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Low Carbon Fuel Standard Program Air Emissions Effects

Final Report

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COORDINATING RESEARCH COUNCIL, INC.

5755 NORTH POINT PARKWAY·SUITE 265·ALPHARETTA, GA 30022

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Low Carbon Fuel Standard Program
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FINAL REPORT

Prepared for:
Coordinating Research Council
5755 North Point Parkway, Suite 265
Alpharetta, Georgia 30022

Prepared by:
Chris Lindhjem
ENVIRON International Corporation
773 San Marin Drive, Suite 2115
Novato, California 94998
www.environcorp.com
P-415-899-0700
F-415-899-0707

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1.0 INTRODUCTION

The purpose of the California Low Carbon Fuel Standard (LCFS) is to reduce greenhouse gas (GHG) emissions by reducing the full fuel-cycle carbon intensity of the transportation fuel pool used in the state. While the LCFS may reduce GHG emissions, the resulting effect on precursor emissions of ozone and particulate matter (PM) and consequential effects on air quality are less well understood.

The California Air Resources Board (ARB, 2009) approved the LCFS regulation in 2009 to reduce GHG emissions by achieving a 10% reduction in the carbon intensity of transportation fuels used in California by 2020 relative to fuels produced in 2010. ARB (2011) approved amendments to the LCFS in December 2011, which became effective on November 26, 2012 and were implemented by ARB on January 1, 2013. To address a court ruling on existing regulations and provide lasting market certainty, ARB intended to propose a comprehensive re-adoption of the LCFS regulation in the fall of 2014. ARB (2009, 2011) has provided two sets of staff reports on the effects of LCFS and will continue to conduct a series of public workshops in preparation for the re-adoption proposal.

Air quality benefits may accrue from LCFS regulation, but, to date, ARB (2009, 2011) has only provided its expectation that emissions will decrease overall. Emissions reductions of some primary pollutants (e.g., sulfur dioxide (SO_2) and carbon monoxide (CO)) would result in nearly proportional reductions in ambient concentrations. Conversely, precursor emissions (e.g., nitrogen oxides (NOx), volatile organic compounds (VOC)) reductions do not always provide air quality benefits (i.e., NOx reductions can result in ozone increases due to the reduction in the titration of ozone by nitric oxide (NO) —known as the NOx disbenefit; this occurs in NOx-rich chemical environments where there is insufficient VOC to form higher levels of ozone); hence, it is important to first understand potential emissions changes before evaluating air quality changes.

The purpose of this report was to critically review the relevant literature of how the LCFS rule may affect air emissions and air quality. We first provide a short general summary of the rule requirements, and then discuss in greater detail the potential emissions changes from implementation.

1.1 Overview of Low Carbon Fuel Standard

The intent of the LCFS is to reduce the carbon intensity of transportation fuels by 10% by 2020 relative to 2010. The LCFS applies to the following types of fuels:

1. California reformulated gasoline (“gasoline” or “CaRFG”);
2. California diesel fuel (“diesel fuel” or “ULSD”);
3. Fossil compressed natural gas (“Fossil CNG”) or fossil liquefied natural gas (“Fossil LNG”);
4. Biogas CNG or biogas LNG;
5. Electricity;
6. Compressed or liquefied hydrogen (“hydrogen”);

7. A fuel blend containing hydrogen ("hydrogen blend");
8. A fuel blend containing greater than 10 % ethanol by volume;
9. A fuel blend containing biomass-based diesel;
10. Denatured fuel ethanol ("E100");
11. Neat biomass-based diesel ("B100"); and
12. Any other liquid or non-liquid fuel.

The LCFS can be met in a number of ways through certifying fuels and/or buying credits generated by alternative fuel/energy types. Credits for the LCFS can be generated for the following fuel/energy types as long as their use in transportation vehicles can be determined and documented:

1. Electricity;
2. Hydrogen;
3. A hydrogen blend;
4. Fossil CNG derived from North American sources;
5. Biogas CNG; and
6. Biogas LNG.

The transportation fuels include fuels sold to intrastate locomotives, harbor craft, and most types of off-road engines. The effect of the LCFS thus extends to most off-road equipment.

2.0 AIR QUALITY IMPACT

The air quality impact of the LCFS will derive from the emissions changes from fuel production and use of low carbon fuels in vehicles and off-road equipment. Emissions changes may result from an increased number of biofuel production facilities and transportation of feedstock and finished fuel to and from those facilities; use of biofuels in vehicles and equipment emissions; or larger numbers of advanced zero-emissions or alternatively-fueled vehicles. While the overall state-wide criteria pollutant emissions may change little or even be reduced, emissions may increase or decrease locally or regionally as a result of this regulation.

ARB (2009) provided its analysis of the criteria pollutant emission changes, and noted in ARB (2011) that regulation modifications from 2009 had not affected criteria pollutant emissions estimates. Discussed below are the background and uncertainties associated with the ARB (2009) analysis of the criteria pollutant emission changes associated with the LCFS.

2.1 Fuel Production

New fuel production facilities in support of the LCFS are most likely to produce biodiesel (Fatty Acid to Methyl Esters - FAME) derived from vegetable oil or animal tallow, renewable diesel (from hydrotreated or Fischer-Tropsch treated biomass or biogas), and ethanol (cellulosic or from crop sugar fermentation). ARB expected that the incremental changes to natural gas, petroleum liquid fuel, or electrical generation demand would have a negligible effect on emissions.

Emissions associated with new fuel production facilities are due to feedstock production and delivery, transportation of finished fuel, and the stationary sources at the processing facilities. Each of these is discussed below.

2.1.1 Feedstock Production, Transportation and Distribution

Feedstock production includes delivery of materials used in making fuel, including waste oil, plant oils, and waste paper or other forms of cellulose. ARB concluded that current corn ethanol production capacity will continue but not be increased, and expected that new ethanol production facilities will produce ethanol from cellulosic feedstock. Likewise, ARB expected most new biodiesel facilities will produce biodiesel from waste oil or vegetable oils and use the Fatty Acids to Hydrocarbon (FAHC) process through hydrotreatment. Table 1 provides the expected emission increases from feedstock supply to new ethanol and biodiesel facilities operating as a result of the LCFS.

Table 1. Criteria pollutant emissions increases in 2020 from transportation of feedstock in support of production and supply of new biofuel production facilities built for LCFS compliance (tons/day) (ARB, 2009).

Fuel Type	VOC	CO	NOx	$PM_{2.5}$
Cellulosic Ethanol	0.02	0.33	0.80	0.02
Biodiesel	0.01	0.09	0.20	0.006

ARB expected that the production facilities would be located close to feedstock, within 50 miles of a biorefinery, as well as close to rail yards, freeways, and other distribution sites or blending terminals, reducing the distance for transportation of feedstock and finished product to and from these facilities.

ENVIRON notes one uncertainty in the forecasts is that it may be difficult to locate such facilities close to both feedstock and distribution sites, increasing the possibility that transportation emissions could be higher than ARB has forecasted. However, we suspect that the fuel distribution transportation distance is more uncertain than transportation distance associated with feedstock production and supply because, for example, important agricultural and forestry waste feedstock likely come from areas further from blending terminals.

2.1.2 Fuel Distribution

ARB stated that there are 45 blending terminals in California, and assumed that fuel production facilities would be sited near these terminals, reducing the distance for transporting finished fuel to an average of 20 miles per round truck trip. It is possible that, because fuel production sites need to be located near available feedstock to be cost effective, the distance to the blending terminals may increase. ARB's estimate of the transportation emissions generated by transportation of biofuel delivery is shown in Table 2.

Table 2. Criteria pollutant emissions increases in 2020 from finished biofuel transportation and distribution from new biofuel production facilities built for LCFS compliance (tons/day).

Fuel Production Facility	VOC	CO	NOx	$PM_{2.5}$
Cellulosic Ethanol	0.04	0.05	3.58	0.063
Biodiesel	0.011	0.047	0.61	0.003

2.1.3 Fuel Production

ARB (2009) forecasted that 18 new cellulosic ethanol and 6 new biodiesel fuel production facilities are to be built within California to supply biofuels for the California market. Based on the map of potential biorefinery locations (Figure VII-1, ARB 2009), most of the new facilities were expected to be located out of urban areas, but ARB noted that emissions from new facilities even if located within nonattainment areas would be offset to meet permit requirements. Table 3 shows the expected emissions change from new biofuel facilities built and operated as a result of the LCFS requirements.

Table 3. Criteria pollutant emissions increase in 2020 from biofuel production facilities built to supply fuel for LCFS compliance (tons/day).

Fuel Production Facility	VOC	CO	NOx	$PM_{2.5}$
Cellulosic Ethanol	12.39	2.49	4.76	0.65
Biodiesel	7.82	3.21	0.95	0.25

Most of the current ethanol facilities are located outside of urban areas, and ARB expected that the trend of siting facilities in rural areas will continue. The emission increases from new

facilities would then occur primarily outside of nonattainment areas or be entirely offset within nonattainment areas. For these reasons, ARB expected no change in statewide or regional emissions from the increases shown in Table 3.

2.1.4 Fuel Production Emissions Uncertainty

ENVIRON notes that the competing interests between fuel production facilities being sited near blending terminals while also near affordable and available feedstock increases the uncertainty in the fuel production and distribution transportation distances.

The need for inexpensive feedstock, especially for cellulosic ethanol facilities, may limit available sites close to both feedstock and blending terminals. Wood or agricultural waste feedstock would likely be generated in rural areas, while municipal waste paper will more likely be collected at urban landfill locations. The proximity of this feedstock and blending terminals to the production facilities is the largest uncertainty in the forecasted fuel transportation emissions estimates.

For biodiesel production, ARB assumed that waste oils delivered to landfill or similar collection sites will be used as the feedstock and therefore production sites would be co-located with landfills. However, FAHC hydrotreatment of waste oils or rurally produced vegetable oils requires hydrogen production, and so FAHC facilities may need to be located near refineries or other similar facilities where hydrogen is generated, increasing the uncertainty in the forecasted delivery distance of feedstock oil.

2.2 Vehicle Emission Effects

ARB estimated the impact of the LCFS on the vehicle emission effects using five hypothetical compliance scenarios. The five scenarios are summarized below:

1. Use of crop-based biofuels with a gradual increase in the number of flex-fueled vehicles (e.g. E85) and advanced (electric or hydrogen) technology vehicles increase to 560,000 vehicles by 2020.
2. Same as Scenario #1 with greater use of cellulosic, renewable, or sugar cane ethanol.
3. Same as Scenario #2 with larger increases of advanced technology vehicles to 1,000,000 by 2020.
4. Same as Scenario #3 with advanced technology vehicles increasing to 2,000,000 by 2020.
5. Same as Scenario #3 with less E85 and less use of cellulosic or other non-conventional ethanol.

ARB grouped the emission impacts for the five scenarios according to the number of advanced technology (zero emitting) vehicles assumed. So Scenarios 1 and 2 had the same emissions estimates with 560,000 advanced technology vehicles by 2020 and were compared with Scenarios 3 & 5 with 1,000,000 advanced technology vehicles, and Scenario 4 with 2,000,000 vehicles. For reference, the number of registered autos in California exceeds 23,000,000, so

about two to nine percent of autos would use zero emissions technology in 2020 if there was no significant change in the fleet size.

ARB expected that biofuels will not affect vehicle emissions when used in a combustion engine, likely because gasoline vehicles can adjust the fuel-air mixtures when varying levels of approved ethanol mixtures are used, and biodiesel must be produced to be at least NOx neutral. ARB estimated that additional emission reductions would accrue from increased use of CNG vehicles and production of surplus low NOx renewable diesel.

2.2.1 Ethanol Fuel Use

ARB assumed that ethanol was blended with gasoline at 10% by volume in 2010 and at the same level in future years in conventional vehicles. ARB expects additional ethanol consumption would occur only with higher ethanol blends used in flex-fueled vehicles designed for ethanol content up to 85%, E85. ARB (2009) did not estimate a change in vehicle or off-road equipment emissions with the introduction of LCFS, except for a small increase in evaporative emissions from comingling and other aspects of higher ethanol blends.

2.2.2 Biodiesel Fuel Use

Biodiesel produced from vegetable oils or animal tallow has been shown to increase NOx. ARB[1] estimated a 4.1% NOx increase from soy-based B20 (20% biodiesel and 80% California diesel) biodiesel blend use, and a 1.6% NOx increase from animal fat B20 use. ARB arrived at this average result based on a compilation of experimental studies, but one reason that animal fat biodiesel could have a lower NOx increase is due to a higher level of saturation of the resulting esters produced from animal fat. ARB[2] in its Alternative Diesel Fuel proposal to mitigate biofuels NOx increases found that the NOx increase to be approximately proportional to the amount of biodiesel used and concluded the following:

- NOx emissions increase about 1% in blends containing five volume percent soy-based biodiesel; however, no NOx increases occur in blends containing five volume percent animal-based biodiesel;
- NOx emissions increase about 2% in blends containing ten volume percent soy-based biodiesel;
- NOx emissions increase about 4% in blends containing twenty volume percent soy-based biodiesel;
- Biodiesel made from animal tallow generally exhibits about half or less the NOx increase compared to soy-based biodiesel;
- Blends containing twenty volume percent soy-based biodiesel, fifty-five volume percent renewable diesel (hydrotreated renewable feedstock or gasified feedstock to liquids with low aromatic and high cetane content) and twenty five volume percent conventional diesel result in no NOx increase;

[1] http://www.arb.ca.gov/fuels/diesel/altdiesel/20130423ADFWorkshopPresentation.pdf
[2] http://www.arb.ca.gov/fuels/diesel/altdiesel/20140729ADF_SRIA_Proposal.pdf

- Use of one volume percent di-tert-butyl peroxide (usually considered a cetane enhancing additive) in blends containing twenty percent soy-based biodiesel exhibit no NOx increase; and
- There are no NOx increases in light duty vehicles or new technology diesel engines (NTDE) due to the use of selective catalytic reduction (SCR); these new engines are expected to represent 95 % of heavy duty engines in-use by 2024.

ARB expected that the proposed Alterative Diesel Fuel regulation would eliminate any NOx increase from use of biodiesel fuel. The following describes the biodiesel regulation requirements:

1. Biodiesel blends less than 1% from soy or non-animal feedstock are assumed to have no NOx increase. Higher blends of soy biodiesel require mitigation using the following options:
    A. Use of di-tert-butyl peroxide
    B. Co-blend with renewable diesel
    C. Certification of alternatives
    D. Area averaging with low NOx diesel
    E. Example Options
        i. 1% di-tert-butyl peroxide with soy B20
        ii. 2.75 gallons of renewable for every gallon of soy-based biodiesel
2. Biodiesel blend less than 5% from animal tallow feedstock are assumed to have no NOx increase. Higher blends of animal tallow biodiesel require mitigation at half the levels suggested for soy biodiesel.

Based on our understanding of the proposal, the Alternative Diesel Fuel regulation would allow a small NOx increase of less than 0.5%. Use of the 'de minimus' blend level would ensure a small NOx increase, and mitigation additives may not fully mitigate the NOx increase found with higher biodiesel content blends. While in the Alternative Diesel Fuel regulation, ARB expected that the potential NOx increase with mitigated biodiesel use would be small and would decrease as SCR systems on new diesel engines become more prevalent. ARB also expected that the LCFS rule will encourage greater use of low NOx renewable (hydrotreated) diesel than the 2.75 to 1 ratio allowed and therefore produce a NOx decrease overall.

2.2.3 CNG Use

New CNG engines have been certified to lower NOx emission standards than comparable diesel engines. Because the LCFS encourages the use of CNG and especially bio-generated CNG (such as from landfill gas or anaerobic digestion), ARB expected that displacement of diesel with CNG vehicles would reduce NOx emissions.

2.2.4 Electric Vehicles

ARB estimated the emissions effects for the five compliance scenarios, and Table 4 shows the expected emission reductions from the LCFS when fully implemented in 2020 (see Section 2.2.5 for a discussion of the reasonableness of the estimates for the number of ZEVs).

Table 4. Criteria pollutant emissions reductions in 2020 from vehicles under the LCFS (tons/day).

Scenario (Zero Emitting Vehicles)	VOC	CO	NOx	$PM_{2.5}$	SOx
1 & 2 (560,000)	2.49	23.29	4.11	0.25	0.74
3 & 5 (1,000,000)	4.11	38.36	6.03	0.41	1.21
4 (2,000,000)	7.95	71.23	14.79	2.47	2.47

2.2.5 Summary of Vehicle Emissions Effects

ARB expected that the number of zero emitting vehicles will largely dictate the emissions change with the introduction of the LCFS, and the summary estimates assumed the middle range estimate of 1,000,000 zero emitting vehicles in use by 2020. In addition, ARB estimated that there will be greater use of low NOx hydrotreated renewable diesel production and increased introduction of CNG vehicles. ARB forecasted the net decrease in statewide emissions, shown in Table 5, demonstrating how advanced technology vehicles and low NOx fuels would offset increased biofuel production and distribution transportation activity.

Table 5. Net change in emissions from LCFS in 2020 (tons/day). (ARB 2009, Table VII-13).

Emission Reduction Source	VOC	CO	NOx	$PM_{2.5}$	SOx
Zero Emitting Vehicles	-4.11	-38.36	-6.03	-0.41	-1.21
Renewable Diesel	0.00	0.00	-2.20	-0.71	0.00
CNG Vehicles	0.00	15.08	-1.64	-0.63	0.00
Transportation and Distribution of Feedstock and Finished Biofuels	0.00	0.52	5.19	0.10	0.03
Total	**-3.88**[a]	**-22.76**	**-4.67**	**-1.65**	**-1.18**

[a] – Includes a small VOC increase from E85 evaporative emissions.

ARB compared the projected emissions reduction from the LCFS rule in Table 5 with a forecast of 2020 statewide total fuel production and all transportation emissions provided in Table 6. This showed that the rule will have a small impact of less than 1% for VOC and NOx and less than 2% $PM_{2.5}$ on statewide emissions from these sources.

Table 6. Baseline transportation fuel production and vehicle emissions in California in 2020 (tons/day). (ARB 2009, Table VII-8).

Source	VOC	CO	NOx	$PM_{2.5}$
Petroleum Production, Refining, and Marketing	104.5	40.0	43.9	7.4
Ethanol and Biodiesel Production	0.5	0.55	1.05	0.15
On and Off-road Gasoline Vehicles and Equipment	636.0	4,947.6	334.6	46.9
On and Off-road Diesel Vehicles and Equipment	73.2	514.9	558.6	19.7
Total	**814**	**5,503**	**938**	**74.2**

To provide an assessment of the maximum effect that the rule may have on regional emissions, ENVIRON chose the South Coast Air Basin (Basin) as a region of significance for air quality planning. ENVIRON estimated that, from the number of vehicles registered[3] or the air quality planning emissions inventory[4], the Basin represents about 30 – 40% of California transportation emissions.

ENVIRON estimated a maximum decrease in emissions in the South Coast if the biofuel production increases occur outside of the air basin. The LCFS rule impact on the Basin could be up to 40% of vehicle and fuel use emission reductions, as shown in Table 5, but without the increase from transportation and distribution of feedstock and biofuels. Table 7 compares the 2020 emission changes with the available planning inventories for 2019 and 2023 showing that our maximum NOx emissions reduction in the South Coast Air Basin could be about -1% and VOC by less than half that level.

Table 7. LCFS maximum emissions decrease in the South Coast Air Basin (tons/day).

Emission Reduction Source	VOC	CO	NOx	$PM_{2.5}$	SOx
LSCF Rule Effect on Vehicle Emissions in 2020[a]	-1.6	-9.3	-3.9	-0.7	-0.5
South Coast Air Basin 2019 Baseline	415	1716	405	70	18
South Coast Air Basin 2023 Baseline	406	1583	328	71	18

[a] – South Coast Air Basin assumed to have 40% of Table 5 low emission vehicles with no Transportation of Feedstock and Finished Biofuel.

The expected emissions reductions will be smaller than shown in Table 7 if fewer advance technology vehicles are introduced than the 1,000,000 estimated. One of the first emission control strategies listed in the South Coast Air Quality Management Plan[5] (ONRD-01 – Accelerated Penetration of Partial Zero-Emission and Zero Emission Vehicles) is similar to one of the expected outcomes of the LCFS regulation. The Air Quality Management Plan estimated that the emission control strategy ONRD-01 would introduce 1,000 zero emission or partially zero emission vehicles per year, or less than the 400,000 (up to 40% of statewide total) new zero emission vehicles by 2020 expected in the Basin as a result of the LCFS regulation. Unless

[3] http://apps.dmv.ca.gov/about/profile/est_fees_pd_by_county.pdf

[4] http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2012-air-quality-management-plan/final-2012-aqmp-(february-2013)/chapter-3-final-2012.pdf

[5] http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2012-air-quality-management-plan/final-2012-aqmp-(february-2013)/chapter-4-final-2012.pdf

the market for zero emission vehicles changes markedly in the next few years however, the number of advanced technology vehicles in use is unlikely to reach the 1,000,000 level by 2020, with about 50,000 reportedly sold so far through 2013.[6]

Alternatively, the expected emissions could increase if a number of expectations are unfulfilled. The number of zero emission or partially zero emission vehicles, use of renewable (low NOx) diesel, and introduction of CNG vehicles could be less than expected. The additional transportation and distribution of feedstock and finished biofuels could then increase emissions regionally. Depending on where biofuel production facilities are located or if, for example, imported ethanol becomes the predominant biofuel,[7] transportation of biofuels could lead to increases in Basin emissions. In an extreme case where no advanced technology vehicles or fewer low NOx renewable diesel fuels are in use in the Basin, ENVIRON estimated that the maximum increase in NOx emissions would be about 0.5% in 2020.

Table 8. LCFS maximum emissions increase in the South Coast Air Basin (tons/day).

Emission Reduction Source	VOC	CO	NOx	$PM_{2.5}$	SOx
LSCF Rule Effect on Biofuel Transport in 2020[a]	0.0	0.2	2.1	0.04	0.0
South Coast Air Basin 2019 Baseline	415	1716	405	70	18
South Coast Air Basin 2023 Baseline	406	1583	328	71	18

[a] – South Coast Air Basin assumed to have 40% of Table 5 Biofuel Transportation emissions and no low or zero emissions vehicles.

[6] http://theenergycollective.com/maxbaumhefner/276876/california-helps-drivers-plug-and-replace-clunkers-cleaner-cars
[7] http://www.eia.gov/todayinenergy/detail.cfm?id=16131

3.0 CONCLUSIONS

The LCFS regulation will lead to changes in fuel production and transportation for a fraction of the fuel supplied in California. ARB (2009) estimated that biofuel production in the state will increase from 485 million gallons to 1.45 billion gallons per year compared to the approximately 18 billion gallons[8] of gasoline and diesel sold in California in 2012. In-state ethanol production increases would reduce intrastate or imported South American ethanol to California, and ARB forecasts that 15% of petroleum diesel would be displaced by a combination of E85, B20, and CNG. In addition, the expected two to nine percent of advanced technology vehicles of the fleet will displace gasoline fuel consumption.

While there remains uncertainty about the effect that the regulation will have on fuel production and the market for advanced vehicle technology (electric or CNG), ENVIRON expects that the positive or negative emission changes of the regulation to be a 1% or lower magnitude increase or decrease of VOC and NOx on a regional basis, for example, in the South Coast Air Basin.

California also has a number of supporting regulations and incentives that will encourage emission reductions from the LCFS rule. Alternative diesel fuel regulations ensure that biodiesel will be produced at nearly NOx neutral levels or better. In addition, California encourages low or zero emission vehicles through a range of incentives, such as the Plug-In Electric Vehicle program.[9] For these reasons, the LCFS rule is more likely to reduce than it is to increase criteria pollutant emissions.

A point-by-point discussion of the ARB-expected emissions impact of the LCFS is provided here.

1. Uncertainties in the emission impacts assessment:

The low end of the emission impact could be nearly emissions neutral if few biofuels facilities are built and sales of advance technology and CNG vehicles continue at current low rates. The emissions increases from biofuel transport would nearly mask the emission reductions from advanced and low emissions vehicle introduction.

The high end emission change could be a reduction in emissions of up to twice the level that ARB forecasted if larger than expected numbers of advance and low emission technology vehicles are introduced and biofuels facilities can be located near feedstock and blending terminals.

2. Temporal and spatial allocation of the emissions increases and reductions:

The spatial allocation of emission changes could result in increases or decreases regionally, regardless of the statewide effect. Emission reductions from new clean fuels or vehicles would be experienced throughout the state. In some regions, the introduction of low emission

[8] http://www.boe.ca.gov/sptaxprog/reports/MVF_10_Year_Report.pdf , http://www.eia.gov/dnav/pet/pet_cons_821dsta_dcu_SCA_a.htm

[9] http://driveclean.ca.gov/pev/

vehicles and fuels may be offset by transportation emission increases near new biofuel facilities. Biofuel facility locations have yet to be determined, but many may be sited outside of urban areas.

There was no basis to suggest that there would be a significant seasonal, day of week, or time of day temporal allocation associated with the forecasted emission reductions.

3. Grid model capability to distinguish the difference in secondary species and the need to model to discover the LCFS effect on the demonstration of attainment:

ARB (2009) did not perform ozone modeling to estimate the impact of the change in criteria pollutant emissions due to the LCFS. ARB asserts that, due to the relatively small magnitude of potential emission reductions associated with LCFS, which are much less than the ~5 percent inventory delta that is an accepted minimum for grid-based modeling to avoid numerical artifacts, it is not practical to expect the air quality model to reasonably predict the cumulative potential benefit on ozone air quality. However, the information described below suggests that such modeling may be warranted.

The South Coast Air Quality Management District (SCAQMD) modeled ozone benefits from various combinations of reductions in NOx and VOC emissions in the Basin as part of their 2012 Air Quality Management Plan (AQMP) for progress towards ozone and $PM_{2.5}$ attainment (SCAQMD, 2013). Figures 1 through 4 provide ozone isopleth plots at different locations in the Basin showing 8-hour ozone concentrations predicted under a given combination of VOC and NOx emissions. The lines within each figure represent the ozone design value at that location for a given amount of NOx and VOC. The upper right corner represents the projected baseline VOC and NOx emissions in 2023. Moving down and left on each figure corresponds to relative emissions reductions from the baseline of NOx (down) and VOC (left), with corresponding changes in ozone concentrations.

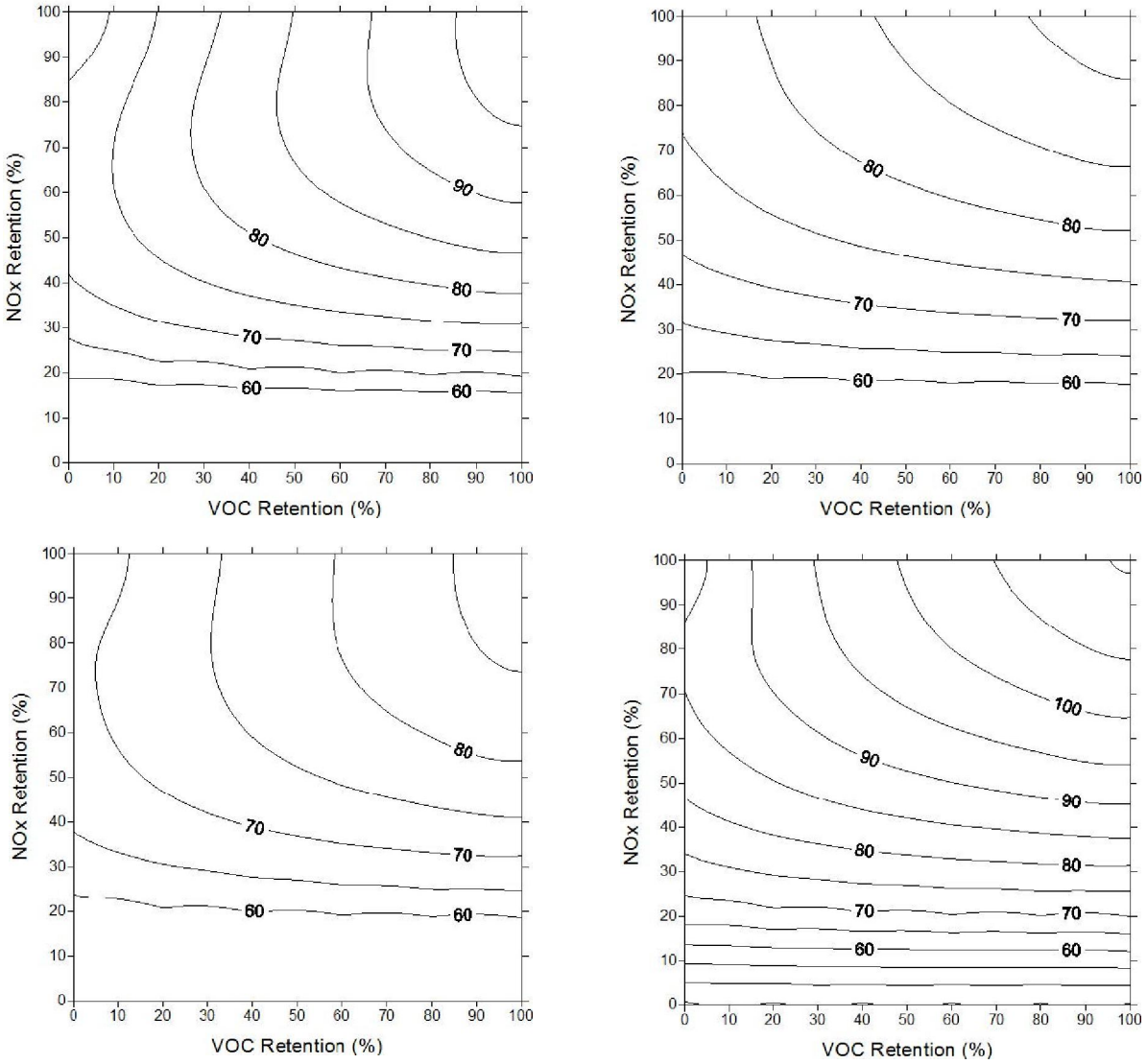

Figure 1. 2023 8-hour ozone isopleths at Azusa (top left), Banning (top right), Burbank (bottom left) and Crestline (bottom right). Source: SCAQMD, 2013.

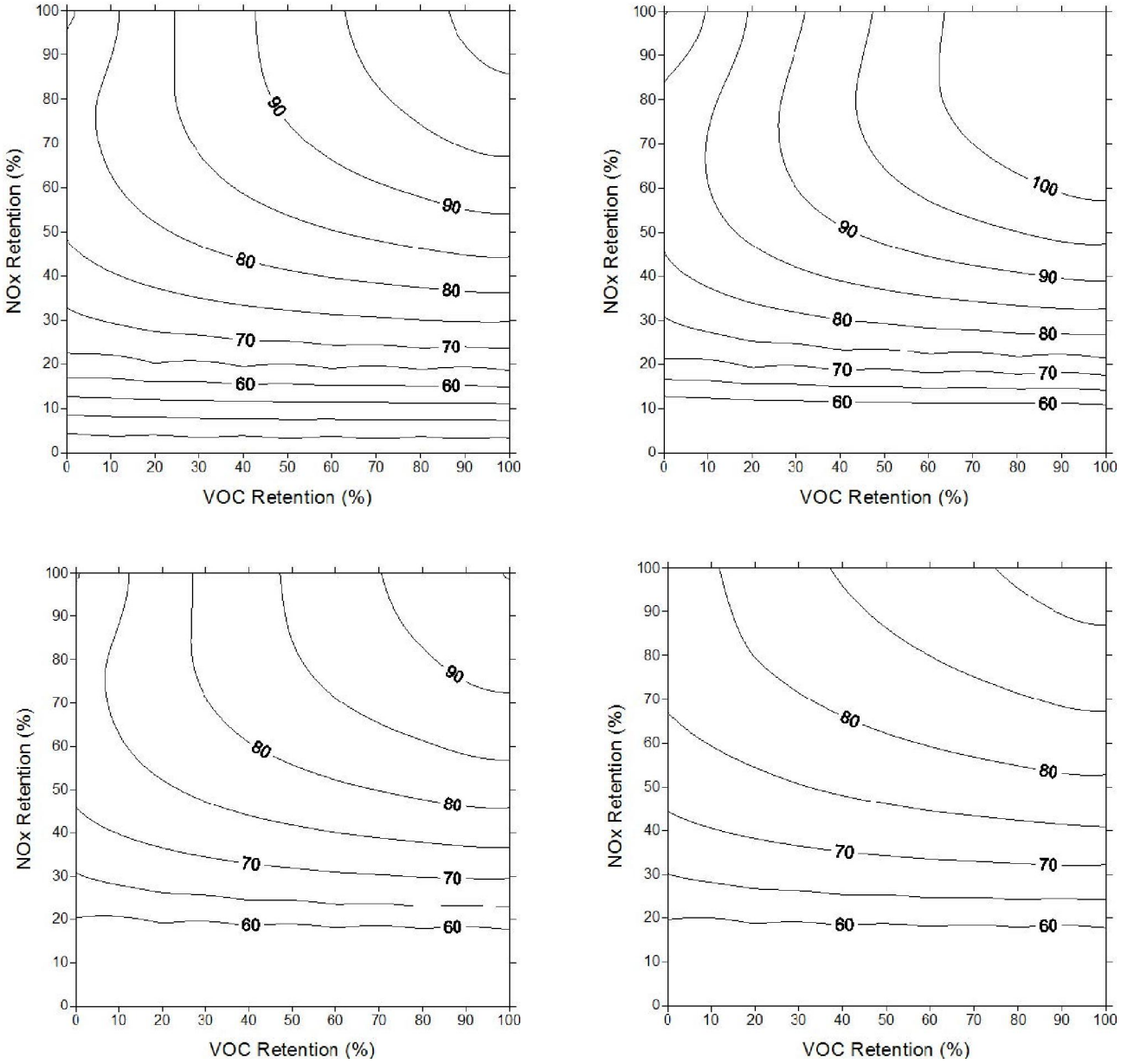

Figure 2. 2023 8-hour ozone isopleths at Fontana (top left), Glendora (top right), Miraloma (bottom left) and Perris (bottom right). Source: SCAQMD, 2013.

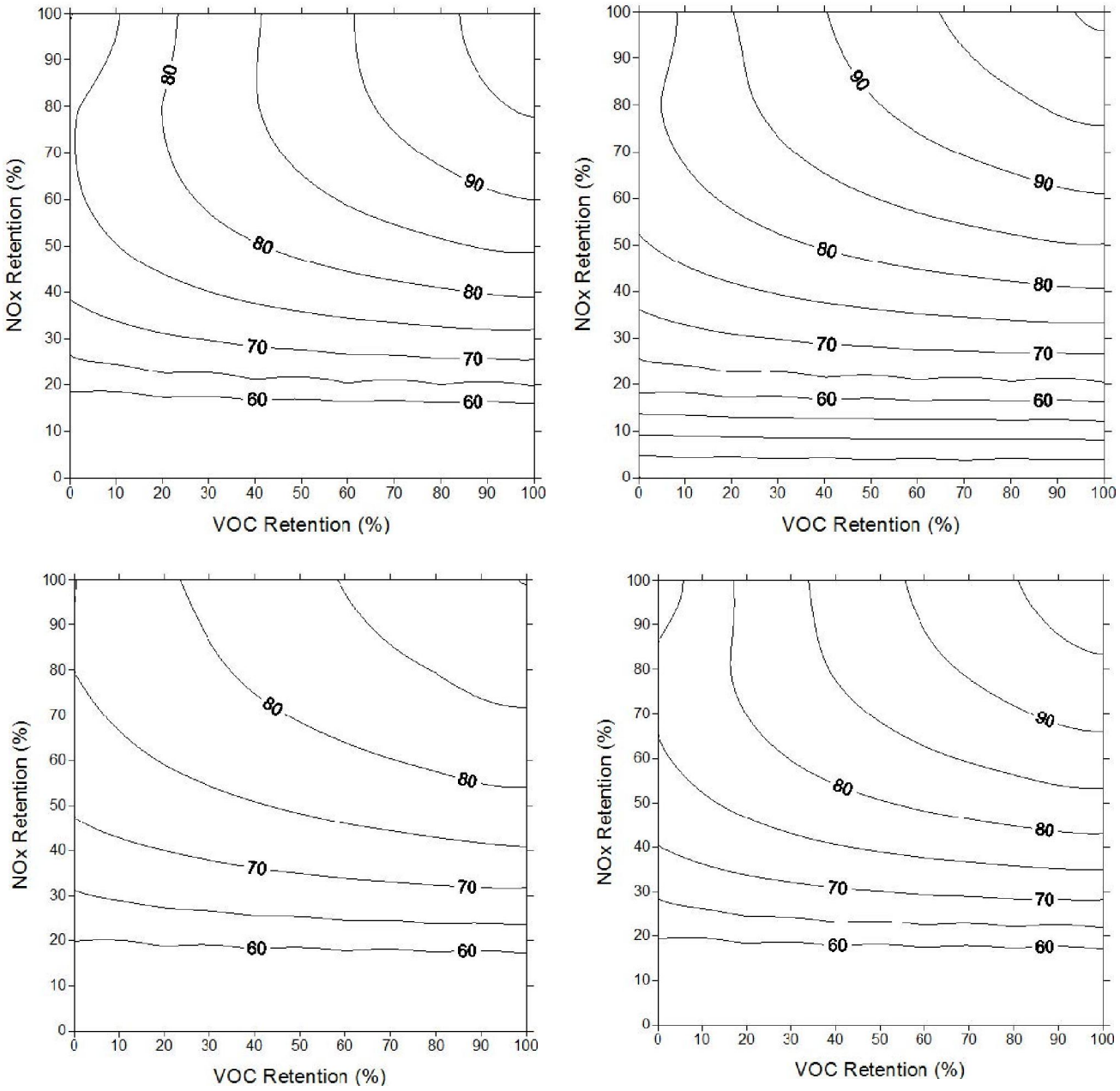

Figure 3. 2023 8-hour ozone isopleths at Pomona (top left), Redlands (top right), Reseda (bottom left) and Riverside (bottom right). Source: SCAQMD, 2013.

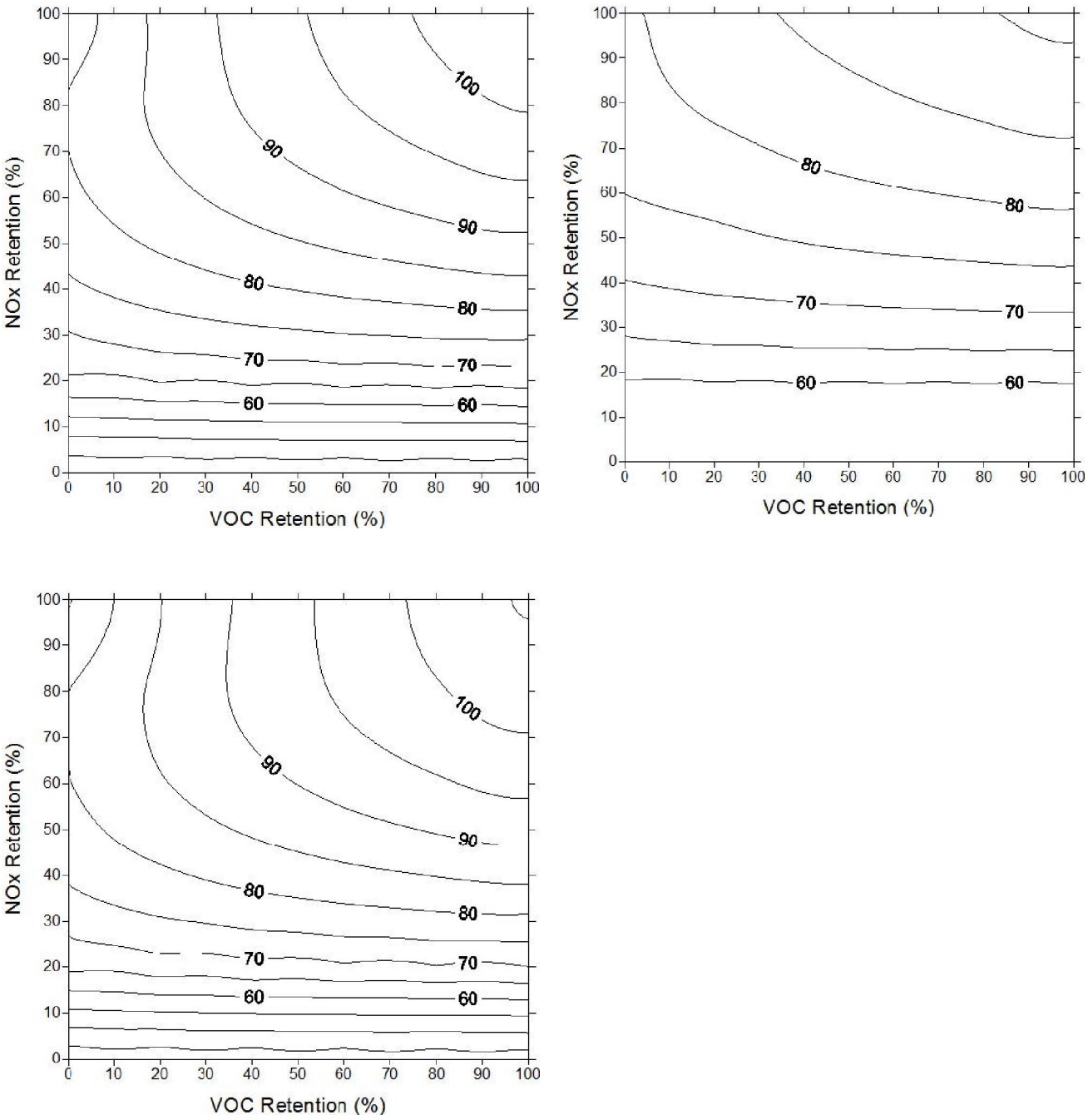

Figure 4. 2023 8-hour ozone isopleths at San Bernardino (top left), Santa Clarita (top right) and Upland (bottom left). Source: SCAQMD, 2013.

The projected baseline NOx emissions inventory in the Basin corresponding to these ozone isopleths is 319 tons/day (SCAQMD, 2013). The reduction in ozone due to a 20% reduction in NOx from the baseline level of NOx (i.e., a reduction of 64 tons/day NOx) at a constant VOC emissions level is approximately 5 ppb at the various locations shown in Figures 1-4. Thus, a 3.9

tons/day reduction in NOx due to the LCFS (Table 7) would result in approximately 0.3 ppb reduction in ozone in the Basin (the number would be slightly larger after accounting for the VOC reduction shown in Table 7). Conversely, a 2.1 tons/day increase in NOx due to the LCFS (Table 8) is predicted to result in an ozone increase of approximately 0.2 ppb in the Basin. We note that while NOx reductions could sometimes increase ozone due to less ozone titration in a NOx-rich environment, this is not expected to happen near the baseline levels of NOx and VOC as seen at the locations shown in Figures 1-4 (the exception being Glendora which shows a stronger potential for the titration dis-benefit near the baseline than the other sites). The uncertainty in the predicted ozone (approximately -0.3 ppb to 0.2 ppb) discussed here is large enough to merit further detailed modeling to understand the impacts of criteria pollutant emissions changes due to the LCFS on ozone concentrations.

4. Unaccounted emissions from allowed interstate product—marine, rail, truck, refinery:

The maximum emissions scenario presented assumed no criteria pollutant emission reduction from clean fuels or vehicles, but emission increases from biofuel transportation. For the South Coast specifically, imported fuel either from South America or other foreign ports or from other areas in California may increase emissions from marine, rail, or truck transport beyond those estimated by ARB. However, biofuel transportation emissions could be much lower than ARB forecast if biofuels facilities can be cited near blending terminals and feedstock. While there may be a decrease in refinery throughput, ARB did not expect refinery emissions to change as a result.

5. Changes in in-state fuel production techniques:

In the evaluation of the rule, ARB has forecasted new biofuels production facilities to be constructed. While it is uncertain where these facilities will be constructed, most current ethanol facilities are located outside of metropolitan areas, and it could be expected that new ethanol facilities will also be sited in more rural areas. In addition, ARB forecasts new renewable diesel production using hydrotreating, and these facilities are likely to be sited coincident with facilities that produce hydrogen, such as refineries, and use waste or plant oils as feedstock.

6. Reduced LD VMT:

ARB forecasted that consumer fuel prices would be the same (no change in price if the forecasted savings is not passed to the consumer) or marginally lower (as much as 8 cents per gallon lower or about 2% of the price for gasoline and as much as 4 cents lower for diesel). The reason that ARB expected fuel prices to be same or lower was due to low carbon fuel incentives and a potential loss of tax revenue. The effect on consumers of the potential price reduction would be less than a 0.5% increase in light-duty VMT based on a price elasticity of -0.22 for gasoline consumption.[10] (E.g, a 2% decrease in price results in a 0.44% increase in VMT.) However, ARB ignored any change to the light or heavy-duty vehicle activity.

[10] http://www.iaee.org/en/students/best_papers/Gillingham.pdf

7. Recommendations on how to frame evaluation of these issues by fuel and vehicle technology (e.g. hybrid electric, plug-in hybrid electric, battery-electric, compressed natural gas, diesel):

The primary uncertainty in the forecasted emissions changes due to the LCFS rule implementation is the level of increase in zero emissions vehicle activity. In the ARB rule evaluation, whether the LCFS rule results in positive or negative changes to ozone precursor emissions (ROG and NOx) largely depends upon how much of the vehicle activity will be replaced with zero emissions technology vehicles. ARB's estimate of zero emissions vehicle introduction encouraged by the LCFS rule exceeds forecasts of zero emissions vehicles in the South Coast Air Quality Management Plan. The LCFS rule constitutes a potential regional control strategy that has not been specifically studied.

Other uncertainties in the forecasted ozone precursor emissions are the amount of renewable (low NOx) diesel used and the number of CNG vehicles introduced. An excess or lack of the forecasted introduction of zero emissions and CNG vehicles and renewable diesel will determine whether emissions decrease or increase compared to the ARB forecast.

8. Bracket the likely range of the expected emissions effects from the regulation:

Presented in this report, the forecasted change in emissions ranged from a maximum increase of about 0.5% in NOx emissions with no change in ROG emissions bracketed by a maximum decrease in NOx and ROG of about 1% to 0.4%, respectively.

4.0 REFERENCES

ARB, 2009. "Proposed Amendments to the Low Carbon Fuel Standard Regulation," Staff Report: Initial Statement of Reasons for Proposed Rulemaking, March 5, 2009.

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