008 Guidance Document and the 2011 Renewable Diesel Tier I report (see Reference list) for specific citations and references supporting the finding summarized below. We begin here with a summary of the multimedia risk assessment process and how it was applied specifically to renewable diesel. We then summarize Tier I and Tier II findings and conclude with overall recommendations.

As required by Section 43830.8 California Health and Safety Code, before adopting new fuel specifications, the California Air Resources Board (CARB) is required to prepare a "multimedia" evaluation and submit it to the California Environmental Policy Council for final review and approval. In general, the State of California needs information that will allow an informed decision as to the relative risk posed by any newly proposed fuel or fuel additive to the State's resources, human health and the environment.

The multimedia risk assessment evaluation includes three components or tiers each designed to provide input to the next stage of the decision-making process. This process is summarized in Table 1 and illustrated in Figure 1.

Table 1.1. Summary of the recommended multimedia risk assessment process.

	Fuel Applicant	Multimedia Work Group Review	MMWG Consultation and Peer Review
Tier I	Fuel Background Summary Report: • Chemistry • Release Scenarios • Environmental behavior	Screens applicant and establishes key risk assessment elements and issues	Technical consultation during development of Tier I Experimental plan including identification of key risk assessment elements and issues
	Mutually agreed upon Experimental Plan for Tier II		
Tier II	Experiments to evaluate key risk assessment elements	Draft Tier II Experimental Summary Report	Technical consultation and independent peer review of Tier II report
Tier III	Multimedia Risk Assessment Report	Prepare recommendations to the Environmental Policy Council based on Multimedia Risk Assessment Report	Independent peer review of Multimedia Risk Assessment report and MMWG recommendations

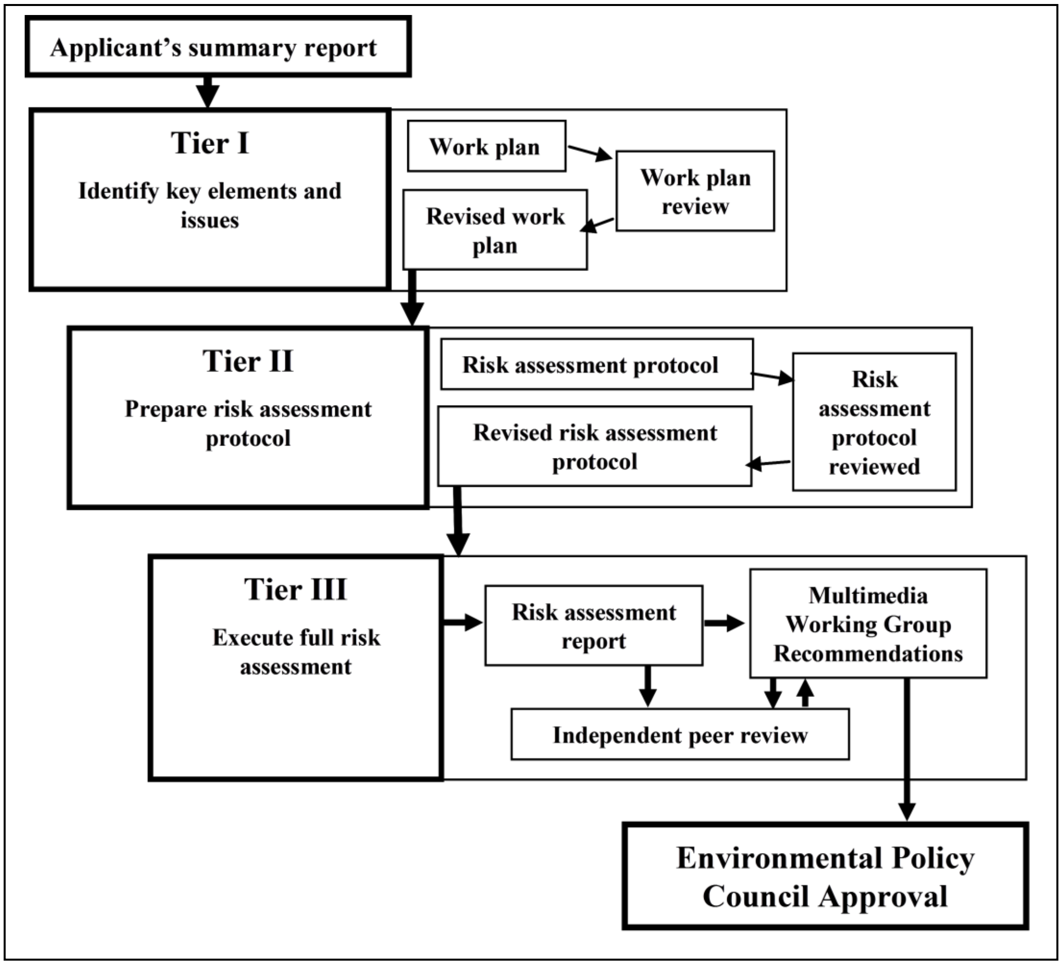

Figure 1.1. Multimedia evaluation process flow chart

The multimedia assessment process requires integration of information across different environmental media, different space and time scales, and different types of populations. New fuels or potential additives must be evaluated not only with regard to engine performance and emission requirements but also with consideration of health and environmental criteria involving air emissions and associated health risks, ozone formation potential, hazardous waste generation and management and surface and groundwater contamination resulting from production, distribution, and use.

The multimedia evaluation process begins with the applicant screening stage. This is a preliminary review by the CalEPA MMWG to assess the proposed fuel plausibility and/or feasibility. The purpose of this tier is screen out any proposals that are not worth pursuing even to Tier I. For example, ideas that clearly violate basic concepts of scientific feasibility—mass balance, the laws of thermodynamics, etc., or ideas that appear to be the work of a team with no financial or technical resources to move forward on the concept. Tier II follows the work plan developed during Tier I to draft a risk assessment protocol report. During Tier III the risk assessment protocol is executed and a report prepared providing the results of the executed multimedia risk assessment.

Once a project has cleared the initial screening review, it moves in sequence through the next three Tiers. Tier I begins with the applicant bringing a summary report on the fuel to CalEPA and ends with the development of a work plan for the multimedia evaluation. A key goal of the Tier I report is to identify important knowledge gaps for a multimedia Assessment and recommend approaches to address these gaps. This does not always involve additional experiments, but could include additional requests for information from the proponents of any new fuel to be used in California.

An important aspect of the applicant's Tier I summary report is an effort to assign measures of importance to all information—both available and missing information. As the Tier I work plan is developed and important information gaps identified, methods and/or experiments for estimating and/or measuring these information gaps are also identified for action during Tier II.

Using the work plan developed in Tier I, the Tier II report comprises further data collection and the development of a risk-assessment experimental design. Tier II concludes with the preparation and MMWG review of a multimedia risk assessment protocol report that identifies the steps to be taken to reduce the identified key uncertainties. The risk assessment protocol should be based on the Tier I work plan and provide a comparison between the proposed fuel or fuel additive and the baseline fuel that the MMWG has agreed should be the basis for comparison in the work plan. Release scenarios of greatest interest will have been identified in the work plan based on the likelihood of adverse impact or occurrence.

During Tier III the risk assessment protocol is executed and a report prepared providing the results of the executed multimedia risk assessment. The Tier III report is submitted to the MMWG for evaluation and preparation of recommendations to the Environmental Policy Council. Prior to submittal to the Environmental Policy Council, the submitted Final multimedia risk assessment report as well as the MMWG recommendation will undergo independent external expert Tier III Peer Review.

2. Summary of Renewable Diesel Tier I

Currently, the majority of biological-source diesel fuels are fatty-acid methyl esters (FAME) produced through transesterification, but there are rapidly emerging alternatives to the transesterification production of diesel biofuels. Renewable diesel (also referred to as co-processed diesel or "green" diesel) is considered an alternative fuel that has potential in California. Renewable diesel is similar to biodiesel in that both use similar feedstocks, but they have different processing methods and can include chemically different components.

Renewable diesel is derived from non-petroleum renewable resources, including, (but not limited to) plant and algae oils, animal fats and wastes, municipal solid waste, sludge and oils derived from wastewater, and other wastes. Hydrogenation-derived renewable diesel (HDRD) is produced by refining fats or vegetable oils—typically in existing oil refineries. This process is also known as the Fatty Acids to Hydrocarbon (Hydrotreatment) or FAHC Hydrotreatment process. In this process, renewable feedstocks such as vegetable oils and animal fats are converted into diesel fuel as well as propane, and other light hydrocarbons through a catalytic treatment that adds hydrogen. Because it is free of ester compounds, renewable diesel has a chemical composition that is almost identical to petroleum-based diesel.

Preliminary evaluations indicate several potential advantages of renewable diesel relative to FAME and petroleum-based diesel. These advantages include:

- Renewable diesel can be used directly in existing diesel-powered vehicles without modification.
- Renewable diesel chemical properties fall within CARB diesel properties. A formal determination may need to be made to assess compatibility and functionality. However, it appears that renewable diesel may not require new or modified pipelines, storage tanks, trucking infrastructure, or retail station pumps.
- Renewable diesel can be produced using existing oil refinery capacity and does not require extensive new production facilities.
- The fuel properties of renewable diesel, specifically its high cetane number, suggest it will provide similar or better vehicle performance than conventional ultra-low sulfur diesel (ULSD).
- The ultra-low sulfur content of renewable diesel enables the use of advance emission control devices.
- The production of renewable diesel through the FAHC process does not produce a glycerin co-product.

Preliminary tests of renewable diesel emissions indicate that, relative to standard diesel, there is a potential for significantly better emissions profile during combustion with reduced particulate-matter (PM), NOx, hydrocarbons, and CO emissions. In addition to producing a fuel that uses recycled carbon, renewable diesel benefits include: a high level of quality control; compliance with ASTM standards; and easy blending with biodiesel.

Although renewable diesel is chemically very similar to conventional diesel, it is produced through a distinct process. The life-cycle risk posed by renewable diesel is assessed as a relative risk compared to the California Air Resources Board (CARB) ultra-low sulfur diesel (ULSD) currently in use.

The renewable Tier I report does not address direct and indirect environmental, ecological, and health impacts associated with biomass production—such as changes in land use and the possible net gain in carbon emissions due to feedstock cultivation.

2.1. Renewable Diesel Release Scenarios

Releases associated with the production, storage, distribution, and use of renewable diesel can be regarded as normal (routine) or off-normal (unplanned but not necessarily unlikely). Different feedstock supplies and production processes may have different normal and off-normal releases and may affect different environmental media and human populations depending on geographic location.

Normal releases during the use of renewable diesel include both the upstream feedstock production and fuel production emissions along with combustion tailpipe emissions, both to the air and to surface waters (in the case of marine use). The specific magnitude of these normal production and use releases within California are not yet well characterized and will remain difficult to quantify until more process-specific data become available and more engine/vehicle combustion tests are conducted.

There are several companies planning to market renewable diesel in California and elsewhere, but they have different production and marketing plans. A key issue for release scenarios upstream from the combustion stage is whether blending renewable diesel stock will occur at a refinery or at a distribution facility.

Normal or routine releases during the production of renewable diesel include:

- hexane or CO_2 released to the air during seed extraction,
- odors associated with waste biomass, and
- used process water discharges of various pH and trace-chemical composition.

Off-normal releases or unanticipated releases can occur primarily during the production, distribution and storage of renewable diesel. Off-normal releases may include spills or leaks of bulk feedstock; releases of production chemicals, such as hexane or blending stocks such as ULSD; or releases of finished renewable diesel fuel. These off-normal releases may be the result of leaks or ruptures of:

- an above-ground or below-ground storage tank and associated piping,
- a liquid-transportation vehicle such as rail tank car, tanker truck, or tanker ship, or
- a bulk-fuel transport pipeline.

For a company that plans to produce 100% renewable diesel and then blend it with conventional diesel post-production, and possibly at some location remote from the production facility, the release scenarios are different from a company that plans to co-process "green" plant or animal oil with conventional crude oil at an existing refinery. In the former case, storage and transport of 100% renewable diesel must be considered in terms of how it differs from experience with conventional and ULSD diesel. Some questions that arise:

- Can it be transported via pipelines?

- What are the spill consequences for 100% renewable diesel releases compared to ULSD releases?

2.2. Renewable Diesel Production, Storage, Distribution and Use

In contrast to a biodiesel that contains mono-alkyl esters, the California Low Carbon Fuel Standard defines a "renewable diesel" fuel as:

"… a motor vehicle fuel or fuel additive which is all the following:
(A) Registered as a motor vehicle fuel or fuel additive under 40 CFR part 79; A-9
(B) Not a mono-alkyl ester;
(C) Intended for use in engines that are designed to run on conventional diesel fuel; and
(D) Derived from nonpetroleum renewable resources."

Renewable diesel, produced from a variety of renewable feedstocks, is not composed of esters and is composed chemically of saturated hydrocarbon chains similar to conventional petroleum. The renewable diesel production process is designed to take advantage of the infrastructure of an existing refinery. Several of the renewable diesel products currently available meet the ASTM standard for conventional diesel. As part of its assessment of the US Renewable Fuel Standard, the US EPA reported that renewable diesel has a slightly higher energy content compared to biodiesel.

There are several different chemical approaches to producing renewable diesel. One is based on hydrotreating vegetable oils or animal fats. Hydrotreating can take place in the same facilities used to process petroleum-based diesel. A second method involves synthesis of hydrocarbons through enzymatic reactions. A third method involves partially combusting a biomass source to produce carbon monoxide and hydrogen—syngas—and then utilizing the Fischer-Tropsch reaction to produce complex hydrocarbons. Because there are currently few plans to engage the Fischer-Tropsch process in California, California Air Resources Board staff have requested that this report focus on the impacts of hydrotreated renewable diesel (HDRD/FAHC) produced in existing refineries. Hydrotreating is a hydrodeoxygenation process used to remove oxygen and nitrogen containing compounds as well as metals from the fuel feedstock.

There are two general production strategies for HDRD production and distribution:

- Co-processing vegetable/animal triglycerides in a conventional petroleum production stream using a hydrotreating process. Currently this results in diesel fuel that has a specified percentage of "green-derived" carbon, e.g., 20% renewable diesel (R20).
- Production of a pure HDRD (R100) in a dedicated hydrotreating facility that does not use conventional petroleum. The resulting fuel can be used as a 100% green fuel or blended with conventional CARB ULSD to any concentration.

Soybeans are expected to be the main feedstock for renewable diesel in California. Oil is extracted from soy by crushing the beans and applying n-hexane as a solvent. Soy-based renewable diesel is sufficiently similar in physical-chemical properties to CARB ULSD that it can be readily used in a range of blending applications.

Palm trees used to produce palm oil are grown primarily in tropical or subtropical areas such as Malaysia and Indonesia. Palm oil is characterized by high concentrations of medium-chain saturated (palmitic acid) and mono-saturated (oleic acid) fatty acids. One of its greatest advantages as a biofuel feedstock is high oil yield.

Canola and Rapeseed oils show promise as renewable diesel feedstock. These oils have properties similar to soy oil. The oil yield of canola, however, is much higher than soy; the seed contains 45% oil.

Animal tallow is a triglyceride material that is recovered by a rendering process, where the animal residues are cooked and the fat is recovered as it rises to the surface. Since it is a waste by-product, it is relatively inexpensive, sustainable, and is available locally. Vegetable oil waste grease and brown trap grease can also be used to make renewable diesel.

Petroleum-based diesel fuels are mixtures of aliphatic (open chain and cyclic compounds that are similar to open chain compounds) and aromatic (benzene and compounds similar to benzene) petroleum hydrocarbons. In addition, they may contain small amounts of nitrogen, sulfur, and other elements as additives. The exact chemical composition (i.e., precise percentage of each constituent) of any particular diesel oil type can vary somewhat, depending on the petroleum source and other factors. Petroleum-based diesel fuels are distinguished from other fuels primarily by their boiling point ranges, and chemical additives.

Renewable diesel is required to meet the same ASTM D975 standards as conventional diesel and is composed of saturated hydrocarbons similar to conventional diesel along with performance and stability additives. The ASTM Standard Specification for Diesel Fuel Oils, when met, allows renewable diesel to be suitable for a variety of diesel engines.

The USEPA specifications for conventional diesel fuel include the requirement for additives. The required additives are:

- corrosion inhibitor,
- emulsifier,
- anti-oxidant, and
- metal deactivator.

Chemical additives are commercially available to address the oxidative stability, cold-flow properties, and microbial contamination of renewable diesel. It is expected that these additives would be the same as or very similar to additives currently in use for conventional diesel fuel.

In general, the handling and storage of renewable diesel that meets ASTM D975 standards are the same as handling and storage for petroleum diesel including the needed protection from ignition sources. Tanks used for transport and storage must be suitable for combustible liquids and precautions must be taken to prevent product spills on to the ground, into drains, and into surface and ground waters. In the evaluation of the multimedia impacts of new diesel formulations, material compatibility and storage stability are important considerations, but little information is available on pure renewable diesel materials compatibility.

Blended HDRD can be transported with the same methods used for conventional diesel, including pipelines, rail cars, tank trucks and drums. The choice of transport vessel depends on the quantity of renewable diesel being transferred and the cold flow properties of the fuel. It is technically straightforward to blend pure HDRD fuels (R100) with conventional diesel. R100 can be blended to as much as 65 to 70 volume % in conventional diesel to fulfill the minimum density requirement.

A key consideration in the Renewable Diesel Tier I review is how levels of criteria and hazardous air pollutants emitted during combustion of ULSD differ from those emitted from an energy-equivalent quantity of renewable diesel.

Although biofuels has been studied extensively over the past 20 years, knowledge gaps still exist and further research was needed to fully characterize the impact renewable diesel has on oxides of nitrogen (NOx) emissions and various other emissions. More recent reviews have emphasized the considerable variations in the results from study to study and engine to engine. Further, many of these studies are limited in their direct application to California, however, because exhaust emissions from diesel engines fueled with biofuels were not compared to these engines fueled with CARB ULSD diesel. Additionally, most of these studies are not as extensive as the testing requirements used in the certification of CARB alternative diesel formulations, which require fuels to be shown to be equivalent to a 10% aromatic reference diesel fuel over a test sequence of 20 or more iterations (CARB, 2004).

There are ongoing emissions testing studies designed to address this issue, but initial studies have revealed that in diesel engines:

- HDRD fuels showed significant emission benefits compared to conventional ultra-low sulfur diesel fuel. Higher blend percentages resulted in greater benefits.
- Blends below 10% renewable diesel can result in reductions in CO and HC, but not PM or NOx.
- While specific (density adjusted) fuel consumption is better with the HDRD, volumetric fuel consumption is 5% higher because of the lower HDRD density.
- HDRD fuels avoid some of the unwanted effects associated with FAME-based biodiesel fuels (instability, hygroscopicity, fouling, catalyst deactivation, etc.).
- Due to the absence of sulfur and aromatic compounds, NExBTL exhaust emissions show significant reductions in many regulated and non-regulated compounds compared to "traditional" petroleum diesel.

2.3. Renewable Diesel Toxicity

A significant challenge that arises in determining the human and ecological toxicity of renewable diesel fuels is that renewable diesel fuel is not a defined chemical formulation or a defined mixture of components, but can be formulated from a number of different feedstocks with different chemical components.

Limited tests on the inherent acute oral and dermal toxicity of pure renewable diesel indicate that renewable diesel has a very low inherent toxicity, but these tests are difficult to interpret since there were no controls using conventional diesel or tests using diesel blend.

There have been some initial mutagenic testing of pure renewable diesel using a reverse mutation assay (Ames Test) and a chromosome aberration test with human lymphocytes *in vitro*. In the Ames test, no significant increases in the frequency of revertant colonies were recorded for any dose, either with or without metabolic activation. In the human lymphocyte test, the pure renewable diesel was considered to be non-clastogenic to human lymphocytes *in vitro*.

Insight on aquatic toxicity comes from acute short-term exposure of fish, water fleas, and green algae to a pure renewable diesel water accommodated fraction. This study concluded that the No-Observed-Effect-Level (NOEL) was greater than 100 mg/L for all three species.

To date, there has been no publication of comprehensive testing of the relative toxicity of the tailpipe emissions from combusting renewable diesel (blends and/or pure fuel) compared to existing diesel and/or biodiesel. The CARB is funding studies that used in-vitro testing to assess and compare the inflammatory toxicity and genotoxicity of biodiesel and renewable diesel blends along with CARB diesel. Preliminary results indicate lower toxicity for renewable diesel. But based on the level of variation in emissions toxicity assessment for petroleum diesel, the chemical similarity of renewable diesel and petroleum diesel, and the likelihood for blends that still contain a significant fraction (80%) of petroleum diesel, we expect that it will be difficult to organize and interpret a study to compare the toxicity of petroleum diesel relative to R20 renewable diesel blends for the full range of vehicle-engine systems used in California. Therefore, unless the fuels market evolves to the point where renewable blends contain more than 50% non-petroleum diesel feedstock, there appears to be little value in calling for extensive emissions toxicity studies for renewable diesel.

Major differences in health and ecological impacts between existing diesel and renewable diesel blends are more likely to be associated with additives than with the hydrocarbon mix. So the key issue with regard to different life-cycle health/ecological impacts from existing diesel blends and renewable diesel blends will likely be linked to differences in additives.

The chemical comparison to conventional diesel is important for determining whether or how much additional toxicity tests are required. If a co-processed “green” renewable diesel is the intended product and is chemically indistinguishable from conventional diesel, then no additional toxicity testing should be conducted. Furthermore, if a post-production 100% pure renewable diesel is blended to a proportion such that it is chemically indistinguishable from conventional diesel, then no additional toxicity testing should be required in this case as well.

2.4. Transport and Fate

The transport and fate of a fuel and its component chemicals in the environment depend on the multimedia transport properties of its constituent chemicals. The purpose of the multimedia evaluation of renewable diesel is to identify impacts that may be different from the existing baseline fuel, which in the case of renewable diesel is conventional petroleum-based ULSD. Based on the fuel chemical composition analysis provided by both Kern Oil and Refining (KOR) and Neste Oil Corp., renewable diesel can be regarded as substantially similar to other conventional diesel fuels. The main difference between conventional ULSD and pure HDRD is that the pure renewable diesel has essentially no sulfur or oxygen and has a very low aromatic compound content. Co-processed 20% renewable diesel can be expected to be even closer in chemical composition to conventional CARB ULSD.

Based on the reported similarities in chemical composition, and thus the physicochemical properties governing fate and transport in the environment, between renewable diesel and conventional CARB ULSD, the multimedia environmental behavior of renewable diesel is also be expected to be similar. The transport and partitioning behavior, as well as biodegradation in soils can be expected to be similar. The release scenarios and materials compatibility issues should be essentially the same as the conventional diesel that is already in wide use.

Even when releases of renewable diesel would not cause significantly greater impacts to the environment, human health, or water resources relative to CARB ULSD, the impact from releases of associated additives and production chemicals could be of concern. The specific chemical composition of the additives used by various renewable diesel manufactures is typically not specified and the environmental impact of these additives is not well described.

In the case of co-processed 20% renewable diesel, it is reasonable to assume that any additives used in renewable diesel are currently used in CARB ULSD and would continue to be used with no substantive difference in environmental impact due to additives. If this is the case, then new studies on multimedia transport and impact from additives would not be necessary under the confirmation that the impacts of additives in CARB ULSD are either acceptable or at lease well-characterized. However, when the additives used in renewable diesel are different from those in ULSD with regard to composition and/or quantity, then a multimedia transport and impact assessment will be needed to determine the magnitude and significance of these additives.

3. Summary of Renewable Diesel Tier II Findings

3.1. Fate and Transport/Toxicity Studies

The Tier I review concluded that there are strong similarities between the chemical composition of petroleum diesel and renewable diesel. These similarities and the strong likelihood that renewable diesel will be blended with petroleum diesel limits the need for additional Tier II multimedia fate and transport/ toxicity experiments or an extensive life-cycle impact assessment.

To support the renewable diesel multimedia assessment, a comprehensive emissions study comparing renewable diesel fuels, to California Air Resources Board (CARB) diesel fuel was conducted. This program was coordinated by CARB in conjunction with researchers from the University of California Riverside (UCR), the University of California Davis (UCD), and others including Arizona State University (ASU)(Citation).

3.2. Air Emission Studies

To support the renewable diesel multimedia assessment, a comprehensive emissions study comparing renewable diesel fuels, to California Air Resources Board (CARB) diesel fuel was conducted. This program was coordinated by CARB in conjunction with researchers from the University of California Riverside (UCR), the University of California Davis (UCD), and others including Arizona State University (ASU)(Citation). The study was divided into two main areas, NOx impacts and filling of knowledge gaps. Two heavy-duty on-road engines were tested at the College of Engineering - Center for Environmental Research and Technology (CE-CERT) and two non-road engines were tested at CARB emissions test facilities in Stockton and El Monte. The second main area was to fill knowledge gaps in the area of health impacts and unregulated emissions. The study was conducted on four vehicles at the CARB's heavy-duty emissions test facility in Los Angeles.

A renewable diesel and a gas-to-liquid (GTL) diesel fuel were used for testing. The renewable diesel was provided by Neste Oil, and it is known as NExBTL. The renewable and the GTL diesel fuel were blended at 20%, 50%, and 100% levels with ULSD and biodiesel. The fuels for all testing utilized the same batches of primary fuels, and the blending for all testing was also done at the same time.

A 2006 Cummins ISM and 2007 MBE4000 engine equipped with a diesel particle filter (DPF) were tested at CE-CERT. For the renewable and gas-to-liquid (GTL) diesel fuels in the 2006 Cummins, the results showed a steady decrease in NOx emissions with increasing levels of renewable/GTL diesel fuel. For the renewable diesel fuel, these reductions ranged from 2.9% to 4.9% for R20, 5.4% to 10.2% for R50, and 9.9% to 18.1% for R100 through all the cycles. For the GTL fuel the reductions were 5.2% and 8.7%, respectively, for GTL50 and GTL100 during the Federal Test Procedure cycle.

Compared to the CARB ULSD, the renewable and GTL fuels provided reductions in PM and CO emissions, with the GTL fuel also providing reductions in THC, although these reductions were sometimes only seen for the higher blend levels. The renewable and GTL fuels provided a slight reduction (2-4% for R100) in CO2 emissions at the higher blends, with a slight, but measureable, increase in fuel consumption. The fuel consumption differences are consistent with the results from previous studies, and can be attributed to the lower density or energy density of the renewable and GTL fuels compared to the CARB baseline fuel.

PAH and Nitro-PAH emissions both decreased as a function of increasing blend level for renewable diesel. The emission trends for Oxy-PAH emissions showed different trends for different compounds, with some compounds showing generally higher emissions in soy and animal-based biodiesels compared to CARB diesel, whereas others decreased in animal biodiesel and renewable diesel. However, for semivolatile nitro-PAHs, the renewable diesel may be slightly more effective in reducing emissions than soy- or animal-based biodiesels.

The emission trends observed renewable diesel were different for different compounds. For example, the results for 1,2-naphthoquinone (2-ring oxy-PAH) showed generally higher emissions in soy and animal-based biodiesels compared to CARB diesel, whereas perinaphthenone, 9-fluorenone, and 1,8-naphthalic anhydride (3-ring oxy-PAHs) emissions decreased in animal biodiesel and renewable diesel.

If blended with biodiesel, the NOx reduction observed for the renewable and GTL fuels may be used to offset the observed increase in NOx emissions from biodiesel alone. The renewable/GTL diesel reduction in NOx was less than the corresponding increases in NOx seen for the soy-based biodiesel, but are more comparable to the increases seen for the animal-based biodiesel blends. This suggests that the renewable and GTL diesel fuel levels need to be blended at higher levels than the corresponding biodiesel in order to mitigate the associated NOx increase, especially for the soy-based biodiesel blends.

Several NOx mitigation formulations were evaluated on 2006 Cummins engine, including those utilizing renewable and GTL diesel fuels, and additives. Successful formulations included those with higher levels of renewable diesel (R80 or R55) with a B20-soy biodiesel. Blends of 15% renewable or GTL diesel were also proved successful in mitigating NOx for a B5 soy blend, giving a formulation more comparable to what might be implemented with the low carbon fuel standard. A 1% di tertiary butyl peroxide (DTBP) additive blend was found to fully mitigate the NOx impacts for a B20 and B10 soy biodiesel, while 2-ethylhexyl nitrate (2-EHN) blends had little impact on improving NOx emissions. It was found that the level of renewable or GTL diesel fuels needed for blending can be reduced if a biodiesel fuel with more favorable NOx characteristics, such as animal-based biodiesel, is used, or if an additive with more favorable NOx characteristics, such as DTBP, is used. For the MBE4000 engine, only two blends were tested, CARB80/R15/B5-S and B-5 soy with a 0.25% DTBP additive. Of these two, only the B-5 soy with a 0.25% DTBP additive provided NOx neutrality. Overall, it appears that different strategies will provide mitigation for different engines, but that the specific response varies from engine to engine.

CARB diesel and renewable diesel all induced inflammatory markers, such as COX-2 and IL-8 in human macrophages and the mucin related MUC5AC markers in Clara type cells, with the inflammatory markers higher in the 2000 Caterpillar C-15 engine vehicle than the 2007 MBE4000 engine vehicle. For the comet assay, at the limited dose levels tested, there was little increase of chromosomal damage (gross DNA damage) from the various fuels tested, including the CARB diesel.

3.3. Renewable Diesel Tier II Conclusions

- As part of the overall multimedia assessment, each company proposing to market renewable diesel within California should provide the California ARB with a production, blending, additives, and distribution strategy that includes potential volumes to be stored and transported along with potential release scenarios that the company may foresee. Each company should also provide a comparative chemical analysis of the product they intend to market. This analysis should be compared to conventional diesel currently in the market place.
- A steady decrease in NOx emissions with increasing levels of renewable/GTL diesel fuel can be expected. Compared to the CARB ULSD, the renewable and GTL fuels provided reductions in PM and CO emissions. PAH and Nitro-PAH emissions both decreased as a function of increasing blend level for renewable diesel.
- If blended with biodiesel, the NOx reduction observed for the renewable and GTL fuels may be used to offset the observed increase in NOx emissions from biodiesel combustion.
- The lower density or energy density of the renewable and GTL fuels compared to the CARB baseline fuel resulted in a slight, but measureable, increase in fuel consumption.
- Overall, it appears that different strategies will provide mitigation for different engines, but that the specific response varies from engine to engine.

4. Renewable Diesel Tier III Conclusion and Recommendations

Through a review of the current knowledge on renewable diesel production, use, and environmental impacts, this report provides an assessment to aid the CalEPA Multimedia Working Group in formulating recommendations to the California Environmental Policy Council regarding the consequences of increased use of renewable diesel in California.

It must be recognized that the multimedia impact assessment is a process and not a product. It is important to realize that much is unknown about an emerging transportation fuel system on the scale of full implantation and will remain uncertain until the full system is created. A life-cycle impact assessment is a contingent process, based on scenarios that will be modified as new knowledge is acquired, and is not intended to make firm predictions.

Adaptive decision-making refers to learning by doing. Life-cycle approaches to emerging fuel options are often difficult to apply and may be burdened by uncertainty such that they become more informative as fuel technologies mature and are deployed. The uncertainties identified will inform decision-makers regarding:

- Investments to improve knowledge base,
- Formulation of processes used to collect and process new information,
- Formulation of processes to evaluate and communicate uncertainty, and
- Adjustment of the risk assessment process to mitigate the practical impact of uncertainty on decision-making.

Renewable diesel offers several beneficial characteristics that will help California meet State renewable fuel goals:

- Renewable diesel is chemically similar to the CARB ultra-low sulfur diesel (ULSD) fuel already in wide use and environmental releases from the life cycle of these fuels can be expected to behave in the environment in a manner similar to CARB ULSD releases.
- Renewable diesel can be used directly in existing diesel-powered vehicles without modification.
- Renewable diesel chemical properties fall within CARB diesel properties. A formal determination may need to be made to assess compatibility and functionality. However, it appears that renewable diesel may not require new or modified pipelines, storage tanks, trucking infrastructure, or retail station pumps.
- Pure renewable diesel has reduced aromatic hydrocarbon content and, since many of the chemicals of environmental concern are aromatic hydrocarbons, this reduction will likely reduce the overall toxic impacts of leaking or spilled fuel.
- A steady decrease in NOx emissions with increasing levels of renewable/GTL diesel fuel can be expected. Compared to the CARB ULSD, the renewable diesel fuels provided reductions in PM and CO emissions. PAH and Nitro-PAH emissions both decreased as a function of increasing blend level for renewable diesel.
- If blended with biodiesel, the NOx reduction observed for the renewable fuels may be used to offset the observed increase in NOx emissions from biodiesel combustion.

- Limited toxicity testing on rats (oral and dermal exposures), water fleas and green algae, and including mutagenic assays, reveals that pure 100% renewable diesel has limited inherent toxicity and that pure renewable diesel formations are unlikely to exceed the inherent toxicity or mutagenicity of standard diesel. Major differences in health and ecological impact between existing diesel and renewable diesel blends are more likely to be associated with additives than with the hydrocarbon mix.
- Renewable diesel fuels that are made from waste products such as tallow will likely have reduced life-cycle environmental impacts compared to fuels made from plant crops. These reduced impacts stem from possible reductions in pesticide, herbicide, and fertilizer use. Furthermore, the use of food supply crops as a fuel feedstock may not be sustainable as global population grows. Further studies are needed to confirm this assertion.
- The results here indicate that life-cycle health impacts of renewable diesel blends are not likely to differ significantly from those of petroleum diesel.

There are, however, concerns that arise from the knowledge gaps associated with renewable diesel use in California. These concerns include:

- **Additives impacts.** To provide a stable, useful, and reliable fuel, additive chemicals may need to be introduced into almost all renewable diesel blends. These additives will be required to address issues such as oxidation, corrosion, foaming, cold temperature flow properties, biodegradation, and water separation. These additives are currently used in conventional diesel fuels, but the specific chemicals and amounts to be used in renewable by various producers has not been yet been fully defined for the emerging industry in California. Nevertheless, the expectation of ARB is that renewable diesel will employ additives similar to those used standard diesel. Given the similarity of renewable diesel and standard diesel in terms of composition and performance, it is reasonable to expect the use of similar performance additives in renewable diesel relative to standard diesel. It follows that health and environmental impacts will also be similar or lower. Additional research may be needed to confirm this finding, but this is not a high priority given the relative low impact of additives within the life cycle of existing standard diesel.
- **Production and storage releases.** Increased renewable diesel production and associated feedstock processing may involve impacts from released reactants and by-products. There are potential impacts to California's air and water during the large-scale industrial operations used to extract seed oils. These impacts may result from air emissions of solvents used to extract the seed oil (e.g., hexane) and from leaking tanks containing process chemicals. There is also the issue of occupational exposures.

  Currently, the possible impacts during seed extraction will be minimal in California since it is anticipated that most of the seed oils will be derived from soy grown and extracted out-of-state. The impacts during seed extraction will be become more of an issue for California as in-state production of plant-derived oils increases and may require further study.

  As the volume of tallow that is rendered out of state and shipped by rail or truck into California increases, there is a potential impact from releases of large volumes of raw triglycerides to soils or water. The impact of such a release has not been documented and additional research would be beneficial as large-scale tallow usage increases.

- **Toxicity Testing.** Based on the level of variation in emissions toxicity assessment, the chemical similarity of renewable diesel and petroleum diesel, that specific mitigation response varies from engine to engine. and the likelihood for blends that still contain a significant fraction (80%) of petroleum diesel, we expect that it will be difficult, if not impossible, to organize and interpret a study to compare the toxicity of petroleum diesel relative to 20% or less renewable diesel blends. Therefore, unless the market evolves to the point where renewable blends contain more than 50% non-petroleum diesel feedstock, there appears to be little value in calling for further toxicity studies for renewable diesel.

Not specifically addressed in the Tier I, II, and III evaluations are the environmental impacts from the increased use of fertilizers and water and land resources if the production of plant oils increases in the State to supply renewable-diesel feedstocks. These factors may be some of the most important eventual impacts to California as the renewable and biofuels industry expands. More sustainable sources of renewable diesel such as yellow or brown grease or tallow may be preferable and should be encouraged.

5. Tier III References

CalEPA (California Environmental Protection Agency). 2008. Guidance Document and Recommendations on the Types of Scientific Information to be Submitted by Applicants for California Fuels Environmental Multimedia Evaluations.

CalEPA (California Environmental Protection Agency) Multimedia Working Group. 2011. California Renewable Diesel Multimedia Evaluation Tier I Final Report, prepared by the University of California, Davis and the University of California, Berkeley. September 2011.

California Air Resources Board (CARB). 2004. The California Diesel Fuel Regulations, Title 13, California Code of Regulations, Sections 2281-2285, Title 17, California Code of Regulations, Sections 93114.

6. Tier III Appendices

6.1. Appendix III-A: California Renewable Diesel Multimedia Evaluation, Tier I Final Report, September, 2011.

California Renewable Diesel Multimedia Evaluation

Tier I
Final Report

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For the

California Environmental Protection Agency
Multimedia Working Group

FINAL

September 2011

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Executive Summary

Background

Currently, the majority of biological-source diesel fuels are fatty-acid methyl esters (FAME) produced through transesterification, but there are rapidly emerging alternatives to the transesterification production of diesel biofuels. Renewable diesel (also referred to as co-processed diesel or "green" diesel) is considered an alternative fuel that has potential in California. Renewable diesel is similar to biodiesel in that both use similar feedstocks, but they have different processing methods and can include chemically different components.

Renewable diesel is derived from non-petroleum renewable resources, including, (but not limited to) plant and algae oils, animal fats and wastes, municipal solid waste, sludge and oils derived from wastewater, and other wastes. Hydrogenation-derived renewable diesel (HDRD) is produced by refining fats or vegetable oils—typically in existing oil refineries. This process is also known as the Fatty Acids to Hydrocarbon (Hydrotreatment) or FAHC Hydrotreatment process. In this process, renewable feedstocks such as vegetable oils and animal fats are converted into diesel fuel as well as propane, and other light hydrocarbons through a catalytic treatment that adds hydrogen. Because it is free of ester compounds, renewable diesel has a chemical composition that is almost identical to petroleum-based diesel.

Preliminary evaluations indicate several potential advantages of renewable diesel relative to FAME and petroleum-based diesel. These advantages include:

- Renewable diesel can be used directly in existing diesel-powered vehicles without modification.
- Renewable diesel is compatible with current diesel distribution infrastructure and does not require new or modified pipelines, storage tanks, trucking infrastructure, or retail station pumps.
- Renewable diesel can be produced using existing oil refinery capacity and does not require extensive new production facilities.
- The fuel properties of renewable diesel, specifically its high cetane number, suggest it will provide similar or better vehicle performance than conventional ultra-low sulfur diesel (ULSD).
- The ultra-low sulfur content of renewable diesel enables the use of advance emission control devices.
- The production of renewable diesel through the FAHC process does not produce a glycerin co-product.

Preliminary tests of renewable diesel emissions indicate that, relative to standard diesel, there is a potential for significantly better emissions profile during combustion with reduced particulate-mattter, NOx, hydrocarbons, and CO emissions. In addition to producing a fuel that uses recycled carbon, renewable diesel benefits include: a high level of quality control; compliance with ASTM standards; and easy blending with biodiesel.

California law states that the "California Air Resources Board cannot adopt any regulation establishing a motor vehicle fuel specification unless a multimedia evaluation is conducted to determine whether the regulation will cause a significant adverse impact on the public health or environment". Although renewable diesel is chemically very similar to conventional diesel, it is produced through a distinct process, and the California Air Resources Board (CARB) must provide a "life cycle multimedia risk assessment" before adopting new fuel specifications that allow renewable diesel blends.

This Tier I Renewable Diesel report is the first step in a three-tier process to evaluate the cumulative health and ecological impacts from releases to air, surface water, groundwater and soil at all stages of the renewable diesel life cycle: feedstock production, fuel production, storage and distribution, and fuel use. The life-cycle risk posed by renewable diesel is assessed as a relative risk compared to the California Air Resources Board (CARB) ultra-low sulfur diesel (ULSD) currently in use.

Study Approach

The goal of this Tier I report is to identify what is currently known about the life-cycle health, ecological, and resource impacts of renewable diesel and identify key uncertainties and data gaps. It provides important input to the Multimedia Working Group with regard to the need for and scope of Tier II and Tier III studies for renewable diesel formulations.

Meeting this goal requires the following elements:

- Identifying the physical and chemical and environmental toxicity characteristics of the reference fuel, candidate fuel, and additive components;
- summarizing all potential production, distribution, storage, and use release scenarios including a discussion of the most likely release scenarios;
- summarizing the expected environmental behavior (transport and fate) associated with a portfolio of release scenarios for proposed fuel or fuel components that may be released; and
- comparing the physical, chemical, and toxic properties of the fuel or additive components to the appropriate and consensus control fuel or fuel components.

The purpose of a life-cycle assessment (LCA) applied to renewable diesel is to quantify and compare environmental flows of resources and pollutants (to and from the environment) associated with both renewable diesel and petroleum-based diesel, over the entire life cycle of the respective products. The flows of resources and pollutants provide the framework for assessing human-health, environmental-systems, and resource impacts. LCA addresses a broad range of requirements and impacts for technologies, industrial processes, and products in order to determine their propensity to consume natural resources or generate pollution.

This report does not address direct and indirect environmental, ecological, and health impacts associated with biomass production—such as changes in land use and the possible net gain in carbon emissions due to feedstock cultivation.

Release Scenarios

Releases associated with the production, storage and distribution, and use of renewable diesel can be regarded as normal (routine) or off-normal (unplanned but not necessarily unlikely). Different feedstock supplies and production processes may have different normal and off-normal releases and may affect different environmental media and human populations depending on geographic location.

Normal releases during the use of renewable diesel include combustion tailpipe emissions, both to the air and to surface waters (in the case of marine use). The specific magnitude of these normal production and use releases within California are not yet well characterized and will remain difficult to quantify until more process-specific data become available and more engine/vehicle combustion tests are conducted.

There are several companies planning to market renewable diesel in California and elsewhere, but they have different production and marketing plans. A key issue for release scenarios upstream from the combustion stage is whether blending renewable diesel stock will occur at a refinery or at a distribution facility.

Normal or routine releases during the production of renewable diesel include:

- hexane or CO_2 released to the air during seed extraction,
- odors associated with waste biomass, and
- used process water discharges of various pH and trace-chemical composition.

Off-normal releases or unanticipated releases can occur primarily during the production, distribution and storage of renewable diesel. Off-normal releases may include spills or leaks of bulk feedstock, production chemicals, such as hexane or blending stocks such as ULSD, or finished renewable diesel fuel. These off-normal releases may be the result of leak or rupture of:

- an above-ground or below-ground storage tank and associated piping,
- a liquid-transportation vehicle such as rail tank car, tanker truck, or tanker ship, or
- a bulk-fuel transport pipeline.

For a company that plans to produce 100% renewable diesel and then blend it with conventional diesel post-production, and possibly at some location remote from the production facility, the release scenarios are different from a company that plans to co-process "green" plant or animal oil with conventional crude oil at an existing refinery. In the former case, storage and transport of 100% renewable diesel must be considered in terms of how it differs from experience with conventional and ULSD diesel. Some questions that arise:

- Can it be transported via pipelines?
- What are the spill consequences for 100% renewable diesel compared to ULSD?

Renewable Diesel Production, Storage, Distribution and Use

In contrast to a biodiesel that contains mono-alkyl esters, the California Low Carbon Fuel Standard defines a "renewable diesel" fuel as:

"… a motor vehicle fuel or fuel additive which is all the following:

(A) Registered as a motor vehicle fuel or fuel additive under 40 CFR part 79; A-9
(B) Not a mono-alkyl ester;
(C) Intended for use in engines that are designed to run on conventional diesel fuel; and
(D) Derived from nonpetroleum renewable resources."

Renewable diesel, produced from a variety of renewable feedstocks, is not composed of esters and is composed chemically of saturated hydrocarbon chains similar to conventional petroleum. The renewable diesel production process is designed to take advantage of the infrastructure of an existing refinery. Several of the renewable diesel products currently available meet the ASTM standard for conventional diesel. As part of the US Renewable Fuel Standard, US EPA reported that renewable diesel has a slightly higher energy content compared to biodiesel.

There are several different chemical approaches to producing renewable diesel. One is based on hydrotreating vegetable oils or animal fats. Hydrotreating can take place in the same facilities used to process petroleum-based diesel. A second method involves systhesis of hydrocarbons through enzymatic reactions. A third method involves partially combusting a biomass source to produce carbon monoxide and hydrogen—syngas—and then utilizing the Fischer-Tropsch reaction to produce complex hydrocarbons. Because there are currently few plans to engage the Fischer-Tropsch process in California, California Air Resources Board staff have requested that this report focus on the impacts of hydrotreated renewable diesel (HDRD/FAHC) produced in existing refineries. Hydrotreating is a hydrodeoxygenation process used to remove oxygen and nitrogen containing compounds as well as metals from the fuel feedstock.

There are two general production strategies for HDRD production and distribution:

- Co-processing vegetable/animal triglycerides in a conventional petroleum production stream using a hydrotreating process. Currently this results in diesel fuel that has a specified percentage of "green-derived" carbon, e.g., 20% renewable diesel (R20).
- Production of a pure HDRD (R100) in a dedicated hydrotreating facility that does not use conventional petroleum. The resulting fuel can be used as a 100% green fuel or blended with conventional CARB ULSD to any concentration.

Soybeans are expected to be the main feedstock for renewable diesel in California. Oil is extracted from soy by crushing the beans and applying n-hexane as a solvent. Soy-based renewable diesel is sufficiently similar in physical-chemical properties to CARB ULSD that it can be readily used in a range of blending applications.

Palm used to produce palm oil are grown primarily in tropical or subtropical areas such as Malaysia and Indonesia. Palm oil is characterized by high concentrations of medium-chain saturated (palmitic acid) and monosaturated (oleic acid) fatty acids. One of its greatest advantages as a biofuel feedstock is high oil yield.

Canola and Rapeseed oils show promise as renewable diesel feedstock. These oils have properties similar to soy oil. The oil yield of canola, however, is much higher than soy; the seed contains 45% oil.

Animal tallow is a triglyceride material that is recovered by a rendering process, where the animal residues are cooked and the fat is recovered as it rises to the surface. Since it is a waste by-product, it is relatively inexpensive, sustainable, and is available locally. Vegetable oil waste grease and brown trap grease can also be used to make renewable diesel.

Petroleum-based diesel fuels are mixtures of aliphatic (open chain and cyclic compounds that are similar to open chain compounds) and aromatic (benzene and compounds similar to benzene) petroleum hydrocarbons. In addition, they may contain small amounts of nitrogen, sulfur, and other elements as additives. The exact chemical composition (i.e., precise percentage of each constituent) of any particular diesel oil type can vary somewhat, depending on the petroleum source and other factors. Petroleum-based diesel fuels are distinguished from each other fuels primarily by their boiling point ranges, and chemical additives.

Renewable diesel is required to meet the same ASTM D975standards as conventional diesel and is composed of saturated hydrocarbons similar to conventional diesel along with performance and stability additives. The ASTM Standard Specification for Diesel Fuel Oils, when met, allows renewable diesel to be suitable for a variety of diesel engines.

The USEPA specifications for conventional diesel fuel include the requirement for additives. The required additives are:

- corrosion Inhibitor,
- demulsifier,
- anti-oxidant, and
- metal deactivator.

Chemical additives are commercially available to address the oxidative stability, cold-flow properties, and microbial contamination of renewable diesel. It is expected that these additives would be the same as or very similar to additives currently in use for conventional diesel fuel.

In general, the handling and storage of renewable diesel that meets ASTM D975 standards is the same as for petroleum diesel including the needed protection from ignition sources. Tanks used for transport and storage must be suitable for combustible liquids and precautions must be taken to prevent product spills on to the ground, into drains, and into surface and ground waters. In the evaluation of the multimedia impacts of new diesel formulations, material compatibility and storage stability are important considerations, but little information is available on pure renewable diesel materials compatibility.

Blended HDRD can be transported via the same methods used for conventional diesel, including pipelines, rail cars, tank trucks and drums. The choice of transport vessel depends on the quantity of renewable diesel being transferred and the cold flow properties of the fuel. It is straight forward technically to blend pure HDRD fuels (R100) with conventional diesel. R100 can be blended to as much as 65 to 70 volume % in conventional diesel to fulfill the minimum density requirement.

A key consideration in this Tier I review is how the levels of criteria and hazardous air pollutants emitted during combustion differ from those emitted from and energy-equivalent quantity of renewable diesel verses ULSD.

While emissions testing is ongoing, initial studies concluded that in diesel engines:

- HDRD fuel showed significant emission benefits compared to ultra-low sulfur conventional diesel fuel. Higher blend percentages resulted in greater benefits.
- Blends below 10% renewable diesel can result in reductions in CO and HC, but not PM or NOx.
- While specific (density adjusted) fuel consumption is better with the HRDF, volumetric fuel consumption is 5% higher because of the lower HRDF density.
- HDRD fuels avoid some of the unwanted effects associated with FAME-based biodiesel fuels (instability, hygroscopicity, fouling, catalyst deactivation, etc).
- Due to the absence of sulfur and aromatic compounds, NExBTL exhaust emissions show significant reductions in many regulated and non-regulated compounds compared to "traditional" petroleum diesel.

Renewable Diesel Toxicity

The greatest difficulty we anticipate with determining the human and ecological toxicity of renewable diesel fuels is that renewable diesel fuel is not a defined chemical formulation or a defined mixture of components, but can be formulated from a number of different feedstocks with different chemical components.

Limited tests on the inherent acute oral and dermal toxicity of pure renewable diesel indicate that renewable diesel has a very low inherent toxicity, but these tests are difficult to interpret since there were no controls using conventional diesel or tests using diesel blend.

There have been some initial mutagenic testing of pure renewable diesel using a reverse mutation assay (Ames Test) and a chromosome aberration test using human lymphocytes *in vitro*. In the Ames test, no significant increases in the frequency of revertant colonies were recorded for any dose, either with or without metabolic activation. In the human lymphocyte test, the pure renewable diesel was considered to be non-clastogenic to human lymphocytes *in vitro*.

Insight on aquatic toxicity comes from acute short-term exposure of fish, water fleas, and green algae to a pure renewable diesel water accommodated fraction. This study concluded that the No-Observed-Effect-Level was greater than 100 mg/L for all three species.

To date, there has been no publication of comprehensive testing of the relative toxicity of the tailpipe emissions from combusting renewable diesel (blends and/or pure fuel) compared to existing diesel and/or biodiesel. The ARB has funding studies that used in-vitro testing to assess and compare the inflammatory toxicity and genotoxicity of biodiesel and renewable diesel blends along with CARB diesel and preliminary results indicate lower toxicity for renewable diesel. But based on the level of variation in emissions toxicity assessment for petroleum diesel, the chemical similarity of renewable diesel and petroleum diesel, and the likelihood for blends that still contain a significant fraction (80%) of petroleum diesel, we expect that it will be difficult to organize and interpret a study to compare the toxicity of petroleum diesel relative to R20 renewable diesel blends for the full range of vehicle-engine systems used in California. Therefore, unless there market evolves to the point where renewable blends contain more than 50% non-petroleum diesel feedstock, there appears to be little value in calling for extensive emissions toxicity studies for renewable diesel.

Major differences in health and ecological impact between existing diesel and renewable diesel blends are more likely to be associated with additives than with the hydrocarbon mix. So the key issue with regard to different life-cycle health/ecological impacts from existing diesel blends and renewable diesel blends will likely be linked to differences in additives.

Additionally, the chemical comparison to conventional diesel is important for determining whether or how much additional toxicity tests are required. If a co-processed “green” renewable diesel is the intended product and is chemically indistinguishable from conventional diesel, then no additional toxicity testing should be conducted. Further, if a post-production 100% pure renewable diesel is blended to a proportion such that it is chemically indistinguishable from conventional diesel, then no additional toxicity testing should be required in this case as well.

Transport and Fate

The transport and fate of a fuel and its component chemicals in the environment depend on the multimedia transport properties of its constituent chemicals. The purpose of the multimedia evaluation of renewable diesel is to identify impacts that may be different from the existing baseline fuel, which in the case of renewable diesel is conventional petroleum-based ULSD. Based on the fuel chemical composition analysis provided by both Kern Oil and Refining (KOR) and Neste Oil Corp., renewable diesel can be regarded as substantially similar to other conventional diesel fuels. The main difference between conventional ULSD and pure HDRD is that the pure renewable diesel has essentially no sulfur or oxygen and has a very low aromatic compound content. Co-processed 20% renewable diesel can be expected to be even closer in chemical composition to conventional CARB ULSD.

Based on the reported similarities in chemical composition, and thus the physicochemical properties governing fate and transport in the environment, between renewable diesel and conventional CARB ULSD, the multimedia environmental behavior of renewable diesel should also be expected to be similar. The transport and partitioning behavior, as well as biodegradation in soils can be expected to be similar. The release scenarios and materials compatibility issues should be essentially the same as the conventional diesel that is already in wide use.

Even when releases of renewable diesel would not cause significantly greater impacts to the environment, human health, or water resources when compared to CARB ULSD, the impact from releases of associated additives and production chemicals could be of concern. The specific chemical composition of the additives used by various renewable diesel manufactures is typically not specified and the environmental impact of these additives is not well described.

In the case of co-processed 20% renewable diesel, it is reasonable to assume that any additives used in renewable diesel are currently in use in CARB ULSD and would continue to be used with no substantive difference in environmental impact due to additives. If this is the case, then new studies on multimedia transport and impact from additives would not be necessary under the confirmaiton that the impacts of additives in CARB ULSD are either acceptable or at lease well-characterized. However, when the additives used in renewable diesel are different from those in ULSD with regard to composition and/or quantity, then a multimedia transport and impact assessment will be needed to determine the magnitude and significance of these additives.

Tier I Conclusions

Through a review of the current knowledge on renewable diesel production, use, and environmental impacts, this report provides an assessment to aid the CalEPA Multimedia Working Group in formulating recommendations to the California Environmental Policy Council regarding the consequences of increased use of renewable diesel in California. A key goal of this report is to identify important knowledge gaps for a Multimedia Assessment and recommend approaches to address these gaps. This does not always involve additional experiments, but could include additional requests for information from the proponents of any new fuel to be used in California.

Renewable diesel offers several beneficial characteristics that will help California meet State renewable fuel goals:

- Renewable diesel is chemically similar to the CARB ultra-low sulfur diesel (ULSD) fuel already in wide use and environmental releases from the life-cycle of these fuels can be expected to behave in the environment in a manner similar to CARB ULSD releases.
- Renewable diesel is compatible with existing refining and distribution infrastructure and can be used in current diesel engines without modification.

- Pure renewable diesel has reduced aromatic hydrocarbon content and, since many of the chemicals of environmental concern are aromatic hydrocarbons, this reduction will likely reduce the overall toxic impacts of leaking or spilled fuel.
- Limited toxicity testing on rats (oral and dermal exposures), water fleas and green algae, and including mutagenic assays, reveals that pure 100% renewable diesel has limited inherent toxicity and that pure renewable diesel formations are unlikely to exceed the inherent toxicity or mutagenicity of standard diesel. Major differences in health and ecological impact between existing diesel and renewable diesel blends are more likely to be associated with additives than with the hydrocarbon mix.
- Renewable diesel fuels that are made from waste products such as tallow will likely have reduced life cycle environmental impacts compared to fuels made from plant crops. These reduced impacts stem from possible reductions in pesticide, herbicide, and fertilizer use. Further, the use of food supply crops as a fuel is not likely sustainable as global population grows. Further studies are needed to confirm this assertion.
- The results here indicate that life-cycle health impacts of renewable diesel blends are not likely to differ significantly from those of petroleum diesel.

There are, however, concerns that arise from the knowledge gaps associated with renewable diesel use in California. These concerns include:

- **Additives impacts.** The most important information gaps are associated with possible differences in additive use. To provide a stable, useful, and reliable fuel, additive chemicals will be introduced into almost all renewable diesel blends. These additives are used to address issues such as oxidation, corrosion, foaming, cold temperature flow properties, biodegradation, water separation, and NO_x formation. While many of these additives are already used in conventional diesel fuels currently in use, the specific chemicals and amounts to be used in renewable diesel by various producers has not been well defined for the emerging industry in California.

  It is important to note that, although the use of additives in diesel fuels (conventional or renewable) is common, the impact of various additives is not well known. A careful evaluation of the possible chemicals used in additives would be beneficial to California and may lead to a "recommended list" or "acceptable list" that would minimize the uncertainty of future impacts as new fuels and industry standards are developed. Additional research on the impacts of a "recommended list" of acceptable additives needs to be considered with respect to releases to water and soils and fugitive emissions to air.
- **Production and storage releases.** Increased renewable diesel production and associated feedstock processing may involve impacts from released reactants and by-products. There are potential impacts to California's air and water during the large-scale industrial operations used to extract seed oils. These impacts may result from air emissions of solvents used to extract the seed oil (e.g., hexane) and from leaking tanks containing process chemicals. There is also the issue of occupational exposures.

  Currently, the possible impacts during seed extraction will be minimal in California since it is anticipated that most of the seed oils will be derived from soy grown and extracted out-of-state. The impacts during seed extraction will be become more of an issue for California as in-state production of plant-derived oils increases and may require further study.

As the volume of tallow that is rendered out of state and shipped by rail or truck into California increases, there is a potential impact from releases of large volumes of raw triglycerides to soils or water. The impact of such a release has not been documented and additional research would be beneficial as large-scale tallow usage increases.

- **Air Emissions Toxicity Testing.** While there has been air-emission toxicity using pure renewable diesel, these studies did not directly compare results to a baseline diesel fuel. Based on the level of variation in emissions toxicity assessment for petroleum diesel, the chemical similarity of renewable diesel and petroleum diesel, and the likelihood for blends that still contain a significant fraction (80%) of petroleum diesel, we expect that it will be difficult, if not impossible, to organize and interpret a study to compare the toxicity of petroleum diesel relative to 20% renewable diesel blends. Therefore, unless the market evolves to the point where renewable blends contain more than 50% non-petroleum diesel feedstock, there appears to be little value in calling for emissions toxicity studies for renewable diesel.
- **Priority list of renewable diesel fuel formulations.** Because the number of potential feedstocks, the number of fuel blends, and the number of additive choices and mixes makes for an unmanageable suite of permutations that may require evaluation, it is critical to identify the priority feedstocks, fuel blends, and additives requiring study for any additional impacts assessment.

Not specifically addressed in this Tier I evaluation are the environmental impacts from the increased use of fertilizers and water and land resources if the production of plant oils increases in the State to supply renewable-diesel feedstocks. These factors may be some of the most important eventual impacts to California as the renewable and biofuels industry expands. More sustainable sources of renewable diesel such as yellow or brown grease or tallow may be preferable and should be encouraged.

During this review, we discovered that there are strong similarities between the chemical composition of petroleum diesel and renewable diesel. These similarities and the likelihood that renewable diesel will be used as a blend with petroleum diesel limits the need for additional Tier II Multimedia experiments or an extensive life-cycle impact assessment.

A key goal of this report is to identify important knowledge gaps for a Multimedia Assessment and recommend approaches to address these gaps. This does not always involve additional experiments, but could include additional requests for information from the proponents of any new fuel to be used in California.

As part of the overall multimedia assessment, each company proposing to market renewable diesel within California should provide the California ARB with a production, blending, additives, and distribution strategy that includes potential volumes to be stored and transported along with potential release scenarios that the company may foresee. Each company should also provide a comparative chemical analysis of the product they intend to market. This analysis should be compared to conventional diesel currently in the market place.

1. Renewable Diesel Background Information

1.1. Introduction

This multimedia assessment provides the State of California information that will support decisions about the relative impacts posed by renewable diesel to the State's resources, human health, and environment. "Renewable diesel" and "biodiesel" are names of alternative diesel-equivalent fuels, derived from biological sources (such as vegetable oils or tallow), which can be used in unmodified diesel-engine vehicles.

Currently, the majority of biological-source diesel fuels are fatty-acid methyl esters (FAME) produced through transesterification, but there are rapidly emerging alternatives to the transesterification production of diesel biofuels. Renewable diesel (also referred to as co-processed diesel or "green" diesel) is considered an alternative fuel that has potential in California. Renewable diesel is similar to biodiesel in that both use similar feedstocks, but they have different processing methods and can include chemically different components (**Figure 1.1**).

Renewable diesel is derived from non-petroleum renewable resources, including, (but not limited to) plant and algae oils, animal fats and wastes, municipal solid waste, sludge and oils derived from wastewater, and other wastes. Hydrogenation-derived renewable diesel (HDRD) is produced by refining fats or vegetable oils—typically in existing oil refineries. This process is also known as the Fatty Acids to Hydrocarbon (Hydrotreatment) or FAHC Hydrotreatment process. In this process, renewable feedstocks such as vegetable oils and animal fats are converted into diesel fuel as well as propane, and other light hydrocarbons through a catalytic treatment that adds hydrogen (Hilber et al., 2007; Knothe, 2010). Because it is free of ester compounds, renewable diesel has a chemical composition that is almost identical to petroleum-based diesel (CEC, 2007).

Preliminary evaluations (CEC, 2007; U.S. DOE, 2010) indicate several potential advantages of renewable diesel relative to FAME and petroleum-based diesel. These advantages include:

- Renewable diesel can be used directly in the current diesel-powered vehicle fleet without modification.
- Renewable diesel is compatible with current diesel distribution infrastructure and does not require new or modified pipelines, storage tanks, trucking infrastructure, or retail station pumps.
- Renewable diesel can be produced using existing oil refinery capacity and does not require extensive new production facilities.
- The fuel properties of renewable diesel fuel, specifically its high cetane number, suggest it will provide similar or better vehicle performance than conventional CARB ultra-low sulfur diesel (ULSD).
- The ultra-low sulfur content of renewable diesel enables the use of advance emission control devices.
- The production of renewable diesel through the FAHC process does not produce a glycerin co-product.

In addition to producing a fuel that uses recycled carbon, renewable diesel benefits include: a high level of quality control; compliance with ASTM D975, Standard Property Descriptions for Diesel Fuel Oils (Appendix A); and easy blending with FAME biodiesel.

Preliminary tests of renewable diesel emissions indicate that, relative to standard diesel, there is a potential for a significantly better emissions profile during combustion with reduced particulate, NOx, hydrocarbons, and CO emissions (Rothe et al, 2005; Kaufman, 2007). Emissions testing for US EPA Tier 1 requirements released by Kern Oil and Refining Co. (Fanick, 2009) report total hydrocarbon, total particulate, carbon monoxide, and NOx emissions that satisfy the requirements for ASTM D975. Analogous testing by Neste Oil Co. (Fanick, 2008) reported reduced emissions of these compounds in comparison of the NExBTL renewable diesel product with European sulfur-free EN590 grade diesel (Fanick, 2008). Disadvantages include less desirable cold flow properties and the need for a lubricity additive.

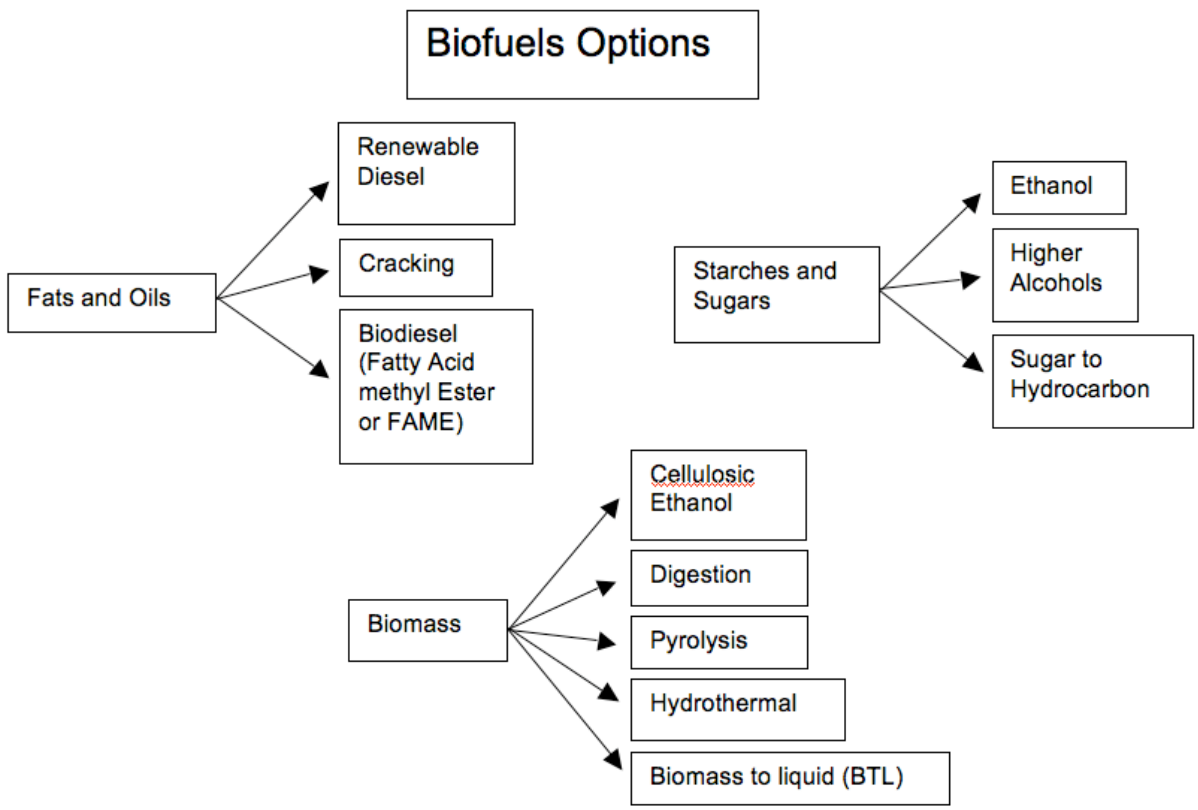

Figure 1.1. Summary of biofuel options.

Although renewable diesel is chemically very similar to conventional diesel, it is produced through a distinct and novel process, and the California Air Resources Board (CARB) must provide a "life cycle multimedia risk assessment" before adopting new fuel specifications that allow renewable diesel blends (as required by California Health and Safety Code, Section 43830.8). In addition, existing law states that the "California Air Resources Board cannot adopt any regulation establishing a motor vehicle fuel specification unless a multimedia evaluation is conducted to determine whether the regulation will cause a significant adverse impact on the public health or environment" (California Senate Bill 140, 2007).

This Tier I Renewable Diesel report is the first step in a three-tier process to evaluate the cumulative health and ecological impacts from releases to air, surface water, groundwater and soil at all stages of the renewable diesel life cycle: feedstock production, fuel production, storage and distribution, and fuel use. The life cycle risk posed by renewable diesel is assessed as a relative risk compared to the California Air Resources Board (CARB) ultra-low sulfur diesel (ULSD) currently in use.

The goal of this Tier I report is to identify what is currently known about the life-cycle health, ecological, and resource impacts of renewable diesel and identify key uncertainties and data gaps. Meeting this goal requires the following elements:

- identifying the physical, and chemical and environmental toxicity characteristics of the reference fuel, candidate fuel, and additive components,
- summarizing all potential production, distribution, storage, and use release scenarios including a discussion of the most likely release scenarios,
- summarizing the expected environmental behavior (transport and fate) associated with a portfolio of release scenarios for proposed fuel or fuel components that may be released, and
- comparing physical, chemical, and toxic properties of the fuel or additive components to an appropriate and consensus control fuel or fuel components.

This report does not address direct and indirect environmental, ecological, and health impacts associated with biomass production—such as changes in land use and the possible net gain in carbon emissions due to feedstock cultivation. There is a scientific debate concerning the sustainability of wide-scale energy conversion from fossil fuels to biofuels (Wang & Haq, 2008, NRC, 2009). Some researchers have suggested that the demand for biomass feedstocks will result in the clearing of virgin rainforests and grasslands and that this clearing with result in high initial "carbon debts" estimated to have decades or even centuries-long pay-back periods due to the modest savings in carbon emissions from burning biofuels (Searchinger et al. 2008). Such issues have led the European Union to propose a ban on certain biofuel sources such as palm oil from Southeast Asia due to associated deforestation and habitat loss and due to non-sustainability of palm tree monoculture (Kantor 2008, Rosenthal 2007). Some end-users (e.g., Virgin Atlantic airlines) seek only sustainable sources of biofuels that are not produced in ways that compete with food-grain production and/or add to deforestation and other land-use conversions (Clark 2008). It is clear that the issue of sustainability and a more complete life cycle impact assessment of biofuels are important aspects of the decision to expand biofuels use.

However such evaluations are beyond the scope of the multimedia working group, which is mandated to focus on the human health, ecological, and resource risks associated with the production, transportation, storage, and use of biofuels and not the broader impacts of increased/decreased use of various raw feedstocks. Because the life-cycle carbon impacts of alternative fuels are addressed in the working reports of the California Low-Carbon Fuels Standard (LCFS) Program, only the issues not explicitly addressed in the LCFS, including health, ecological, and resource impacts, are the primary objectives of this report.

This Tier I report sets the stage for determining whether subsequent Tier II and Tier III multimedia assessments are needed and if so with what level of detail. The process follows the guidance set forth in the report "Guidance Document and Recommendations on the Types of

Scientific Information to be Submitted by Applicants for California Fuels Environmental Multimedia Evaluations" (CalEPA, 2008).

In any Tier-II activities, the guidance noted above requires Cal-EPA together with its collaborators at the University of California to evaluate critical uncertainties and data gaps identified during Tier I evaluations and propose any action needed to address potential life-cycle impacts renewable diesel may have to the State's resources, human health and environment. During Tier III activities, potential life cycle impacts are compared to the selected baseline fuel and the results and conclusions are reported to California Environmental Policy Council. **Figure 1.2** provides an overview of the life-cycle stages that we address in this report. We consider four major life stages—feedstock production/collection, renewable diesel production, transport and storage, and fuel use (combustion).

In an earlier report, the Multimedia Working Group has already issued a Tier I multimedia assessment for FAME biodiesel, produced through a transesterification process. In addition the Tier II and Tier III reports for FAME biodiesel are in process (CARB, 2009).

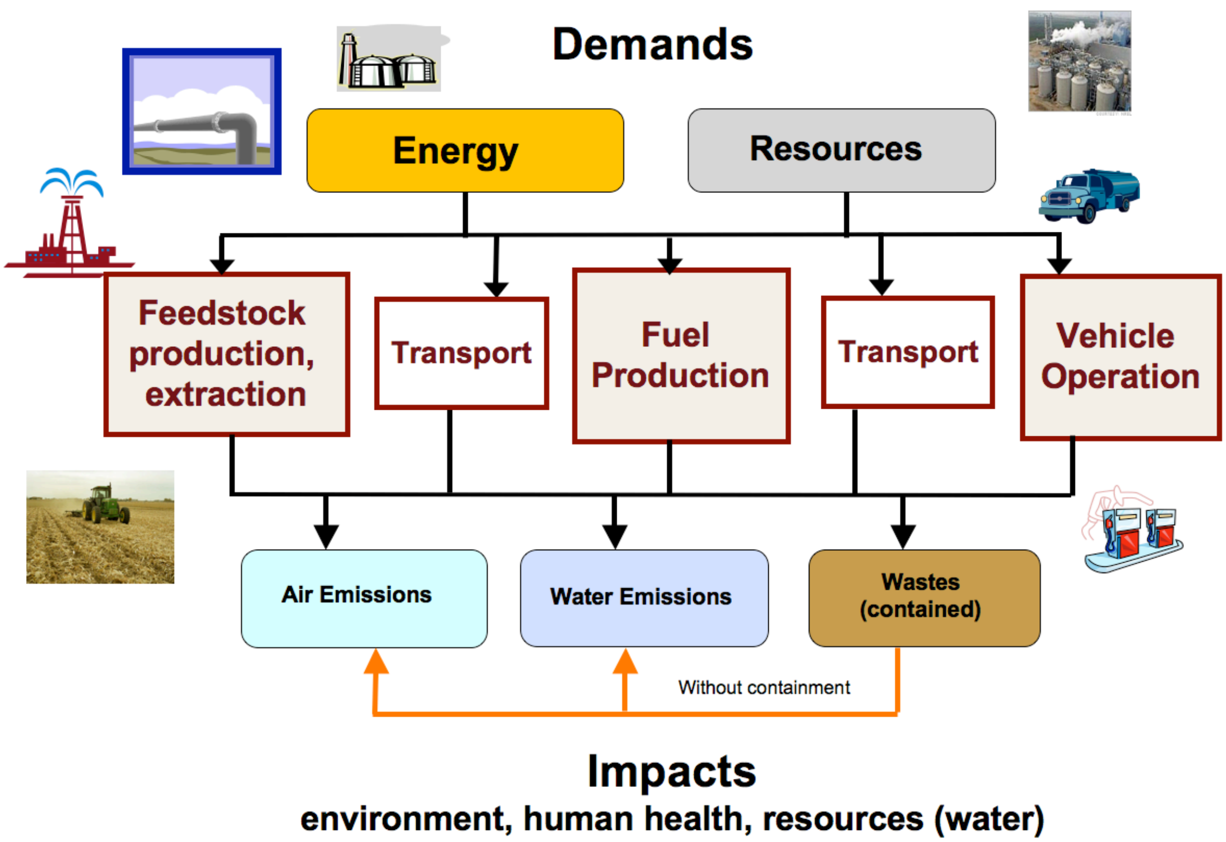

Figure 1.2. Generalized summary of renewable diesel life cycle impacts.

1.2. History

Raw vegetable and animal oils contain an abundance of triglycerides that have value as sources of combustion energy and feedstocks to produce motor vehicle fuels. Although these oils can be used directly in diesel engines and provide reliable short-term performance, engine manufacturers discourage this practice because it can cause severe engine problems in the long term (US EPAa, 2010). This concern is primarily due to the raw oils forming engine deposits, as well as coking and plugging in engine injector nozzles, piston rings, and lubricating oil. This happens due to polymerization of the triglycerides in the raw oils as the fuel is combusted. To prevent these problems, it is necessary to convert the raw oils into a more appropriate form of biomass-based diesel fuel—either esters or hydrocarbons. It has been recognized for a number of years that triglycerides can be hydrogenated into linear alkanes in a refinery hydrotreating unit with the presence of conventional sulfated hydrodesulphurization catalysts (Donnis et al., 2009). This process is referred to here as the Fatty Acids to Hydrocarbon Hydrotreatment (FAHC-Hydrotreatment) process.

Hydrogenation-derived renewable diesel (HDRD) processes have been used at fossil fuel refineries since the 1950s to remove impurities and to produce higher quality oil (Donnis et al., 2009). The first work describing hydroprocessing of bio-oils was by Nunes (1984), who described a reaction of soy oil with hydrogen over silica- and alumina-supported catalysts. During the 1980s Elliot and others successfully hydrotreated pyrolysis-derived oils at Pacific Northwest National Laboratories (PNNL) (Elliot and Baker, 1988). Research at PNNL and the National Renewable Energy Laboratory (NREL) has lead to contemporary commercial development of the process by Neste, UOP, and Conoco-Phillips (Elliot, 2007).

A number of manufacturers around the world are developing HDRD refining processes and testing them in commercial trials. The following paragraphs provide brief descriptions of some of these projects (US DOE, 2010):

ConocoPhillips (United States, Ireland)

Conoco Phillips has been producing HDRD at its Whitegate refinery in Cork, Ireland since 2006. The primary renewable feedstock is soybean oil, but other vegetable oils and animal fats could be used as well. The HDRD is being produced using existing refinery equipment and is blended and transported with petroleum-based diesel. Initial production has been 1,000 barrels per day. ConocoPhillips has also partnered with Tyson Foods to produce HDRD using animal fat, beginning in 2007 with projections for having ramped up to as much as 11,000 barrels per day by 2009. Currently the tallow used to make renewable diesel is commonly used to make cosmetics, soaps, candles, and some pet food.

Neste Oil (Finland)

Neste Oil has been producing pure HDRD using its NExBTL process at its Porvoo refinery in Kilpilahti, Finland since 2007. A second plant was added to the Porvoo refinery in 2009, for a total production capacity of 340,000 metric tons per year at this facility. US EPA registration and toxicity and biodegradability testing has been submitted. Neste Oil is 50% owned by the Finnish government.

Petrobras (Brazil, Portugal)

Brazilian oil company Petrobras developed the H-Bio process, which produces HDRD using hydrotreating units in existing oil refineries. Petrobras had employed the H-BIO process in three of its refineries by 2007 with plans for more facilities to reach a total vegetable oil consumption of more than 7,000 barrels per day. More recently, Petrobras has announced plans in partnership with Galp Energia to develop production facilities in Portugal for up to 250,000 tons of biodiesel per year, from Brazilian palm feedstocks, by 2018.

Syntroleum (United States)

Syntroleum formed a joint venture with Tyson Foods to produce HDRD and jet fuel using its Biofining process. Production from its first plant was scheduled to come online in 2010 at a rate of about 5,000 barrels of synthetic fuel per day.

UOP-Eni (United States, Italy)

UOP-Eni is an American (UOP LLC, a Honeywell company) and Italian oil and gas company (Eni) project supported by the U.S. Department of Energy (DOE) to build a commercial scale facility at Eni's Livorno, Italy refinery. The U.S. Department of Energy has supported UOP's Renewable Energy and Chemicals unit in developing HDRD production technologies. The first "Ecofining" facility developed by UOP and Eni was scheduled to come online in 2009, processing 6,500 barrels per day of vegetable oils.

Other companies that have plans to produce renewable diesel through hydrogenation include Nippon Oil in Japan, and BP in Australia (co-processed R5),. The Nippon Oil plant expects to be operating commercially in three years. The BP plant is planned to have a demonstrated capacity of 80,000 gallons per day.

UOP, NesteOil, LiveFuels, and Sapphire Energy each independently introduced "green crude" or biocrude from algae as a petroleum substitute.

1.3. Legislative Incentives for Biofuels

Over the last decade, there have been a number of state and federal mandates to encourage the development and use of a broad range of biofuels. To reduce US dependence on imported oil, the US Congress passed the Energy Policy Act of 1992 (EPAct). The Energy Conservation and Reauthorization Act of 1998 amended and updated many elements of the 1992 EPAct. The 1998 amendment allowed "qualified fleets to use B20 in existing vehicles to generate alternative fuel vehicle purchase credits, with some limitations". This amendment significantly increased the use of B20 by government and alternative-fuel-provider fleets.

The Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 (EISA) provide tax incentives and research funds for biofuels. The Energy Policy Act of 2005 was signed into law in August 2005. This legislation supports the growth of the biodiesel and renewable diesel industry. Consumer and business federal tax credits for biofuels were extended to 2008 and credits were provided to small agri-biofuel producers. This legislation also requires a comprehensive two-year "analysis of impacts from biodiesel on engine operation for both existing and expected future diesel technologies, and provides recommendations for ensuring optimal emissions reductions and engine performance with biodiesel." (Federal Record, 2005).

The Renewable Fuels Standards (RFS) program was created under the EPAct of 2005, and established the first renewable fuel volume mandate in the United States. As required under EPAct, the original RFS program (RFS1) required 7.5 billion gallons of renewable fuel to be blended into gasoline by 2012 (US EPA, 2010c,d). This Act requires that 75% of new vehicle purchases made by federal and state governments must be alternative fuel-vehicles. Compliance was mandatory for the agencies that operated, leased, or controlled 50 or more lightweight vehicles. The alternative fuels on which these vehicles could run included: pure biodiesel (B100), renewable diesel blends or biodesel blends, blends of 85% or more of ethanol with gasoline (E85), natural gas and liquid fuels domestically produced from natural gas, hydrogen, electricity, coal-derived liquid fuels, and liquefied petroleum gas (CEC, 2007).

Under the Energy Independence and Security Act (EISA) of 2007, the RFS program was expanded in several key ways (RFS2):

- EISA expanded the RFS program to include diesel, in addition to gasoline;
- EISA increased the volume of renewable fuel required to be blended into transportation fuel from 9 billion gallons in 2008 to 36 billion gallons by 2022;
- EISA established new categories of renewable fuel, and set separate volume requirements for each one.
- EISA required EPA to apply lifecycle greenhouse gas performance threshold standards to ensure that each category of renewable fuel emits fewer greenhouse gases than the petroleum fuel it replaces.

RFS2 lays the foundation for achieving significant reductions of greenhouse gas emissions through the use of renewable fuels, reducing imported petroleum, and encouraging the development and expansion of the US renewable fuels sector (US EPA 2010c,d). While most of the focus to date has been on FAME biodiesel (B100, B20) and ethanol, there is increased interest on HDRD renewable diesel (R100, R20) because of its infrastructure and performance advantages.

In 2006, Governor Arnold Schwarzenegger signed the California Global Warming Solutions Act, requiring by 2020 reductions in greenhouse gas (GHG) emissions down to 1990 levels (California Office of the Governor, 2006; Young, 2008). It is the responsibility of the California Air Resources Board (CARB) to determine the technologically and economically feasible methods of achieving these goals. The first goal of the agency was to quantify 1990 emissions levels and create a framework for reporting emissions from industrial sources. The emissions goal was set at "427 million metric tons of carbon dioxide equivalents" in December 2008 and to be achieved by 2020. In June 2008, CARB released a scoping plan to "reduce overall carbon emissions in California, improve our environment, reduce our dependence on oil, diversify our energy sources, save energy, and enhance public health while creating new jobs and enhancing the growth in California's economy" (CARB, 2008). Goals include strengthening energy efficiency programs, increasing electricity production from renewable sources and approving new fuels that meet the California Low Carbon Fuel Standard (LCFS). Executive Order S-1-07 initiated the LCFS, with the goal of reducing transportation-based emissions. On April 23, 2009, the Air Resources Board approved the specific rules and carbon intensity reference values for the LCFS that will go into effect on January 1, 2011. The Board approved the technical proposal without modifications by a 9-1 vote. This technical proposal sets the 2020 maximum carbon intensity reference value for gasoline to 86 g of carbon dioxide equivalent released per MJ of energy produced. The regulation is based on an average declining standard of carbon intensity that is expected to achieve 16 million metric tons of greenhouse gas emission reductions by 2020. One standard was established for gasoline and its alternatives, and a second similar standard was set for diesel fuel and its alternatives.

The Internal Revenue Service (IRS) gives renewable diesel the same tax credit given to plant-derived biodiesel ($1/gal tax credit). To attain this credit the renewable diesel fuel must meet US EPA registration requirements for fuel and fuel additives under the Clean Air Act, and the ASTM standard for conventional petroleum diesel (D975).

2. Renewable Diesel Life Cycle Impacts

2.1. Life Cycle Assessment

The purpose of a life-cycle assessment (LCA) applied to renewable diesel is to quantify and compare environmental flows of resources and pollutants (to and from the environment) associated with both renewable diesel and petroleum-based diesel, over the entire life cycle of the respective products. The flows of resources and pollutants provide framework for assessing human-health, environmental-systems and resource impacts. LCA addresses a broad range of requirements and impacts for technologies, industrial processes and products in order to determine their propensity to consume natural resources or generate pollution. The term "life cycle" refers to the need to include all stages of a process—raw material extraction, manufacturing, distribution, use and disposal including all intervening transportation steps—so as to provide a balanced and objective assessment of alternatives. An LCA includes three types of activities: (1) collecting life cycle inventory data on materials and energy flows and processes; (2) conducting a life-cycle impact assessment (LCIA) that provides characterization factors to compare the impacts of different product components; and (3) life-cycle management, which is the integration of all this information into a form that supports decision-making. A comprehensive LCA for renewable diesel must address cumulative impacts to human health and the environment from all stages, impacts from alternative materials, and impacts from obtaining feedstocks and raw materials. **Figure 2.1** illustrates our approach for renewable diesel LCA.

The focus of the Multimedia Working Group efforts is on the direct health and environmental impacts associated with pollutant emissions from renewable diesel production and use. There are many other life-cycle issues that are of interest—including green-house-gas (GHG) emissions, water use, energy balance, land conversion, and competing uses for food crops. These are outside of the scope of this effort and are being addressed in detail by other California programs—particularly the LCFS program (CalOAL, 2010).

There are other ongoing efforts to evaluate lifecycle impacts of non-petroleum diesels (e.g., Huo et al., 2008; 2009, focusing on biodiesel and renewable diesel derived from soy feedstocks; Kalnes et al., 2009, comparing biodiesel and renewable diesel) and this literature is expected to continue to grow.

The life-cycle of renewable diesel fuels include the following stages:

- Biomass production and preparation (for renewable diesel derived from plant biomass),
- Oil extraction processes (for renewable diesel derived from plant biomass),
- Collection of recycled oils, greases, and tallow,
- Renewable diesel production--refining the final product blend,
- Transportation, storage and distribution of renewable diesel product, and
- End-use of the fuel product--combustion.

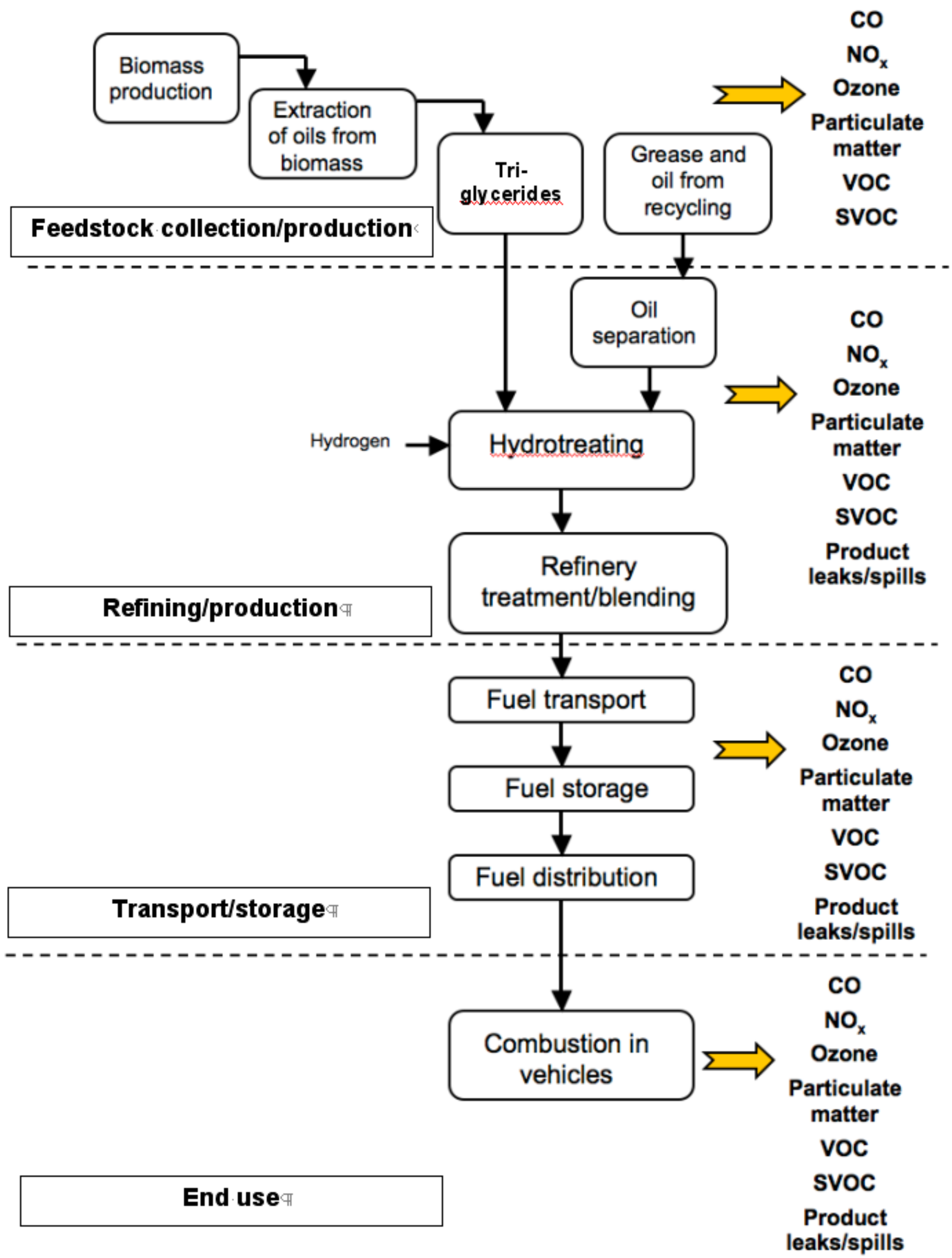

Figure 2.1. An illustration of life cycle stages and some potential life-cycle pollutant emissions for renewable diesel fuels.

For each of these stages we must address emissions to the environment for the following pollutant categories:

- carbon monoxide (CO),
- nitrogen oxides (NO_x),
- ozone,
- particulate matter,
- volatile organic compounds (VOCs) such as benzene, formaldehyde, etc.,
- semi-volatile organic compounds (SVOCs) such as polycyclic aromatic hydrocarbons,
- metals,
- fuel product leaks and spills, and
- hazardous wastes.

Modeling damages from the life-cycle emissions attributable to petroleum-based or renewable fuels requires characterization of emissions factors for both the life cycle of the fuel and the operation of the vehicle.

2.2. US EPA Life Cycle Assessment of Renewable Fuels

As part of the U.S. EPA RFS2 rulemaking, a life cycle assessment of alternative and petroleum transportation fuels was conducted. EPA used a variety of agricultural and process engineering models and spreadsheet analysis tools, including the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model; the Forest and Agricultural Sector Optimization Model (FASOM); and the Food and Agricultural Policy Research Institute (FAPRI) model, to analyze life cycle impacts of petroleum and renewable fuels (US EPA 2010a,b).

The EPA LCA analysis addressed production emission factors for the biofuels, ethanol, biodiesel, and renewable diesel. Emissions from the production of biofuels include the emissions from the production facility itself as well as the emissions from production and transport of the biomass and any other fuels used by the biofuel plant, such as natural gas, coal, and electricity. Table 2.1., which includes results from the EPA LCA study, shows that compared to ethanol (including wet and dry milled biomass, and cellulosic production) or biodiesel, renewable diesel had the lowest production plant emissions.

Table 2.2., which also provides results from the US EPA LCA study, compares the projected renewable diesel use volumes to other biofuel volumes (in billion gallons per year). The US EPA LCA assumes that ethanol and biodiesel will be the major fuels used to meet Renewable Fuel Standards in the future. As a result, the US EPA LCA did not address distribution or use impacts because it was assumed that renewable diesel production would constitute less than 0.5 billion gallons per year.

Table 2.1. Biofuel Production Plant Emission Factors in 2022 (grams per gallon produced)(US EPA, 2010a)**.**

Biofuel Production Plant Type	VOC	CO	NOx	PM10	PM2.5	SOx	NH3
Corn Ethanol, Dry Mill NG	4.000	1.900	5.500	2.200	0.265	7.000	0.000
Corn Ethanol, Dry Mill NG (wet DGS)	4.000	1.900	5.500	2.200	0.222	7.000	0.000
Corn Ethanol, Dry Mill Coal	4.000	1.900	5.500	2.200	1.884	7.000	0.000
Corn Ethanol, Dry Mill Biomass	4.000	1.900	5.500	2.200	0.421	7.000	0.000
Corn Ethanol, Dry Mill Biomass (wet DGS)	4.000	1.900	5.500	2.200	0.313	7.000	0.000
Corn Ethanol, Wet Mill NG	2.330	1.039	1.677	0.998	0.288	0.012	0.000
Corn Ethanol, Wet Mill Coal	2.334	3.501	4.857	4.532	1.984	4.595	0.000
Cellulosic Ethanol (switchgrass or corn stover, enzymatic)	1.937	11.722	16.806	2.792	1.116	0.625	0.000
Cellulosic Ethanol (forest waste, thermochemical)	0.363	5.154	7.427	0.854	0.435	0.271	0.000
Biodiesel, Soybean oil	0.040	0.454	0.733	0.062	0.062	0.005	0.000
Renewable Diesel, Soybean Oil	**0.029**	**0.329**	**0.530**	**0.045**	**0.045**	**0.004**	**0.000**

Table 2.2. Projected Renewable Fuel Volumes (billion gallons)(US EPA, 2010a).

	Advanced Biofuel					**Non-Advanced Biofuel**	
	Cellulosic Biofuel	**Biomass-Based Diesel[a]**		**Other Advanced Biofuel**			
Year	**Cellulosic Ethanol**	**FAME[b] Biodiesel**	**Non-Co-processed Renewable Diesel**	**Co-processed Renewable Diesel**	**Imported Ethanol**	**Corn Ethanol**	**Total Renewable Fuel**
2009	0.00	0.50	**0.00**	**0.00**	0.50	9.85	10.85
2010	0.10	0.64	**0.01**	**0.01**	0.29	11.55	12.60
2011	0.25	0.77	**0.03**	**0.03**	0.16	12.29	13.53
2012	0.50	0.96	**0.04**	**0.04**	0.18	12.94	14.66
2013	1.00	0.94	**0.06**	**0.06**	0.19	13.75	16.00
2014	1.75	0.93	**0.07**	**0.07**	0.36	14.40	17.58
2015	3.00	0.91	**0.09**	**0.09**	0.83	15.00	19.92
2016	4.25	0.90	**0.10**	**0.10**	1.31	15.00	21.66
2017	5.50	0.88	**0.12**	**0.12**	1.78	15.00	23.40
2018	7.00	0.87	**0.13**	**0.13**	2.25	15.00	25.38
2019	8.50	0.85	**0.15**	**0.15**	2.72	15.00	27.37
2020	10.50	0.84	**0.16**	**0.16**	2.70	15.00	29.36
2021	13.50	0.83	**0.17**	**0.17**	2.67	15.00	32.34
2022	16.00	0.81	**0.19**	**0.19**	3.14	15.00	35.33

[a]Biomass-Based Diesel includes FAME biodiesel, cellulosic diesel, and non-co-processed renewable diesel.
[b]Fatty acid methyl ester (FAME) biodiesel.

2.3. Life Cycle Impacts and Information Gaps

A recent study by the National Research Council on the "Hidden Costs of Energy" (NRC, 2009) used life-cycle assessment to consider health impacts for a range of both light-duty and heavy-duty fuel/vehicle combinations. This study evaluated motor-vehicle damages over four life-cycle stages: 1) vehicle operation, which results in tailpipe emissions and evaporative emissions; (2) production of feedstock, including the extraction of the feedstock resource (oil for gasoline, biomass for biofuels, or fossil fuels for electricity) and its transportation to the refinery; (3) refining or conversion of the feedstock into usable fuel and its transportation to the dispenser; and (4) manufacturing and production of the vehicle. Importantly, the study found that vehicle operation accounted in most cases for less than one-third of total damages, with other components of the life cycle contributing the rest. While life-cycle stages 1, 2, and 3 were somewhat proportional to actual fuel use, stage 4 (which is a significant source of life-cycle emissions that form criteria pollutants) was not.

The NRC estimates of damage per vehicle-mile traveled (VMT) among different combinations of fuels and vehicle technologies were remarkably similar. Because these assessments were so close, the NRC (2009) noted that it is essential to be cautious when interpreting small differences between fuel/vehicle combinations.

The NRC considered annual health damage for 2005 as base year and 2030 as a future scenario. Although diesel-fueled light-duty vehicles had some of the highest damages per VMT in 2005, diesel-fuel use in light-duty vehicles are expected to have some of the lowest impacts per VMT in 2030. This change assumes full implementation of the Tier-2 vehicle emission standards of the U.S. Environmental Protection Agency (EPA). This regulation, which requires the use of low-sulfur diesel, is expected to significantly reduce PM and NOx emissions, resulting in significant reductions of population exposures to direct and indirect fine-particle pollutants.

Heavy-duty vehicles have much higher damages per VMT than light-duty vehicles because they carry more cargo or people and therefore have lower fuel economies. However, between 2005 and 2030, these damages are expected to drop significantly, assuming the full implementation of the EPA Heavy-Duty Highway Vehicle Rule.

The finding that life-cycle impacts are insensitive to a range of vehicle/fuel combinations (differences between vehicle/fuel combinations were often less than the confidence interval for each single fuel/vehicle combination) indicates that any life-cycle impact study for renewable diesel will be unlikely to resolve any key differences in health/ecological impacts between petroleum-based diesel and renewable diesel blends.

A review of this analysis was commissioned by the American Petroleum Institute (Unnasch et al. 2010) and found several questionable assumptions and concerns with the use of the GREET model. With regard to biofuels, the review concluded that optimistic assumptions make biofuels look very feasible. With regard to petroleum usage, the review concluded that the analysis could be refined to reflect appropriate data. Unnasch et al. (2010) also noted that a key challenge in applying the GREET LCA model is in identifying input assumptions that are appropriate for these complex models and EPA should review and better justify the input assumptions adopted. They further noted that there was no uncertainty analysis, only sensitivity case studies.

3. Release Scenarios

3.1. Defining Release Scenarios

For the Tier I evaluation of release scenarios, we focus on identifying releases that could have the greatest impact on the environment, human health, and important resources such as surface and ground waters. In order to define release scenarios it is important to understand differences in fuel production, blending, and distribution plans among the different fuel products.

There are a several companies planning to market renewable diesel in California and elsewhere; however, they have different production and marketing plans. A key issue for release scenarios upstream from the combustion stage is whether blending renewable diesel stock will occur at the refinery or at a distribution facility.

An additional challenge in setting up scenarios is that feedstock sources will be widely distributed geographically and will use a variety of transportation options. Palm oil will likely arrive from distant global sources via tanker ship. Soy oil will likely arrive via rail tank car from the Midwestern United States. Yellow grease will be collected from a variety of sources within a city or region and transported by truck to a processing facility. Tallow from the southern United States may be shipped by rail to an out-of-state oil refinery to produce renewable diesel that is transported to California via existing fuel pipelines.

Releases associated with the production, storage and distribution, and use of renewable diesel can be regarded as normal (routine) or off-normal (unplanned but not necessarily unlikely). Different feedstock supplies and production processes may have different normal and off-normal releases and may affect different environmental media and human populations depending on geographic location.

3.2. Normal Releases

There are various regulations in place to address normal releases from renewable diesel production, transport, and use. At the federal level, the 1972 Clean Water Act (CWA) (33 U.S.C. §1251 et seq.) and the 1990 Oil Pollution Act (OPA) (33 U.S.C. §2702 et seq.) "outline various requirements that must be met in order to comply with regulations" (Van Gerpen, 2004). Under these acts, there is no distinction between petroleum oils, vegetable oils, and animal fats, as they share common physical properties and produce similar environmental effects.

Normal or routine releases during the production of renewable diesel include:

- hexane or CO_2 released to the air during seed extraction,
- odors associated with waste biomass, and
- used process water discharges of various pH and trace-chemical composition.

Normal releases during the use of renewable diesel include combustion tailpipe emissions, both to the air and to surface waters in the case of marine use. The specific magnitude of these normal production- and use-releases within California are not yet well characterized and will remain difficult to quantify until more process specific data become available as well as more engine/vehicle combustion tests are conducted.

3.3. Off-Normal Releases

Off-normal or unanticipated releases can occur primarily during the production, distribution and storage of renewable diesel. Off-normal releases may include spills or leaks of bulk feedstock, production chemicals, such as hexane or blending stocks such as ULSD, or finished renewable diesel fuel. These off-normal releases may be the result of a leak or rupture of:

- an above-ground or below-ground storage tank and associated piping,
- a liquid-transportation vehicle such as rail tank car, tanker truck, or tanker ship, or
- a bulk-fuel transport pipeline.

The amendment of the Oil Pollution Act in 2002 introduced the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This legislation requires "owners or operators of vessels and certain facilities that pose a serious threat to the environment to prepare facility response plans" (Van Gerpen, 2004). Greater contingency planning can reduce spills during transportation and at the plant.

In 2002, the EPA published a Spill Prevention Control and Countermeasure (SPCC) rule within Part 112 of Title 40 of the Code of Federal Regulations, (40 CFR 112) to ensure that fuel production/distribution facilities put in place containment and other countermeasures that would prevent oil spills. While each SPCC is unique to the facility, all should clearly address "operating procedures that prevent oil spills, control measures installed to prevent a spill from reaching navigable waters, and countermeasures to contain, clean up, and mitigate the effects of an oil spill that reaches navigable waters" (Van Gerpen, 2004).

For a company that plans to produce 100% renewable diesel and then blend it with CARB ULSD post-production, possibly at some location remote from the production facility, the release scenarios may be different from a company that plans to co-process "green" plant or animal oil along with conventional crude oil. In the former case, storage and transport of 100% renewable diesel must be considered in terms of how it differs from experience with conventional and ULSD diesel. Some questions that arise:

- Can it be transported via pipelines?
- What are the spill consequences for 100% renewable diesel compared to ULSD?

4. Production of Renewable Diesel

4.1. Renewable Diesel Production Chemistry

There are several different chemical approaches available to produce renewable diesel. One is based on hydrotreating vegetable oils or animal fats. Hydrotreating can take place in the same facilities used to process petroleum-based diesel. A second method involves synthesis of hydrocarbons through enzymatic reactions. A third method involves partially combusting a biomass source to produce carbon monoxide and hydrogen—syngas—and then utilizing the Fischer-Tropsch reaction to produce complex hydrocarbons. Because there are currently few plans to engage the Fischer-Tropsch process in California, the California Air Resources Board (ARB) staff have requested that this report focus on the impacts of hydrotreated renewable diesel (HDRD/FAHC) produced in existing refineries.

Hydrotreating is a hydrodeoxygenation process used to remove oxygen and nitrogen containing compounds as well as metals from the fuel feedstock. Both crude oil and bio-oils contain minerals as well as aromatic and oxygenated compounds that provide only minor contributions to the combustion performance and emission profile of the fuel. With hydrotreating, the feedstock oil flows through a fixed bed reactor under high pressure, where it is mixed and reacted with hydrogen gas. Marker et al. (2005) describe this process as having hydrogen gas injected at approximately 1.5% the mass of vegetable oil feedstock with lower amounts required for a predominately saturated fatty acid feedstock such as coconut oil.

Olefins and aromatic compounds react with hydrogen atoms, converting them into paraffins. Cobalt-Molybdenum and other catalysts are used to increase the rates of reaction (Gary et al., 2007). Aromatic rings are broken in catalyzed reactions with hydrogen, forming saturated hydrocarbons and methyl functional groups attached to carbon chains creating iso-paraffins (Liu et al., 2008). Hydrotreatment of vegetable oils produces alkanes with one carbon atom less than the fatty acid chains, although the exact nature of the product mix depends on reaction conditions and catalysts used. As a result, avvegetable oil consisting of the typical C16 and C18 fatty acids would yield C15 and C17 alkanes (Knothe, 2010).

According to Gary et al. (2007), hydrogen gas for this process can be produced by reacting steam and methane, where the gas and vapors pass through catalysts in a heated reactor. This reaction is illustrated in **Figure 4.1**. The reaction also produces carbon monoxide, which is converted to CO_2 in a second stage, where the reactants are again mixed with steam, and pass over solid chromium and iron oxide catalyst. CO_2 is then removed from the gas phase through absorption processes.

$$CH_4 + 2H_2O \xrightarrow{Catalyst} CO_2 + 4H_2$$

Figure 4.1. Hydrogen production from methane, adapted from Gary et al. (2007).

Hydrotreating can alter the sulfur and aromatic content of crude oil for the production of ULSD (Gary et al., 2007). Metals bonded to aromatics and hydrocarbon chains are released and replaced by hydrogen, however some bonding sites have a higher affinity for nitrogen compounds, potentially inhibiting the desulphurization reactions (Liu et al., 2008). Minerals shed from the organic compounds are deposited on catalyst surfaces, extinguishing capacity over time (Gary et al., 2007). For this reason, it has been argued that the use of conventional refining facilities for production of renewable diesel may be less cost-effective in the long-term than establishment of dedicated facilities (Kalnes et al., 2009). Hydrogen sulfide, ammonia and CO_2 are produced as gasses and must be captured by emission control devices.

4.2. Renewable Diesel Reactor Configuration and Design

Many of the companies that are now making renewable diesel, including UOP (Green Diesel), Neste (NexBTL) and Conoco-Philips, have developed proprietary processes for the hydrogenation of non-petroleum feedstocks with hydrogen gas. These processes remove impurities from the feedstock while saturating free fatty acids (Kalnes et al., 2007).

There are two general production strategies for HDRD production and distribution:

- Co-processing vegetable/animal triglycerides in a conventional petroleum production stream using a hydrotreating process. Currently this results in diesel fuel that has a specified percentage of “green-derived” carbon, e.g., 20% renewable diesel (R20).
- Production of a pure HDRD (R100) in a dedicated hydrotreating facility that does not use conventional petroleum. The resulting fuel can be used as a 100% green fuel or blended with conventional ULSD to any concentration.

As an illustration of the chemical processes that take place in renewable diesel reactors, we consider the case of vegetable oils that are composed primarily of triglycerides. These are organic molecules that include chains of carbon atoms bonded to hydrogen atoms and various functional groups. Soy and canola oils are largely unsaturated fatty acids—that is only some carbon atoms are double bonded. Fully saturated fatty acids are composed solely of single bonds between carbon atoms and achieve a stable valence state through bonding to hydrogen atoms (Petrucci et al., 2002). Saturated fatty acids are less susceptible to oxidation and decomposition from heat and therefore provide a more stable fuel. **Figure 4.2** illustrates the hydrogenation of triglycerides.

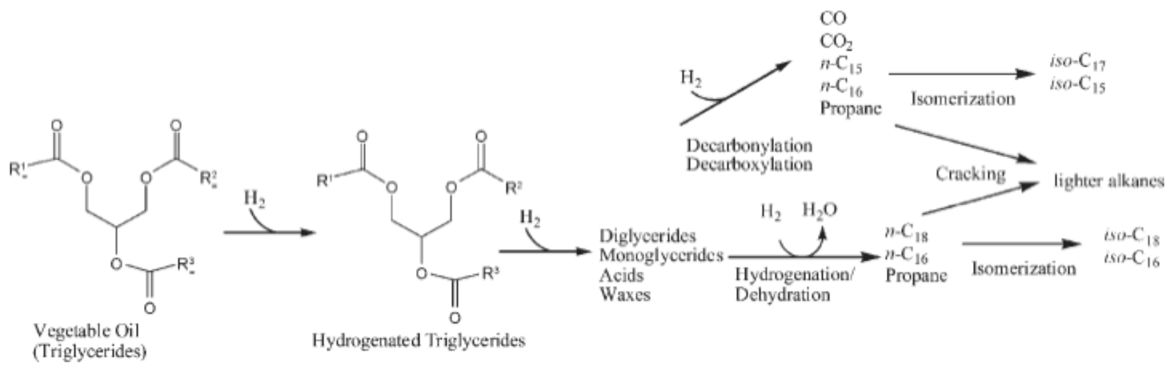

Figure 4.2. Hydrogenation of Triglycerides

Hydrogen for saturation can be generated onsite through reactions with methane (Huo et al., 2008). Neste's NexBTL process requires the input of sodium hydroxide and phosphoric acid as a step in the pretreatment of the oil. Any additional chemical inputs used in the UOP Green Diesel process have not been specified.

To carry out hydrotreating, existing refineries can be retrofitted with additional equipment (see **Figure 4.3** for an example) rather than needing completely new infrastructure as is the case with fast pyrolysis oil production (Huber et al., 2007). However it has been pointed out that it may be more cost-effective to construct a dedicated unit for processing of vegetable oils, due to the apparent competition between hydrodeoxygenation and hydrodesulfurization applied to obtain ultra-low sulfur petrodiesel (Kalnes et al., 2009; Knothe, 2010).

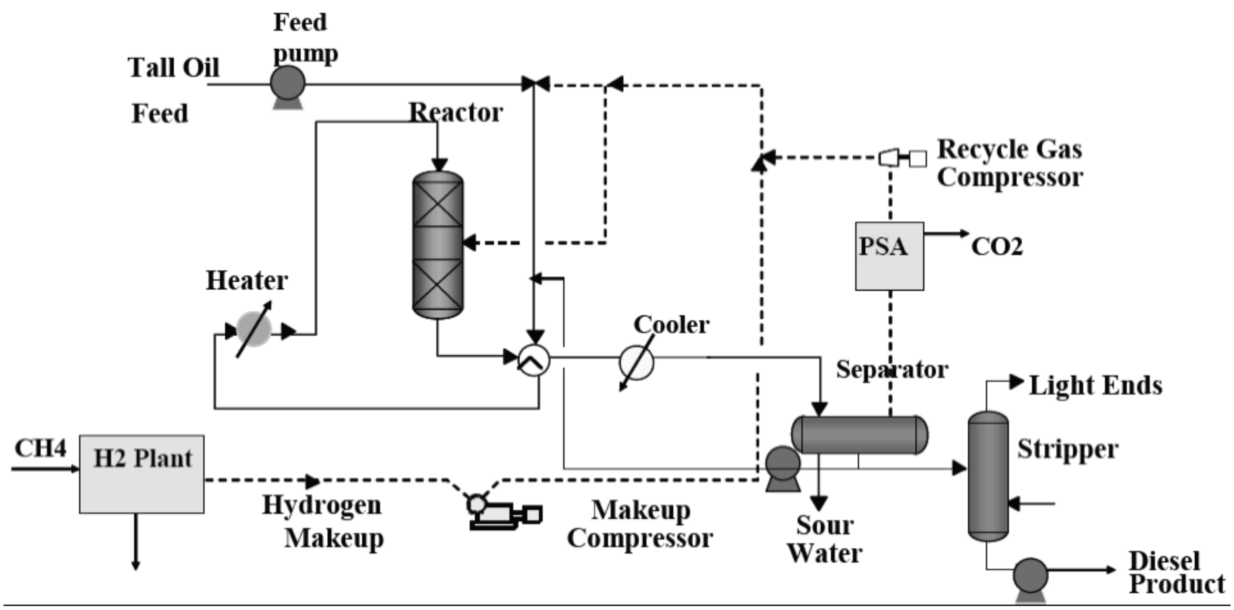

Figure 4.3. Stand-alone Renewable Diesel Production Unit used to produce a pure HDRD product (R100). Adapted from Kalnes et al. (2007).

Most published evaluations on the performance of renewable diesel refineries are based on the use of soybean oil, however palm oil, yellow grease, and tallow have also been proposed as feedstocks (Marker, et al., 2005).

Oxygenated compounds provide less energy per unit mass of fuel, and are thus considered to act as a "reduced combustion" volume, lowering the heating value (Fitzgerald, 2008). UOP has considered both a hydrodeoxygenation (HDO) and decarboxylation (DeCO2) as reaction pathways for removing oxygen from compounds in the diesel feedstock oils. These reaction pathways are illustrated in **Figure 4.4**.

Decarboxylation requires less hydrogen influent and allows for longer catalyst life. However if feedstock sulfur concentrations are too high, it is not effective (Marker, et al., 2005). Hydrocarbons bonded to carboxyl groups are converted into paraffins, CO_2 or water.

Decarboxylation

$$C_n\,COOH \xrightarrow{Pd\,/\,H} C_n + CO_2$$

Hydrodeoxygenation

$$C_n\,COOH \xrightarrow[+3H_2]{} C_{n+1} + 2H_2O$$

Figure 4.4. Chemical reaction pathways that remove carbon dioxide and oxygen from renewable diesel (adapted from Marker et al., 2005).

4.3. Overview of Renewable Diesel Feedstocks

In this section we review the characteristics, technical issues, and potential life-cycle implications of the four most-frequently proposed feedstocks for renewable diesel. This includes soybean oil, palm oil, waste grease, canola and rapeseed oils, and animal tallow.

Soybean Feedstock

Soybeans are expected to be the main feedstock for renewable diesel in California. In 2006, soy was grown on 74.6 million acres of US farmland, producing on average 42.7 bushels per acre (Huo, et al., 2008). Oil is extracted from soy by crushing the beans and applying n-hexane as a solvent. When n-hexane is used as a solvent in soy oil extraction; there is the potential for leaks and spills at processing facilities (Huo, et al., 2008). Growing, harvesting, and extracting the oil require fossil fuel energy sources and generate some greenhouse gas emissions (Huo et al., 2008; 2009).

Soybean Physical Characteristics

Soy is expected to provide an oil yield on the order of 20% of feedstock mass (Huo, et al., 2008). Soy based renewable diesel (Green Diesel) has a "higher heating value" (HHV also known as the gross calorific value or gross energy) that exceeds than both FAME biodiesel and nearly doubles that of pyrolysis-based fuels (Marker, et al., 2005). Kalnes et al. (2007) observe that soy-based renewable diesel is sufficiently similar in physical-chemical properties to ULSD that it can be readily used in a range of blending applications.

Soybean Chemical Composition

The carbon content of the UOP renewable diesel called "Green Diesel" is approximately 87.2% with no oxygen present (Huo, et al., 2008). The sulfur content of Green Diesel is reported to be below 10 ppm (Marker, et al., 2005), which is comparable to ULSD and FAME biodiesel. Co-products of the process include propane and naphtha, which can be used as inputs to gasoline production. The current literature provides no discussion of preservatives and anti-corrosive additives for renewable diesel from soy. Due to its relatively low cloud point, it is expected that additives would be required for normal engine operation in cold climates.

Palm Oil

The Palms used to produce palm oil are grown primarily in tropical or subtropical areas such as Malaysia and Indonesia. Palm oil is characterized by high concentrations of medium-chain saturated (palmitic acid) and monounsaturated (oleic acid) fatty acids. One of the significant advantages of palm oil as a biofuel feedstock is high oil yield (Kemp, 2006). Palm plantations "typically produce about 610 gallons per acre of palm oil plantings, compared with 122 gallons per acre for rapeseed and 46 gallons per acre for soybeans"(Jessen, 2007). Also, the production costs of palm oil are low, providing a moderate world-market price compared to other edible vegetable oils.

Palm oil sustainability is an issue of concern. With the recent increased demand for palm oil, Indonesia and Malaysia, the world's top producers, are clear-cutting and burning forests to build palm plantations. This deforestation releases greenhouse gas emissions and threatens the rich biodiversity of the ecosystem (Jessen, 2007).

Greenhouse gas emissions from existing palm oil forests are also a concern. After the forests are destroyed, the lands are filled to make peat bogs where the palm oil trees can be grown. A four-year study conducted by the Wetlands International, Delft Hydraulics and Alterra Research Center of Wageningen University in Holland examined the carbon release from peat swamps in Indonesia and Malaysia in recent years. It was determined that on average, 600 million tons of carbon dioxide seep into the air each year from these peat bogs. It has been estimated that these carbon dioxide releases, combined with releases from burning of rain forests during clearing, equate to approximately 8% of the world's current carbon output from fossil fuels (Max, 2007).

To help efforts towards sustainability, a global, nonprofit organization known as the Roundtable on Sustainable Palm Oil (RSPO) was formed in April 2004. It is composed of 144 members who represent growers, processors, consumer-goods companies, retailers and other non-governmental organizations. In November, 2005, the RSPO adopted eight criteria for sustainable palm oil production which include:

1. Commitment to transparency;
2. Compliance with applicable laws and regulations;
3. Commitment to long-term economic and financial viability;
4. Use of appropriate best practices by growers and millers;
5. Environmental responsibility and conservation of natural resources and biodiversity;
6. Responsible consideration of employees, individuals and communities affected by growers and mills;
7. Responsible development of new plantings;
8. Commitment to continuous improvement in key areas of activity.

Waste Grease

There are two primary types of waste grease based on the source of the grease—yellow grease and trap grease (brown grease). Yellow grease consists of waste vegetable oils (WVO) such as soy, peanut, canola, and sunflower as well as used cooking lard, that are recycled from industrial cooking, franchise cooking operations, or other large scale cooking projects. It is estimated that recycling and processing waste oils can generate over 1.25 billion kg of yellow grease annually (Kemp, 2006). Since yellow grease is a waste product, it is relatively inexpensive and available in all regions. Trap grease or brown grease is the oil that is recovered from the bottom of commercial frying systems and from grease traps. Typically restaurants install grease traps as part of a discharge system to collect the grease that is washed down the drain. The trap collects grease before it enters the sewer, where it can congeal on the pipe walls and restrict flow. Restaurants normally pay to have these traps emptied and for the grease to be disposed. Since the grease currently has no other market value, its cost is extremely low.

Physical and flow properties of brown and yellow grease have not yet been published. Further research is needed to determine whether these feedstocks produce fuel products significantly different from soybean oils. Due to the acidity of yellow and brown grease, Marker et al. (2005) note that refinery piping must be constructed with 317L stainless steel. It is assumed that less resilient materials can be corroded in normal use.

Canola and Rapeseed Oils

Canola and Rapeseed oils also show promise as renewable diesel feedstock. These oils have properties similar to soy oil. But the oil yield of canola, with seeds containing more than 30% by mass oil, is much higher than soy, with seeds containing on the order of 20% oil..

Canola was developed through conventional plant breeding with rapeseed. To improve the characteristics of rapeseed, breeders created cultivars with reduced levels of erucic acid and glucosinolates. The end product, canola, is now widely grown in Canada, along with some production in the United States. North Dakota is the leading US state in the production of canola and typically grows approximately 90% of the total US domestic production of Canola.

There are currently tests plots in California that produce canola-fuel feedstock. There is little experience with canola in California, but much may be learned from Australia's success in cultivating the crop. The climate where canola is grown in Australia is similar to the California Central Valley from Bakersfield to Redding (Kaffka, 2007). Canola is considered a relatively drought tolerant crop that typically requires around 18 inches of water a year (under Australian conditions) (Johnson, 2007). California's similar climate and the crop's relatively low water requirement suggest that canola could be widely produced within the state. Steve Kaffka, a University of California Cooperative Extension agronomist, is conducting a UC study on the conditions required to grow canola efficiently in California. As part of the study, trial canola varieties have been planted in Chico, Davis, the West Side Field Station, and the Imperial Valley.

Rapeseed oil is composed of oleic, linoleic, linolenic, eicoscenoic, erucic, stearic, and palmitic acids, which are prone to oxidation. Hydrotreating this oil feedstock saturates the carbon-to-hydrogen bonds, providing oxidative stability and improved flow properties. Oil extraction is accomplished with the addition of steam and phosphate compounds for de-gumming, followed by alkali refining and bleaching. Sodium hydroxide is used to precipitate impurities in the oil, although it does not remove chlorophyll compounds. Process wastewater must be treated, since phosphorus contributes to nutrient loading in natural waters and chlorine compounds are toxic to many species (Mag, 1983).

In Europe, rapeseed is primarily used as a source for renewable diesel plant oils. Harvest is accomplished by direct thrashing and rapeseed straw is incorporated into the soil. The rapeseed is dried, cleaned and stored.

Once transported to the oil mill, the seed is pressed and the crude rapeseed oil extracted. Rapeseed meal is a by-product of this process and is used as animal feed, which can be used in place of soy meal imported from North America.

Animal Tallow

Animal tallow is a triglyceride material that is recovered by a rendering process, wherein the animal residues are cooked and the fat is recovered after rising to the surface. Since it is a waste by-product, it is relatively inexpensive, sustainable, and is locally available (Hilber, et al. 2007).

4.4. Overview of Renewable Diesel Chemical Composition

Here we consider the composition of renewable diesel with particular emphasis on how renewable diesel differs from FAME biodiesel and ULSD with respect to overall chemistry, environmental performance, and combustion performance. We begin with a review of EPA registrations that provide some information needed for this analysis. We also consider information provided by the fuel producers regarding the composition of their product.

4.4.1. U.S. EPA Registration

US EPA requirements for registration and analysis of designated fuels and fuel additives is stipulated in sections 211(b) and 211(e) of the Clean Air Act (CAA). The US EPA Tier I emission testing requirements are identified in 40 CFR Part 79, subpart F, Section 7.57. These regulations require that manufactures or importers of gasoline, diesel fuel, or a fuel additive provide a chemical description of the product and certain technical, marketing and health-effects information. The registration requirements are organized in a three-tiered structure. Standard mandatory requirements are contained in the first two tiers. The third tier provides for additional testing as needed.

Two renewable diesel producers have provided the California ARB with US EPA Tier I documents. These producers are Kern Oil Company, which produces a co-processed HDRD (R20), and Neste Oil Corporation, which uses a “bio-only” hydrotreating process to produce a pure HDRD (R100). We use these documents reporting our efforts to characterize the chemical composition of potential renewable diesel fuels that may be used in California.

4.4.2. Renewable Diesel versus FAME Biodiesel

Both renewable diesel and FAME biodiesel are “biomass-based fuels”, which according to the California Low-Carbon Fuels Standard (LCFS) (CalOAL, 2010) are defined as “a biodiesel (mono-alkyl ester) or a renewable diesel that complies with ASTM D975-08ae1…”.

Biodiesel is chemically distinct from petroleum diesel and has a separate ASTM standard (D6751), which specifies the standard for biodiesel when it is used as a blend component with petroleum diesel.

In contrast to a biodiesel that contains mono-alkyl esters, the California LCFS and US EPA defines a “renewable diesel” fuel as:

“… a motor vehicle fuel or fuel additive which is all the following:

(A) Registered as a motor vehicle fuel or fuel additive under 40 CFR part 79; A-9
(B) Not a mono-alkyl ester;
(C) Intended for use in engines that are designed to run on conventional diesel fuel; and
(D) Derived from nonpetroleum renewable resources.”

Renewable diesel, produced from a variety of renewable feedstocks, is not composed of esters and is composed chemically of saturated hydrocarbon chains similar to conventional petroleum (e.g., Knothe, 2010; Federal Register, 2007). The renewable production process is designed to take advantage of the infrastructure of an existing refinery. Several of the renewable diesel products currently available meet the ASTM standard for conventional diesel (D975). As part of the RFS, US EPA reported that renewable diesel has a slightly higher energy content compared to biodiesel (US EPA, 2010a, 2010d,).

4.4.3. Chemical Composition of Renewable Diesel Compared to Conventional Diesel

Petroleum-based diesel fuels are mixtures of aliphatic (open chain compounds and cyclic compounds that are similar to open chain compounds) and aromatic petroleum hydrocarbons (benzene and compounds similar to benzene). In addition, they may contain small amounts of nitrogen, sulfur, and other elements as additive compounds. The exact chemical composition (i.e., precise percentage of each constituent) of any particular diesel oil type can vary somewhat, depending on the petroleum source and other factors. Petroleum-based diesel fuels are distinguished from other fuels primarily by their boiling point ranges, and chemical additives.

Current examples of a non-ester renewable diesel include: ‘‘Renewable diesel’’ produced by the Neste, Kern Oil and Refining, or UOP process, or diesel fuel produced by processing fats and oils through a refinery hydrotreating process. These renewable diesel fuels consists of a mixture of hydrocarbons that meets the ASTM D 975 standard for petroleum diesel and can include performance and stability additives along with some aromatic hydrocarbons. ASTM fuel standards are the minimum accepted values for properties of the fuel to provide adequate customer satisfaction and/or protection. For diesel fuel, the ASTM standard is ASTM D 975. All engine and fuel injection manufacturers design their engines around ASTM D 975 (ASTM, 2009).

The US EPA has not included ASTM 975 in their rule making, but notes that information received to date indicates that renewable diesels will in general be indistinguishable from petroleum-based diesel at the molecular-composition level (US EPA, 2007). For the purpose of tax credits, the US Internal Revenue Service defines renewable diesel as a fuel that “meets the registration requirements for fuels and fuel additives established by US EPA under Section 211 of the Clean Air Act, and the requirements of the ASTM D975 …” (Internal Revenue Service, 2010).

Co-Processed HDRD (R20)

In response to the requirements of the 211(b) fuel analysis, Kern Oil and Refining (KOR) Company submitted to Southwest Research Institute a co-processed renewable diesel (R20) for detailed chemical analysis and speciation (Fanick, 2009a). The fuel was manufactured by co-processing a conventional petroleum stream and a triglyceride (tallow) in a hydrotreating process. The fuel contained less than 15% sulfur. The results were compared to Title 40 CFR, Subpart 86, and ASTM D975 property specifications, and the results of a USEPA 1990 survey of diesel fuels.

Three techniques were used to evaluate the fuel composition, hydrocarbon speciation, direct filter injection/gas chromatography (DFI/GC), and High Temperature Programmable Temperature Vaporization Gas Chromatography/Mass Spectroscopy (HTPTV-GCMS). Each technique characterizes a different hydrocarbon block within in the fuel. The SwRI analysis was performed using replicate samples from two separate fuel totes. The analysis agreed closely between totes. The average result is reported in Table 4.1.

Table 4.1. Comparison of Kern Oil and Refining Company R20 renewable diesel analysis performed by Southwest Research institute to three diesel fuel specifications.

Fuel Property	Test method	EPA Certification Fuel Specification [a]	1990 USEPA Diesel Fuel Survey [b]	ASTM D975	SwRI Analysis
Sulfur, ppm	D5453	7-15	240-1600	<15	6.65
Aromatics, vol %	D1319	27 min.	23.7-54.3	35 max.	29.4
Olefines, vol %	D1319	NA[c]	0.6-3.3	NA	1.6
Saturates, vol %	D1319	NA	45.9-75.0	NA	69.05
Cetane Number	D613	40-50	40.8-51.2	40 min.	53.05
Cetane Index	D976	40-50	43.3-49.9	40 min.	44.5
API Gravity	D287	32-37	NA	NA	36.45
Flash Point, F^o (C^o)	D93	130 (54) min.	NA	126 (52) min.	141 (60.6)
Viscosity@ 40°C	D445	2.0-3.2	NA	1.9-4.1	2.219
Lubricity, HFRR@60°C, micron	D6079	NA	NA	520 max.	442.5
Ash, % mass	D482	NA	NA	0.01	<0.001
Cloud Point, °C	D2500	NA	NA	D975 spec.[d]	-15.25
Cold Filter Plugging Point, °C	D6371	NA	NA	D975 spec.[d]	-19
Copper Strip Corrosion	D130	NA	NA	No. 3 max.	1B
Water & Sediment, vol %	D2709	NA	NA	0.05 max.	0.01
Ramsbottom, wt %	D524	NA	NA	0.35 max.	0.115
IBP, °C	D86	171-204	146-201	NA	163
10%, °C	D86	204-238	194-258	NA	197
50%, °C	D86	243-282	240-284	NA	245
90%, °C	D86	293-321	293-337	282-338	314
EP, °C	D86	321-366	319-355	NA	343

[a] Data from an April 13, 1992 EPA memorandum from james Greaves, subject "Revised Base diesel Fuel Determination Procedures for the Fuels and Fuel Additives Rulemaking" put into Docket No. A-90-07.
[b] Certification diesel fuel specification in the Title 40 CFR Part 86, Subpart N, 86.1313-2007.
[c] Not Applicable.
[d] "It is unreasonable to specify low-temperature properties that will ensure satisfactory operation at all ambient temperature. The appropriate low-temperature operability properties should be agreed upon between the purchaser for the intended use." (ASTM D975).

Aside from the SwRI assessments there are very few comparative chemical analysis available among various renewable diesel products. There is however a common expectation among producers and researchers that R100 products will have significantly reduced aromatic hydrocarbons compared to conventional petroleum diesel. Other blends such as R20 would be expected to meet ASTM D 975 criteria and regulated combustion emission standards.

The SwRI hydrocarbon speciation analysis of R20 showed that the lower molecular weight n-, iso-paraffins, and cycloparaffins accounted for between 13 and 16 percent of the total saturates; the olefins were between 1.3 and 1.5 percent of the hydrocarbons, and the aromatics were between 29 and 30 percent. The unidentified C^9 – C^{12+} hydrocarbons accounted for the remainder of the hydrocarbons, with a mass percentage between 53 and 55 percent.

The DFI/GC analysis showed that the majority of the hydrocarbons were between C^{12} and C^{18}. Between 15 and 17 percent of the hydrocarbons were between C^{19} and C^{24}, and the concentrations decreased above C^{24}.

The HTPTV-GSMS analysis showed that identified individual hydrocarbons ranged from toluene (C^7H^9) to tricosane (C^{23}). In general, about 60 percent of the compounds were saturates and between 44 and 47 percent of the hydrocarbons were straight-chain hydrocarbons. Between 30 and 34 percent of the hydrocarbons were straight-chain compounds between C^{13} and C^{19}. Between 13 and 16 percent of the total hydrocarbons were branched-chain compounds between C^{15} and C^{19}.

The KOR R20 diesel fuel met both the USEPA certification and ASTM specifications except for the cetane number (slightly higher for both the USEPA certification specifications and 1990 Survey), and Initial Boiling Point and the 10 percent Boiling Point for the USEPA certification specification. In 2007 the maximum allowable sulfur concentration in diesel fuel was lowered to 15 ppm so the comparison to 1990 sulfur concentrations is now inappropriate.

The SwRI study concluded that the KOR R20 fuel was substantially similar to other conventional diesel fuels when compared to two different fuel specifications and the results of an USEPA fuel survey.

Bio-only Pure HDRD (R100)

One of the renewable diesel fuels proposed for use in California is a Bio-only Pure HDRD produced by Neste Oil Corporation using the NExBTL process. In the NExBTL renewable diesel process, animal fats and vegetable oils (triglycerides) are converted into diesel fuel components. The process uses all types of vegetable oils as well as all kinds of animal greases and fats. All of these oils and fats have a similar chemical structure that is comprised of three fatty acid chains joined to a glycerol to form a triglyceride.

The process steps utilize technology adapted from normal refinery processes. The process steps are:

- Feedstock pre-treatment to reduce contaminants to very low levels. During this step, commercial vegetable oil de-gumming technology is used. This step is needed to achieve purity levels required to maintain a long catalyst lifetime.
- Hydrotreating to remove oxygen in which paraffins are formed and branched. In this step, hydrogen is fed into a reactor vessel under pressure together with the feedstock. The resulting product is an iso-paraffin with significantly improved cold flow characteristics, lowering the cloud point to -25 °C or even lower. The extent of this process step is controlled depending on the grade of fuel required. Cold flow properties (cloud point) can be adjusted to between -5 to -30 °C to be applicable to winter operating conditions.
- Product finishing and stabilization. Lubricity can be improved with additives, as is commonly done with conventional sulfur-free fuels.

"Bio-only" hydrotreated plant oils result in a HDRD that is a pure hydrocarbon product, which meets sulfur free diesel specifications in all aspects except for density. It is free of sulfur and oxygen, and has a very low content of aromatics (<0.02%). HDRD typically has a very high cetane number. In the case of NExBTL, the blending cetane number varies between 85 and 99 as measured with standard method ASTM D 613-03b. Conversely, HDRD fuels are less dense than conventional diesel fuels. Pure NExBTL fuel meets European EN590 ultra-low sulfur fuel specifications except for density.

The chemical composition of the resulting pure R100 is a combination of straight and branched chain paraffins or alkanes. Neste has determined the chemical speciation of the pure R100 using gas chromatography and mass spectrographic analysis.

The carbon numbers range from $C^{10} – C^{20}$ and the boiling range is from 120 °C to 320 °C, values that are within the range of conventional diesel. Other analyses indicate Neste's NExBTL consists of n- and iso-parrafins (Rantanen, et al, 2005) and contains very low amounts of poly-aromatic hydrocarbons, oxygenated compounds and sulfur. In 2005, VTT Processes in Finland conducted physical properties characterization tests on Neste's fuel (Rothe, et al., unpublished document). The fuel was produced from vegetable oils (canola/rapeseed or palm oil). Table 4.2 summarizes the reported fuel properties of R100 fuel produced by Neste (NExBTL). The NExBTL fuel was found to be similar to the European Union's EN90 and Sweden's EC1 ULSD equivalent fuels.

Table 4.2. Comparative fuel properties for conventional low-sulfur diesel and a HRDF (NExBTL) (Rothe, et al., unpublished document)**.**

Fuel Property	Units	EN590*	NExBTL
Density @ 15°C	kg/m^3	833	783
Viscosity @ 40°C	mm^2s^{-1}	2.35	3.4
Sulfur Content	mg/kg	6	<1
CH_x		1.86	2.1
IBP**	°C	171	216
FBP***	°C	364	321
Total Aromatics	vol %	24.9	<0.02
Cetane Index		49.7	97.9

* European ultra-low sulfur diesel fuel
** Initial boiling point
*** Final boiling point

Neste Oil Corporation has also conducted a life-cycle assessment of the energy and greenhouse gas balance of its R100 NExBRL fuel (Gartner, et al., 2006). This assessment was conducted using an approach consistent with the ISO 14040-43 standard. During this analysis, the consumption of non-renewable energy sources, i.e., non-renewable fossil fuels, natural gas, coal, etc., and production of greenhouse gases, i.e., carbon dioxide, methane, nitrous oxide, were considered. The feedstocks considered were rapeseed (canola) and palm oil. For all comparisons, scenarios and sensitivity analyses considered, the assessment found that use of NExBTL R100 saves primary energy and greenhouse gas emissions over its entire life-cycle when compared to conventional-fossil diesel fuel. The biggest variation in the results was associated with impacts from the production, transportation, and extraction of the crude plant oils used to make the R100. The rapeseed energy savings ranged from 30 to 33 giga-joule (GJ) primary energy per ton of NExBTL. The rapeseed greenhouse gas savings ranged from 1.2 – 2.5 tons of CO_2-equivalents per ton of NExBTL.

The energy savings for palm oil ranged from 44 GJ to 16 GJ primary energy per ton NExBRL. The greenhouse gas savings ranged from 2.2 tons to 1 ton CO_2-equivalents per ton of NExBTL. The results for palm oil depended mainly on the land use practices on the plantations used to grow the palms. "Good practice" palm oil resulted in about 65% higher savings compared to "typical practice" palm oil. The report cautioned that these results cannot be transferred to other environmental impacts such as acidification, eutrophication, and biodiversity that may arise during palm oil production.

4.5. Solid Waste and Emissions to Water

In evaluating the production of renewable (and other alternative diesel-fuel options) it is important for the multimedia assessment and the life-cycle assessment to identify where and what kind(s) of hazardous waste(s) may be generated. For example, co-processed HDRD produces propane, carbon dioxide, and water from the oil/fat feedstock, and the fermentation of palm oil mill effluent leads to significant biogas emissions.

Proper identification and management of the waste solvents during oil extraction are required to comply with hazardous waste laws and regulations. Degradation of the fuel could be caused by temperature, oxidation, and/or material incompatibility.

Once the sources, composition, and magnitude of waste streams from renewable diesel fuel feedstock and fuel production have been identified, there is a need to identify management approaches that could be applied to the identified hazardous waste streams. When generated hazardous wastes are identified, the appropriate waste management approaches, such as treatment, storage, and disposal should be specified and described in the Tier II and Tier III reports. Among the waste management strategies considered, priority should be given to available alternatives for hazardous waste reduction and pollution prevention. To address these and other hazardous-waste issues, the Tier II and Tier III reports will include a section that provides a work plan to specify the hazardous waste storage, transportation, treatment, disposal, waste reduction, and emergency planning for the renewable diesel life cycle.

Hazardous and non-hazardous wastes are generated from many of the refining processes, petroleum handling operations, as well as wastewater treatment. The petroleum refining industry generates relatively large volumes of wastewater, including contaminated surface water runoff and process water. Accidental releases of liquid hydrocarbons have the potential to contaminate large volumes of ground water and surface water with a potential risk to human health and the environment. The extraction of crude oil accounts for 78% of the total wastewater flow in petroleum-based diesel's life cycle, while only 12% is associated with the refinery process. The largest contributor to the wastewater flows of biofuels comes from soybean and oil processing (66%).

The life cycle assessments also include two classifications of solid waste: hazardous and non-hazardous. Almost all of renewable diesel's hazardous solid waste is derived from the refining process. Agriculture accounts for a very small fraction of renewable diesel's hazardous waste, "but these flows are indirect charges against agriculture for hazardous waste flows associated with the production of diesel fuel and gasoline used on the farm" (USDA and USDOE, 1998). The total hazardous waste generation of current petroleum-based diesel is 0.41g/bhp-h of engine work and there is no reliable estimate yet available for renewable diesel.

The non-hazardous waste generated within renewable diesel's life cycle is largely attributed to the trash and trap metals that are removed from the soybeans after the crushing stage. Diesel's non-hazardous waste is significantly lower with an estimated waste generation of only 2.8 g/bhp-h of engine work. This waste is primarily generated in diesel's crude oil refining and extraction steps.

5. Storage and Distribution of Renewable Diesel

In this section we review information that is needed to assess multimedia health and environmental impacts associated with storage and distribution of renewable diesel. A key consideration in this review is materials compatibility, which determines potential for leaks into soil, ground water, and surface water.

Soybean oil, canola oil, and rapeseed oil are composed of oleic, linoleic, linolenic, eicoscenoic, erucic, stearic, and palmitic acids, all of which are prone to oxidation. This report does not address how to solve the poor stability and corrosive problems of these feedstock oils during storage and transportation, because these issues are not relevant to materials compatibility and health/resource impacts that are the topic of this report. But stability is an issue that will be important for fuel proponents to address with respect to the overall potential of renewable diesel.

5.1. Material Compatibility and Storage Stability

In general, the handling and storage of renewable diesel that meets ASTM D 975 standards is the same as for petroleum diesel including the needed protection from ignition sources. Tanks used for transport and storage must be suitable for combustible liquids and precautions must be taken to prevent product spills on to the ground, into drains, and into surface and ground waters.

In the evaluation of the multimedia impacts of new diesel formulations, materials compatibility and storage stability are important considerations, but little information is available on pure renewable diesel materials compatibility.

As noted above, the feedstocks for renewable diesel include vegetable oils, fryer grease and tallow. Relative to petroleum, these feedstocks are more acidic, with an expected *Total Acid Number* between 2 and 200 (Marker, et al., 2005). Therefore, existing refineries must be retrofitted with more resistant pipes, seals and pumps (Marker, et al., 2005). Nitrile rubber, neoprene, or PVC gloves are protective equipment required to handle renewable diesel (ASTM F739/Diesel Fuel).

Storage stability refers to the ability of the fuel to resist chemical changes during long-term storage. While storage stability is an important parameter for any diesel fuel, little information is available regarding pure renewable diesel. Because renewable diesel typically does not contain unsaturated materials, it can be expected to have good stability, particularly if blended with conventional ULSD.

5.2. Distribution and Blending of Renewable Diesel

Blended HDRD can be transported via the same methods used for conventional diesel, including pipelines, rail cars, tank trucks and drums. The choice of transport vessel depends on the quantity of renewable diesel being transferred and the cold flow properties of the fuel.

It is straight forward technically to blend pure HDRD fuels (R100) with conventional diesel. R100 can be blended to as much as 65 to 70 volume % in conventional diesel to fulfill the minimum density requirement.

5.3. Use of Additives

The USEPA 211(b) specifications for baseline fuel include the requirement for additives. The required additives are:

- corrosion Inhibitor, 4.5 pounds per thousand barrels of fuel (ptb),
- demulsifier, 2 ptb,
- anti-oxidant, 2 ptb, and
- metal deactivator, 2 ptb.

Chemical additives are commercially available to address the oxidative stability, cold-flow properties, and microbial contamination of renewable diesel. It is expected that these additives would be the same as or very similar to additives currently in use for conventional diesel fuel. In addition, R100 renewable diesel fuels will need to have a lubricity additive.

Cold flow properties including cloud point and pour point for renewable diesel are generally better than those of biodiesel and similar to or better than those of ULSD (Knothe, 2010). For instance, cloud point ranges for renewable diesel range generally between -25 and -5 °C (e.g., Table 4.1; Knothe, 2010) although values as high as 7 degrees C have been reported, and cloud point for ULSD ranges around -12 °C (Phillips Petroleum, 2002).

Unlike biodiesel that, by virtue of the ester moiety, has intrinsic lubricity (Knothe and Steidly 2005), renewable diesel requires a lubricity additive similar to petroleum-based ULSD. Knothe (2010) points out that blends involving more than 2% biodiesel restores lubricity.

5.3.1. Residual Water

Similar to conventional diesel, renewable diesel is generally considered to be insoluble in water, it can actually contain as much as 0.05 % by volume of water. Storage stability of renewable diesel is also affected by the presence of water within the tank used for storage or transport (ASTM 2003).

Water in vapor phase (humidity) can enter through vents and seals of fuel tanks where it either condenses or dissolves into the fuel. According to Van Gerpen et al. (1996), virtually all diesel fuel storage tanks can be assumed to contain some water. Water can cause hydrolytic degradation of the fuel, contribute to microbial growth in the fuel, and cause corrosion of fuel systems and tanks.

The presence of water within renewable diesel can cause corrosion of fuel tanks and engine fuel system components. The most direct form of corrosion is rust, "but water can become acidic with time and the resulting acid corrosion can attack storage tanks" (Wedel, 1999). Hydrolytic degradation can also occur if concentrations of water are present within the tank.

Condensed water in a fuel tank can support the growth of bacteria and mold that use the hydrocarbons in the renewable diesel as a food source. These "hydrocarbon-degrading bacteria and molds will grow as a film or slime in the tank and accumulate as sediment" (Wedel, 1999).

The control of water is primarily a housekeeping issue (i.e. keeping storage tanks clean) and a problem frequently addressed by using fuel filters (ASTM 2003). Additives may also be used to address residual water problems (ASTM 2003).

5.3.2. Additives to Inhibit Biodegradation of Stored Diesel Fuel

Additives used to control microbes in fuel storage tanks are generally water-soluble and migrate into any water phase residing in the fuel storage tank. Given the expected potential for biodegradation of renewable diesel at rates similar to rates of biodegradation of petroleum diesel (Knothe, 2010), the same biocides used in petroleum-based diesel fuel systems can be expected to be used with biofuels. Biocides are too expensive to be widely deployed upstream in the distribution process, and there is an added concern of creating microbial resistance, so biocides are typically used on an "as-needed" basis in the distribution chain wherever and whenever microbial contamination is detected as a problem (Irwin, 2007; Cheznow, 2008, personal communication).

The biocide with the largest current market share is manufactured by Rohm and Haas Corporation and is sold under the product name of Kathon FP 1.5. The active ingredients in the Kathon product, isothiazols, are shown in **Figure 5.1** and listed in Appendix C, Table C-4.

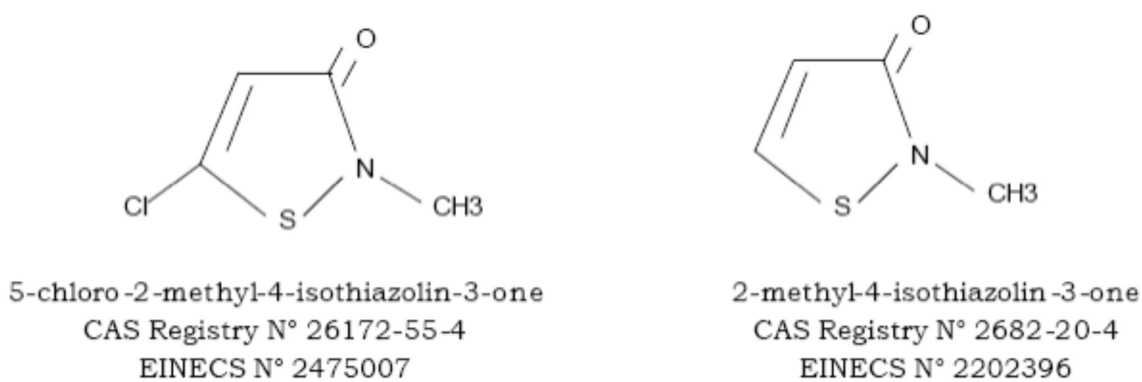

Figure 5.1. Rohm and Haas Kathon FP 1.5 Biocide (Rohm and Haas, 1999).

Other common fuel biocide chemicals are methylene-bis-thiocyanate (MBT) and nitro-morphalines (Cheznow, 2008, personal communication). MBT is often used as a biocide in water treatment plants, paper mills, and other industrial processes involving large-scale water use. Carbamates also appear on the material safety data sheets (MSDSs) of some commercial biocides listed in Table 4 of Appendix C.

An additional environmental issue for biocides involves the treatment and disposal of biocide-containing effluent drained from the storage tanks. The Rohm and Haas literature discusses this process and proper deactivation, which involves the use of sodium metabisulphate or sodium bisulphate (Rohm and Haas, 1999).

6. Use of Renewable Diesel

In this section we review and evaluate multimedia health and environmental impacts associated with the use, that is combustion, of renewable diesel. We first consider the quality of renewable diesel as a substitute for ULSD in terms of energy performance. A second key consideration in this review is how the emissions of criteria and hazardous air pollutants from renewable diesel combustion differ from those emitted by an energy-equivalent quantity of combusted ULSD.

6.1. Renewable Diesel Standardization and Fuel Quality

Renewable diesel is required to meet the same performance standards as conventional diesel. ASTM Standard Specification for Diesel Fuel Oils (D975-09b) (ASTM, 2009) provides standards that, when met, allow renewable diesel to be suitable for a variety of diesel engines. Appendix A summarizes these standards. Additionally, the American Society for Testing and Materials (ASTM) identifies seven grades of diesel fuel oils that can be used in a variety of diesel engines (Table 6.1).

Table 6.1. ASTM Diesel Fuel Grades (ASTM 2009).

Diesel Fuel Grade*	Description
1-D S15**	Special-purpose, light middle distillate for engines requiring 15 ppm sulfur (maximum) and higher volatility than provided by Grade 2-D S15 fuel.
1-D S500**	Special-purpose, light middle distillate for engines requiring 500 ppm sulfur (maximum) and higher volatility than provided by Grade 2-D S500 fuel.
1-D S5000	Special-purpose, light middle distillate for engines requiring 5000 ppm sulfur (maximum) and higher volatility than provided by Grade 2-D S5000 fuel.
2-D S15**	General-purpose, middle distillate for engines requiring 15 ppm sulfur (maximum). Especially suitable for varying speed and load conditions.
2-D S500**	General-purpose, middle distillate for engines requiring 500 ppm sulfur (maximum). Especially suitable for varying speed and load conditions.
2-D S5000	General-purpose, middle distillate for engines requiring 5000 ppm sulfur (maximum). Especially suitable for varying speed and load conditions.
4-D	Heavy distillate fuel or a blend of distillate and residual oil. Suitable for constant load and speed application.

* S5000 grades of diesel fuel refer to so-called "Regular" sulfur grades. S500 grades refer to so-called "Low Sulfur" grades. S15 grades are commonly referred to as "Ultra-Low Sulfur" grades or ULSD.
** Meets 40 CFR Part 80 fuel quality regulations for highway diesel fuel sold in 1993 and later years.

6.2. Emissions of Pollutants to Air

In terms of human health damage, the air emissions for the life-cycle of any diesel fuel take place during refining, fuel loading/transport, and fuel combustion. Pollutants generated during crude oil refining typically include volatile organic compounds (VOCs), carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), particulates, ammonia (NH_3), hydrogen sulfide (H_2S), metals, spent acids, and numerous toxic organic compounds. Emissions occur throughout refineries and arise from the thousands of potential sources such as valves, pumps, tanks, pressure-relief valves, and flanges. Emissions also originate from the loading and unloading of materials (such as VOCs released during charging of tanks and loading of barges), as well as from wastewater treatment processes (such as aeration and holding ponds). Storage tanks are used throughout the refining process to store crude oil, intermediate products, finished products, and other materials. The tanks can be a significnat source of VOC emissions. Combustion of petroleum-based and renewable diesel fuels by motor vehicles results in exhaust emissions that include VOCs, nitrogen oxides, particulate matter, carbon monoxide, hazardous air pollutants, and carbon dioxide. These pollutant categories include known carcinogens, such as benzene, and probable human carcinogens, such as formaldehyde or diesel particulate matter.

6.3. Renewable Diesel Impact on Air Quality

Because of the importance of the combustion emissions, we explore here air-quality impacts of renewable diesel relative to extant diesel fuels. Emission testing data is available for renewable diesel from Conoco-Phillips, Kern Oil Refining Company co-processed HDRD, and Neste Oil.

Conoco-Phillips conducted tests using a 2006 International 6.0-L V8 engine. Blends of R5 to R30 produced from soy oil showed reduction in most criteria pollutants relative to conventional ULSD. For an R20 blend, non-methane hydrocarbon emissions were reduced by about 50%, NOx emissions by about 8%, and CO emissions by about 60% relative to ULSD. Particulate matter (PM) emissions showed only a slight decrease compared to ULSD, and did not improve with higher blend concentrations. (Kaufman, 2007).

Conoco-Phillips renewable diesel emissions testing was also conducted using beef tallow, canola, poultry fat, and yellow grease feedstocks. There were some emissions variation both up and down compared to soy renewable diesel, but all feedstock sources showed lower emissions compared to baseline ULSD.

As part of the required 211(b) fuel analysis, Kern Oil Refining Co. submitted its renewable diesel fuel to Southwest Research Institute for emissions analysis (Fanick, 2009a). The KOR renewable diesel fuel was 20% co-processed tallow and conventional petroleum (R20). The emissions testing was conducted using a 2007 6.4-L Navistar A350 heavy-duty diesel engine. In general, the engine met 2009 emission standards except for NOx. The 2009 emission standard for NOx is 0.2 g/bhp-hr, and the KOA renewable diesel resulted in NOx 0.1 g/bhp-hr higher than the standard. All other emissions tested—CO, PM, and non-methane hydrocarbons—were significantly lower than the 2009 standard.

As part of the required 211(b) fuel analysis, Neste Oil Corporation also submitted its NExBTL fuel for emissions analysis by Southwest Research Institute (Fanick, 2008). The NExBTL fuel tested was a bio-only pure HDRD (R100). Comparative duty diesel engine combustion emissions testing by Neste and the Nutzfahrzeuge Gruppe (Rothe et al, 2005) are summarized in Table 6.2.

Table 6.2. Effect of blending on an HRDF emissions (NExBTL) (Rothe et al, 2005).

	100% NExBTL	**50% NExBTL***	**10% NExBTL***
Emissions			
PM	-28%	-5%	0
NOx	-10%	-6%	0
HC	-48%	-48%	-33%
CO	-28%	-22%	-11%
Fuel consumption			
specific**	+5%	+2%	0
volumetric	-1.75%	-1%	0

* Blended with EN 590 ultra-low sulfur fuel.

** Adjusted for density differences in fuels

Neste also conducted emissions testing using a 2007 6.4-L Navistar A350 heavy duty diesel engine with after-treatment running NExBTL (R100) fuel. These test found CO emissions were slightly higher compared to a baseline ULSD fuel (0.05 g/bhp-hr). Emissions were 17% lower for NOx with no relative change for HC and PM (Fanick, 2008).

During combustion there are also concerns about speciation of volatile- and particulate-phase polycyclic aromatic hydrocarbons (PAHs) and nitrated polycyclic aromatic hydrocarbons (NPAHs). For all fuels, the particulate-phase PAHs and NPAH emissions are higher than the volatile-phase compounds. In the emissions test cited above, the total PAH and NPAH emissions for the NExBTL fuel was lower than the baseline ULSD (Fanick, 2008).

The Neste studies concluded that in diesel engines:

- HDRD fuel (NExBTL) showed significant emission benefits compared to ultra-low sulfur conventional diesel fuel. Higher blend percentages resulted in greater benefits.
- Blends below R10 can result in reductions in CO and HC, but not PM or NOx.
- Specific (density adjusted) fuel consumption is better with the HRDF, but volumetric fuel consumption is 5% higher because of the lower HRDF density.
- HDRD fuels avoid some of the unwanted effects associated with FAME-based biodiesel fuels (instability, hygroscopicity, fouling, catalyst deactivation, etc).
- Due to the absence of sulfur and aromatic compounds, NExBTL exhaust emissions show significant reductions in many regulated and non-regulated compounds compared to “traditional” petroleum diesel.

7. Renewable Diesel Toxicity

7.1. Human and Ecological Risk Assessment

As is the case with any new fuel formulation where large quantities of processed and synthetic chemicals enter into California commerce, renewable diesel fuels raise concerns about the potential toxicity to humans and to the environment from chemical emissions associated with fuel production, transport, storage and combustion. Estimating toxic chemical risk requires that we follow a standard paradigm for risk assessment applied to renewable-diesel components and combustion. This assessment process includes:

1. Hazard identification,
2. Toxicity assessment,
3. Evaluation of the potential for human and ecological exposure, and
4. Definition of sensitive populations at risk of exposure.

The greatest difficulty we anticipate with determining the human and ecological toxicity of renewable diesel fuels is that renewable diesel fuel is not a defined chemical formulation or a defined mixture of components, but can be formulated from a wide array of different feedstocks with different chemical components. It is beyond the scope of the multimedia-working group to attempt to consider all of these possibilities. Instead we make recommendations with the understanding that it is useful to focus on the toxicity impacts from the life cycle of one or two typical feedstocks for renewable diesel formulations and then attempt to draw generalizations from these results. Refining and production of renewable diesel fuel may well occur, at least in part, in California, so we will have to consider potential releases of chemicals involved in synthesis and use of renewable diesel, as well as their appropriate disposal, and their degradation products. Extraction of oils from plants will generally require the use of organic solvents such as hexane. Thus, we must consider potential adverse health effects and ecological damage related to release scenarios for organic solvents as well. Finally, there may be significant amounts of fuel additives put into renewable diesel formulations. The toxicity of these compounds and their potential release products will also have to be considered. Significant routes of exposure that must be considered include inhalation, ingestion through water and food, and dermal contact. We find that significant data gaps exist at every stage of tracking sources to exposure and risk.

7.2. Acute Oral and Acute Dermal Toxicity

The acute oral and dermal toxicity of pure NExBTL renewable diesel was assessed for Neste Oil Corporation in testing conducted by SafePharm Laboratories (Mullaney, 2005). Both oral and dermal testing were conducted using the Sprague-Dawley CD strain rat and Organization for Economic Co-operation and Development (OECD) testing Guidelines (RIVM, 1994).

During the acute oral testing, two groups of three female rats were administered an undiluted oral dose at a level of 2,000 mg/kg bodyweight (Mullaney 2005). The rats were monitored for clinical signs and subjected to gross necropsy after 14 days.

There were no observed mortalities or observed evidence of systemic toxicity. All animals showed expected gains in body weight. No abnormalities were observed at necropsy. The acute oral median lethal dose (LD_{50}) of NExBTL in female Sprague-Dawley rats is estimated to be greater than 2,500 mg/kg bodyweight.

During the acute dermal exposures, a group of ten rats (five males and five females) was given a single 24-hour, semi-occluded dermal application of undiluted NExBTL renewable diesel to intact skin at a dose level of 2,000 mg/kg bodyweight (Mullaney, 2005). The rats were monitored for clinical signs and subjected to gross necropsy after 14 days.

The dermal-toxicity study on rats showed no mortalities or systemic toxicity. There were no signs of dermal irritation in the male rats. All animals show expected gains in body weight. No abnormalities were observed at necropsy. Hyperkeratinisation or crust formation with or without small superficial scattered scabs, possibly caused by the animals scratching at the treatment site, was noted in females during the study. This may be due to a drying/defatting effect caused by application of the test material. The acute dermal median lethal dose (LD_{50}) of NExBTL in Sprague-Dawley rats was determined to be greater than 2,000 mg/kg bodyweight (Mullaney, 2005).

7.3. Human Health

Mutagenic Assays

Using pure NExBTL, SafePham Laboritories conducted a reverse mutation assay (Ames Test) and a chromosome aberration test using human lymphocytes *in vitro*. Testing was conducted for Neste Oil Corporation using OECD guidelines.

During the Ames Test assay, *Salmonella typhimurium* bacteria cultures were treated with NExBTL at five dose levels (50, 150, 500, 1500, and 5000 µg/plate) in triplicate, both with and without rat liver metabolic activation (Thompson 2005). There was no visible reduction in growth of the bacterial background lawn at any dose level. An oily precipitate was observed at and above 1,500 µg/plate, but this did not prevent scoring of revertant colonies. No significant increases in the frequency of revertant colonies were recorded for any dose, either with or without metabolic activation. The study concluded that NExBTL can be considered non-mutagenic under the conditions of this test.

The in vitro human lymphocyte assay supplements the microbial (Ames Test) assays insofar as it identifies potential mutagens that produce chromosomal aberrations rather than gene mutations (Scott et al, 1990). Duplicate cultures of human lymphocytes, treated with pure NExBTL, were evaluated for chromosomal aberrations using four dose levels along with appropriate vehicle controls and positive controls (Wright, 2007). The final concentrations of NExBTL used were 78.13, 156.25, 312.5, 625, 1,250, and 2,500 µg/ml. An oily precipitate of test material was noted above 78.13 µg/ml. The dose levels did not induce a statistically significant increase in the frequency of cells with chromosome aberrations in either the absence or presence of a liver enzyme metabolic activation system in either of two separate experiments. The NExBTL was considered to be non-clastogenic to human lymphocytes in vitro.

7.4. Toxicity Testing of Renewable Diesel Fuel Exhaust Emissions

Diesel exhaust (DE) is a complex mixture of gaseous and particulate matter (PM) components containing hundreds of compounds with the particles less than 2.5 µm having the most relevance for human health impacts (Madden, 2008). Exposure to PM induces increased mortality and some types of morbidity, such as hospitalizations for cardiopulmonary problems. In spite of a large literature on the health impacts of combustion emissions from petroleum diesel, a key uncertainty relates to a range of dose-response relationships. Lung disease links to DE have been examined with variable findings using controlled exposures, but to date relatively little is known about cardiovascular responses (Madden, 2008). Induction of other health effects from DE exposure has been examined mainly through either controlled nonhuman animal model exposures or epidemiological approaches.

To date there are no studies comparing the toxicity of combustion emissions from petroleum diesel with those from renewable diesel and it is unlikely that such comparisons can provide any results useful for decision makers. There are two issues that mitigate the value of these comparisons. First, due to changing regulations and emerging technologies to achieve compliance with regulatory standards, DE from emissions associated with more recent engine/fuel combinations contains less PM and less of certain gases than older engine technologies and fuels (Madden, 2008). This makes both the comparisons to older emissions and the choice of a petroleum baseline for renewable diesel complicated. In more recent diesel formulations, the gas-phase emissions contain proportionally more mass than the PM phase, presenting technological problems in terms of the collection of the DE for future studies and across-laboratory comparison. A second problem is the uncertainty and variation in blending ratios.

In December of 2010, Vogel (2010) presented preliminary results of ARB-funded studies that used *in-vitro* testing to assess and compare the inflammatory toxicity and genotoxicity of biodiesel and renewable diesel blends along with CARB diesel (ultra low sulfur diesel). These experiments used human cell models to test for the inflammatory response to diesel combustion emissions—(a) human macrophages (U937), phagocytotic cell types that serve as first line of defense, and (b) lung Clara cells from pulmonary epithelium (NCI H441). The Comet assay was also used to test for genotoxicity. The combustion emissions from CARB diesel were compared to renewable diesel, pure biodiesel, and six biodiesel blends using CARB diesel:

- 100 percent biodiesel derived from soy (S B100)
  and from animal fat (A B100)
- 100 percent renewable diesel (R100)
- CARB diesel blended with:
  - 50 percent soy-derived biodiesel (S B50)
  - 20 percent soy-derived biodiesel (S B20)
  - 50 percent animal-derived biodiesel (A B50)
  - 20 percent animal-derived biodiesel (A B20)
  - 50 percent renewable diesel (R50)
  - 20 percent renewable diesel (R50)

The preliminary results from these studies reveal that PAHs in the CARB diesel, biodiesel blends and renewable diesel blends can activate the aryl hydrocarbon (Ah) receptor (by inducing cytochrome P450 [CYP1A1]) indicating the potential for inflammatory response, but the rate of activation from renewable diesel blends was lower than from biodiesel blends and CARB diesel. CARB diesel, biodiesel blends and renewable diesel blends all induce inflammatory markers such as COX-2 and IL-8 in macrophages and MUC5AC in lung Clara cell type (NCI H441), but the effect renewable diesel blends on inflammatory markers such as COX-2 and IL-8 were consistently lower than CARB diesel. The Comet assay indicated no genotoxic effects of renewable blends at 200 □g/ml. More details of these experiments will be provided in Teir II and Tier III renewable diesel assessments.

7.5. Aquatic Toxicity

SafePharm Laboratories conducted acute short-term tests for Neste Oil Corporation with exposures of fish, water flea, and green alga to a pure NExBTL renewable diesel water accommodated fraction (WAF). Testing using NExBTL WAF has also been conducted on Rainbow Trout (*Onchorynchus mykiss*) (Goodband 2006), *Daphnia magna* (Goodband, 2005), and green alga (*Scenedesmus subspicatus*) (Vryenhoef 2005) following OECD Guidelines.

The WAF in these experiments was prepared by loading dechlorinated tap water with pure NExBTL and stirring the mixture for 23 hours. After a one-hour settling period, a clear colorless water column with a clear oily slick at the surface was observed. The WAF was removed from the middle of the column and used for the toxicity-test exposure. The total organic carbon analysis of all the WAFs used showed no difference from controls that contained no NExBTL. The concentration, homogeneity, and stability of the WAF test material were not determined. No comparisons to conventional diesel or renewable diesel blends were conducted. The concentration, homogeneity and stability of the WAF test material were not determined at the request of Neste Corp.

Rainbow Trout were examined for mortality and abnormalities at 3, 6, 24, 48, 72, and 96 hours. No mortalities or abnormalities were observed throughout all testing and the study concluded that the No Observed Effect Loading rate for Rainbow Trout was greater than 1000 mg/l.

Daphnia were examined for immobility at 24 and 48 hours. No *Daphnia* immobilization was observed throughout all testing and the study concluded that the No Observed Effect Loading rate was greater than 100 mg/l.

Neither the growth nor the biomass of *Scenedesmus subspicatus* was affected by a 72 hr exposure to a WAF loading rate of 100 mg/l. The No Observed Effect Loading rate was greater than 100 mg/l.

7.6. Toxicity and Biodegradation in Aerated Soil

The constantly increasing number of motor vehicles and the increasing volume of oil products transport/distribution has made soil pollution by petroleum-based hydrocarbons a topic of interest to impact assessors (Lapinskiene, et al., 2005). For the impact of petroleum diesel and other oils on soil, there is a vast literature, which demonstrates that small quantities of oil encourage the growth of microorganisms since hydrocarbons can serve as nutrients. At higher levels of pollution, the numbers of microorganisms decrease and their relative composition changes along with quantitative indicators of microbiological processes, such as enzyme activity. There are also studies of the influence of oil products on the population of earthworms. Lapinskiene, et al. (2005) compared the soil impacts of diesel fuel to FAME biodiesel by quantitatively evaluating the microbial transformation of these materials in non-adapted aerated soil. The toxicity levels were determined by measuring the respiration of soil microorganisms as well as the activity of soil dehydrogenases. Lapinskiene, et al. (2005) found that conventional diesel fuel is more resistant to biodegradation and produces more humus products than biodiesel. To date, there are no published comparisons of this type for petroleum and renewable diesel (Knothe, 2010). In a marine context, DeMello et al. (2007) found that n-alkanes decomposed at approximately the same rate as fatty acid methyl esters, and this may indicate potential for renewable diesel degradation rates between that of petroleum diesel and biodiesel. Overall, however, the similar chemistry of renewable and petroleum diesel fuels would suggest that their impacts on soil ecosystems would not be significantly different, particularly when the renewable diesel is in a blend (Knothe, 2010). Major differences in soil impact are more likely to be associated with additives than with the hydrocarbon mix. So the key issue with regard to different impact on soil organisms from existing diesel blends and renewable diesel blends will likely be linked to differences in additives.

7.7. Summary of Toxicity Issues

Limited tests on the inherent acute oral and dermal toxicity of pure renewable diesel indicate that renewable diesel has a very low inherent toxicity. In these tests, two groups of three female rats were administered an undiluted oral dose at a level of 2000 mg/kg bodyweight (Mullaney 2005). The rats were monitored for clinical signs and subjected to gross necropsy after 14 days. No increases in mortality or systemic toxicity were found. But these tests are difficult to interpret since there were no controls using conventional diesel or tests using diesel blend.

There have been some initial mutagenic testing of pure (NExBLT) renewable diesel using reverse mutation assay (Ames Test) and the chromosome aberration test using human lymphocytes in vitro were conducted using pure NExBTL. In the Ames test, no significant increases in the frequency of revertant colonies were recorded for any dose, either with or without metabolic activation. In the human lymphocyte test, the pure (NExBTL) renewable diesel was considered to be non-clastogenic to human lymphocytes in vitro.

Insight on aquatic toxicity comes from acute short-term exposure of fish, water flea, and green alga to a pure NExBTL renewable diesel water accommodated fraction (WAF). This study concluded that the No Observed Effect Loading rate was greater than 100 mg/L for all three species.

At this point, there has been only limited testing of the relative toxicity of the emissions from combusting renewable diesel (blends and/or pure fuel) compared to existing diesel and/or biodiesel. Based on the level of variation in emissions toxicity assessment for petroleum diesel, the chemical similarity of renewable diesel and petroleum diesel, and the likelihood for blends that still contain a significant fraction of petroleum diesel, we expect that it will be difficult if not impossible to organize and interpret a study to compare the toxicity of petroleum diesel relative to renewable diesel blends. Therefore, unless there market evolves to the point where renewable blends contain more than 50% non-petroleum diesel feedstock, there appears to be little value in calling for emissions toxicity studies for renewable diesel.

Among the limited renewable diesel blends tested to date, toxicity testing indicates limited inherent toxicity and that pure renewable diesel formations are unlikely to exceed the inherent toxicity or mutagenicity of standard diesel. Major differences in health and ecological impact between existing diesel and renewable diesel blends are more likely to be associated with additives than with the hydrocarbon mix. Any difference in life-cycle health/ecological impacts between existing and renewable diesel blends will likely be linked to differences in additives.

Additionally, the chemical comparison to conventional diesel is important for determining whether or how much additional toxicity tests are required. If a co-processed “green” renewable diesel is the intended product and is chemically indistinguishable from conventional diesel, then no additional toxicity testing is needed. Further, if a post-production 100% pure renewable diesel is blended to a proportion such that it is chemically indistinguishable from conventional diesel, then no additional toxicity testing is likely needed.

8. Environmental Transport and Fate of Renewable Diesel

The fate and transport of a fuel and its component chemicals in the environment depend on the multimedia transport properties of its constituent chemicals. The purpose of the multimedia evaluation of renewable diesel is to identify impacts that may be different from the existing baseline fuel, conventional petroleum-based ULSD in the case of renewable diesel. Based on the fuel chemical composition analysis provided by both KOR and Neste Oil Corp., renewable diesel can be regarded as substantially similar to other conventional diesel fuels (Fanick, 2008; Fanick, 2009). The main difference between conventional ULSD and R100 is that the pure HDRD has no sulfur or oxygen and has a very low aromatic compound content. R20 co-processed renewable diesel can be expected to be even closer in chemical composition to conventional ULSD.

Based on the reported similarities in chemical composition, and thus the physicochemical properties governing fate and transport in the environment, between renewable diesel and conventional ULSD, the multimedia environmental behavior of renewable diesel should be expected to also be similar and difficult to observed based on the reliability of existing models and measurement methods. The transport and partitioning behavior, as well as biodegradation in soils (as noted in Section 7) can be expected to be similar. The release scenarios and materials compatibility issues should be essentially the same as conventional diesel that is already in wide use.

Even when releases of renewable diesel do not cause significantly greater impacts to the environment, human health, or water resources when compared to ULSD, the impact from releases of associated additives and production chemicals can be of concern. The specific chemical composition of the additives used by various renewable diesel manufactures is not available and the environmental impact of available additives is not well described.

In the case of co-processed R20, it may transpire that any additives used in renewable diesel are currently in use in ULSD and would continue to be used with no substantive difference in environmental impact attributable to additives. If this is the case, then new studies on multimedia transport and impact from additives would not be necessary under the assumption that the impacts of additives in ULSD are either acceptable or at lease well-characterized. However, when the additives used in renewable diesel are different from those in ULSD with regard to composition and/or quantity, then a multimedia transport and impact assessment will be needed to determine the magnitude and significance of any potential impacts associated with these additives.

9. Tier I Conclusions

Through a review of the current knowledge on renewable diesel production, use, and environmental impacts, this report provides a foundation to aid the CalEPA Multimedia Working Group formulate recommendations to the California Environmental Policy Council regarding the consequences of increased use of renewable diesel in California. A key goal of this report is to identify important knowledge gaps for a Multimedia Assessment and recommend approaches to address these gaps. This does not always involve additional experiments, but could include additional requests for information from the proponents of any new fuel to be used in California.

Renewable diesel offers several beneficial characteristics that will help California meet State renewable fuel goals:

- Renewable diesel is chemically similar to the ultra-low sulfur diesel (ULSD) fuel already in wide use such that environmental releases from the life-cycle of renewable diesel can be expected to behave in the environment in a manner similar to ULSD releases.
- Renewable diesel is compatible with existing refining and distribution infrastructure and can be used in current diesel engines without modification.
- Pure renewable diesel (R100) has reduced aromatic hydrocarbon content and, since many of the chemicals of environmental concern are aromatic hydrocarbons, this reduction will likely reduce the overall environmental toxicity of the fuel.
- Limited toxicity testing on rats (oral and dermal exposures), water fleas and green algae, and including mutagenic assays, reveals that R100 has limited inherent toxicity and that pure renewable diesel formations are unlikely to exceed the inherent toxicity or mutagenicity of standard diesel. Major differences in health and ecological impact between existing diesel and renewable diesel blends are more likely to be associated with additives than with the hydrocarbon mix.
- Preliminary results of ARB-funded studies that used *in-vitro* testing to assess and compare the inflammatory toxicity and genotoxicity of renewable diesel blends and CARB diesel indicate that the impact of renewable diesel blends on inflammatory markers tend to be consistently lower than CARB diesel and a Comet assay indicated no genotoxic effects of biodiesel blends at 200 g/ml.
- Renewable diesel fuels that are made from waste products such as tallow will likely have reduced life-cycle environmental impacts compared to fuels made from plant crops. These reduced impacts stem from possible reductions in pesticide, herbicide, and fertilizer use. In addition there are sustainability concerns about the use of food supply crops as a fuel as global population grows. Further studies are needed to address this concern.

  One life-cycle study sponsored by Neste Oil Corporation found pure renewable diesel (R100) from rapeseed oil or palm oil has a quantitative advantage in energy and greenhouse gas balance compared to conventional diesel. For renewable diesel blends, recent studies on the life-cycle impact considered a range of fuel/vehicle combinations. The results indicate that life-cycle health impacts of renewable diesel blends are not likely to differ significantly from those of petroleum diesel.

In spite of the many benefits identified here for renewable diesel there are also knowledge gaps associated with renewable diesel use in California that may need to be addressed in more detail before these fuels enter the market. The knowledge gaps identified here include:

- **Additives impacts.** Key information gaps are associated with possible differences in additive use. To provide a stable, useful, and reliable fuel, additive chemicals will need to be introduced into almost all renewable diesel blends. These additives will be required to address issues such as oxidation, corrosion, foaming, cold temperature flow properties, biodegradation, water separation, and NO_x formation. While many of these additives are currently used in conventional diesel fuels, the specific chemicals and amounts to be used in renewable by various producers has not been well defined for the emerging industry in California.

  It is important to note that although the use of additives in diesel fuels (conventional or renewable) is common, the impact of various additives is not well known. A careful evaluation of the possible chemicals used in additives would be beneficial to California and may lead to a "recommended list" or "acceptable list" that would minimize the uncertainty of future impacts as new fuels and industry standards are developed. Additional research on the impacts of a "recommended list" of acceptable additives needs to be considered with respect to releases to water and soils and fugitive emissions to air.

- **Production and storage releases.** Increased renewable diesel production and associated feedstock processing may involve impacts from released reactants and by-products. There are potential impacts to California's air and water during the large-scale industrial operations use to extract seed oils. These impacts may result from air emissions of solvents used to extract the seed oil (e.g., hexane) and from leaking tanks containing process chemicals. There is also the issue of occupational exposures.

  Currently, the possible impacts during seed extraction will be minimal in California since it is anticipated that most of the seed oils will be derived from soy grown and extracted out-of-state. The impacts during seed extraction will be become more of an issue for California as in-state production of plant-derived oils increases and may require further study.

  As the volume of tallow that is rendered out of state and shipped by rail or truck into California increases, there is a potential impact from releases of large volumes of raw triglycerides to soils or water. The impact of such a release is not well known and additional research would be beneficial as large-scale tallow usage increases.

- **Air Emissions Toxicity Testing.** The currently-published emission toxicity for renewable diesel is based on pure renewable diesel (R100) and do not directly compare results to a baseline diesel fuel. The ARB is funding studies that used in-vitro testing to assess and compare the inflammatory toxicity and genotoxicity of biodiesel and renewable diesel blends along with CARB diesel and early results indicate lower toxicity for renewable diesel. But based on the level of variation in emissions toxicity assessment for petroleum diesel, the chemical similarity of renewable diesel and petroleum diesel, and the likelihood for blends that still contain a significant fraction (80%) of petroleum diesel, we expect that it will be difficult to organize and interpret a study to compare the toxicity of petroleum diesel relative to R20 renewable diesel blends for the full range of vehicle-engine systems used in California. Therefore, unless there market evolves to the point where renewable blends contain more than 50% non-petroleum diesel feedstock, there appears to be little value in calling for extensive emissions toxicity studies for renewable diesel.

- **Priority list of renewable diesel fuel formulations.** Because the number of potential feedstocks, the number of fuel blends, and the number of additive choices and mixes makes for an unmanageable suite of permutations that may require evaluation, it is critical to identify the priority feedstocks, fuel blends, and additives requiring study for any additional impacts assessment.

Not specifically addressed in this Tier I evaluation are the environmental impacts from the increased use of fertilizers and water and land resources as the production of plant oils increases in the State. These factors may be some of the most important eventual impacts to California as the renewable and biofuels industry expands. More sustainable sources of renewable diesel such as yellow or brown grease or tallow may be preferable and should be encouraged.

During this review, we discovered that there are strong similarities between the chemical composition of petroleum diesel and renewable diesel. These similarities and the likelihood that renewable diesel will be used as a blend with petroleum diesel limits the need for additional Tier II Multimedia experiments or an extensive life-cycle impact assessment.

A key goal of this report is to identify important knowledge gaps for a Multimedia Assessment and recommend approaches to address these gaps. This does not always involve additional experiments, but could include additional requests for information from the proponents of any new fuel to be used in California.

As part of the overall multimedia assessment, each company proposing to market renewable diesel within California should provide the California ARB with a production, blending, additives, and distribution strategy that includes potential volumes to be stored and transported along with potential release scenarios that the company may foresee. Each company should also provide a comparative chemical analysis of the product they intend to market (blend or other wise). This analysis should be compared to conventional diesel currently in the market place.

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11. Appendices

11.1. Appendix A: ASTM D975-09b Standard Property Descriptions for Diesel Fuel Oils

Flash Point
This is the minimum temperature at which the fuel ignites on application of an ignition source; it has no direct relationship to engine performance but instead indicates the level of fire safety (Test Methods D 93, D 3828, or D 56)(ASTM 2009).

Water and Sediment
These are primarily considered as post-production parameters since fuel most commonly comes into contact with water and sediment during storage.

Sediment “may consist of suspended rust and dirt particles or it may originate from the fuel as insoluble compounds formed during fuel oxidation” (Van Gerpen et al., 2004). These sediments can cause fuel filter plugging problems (Test Method D 2709 for all fuel grades except D-4 which requires Test Method D 1796)(ASTM 2009).

Distillation
Distillation is a measure of the volatility of a fuel. “The fuel volatility requirements depend on engine design, size, nature of speed and load variations.” Note that heavier fuels will provide the best fuel economy due to having greater heat content (Test Method D 86 or D 2887)(ASTM 2009).

Kinematic Viscosity
It is important to designate a minimum viscosity, as there can be issues of power loss due to injection pump and injector leakage when fuels with low viscosity are used. Likewise, a maximum viscosity must be met for considerations involved in engine design, size, and characteristics of the injection system (Test Method D 445)(ASTM, 2009).

Ash
The ash content describes the amount of inorganic contaminants such as abrasive solids and soluble metallic soaps. “These can contribute to injector, fuel pump, piston and ring wear, engine deposits”, and filter plugging (Test Method D 482)(ASTM 2009).

Sulfur
Limits have been placed on sulfur content for environmental reasons. The limits for Grade S15, Grade S500, and Grade S5000 indicate a limit of 15 ppm, 500 ppm and 5000 ppm of sulfur content, respectively. Note: “other sulfur limits can apply in selected areas in the United States and in other countries” (Test Methods D 129, D 1266, D 1552, D 2622, D 3120, D 4294, or D 5453)(ASTM 2009). In California, the California Air and Resource Board has set the sulfur content for diesel fuels at 15 ppm or less (ULSD).

Copper Strip Corrosion Rating
This is a test to measure the presence of acids or sulfur-containing compounds in the fuel. A copper strip is immersed in the fuel to determine the level of corrosion that would occur if diesel came in contact with metals such as copper, brass, or bronze. Grade 4-D does not have a copper corrosion requirement. (D 130)(ASTM 2009).

Cetane Number
The cetane number is a measure of the ignition quality of the fuel. To obtain the highest fuel availability, the cetane number should be as low as possible; otherwise fuel will be ignited too

quickly. For diesel fuels, a minimum cetane number of 40 is recommended, except for grade 4-D which is 30 (D 613 or D 6890)(ASTM 2009).

Cetane Index

"Cetane Index is a specified as a limitation on the amount of high aromatic components in Grades No. 1-D S15, No. 1-D S500, No. 2-D S15 and No. 2-D S500." The index for all four mentioned grades is 40. Note that it is required that either the cetane index or the aromaticity be met. Grades 1-D S 5000 and 2-D S 5000 and 4-D do not have aromatic content requirements (Test Method D 976-80) (ASTM 2009).

Aromaticity

Aromatics content is significant since it is important to "prevent an increase in the average aromatics content in Grades No. 1-D S15, No. 1-D S500, No 2-D S15 and No. 2-D S500 fuels" since they have a negative impact on emissions. For diesel fuels, the maximum percent volume of aromatics is 35. Grades 1-D S 5000 and 2-D S 5000 and 4-D do not have aromatic content requirements (Test Method D 1319(ASTM 2009).

Operability Requirements

Operability temperature limits for Grades No. 1-D S500, No. 1-D S5000, No. 2-D S500, and No. 2-DS5000 may be estimated by a Low Temperature Flow Test, and Cold Filter Plugging Point Test. Note that satisfactory operability below the cloud point may be achieved depending on use of flow-improver additives, equipment design, and operating conditions. Note that it is "unrealistic to specify low temperature properties that will ensure satisfactory operation at all ambient conditions" (ASTM 2009).

Cloud Point

This is an important property as it "defines the temperature at which a cloud or haze of wax crystals appears in the oil [and] relates to the temperature at which wax crystals begin to precipitate from the oil in use". Petroleum based diesel fuel generally has a low cloud point as it is not as susceptible to cold temperatures. There is currently no cloud point specification for diesel (Test methods D 5771, D5772, D5773, or D 2500)(ASTM 2009).

Carbon Residue

"Carbon residue is a measure of carbon depositing tendencies of a fuel oil when heated under prescribed conditions". This property is an approximation since it is not directly correlated with engine deposits. For diesel fuels Grades No. 1-D S15, S500, S5000, the residue maximum is 0.15% mass, whereas for Grades No. 2-D S15, S500, S5000, it is 0.35% mass (Test Method D 524). Note that there is no standard for Grade No. 4-D (ASTM 2009).

Lubricity

In some cases, diesel fuel may have insufficient lubricating properties that can negatively impact the operability of diesel fuel injection systems. This occurs due to by "low viscosity and lack of sufficient quantities of trace components that have an affinity for surfaces". Experts agree that lubricity values above 600 microns may not prevent operability issues, whereas fuels with less than 450 microns should have satisfactory lubricity. The standard for diesel fuels is a maximum of 520 microns for an HFFR test at $60^{o}C$ (Test Method D 6079)(ASTM 2009).

11.2. Appendix B: Renewable Diesel Additive Chemicals

Figure B-1: Common Antioxidants.

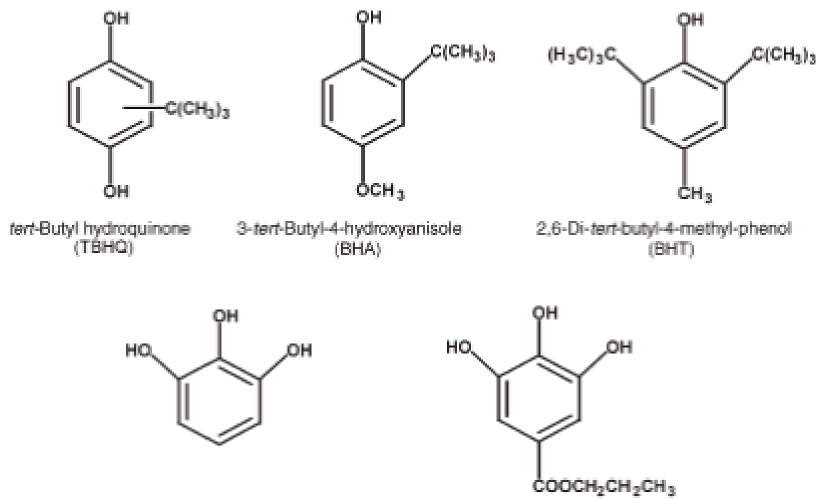
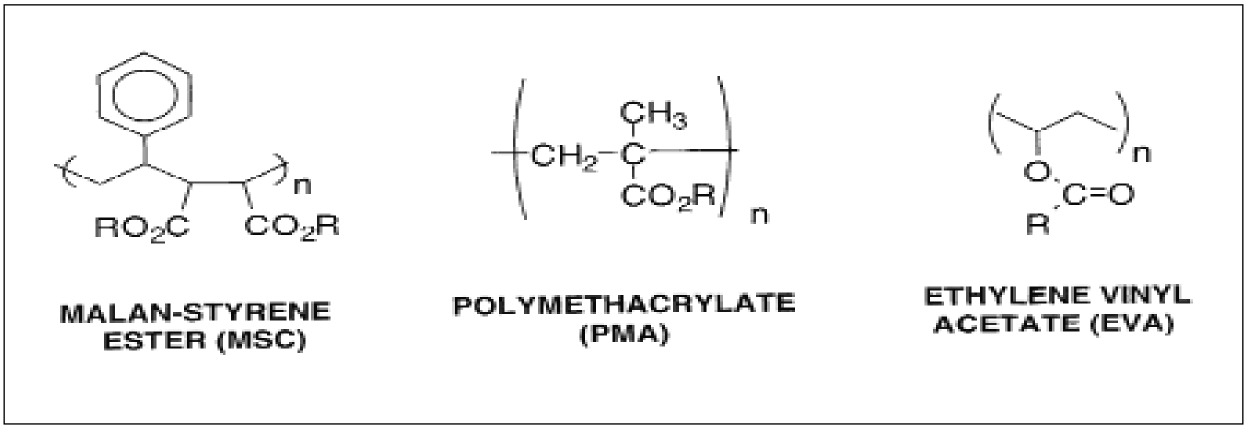


Table B-1. Commercial Biodiesel Antioxidants**.**

Manufacturer	Product Name	Chemical Components	%
Albemarle	Ethanox 4737	2,6 di-t-butylphenol 2,4,6 tri-tert butylphenol 2-tert-butylphenol Phenol Naptha Petroleum	52.5% 10.5% 7% 1.1% 25-30% 2%
Biofuel Systems	Baynox	2,6 di-tert-butyl-4-methylphenol	20%
Chemiphase	AllClear	Methyl Alcohol	18-24%
Eastman Chemical	Bioextend30	2-tert-butylhydroquinone Butyle acetate Diethylene glycol monobutyl ether	20% 30% 30%
Eastman Chemical	Tenox 21	Tertiary butylhydroquinone	20%
Lubrizol	8471U	Butylated phenol	70-79%

Source: Company MSDSs and Product Data Sheets

Figure B-2. Lubrizol Corporation Cold Flow Additive Chemicals*.



*Data from Chor et al., 2000. Lubrizol cold-flow additives are formulated for all diesel fuels and can be used with standard diesel and biodiesel formulations.

Table B-2. Commercial Cold Flow Additives.

Manufacturer	Product Name	Chemical Components	%
Biofuel Systems	Wintron XC30	Toluene	2%
Chemiphase	Coldflow 350	Toluene	2%
Hammonds	ColdFlo	Vinyl copolymer in hydrocarbon solvent Naptha	N/A 40-70%
Lubrizol	FloZol502	Copolymer Ester Toluene	N/A 2%
Lubrizol	FlowZol503	Naptha Napthalene Trimetheyl Benzene Ethylbenzene Alkylphenol Xylene	40-49% 4.4% 1.4.9% 1.6% 5-9.9% 6.4%

Source: Company MSDSs and Product Data Sheets

Table B-3. Commercial Biocides.

Manufacturer	Product Name	Chemical Components	%
Chemiphase	AllKlear, FilterClear	Sodium dodecyclbenzene sulfonate	2-32%
FPPF Chemical	Kill-Em	Disodium ethylenebisdithiocarbamate Sodium dimethyldithiocarbamate Ethylene thiourea	15% 15% 1%
Hammonds	Biobor JF	Naptha 2,2-(1-methyltrimethylenedioxy)bis-(4-methyl-1,3,2 dioxyborinane; 2,2,oxybis(4,4,6-trimethyl-1,3,2-dioxaborinane) [Substituted dioxaborinanes]	4.5% 95%
Power Serve Products	Bio-Kleen	4-(2-nitrobutyl)-morpholine 4,4, (2-ethyl-2-nitrotrimethylene)-dimorpholine Methylene dimorpholine Morpholine 1-Nitropropane	76-85% 2-7% 3.9-6.5% 3-6% .3-5.3%
Rohm and Haas	Kathon FP 1.5	Magnesium nitrate 5-chloro-2-methyl-4-isothiazol-3-one 2-methyl-4-isothiazol-3-one	1-2.5% 1-2.5% To 1 mix
Star Brite Corp	Biodiesel Biocide	Sodium dimethyldithiocarbamate Ethylenedimine Dimethylamine Ethylene thiourea Nabam	15-20.2% 0.0-0.75% 0.0-0.75 0-1.0% 15-20%

Table C-4. NOx Reduction.

Manufacturer	Product Name	Chemical Components	%
Clean Diesel Technologies	Aris2000 Injection system	Urea or Ammonia injected into exhaust	N/A
Oryxe	LED for biodiesel (and diesel)	2-ethylhexyl nitrate Toluene	45% w/w 45-55 w/w
Viscon USA	Viscon	Polyisobutylene (Polyalphaolefin) Polymer	5%

APPENDIX H

Request for Peer Review of the Renewable Diesel Multimedia Evaluation

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Air Resources Board

Mary D. Nichols, Chairman
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Sacramento, California 95812 • www.arb.ca.gov

Matthew Rodriquez
Secretary for Environmental Protection

Edmund G. Brown Jr.
Governor

TO: Gerald W. Bowes, Ph.D.
Manager, California Environmental Protection Agency
Scientific Peer Review Program
Office of Research, Planning and Performance

FROM: Floyd V. Vergara, Esq., P.E. *Original Signed*
Assistant Chief, Mobile Source Control Division
(Formerly Chief, Alternative Fuels Branch)

DATE: November 19, 2013

SUBJECT: REQUEST FOR EXTERNAL PEER REVIEWERS FOR THE MULTIMEDIA WORKING GROUP'S ASSESSMENT OF THE BIODIESEL AND RENEWABLE DIESEL MULTIMEDIA EVALUATIONS

In accordance with Health and Safety Code (H&SC) sections 43830.8 and 57004, the California Air Resources Board (ARB) staff requests external peer reviewers for two staff reports entitled, "*Staff Report: Multimedia Evaluation of Biodiesel*" (Biodiesel Staff Report) and "*Staff Report: Multimedia Evaluation of Renewable Diesel"* (Renewable Diesel Staff Report), which were authored by the Multimedia Working Group (MMWG). The MMWG is composed of representatives from various California Environmental Protection Agency organizations.

The staff reports consist of the MMWG's assessment of the biodiesel and renewable diesel multimedia evaluations conducted by researchers at the University of California (UC), Berkeley, and UC Davis, and the MMWG's analysis of potential significant adverse impacts on public health and the environment.

For this peer review, we suggest that the reviewers have expertise in environmental and multimedia impacts analysis, including: (1) air quality; (2) surface and ground water quality; (3) public health, and (4) soil impacts and hazardous waste. We estimate that six reviewers would be sufficient to cover all needed areas of expertise.

Peer review comments will be addressed by the MMWG in the staff reports, and the MMWG's summary and recommendations will be finalized and submitted to the California Environmental Policy Council (CEPC or Council) to complete the multimedia evaluation. The CEPC consists of the following Council members: Secretary for Environmental Protection, Chairman of ARB, Director of the Office of Environmental

Health Hazard Assessment (OEHHA), Chairman of the State Water Resources Control Board (SWRCB), Director of the Department of Toxic Substances Control (DTSC), Director of the Department of Pesticide Regulation, and Director of the Department of Resources Recycling and Recovery.

The CEPC will determine whether the use of biodiesel and renewable diesel fuel will cause a significant adverse impact on public health or the environment. Before fuel specifications are established, a multimedia evaluation must be conducted pursuant to H&SC section 43830.8. Pending completion of the biodiesel and renewable diesel multimedia evaluations, ARB staff intends to establish fuel quality specifications for biodiesel and renewable diesel fuel.

The following attachments are enclosed:

1. Attachment 1 - Plain English Summary of the Biodiesel Multimedia Evaluation and Renewable Diesel Multimedia Evaluation
2. Attachment 2 - Description of Scientific Conclusions to be Addressed by Peer Reviewers
3. Attachment 3 - List of Participants
4. Attachment 4 - References

The staff reports prepared by the MMWG and other supporting documentation will be ready for review by November 20, 2013. Staff requests that the peer review be completed and comments from the reviewers be received by **December 23, 2013.**

If you should have questions regarding this request, please contact Ms. Aubrey Gonzalez, Air Resources Engineer, Substance Evaluation Section at (916) 324-3334 or via email at agonzale@arb.ca.gov. Thank you for your time and consideration of this request.

Attachments (4)

cc: Aubrey Gonzalez
Air Resources Engineer
Substance Evaluation Section

Jim Aguila, Manager
Substance Evaluation Section

ATTACHMENT 1

Plain English Summary of the Biodiesel Multimedia Evaluation and Renewable Diesel Multimedia Evaluation

The Multimedia Working Group (MMWG) prepared two staff reports, one for the multimedia evaluation of biodiesel and the other for the multimedia evaluation of renewable diesel. The complete titles of each of these reports are provided below:

1. Staff Report: Multimedia Evaluation of Biodiesel including 10 appendices (Biodiesel Staff Report)
2. Staff Report: Multimedia Evaluation of Renewable Diesel including 10 appendices (Renewable Diesel Staff Report)

The staff reports consist of the MMWG's assessment of the biodiesel and renewable diesel multimedia evaluations conducted by researchers at the University of California (UC), Berkeley, and UC Davis, and the MMWG's analysis of potential significant adverse impacts on public health and the environment.

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

Biodiesel Multimedia Evaluation

"Biodiesel" is composed of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats and meets the specifications set forth by ASTM International standard D6751.

The MMWG completed their assessment of the biodiesel multimedia evaluation and potential impacts on public health and the environment. The evaluation is a relative comparison between biodiesel fuel and diesel fuel meeting Air Resources Board (ARB) motor vehicle diesel fuel specifications (CARB diesel).

Based on the results of the biodiesel multimedia evaluation and the information provided in the UC's Biodiesel Final Tier III Report, the MMWG makes the overall conclusion that biodiesel specifically evaluated within the scope of the evaluation will not cause a significant adverse impact on public health or the environment.

Renewable Diesel Multimedia Evaluation

"Renewable diesel" is produced from non-petroleum renewable resources and is not a mono-alkyl ester. Renewable diesel consists solely of hydrocarbons and meets ARB motor vehicle fuel specifications under title 13, California Code of Regulations, section 2281 et seq.

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

Based on the results of the multimedia evaluation and the information provided in the UC's Renewable Diesel Final Tier III Report, the MMWG makes the overall conclusion that renewable diesel specifically evaluated within the scope of the evaluation will not cause a significant adverse impact on public health or the environment.
Hard copies of the MMWG Biodiesel Staff Report and Renewable Diesel Staff Report, including the UC Biodiesel Final Tier III Report and Renewable Diesel Final Tier III Report, will be provided. Also, all references cited in each of the staff reports will be provided electronically on a compact disk.

ATTACHMENT 2

Description of Scientific Conclusions to be Addressed by Peer Reviewers

The statutory mandate for external scientific peer review (H&SC section 57004) states that the reviewer's responsibility is to determine whether the scientific basis or portion of the proposed rule is based upon sound scientific knowledge, methods, and practices.

We request your review to allow you to make this determination for each of the following conclusions that constitute the scientific basis of the staff reports. An explanatory statement is provided for each conclusion to focus the review.

For those work products which are not proposed rules, as is the case here, reviewers must measure the quality of the product with respect to the same exacting standard as if it was subject to H&SC section 57004.

The following conclusions are based on information provided in the Multimedia Working Group's (MMWG's) staff reports:

1. Staff Report: Multimedia Evaluation of Biodiesel including 10 appendices (Biodiesel Staff Report)
2. Staff Report: Multimedia Evaluation of Renewable Diesel including 10 appendices (Renewable Diesel Staff Report)

Biodiesel and renewable diesel are defined in Attachment 1.

1. Biodiesel

The MMWG concludes that the use of biodiesel fuel in California, as specified in the biodiesel multimedia evaluation, does not pose a significant adverse impact on public health or the environment relative to diesel fuel meeting Air Resources Board (ARB) motor vehicle diesel fuel specifications (CARB diesel).

Based on the results of the biodiesel multimedia evaluation and the information provided in the University of California (UC) final report, "California Biodiesel Multimedia Evaluation Final Tier III Report" (Ginn, T.R., *et al.*, May 2013), the MMWG makes the overall conclusion that biodiesel specifically evaluated within the scope of the biodiesel multimedia evaluation will not cause a significant adverse impact on public health or the environment relative to CARB diesel. The MMWG based their conclusion on each individual agency's assessment of the biodiesel multimedia evaluation. (Biodiesel Staff Report, Chapter 3)

a. **Air Emissions Evaluation. Air Resources Board (ARB) staff concludes that the use of biodiesel does not pose a significant adverse impact on public**

health or the environment from potential air quality impacts. ARB staff completed a comparative air quality assessment of biodiesel fuel relative to CARB diesel. ARB staff made conclusions based on their assessment of various emissions test results and air quality data, including criteria pollutants, toxic air contaminants, ozone precursors, and greenhouse gas emissions data. (Biodiesel Staff Report, Chapters 2 and 3)

b. **Water Evaluation. State Water Resources Control Board (SWRCB) staff concludes that there are minimal additional risks to beneficial uses of California waters posed by biodiesel than that posed by CARB diesel alone.** SWRCB staff completed an evaluation of potential surface water and groundwater impacts from biodiesel fuel and made conclusions based on their assessment of potential water impacts and materials compatibility, functionality, and fate and transport information. (Biodiesel Staff Report, Chapter 2 and 3)

c. **Public Health Evaluation. Office of Environmental Health Hazard Assessment (OEHHA) staff concludes that the substitution of biodiesel for CARB diesel reduces the rate of addition of carbon dioxide to the atmosphere and reduces the amount of particulate matter (PM), benzene, ethyl benzene, and polycyclic aromatic hydrocarbons (PAHs) released into the atmosphere, but may increase emissions of oxides of nitrogen ($NO_{x)}$ and acrolein for certain blends.** OEHHA staff evaluated potential human health impacts from the use of biodiesel and made conclusions based on their analysis of potential impacts on atmospheric carbon dioxide and combustion emissions results. (Biodiesel Staff Report, Chapter 2 and 3)

d. **Soil and Hazardous Waste Evaluation. Department of Toxic Substances Control (DTSC) staff concludes that biodiesel aerobically biodegrades more readily than CARB diesel, has potentially higher aquatic toxicity for a small subset of tested species, and generally has no significant difference in vadose zone infiltration rate.** DTSC staff evaluated impacts of biodiesel to human health and the environment and made conclusions based on their evaluation of screening aquatic toxicity testing, hazardous waste generation during the production, use, storage, and disposal of biodiesel and biodiesel blends, and potential impacts on the fate and transport of biodiesel fuel in the subsurface soil from unauthorized spills or releases. (Biodiesel Staff Report, Chapter 2 and 3)

2. Renewable Diesel

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

Based on the results of the renewable diesel multimedia evaluation and the information provided in the UC final report, "California Renewable Diesel Multimedia Evaluation Final Tier III Report" (McKone, T.E. *et al.*, April 2012), the MMWG makes the overall conclusion that renewable diesel specifically evaluated within the scope of the renewable diesel multimedia evaluation will not cause a significant adverse impact on public health or the environment relative to CARB diesel. The MMWG based their conclusion on each individual agency's assessment of the multimedia evaluation. (Renewable Diesel Staff Report, Chapter 3)

a. **Air Emissions Evaluation. ARB staff concludes that the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts**. ARB staff completed a comparative air quality assessment and impacts analysis of renewable diesel fuel relative to CARB diesel. ARB staff made conclusions based on their assessment of various emissions test results and air quality data, including criteria pollutants, toxic air contaminants, and greenhouse gas emissions data. (Renewable Diesel Staff Report, Chapter 2 and 3)

b. **Water Evaluation. SWRCB staff concludes that there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone.** SWRCB staff completed an evaluation of potential surface water and groundwater impacts from renewable diesel and made conclusions based on their assessment of potential water impacts and material compatibility, functionality, and fate and transport information. (Renewable Diesel Staff Report, Chapter 2 and 3)

c. **Public Health Evaluation. OEHHA staff concludes that PM, benzene, ethyl benzene, and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel.** OEHHA staff evaluated potential human health impacts from the use of renewable diesel and made conclusions based on their analysis of toxicity testing data and combustion emissions results. (Renewable Diesel Staff Report, Chapter 2 and 3)

d. **Soil and Hazardous Waste Evaluation. DTSC staff concludes that renewable diesel is free of ester compounds and has low aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel.** DTSC staff assessed potential impacts to human health and the environment from the production and use of renewable diesel compared to CARB diesel, and made conclusions based on their analysis of hazardous waste generation during the production, use, and storage of renewable diesel in California and cleanup of contaminated sites in case of unauthorized spills or releases. (Renewable Diesel Staff Report, Chapter 2 and 3)

3. MMWG's Recommendations to the California Environmental Policy Council

The MMWG recommends that the California Environmental Policy Council (CEPC) find that the use of biodiesel and renewable diesel, as specified in the respective multimedia evaluations, does not pose a significant adverse impact on public health or the environment. Based on the MMWG's conclusions in Chapter 3 of the Biodiesel Staff Report and the Renewable Diesel Staff Report, the MMWG proposes recommendations to the CEPC. (Biodiesel Staff Report and Renewable Diesel Staff Report, Chapter 4)

4. Big Picture

Reviewers are not limited to addressing only the specific conclusions presented above, and are asked to contemplate the following questions:

(a) In reading the staff report and supporting documentation, are there any additional scientific issues that are part of the scientific basis or conclusion of the multimedia evaluation not described above? If so, please provide further comments.

(b) Taken as a whole, are the conclusions and scientific portions of the multimedia evaluation based upon sound scientific knowledge, methods, and practices?

Reviewers should note that in some instances, the conclusions may rely on the professional judgment where the scientific data may be less than ideal. In these situations, every effort was made to ensure that the data was scientifically defensible.

The proceeding guidance will ensure that reviewers have an opportunity to comment on all aspects of the scientific basis of the multimedia evaluation of the proposed fuels. At the same time, reviewers also should recognize that the Board has a legal obligation to consider and respond to all feedback on the scientific portions of the multimedia evaluation. Because of this obligation, reviewers are encouraged to focus feedback on scientific issues that are relevant to the central regulatory elements being proposed.

ATTACHMENT 3

List of Participants*

Principal Investigators, Authors, Researchers, and Students Involved in the Biodiesel and Renewable Diesel Multimedia Evaluation

Principal Investigators and Authors of the Multimedia Evaluation (MME) Final Reports

Thomas McKone	University of California, Berkeley
David Rice	University of California, Berkeley consultant Lawrence Livermore National Laboratory (retired)
Timothy Ginn	University of California, Davis
Tyler Hatch	University of California, Davis

Test Program Researchers and Authors of MME Tier II Associated Reports

Kate Scow	University of California, Davis
Michael Johnson	University of California, Davis (retired)
Jeffrey Miller	University of California, Davis
Eric LaBolle	University of California, Davis
Jerry Last	University of California, Davis
Randy Maddalena	University of California, Berkeley
Thomas Durbin	University of California, Riverside

Students Involved in the Multimedia Evaluation Process

Tomer Schetrit	University of California, Davis
Vanessa Nino	University of California, Davis
Amande Epple	University of California, Davis
Tammer Barkouki	University of California, Davis
Idy Lui	University of California, Davis
Shima Motlagh	University of California, Davis
Laleh Rastegarzadeh	University of California, Davis
Josue Villagomez	University of California, Davis

Note: None of the University of California principal investigators, authors, researchers, nor students involved in the biodiesel and renewable multimedia evaluations participated in the development of ARB's proposed rulemaking to establish fuel quality specifications for biodiesel and renewable diesel fuel.

Members of the Multimedia Workgroup

Aubrey Gonzalez	Air Resources Board
Alexander Mitchell	Air Resources Board
Stephen d'Esterhazy	Air Resources Board
Susie Chung	Air Resources Board
Jim Aguila	Air Resources Board
Floyd Vergara	Air Resources Board
Jim Guthrie	Air Resources Board
Mark Schuy	Air Resources Board
Patrick Wong	Air Resources Board
Russel Hansen	State Water Resources Control Board
Laura Fisher	State Water Resources Control Board
Shahla Farahnak	State Water Resources Control Board
Li Tang	Department of Toxic Substances Control
Adriana Ortegon	Department of Toxic Substances Control
Andre Algazi	Department of Toxic Substances Control
Donn Diebert	Department of Toxic Substances Control
Page Painter	Office of Environmental Health Hazard Assessment
Hristo Hristov	Office of Environmental Health Hazard Assessment
John Budroe	Office of Environmental Health Hazard Assessment

* No person may serve as an external scientific peer reviewer for the scientific portion of the multimedia evaluation if that person participated in the development of the scientific basis or scientific portion of the multimedia evaluation.

ATTACHMENT 4

References

All references cited in the Biodiesel Staff Report and the Renewable Diesel Staff Report will be provided on a compact disk. For references available online, electronic links will also be provided in the staff reports.

APPENDIX I

External Scientific Peer Reviews

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Reviews of Renewable Diesel Assessment Reports and Supporting Documents (7)

a) Edward J. Bouwer, Ph.D. - John Hopkins University
b) Tracey Holloway, Ph.D. - University of Wisconsin - Madison
c) An Li, Ph.D. - University of Illinois - Chicago
d) Stephen Nesnow, Ph.D. - Stephen Nesnow Consulting
e) Lisa A. Rodenburg, Ph.D. - Rutgers University
f) Paul White, Ph.D. - University of Ottawa
g) Xiusheng (Harrison) Yang, Ph.D. - University of Connecticut

Department of Geography and Environmental Engineering
Whiting School of Engineering

JOHNS HOPKINS UNIVERSITY

Edward J. Bouwer (410) 516-7437; E-mail: bouwer@jhu.edu

January 7, 2014

Gerald W. Bowes, Ph.D.
Manager, California Environmental Protection Agency
Scientific Peer Review Program
Office of Research, Planning, and Performance

Dear Dr. Bowes:

I have reviewed the **Staff Report: Multimedia Evaluation of Renewable Diesel** including 10 appendices. My expertise is microbial engineering that is applied to biodegradation of organic contaminants, transport and fate of bacteria in soil and aquifers, biofilm reactors, and contaminated sediments. I am providing external scientific peer review comments below mainly for the two sections on Water Evaluation and Soil and Hazardous Waste Evaluation.

Water Evaluation. The chemical properties and composition of renewable diesel without additives are similar to that of petroleum diesel (CARB diesel), so I agree with the conclusion that there are likely to be minimal additional risks to the waters of California from the use of renewable diesel. A general tendency is that liquid products from biomass are highly biodegradable under the proper conditions. For example, most liquid petroleum hydrocarbons (e.g., gasoline, diesel, jet fuel, and oils) can be biodegraded under aerobic conditions by many different species of bacteria. Several of these species of bacteria capable of petroleum hydrocarbon biodegradation are commonly found in rivers, lakes, and oceans and in the subsurface. Consequently, these liquid products tend not to persist for long periods when they are released to the environment. The biodegradability of renewable diesel and CARB diesel will be similar, so there is not an expected increase in risk from the use of renewable diesel in comparison to CARB diesel when they come in contact with surface waters or groundwaters.

The one factor that "clouds" the above conclusion is that additives are likely to be introduced in almost all renewable diesel blends. These additives address issues of oxidation, corrosion, foaming, cold temperature flow properties, biodegradation during storage, and water separation. As long as the expectation holds that renewable diesel will employ additives similar to those used currently in CARB diesel, then it follows that the health and environmental impacts of the two mixtures will be similar. If different additives are employed that might make the renewable diesel mixture either more toxic or less biodegradable, then additional studies will need to be conducted to demonstrate the environmental health and safety of the renewable diesel mixture planned for use.

Soil and Hazardous Waste Evaluation. Essentially, the same analysis provided for the Water Evaluation above applies for this topic. The similar chemical properties and composition for renewable diesel and CARB diesel means that the transport and fate of the two products should be similar if they are released to the subsurface. Consequently, there is not likely to be an increased risk to the environment with the use of renewable diesel. The limited knowledge regarding the additives that will be used for renewable diesel does add uncertainty to this conclusion. If such additives are different from the ones used for CARB diesel, then there is potential for the renewable diesel mixture to behave differently in the environment, such as increased toxicity or reduced biodegradability. If different additives are used for renewable diesel, then additional studies are recommended to properly document the new transport and fate properties.

In addition to the above comments for the major conclusions offered by the Staff Report, I provide following comments on specific sections of the report:

1. The Opening Glossary should contain CARB. The opening section does not define CARB diesel (page 4). CARB diesel is defined later in the report. If a reader starts with the opening section as I did, it will be confusing to not have a definition of CARB diesel up front. I believe that "conventional petroleum diesel" or simply "petroleum diesel" is another term that is synonymous with CARB diesel. The broader community is likely to be more familiar with the term conventional petroleum diesel or petroleum diesel in comparison to CARB diesel.

2. Add CARB to the list of acronyms on page 8 of Appendix A. ARB is listed, but not CARB.

3. In Appendix C on pages 10 and 11, the figure captions should be modified. The phrase "relative to CARB diesel" implies that the data are normalized to the CARB diesel value. Such normalized values are not plotted. The results for each of the test conditions are plotted to make an easier visual comparison between the CARB Diesel and the R20, R50, and R100 values. As an example, the Graph 1 caption should read "PM Emissions of R20, R50, R100, and CARB Diesel". The data points connected by lines on pages 10 and 11 imply that there is a predictive relationship between the different blends and the CARB Diesel. It is recommended that the data be plotted as a stacked column or bar chart to convey the data visually to avoid using a line plot.

4. On page A-52 in Appendix G, there is a Section 8 with header Environmental Transport and Fate of Renewable Diesel. The second paragraph on page A-52 has a poorly worded opening sentence regarding the environmental behavior of renewable diesel and conventional ULSD. I agree with the first theme that the chemical composition of renewable diesel is similar to conventional ULSD, so that behavior of these two products in aquatic and soil systems will be similar. The second theme of the opening sentence is poorly worded. I believe the intent of the sentence is to state that existing models and measurements are not able to reliably predict any differences in the behavior of renewable diesel and conventional ULSD. The suggested text better supports the conclusion that the use of renewable diesel does not pose a significant adverse impact on public health or the environment relative to CARB diesel.

5. The Staff Report on Multimedia Evaluation of Biodiesel indicates that there are material compatibility issues between biodiesel and CARB diesel. There is limited discussion

about material compatibility with renewable diesel on page A-41 of Appendix G because of limited data. As stated on page A-52, the chemical composition of renewable diesel is similar to that of CARB diesel. It should then follow that few material incompatibilities are expected for renewable diesel in comparison to CARB diesel. A few sentences to strengthen the discussion of compatible materials will be helpful.

6. As acknowledged thoroughly in the report, the presence of additives in the renewable diesel is a source of uncertainty for the chemical and physical properties of the renewable diesel (e.g., page A-54 in Appendix G). It would be helpful to provide some documentation on whether or not existing stocks of renewable diesel are likely to contain the same additives used in CARB Diesel. The database might be limited, but any evidence to support a statement about identical or similar additives will be helpful to support a conclusion that renewable diesel is just as acceptable as CARB diesel.

7. Typos: Appendix G, page A-52: line 5 from the bottom: “lease” should be “least”.

Sincerely,

Edward J. Bouwer, Ph.D.
Abel Wolman Professor of Environmental Engineering
Department Chair

Review of

"Staff Report: Multimedia Evaluation of Renewable Diesel"
Prepared by the Multimedia Working Group

Tracey Holloway, Ph.D.
University of Wisconsin--Madison

The California Air Resources Board (ARB) is proposing the development of new regulation for renewable diesel. Like biodiesel, renewable diesel is made from vegetable and animal oil feedstocks, but produced through different processing, and with different chemical composition. Renewable diesel is considered a potentially desirable fuel alternative, given the lower carbon intensity relative to petroleum diesel fuel and other possible benefits. In this report, all conclusions about renewable diesel are given relative to diesel fuel meeting ARB specifications, referred to in the report as "CARB diesel."

This review follows the topical areas of the MMWG report:

1. Renewable Diesel

Overall, the conclusions of the staff report are supported by the California Renewable Diesel Multimedia Evaluation (Final Tier I and III reports; there was no Tier II) from researchers at UC Davis and UC Berkeley. In particular, the major conclusion that "the use of renewable diesel in California...does not pose a significant adverse impact on public health or the environment relative to CARB diesel" is in line with the findings of the Multimedia Evaluation.

Although the report uses nomenclature of R20, R50, and R100 to reflect blending levels, where R20 = a 20% by volume blending of renewable diesel with CARB diesel, Appendix A defines only B5 and B20 and does not provide similar definitions of R20, etc.

a. Air Emissions Evaluation

The conclusion that "the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts" is supported by the Multimedia Evaluation and discussion in the staff report. This conclusion is based on an analysis of criteria pollutant emissions (including ozone precursor emissions), toxic air emissions, and greenhouse gas emissions.

There is a small typo, in that p. 6, paragraph 3 refers to the Tier II report from the UC multimedia assessment, whereas the renewable diesel evaluation only included Tier I and III reports.

Conclusions are drawn primarily from emission tests conducted at UC Riverside and at ARB test facilities. All emissions types decrease, except for a small increase in CO emissions under certain operating conditions. These emission reductions suggest benefits to renewable diesel as a substitute for CARB diesel. Appendix C is especially helpful in presenting these results graphically.

The findings of the air emissions evaluation are also presented in the health evaluation, Section C1 (p. 8-13). It would be useful to integrate Section A and C more clearly, and separate the emission test results for renewable fuels (which belong in Section A) from the toxicity and health impacts (which belong in Section C).

Section A1. (p. 6) is labeled "Criteria Pollutants." This section should begin with a discussion of what pollutants fall into this category, and which are evaluated here for renewable diesel. As written, Section A1 includes PM, nitrogen oxides (NO_x = NO + NO_2), total hydrocarbons (THC), carbon monoxide (CO) and brake specific fuel consumption (BSFC). However, THC and BSFC are not criteria pollutants and do not belong in this section. SO_2 is a criteria pollutant that is not discussed here, but is referenced in the "Renewable Diesel Background Information" on p. 4. Section A1 should report should comment on all criteria pollutant emissions (or precursor emissions) in some way, and omit discussion of metrics that are not criteria pollutants.

Section A3 (p. 7) discusses "Ozone Precursors." Because ozone is a criteria pollutant, this section would seem to be a better fit with Section 1 and/or follow directly afterward. For the benefit of readers unfamiliar with ozone chemistry, some brief comment should be added explaining that THC and NO_x emissions create ambient ozone.

Section A4 (p. 7) reports on Greenhouse Gas Emissions. This section would benefit from a number of changes. First, clarifying which greenhouse gas emissions have been evaluated - it appears only CO_2. It would also benefit from more detail on what steps in the lifecycle were considered. In particular, it would be helpful to note that the 80% reduction in GHG emissions would arise from tallow feedstock use, whereas the 15% reduction in GHG emissions would arise from soybean production in the Midwestern U.S. Detail on this point is provided in Appendix C, but a brief comment in the main report would improve clarity.

In the main discussion of renewable diesel lifecycle assessment in Appendix C (p. 12), more detail would also be useful. Table 8 presents two of the four scenarios based on tallow, which is assumed to have no indirect carbon intensity. Some comment should be included on the source of the tallow, and whether it is assumed to be a waste product.

b. Water Evaluation

The MMWG concludes that renewable diesel is equivalent to CARB diesel in terms of aquatic toxicity, compliance with underground storage tanks, biodegradability, and other factors. These conclusions are consistent with the UC multimedia evaluation.

c. Public Health Evaluation

Overall, the public health evaluation seemed to be provided with too much detail to clearly assess main points. Also, the content was somewhat redundant with the air emissions evaluation.

Conclusions that health-relevant air emissions are reduced with renewable diesel are well supported. Conclusions about emissions toxicity are uncertain due to limited testing. This result is consistent with the Tier III report, but should be stated more clearly.

d. Soil and Hazardous Waste Evaluation

Hazardous waste is outside the expertise of this reviewer. However, the discussion overall was clearly presented and seemed consistent with findings from the Multimedia Evaluation.

Review Comments

An Li, PhD, Professor
School of Public Health, University of Illinois at Chicago
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Phone: 312-996-9597, Fax: 312-413-9898, Email: anli@uic.edu

Submitted to Dr. Gerald W. Bowes (Gerald.Bowes@waterboards.ca.gov) on January 7, 2014

Document Reviewed: Staff Report: Multimedia Evaluation of Renewable Diesel by the Multimedia Working Group (MMWG), California Environmental Protection Agency, November 2013

Topic/Area Reviewed: Surface and Ground Water Quality

Summary Comments

The document reviewed here is a Staff Report prepared by MMWG of CEPA for the California Environmental Policy Council (CEPC), which will determine whether the proposed regulation on commercialization of new alternative diesel fuels poses significant adverse impact on public health or the environment. This is part of the process towards legally accepting and commercializing alternative diesel fuels in California.

The assignment to this reviewer is to help determine whether the scientific portions, particularly in the water quality section, of the MMWG Staff Report are based upon sound scientific knowledge, methods, and practice. The sections regarding water quality are mostly based on the evaluation by the State Water Resources Control Board (SWRCB) (Appendix D). The scientific knowledge is provided primarily in the Final Tiers I and III Reports (Appendix G).

I have read the main Staff Report and its Appendices A, D, and G. I consider the tiered multimedia evaluation well designed, and the Tiers Reports (Appendix G) were well written. In Tier I, the key knowledge gaps were identified through literature search, and a work plan was built, reviewed and revised. Tier II provided new experimental data showing the reduced emissions of most air pollutants including PM, CO, most PAHs, and, in contrast to biodiesel, NOx, from blended renewable diesels. Tier III is a summary of all the work with qualitative risk assessment in some sections. The Proposed Regulation Order (Appendix A) specifies the stages for commercializing new alternative diesel fuels.

Provided below are my Overall comments, Comments on water quality impact assessment, and Document specific minor comments.

Overall Comments

1. Within the scopes of my review and my expertise, I do not found the major flaws in the scientific knowledge, methods, and practice presented in the main Staff Report and its Appendices A, D and G.
2. The major MMWG conclusion – renewable diesel specifically evaluated within the scope of the evaluation will not cause a significant adverse impact on public health or the environment – is reasonable given the similarities and advantages of renewable diesel when compared with petroleum based CARB diesel. The chemistry and the technology (e.g. hydrocracking) for producing renewable diesel from the intended feedstock are basically the same as those petroleum industry has been using

for many decades. The advantage and benefits of adopting renewable diesel outweigh the slightly lowered fuel efficiency and the potential risks.

3. I suggest summarizing the limitations of this multimedia evaluation in the main Staff Report, section I-C. Some limitations are well described in the Tiers Reports, but are absent in the Staff Report. The limitations are different from the conditions in section IV Recommendations part 2 (page 17).
4. The definition of R20 (similarly Rxx) is a bit confusing to this reviewer. It seems both blended (20% R100 + 80% CARB diesel) and co-processed (manufactured by co-processing petroleum and some bio-source, such as tallow as in the case shown in Tier-I Report pages A-36 to A-38) renewable diesels are called R20. A clarification somewhere can be helpful. If the "Rxx" is based on chemical composition of the final product regardless its production methods (blended or co-processes), please say so.
5. No comparison between renewable diesel and biodiesel was made. The advantages of each over the other are quantitatively or qualitatively mentioned. According to UOP (2005), renewable diesel has a lower environmental impact than biodiesel and requires less capital investment to produce. This is in agreement with what I learned from reading the documents provided. However, I failed to find answers to the questions whether biodiesel is indeed needed and why biodiesel is being proposed as the first alternative diesel fuel in California, given the apparent advantages of the renewable diesel.
6. The assessment of the supply and demand is not within the scope of this multimedia assessment. According to Hill et al. (2006), even dedicating all U.S. corn and soybean production to biofuels would meet only 12% of the gasoline and 6% of diesel demands in the country. Even with R20 or lower blends, whether all the available resources would meet the demand is unclear.
7. In the near future, the major feedstock could be soybeans grown in the US Midwest, as mentioned in Tier III report, page 7. Various adverse impacts on the ecosystem in the Midwest states have already been reported. Although a complete evaluation of the impact outside California is beyond this work, a summary of available information on the impacts of the upstream processes (feedstock production, extraction, blending, etc.) on the environment and human health will be helpful and could have been included.

Comments on Surface and Ground Water Quality Assessment

1. Within the scope of this multimedia evaluation, the SWRCB conclusion – there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone – is reasonable given the similarities in chemical composition (including the needed additives) of renewable diesel when compared with petroleum based CARB diesel.
2. However, the impact of additives is not considered, which constitutes a major concern. Some conclusions, particularly those concerning water quality and toxicity, were made based only on the similarities in fuel properties and chemical compositions between the renewable diesel and CARB diesel, without conducting any laboratory experiments or model simulations.
3. Main Staff Report, pages 7-8, section II-B: Compared with other sections in chapter II, the summary for water quality impact is very brief. It reads more like conclusions rather than a summary, and may not be sufficient for CEPC review. I suggest adding sufficient information to allow an understanding on the assessment methods and the results, with references. Take part 1 Water Impacts as an example, where and when was the aquatic toxicity test conducted? What type(s) of aquatic toxicity was tested with what test species and what method? Was the test on R100 or any blends? Do the data show higher or lower toxicity compared with CARB diesel? … For all 4 parts of this summary, references of

the data sources and major scientific knowledge should be cited. The data source information is needed here because, based on my understanding from reading Tier III report page 12 paragraph 1, Tier II experiments were not conducted for toxicity and fate and transport.

4. Page 15, section III-B: This paragraph may be improved by including more specific information, which could come from page 8. The last several words need to be changed from "public health or the environment" to "the quality of surface water and groundwater in California".

Document Specific Minor Comments

Main Report (20 pages)

Table of Contents: I suggest changing II title from "Summary" to "Section Summaries" or "Summaries of Reports from Participating State Agencies", in order to avoid confusion with the summary of this Main Report.

Page 1, section A: There are three bulleted lines for air, water and wastes, respectively. It is not clear why public health is not included here. Risk assessment on the public health focuses on human, in contrast to those on environmental media. The same can be said for the bulleted lines in Page 2, section 2.

Page 5, section C: I suggest including one brief sentence on line 4 indicating that CARB diesel is conventional petroleum based ultra-low sulfur diesel, along with a brief time line. One or more references should be helpful, directing readers to information on CARB diesel development and adoption, quantity of use in the state, its environmental and human health impacts, etc. This is especially helpful to stakeholders who reside outside California and are unfamiliar with the phrase "CARB diesel".

Page 7, section 4 Greenhouse Gas Emissions, line 1: Please check if the word "decreased" should be "increased". The word "decreased" appears to conflict with the statement in page 6, last sentence.

Appendix A – Proposed Regulation Order (36 page)

Page 4, (a), (1): If ADF means any non-CARB diesel fuel that does not consist solely of hydrocarbons, a question arises whether "renewable diesel" as defined in the 3-tier multimedia evaluation is an ADF. The renewable diesel, to my understanding, consists of predominantly hydrocarbons.

Page 5, (8): The definition for "CARB Diesel fuel" in this proposed regulation appears different from that for "CARB Diesel" used in the 3-tier multimedia evaluation. The former includes 5%v of FAME, while the latter is a pure ultra-low-sulfur diesel (ULSD) derived from petroleum.

Page 22, top lines: The definition of NBV is repeated.

Page 22, Table A.2. "Limit" column: The sign "≥" for both total aromatics and polycyclic aromatic hydrocarbons could be "≤".

Page 30, Table A.9, column "fuel Specifications", row 4 for PAHs w%: The 10% maximum seems incorrect for PAHs in a reference fuel. Please check.

Appendix D – SWRCB Submittal (5 pages)

Relevant to this review is Attachment #2 (2 pages).

Most part of Attachment #2 is the same as presented in the main Staff Report. Thus, same comments as explained above are applicable.

Appendix G – Final Tier III Report (19 pages)

Following the excellent summaries of Tier I (chapter 2) and Tier II (chapter 3), it is logical and helpful to have a chapter providing details on the work executed in Tier III stage. How was the risk assessment carried out? Which model(s) was used? A description of the protocol and a result summary would be very helpful to interested stakeholders. In the current version of this report, chapter 4 gives conclusions and recommendations, but it is not clear on what was done and how.

Page 12: The 2nd paragraph should be deleted. It should not be under 3.1, and repeats the first two sentences in 3.2. Also, "(Citation)" needs to be changed to the reference information.

Page 16, 5th line from bottom: "will be become" should be "will become".

Appendix G, Appendix – Tier I Report (65 pages optional)

The only comment is that references should be cited at places. For example, the numbers used in the last three paragraphs on page A-40 need references.

Literature Cited

Hill, J. et al. 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. PNAS 103 (30), 11206–11210. (http://www.pnas.org/content/103/30/11206.abstract)

UOP, 2005. Opportunities for Biorenewables in Oil Refineries. Final Technical Report. DE-FG36-05GO15085. Des Plaines, Illinois. http://www.osti.gov/scitech/biblio/861458

Peer Review of Staff Report: Multimedia Evaluation Renewable Diesel (Renewable Diesel Staff Report)

Prepared by:

Stephen Nesnow, Ph.D.
Stephen Nesnow, Consulting
Chapel Hill, NC

January 6, 2014

1. Preface

The purpose of this document is to review The Staff Report: Multimedia Evaluation of Renewable Diesel to determine whether the scientific portions of the MMWG staff report are based upon "sound scientific knowledge, methods, and practices." The Staff Report: Multimedia Evaluation of Renewable Diesel is based on three previous documents the California Renewable Diesel Multimedia Evaluation Final Tier I, II and III Reports that contain data and analyses from government reports, literature documents, and from reports of studies commissioned by the CARB.

2. General comments

Emissions from diesel fueled engines are a complex mixture consisting of both gaseous and particulate components. The gaseous phase contains ozone, sulfur oxides and the criteria pollutants, carbon monoxide, particulate matter, nitrogen dioxide and ozone. Many organic compounds are also present, such as acetaldehyde, acrolein, benzene, 1,3-butadiene, ethylbenzene, toluene, formaldehyde, polycyclic aromatic hydrocarbons and nitro-polycyclic aromatic hydrocarbons. Particulate matter, benzene, 1,3-butadiene, formaldehyde and benzo[a]pyrene are carcinogenic in experimental animals and are classified as human carcinogens and acetaldehyde, ethylbenzene and a number of other polycyclic aromatic hydrocarbons and nitro-polycyclic aromatic hydrocarbons have been classified as probably or possibly carcinogenic to humans by the International Agency for Research on Cancer (IARC, 2013). Toluene is not classifiable as to its carcinogenicity to humans (IARC, 2013). The particulate phase also contains trace metals such as lead, manganese arsenic and chromium and metals from the catalyst after treatment system, vanadium, copper and iron. Arsenic and arsenic inorganic compounds and chromium VI are classified as human carcinogens by IARC while lead and inorganic lead compounds as classified as probably or possibly carcinogenic to human, respectively by IARC. Moreover, diesel engine exhaust, diesel exhaust particles, diesel-exhaust condensates, and organic solvent extracts of diesel-engine exhaust were genotoxic. Increases in bulky DNA adducts were detected the lung tissues of rodents exposed to whole diesel exhaust and in workers exposed to diesel exhaust. In addition to lung cancer, diesel exhaust exposure in humans has been linked to lung inflammation, cardiovascular disease and cardiopulmonary disease (Madden et al., 2011).

The biological and toxicological information available for renewable diesel emissions are extremely limited compared to the rich compendium available for diesel emissions and many of the biological and toxicological measures available for conventional diesel are not available for renewable diesel. Therefore, surrogate measures need to be employed to make meaningful comparisons between the emission types. These measures include chemical and physical analyses of the renewable diesel emissions and to a limited extent some toxicological data on the renewable diesel emissions.

The Staff Report bases the comparisons (chemical, physical and toxicological) of the renewable diesel fuel emissions to those properties of CARB diesel emissions. The crux of each document's conclusion is that the selected parameters (chemical, physical and toxicological) examined were lower (with some exceptions) in emissions from engines fueled with renewable diesel compared to CARB diesel. Thus, the public health risk would not be greater than that already established for CARB diesel. The underlying premise is that lower levels of specific emissions will equate to lower human health risk or adverse health effects. This premise is generally consistent with the quantitative results from many studies in animals and in human populations of each specific constituent as well as studies in animals and human populations exposed to whole diesel exhaust emissions. Much of the data on emissions from the combustion of renewable diesel fuel is from quantitative chemical analysis and that is used to equate to lower toxic or adverse effects in exposed humans. The agents selected for comparison are from the group of EPA criteria pollutants and from selected VOCs commonly found in diesel exhaust and in ambient air. Each exhibits its own toxicity profile. Genotoxicity evaluations were based on organic extracts of particulates or the vapor phase fraction using bacterial tests for mutagenic activity. Some genotoxicity data in mammalian cells in culture were also available as well as bioassays for cytotoxicity, oxidative stress, inflammation and apoptosis. There are a number of toxicological evaluations of the particulate matter. There no studies in whole animals exposed to complete exhaust emissions and there are no studies that I know of in humans exposed to complete exhaust emissions from renewable diesel.

The MMWG concludes that the use of renewable diesel fuel in California, as specified in the renewable diesel multimedia evaluation, does not pose a significant adverse impact on public health or the environment relative to CARB diesel.
Based on the results of the renewable diesel multimedia evaluation and the information provided in the UC final report, "California Renewable Diesel Multimedia Evaluation Final Tier III Report" (McKone, T.E. *et al.*, April 2012), the MMWG makes the overall conclusion that renewable diesel specifically evaluated within the scope of the renewable diesel multimedia evaluation will not cause a significant adverse impact on public health or the environment relative to CARB diesel. The MMWG based their conclusion on each individual agency's assessment of the multimedia evaluation. (Renewable Diesel Staff Report, Chapter 3)

Public Health Evaluation. OEHHA staff concludes that PM, benzene, ethylbenzene, and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel. OEHHA staff evaluated potential human health impacts from the use of renewable diesel and made conclusions based on their analysis of toxicity testing data and combustion emissions results. (Renewable Diesel Staff Report, Chapter 2 and 3)

3. Peer review of the scientific issues

The basic premise of the conclusion: "that renewable diesel specifically evaluated within the scope of the renewable diesel multimedia evaluation will not cause a significant adverse impact on public health or the environment relative to CARB diesel" is based in large part on the measurements of the levels of key toxic components of emissions from renewable diesel and CARB diesel and to a minor degree on some toxicological measurements of these emissions.

Some of the issues of concern include: Are the metrics used to compare the levels and toxicity of individual or groups of pollutants of renewable diesel to CARB diesel appropriate, relevant, specific, sensitive and accurate?; Are the CARB renewable diesel results consistent with those reported by others in the literature?; Are all of most toxic components known to be present in diesel exhaust being measured in the CARB renewable diesel studies?; Is the toxicological dataset detailed, compete and extensive?; Are the selected indicators of adverse human health accurate and comprehensive?; Are there additional markers that could be included?

In general, there is a very limited body of information about the combustion emissions of renewable diesel compared to diesel as the data cited in the Report comes from studies commissioned by the CARB and reported in Durbin et al. (2011) and from three peer-reviewed publications. Comparisons of the Durbin et al. (2011) results to those published by others can be made but the results vary given the different fuel types, blends, engines, catalysts, and test cycles used in the studies.

The conclusion that the use of renewable diesel compared to diesel reduces the amount of particulate matter is supported by a majority of studies cited in the Report in that under specific experimental conditions the use of renewable diesel reduces the levels of particulate matter. The results of these studies comparing the levels of particulate matter from renewable diesel to diesel showed a variety of results (equal, greater than and less than) in levels of particulate matter between the two fuel types depending on fuel, blend, engine type, cycle and the presence or absence of a catalyst. To reinforce this point, a recent study by Westphal et al. (2013) who used a heavy duty diesel engine combusting hydrotreated vegetable oil reported an 8% decrease in particulate matter compared to the combustion of diesel fuel. Therefore, the conclusion of lower particulate matter from renewable diesel engines is not applicable to all exposure scenarios.

The conclusion that benzene, ethylbenzene and toluene levels are lower in emissions from renewable diesel fueled vehicles compared to those vehicles using CARB diesel are from the Durbin et al (2011) report who collected data from several engines under several test cycle protocols. There are no other sources of this data to verify these results.

The toxicological evaluation of emissions from renewable diesel fueled vehicles compared to those vehicles using diesel is limited. The assays and methods selected to determine the genotoxicity, oxidative stress, cytotoxicity, inflammation and apoptosis induced by the emissions are well accepted as measures of these endpoints. The conclusions and interpretations drawn from the data are acceptable.

The mutagenic activities of extracts of particulate matter and/or vapor phase fraction collected from diesel engines combusting renewable diesel and diesel were based on two studies cited in the Report and by Westphal et al. (2013) who reported that mutagenic activities of particulate extracts and condensates were lower in the hydrotreated vegetable emissions compared to diesel fuel emissions. Several of these studies used *Salmonella typhimurium* strains TA98 and TA100 for the analyses, while one study only used TA98. Overall, the studies showed different extents of reduction in mutagenic activities, or under some experimental conditions, no mutagenicity.

The genotoxicity, oxidative stress, cytotoxicity, inflammation and apoptosis data comparing emissions of renewable diesel to diesel are based on two studies (Durbin et al. (2011). The inflammation and oxidative stress analyses showed that renewable diesel produced lower responses in the HO-1, IL-8, and CYP1A1 assays in U937 macrophages and no differences in the CYP1A1, MUC5A and COX-2 assays in NCI-H441 lung Clara cells. The comet assay in U937 cells gave no differences between renewable diesel and CARB diesel. The other study used particulate matter from a diesel engine fueled hydrotreated vegetable oil renewable diesel or conventional diesel with, and without, a catalyst. Cytotoxicity and apoptosis assays using these cells showed no differences between the two fuels. Also reported were effects of the particulate matter samples from an engine combusting the two fuels on the release of cytokines that mediate inflammation using mouse macrophage cells. Some differences were noted in the absence of a catalyst while no significant difference was noted when a catalyst was used. In the same study the Comet assay results showed that the particulate matter from a diesel engine without a catalyst combusting hydrotreated vegetable oil diesel showed decreased DNA damage in a macrophage cell line (RAW264.7) compared to the particulate matter using conventional diesel. With a catalyst no significant differences were observed between the two fuels.

Specific comments: There are several duplications of text: P12, 2nd para is the same text as P13, 4th para (an analyses of Jalava et al. (2012)). P12, 3rd para has much of the same text as P13, 5th para but with the opposite interpretation of the Comet assay results with respect to HVORD fueled engine particulate matter vs. EN590 fueled engine particulate matter in the absence of a DOC/POC. The data in Jalava et al. (2012) clearly show DNA damage in mouse macrophage RAW264.7 cells treated in vitro with HVORD-fueled engine particulate matter was decreased compared to cells treated with EN590-fueled engine particulate matter in the absence of a DOC/POC.

A major shortcoming in the existing toxicology dataset is that there are no data from in vivo or ex-vivo studies of emissions of renewable diesel, a data need.

4. The Big Picture

It is noted that the levels of the constituents cited above have not been determined for the many different combinations of engine types (heavy and light duty) technology (old, new, catalyst type, test cycle and load), feed stock sources (plant and animal based) and mixture blends therefore, some caution needs to be exercised in accepting these conclusions without further data on the most prevalent combinations. Decisions on the impact of the toxicity of emissions from the multitude of combinations should be revisited after more data is available.

The data base on the physical, chemical and toxicological endpoints for renewable diesel is not as robust at that for biodiesel or diesel. The basis for the conclusion that particulate matter in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using diesel is based on a several studies, while some other studies show generally equal or slightly lower levels.

The basis for the conclusion that benzene, ethylbenzene and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel is based on a single study using a single engine, albeit using multiple blends and several test cycle protocols.

The available toxicological data comparing the emissions from renewable diesel and diesel is quite limited and contains no data from in vivo or ex-vivo studies of emissions of renewable diesel which is a concern.

In my opinion, the conclusions and scientific portions of the multimedia evaluation were based upon sound scientific knowledge, methods, and practices. However, it is noted that the conclusion that the use of renewable diesel fuel in California, as specified in the renewable diesel multimedia evaluation does not pose a significant adverse impact on public health or the environment relative to CARB diesel is based on data limited in scope, breadth and content.

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January 7, 2014

External scientific peer review of the Multimedia Working Group's assessment of the renewable diesel multimedia evaluation

As reviewers we're specifically asked to evaluate the following statements:

A. **Air emissions evaluation. ARB staff concludes that the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts.**
I find that this conclusion of the report is based on sound scientific knowledge, methods, and practices. The tier two investigations indicate that changes in emissions of most air pollutants including total hydrocarbons carbon monoxide, NOx, and particulate matter are minimal. Because there are many possible types of renewable diesel and only a few were tested, any changes in emissions of these types of pollutants are not necessarily statistically significant. However these tests do suggest that renewable diesel is no worse than regular diesel.

B. **Water evaluation. SWRCB staff concludes that there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone.**
I find that this conclusion of the report is based on sound scientific knowledge, methods, and practices. Because the chemical composition of renewable diesel is so similar to regular diesel the impacts on water resources are almost identical.

C. **Public health evaluation. OEHHA staff concludes that PM, benzene, ethylbenzene, and toluene in combustion emissions from diesel engines using hydro treated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel.**
I find that this conclusion of the report is based on sound scientific knowledge, methods, and practices. While the chemical composition of renewable diesel is very similar to that of regular diesel, the emissions tests performed as part of the tier II assessment do show what appear to be significant decreases in emissions of some of these hazardous air pollutants vs. regular diesel.

D. **Soil and hazardous waste evaluation. DTSC staff concludes that renewable diesel is free of ester compounds and as low aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel.**

I find that this conclusion of the report is based on sound scientific knowledge, methods, and practices. The characterization of renewable diesel has been very thorough and state of the art. While it is not possible to characterize every chemical component of either regular diesel or renewable diesel, the characterization that was performed is conclusive. The conclusion that the impacts on human health and the environment from spills of renewable diesel and regular diesel will be indistinguishable is reasonable.

In addition, as a reviewer I have been asked to evaluate the following statement.

The MMWG recommends that the California environmental policy council find that the use of biodiesel and renewable diesel, as specified in the respective multimedia evaluations, does not pose a significant adverse impact on public health or the environment.
I find that this conclusion is based on sound scientific knowledge, methods, and practices. As noted in the report, renewable diesel maybe formed from many sources. It is not possible to characterize all of those sources. However, because renewable diesel is so chemically similar to regular diesel, the conclusion that renewable diesel may be used without significant adverse impact on public health and the environment is sound. As opposed to the use of biodiesel, the use of renewable diesel is less likely to require changes in the materials used in tanks and pipelines used to store and transport the fuel, changes in the types of additives used in the fuel, or the construction of new facilities for production of renewable diesel.

As a reviewer, and also been asked whether there are additional scientific issues that are not described in the report.

Additional comments.

Staff Report

Page 6. Here and elsewhere, the report states that the renewable diesel emits less PM, NOx, THC, and CO, but that the BSFC is lower. It is important to explain to the reader that the emissions of criteria pollutants are expressed as g per hour or g per distance, such that differences in fuel consumption are already factored in.

Tier I Final Report

Pages A24-25 and table 2.1 on page A-25. The emission factors are on a grams per gallon basis. Because the different fuels have different mpg ratings, it would be useful to include a statement about whether their relative emission factors would change if they were expressed on a grams per vehicle mile travelled basis.

Appendix C: Air Resources Board: Impact Assessment of Renewable Diesel on Exhaust Emissions from Compression Ignition Engines

Page 9, tables 5, 6, & 7. Units are missing. Are these expressed on a g/bhp-hr basis as in the biodiesel report? Do values in bold represent those that are significant ($P < 0.05$)? Again, it would be useful to stress in the narrative that these units have already taken differences in fuel efficiency into account.

Appendix G: California Renewable Diesel Multimedia Evaluation Tier I Final Report

Page A-19 In comparing the production volumes across ConocoPhillips, Nest, and Petrobras, it would be helpful if all could be expressed in the same units, either metric tons per year of barrels per day. For Petrobras, the tons per year is presumably metric tons?

Page A-25 Table 2.1. Again, it would helpful to point out how fuel efficiency affects the emissions factors. If I'm not mistaken, ethanol's relatively poor mpg rating means that on a vehicle miles travelled basis, renewable diesel and biodiesel both look even better.

Page A-29 typo: avvegetable

Page A-30 top of page. Establishment of dedicated facilities for renewable diesel production will be problematic in terms of land use. This should be factored into the LCA if it becomes clear that these new facilities will, in fact, be required.

Page A-36 Unless I am mistaken, the sulfur content should be reported as less than 15 ppm, not 15%.

Pages A-49 and A-53 typo: missing symbol in 200 ?g/ml.

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External Peer Review of "Multimedia Evaluation of Renewable Diesel"

Re-statement of Objectives –

External peer reviewers are instructed to evaluate the scientific portions of the Multimedia Working Group (MMWG) report, and ensure that they are based on "sound scientific knowledge, methods and practices".

This review is primarily focussed on the *Public Health Evaluation* by the Office of Environmental Health Hazard Assessment (OEHHA), as well as additional components of the evaluation that relate to the toxicological hazards of biodiesel and biodiesel emissions (e.g., results of aquatic toxicity tests). The review encompasses the MMWG Staff Report "Multimedia Evaluation of Renewable Diesel", as well as the Tier I and Tier III reports, and related documents (e.g., *CARB Assessment of the Emissions from the Use of Biodiesel as a Motor Vehicle Fuel in California*).

Recap of Scientific Conclusions to be addressed by Peer Reviewers (Renewable Diesel) –

(1) ARB staff concludes that the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts.
(2) SWRCB staff concludes that there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone.
(3) OEHHA staff concludes that PM, benzene, ethyl benzene, and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel.
(4) DTSC staff concludes that renewable diesel is free of ester compounds and has a low aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel.

Evaluation of MMWG Conclusions –

Despite the fact that the MMWG did not review the literature pertaining to emissions from diesel engines fuelled with pure plant oils (PPO), this reviewer ***supports the ARB and OEHHA conclusions listed above*** (i.e., 1 and 3). However, since the MMWG's evaluation is restricted to hydrotreated vegetable oils, it would be prudent to ***explicitly restrict the concluding statements to this type of renewable diesel***. With respect to the SWRBC and DTSC conclusions, this reviewer's limited analysis of the presented information did not reveal any problems or inconsistencies.

This reviewer also supports the MMWG's recommendations to the California Environmental Policy Council (i.e., "that the use of renewable diesel, as specified in the multimedia evaluations, does not pose a significant adverse impact on public health and the environment"). **However, as noted above, the statements should be restricted to hydrotreated vegetable oils.**

In this reviewer's opinion, a comprehensive evaluation of renewable diesels should include PPOs and/or heated plant oils, in addition to hydrotreated oils. Consequently, to provide a comprehensive evaluation of the MMWG documents, this reviewer collected, reviewed, and evaluated the publicly-available scientific information pertaining to the relative toxicological activity of pure plant oil (PPO) emissions relative to petroleum diesel emissions. This review, which is contained in the *Peer Review of the MMWG Evaluation and Related Documents* provided below, is based on the scientific information summarised in a series of appended tables (i.e., Appendix I). Although the publicly-available information is limited, there is some evidence to support the assertion that PPO-fuelled engines emit more PM; and moreover, that the mutagenic hazards of the particulate emissions are greater than those of conventional diesel.

Peer Review of the MMWG Evaluation and Related Documents

First and foremost, it is important to note that the ***overall quality of the MMWG report on renewable diesel***, as well as the associated Tier I and III reports, are far superior to the analogous biodiesel reports. For the most part, they are well written, clear and comprehensive, and the interpretation is informed and balanced. With respect to the MMWG reports, renewable diesel is defined as hydrotreated vegetable oil (e.g., NExBTL HVO), and the authors have done a thorough job assessing the state of knowledge regarding the toxicological properties of HVO emissions. The MMWG reports document the chemical similarities of HVO and ULSD; noting that the former is chemically distinct from biologically-derived fatty acid esters (i.e., biodiesel). The chemical similarity, particularly between 20% v/v renewable diesel in ULSD and 100% ULSD, suggests that, as asserted by the MMWG, additional studies on the relative toxicological activity of renewable diesel blends, and/or emissions from engines fuelled with renewable diesel blends, are not necessary. This appears to be a sound assertion.

Few studies have examined the relative toxicological activity of emissions from renewable diesel fuelled engines, relative to conventional diesel. Indeed, the publicly-available scientific literature contains only 3 studies that employed cultured mammalian cells (e.g., mouse macrophages) to examine the toxicological activity of emissions from HVO-fuelled engines, relative to conventional diesel emissions. As noted by the MMWG, the Jalava et al (2010 and 2012) studies showed that the magnitude and direction of changes in cytotoxicity and the ability to induce inflammatory signalling (expressed per mg PM) vary according to fuel formulation and exhaust aftertreatment. Nevertheless, despite some indication of enhanced cytotoxicity and inflammatory signalling (Jalava et al, 2012), emissions of HVO-fuelled engines are generally associated, as noted by the MMWG, with reductions in cytotoxicity, genotoxicity and inflammatory signalling in murine cells exposed *in vitro*. A study by Ihalainen et al (2009), which was not reviewed by the MMWG, also showed reductions in inflammatory signalling for HVO emissions, relative to conventional diesel. Finally, the Durbin et al (2011) analyses clearly shows reductions in inflammatory signalling in human cells (i.e., macrophage and Clara cell lines) exposed to organic extracts of HVO DEP (diesel exhaust particulates), relative to extracts of conventional diesel DEP. Observed reductions in the oxidative stress response (as HO-1) were even more pronounced.

A study by Westphal et al (2013), which was also not reviewed by the MMWG, noted that the mutagenic activity of SVOCs and extracts of DEP from HVO emissions are markedly lower (unit not provided) than that observed for conventional diesel.

Despite the fact that the MMWG defines renewable diesel as a fuel from a “non-petroleum renewable resource”, the MMWG reports do not review the admittedly limited scientific literature on emissions from engines fuelled with unaltered or heated pure plant oils. In this reviewer’s opinion, it would be useful (i.e., for the reader) for the MMWG to review the few published studies on emissions from PPO-fuelled engines. Since the external peer review process provides the latitude to include any scientific information that is deemed to be pertinent, this reviewer also examined publicly-available information pertaining to “pure plant oils”. **A detailed summary of the information is presented in a series of appended tables (i.e., Appendix I).**

It is important to note that this reviewer does acknowledge the information presented in the Tier I report (e.g., p. A-19) suggesting that unaltered plant oils are not likely to become popular fuels for compression-ignition engines. As indicated, although pure plant oils can provide reliable short-term performance, long term use can contribute to undesirable engine fouling

Several noteworthy studies, such as those by Bunger et al (2007), Krahl et al (2007) and Krahl et al (2009), examined the mutagenic activity of organic extracts from plant oil DEP (i.e., RSO or heated RSO), and noted that the potency expressed per L of exhaust is greater than that of samples from conventional diesel. Kooter et al (2011) noted similar increases (unit not provided) for PPO-fuelled engine emissions. The Krahl et al studies also noted that combustion of RSO is associated with an increase in PM emission rate (per kWhr). Thus, there is evidence that PPO-fuelled engines emit more PM; and moreover, that the mutagenic hazards of the particulate emissions is greater than that of conventional diesel.

One study examined the ability of organic extracts of DEP from PPO emissions, relative to conventional diesel, to induce oxidative stress and reductions in the viability of mouse macrophages (Kooter et al, 2011). The results indicate that extracts of PPO DEP are less cytotoxic, with no appreciable differences in induction of oxidative stress signalling.

The MMWG reports clearly outline the relative differences in emission rates of criteria air pollutants and air toxics between HVO and conventional diesel. It is quite clear from the Durbin et al (2011) work that R100 (i.e., 100% HVO) is associated with reductions in the emission rates of PM, CO, NOx and HCs, relative to conventional diesel. Additional analyses showed declines in PAH, nitro-PAH and V OC emissions rates; moreover, that PAH and nitro-PAH emission rates declined with increasing blending levels. Importantly, emission rates for toxic aldehydes such as acrolein were not significantly different between HVO and conventional diesel emissions. These results are generally consistent with published information showing reduced PM and PAH emission rates for HVO relative to conventional diesel (Westphal et al, 2013; Ihalainen et al., 2009; Jalava et al, 2010; Jalava et al., 2012). Nevertheless, as noted in the MMWG report, the PAH emission rate from engines equipped with DOC/POC aftertreatment has been shown to be elevated for HVO exhaust, relative to conventional diesel.

Studies of pure plant oils (e.g., Kooter et al, 2011) have also recorded declines in the emission rates of PAHs, oxy-PAHs and nitro-PAHs, relative to conventional diesel.

Miscellaneous Editorial Comments –
Durbin et al (2011), pages 222 and 224: “Marcophage” should be macrophage.

MMWG Evaluation of renewable diesel, p. 13: Third paragraph “was noted” appears twice in same sentence. Firth paragraph – “reactive production” should be relative production. There are many similar editorial issues throughout the documents.

Renewable diesel Tier 1 report, page A-49: Why do the authors cite a presentation by Vogel et al? All the information is presumably presented in the Durbin et al report.

Renewable diesel Tier 1 report, page A-49: Penultimate line – should be μg/mL. Same on p. A-53.

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APPENDIX I: Summary of Published Information Regarding the Relative Toxicological Properties of Renewable Diesel and Petroleum Diesel Emissions.

Table 1. Summary of the published *in vitro* studies in cultured animal cells

Engine	Fuels Examined	Exposure System	Endpoint(s) Examined	Results Obtained	Reference
Kubota 1.123L D1105-T diesel engine (EPA Tier I), ISO C1 cycle, with or without DOC/POC, DEP collected using HVCI.	ULSD, HVO and RME	RAW264.7 mouse macrophage cells exposed to DEP suspension for 24 h	Production and release of proinflammatory cytokine TNF-α.	At 150 µg/mL decreased response for RME, relative to DF. HVO similar to DF. When based on per kW-hr exposures, reduced response for RME, especially with DOC/POC. Small reduction for HVO, relative to DF, without aftertreatment only. PM emission rates reduced for RME and HVO, relative to DF. Aftertreatment reduced PM emissions rates by 50-60%.	[1]
Kubota 1.123L D1105-T diesel engine (EPA Tier I), ISO C1 cycle, with or without DOC/POC, DEP collected using an HVCI with downstream polyurethane foam (PUF) and Teflon®-coated membrane, ultrasonic extraction with methanol.	ULSD, HVO and RME	RAW264.7 mouse macrophage cells exposed to 5–300µg/mL DEP extract and suspension of insoluble material for 24 h	DNA strand breaks by comet assay, proinflammatory cytokine production (Tnf-α, Mip-2), MTT reduction for cytotoxicity, apoptosis by flow cytometric analysis.	All samples yielded a significant concentration-related increase in cytotoxicity and DNA strand breaks. No difference in cytotoxicity across fuels types and aftertreatment. DOC/POC aftertreatment significantly reduced RME response only. ULSD and HVO elicited larger inflammatory response than RME. DOC/POC increased oxidative potential on a per mass basis; aftertreatment reduced PM emission rates by more than 50%.	[2]
2005 Scania 6-cylinder 11.7L Euro 4 engine with EGR, Braunschweig (bus) cycle, with or without DOC/POC (for LSDF and HVO 100 only), DEP collected on Teflon® filter, ultrasonic extraction with methanol.	LSDF, RME (B100 and B30), HVO (B100 and B30)	RAW264.7 mouse macrophage cells exposed to 15–300µg/mL DEP extract and suspension of insoluble material for 24 h	MTT reduction for cytotoxicity, proinflammatory cytokine production (Tnf-α, Mip-2), apoptosis, cell cycle and membrane permeability by flow cytometry. DNA strand breaks by comet assay.	Little differences in cytotoxicity across the fuels and aftertreatment conditions examined. Higher inflammatory response for HVO samples; lowest for RME. Little differences in apoptosis across conditions examined; some indication of higher levels for HVO. DOC/POC greatly reduced PM emission rate and PAH content of PM.	[3]

Engine	Fuels Examined	Exposure System	Endpoint(s) Examined	Results Obtained	Reference
Six cylinder 12L Euro III truck, no DOC, with or without DPF, 13-mode ESC, DEP collected on Teflon®-coated GFFs, ethanol/DCM (1:1) sonication extract	DF, B100, B5, B10, B20, PPO	RAW264.7 mouse macrophage cells exposed to DEP extract for 24 h	Cytotoxicity via LDH release, oxidative stress as *Ho-1* gene expression.	Biodiesel blends and PPO elicited less cytotoxicity relative to DF; B100 significantly more cytotoxic (unit unknown). No differences in *HO-1* expression. Biodiesel associated with reductions in PM (g/kWh), PAHs and oxy-PAHs (μg/kWh).	[4]
2000 Caterpillar C15 six cylinder 14.6L engine, 2007 MBE 4000 six cylinder 12.8L engine with EGR and DOC/DPF combination, chassis dynamometer UDDS and HHDDT, DEP collected on Teflon®-filters, PFE extraction with DCM followed b y DCM/Tol, SVOCs on PUF/XAD cartridges, DCM extraction.	CARB DF, SME and AFME blends, renewable (NExBTL HVO)	Human U937 macrophages and NCI-H441 Clara cell line (exposure details not provided)	Expression of oxidative and inflammatory stress markers (CYP1A1, COX-2, IL-8, HO-1, MUC5AC). Details not provided. DNA damage by comet.	For C15, some evidence of declines in oxidative stress and inflammatory responses (per engine mile) for biodiesels relative to DF. Strong declines in oxidative stress for HVO (R100). For MBE 4000 some evidence for increase in oxidative stress and inflammatory signalling (SME and AFME only). No appreciable changes in DNA damage (all blends). Nevertheless, some indication of declines for HVO and SME relative to DF, reverse for AFME.	[5]

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Table 2. Summary of published *in vitro* analyses of naked DNA exposed to diesel exhaust particulate extract

Test Article	Fuels Examined	Exposure System	Endpoint(s) Examined	Results Obtained	Reference
2003 4.5L Cummins ISBe4 engine and 2007 Zetor Euro 3 engine, ESC, WHSC and NRSC driving cycles. DEP collected with a high-volume sampler, DCM extract.	DF, RME (B100) and RSO	Incubation of Calf thymus DNA with DEP extract for 24 h with and without rat liver S9.	Frequency of stable, bulky DNA adducts by ^{32}P-postlabelling.	Significant concentration-related increases in adduct frequency for all samples; higher responses with S9. Potency per mg PM similar for two engines, and similar across fuel types, diesel higher for WHSC. Similar potency trend per kWh.	[6]

Table 3. Summary of published results of Salmonella mutagenicity analyses of diesel exhaust particulate extracts

Test Article	Fuels Examined	Salmonella Strains[a]/Test Version	Results Obtained	Reference
DEP and exhaust condensate from a Mercedes-Benz Euro 3 6.37L, 6-cylinder engine, 13-mode ESC, Teflon®-coated GFFs, DCM Soxhlet extract of DEP	DF, RSO, RME, GTL	TA98 and TA100, standard plate-incorporation assay, PB/5,6BF-induced rat liver S9	All samples elicited significant positive responses. Potency (per L exhaust) higher without S9 for TA100 only. DEP extracts for RSO and heated RSO fuels yielded the highest potency samples (9.7- to 59 fold greater than DF for TA98 and 5.4- to 22.3-fold for TA100). DEP extracts for RME also significant higher than DF. Condensate samples for RSO and heated RSO also significantly elevated relative to DF (up to 13.5-fold).	7
DEP from 3 diesel engines, 1.686L, 4-cylinder light-duty, 10.8L, 6-cylinder heavy-duty with DPF and SCR, 10.52L, 6-cylinder, heavy-duty with DPF, DEP collected on GFF, DCM Soxhlet extract	DF and plant oils (peanut, rapeseed, soy, sunflower)	TA98, TA100, TA Mix, fluctuation assay (Xenometrics)	All samples in the range of the negative control with no evidence of differences in activity between the fuels.	8
DEP and SVOCs from a Mercedes-Benz, 6.37L, 6-cylinder engine, 13-mode ESC. DEP collected on Teflon®-coated GFFs, DCM Soxhlet extract, and condensates from gas phase collected at 50 °C	DF, RME, GTL, RSO, modified RSO	TA98 and TA100, standard plate-incorporation assay, PB/5,6BF-induced rat liver S9	DEP extract for RSO yielded the highest potency values (9.7- to 17-fold higher than DF on TA98 and 5.4- to 6.4-fold higher than DF on TA100). Modified RSO potency 2.4- to 3.5-fold higher than RSO. RSO condensate samples also yielded the highest potency values (up to 3-fold DF). Modified RSO 3- to 5-fold higher than RSO. Few differences between DEP extracts for DF, RME and GTL, although RME significantly greater than DF on TA98 with S9 and TA100 without S9.	9, 10
DEP from a Mercedes-Benz 6.37L, 6-cylinder and an IVECO 5.9L, 6-cylinder diesel test engine with SCR, 13-mode ESC. DEP collected on Teflon®-coated GFFs, DCM Soxhlet extract.	DF, RME, RSO, SMDS, B5 RME in SMDS, DF/RME/GTL blend.	TA98 and TA100, standard plate-incorporation assay, PB/5,6BF-induced rat liver S9	For the Mercedes engine, no significant difference in potency (per L exhaust gas) between DF, RME, SMDS and DF/RME/GTL blend. RO yielded significantly elevated potency (approximately 10-fold), also highest PM output in g/kWh. For the IVECO engine, SCR significantly reduced mutagenic potency, no difference between DF and RME, after 1000hrs SCR less effective. RME associated with reduced PM emissions (g/kWh).	11, 12

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Table 3. Summary of published results of Salmonella mutagenicity analyses of diesel exhaust particulate extracts

Test Article	Fuels Examined	Salmonella Strains[a]/Test Version	Results Obtained	Reference
DEP from a 12L 6 cylinder Euro III truck, no DOC, with or without DFP, 13-mode ESC, DEP collected on Teflon®-coated GFFs, ethanol/DCM (1:1) sonication extract	DF, B100, B5, B10, B20, PPO (pure plant oil)	TA98 and YG1024, YG1029. Standard plate incorporation version, Aroclor-induced rat liver S9	No significant response in the presence of S9 for any sample. For TA98, significant response for B20 and PPO only. For YG1024, significant responses for B10, B100 and PPO only. Maximum responses on YG1024 for B100 and PPO (per µg PM). Biodiesel associated with reductions in PM (g/kWh), PAHs and oxy-PAHs (µg/kWh).	[4]
DEP and SVOCs from a heavy-duty, 6-cylinder 6.4L Mercedes-Benz OM 906 LA Euro 3-compliant engine, ESC steady state cycle. DEP collected on Teflon®-coated GFFs, DCM Soxhlet extract, SVOC on chilled surface	DF, HVO, RME, JME	TA98, TA100 standard plate incorporation assay, with and without S9 (source not indicated)	Stronger responses for SVOC samples, relative to DEP extracts. SVOC samples and PM extracts for RME and JME elicited similar or greater responses on TA98 (unit not indicated), relative to DF. HVO responses much lower. RME and JME responses on TA100 substantial greater than DF. PM emission rates (g/kWhr) for RME and JME substantially lower than DF. HVO slightly lower. PAH emission rates (ng/test) substantially lower for biodiesels, relative to DF with HVO being the lowest.	[13]
2000 Caterpillar C15 six cylinder 14.6L engine, 2007 MBE 4000 six cylinder 12.8L engine with EGR and DOC/DPF combination, chassis dynamometer UDDS and HHDDT, DEP collected on Teflon®-filters, PFE extraction with DCM followed b y DCM/Tol, SVOCs on PUF/XAD cartridges, DCM extraction.	CARB DF, SME and AFME blends, renewable (NExBTL HVO).	TA98, TA100, microsuspension preincubation version, rat liver S9	C15 engine DEP extracts, for both TA98 and TA100, general decline in potency (per engine mile) with increasing concentrations of biodiesel. For SVOCs, appreciable decline for HVO only. For MBE4000 samples, appreciable decline in potency for SME blends only.	[5]

[a]YG1021 – TA98 with plasmid pYG216, nitroreductase overproducing strain. YG1024 – TA98 with plasmid pYG219, *O*-acetyltransferase overproducing strain. YG1041 – TA98 with plasmid pYG233, nitroreductase and *O*-acetyl transferase overproducing strain. YG1026 – TA100 with plasmid pYG216, nitroreductase overproducing strain. YG1029 – TA100 with plasmid pYG219, *O*-acetyl transferase overproducing strain. YG1042 – TA100 with plasmid pYG233, nitroreductase and *O*-acetyl transferase overproducing strain.

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11. Krahl J, Munack A, Grope N, Ruschel Y, Schroder O, Bunger J. Biodiesel, rapeseed oil, gas-to-liquid, and a premium diesel fuel in heavy duty diesel engines: endurance, emissions and health effects. (Special Issue: Celebrating the 60th birthday of Professor Mufit Bahadir.). *CLEAN - Soil, Air, Water* 2007;35:417-26.

12. Krahl J, Munack A, Ruschel Y, Schroder O, Schwarz S, Hofmann L, et al. Influence of the Phosphorus Content in Rapeseed Oil Methyl Esters During a 1000 Hours Endurance Test on the Function of a SCR-system Measured by Exhaust Gas Emissions and Health Effects. Warrendale, PA: SAE International; 2006. Report No.: SAE Technical Paper Series 2006-01-3282.

13. Westphal GA, Krahl J, Munack A, Rosenkranz N, Schroder O, Schaak J, et al. Combustion of hydrotreated vegetable oil and jatropha methyl ester in a heavy duty engine: Emissions and bacterial mutagenicity. *Environmental Science and Technology* 2013;47:6038-46.

Review of
Staff Report: Multimedia Evaluation of Renewable Diesel

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January 7, 2014

The staff report, prepared by the Multimedia Working Group (MMWG), provides an overall assessment of potential adverse impacts on public health and the environment that may result from the production, use, and disposal of renewable diesel, which is produced from non-petroleum resources and is not a mono-alkyl ester. Renewable diesel consists of hydrocarbons and meets ARB motor vehicle fuel specifications of California. The report concludes that the use of renewable diesel fuel in California does not pose a significant adverse impact on public health or the environment relative to California Air Resources Board (CARB) diesel. The conclusion was made largely based on the results of the "California Renewable Diesel Multimedia Evaluation Final Tier III Report" from the researchers at University of California. As requested, this reviewer provides the following assessment and determination of whether each of the conclusions that constitute the basis of the staff report is based on sound scientific knowledge, methods, and practices, and if additional issues need to be addressed.

Overall Comments on the reports

The Staff Report is based on a cascade of studies conducted by University of California (UC) researchers. The PIs are known scientists in the field. The evaluation procedure, as outlined in their final Tier III report, is sequential and logic. Literature cited in their reports is quite complete and up to date. Experiments were well designed and conducted. Data were carefully collected and analyzed. Therefore, this reviewer would conclude that the UC final Tier III report and the Staff Report are based on sound scientific knowledge, methods, and practices. And consequently, the conclusions of the Staff Report are acceptable.

Comments on specific conclusion statements

1. Air Emissions Evaluation. Air Resources Board (ARB) staff concludes that the use of renewable diesel does not pose a significant adverse impact on public health or the environment from potential air quality impacts.

Based on engine and vehicle emissions testing on multiple blends of renewable diesel compared to the baseline CARB diesel fuel, the report concludes that for use of renewable diesel would reduce emissions of most criteria pollutants, ozone precursors, toxic pollutants, and greenhouse gases (including PM, NOx, CO, and THC in diesel exhaust), and therefore does not pose a significant adverse impact on public health or the environment. This reviewer in general agrees with the findings of the evaluation studies that focused on the use of renewable diesel. If renewable diesel is going to be produced in state, additional studies are encouraged to evaluate the impact on air quality from collection, storage, and transport of large amount of biological feedstock for renewable diesel production.

2. Water Evaluation. State Water Resources Control Board (SWRCB) staff concludes that there are minimal additional risks to beneficial uses of California waters posed by renewable diesel than that posed by CARB diesel alone.

Water evaluation focused on aquatic toxicity and risks associated with fuel production, transport, storage, and disposal. Renewable diesel is refined in a similar way as for petroleum diesel with almost an identical chemical composition, and uses the same additives. Based on studies conducted by UC researchers, the report concluded that the use of renewable diesel in California poses minimal adverse impact on public health and the environment. Similar to the air emissions evaluation, the study does not include the effect of growing, collection, storage, and transportation of large amount of biological feedstock, if some of the renewable diesel is produced in the State of California using local resources.

3. Public Health Evaluation. Office of Environmental Health Hazard Assessment (OEHHA) staff concludes that PM, benzene, ethyl benzene, and toluene in combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel.

Impact of renewable diesel on public health was assessed by comparing the combustion emissions from diesel engines using hydrotreated vegetable oil renewable diesel against that with petroleum based diesel fuel. Data show that there is a significant reduction in PM, benzene, ethyl benzene, and toluene using the tested renewable diesel. Tests on emissions toxicity also indicated that there is no significant difference between the tested renewable diesel and CARB diesel. Conclusions made by the OEHHA staff are acceptable based on the limited studies. Again, the report did not address the impact of growing, storage, and transportation of large amount of biological feedstock for local production of renewable diesel.

4. Soil and Hazardous Waste Evaluation. Department of Toxic Substances Control (DTSC) staff concludes that renewable diesel is free of ester compounds and has low aromatic content. The chemical compositions of renewable diesel are almost identical to that of CARB diesel. Therefore, the impacts on human health and the environment in case of a spill to soil, groundwater, and surface waters would be expected to be similar to those of CARB diesel.

Because the chemical composition of renewable diesel is similar to that of CARB diesel and renewable diesel has a lower content of aromatic hydrocarbons than CARB diesel, I agree with the DTSC staff on that the impacts on soil, surface water and groundwater of renewable diesel are similar to or less severe than that of CARB diesel. As pointed out by the DTSC Staff Report, the chemical composition and additives may vary with different feedstock and production processes. Large amount of biological feedstock also needs to be transported, stored, and processed should certain renewable diesel be produced locally. Therefore, additional studies may be needed in the future for regulatory purposes.

APPENDIX J

Multimedia Working Group
Response to Peer Review Comments

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Multimedia Working Group Response
to Peer Review Comments

The Multimedia Working Group (MMWG) appreciates the thorough written reviews submitted by the peer reviewers. The reviews and comments by the peer review panel have prompted the MMWG to further clarify and improve the "*Staff Report: Multimedia Evaluation of Renewable Diesel"* (Renewable Diesel Staff Report) in preparation for the MMWG's final submittal to the California Environmental Policy Council (CEPC).

In this appendix, each reviewer's comments are organized by topic and reproduced as submitted. The MMWG's corresponding response follows each comment. The MMWG includes staff from the Air Resources Control Board (ARB), Office of Environmental Health and Hazard Assessment (OEHHA), State Water Resources Control Board (SWRCB), and Department of Toxic Substances Control (DTSC). Based on the topic, the appropriate agency staff within the MMWG prepared a detailed response to each comment. The following format is used to present the reviewer's comments and the MWMG's responses:

<u>Topic</u> [***Comment Number.***] **Comment:** [*Reviewer's Comment.*] (*Reviewer's last name, page number*) **Response:** [*MMWG Agency's Response.*] (*Agency*)

Similar comments with the same response are grouped together. Also, the citations included in the MMWG's responses are referenced as footnotes at the bottom of the page. Where applicable, the information provided in the responses has been incorporated in the Renewable Diesel Staff Report.

Comments and Responses

<u>Air Quality</u>

A-1. **Comment:** Section A1. (p. 6) is labeled "Criteria Pollutants." This section should begin with a discussion of what pollutants fall into this category, and which are evaluated here for renewable diesel. As written, Section A1 includes PM, nitrogen oxides ($NOx = NO + NO_2$), total hydrocarbons (THC), carbon monoxide (CO) and brake specific fuel consumption (BSFC). However, THC and BSFC are not criteria pollutants and do not belong in this section. SO_2 is a criteria pollutant that is not discussed here, but is referenced in the "Renewable Diesel Background Information" on p. 4. Section A1 should report should comment on all criteria pollutant emissions (or precursor emissions) in some way, and omit discussion of metrics that are not criteria pollutants. (Holloway, pg 2)

Response: Sections 1 through 4 of Part A (ARB Evaluation) of the Renewable Diesel Staff Report were revised to further clarify the content of the report and minimize redundancy. As suggested by the reviewer during the second peer review of biodiesel, Part A may be revised to clarify two separate goals of air emission controls: health protection and climate change mitigation. Please refer to Appendix L of the "*Staff Report: Multimedia Evaluation of Biodiesel"* (Biodiesel Staff Report) for the commenter's specific recommendations and the MMWG response and corresponding revisions to the Biodiesel Staff Report.

The Renewable Diesel Staff Report was revised accordingly. The title of Section 1 was revised from "Criteria Pollutants" to "Health-Relevant Air Emissions." The content of previous Section 2 ("Toxic Air Contaminants") was added to Section 1 and the paragraphs on carbon dioxide (CO_2) emissions and fuel consumption were moved to Section 3 ("Greenhouse Gas Emissions"). Accordingly, previous Section 2 ("Toxic Air Contaminants") was deleted because the entire content of that section was moved to revised Section 1 ("Health-Relevant Air Emissions).

Previous Section 3 ("Greenhouse Gas Emissions") was then renumbered to Section 2 and the title was revised to "Climate-Relevant Air Emissions." These revisions clarify the difference between health-relevant emissions provided in Section 1 and climate-relevant emissions described in revised Section 2.

Previous Section 4 ("Ozone Precursors") was renumbered to Section 3 and the title was revised to "Secondary Air Pollutants." Section 3 (previously Section 4) was also revised to include more general information about secondary air pollutants and identifies ozone as an example. (ARB)

A-2. **Comment:** Section A3 (p. 7) discusses "Ozone Precursors." Because ozone is a criteria pollutant, this section would seem to be a better fit with Section 1 and/or follow directly afterward. For the benefit of readers unfamiliar with ozone chemistry, some brief comment should be added explaining that THC and NOx emissions create ambient ozone. (Holloway, pg 2)

Response: The overall organization of Part A of the Renewable Diesel Staff Report was revised to distinguish health-relevant emissions from climate-relevant emissions. Previous Section 4 ("Ozone Precursors") was renumbered to Section 3 and retitled to "Secondary Air Pollutants." Section 3 (previously Section 4) was also revised to include more general information about secondary air pollutants and identifies ozone as an example.

Please also see response to comment A-1. (ARB)

A-3. **Comment:** Section A4 (p. 7) reports on Greenhouse Gas Emissions. This section would benefit from a number of changes. First, clarifying which greenhouse gas emissions have been evaluated – it appears only CO_2. It would also benefit from more detail on what steps in the lifecycle were considered. In particular, it would be helpful to note that the 80% reduction in GHG emissions would arise from tallow feedstock use, whereas the 15% reduction in GHG emissions would arise from soybean production in the Midwestern U.S. Detail on this point is provided in Appendix C, but a brief comment in the main report would improve clarity. (Holloway, pg 2)

Response: Previous Section 3 ("Greenhouse Gas Emissions") was renumbered to Section 2 and retitled to "Climate-Relevant Air Emissions." This revision distinguishes health-relevant emissions in Section 1 from climate-relevant emissions in revised Section 2.

Revised Section 2 (previously Section 3) was also revised to include more general information about GHG emissions and includes CO_2 as one of the GHGs tested under the ARB Emissions Study.

Please also see response to comment A-1. (ARB)

A-4. **Comment:** Page 7, section 4 Greenhouse Gas Emissions, line 1: Please check if the word "decreased" should be "increased." The word "decreased" appears to conflict with the statement in page 6, last sentence. (Li, pg 3)

Comment: Page 6 *(Staff Report)*. Here and elsewhere, the report states that the renewable diesel emits less PM, NOx, THC, and CO, but that the BSFC is lower. It is important to explain to the reader that the emissions of criteria pollutants are expressed as a g per hour or g per distance, such that differences in fuel consumption are already factored in. (Rodenburg, pg 2)

Response: The original statement on page 7 was incorrect. The sentence in revised Section 2 (Climate-Relevant Air Emissions") was corrected from "decreased" to "increased" BSFC. The statement is now consistent with page 6 of the staff report and the source data provided in the ARB Emissions Study. (ARB)

A-5. **Comment:** In the main discussion of renewable diesel lifecycle assessment in Appendix C (p. 12), more detail would also be useful. Table 8 presents two of the four scenarios based on tallow, which is assumed to have no indirect carbon intensity. Some comment should be included on the source of the tallow, and whether it is assumed to be a waste product. (Holloway, pg 2)

Response: Appendix C was revised with more information on tallow and the two pathways presented in Table 8. The following two pathways were modeled for renewable diesel produced from tallow:

- Conversion of tallow to renewable diesel using higher energy use for rendering
- Conversion of tallow to renewable diesel using lower energy use for rendering

There two pathways were modeled because traditional plants need higher energy use but newer plants need lower energy use for the rendering of tallow. Complete details on the the pathways are provided in the *Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U.S. Sourced)*.[1]

Tallow is animal fat derived from waste at a meat processing plant. Rendering produces two types of tallow: edible and inedible tallow. Edible tallow is used by the food industry and most of the inedible tallow is currently used as a supplement in animal feed. New regulations under development by the Food and Drug Administration are likely to ban the use of tallow and other animal based waste products in animal feed (due to bovine spongiform encephalopathy and other similar diseases) and it is likely that use of inedible tallow as feed supplements will diminish in the future. Edible tallow that is generated from the rendering process is not considered a feedstock from renewable diesel production. Only inedible tallow is considered in the LCFS pathway analyses.

The transformation of tallow to renewable diesel includes transport of tallow produced in the Mid-Western United States to a California refinery via rail. The tallow is then co-processed with traditional crude in a refinery to produce renewable diesel.[2] (ARB)

<u>Public Health</u>

B-1. Comment: (*Renewable Diesel Staff Report*)
There are several duplications of text: P12, 2nd para is the same text as P13, 4th para (an analyses of Jalava et al. (2012)). P12, 3rd para has much of the same text as P13, 5th para but with the opposite interpretation of the Comet assay results with respect to HVORD fueled engine particulate matter vs. EN590 fueled engine particulate matter in the absence of a DOC/POC. The data in Jalava et al, (2012) clearly show DNA damage in mouse macrophase RAW264.7 cells treated in vitro with HVORD fueled engine particulate matter was decreased compared to cells treated with EN590-fueled engine particulate matter in the absence of a DOC/POC. (Nesnow, pg 5)

Response: The footnote for the statements referenced in the comment (previous footnote 24) incorrectly references the Jalava et al. (2012) research article. The correct reference is the Jalava et al. (2010) article in previous footnote 26. The staff report was revised with the correct reference and additional clarifying details.

[1] Air Resources Board. Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U.S. Sourced). September 23, 2009, Version 2.0.
[2] Air Resources Board. Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U.S. Sourced). September 23, 2009. Version 2.0, 2-3.

Based on the Jalava et al. (2012) study, DNA damage (Comet assay) in mouse macrophage RAW264.7 cells treated *in vitro* with HVORD-fueled engine PM was statistically significantly increased compared to cells treated with EN590-fueled engine PM in the absence of a diesel oxidation catalyst (DOC)/particulate oxidation catalyst (POC) catalytic converter. However, the Heikkila et al. (2012) study showed opposite results than the Jalava et al. (2012) study. DNA damage in mouse macrophage RAW264.7 cells treated *in vitro* with HVORD-fueled engine PM was decreased compared to cells treated with EN590-fueled engine PM in the absence of a DOC/POC catalytic converter. (OEHHA)

B-2. **Comment:** Conclusions that health-relevant air emissions are reduced with renewable diesel are well supported. Conclusions about emissions toxicity are uncertain due to limited testing. This result is consistent with the Tier III report, but should be stated more clearly. (Holloway, pg 2)

Comment: The basis for the conclusion that benzene, ethylbenzene and toluene in combustion emission from diesel engines using hydrotreated vegetable oil renewable diesel are significantly lower than combustion emissions using CARB diesel is based on a single study using a single engine, albeit using multiple blends and several test cycle protocols. (Nesnow, pg 5)

Comment: It is noted that the levels of the constituents cited above have not been determined for the many different combinations of engine types (heavy and light duty) technology (old, new, catalyst type, test cycle and load), feed stock sources (plant and animal based) and mixture blends therefore, some caution needs to be exercised in accepting these conclusions without further data on the most prevalent combinations. Decisions on the impact of the toxicity of emissions from the multitude of combinations should be revisited after more data is available. (Nesnow, pg 5)

Response: The staff report was revised with an updated summary report. The conclusions of OEHHA in the Renewable Diesel Staff Report provided to peer reviewers were based on review of the ARB Emissions Study and on review of scientific journal articles on physical and chemical properties and toxic effects of emissions from HVORD-fueled engines. OEHHA staff prepared a summary of information reviewed, but the summary was in draft at the time the initial staff report was sent to peer reviewers. The summary of material reviewed has been completed and is now included as Appendix E. The studies reviewed by OEHHA compared HVORD to conventional diesel, and the conclusions in the OEHHA summary state that they are limited to renewable diesel produced by hydrotreating fatty acids derived from plant sources. (OEHHA)

<u>Water Quality</u>

C-1. **Comment:** Main Staff Report, pages 7-8, section II-B: Compared with other sections in chapter II, the summary for water quality impact is very brief. It reads more like conclusions rather than a summary, and may not be sufficient for CEPC review. I suggest adding sufficient information to allow an understanding on the assessment methods and the results, with references. Take part 1 Water Impacts as an example, where and when was the aquatic toxicity test conducted? What type(s) of aquatic toxicity was tested with what test species and what method? Was the test on R100 or any blends? Do the data show higher or lower toxicity compared with CARB diesel?… For all 4 parts of this summary, references of the data sources and major scientific knowledge should be cited. The data source information is needed here because, based on my understanding from reading Tier III report page 12 paragraph 1,Tier II experiments were not conducted for toxicity and fate and transport. (Li, pg 2)

Response: State Water Board staff agrees that the report could be improved by implementing the suggested editorial changes. (SWRCB)

C-2. Comment: Page 15, section III-B: This paragraph may be improved by including more specific information, which could come from page 8. The last several words need to be changed from "public health or the environment" to "the quality of surface water and groundwater in California". (Li, pg 3)

Response: State Water Board staff agrees that the report could be improved by implementing the suggested editorial changes. (SWRCB)

C-3. Comment: The Staff Report on Multimedia Evaluation of Biodiesel indicates that there are material compatibility issues between biodiesel and CARB diesel. There is limited discussion about material compatibility with renewable diesel on page A-41 of Appendix G because of limited data. As stated on page A-52, the chemical composition of renewable diesel is similar to that of CARB diesel. It should then follow that few material incompatibilities are expected for renewable diesel in comparison to CARB diesel. A few sentences to strengthen the discussion of compatible materials will be helpful. (Bouwer, pg 2)

Response: The staff report and Appendix C were revised with additional information to further clarify that renewable diesel is chemically indistinguishable from conventional diesel fuel. Renewable diesel consists solely of hydrocarbons and is simply diesel made from renewable diesel feedstock.[3] Renewable diesel also meets the definition of "diesel fuel" in the California diesel fuel regulations (13 CCR 2281(b)(1))[4] and the ASTM International standard specification for diesel fuel oils (ASTM D975-12a).[5] Therefore, renewable diesel is compatible with current diesel distribution infrastructure and does not require new or modified pipelines, storage tanks, trucking infrastructure, or retail station pumps. (ARB)

[3] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011.
[4] California Code of Regulations. Title 13, Division 3, Chapter 5, Article 2. Standards for Diesel Fuel. Section 2281(b)(1).
[5] ASTM International. *Standard Specification for Diesel Fuel Oils,* D975-12a, 2012.

Multimedia Evaluation

D-1. Comment: (*Air Emissions Evaluation*). This reviewer in general agrees with the findings of the evaluation studies that focused on the use of renewable diesel. If renewable diesel is going to be produced in state, additional studies are encouraged to evaluate the impact on air quality from collection, storage, and transport of large amount of biological feedstock for renewable diesel production. (Yang, pg. 2)

Comment: (*Water Evaluation*). Based on studies conducted by UC researchers, the report concluded that the use of renewable diesel in California poses minimal adverse impact on the public health and the environment. Similar to the air emissions evaluation, the study does not include the effect of growing, collection, storage, and transportation of large amount of biological feedstock, if some of the renewable diesel is produced in the State of California using local resources. (Yang, pg. 2)

Comment: (*Public Health Evaluation*). Again, the report did not address the impact of growing, storage, and transportation of large amount of biological feedstock for local production of renewable diesel. (Yang, pg. 2)

Comment: (*Soil and Hazardous Waste Evaluation*). As pointed out by the DTSC Staff Report, the chemical composition and additives may vary with different feedstock and production processes. Large amount of biological feedstock also needs to be transported, stored, and processed should certain renewable diesel be produced locally. Therefore, additional studies may be needed in the future for regulatory purposes. (Yang, pg. 3)

Response: Each agency's evaluation and conclusions are based primarily on the results of the multimedia evaluation and information provided in the "*California Renewable Diesel Multimedia Evaluation Tier I Final* Report" (Tier I Report)[6] and "*California Renewable Diesel Multimedia Evaluation Tier III Final* Report" (Tier III Report)[7] by the University of California (UC), Berkeley and UC Davis.

The purpose of the multimedia evaluation is to provide the information needed for the development of fuel regulations and to inform the overall rulemaking process. Under Health and Safety Code (HSC) section 43830.8(b), a multimedia evaluation is defined as "the identification and evaluation of any significant adverse impact on public health or the environment, including air, water, and soil, that may result from the production, use, or disposal of the motor vehicle fuel that may be used to meet the state board's motor vehicle fuel specifications." [8]

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[6] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011.
[7] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier III Report*, Apr 2012.
[8] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(b).

Therefore, the primary focus of a multimedia evaluation is the direct health and environmental impacts from renewable diesel fuel. As mentioned in the Tier I Report, other indirect and lifecycle considerations may be of interest, including land use and the production and use of raw feedstocks. These are outside the scope of this evaluation but are addressed under the LCFS program.[9]

The LCFS lifecycle analysis includes the direct emissions associated with producing, transporting and using the fuel, as well as indirect effects such as land use change. For more information on the full fuel lifecycle analysis of renewable diesel fuels produced from various feedstocks, please refer to the detailed fuel pathway documents posted on the LCFS Fuel Pathways Documents webpage.[10]

For renewable diesel, soybeans are expected to be the main feedstock in California. Oil is extracted from soy by crushing the beans and applying n-hexane as a solvent. Soy-based renewable diesel is sufficiently similar in physical-chemical properties to CARB diesel that it can be readily used in a range of blending applications.[11] Complete details on the full lifecycle analysis of soybean derived renewable diesel are provided in the *Detailed California-Modified GREET Pathway for Conversion of Midwest Soybeans to Renewable Diesel*.[12] The analysis documented here includes soybean farming, soybean transport, soyoil extraction in the Midwest, renewable diesel production, transportation, distribution, and use of renewable diesel in an internal combustion engine. (ARB)

D-2. **Comment:** Page A-30 top of page. (*Tier 1 Final Report*) Establishment of dedicated facilities for renewable diesel production will be problematic in terms of land use. This should be factored into the LCA if it becomes clear that these new facilities will, in fact, be required. (Rodenburg, pg 3)

Response: A multimedia evaluation focuses primarily on direct environmental and public health impacts in the State.[13] Land use change and other indirect and lifecycle impacts are not within the scope of this multimedia evaluation but were assessed under the LCFS program. For more information on the full fuel lifecycle analysis of specific renewable diesel fuels in the State, please refer to the detailed fuel pathway documents provided on the LCFS Fuel Pathways Documents webpage.[14]

Please also see response to comment D-1. (ARB)

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[9] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011. A-22, A-17, A-7.

[10] Air Resources Board Low Carbon Fuel Standard Fuel Pathways Documents webpage: http://www.arb.ca.gov/fuels/lcfs/workgroups/workgroups.htm#pathways.

[11] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011. A-9.

[12] Air Resources Board. Detailed California-Modified GREET Pathway for Conversion of Midwest Soybeans to Renewable Diesel. December 14, 2009, Version 3.0.

[13] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(b).

[14] Air Resources Board Low Carbon Fuel Standard Fuel Pathways Documents webpage: http://www.arb.ca.gov/fuels/lcfs/workgroups/workgroups.htm#pathways.

D-3. Comment: In the near future, the major feedstock could be soybeans grown in the US Midwest, as mentioned in Tier III report, page 7. Various adverse impacts on the ecosystem in the Midwest states have already been reported. Although a complete evaluation of the impact outside California is beyond this work, a summary of available information on the impacts of the upstream processes (feedstock production, extraction, blending, etc.) on the environment and human health will be helpful and could have been included. (Li pg 2)

Response: A multimedia evaluation focuses primarily on potential environmental and public health impacts in the State.[15] Therefore, out-of-State considerations and potential impacts were assessed but not thoroughly addressed as part of this evaluation.

Nonetheless, the UC Tier I and III reports provide important information on upstream processes (production, storage, and distribution) for renewable diesel throughout the life of the fuel, including potential impacts and other important considerations outside of California.[16,17] As previously stated, further details on specific renewable diesel fuels and pathways under the LCFS are available on the LCFS Fuel Pathways Documents webpage.[18]

Please also see response to comment D-1. (ARB)

D-4. Comment: The assessment of the supply and demand is not within the scope of this multimedia assessment. According to Hill et al. (2006), even dedicating all U.S. corn and soybean production to biofuels would meet only 12% of the gasoline and 6% of diesel demands in the country. Even with R20 or lower blends, whether all the available resources would meet the demand is unclear. (Li, pg 2)

Response: A multimedia evaluation focuses primarily on potential environmental and public health impacts in the State.[19] Therefore, the supply and demand of renewable diesel fuel, including specific feedstocks, is not within the scope of this evaluation.

However, as part of the rulemaking process, an economic impact assessment is required pursuant to Government Code section 11346.3(b).[20] In general, the Administrative Procedure Act (APA) establishes rulemaking procedures and standards for state agencies in California. The APA is found in the California Government Code section 11340 et seq. State regulations must also be adopted in compliance with

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[15] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(b).
[16] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier III Report*, Apr 2012.
[17] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011.
[18] Low Carbon Fuel Standard Fuel Pathways Documents webpage: http://www.arb.ca.gov/fuels/lcfs/workgroups/workgroups.htm#pathways.
[19] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(b).
[20] California Government Code. Article 5, Section 11346.3(b).

regulations adopted by the Office of Administrative Law in the California Code of Regulations sections 1 – 280.[21,22]

Therefore, although these other topic areas are not within the scope of the multimedia evaluation, a detailed economic assessment is conducted as part of the rulemaking process for the proposed ADF regulation. (ARB)

D-5. Comment: Page 1, section A: There are three bulleted lines for air, water and wastes, respectively. It is not clear why public health is not included here. Risk assessment on the public health focuses on human, in contrast to those on environmental media. The same can be said for the bulleted lines in Page 2, section 2. (Li, pg 3)

Response: In addition to environment impacts, public health impacts were also included as part of the multimedia evaluation of renewable diesel. The three areas specifically listed in the staff report are the same as those listed in Health and Safety Code (HSC) section 43830.8(c). This section requires that, at minimum, the evaluation must address impacts associated with:

- Emissions of air pollutants;
- Contamination of surface, groundwater, and soil;
- Disposal or use of byproducts and waste materials from the productions of the fuel. [23]

However, public health impacts were also included as part of the evaluation. Under HSC section 43830.8(b), a multimedia evaluation is defined as “the identification and evaluation of any significant adverse impact on public health or the environment, including air, water, and soil, that may result from the production, use, or disposal of the motor vehicle fuel that may be used to meet the state board’s motor vehicle fuel specifications.” [24] Therefore, a multimedia evaluation must include an evaluation of both public health and environmental impacts. (ARB)

D-6. Comment: Despite the fact that the MMWG did not review the literature pertaining to emissions from diesel engines fuelled with pure plant oils (PPO), this reviewer supports the ARB and OEHHA conclusions listed above (i.e., 1 and 3). However, since the MMWG’s evaluation is restricted to hydrotreated vegetable oils, it would be prudent to explicitly restrict the concluding statements to this type of renewable diesel. (White, pg. 1)

[21] California Code of Regulations. Title 1, Sections 1 – 280.
[22] Office of Administrative Law. Administrative Procedure Act and APA Regulations webpage: http://www.oal.ca.gov/Administrative_Procedure_Act.htm.
[23] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(c).
[24] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 43830.8(b).

Comment: In this reviewer's opinion, a comprehensive evaluation of renewable diesels should include pure plant oils (PPOs) and/or heated plant oil, in addition to hydrotreated oils. Consequently, to provide a comprehensive evaluation of the MMWG documents, this reviewer collected, reviewed, and evaluated the publicly-available scientific information pertaining to the relative toxicological activity of pure plant oil emissions relative to petroleum diesel emissions. This review, which is contained in the Peer Review of the MMWG Evaluation and Related Documents provided below, is based on the scientific information summarised in a series of appended tables (i.e., Appendix I). Although the publicly-available information is limited, there is some evidence to support the assertion that PPO-fuelled engines emit more PM; and moreover, that the mutagenic hazards of the particulate emissions are greater than those of conventional diesel. (White, pg 1-2)

Response: The staff report was revised to clarify that the multimedia evaluation covered hydrotreated renewable diesel and, therefore, the conclusions of the evaluation are limited to hydrotreated renewable diesel fuel only. (ARB)

Please also see OEHHA response to comment B-3. (OEHHA)

D-7. **Comment:** Water Evaluation. The chemical properties and composition of renewable diesel without additives are similar to that of petroleum diesel (CARB diesel), so I agree with the conclusion that there are likely to be minimal additional risks to the waters of California from the use of renewable diesel. A general tendency is that liquid products from biomass are highly biodegradable under the proper conditions. For example, most liquid petroleum hydrocarbons (e.g., gasoline, diesel, jet fuel, and oils) can be biodegraded under aerobic conditions by many different species of bacteria. Several of these species of bacteria capable of petroleum hydrocarbon biodegradation are commonly found in rivers, lakes, and oceans and in the subsurface. Consequently, these liquid products tend not to persist for long periods when they are released into the environment. The biodegradability of renewable diesel and CARB diesel will be similar, so there is not an expected increase in risk from the use of renewable diesel in comparison to CARB diesel when they come in contact with surface waters or groundwaters.

The one factor that "clouds" the above conclusion is that additives are likely to be introduced in almost all renewable diesel blends. These additives address issues of oxidation, corrosion, foaming, cold temperature flow properties, biodegradation during storage, and water separation. As long as the expectation holds that renewable diesel will employ additives similar to those used currently in CARB diesel, then it follows that the health and environmental impacts of the two mixtures will be similar. If different additives are employed that might make the renewable diesel mixture either more toxic or less biodegradable, then additional studies will need to be conducted to demonstrate the environmental health and safety of the renewable diesel mixture planned for use. (Bouwer, pg 1)

Comment: Soil and Hazardous Waste Evaluation. Essentially, the same analysis provided for the Water Evaluation above applies for this topic. The similar chemical properties and composition for renewable diesel and CARB diesel means that the transport and fate of the two products should be similar if they are released to the subsurface. Consequently, there is not likely to be an increased risk to the environment with the use of renewable diesel. The limited knowledge regarding the additives that will be used for renewable diesel does add uncertainty to this conclusion. If such additives are different from the ones used for CARB diesel, then there is potential for the renewable diesel mixture to behave differently in the environment, such as increased toxicity or reduced biodegradability. If different additives are used for renewable diesel, then additional studies are recommended to properly document the new transport and fate properties. (Bouwer, pg 2)

Comment: As acknowledged thoroughly in the report, the presence of additives in the renewable diesel is a source of uncertainty for the chemical and physical properties of the renewable diesel (e.g., page A-54 in Appendix G). It would be helpful to provide some documentation on whether or not existing stocks of renewable diesel are likely to contain the same additives used in CARB Diesel. The database might be limited, but any evidence to support a statement about identical or similar additives will be helpful to support a conclusion that renewable diesel is just as acceptable as CARB diesel. (Bouwer, pg 3)

Comment: However, the impact of additives is not considered, which constitutes a major concern. Some conclusions, particularly those concerning water quality and toxicity, were made based only on the similarities in fuel properties and chemical compositions between the renewable diesel and CARB diesel, without conducting any laboratory experiments or model simulations. (Li, pg 2)

Response: It is SWRCB staff's understanding that renewable diesel will employ the same additives currently used in CARB diesel. SWRCB staff recommends that the ARB identify those additives and clearly state that additives used other than those identified are be evaluated separately by the MMWG. (SWRCB)

Renewable diesel consists solely of hydrocarbons and is simply diesel made from renewable diesel feedstock.[25] Renewable diesel is chemically indistinguishable from conventional diesel and meets the definition of "diesel fuel" in the California diesel fuel regulations (13 CCR 2281(b)(1))[26] and the ASTM International standard specification for

[25] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011.
[26] California Code of Regulations. Title 13, Division 3, Chapter 5, Article 2. Standards for Diesel Fuel. Section 2281(b)(1).

diesel fuel oils (ASTM D975-12a).[27] Therefore, additives typically used in renewable diesel are expected to be the same or similar to those used in CARB diesel. (ARB)

D-8. Comment: No comparison between renewable diesel and biodiesel was made. The advantages of each over the other are quantitatively or qualitatively mentioned. According to UOP (2005), renewable diesel has a lower environmental impact than biodiesel and requires less capital investment to produce. This is in agreement with what I learned from reading the documents provided. However, I failed to find answers to the questions whether biodiesel is indeed needed and why biodiesel is being proposed as the first alternative diesel fuel in California, given the apparent advantages of the renewable diesel. (Li, pg 2)

Response: Each fuel undergoing a multimedia evaluation is compared to the fuel it is displacing. Therefore, the baseline or reference fuel for renewable diesel is CARB diesel. In general, a comparative analysis between a specific fuel and another fuel undergoing a multimedia evaluation is not within the scope of the evaluation. Furthermore, a comparison of the benefits of one fuel over another is not within the scope of the evaluation.

The staff report was not revised in response to this comment but the following background information is provided for further clarification on renewable diesel and biodiesel within the proposed ADF regulation.

Consumption of ADFs, such as biodiesel and renewable diesel, is expected to increase due to a variety of policy incentives including the RFS, LCFS, and federal blending tax credits. Thus, it is important to ensure that the full commercialization of these fuels do not increase air pollution or cause other environmental concerns. The proposed ADF regulation will ensure this by subjecting new fuels to a rigorous environmental review, including a complete multimedia evaluation. [28]

In general, the proposed ADF regulation will establish a standard three-stage process for the commercialization of new ADFs and also set mitigation measures, as needed. Although this will be a new regulation, many provisions in this regulation are already required under existing State law and would consolidate current administrative and regulatory practices to provide a clear pathway to commercialization of ADFs.[29]

Since the regulation was based primarily on staff's experience with analyzing biodiesel over the past several years, the first ADF under the proposed ADF regulation is biodiesel. While renewable diesel is also an innovative diesel fuel replacement, it consists solely of hydrocarbons and is virtually indistinguishable from conventional

[27] ASTM International. *Standard Specification for Diesel Fuel Oils,* D975-12a, 2012.
[28] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*. October 23, 2013, ES-1, ES-4.
[29] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*. October 23, 2013, ES-1.

diesel fuel. Therefore, renewable diesel is not considered an ADF under the proposed regulation.[30]

D-9. Comment: I suggest summarizing the limitations of this multimedia evaluation in the main staff report, section I-C. Some limitations are well described in the Tiers Reports, but are absent in the staff report. The limitations are different from the conditions in section IV Recommendations part 2 (page 17). (Li, pg 2)

Response: The purpose of the staff report is to provide a summary of the renewable diesel multimedia evaluation (i.e., the UC Tier I and III reports) and based on the evaluation provide the MMWG's overall conclusions and recommendations to the CEPC. The details of the evaluation, including the sources and specific limitations of the evaluation, are provided in the UC reports. The Final Tier III Report provides a comprehensive summary of the Tier I findings as well as Tier III conclusions where corresponding limitations are clearly explained.

The staff report was revised to include more details on the overall scope of the multimedia evaluation and purpose of the report in the Introduction (Chapter I). The staff report now states that the purpose and scope of the multimedia evaluation is to provide the information needed for the development of fuel regulations and inform the overall rulemaking process. For the proposed ADF regulation, the MMWG prepared the staff report for submittal to the CEPC. (ARB)

D-10. Comment: The findings of the air emission evaluation are also presented in the health evaluation, Section C1 (p. 8-13). It would be useful to integrate Section A and C more clearly, and separate the emission test results for renewable fuels (which belong in Section A) from the toxicity and health impacts (which belongs in Section C). (Holloway, pg. 2)

Response: ARB and OEHHA staff completed separate evaluations and made separate conclusions based on the information provided in the Tier I and Tier III reports and the results of the multimedia evaluation. OEHHA staff evaluated potential human health impacts and made conclusions based on their analysis of toxicity testing data and combustion emissions results. ARB staff evaluated potential air quality impacts and made conclusions based on their analysis of air quality data and the same emissions test results.

To provide the complete scope of each agency's evaluation, the staff report was not revised. The content and organization of the ARB and OEHHA summaries (Section A and Section C) were not changed. (ARB)

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[30] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*. October 23, 2013, ES-1, 1.

Staff Report

E-1. **Comment:** The Opening Glossary should contain CARB. The opening section does not define CARB diesel (page 4). CARB diesel is defined later in the report. If a reader starts with the opening section as I did, it will be confusing to not have a definition of CARB diesel up front. I believe that "conventional petroleum diesel" or simply "petroleum diesel" is another term that is synonymous with CARB diesel. The broader community is likely to be more familiar with the term conventional petroleum diesel of petroleum diesel in comparison to CARB diesel. (Bouwer, pg 2)

Comment: (Appendix A – Proposed Regulation Order) Page 5, (8): The definition for "CARB Diesel fuel" in this proposed regulation appears different from that for "CARB Diesel" used in the 3-tier multimedia evaluation. The former includes 5%v of FAME, while the latter is a pure ultra-low-sulfur diesel (ULSD) derived from petroleum. (Li, pg 3)

Comment: Add CARB to the list of acronyms on page 8 of Appendix A. ARB is listed, but not CARB. (Bouwer, pg 2)

Response: The staff report was revised to include "CARB" in the Glossary. The definition of CARB diesel was also added to the Introduction (Chapter I, part C).

The renewable diesel multimedia evaluation is a relative comparison between renewable diesel fuel and CARB diesel fuel. The proposed ADF regulation defines "CARB diesel fuel" as a light or middle distillate fuel which may be comingled with up to five volume percent biodiesel, and meeting the definition and requirements for "diesel fuel" or "California non-vehicular diesel fuel" as specified in 13 CCR 2281 et seq.[31]

In the UC Tier I and III reports, "CARB diesel," "petroleum diesel," "conventional petroleum diesel," and "Ultra Low Sulfur Diesel (ULSD)" are used interchangeably. (ARB)

E-2. **Comment:** Page 5, section C: I suggest including one brief sentence on line 4 indicating that CARB diesel is conventional petroleum based ultra-low sulfur diesel, along with a brief time line. One or more references should be helpful, directing readers to information on CARB diesel development and adoption, quantity of use in the state, its environmental and human health impacts, etc. This is especially helpful to stakeholders who reside outside California and are unfamiliar with the phrase "CARB diesel." (Li, pg 3)

Response: The staff report was revised to include the definition of CARB diesel at the beginning of the report (Introduction section, part D).

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[31] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*. October 23, 2013, 5.

Please also see response to comment E-1. (ARB)

E-3. **Comment:** The definition of R20 (similarly Rxx) is a bit confusing to this reviewer. It seems both blended (20% R100 + 80% CARB diesel) and co-processed (manufactured by co-processing petroleum and some bio-source, such as tallow as in the case shown in Tier-I Report pages A-36 to A-38) renewable diesels are called R20. A clarification somewhere can be helpful. If the "Rxx" is based on chemical composition of the final product regardless its production methods (blended or co-processes), please say so. (Li, pg 2)

Comment: Although the report uses nomenclature of R20, R50, and R100 to reflect blending levels. Where R20 = a 20% by volume blending of renewable diesel with CARB diesel, Appendix A defines only B5 and B20 and does not provide similar definition of R20, etc. (Holloway, pg 1)

Response: CARB diesel blended with a specific volume percent renewable diesel is denoted accordingly. For example, CARB diesel blended with 20% or 50% renewable diesel is denoted "R20" and "R50," respectively. Pure or 100% renewable diesel is denoted "R100." Thus, regardless of the fuels' production method, "Rxx" refers to the volume percent of renewable diesel in the final product.

Furthermore, the proposed ADF Regulation defines renewable diesel as follows:

(22) "Non-ester renewable diesel" means a diesel fuel that is produced from nonpetroleum renewable resources but is not a mono-alkyl ester and which is registered as a motor vehicle fuel or fuel additive under 40 CFR Part 79, as amended by Pub. L. 91-604.

(23) "Non-ester renewable diesel blend" means non-ester renewable diesel blended with petroleum-based diesel fuel.

(24) "Non-petroleum renewable resources" means non-fossil fuel resources including but not limited to biomass, waste materials, and renewable crude.

The staff report was revised to include more information on the definition of renewable diesel and how renewable diesel blends are referenced. (ARB)

E-4. **Comment:** In Appendix C on page 10 and 11, the figure captions should be modified. The phrase "relative to CARB diesel" implies that the data are normalized to the CARB diesel value. Such normalized values are not plotted. The results for each of the test conditions are plotted to make an easier visual comparison between the CARB Diesel and the R20, R50, and R100 values. As an example, the Graph 1 caption should read "PM Emissions of R20, R50, R100 and CARB Diesel." The data points connected by lines on pages 10 and 11 imply that there is a predictive relationship between the different blends and the

CARB Diesel. It is recommended that the data be plotted as a stacked column or bar chart to convey the data visually to avoid using a line plot. (Bouwer, pg 2)

Response: The titles of Graphs 1, 2, 3 and 4 of Appendix C were revised by the deletion of "relative to CARB diesel" so that the titles no longer imply normalized data. (ARB)

E-5. Comment: Table of Contents: I suggest changing II title from "Summary" to "Section Summaries" or "Summaries of Reports from Participating State Agencies", in order to avoid confusion with the summary of this Main Report. (Li, pg 3)

Response: The title of Chapter II ("Summary") was changed to "Evaluation Summaries" and the Table of Contents was updated. (ARB)

E-6. Comment: Page 9, table 5, 6, & 7 (*Appendix C*). Units are missing. Are these expressed on a g/bhp-hr basis as in the biodiesel report? Do values in bold represent those that are significant ($P< 0.05$)? Again, it would be useful to stress in the narrative that these units have already taken differences in fuel efficiency into account. (Rodenburg, pg 3)

Response: Tables 5, 6, and 7 were revised to include units (g/bhp-hr and percent). Staff also revised the report to include more information on the emissions results and clarify that BSFC accounts for the differences in fuel consumption. (ARB)

<u>Source Reports</u>

F-1. Comment: <u>Appendix G, Appendix – Tier I Report.</u> The conclusion that the use of renewable diesel compared to diesel reduces the amount of particulate matter is supported by a majority of studies cited in the Report in that under specific experimental conditions the use of renewable diesel reduces the levels of particulate matter. The results of these studies comparing the levels of particulate matter from renewable diesel to diesel showed a variety of results (equal, greater than and less than) in levels of particulate matter between the two fuel types depending on fuel, blend, engine type, cycle and the presence or absence of a catalyst. To reinforce this point, a recent study by Westphal et al. (2013) who used a heavy duty diesel engine combusting hydrotreated vegetable oil reported an 8% decrease in particulate matter compared to the combustion of diesel fuel. Therefore, the conclusion of lower particulate matter from renewable diesel engines is not applicable to all exposure scenarios. (Nesnow, pg 4)

Response: The goal of the UC Tier I Report is to identify what is currently known about the production, use, and environmental impacts of renewable diesel fuel in California and identify key uncertainties and data gaps.[32] Through a review of the current

[32] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011. A-12, A-7.

knowledge of renewable diesel fuel in the State, Tier I of the multimedia evaluation consists of a comprehensive review of renewable diesel fuel compared to conventional diesel fuel. Regarding potential air quality impacts, Chapter 6.3 of the Tier I Report provides combustion emissions results and test data for various renewable diesel fuels. Overall results show general decreases of PM emissions, ranging from slight decreases at lower blend levels, R5 to R30, to about 28% at R100.[33]

Based on the multimedia evaluation and information provided in the Tier I report, staff agrees that the studies cited in the report support the general conclusion that the use of renewable diesel fuel reduces PM in certain circumstances. Emissions results vary, depending on various factors including production process, feedstock(s) used, and blend level. For more information, please refer to Chapter 4. Production of Renewable Diesel, 4.3 Overview of Renewable Diesel Feedstocks, and 4.4 Overview of Renewable Diesel Chemical Composition of the Tier I Report.

Staff did not request the UC researchers to revise the report because this would not change the MMWG's overall conclusions or recommendations to the CEPC. (ARB)

F-2. **Comment:** On page A-52 in Appendix G, there is a Section 8 with header Environmental Transport and Fate of Renewable Diesel. The second paragraph on page A-52 has a poorly worded opening sentence regarding the environmental behavior of renewable diesel and conventional ULSD. I agree with the first theme that the chemical composition of renewable diesel is similar to conventional ULSD, so that behavior of these two products in aquatic and soil systems will be similar. The second theme of the opening sentence is poorly worded. I believe the intent of the sentence is to state that existing models and measurements are not able to reliably predict any differences in the behavior of renewable diesel and conventional ULSD. The suggested text better supports the conclusion that the use of renewable diesel does not pose a significant adverse impact on public health or the environment relative to CARB diesel. (Bouwer, pg 2)

Response: Staff agrees with the commenter regarding the intent of the sentence noted above. Therefore, staff did not request the UC researchers to revise the report for further clarification. The MMWG's overall conclusions and recommendations to the CEPC also would not change. (ARB)

F-3. **Comment:** <u>Appendix G – Final Tier III Report.</u> Following the excellent summaries of Tier I (chapter 2) and Tier II (chapter 3), it is logical and helpful to have a chapter providing details on the work executed in Tier III stage. How was the risk assessment carried out? Which model(s) was used? A description of the protocol and a result summary would be very helpful to interested stakeholders. In the current version of this report, chapter 4 gives conclusions and recommendations, but it is not clear on what was done and how. (Li, pg 4)

[33] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011. A-45.

Response: The purpose of the Tier III Report is to summarize the findings of Tier I and provide the overall conclusions from the evaluation. Due to the specific fuel properties and chemical compositions of renewable diesel and CARB diesel, the UC researchers and the MMWG determined that no significant data gaps existed after Tier I and no additional Tier II experiments were needed. Therefore, after Tier I the UC researchers proceeded directly to Tier III of the evaluation.

Staff did not request the UC researchers to revise the report with additional information in the Tier III Report since the details of the evaluation and important findings are provided in the Tier I Report. (ARB)

F-4. **Comment:** Appendix G, Appendix – Tier I Report. The conclusion that benzene, ethylbenzene and toluene levels are lower in emissions from renewable diesel fueled vehicles compared to those vehicles using CARB diesel are from the Durbin et al (2011) report who collected data from several engines under several test cycle protocols. There are no other sources of this data to verify these results. (Nesnow, pg 4)

Response: The purpose of the UC Tier I Report is to evaluate what is currently known about the production, use, and potential environmental and public health impacts of renewable diesel fuel in California, and identify key uncertainties and data gaps.[34] Although we may expect additional studies and publications to be released in the future, the Tier I report is based on the best available scientific data and information, and consists of a comprehensive review of the current body of literature at the time. (ARB)

F-5. **Comment:** Pages A24-25 and table 2.1 on page A-25 (*Tier I Report*). The emission factors are on a grams per gallon basis. Because the different fuels have different mpg ratings, it would be useful include a statement about whether their relative emission factors would change if they were expressed on a grams per vehicle mile travelled basis. (Rodenburg, pg 2)

Comment: Page A-25 Table 2.1. (*Tier 1 Final Report*) Again, it would be helpful to point out how fuel efficiency affects the emissions factors. If I'm not mistaken, ethanol's relatively poor mpg rating means that on a vehicle miles travelled basis, renewable diesel and biodiesel both look even better. (Rodenburg, pg 3)

Response: Staff acknowledges that since there is a difference in the fuel efficiency in the fuels listed in Table 2.1, there would be relatively more emissions from the production of ethanol compared to biodiesel or renewable diesel since more ethanol would be needed to fuel the same vehicles. However, staff did not request the UC researchers to revise the report because this would not change the MMWG's overall conclusions or recommendations to the CEPC. (ARB)

[34] McKone, T.E. et al. *California Renewable Diesel Multimedia Evaluation Tier I Report*, Sept 2011. A-12, A-7.

F-6. **Comment:** Page A-19 (Tier I Final Report) In comparing the production volumes across ConocoPhillips, Nest, and Petrobra, it would be helpful if all could be expressed in the same units, either metric tons per year of barrels per day. For Petrobras, the tons per year is presumably metric tons? (Rodenburg, pg 3)

Response: Staff did not request the UC researchers to revise the Tier I report with the same units. Since the overall conclusions and recommendations did not change, staff did not find it necessary to request the UC to revise the report. (ARB)

F-7. **Comment:** Page A-36 (Tier 1 Final Report) Unless I am mistaken, the sulfur content should be reported as less than 15 ppm, not 15%. (Rodenburg, pg 3)

Response: Staff agrees with the commenter but did not request the UC researchers to revise the report because this would not change the MMWG's overall conclusions or recommendations to the CEPC. (ARB)

F-8. **Comment:** Appendix G, Appendix – Tier I Report. The only comment is that references should be cited at places. For example, the numbers used in the last three paragraphs on page A-40 need references. (Li, pg 4)

Comment: Appendix G – Final Tier III Report. Page 12: The 2nd paragraph should be deleted. It should not be under 3.1, and repeats the first two sentences in 3.2. Also, "(Citation)" needs to be changed to the reference information. (Li, pg 4)

Response: Staff did not request the UC researchers to revise the Tier I and Tier III reports because this would not change the MMWG's overall conclusions or recommendations to the CEPC. (ARB)

F-9. **Comment:** Typos: Appendix G, page A-52: line 5 from the bottom: "lease" should be "least". (Bouwer, pg 3)

Comment: Page A-29 (*Tier 1 Final Report*) typo: avvegetable (Rodenburg, pg 3)

Comment: Page A-49 and A-53 (*Tier 1 Final Report*) typo: missing symbol in 200 ?g/ml**.** (Rodenburg, pg 3)

Comment: There is a small typo, in that p. 6, paragraph 3 refers to the Tier II report from the UC multimedia assessment, whereas the renewable diesel evaluation only included Tier I and III reports. (Holloway, pg 1)

Comment: Appendix G – Final Tier III Report. Page 16, 5th line from bottom: "will be become" should be "will become". (Li, pg 4)

Response: Staff did not request the UC researchers to revise the Tier I and Tier III reports to correct these typographical errors. Since the overall conclusions and recommendations did not change, staff did not find it necessary to request the UC to revise the reports. (ARB)

<u>Proposed Regulation</u>

G-1. Comment: (Appendix A – Proposed Regulation Order) Page 4, (a), (1): If ADF means any non-CARB diesel fuel that does not consist solely of hydrocarbons, a question arises whether "renewable diesel" as defined in the 3-tier multimedia evaluation is an ADF. The renewable diesel, to my understanding, consists of predominantly hydrocarbons. (Li, pg 3)

Response: While renewable diesel is an innovative diesel fuel replacement, it consists solely of hydrocarbons and is virtually indistinguishable from conventional diesel fuel. Therefore, renewable diesel is not considered an ADF under the proposed regulation.[35]

Please see response to comment E-3 for the complete definition of renewable diesel. (ARB)

G-2. Comment: (Appendix A – Proposed Regulation Order) Page 22, top lines: The definition of NBV is repeated. (Li, pg 3)

Comment: (Appendix A – Proposed Regulation Order) Page 22, Table A.2. "Limit" column: The sign "≥" for both total aromatics and polycyclic aromatic hydrocarbons could be "≤". (Li, pg 3)

Comment: (Appendix A – Proposed Regulation Order) Page 30, Table A.9, column "fuel Specifications", row 4 for PAHs w%: The 10% maximum seems incorrect for PAHs in a reference fuel. Please check. (Li, pg 3)

Response: The proposed regulation was revised accordingly. (ARB)

[35] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*. October 23, 2013, ES-1, 1.