State of California
California Environmental Protection Agency

STAFF REPORT
Multimedia Evaluation of Renewable Diesel



Prepared by the
Multimedia Working Group

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Principal Contributors

ARB

Alexander Mitchell
Aubrey Gonzalez
Jim Aguila
Floyd Vergara

SWRCB

Laura Fisher
Eric Morita
Russell Hansen

OEHHA

Page Painter
John Budroe
Hristo Hristov

DTSC

Li Tang
Adriana Ortegon
Andre Algazi
Donn Diebert

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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
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 for renewable diesel as part of the proposed regulation on the commercialization of new alternative diesel fuels (ADFs). The ADF regulation[1] is intended to provide a legal pathway for new, emerging diesel fuel substitutes to enter the commercial market in California, while managing and minimizing environmental and public health impacts, and to preserve the emissions benefits derived from the ARB motor vehicle diesel regulations. The proposed regulation order is provided in Appendix A.

Before new fuel specifications are established, Health and Safety Code (H&SC) 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] Therefore, a multimedia evaluation of renewable diesel was conducted pursuant to H&SC section 43830.8.

This staff report was prepared by the Multimedia Working Group (MMWG) for review by the CEPC. The 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. This staff report provides a summary of the renewable diesel multimedia evaluation, including independent agency assessments, 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.
- Disposal or use of the byproducts and waste materials from the production of the fuel.

[1] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*, October 23, 2013.
[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).

As specified in H&SC 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 of the evaluation, including the MMWG's conclusions and recommendations to the CEPC, and submit it for peer review pursuant to H&SC 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 regarding the acceptability of new fuel formulations proposed for use in the State. The MMWG includes representatives from the ARB, State Water Resources Control Board (SWRCB), Office of Environmental Health Hazard Assessment (OEHHA), and Department of Toxic Substances Control (DTSC). The complete list of all members of the MMWG is provided in Appendix B. The MMWG may also consult with other agencies and experts, as needed.

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. For the evaluation, ARB staff was responsible for the air quality impact assessment and the overall coordination of the evaluation process. SWRCB staff was responsible for evaluating potential surface water and groundwater quality impacts, OEHHA staff was responsible for evaluating potential public health 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 H&SC 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 work plan report identifies any key knowledge gaps about the fuel and establishes the overall scope of the evaluation. Tier II follows the work plan developed in Tier I to fill key knowledge gaps, if any, and prepare a Tier II risk assessment protocol report. 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 from Tier I 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.[4]

The multimedia evaluation process is summarized in Table 1.

Table 1. Summary of the Multimedia Evaluation Process[5]

	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 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 of Tier II report
Tier III	Execution of Risk Assessment and preparation of Multimedia Risk Assessment Final Report	Prepare recommendations to the Environmental Policy Council based on Multimedia Risk Assessment report.	Independent peer review of the Multimedia Risk Assessment report and 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.
[5] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier III Report*. Apr 2012, 2.

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 H&SC section 43830.8(d), an external scientific peer review of the multimedia evaluation must be conducted pursuant to H&SC 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." [6]

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 issues to be addressed, and list of recommended areas of expertise. The memorandum is appended as Appendix H. Upon approval, the University of California (UC), through an interagency agreement with Cal/EPA, identifies candidates it considers qualified to complete the review.

Peer reviewers will be identified for the scientific review of the staff report. Once reviews are received, the MMWG will address all comments in a written response and make any necessary revisions to the report where appropriate. The MMWG will hold internal meetings to discuss and address each comment submitted by the reviewers.

B. <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.[7]

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

[6] California Air Pollution Control Laws. Health and Safety Code, Division 26, Part 5, Chapter 4, Section 57004(d)(2).
[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.

feedstocks but has different processing methods and can include chemically different components. [8]

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.

C. Multimedia Evaluation of Renewable Diesel

Pursuant to H&SC section 43830.8, researchers from UC Berkeley and UC Davis conducted the multimedia evaluation of renewable diesel compared to diesel fuel that meets ARB motor vehicle diesel fuel specifications (CARB diesel) under 13 CCR 2281 et seq. Due to the specific fuel properties and indistinguishable chemical compositions of renewable diesel and CARB diesel, the UC researchers and the MMWG determined that no significant data gaps existed and therefore, no additional Tier II experiments were needed. Consequently, after Tier I, the UC researchers proceeded directly to Tier III of the multimedia 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 fuel, as specified in this multimedia evaluation and the proposed regulation, does not pose a significant adverse impact on public health or the environment.

[8] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier III Report*. Apr 2012, 5.
[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. Summary

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 potential environmental and public health impacts from changes to air emissions, water quality, soil quality, and hazardous waste generation were evaluated. 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 testing protocol and impact analysis on criteria pollutants, 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 multimedia reports (Final Tier I, Tier II, and Tier III reports) and the CARB 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.

1. Criteria Pollutants

Emissions testing was conducted on renewable diesel (R100) and two renewable diesel blends (R20 and R50) compared to the baseline CARB diesel 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.

Test results on pure renewable diesel fuel, R100, showed that particulate matter (PM) emissions generally decreased by about 30% and oxides of nitrogen (NOx) emissions generally decreased by about 10%. Total hydrocarbons (THC) generally decreased by about 5% and carbon monoxide (CO) generally decreased by about 10%, but brake specific fuel consumption (BSFC) generally increased by about 5%.[12]

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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.

[12] 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 ES-6, xxxvii.

2. Toxic Air Contaminants

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. 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]

3. Ozone Precursors

Test results show a decrease in NOx emissions and most VOCs. THC emissions generally decreased by about 10% 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.[15]

4. Greenhouse Gas Emissions

The use of renewable diesel decreased BSFC by about 5%. However, as with any alternative fuel, determination of greenhouse gas (GHG) emissions impact is the result of a full lifecycle analysis of the fuel. The outcome of a full lifecycle analysis is greatly dependent on the feedstock source. The Low Carbon Fuel Standard lifecycle analysis of renewable diesel shows reductions in GHGs of about 15% to 80% depending on feedstock source.[16]

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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[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] 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.

[16] 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).

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.[17] The renewable diesel fuel was produced by Neste Oil and denoted NExBTL fuel. The CARB fuel used was certified CARB diesel fuel.

[17] 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.

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 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.

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.

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.

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 renewable diesel in CARB-renewable diesel blends (R20, R50 and R100).

Murtonen *et al.*[18] 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

[18] 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.

Standards Organization (ISO) C1 steady-state test cycle. Both regulated and unregulated emission outputs were expressed in units of weight/distance (e.g. 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.

In the presence of a DOC/POC, 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. 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 a EN590-fueled engine was described by the authors as “minor” (93% reduction compared to a non-DOC/POC equipped-engine). Total hydrocarbons were below the detection limit for both fuel types, and aldehydes/ketones could not be measured in the DOC/POC output due to analytical interference.

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.

Jalava *et al.*[19] 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 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, but 18% greater when a DOC/POC was used.

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. HVORD-fueled engine emissions demonstrated moderately reduced total particulate-phase PAH emissions (31%) and genotoxic particulate-phase

[19] 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.

PAH emissions (11%) compared to a EN590-fueled engine in the presence of a DOC/POC.

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 (64% and 66%, respectively) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in the absence of a DOC/POC. In the presence of a DOC/POC, total PAHs were moderately reduced (18%) while genotoxic PAHs were slightly increased (6%) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust.

2. Toxicity Testing of Combustion Emissions

In the combustion emissions study performed at CE-CERT,[20] *Salmonella typhimurium* test strains TA98 and TA100 were exposed to emissions samples from an engine run on either CARB ULSD fuel, or R20, R50, or R100 HVORD, 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.

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.

HVORD or HVORD blend-fueled engine particulate phase exhaust extracts did not increase 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 compared when exposed to particulate phase exhaust extract from a CARB diesel-fueled engine.

Jalava *et al*.[21] compared exhaust toxicities from a 2005 model year Scania heavy-duty diesel engine equipped with a DOC/POC and fueled with EN590 or HVORD using a Braunschweig test cycle (Murtonen *et al*. [22]). 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

[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.

[21] 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.

[22] 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.

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.

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. There was no significant difference in release of either cytokine between the fuel types when a DOC/POC was used.

DNA damage (Comet assay) in mouse macrophage RAW264.7 cells treated *in vitro* with by HVORD-fueled engine PM was substantially increased compared to cells treated with EN590-fueled engine PM in the absence of a DOC/POC. However, in the presence of a DOC/POC 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.

Heikkilä *et al*.[23] tested the comparative exhaust emissions of an off-road diesel engine operated on a steady-state cycle without a DOC/POC and fueled with either EN590 or HVORD. PM output with HVORD fuel was reduced approximately 28% to 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.

Jalava *et al*.[24] compared exhaust toxicities from a 2005 model year Scania heavy-duty diesel engine equipped with a DOC/POC and fueled with EN590 or HVORD using a Braunschweig test cycle (Murtonen *et al*. [25]).

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[23] 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.

[24] 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.

[25] 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.

Particulate-phase total and genotoxic PAHs (expressed as ng/mg PM) were reduced in 100% HVORD-fueled engine exhaust (approximately 25% reduction) but not in 30% HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in engines not fitted with DOC/POCs. In contrast, 78% and 88% increases in particulate-phase PAHs (total and genotoxic, respectively) were noted for the HVORD-fueled engine compared to the EN590-fueled engine when the engine was equipped with a DOC/POC.

Similar to the Jalava *et al*.[26] 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. 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.

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 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.

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. There was no significant difference in release of either cytokine between the fuel types when a DOC/POC was used.

DNA damage 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. In the same study, there was no significant difference in reactive production between the two test groups in the presence or absence of a DOC/POC.

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

[26] 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.

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 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 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 renewable diesel, ARB staff concludes that the use of renewable diesel and the resulting air emissions do not pose a significant adverse impact on public health or the environment.

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 CARB 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.

D. Conclusions on Soil and Hazardous Waste Impact

In comparing renewable diesel with CARB diesel, DTSC's review concludes that renewable diesel is free of the ester compounds found in fatty acid methyl ester biodiesel, 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, 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 California diesel fuel.

2. Condition the finding on the following:

    a. Renewable diesel that does not meet the specifications in the proposed regulation must undergo an emissions equivalence comparison certification program.

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

    b. Specific 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.

    c. In the event that relevant available information indicate 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. 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).

6. 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).

7. Same as Footnote 1.

8. Same as Footnote 5.

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 5.

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. Same as Footnote 11.

13. Same as Footnote 11.

14. Same as Footnote 11.

15. Same as Footnote 11.

16. 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).

17. Same as Footnote 11.

18. 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.

19. 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. http://informahealthcare.com/doi/pdf/10.3109/08958378.2010.519009 (accessed November 4, 2013).

20. Same as Footnote 11.

21. 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. http://www.particleandfibretoxicology.com/content/pdf/1743-8977-9-37.pdf (accessed November 4, 2013).

22. Same as Footnote 17.

23. 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. http://www.tandfonline.com/doi/pdf/10.1080/10962247.2012.708383 (accessed November 4, 2013).

24. Same as Footnote 20.

25. Same as Footnote 17.

26. Same as Footnote 18.

APPENDICES

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APPENDIX A

Proposed Regulation Order on the Commercialization of New Alternative Diesel Fuels

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Appendix A
PROPOSED REGULATION ORDER

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, title 13, California Code of Regulations (CCR), 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 and shown as plain text. 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). Existing sections 2293 and 2293.5 would be renumbered to 2294 and 2295 and would be 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 remain unchanged and are indicated by the symbol are shown in s 2293 and .]

Chapter 5. Standards for Motor Vehicle Fuels
Article 3. Specifications for Alternative Motor Vehicle Fuels

Subarticle 1. Specifications for Current Alternative Motor Vehicle Fuels

§2290. Definitions.

* * * * *

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.

* * * * *

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.

* * * * *

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.

* * * * *

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.

* * * * *

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.

* * * * *

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 New Alternative Diesel Fuels

§2293. Purpose.

The purpose of this regulation is to establish a comprehensive, multi-stage process governing the commercialization of new 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 ensuring no significant adverse impacts overall on public health or the environment relative to conventional, petroleum-based CARB diesel.

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).

§2293.1. Applicability.

(a) Starting January 1, 2015, no person shall sell, offer for sale or supply an alternative diesel fuel (ADF) intended for use in California unless the person is conducting such transactions pursuant to an approved Memorandum of Understanding issued to or otherwise applicable to that person under Stage 1 or 2 of this program, or the person is meeting all the applicable requirements under Stage 3A or 3B of this program.

(b) An ADF 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 diesel 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 diesel 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 subarticle, each retail sale of alternative diesel fuel for use in a motor vehicle, and each supply of alternative diesel 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 diesel fuel 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, 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).

§ 2293.2. Definitions.

(a) For the purposes of sections 2293 through 2293.9, the definitions in Health and Safety Code sections 39010 through 39060 shall apply, except as otherwise specified in this subarticle 2:

(1) "Alternative diesel fuel" or "ADF" means any non-CARB diesel fuel used in a compression ignition engine that does not consist solely of hydrocarbons, and is not subject to a specification under title 13, CCR, section 2292. All ADFs that are substantially similar to an ADF subject to an approved Executive Order or MOU shall be deemed to fall within the class of ADFs subject to that same approved Executive Order or MOU.

(2) "Biodiesel" means a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100, and meeting the specifications set forth by the 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 4 CCR 4140(a).

(3) "Biodiesel Blend" means biodiesel blended with petroleum-based diesel fuel.

(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 50% by volume biodiesel/CARB diesel blend is denoted as "B50").

(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 up to 20 percent biodiesel by volume.

(8) “CARB Diesel fuel” means 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 nonvehicular diesel fuel” as specified in 13 CCR 2281 et seq. “CARB Diesel fuel” may include, 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.

(9) “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. A list of air pollutants for which a CAAQS or NAAQS has been established can be found at http://www.arb.ca.gov/research/aaqs/aaqs2.pdf, June 2013, which is incorporated herein by reference.

(10) “Diesel Substitute” means any liquid fuel that is intended for use with CARB diesel or CARB diesel blends in a compression ignition engine. “Diesel substitute” includes, but is not limited to, 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.

(11) “Effective ADF Blend Level” means the actual, statewide-average ADF blend level, adjusted to account for various air pollution mitigating considerations, which may include but are not limited to, the use of various diesel substitutes that reduce air emissions of the pollutant for which the significance threshold was identified (e.g., renewable diesel, which reduces NOx emissions); the fleet penetration of new technology diesel engines; composition of the feedstocks used to produce the ADF; volumes of lower-emission CARB diesel fuel, including those with emissions-reducing additives; and other factors as deemed appropriate by the Executive Officer. The effective ADF blend level is compared to the significance threshold to determine when to apply mitigation strategies for those ADFs for which the Executive Officer has identified a significance threshold.

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

(13) “Executive Order” means the document signed by the Executive Officer, or his or her designee, which specifies the stage at which a regulated party(ies) for an ADF is or will be operating under, as provided in this subarticle, and any

enforceable terms, conditions, and requirements applicable to the regulated party(ies) must meet in order to sell, offer for sale, or supply that 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 (17 CCR 95481(a)).

(17) "LCFS" means the Low Carbon Fuel Standard (17 CCR 95480—95490).

(18) "Memorandum of Understanding (MOU)" means an enforceable agreement, executed between the Executive Officer and an applicant(s), which meets the requirements of this subarticle and specifies the terms and conditions by which the ADF at issue will be sold and used in California. MOUs issued under this subarticle are not subject to the Board's reservation of powers pursuant to Board Resolution 78-10 (February 23, 1978) or Resolution 05-40 (July 21, 2005).

(19) "Multimedia Evaluation" has the same meaning as defined in Health and Safety Code section 43830.8(b).

(20) "Multimedia Evaluation Guidance Document" means the procedure governing the Executive Officer's multimedia evaluation conducted prior to establishing a motor vehicle fuel specification. The multimedia evaluation guidance document ("Guidance Document and Recommendations on the Types of Scientific Information Submitted by Applicants for California Fuels Environmental Multimedia Evaluations") is available at www.arb.ca.gov/fuels/multimedia/guidancedoc.pdf, June 2008, which is incorporated herein by reference.

(21) "New Technology Diesel Engine (NTDE)" means a diesel engine that meets at least one of the following criteria:

(A) 2010 ARB emission standards for on-road heavy duty diesel engines under 13 CCR 1956.8.
(B) Tier 4 emission standards for non-road compression ignition engines under 13 CCR 2421, 2423, 2424, 2425, 2425.1, 2426, and 2427.
(C) Equipped with or employs a Diesel Emissions Control Strategy (DECS), verified by ARB pursuant to 13 CCR 2700 et seq., which uses selective catalytic reduction to control NOx.

(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.

(25) "Performance Criteria" means a list of indicators, including but not limited to the total volume and volume percent represented by an ADF's sales in California, that are specified by the Executive Officer for use in determining whether the significance level for a pollutant has been reached or will be reached.

(26) "Person" has the same meaning as defined in Health and Safety Code section 39047 and includes, but is not limited to, alternative diesel fuel 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.

(27) "Producer" has the same meaning as defined in the Low Carbon Fuel Standard (17 CCR 94581(a)).

(28) "Reference CARB Diesel" has the same meaning as "reference fuel" as that term is defined in 13 CCR 2282(g)(3).

(29) "Significance Level" means, for a given pollutant X, either of the following, whichever applies:

(A) For an ADF blended with CARB diesel, the significance level means the blend level of the ADF below which the combined effects of:

1. the use of the ADF in new technology diesel engines, and
2. the use of diesel substitutes that reduce emissions of X result in no increase in the emissions of X.

(B) For an ADF used as a neat fuel, the significance level means any use of the ADF below which there is no increase in the emissions of X.

(30) "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 sections 39655 or 39657, or is designated as a hazardous air pollutant under section 112 of the federal Clean Air Act (42 U.S.C 7412).

(31) “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 Fuels
ARB or Board	California Air Resources Board
CAA or the Act	Clean Air Act
CDFA	California Department of Food and Agriculture
CEPC or Council	California Environmental Policy Council
CEQA	California Environmental Quality Act
CO	Carbon Monoxide
CCR	California Code of Regulations
DME	Dimethyl Ether
DMS	Division of Measurement Standards, (Division within CDFA)
EISA	Energy Independence and Security Act of 2007
EO	Executive Officer
FAME	Fatty Acid Methyl Esters
GHG	Greenhouse Gas
HC	Hydrocarbons
H&SC	California Health and Safety Code
LCFS	California Low Carbon Fuel Standard
MMT	Million Metric Tons
MMWG	Multimedia Working Group
MOU	Memorandum of Understanding
NOx	Oxides of Nitrogen
NREL	National Renewable Energy Lab
NTDE	New technology diesel engines
OSFM	Office of the State Fire Marshal
PAHs	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
ppmw	Parts per Million by Weight
RFS	Renewable Fuels Standard
SCR	Selective Catalytic Reduction
SWRCB	California State Water Resources Control Board
SVO	Straight Vegetable Oil
U.S. EPA	U.S. Environmental Protection Agency

UST	Underground Storage Tanks
WVO	Waste Vegetable Oil

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).

§2293.3. Exemptions.

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

(a) Fuels that have a specification under sections 2292—2292.7 of subarticle 1;

(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 provision does not apply to additives used pursuant to the mitigation measures specified in Appendix 1;

(c) ADF fuels used in fleets comprising 95 percent or more new technology diesel engines (NTDE) are presumed to be exempt from the mitigation requirements specified in this subarticle. To the extent the use of an ADF in such NTDEs reduce or result in no greater emissions of one or more criteria, toxic, or other air pollutants relative to conventional CARB diesel, the Executive Officer may include the volume and emission reduction ability of that ADF in those NTDEs when determining whether the significance threshold has been reached in a specified year and, if so, the extent mitigation is required pursuant to section 2293.6; and

(d) CARB diesel fuel is exempt from the mitigation requirements specified in this subarticle. To the extent the use of CARB diesel fuel with beneficial properties reduces emissions of one or more criteria, toxic, or other air pollutants relative to conventional CARB diesel, the Executive Officer may include the volume and emission reduction ability of that CARB diesel fuel when determining whether the significance threshold has been reached in a given year and, if so, the extent mitigation is required pursuant to section 2293.6.

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).

§2293.4. General Requirements Applicable to All ADFs.

In addition to the requirements in 2293.5, starting January 1, 2015, no person shall sell, offer for sale or supply an ADF intended for use in motor vehicles in California unless that ADF meets the requirements set forth in this subarticle 2.

(a) Has been registered with U.S. EPA under 40 CFR part 79 prior to its first sale, offer for sale, or supply for use in California.

(b) Meets all applicable regulatory requirements promulgated by the California Department of Food and Agriculture (including, but not limited to, 4 CCR sections 4140—4148, 4200, and 4202—4205).

(c) Meets 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, 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 any significant adverse environmental impacts relative to conventional CARB diesel, and identify any vehicle/engine performance issues such fuels may have.]

It is a violation of this article for any person to sell, offer for sale, or supply an ADF intended for use in motor vehicles in California that does not meet the requirements of this subarticle or an approved Stage 1 MOU, Stage 2 MOU, or an applicable fuel specification under Stage 3A or 3B, as provided in this subarticle.

(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.

No person, who is not already subject to Stage 2 or has obtained an approved fuel specification under Stage 3A or 3B, may sell, offer for sale, or supply a candidate ADF intended for use in motor vehicles in California without an approved Stage 1 MOU governing the limited sales and use of that candidate ADF. A person seeking a Stage 1 MOU must by 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:

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,

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

4. 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 ADF has been registered 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 20 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 at 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 20 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 Memorandum of Understanding (MOU) executed between the Executive Officer and the applicant(s). The MOU 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 MOU. 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 MOU, 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 MOU.

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

(B) The Executive Officer may terminate or modify a MOU, 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 MOU, 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 MOU without first affording the applicant an opportunity for a hearing in accordance with 17 CCR 60040 et seq.;

(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 MOU, 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 an associated significance threshold for any criteria, toxic, or other air pollutant. The establishment of a significance threshold determines whether the candidate ADF can proceed to mitigated sales under Stage 3A or unmitigated sales under Stage 3B.]

(1) Stage 2 Application.

A person who has successfully completed a pilot program for a candidate ADF under section 2293.5(a) may apply for entrance into a Stage 2 for that candidate ADF. 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 20 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 20 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 Memorandum of Understanding (MOU) executed between the Executive Officer and the applicant(s). The MOU shall include terms and conditions that the applicant must meet in order to provide the ADF fuel in California during the term of the MOU. 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 MOU (e.g., Westport, Volvo, etc.), 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 MOU.

(4) Operation under a Stage 2 MOU

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

(B) The Executive Officer may terminate a MOU, 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 MOU, 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 Significance Threshold

(A) Pursuant to the approved Stage 2 MOU, 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 conventional CARB diesel, under Stage 2, 3A, and 3B;

(C) In addition to determining any significant impacts, the multimedia assessment shall also include an evaluation of potential mitigation measures for 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;

(E) The Executive Officer shall identify a significance threshold based on the multimedia evaluation conducted pursuant to this subsection. Approved significance thresholds shall be listed in Table 1 of section 2293.6.

(6) Completion of Stage 2

No person operating under Stage 2 may sell, offer for sale, or supply an ADF for use in motor vehicles in California under Stage 3A or 3B unless the Executive Office has determined in writing that the person has successfully completed the requirements of Stage 2. To be deemed as successfully completing Stage 2, the applicant must meet all the following requirements:

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

(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 for the ADF and obtained written approval of those specifications by the Executive Officer;

(E) Identify appropriate mitigation strategies for the ADF to be applied in the event the significance threshold identified by the Executive Officer is reached; and

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

In the event the Executive Officer identifies a significance threshold under (5)(D) above, the Executive Officer shall post notice on the ARB website his/her intent to initiate a rulemaking to incorporate the significance threshold and approved mitigation strategies into this subarticle. Upon completion of that rulemaking, 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 Mitigation*

In the event the Executive Officer has determined there is a significance threshold for an ADF, the following procedure shall apply:

(1) The Executive Officer shall first determine the current ADF blend level and the blend level trajectory based on an analysis of ADF sales in recent years;

(2) Based on the analysis in (c)(1), the Executive Officer shall estimate the year(s) in which the effective ADF blend level is projected to reach 25%, 50%, 75%, and 95% of the significance threshold.

(A) In estimating these levels, the Executive Officer shall consider mitigating effects from various factors, including various diesel substitutes that reduce air emissions of the pollutant for which the significance threshold was identified (e.g., renewable diesel, which reduces NOx emissions); the fleet penetration of new technology diesel engines; composition of the feedstocks used to produce the ADF; volumes of lower-emission CARB diesel fuel, including those with emissions-reducing additives; and other factors as deemed appropriate by the Executive Officer. These factors shall be considered in determining the effective ADF blend level at a specific point (e.g., the ADF blend level adjusted to account for various mitigating factors such as the use of new technology diesel engines and renewable diesel). The effective ADF blend level will then be compared to the significance threshold to determine when mitigation must be applied. The methodology for calculating the effective ADF blend level is specified in section 2293.6.

(B) The Executive Officer shall post the results of and basis for such estimates on the ARB's website;

(3) When the effective ADF blend level reaches 75% of the significance threshold, the Executive Officer shall post on the ARB website a notice of intent to apply the mitigation strategies identified in Appendix 1 for the ADF

when the effective ADF blend level is projected to reach 95% of the significance threshold. Once the 75% level is reached, all suppliers of an affected ADF shall provide monthly reports to the Executive Officer, as specified in section 2293.8, additionally at this point all producers and importers of the affected ADF shall submit a mitigation plan in accordance with 2293.5(c)(5);

(4) Once the effective ADF blend level has reached 95% of the significance threshold, the requirement to apply mitigation becomes effective and any producer or importer of the affected ADF shall comply with the terms of the mitigation plan by which they are covered. Each mitigation plan shall apply mitigation on a proportion of their total fuel equal to difference between the projected effective blend level and 95 percent of the significance level for each year.

(5) Individual producers or importers of ADF or a group of producers or importers of an ADF may apply to the Executive Officer for a mitigation plan. The application shall include the location of each production or import facility included in the plan, the amount of ADF production or importation capacity of each facility, the amount of ADF produced or imported at each facility for the prior two years, and an exact description of how the producer, importer, or group intends to mitigate emissions of pollutants of concern related to their production or importation using the mitigation options in Appendix 1. After receiving an application for a mitigation plan, the Executive Officer shall advise the applicant in writing within 20 business days either that the application is complete or that specified additional information is required to make it complete. After receiving additional information, the Executive Officer shall advise the applicant in writing within 15 business days that either the application is now complete or that specified additional information is still required to make it complete. After deeming an application complete, the Executive Officer shall approve or deny the application. In determining whether or not to approve the application the Executive Officer shall consider in their analysis any regional or seasonal effects that may occur based on the mitigation plan. If the Executive officer denies the application, he/she shall notify the applicant in writing of that determination. If the Executive Officer approves the application, he/she shall issue an Executive Order to the applicant(s) deeming them in compliance with the mitigation portion requirements of this regulation.

Stage 3B: Commercial Sales Subject to No Mitigation

If the Executive Officer has determined that there is no significance threshold for an ADF, no mitigation measures or sales restrictions are required for that ADF. 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 the fuel provider sold, offered for sale, or supplied for use in California:

(1) The volume of ADF (A100) blendstock, if applicable;
(2) The volume of ADF (A100) neat fuel, if applicable;
(3) The volume of ADF/CARB diesel blend, if applicable.

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, 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).

§2293.6. Significance Thresholds and Effective ADF Blend Levels.

An ADF for which a significance threshold has been determined by the Executive Officer shall be subject to the Stage 3A provisions specified in section 2293.5. The specific mitigation requirements in Appendix 1 shall apply at the time the Executive Officer determines the effective ADF blend level will be at least 95% of the significance threshold.

Table A.1. Significance Thresholds

Alternative Diesel Fuel	**Significance Threshold**	**Effective ADF Blend Level**	**Comments**
Biodiesel	10 % blend level	See 2293.6(a)	NOx is the pollutant of concern
[Reserved]	[Reserved]	[Reserved]	[Reserved]
[Reserved]	[Reserved]	[Reserved]	[Reserved]

(a) The effective ADF blend level for biodiesel is calculated as follows:

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

Where,

EB = effective ADF blend level, expressed as percent biodiesel

NBV = net volume of biodiesel used in compression-ignition engines in California, excluding gallons used in B5 or less, expressed in gallons

NBV = net volume of biodiesel used in compression-ignition engines in California, excluding gallons used in B5 or less, expressed in gallons

LN = volume of low-NOx diesel used in compression-ignition engines in California, excluding renewable diesel, expressed in gallons

RD = volume of renewable diesel used in compression-ignition engines in California, expressed in gallons

VM = volume of biodiesel, employing one of the mitigation strategies specified in Appendix 1 prior to the date mitigation is required under 2293.5(c)(4), used in compression-ignition engines in California, expressed in gallons

AB = volume of animal-fats-based biodiesel used in compression-ignition engines in California, excluding gallons used in B5 or less, expressed in gallons

TCV = total volume of all fuels used in compression-ignition engines in California (not including any fuel with a specification under 13 CCR 2292), expressed in gallons

Low-NOx diesel (LN) means a diesel fuel that meets the following specifications:

Table A.2. Fuel Specifications for Low-NOx Diesel Fuel

Property	**Test Method**	**Limit**
Unadditized Cetane Number	ASTM D6890-13a	$\geq$ 67
Total Aromatics	ASTM D5186-03(2009)	$\geq$ 6.4 mass %
Polycyclic Aromatic Hydrocarbons	ASTM D5186-03(2009)	$\geq$ 0.6 mass %
API Gravity	ASTM D287-12b	$\geq$ 47.4 degrees API

When the ratio of New Technology Diesel Engines in the California heavy duty vehicle fleet is 95 percent or greater, as determined using the latest version of EMFAC, the effective blend level will be deemed to be B0 or zero percent, and no mitigation will be required.

(b) The effective ADF blend level for other ADFs is calculated as follows:

[Reserved for future use]

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).

§2293.7. Specifications for Alternative Diesel Fuels.

Unless otherwise required by a mitigation strategy in effect, 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).*

Table A.3. Fuel Specifications for B100

Property	Test Method	Value
Unadditized Cetane Number	ASTM D613-10ae1	≥47
API Gravity	ASTM D287-12b	≥27 degrees API
Sulfur	ASTM D5453-93	≤15 ppm

(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.

(b) Specifications for Other Alternative Diesel Fuels:

Table A.4. Fuel Specifications for Other ADFs

ADF	Property	Test Method	Value
[Reserved]	[Reserved]	[Reserved]	[Reserved]
[Reserved]	[Reserved]	[Reserved]	[Reserved]
[Reserved]	[Reserved]	[Reserved]	[Reserved]
[Reserved]	[Reserved]	[Reserved]	[Reserved]

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).

§2293.8. Reporting and Recordkeeping.

(a) Sampling

For reporting of fuel properties as required by the MOU, an applicable sampling methodology set forth in 13 CCR section 2296 shall be used.

(b) Reporting

(1) For Stages 1 and 2

A person operating under a Stage 1 or Stage 2 MOU must submit quarterly reports to the Executive Officer throughout the term of the MOU. 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 MOU;
(C) Progress made toward completing the terms of the MOU;
(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 monthly 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 MOU;
(C) The volume of other applicable quantity of the mitigation strategy used during each month;
(D) The blend rate of mitigation strategies used during each month, if applicable.

If the Executive Officer publishes notice that the effective ADF blend level has reached 75% of the significance threshold pursuant to section 2293.6(c)(2) and (3), any person subject to this provision shall report the information specified in (1)-(3) above for the affected ADF by the end of each month following the notice publication.

(3) For Stage 3B

A person operating within Stage 3B must submit monthly reports to the Executive Officer, with each reporting 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 specified in the MOU.

(c) Recordkeeping

(1) The 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.

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).

§2293.9. 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 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 3. Ancillary Provisions

§~~2293~~<u>2294</u>. Equivalent Test Methods.

* * * * *

<u>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).</u>

§~~2293.5~~<u>2295</u>. Exemptions for Alternative Motor Vehicle Fuel Used in Test Programs.

The <u>E</u>~~e~~xecutive ~~o~~<u>O</u>fficer 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. Mitigation Measures.

A person subject to the Stage 3 mitigation requirements (section 2293.5(c)) may meet the mitigation requirement by implementing any of the following mitigation measures as applicable, either alone or in combination:

Additives approved for mitigation purposes, Low-NOx diesel (i.e., CARB diesel that has properties such that the pollutant that has triggered the significance level finding is already mitigated to the degree necessary to reduce the pollutant emissions below the significance level), 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 as well as allowed blend level:

(A) Di-tert-butyl peroxide (DTBP): Biodiesel blends that contain DTBP by volume in the amounts specified in the table below are considered NOx mitigated. Any person who blends DTBP with a biodiesel blend in accordance with this report these volumes under the requirements of 2293.8, and whenever a report or record is made, the amount of biodiesel mitigated using each of the levels below must be included along with the actual amount of DTBP used.

Table A.5: DTBP Mitigation Blend Level

Biodiesel Blend Level	**Required level of DTBP**
B0 to <B10	0 ppm
B10 to <B15	≥0.75 percent
B15 to B20	≥1.0 percent
Above B20	Cannot be mitigated by DTBP alone

(B) [Reserved for Future Use]

(2) Low-NOx Diesel base fuel.

Hydrocarbon diesel fuel that meets the following specifications shall be considered Low-NOx diesel.

Table A.6: Low-NOx Diesel Fuel Parameters

Property	Test Method	Limit
Unadditized Cetane Number	ASTM D6890-13a	≥ 67
Total Aromatics	ASTM D5186-03(2009)	≤ 6.4 mass%
PAH	ASTM D5186-03(2009)	≤ 0.6 mass%
API Gravity	ASTM D287-12b	≥ 47.4 degrees API

Any biodiesel blend below B20 that was derived from at least 4.0 gallons of Low-NOx diesel for each gallon of biodiesel in the blend, will be considered NOx mitigated.

(3) 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)(3) 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)(3)(F) of this appendix; (B) test procedures consistent with the requirements of (a)(3) of this appendix; (C) test data showing that the fuel to be used as the reference fuel satisfies the specifications identified in (a)(3)(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)(3) 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)(3)(F)(iii)2. 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)(3)(F)(iii)2. of this appendix, a demonstration that the candidate fuel meets the requirements for certification set forth in (a)(3) 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)(3)(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 fuel. 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 fuel. 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.*

The applicant shall report all of the properties of the candidate fuel listed below. 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.

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 D613-10ae1
API Gravity	ASTM D287-12b
Viscosity at 40°C, cSt	ASTM D445-12
Flash Point, °F, minimum	ASTM D93-13
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 D613-10ae1	47-50
API Gravity	ASTM D287-12b	27 – 33
Viscosity at 40°C, cSt	ASTM D445-12	2.0 – 4.1
Flash Point, °F, minimum	ASTM D93-13	266
Distillation, °F	ASTM D86-12	
90 % Recovered		620-680
FAME Content %	EN 14103:2011	Report

(E) *The reference fuel.* The reference fuel used in the comparative testing described in (a)(3)(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 D613-10ae1	48 minimum
API Gravity	ASTM D287-12b	33 – 39
Viscosity at 40°C, cSt	ASTM D445-12	2.0 – 4.1
Flash Point, °F, minimum	ASTM D93-13	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 fuel 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 fuel before each cold start procedure using the reference fuel. 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 fuel 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 fuel 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 fuel 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)(iii) 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 fuel, applying one-sided Student's t statistics as set forth in Snedecor and Cochran, *Statistical Methods* (7th 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)(i) and (a)(3)(G)(ii) below, after applying the criteria of (a)(3)(G)(iii) 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 fuel.

2. Use of any additive identified pursuant to (a)(3)(b)(ii) 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)(3)(G)(i) of this appendix to be made, for each referenced pollutant the candidate fuel shall satisfy the following relationship:

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

Where:

$\bar{x}_C$ =	Average emissions during testing with the candidate fuel
$\bar{x}_R$ =	Average emissions during testing with the reference fuel
δ =	tolerance level equal to 1 percent of $\bar{x}_R$ NOx, 2 percent of $\bar{x}_R$ 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 and reference fuel

(H) If the Executive Officer finds that a candidate fuel has been properly tested in accordance with (a)(3) of this appendix, and makes the determinations specified in (a)(3)(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)(3)(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)(3)(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)(3)(H) of this appendix, but does not meet the criteria of (a)(3)(G) of this appendix when tested in accordance with (a)(3)(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)(3)(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

October 2013

ARB

Aubrey Gonzalez, Substance Evaluation Section
Alexander Mitchell, Substance Evaluation Section
Stephen d'Esterhazy, Substance Evaluation Section
Susie Chung, Substance Evaluation Section
Jim Peterson, Substance Evaluation Section
Jim Guthrie, Fuels Section
Patrick Wong, Health and Ecosystems Assessment Section
Mark Schuy, Retrofit Assessment Section
Jim Aguila, Manager, Substance Evaluation Section
Floyd Vergara, Chief, Alternative Fuels Branch

SWRCB

Eric Morita, Underground Storage Tank Program Section
Laura Fisher, Assistant Division Chief, Division of Water Quality

OEHHA

Hristo Hristov, Integrated Risk Assessment and Research Section
Page Painter, Supervisor, Integrated Exposure Assessment Section

DTSC

Li Tang, Multimedia Products Section
Donn Diebert, Chief, Program Implementation Unit

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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

November 2013

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1. INTRODUCTION

The staff of the Air Resources Board (ARB or Board) intends to establish new motor vehicle fuel specifications for biodiesel as part of the proposed regulation on the commercialization of new alternative diesel fuels (ADFs). The ADF regulation[1] is intended to provide a legal pathway for new, emerging alternative diesel fuels to enter the commercial market in California, while managing and minimizing environmental and public health impacts, and to preserve the emissions benefits derived from the ARB motor vehicle diesel regulations.

Health and Safety Code (H&SC) 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. "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 a summary of the renewable diesel multimedia evaluation and staff's internal assessment of emissions data and air quality impact information obtained during the multimedia evaluation process. This report also provides staff's overall conclusions and recommendations to the CEPC.

A. Multimedia Evaluation of Renewable Diesel

Pursuant to H&SC section 43830.8, researchers from the University of California (UC), Berkeley and UC Davis conducted the multimedia evaluation of renewable diesel compared to CARB diesel. Due to the specific fuel properties and indistinguishable chemical compositions of renewable diesel and CARB diesel, the UC researchers and the MMWG determined that additional Tier II experiments were not needed. Therefore, 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)[3]
- California Renewable Diesel Multimedia Evaluation Final Tier III Report (Final Tier III Report or Renewable Diesel Final Report)[4]

During Tier I of the multimedia evaluation of renewable diesel, the UC researchers completed a detailed review of the fuel, evaluated potential impacts, and identified

[1] Air Resources Board. *Proposed Regulation on the Commercialization of New Alternative Diesel Fuels Staff Report: Initial Statement of Reasons*, October 23, 2013.
[2] Health and Safety Code section 43830.8(b).
[3] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier I Report*, Sept 2011.
[4] McKone, T.E. et al.*California Renewable Diesel Multimedia Evaluation Final Tier III Report*, Apr 2012.

knowledge gaps. The overall scope of the evaluation was also established. The scope and knowledge gaps identified in Tier I did not require further Tier II testing or impact assessments.

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 fuel, as specified in the multimedia evaluation and proposed regulation, does not pose a significant adverse impact on public health or the environment.

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 (CARB Emissions Study).[5] 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.

[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.

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.[6] 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." [7]

Renewable diesel is required to meet the same ASTM D975 standards as conventional diesel and is composed of saturated hydrocarbons similar to conventional CARB diesel along with performance and stability additives.[8]

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.

[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.
[7] *Low Carbon Fuel Standard.* Title 17, CCR, Sections 95480-95490,16.
[8] McKone, T.E.et al. *California Renewable Diesel Multimedia Evaluation Final Tier III Report*. Apr 2012, 8.

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.[9]

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]

[9] 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.[10] 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.[11] 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.[12] Emerald Biofuels plans to build a renewable diesel facility using the Honeywell process, with a production capacity of 85 million gallons per year.[13]

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[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).

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. [14]

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

[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.

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.[15]

i. Criteria Pollutant Emissions and Ozone Precursors Results

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.

[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.

Table 5. Emissions Results on UDDS Cycle

	THC	ΔTHC	CO	ΔCO	NOx	ΔNOx	PM	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

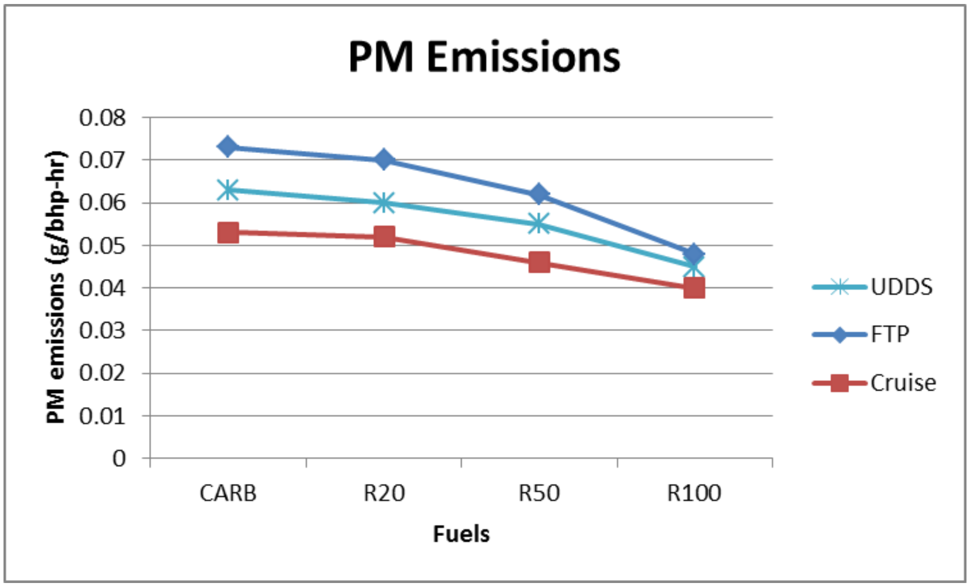
	THC	ΔTHC	CO	ΔCO	NOx	ΔNOx	PM	ΔPM
CARB	0.294	*0.0%*	0.701	*0.0%*	2.088	*0.0%*	0.073	*0.0%*
R20	0.296	*0.7%*	0.675	*-3.7%*	2.027	*-2.9%*	0.07	*-4.1%*
R50	0.293	*-0.3%*	0.643	*-8.3%*	1.975	*-5.4%*	0.062	*-15.1%*
R100	0.284	***-3.4%***	0.614	***-12.4%***	1.882	***-9.9%***	0.048	***-34.2%***

Table 7. Emissions Results on 50 mph Cruise Cycle

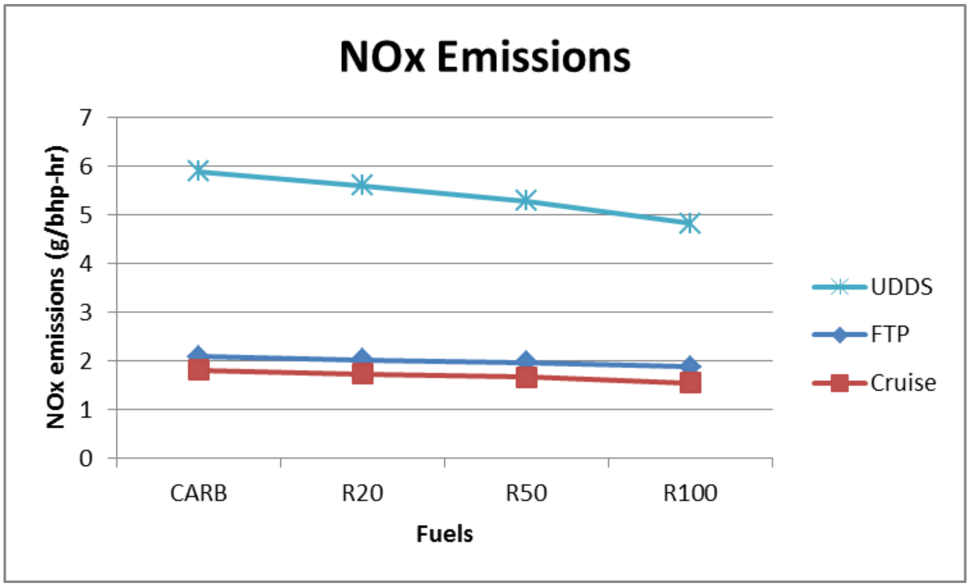
	THC	ΔTHC	CO	ΔCO	NOx	ΔNOx	PM	ΔPM
CARB	0.176	*0.0%*	0.452	*0.0%*	1.809	*0.0%*	0.053	*0.0%*
R20	0.18	*2.3%*	0.454	*0.4%*	1.74	*-3.8%*	0.052	*-1.9%*
R50	0.18	*2.3%*	0.459	*1.5%*	1.667	*-7.8%*	0.046	*-13.2%*
R100	0.174	***-1.1%***	0.467	***3.3%***	1.553	***-14.2%***	0.04	***-24.5%***

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, 2, 3, and 4 show PM, NOx, CO, and THC emissions, respectively.

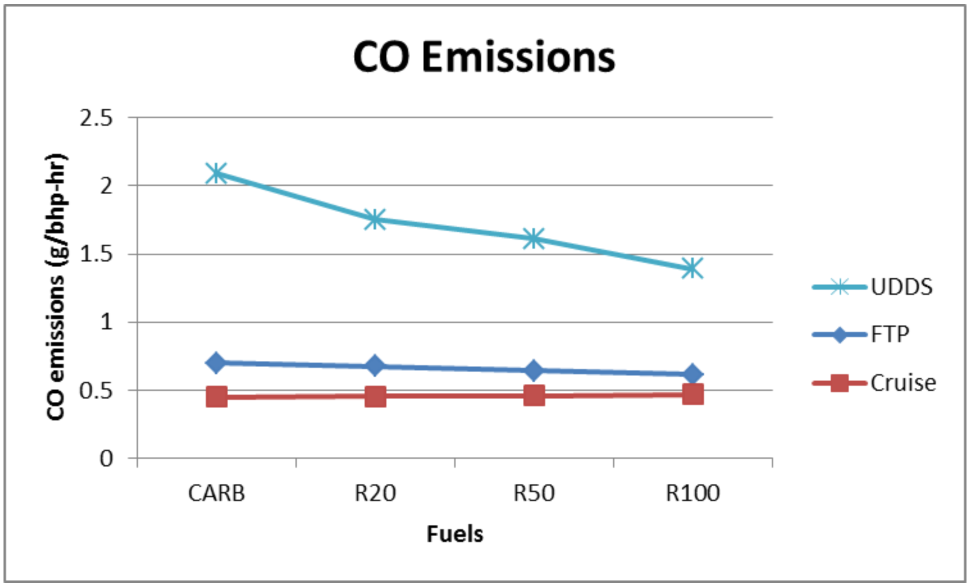
Graph 1. PM Emissions of R20, R50, and R100 Relative to CARB Diesel by Test Cycle



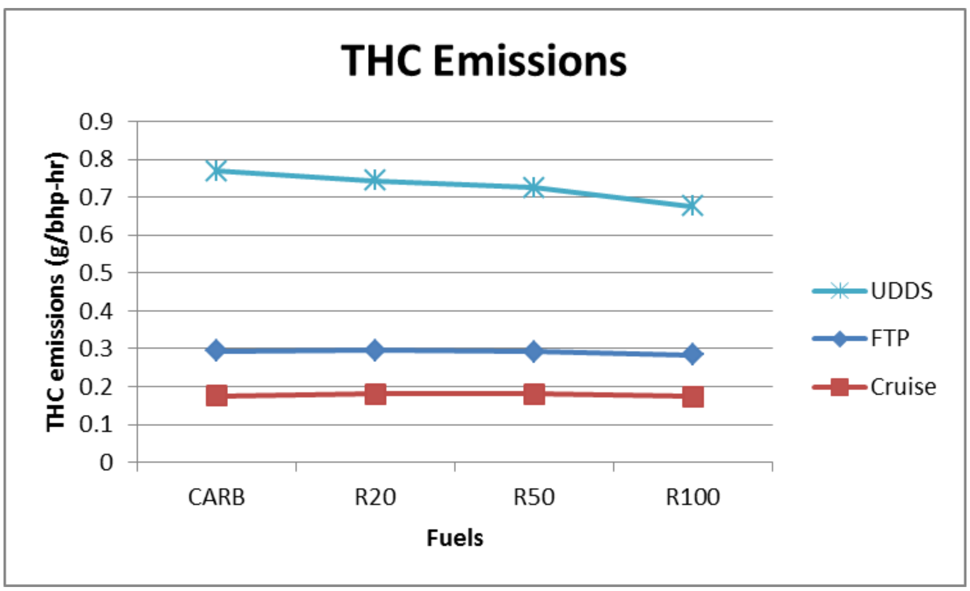
Graph 2. NOx Emissions of R20, R50, and R100 Relative to CARB Diesel by Test Cycle



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



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



ii. <u>Toxic Pollutant Emissions Results</u>

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

iii. Greenhouse Gas Emissions

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.[16]

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

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%.

[16] 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).

4. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In this chapter, staff provides the multimedia evaluation 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 emission testing protocol and impact analysis on criteria pollutants, toxic air contaminants, and ozone precursors.

Staff's assessment is based on the data and information provided for the renewable diesel multimedia evaluation, including the UC multimedia reports (Final Tier I, Tier II, and Tier III reports) and the CARB Emissions Study[17] report by UC Riverside from emissions testing conducted at CE-CERT and ARB emissions test facilities in Stockton and El Monte, California.

i. Criteria Pollutants

Emissions testing was conducted on renewable diesel (R100) and two renewable diesel blends (R20 and R50) compared to the baseline CARB diesel 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.

Test results on pure renewable diesel fuel, R100, showed that PM emissions generally decreased by about 30% and NOx emissions generally decreased by about 10%. THC generally decreased by about 5% and CO generally decreased by about 10%, but BSFC generally increased by about 5%.[18]

ii. Toxic Air Contaminants

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.

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[17] 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.

[18] 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.

Test results show that the use of renewable diesel reduces PM emissions by about 30%.[19]

Other toxic emissions tests were conducted for various carbonyls, VOCs, and 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 performed on the fuels and in all cases renewable diesel showed either reduced toxicity compared to CARB diesel or no difference in toxicity.[20]

iii. Ozone Precursors

Test results show a decrease in NOx emissions and most VOCs. THC emissions decreased generally by about 10% from CARB diesel emissions levels. Overall, it's expected that use of renewable diesel would result in an improvement in ground level ozone compared to use of CARB diesel.[21]

iv. Greenhouse Gas Emissions

The use of renewable diesel decreased 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. The outcome of an LCA is greatly dependent on the feedstock source. The LCFS LCA of renewable diesel shows reductions in GHGs of about 15% to 80% depending on feedstock source.[22]

B. Conclusions

Based on a relative comparison between CARB diesel and renewable diesel, ARB staff concludes that the use of renewable diesel and the resulting air emissions do not pose a significant adverse impact on public health or the environment.

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.

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[19] 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, 85.

[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, 148,164.

[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.

[22] 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).

- 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 emission impacts from the use of renewable diesel, ARB staff recommends that the CEPC find that the use of renewable diesel, as specified in this 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 4.

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. 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).
17. Same as Footnote 5.
18. Same as Footnote 5.
19. Same as Footnote 5.
20. Same as Footnote 5.
21. Same as Footnote 5.
22. Same as Footnote 16.

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.

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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 Effects of Renewable Diesel Fuel

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Staff Report on Health Impacts of Renewable Diesel Fuel

March 2013

Office of Environmental Health Hazard Assessment
California Environmental Protection Agency

Document Authors

John Budroe, Ph.D., D.A.B.T.
Hristo Hristov, M.D., Ph.D.
Page Painter, Ph.D., M.D.

Document Reviewers

Allan Hirsch
Lauren Zeise, Ph.D.

Introduction

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

Combustion emissions

Diesel engine emissions from combustion of HVORD and CARB ULSD were quantified by the Center for Environmental Research and Technology at the University of California, Riverside (CARB, 2011). The renewable diesel fuel was produced by Neste Oil and denoted NExBTL fuel. The CARB fuel used was certified CARB ULSD. 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.

Particulate matter (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 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 ISN 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, 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 significant increase in CO using R100 during the 50 mph cruise simulation protocol.

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.

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.

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 renewable diesel in CARB-renewable diesel blends (R20, R50 and R100).

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) (< 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 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. 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 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.

In the presence of a DOC/POC, 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. 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 a EN590-fueled engine was described by the authors as “minor” (93% reduction compared to a non-DOC/POC equipped-engine). Total hydrocarbons were below the detection limit for both fuel types, and aldehydes/ketones could not be measured in the DOC/POC output due to analytical interference.

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.

Jalava *et al*. (2010) 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 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, but 18% greater when a DOC/POC was used.

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. 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.

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 (64 and 66 percent, respectively) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in the absence of a DOC/POC. In the presence of a DOC/POC, total PAHs were moderately reduced (18%) while genotoxic PAHs were slightly increased (6%) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust.

Toxicity testing of combustion emissions

In the combustion emissions study performed for the California Air Resources Board (CARB, 2011), *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.

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.

HVORD or HVORD blend-fueled engine particulate phase exhaust extracts did not increase 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 compared when exposed to particulate phase exhaust extract from a ULSD-fueled engine.

Jalava *et al*. (2012) compared exhaust toxicities from a 2005 model year Scania heavy-duty diesel engine equipped with a DOC/POC 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.

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. There was no significant difference in release of either cytokine between the fuel types when a DOC/POC was used.

DNA damage (Comet assay) in mouse macrophage RAW264.7 cells treated *in vitro* with by HVORD-fueled engine PM was substantially increased compared to cells treated with EN590-fueled engine PM in the absence of a DOC/POC. However, in the presence of a DOC/POC 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.

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 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.

Jalava *et al*. (2012) compared exhaust toxicities from a 2005 model year Scania heavy-duty diesel engine equipped with a DOC/POC and fueled with EN590 or HVORD using a Braunschweig test cycle (Murtonen *et al*.,2009).

Particulate-phase total and genotoxic PAHs (expressed as ng/mg PM) were reduced in 100% HVORD-fueled engine exhaust (approximately 25% reduction) but not in 30% HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in engines not fitted with DOC/POCs. In contrast, 78 and 88% increases in particulate-phase PAHs (total and genotoxic, respectively) were noted for the HVORD-fueled engine compared to the EN590-fueled engine when the engine was equipped with a DOC/POC.

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 percent, respectively) in HVORD-fueled engine exhaust compared to EN590-fueled engine exhaust in the absence of a DOC/POC. 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.

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 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.

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. There was no significant difference in release of either cytokine between the fuel types when a DOC/POC was used.

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. 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.

Conclusions

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 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 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 some CARB ULSD use by HVORD use.

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APPENDIX F

Department of Toxic Substances Control: Recommendation on Proposed Renewable Diesel

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Department of Toxic Substances Control

Matthew Rodriquez
Secretary for
Environmental Protection

Deborah O. Raphael, Director
1001 "I" Street
P.O. Box 806
Sacramento, California 95812-0806

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

Thomas E. McKone
David W. Rice
University of California, Berkeley

Timothy R. Ginn
University of California, Davis

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

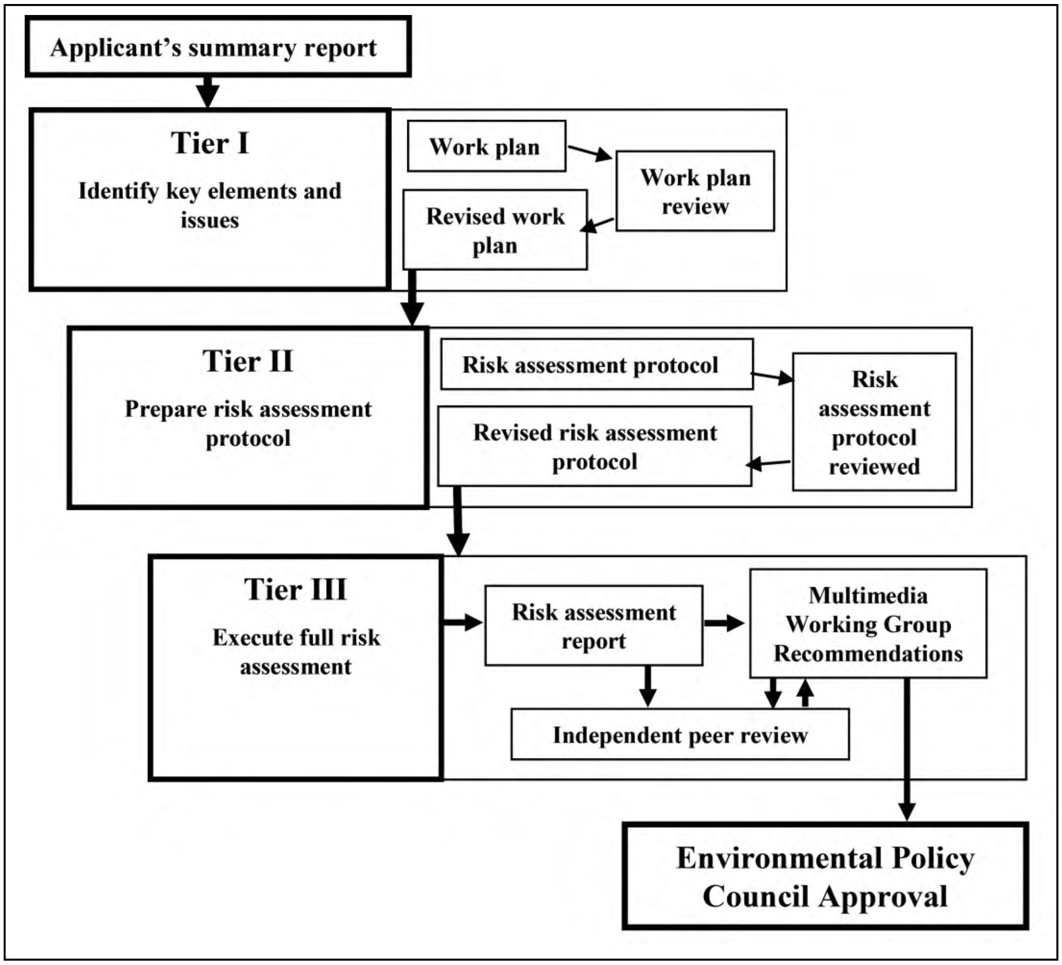

Figure 1.1. Multimedia evaluation process flow chart

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

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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

Prepared By

Thomas E. McKone
David W. Rice
University of California, Berkeley

Timothy R. Ginn
University of California, Davis

For the

California Environmental Protection Agency
Multimedia Working Group

FINAL

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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.

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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.

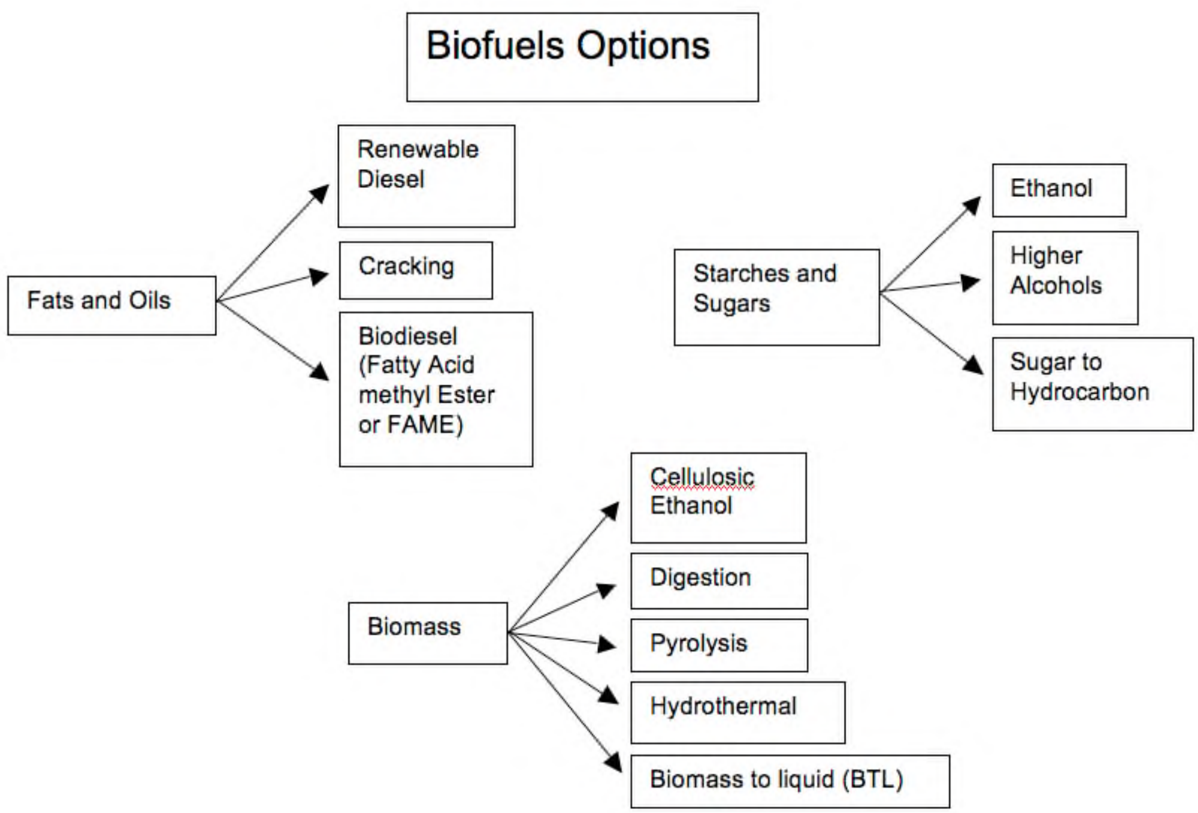

Figure 1.1. Summary of biofuel options.

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).

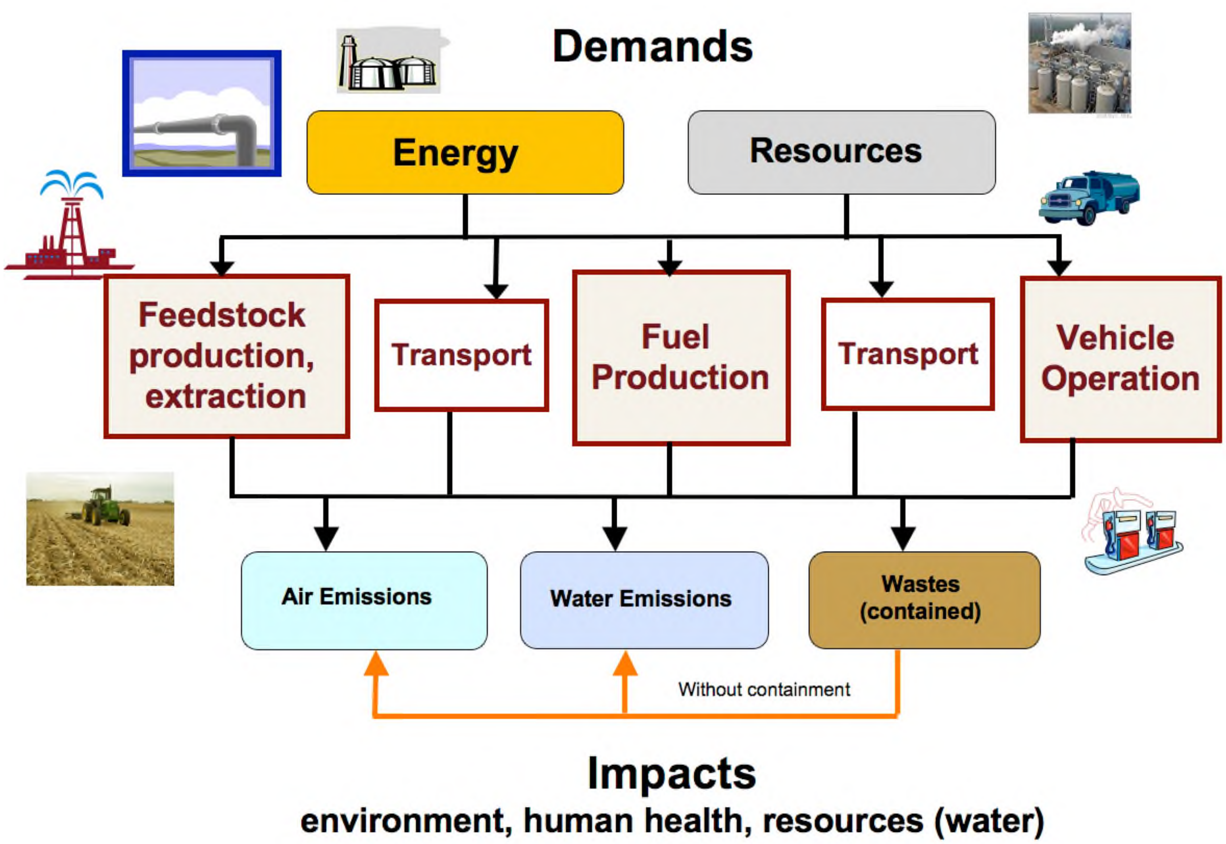

Figure 1.2. Generalized summary of renewable diesel life cycle impacts.

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.

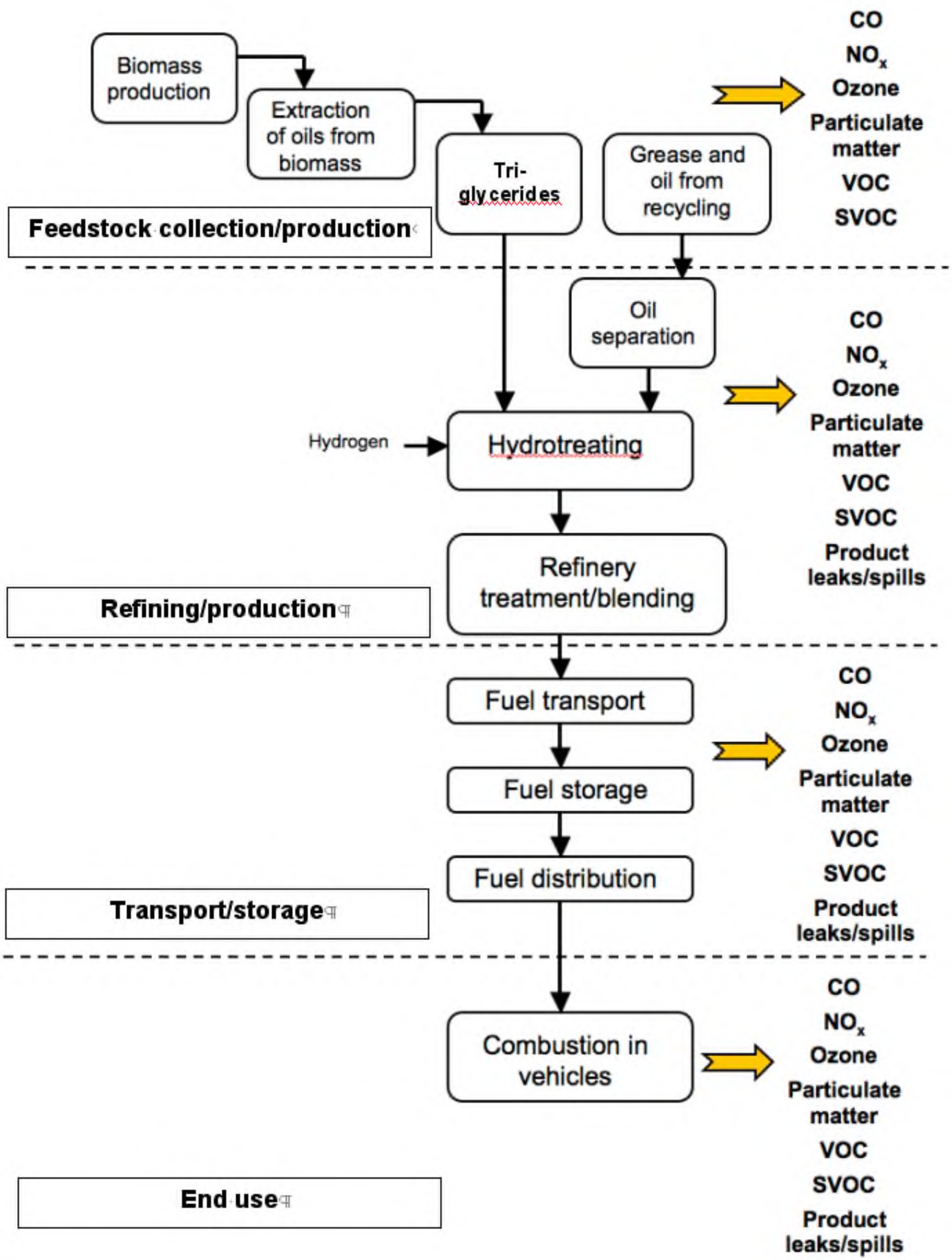

Figure 2.1. An illustration of life cycle stages and some potential life-cycle pollutant emissions for renewable diesel fuels.

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).

Year	**Advanced Biofuel**					**Non-Advanced Biofuel**	**Total Renewable Fuel**
	Cellulosic Biofuel	**Biomass-Based Diesel[a]**		**Other Advanced Biofuel**			
	Cellulosic Ethanol	**FAME[b] Biodiesel**	**Non-Co-processed Renewable Diesel**	**Co-processed Renewable Diesel**	**Imported Ethanol**	**Corn Ethanol**	
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.

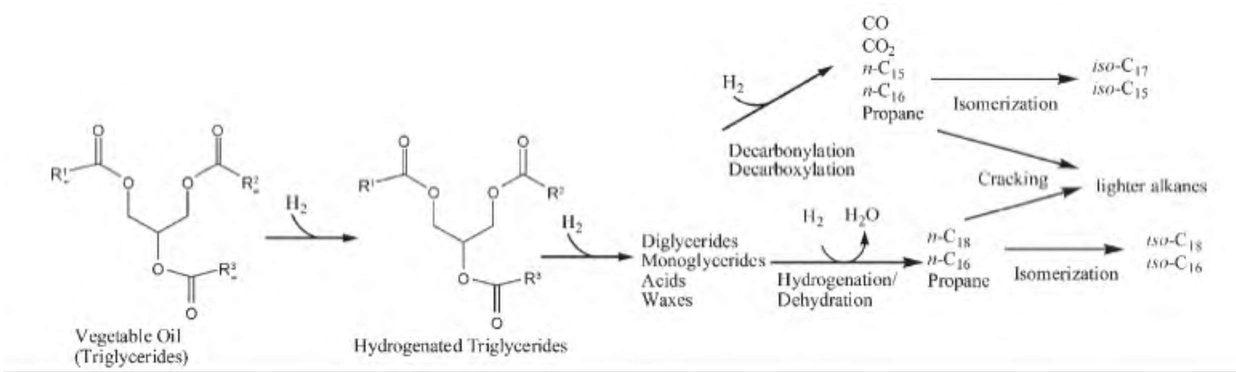

Figure 4.2. Hydrogenation of Triglycerides

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).

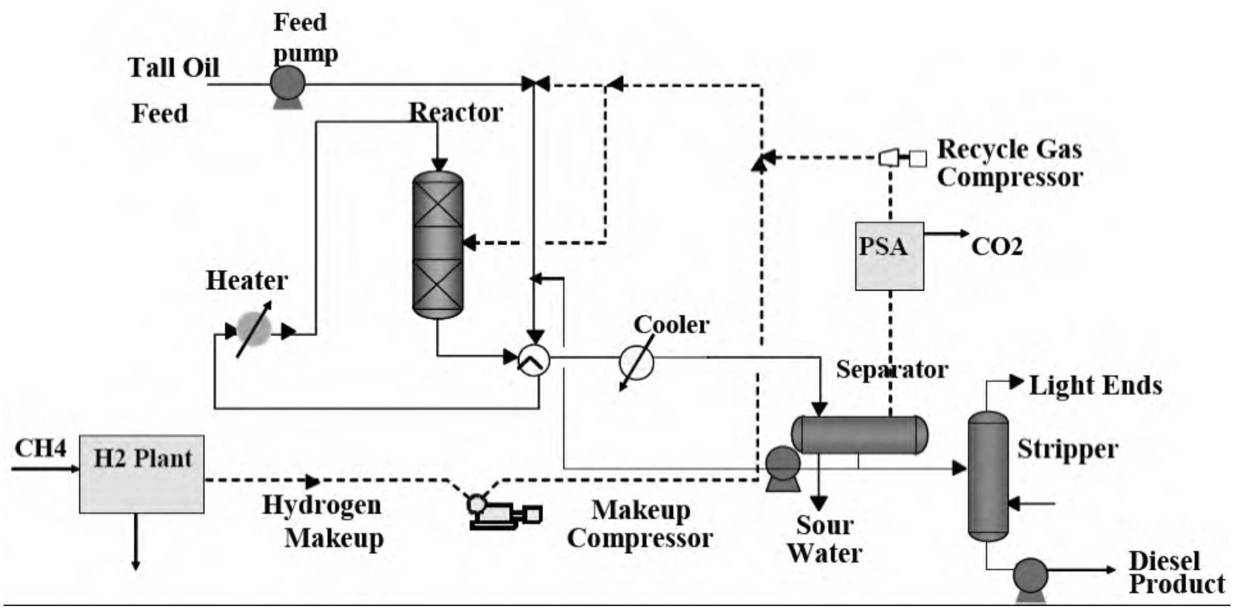

Figure 4.3. Stand-alone Renewable Diesel Production Unit used to produce a pure HDRD product (R100). Adapted from Kalnes et al. (2007).

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^{o}C	D445	2.0-3.2	NA	1.9-4.1	2.219
Lubricity, HFRR@60^{o}C, micron	D6079	NA	NA	520 max.	442.5
Ash, % mass	D482	NA	NA	0.01	<0.001
Cloud Point, ^{o}C	D2500	NA	NA	D975 spec.[d]	-15.25
Cold Filter Plugging Point, ^{o}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, ^{o}C	D86	171-204	146-201	NA	163
10%, ^{o}C	D86	204-238	194-258	NA	197
50%, ^{o}C	D86	243-282	240-284	NA	245
90%, ^{o}C	D86	293-321	293-337	282-338	314
EP, ^{o}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.

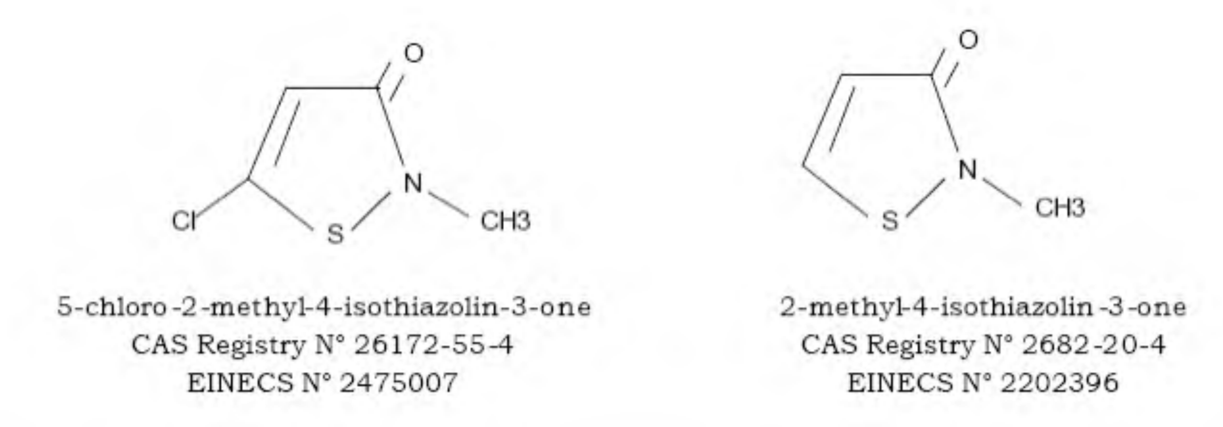

Figure 5.1. Rohm and Haas Kathon FP 1.5 Biocide (Rohm and Haas, 1999).

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 μg/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.

10. References

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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.

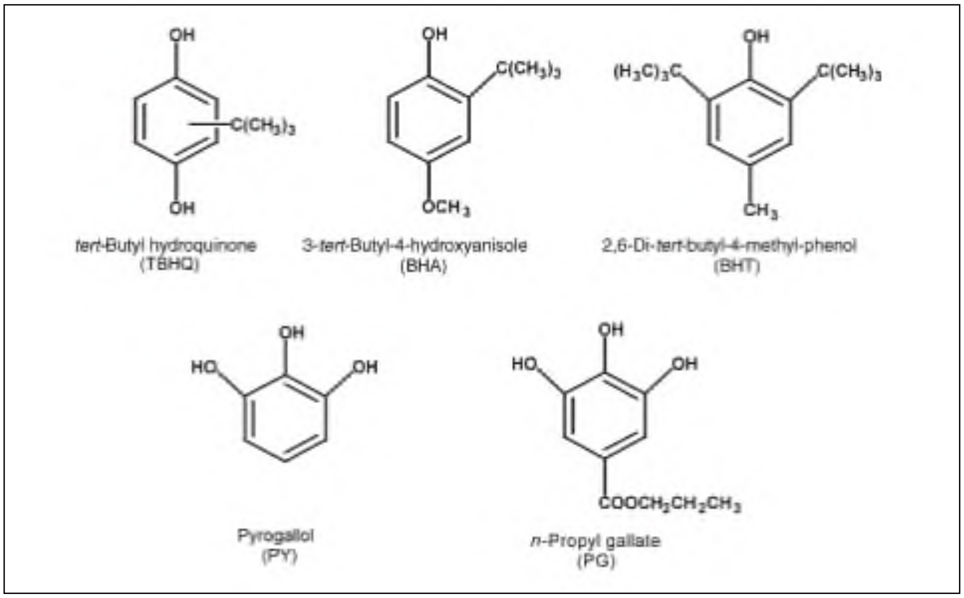
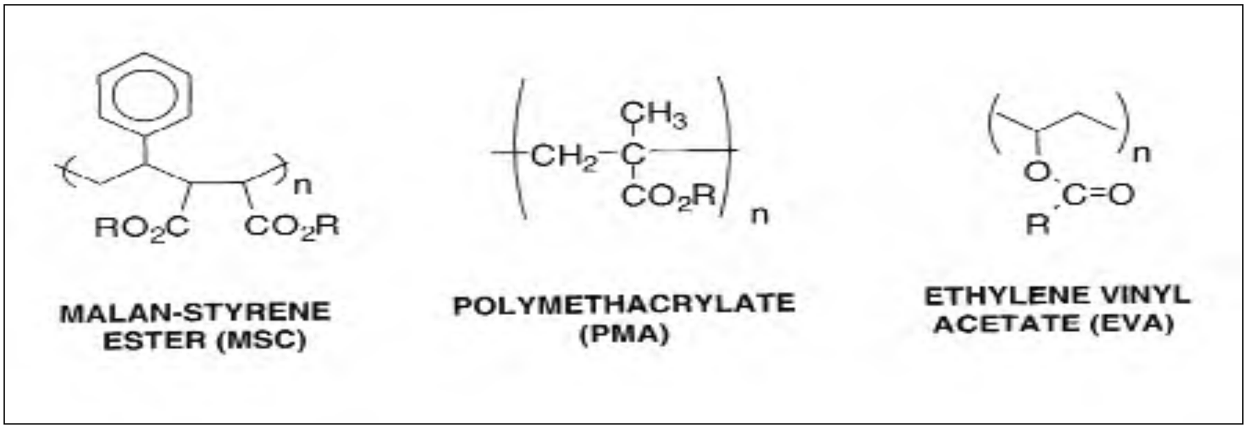


Table B-1. Commercial Biodiesel Antioxidants**.**

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 External Peer Review of the Multimedia Evaluation of Renewable Diesel

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Air Resources Board

Mary D. Nichols, Chairman
1001 I Street • P.O. Box 2815
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 Review Comments

WILL BE ADDED
AFTER PEER REVIEW IS COMPLETE

APPENDIX J

Multimedia Working Group Responses to Peer Review Comments and Individual Agency Responses to Comments

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