FINAL REPORT (Revised)

IMPACTS OF POTENTIAL MTBE PHASEOUT

IN ARIZONA

A study performed for

Arizona Department of Environmental Quality

under

ADEQ Contract No. 98-0159-BL
Task Assignment 00-0202-01

by

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EXECUTIVE SUMMARY

The Arizona Department of Environmental Quality (ADEQ) retained Energy and Environmental Analysis, Inc. (prime contractor) and MathPro Inc. (sub-contractor) to assess the economic and technical implications of the legislated phase-out of MTBE-blended gasoline in Arizona.

> The Arizona phase-out is to take effect in the first half of 2003 – not later than one hundred eighty days after California's MTBE phase-out (scheduled for 1 January 2003).

We conducted this study pursuant to Task Assignment No. 00-0202-01 under Prime Contract No. 98-0159-BL.

The study had three primary components.

- Estimating (1) the average blend properties of candidate formulations, or variants, of Arizona Cleaner Burning Gasoline (CBG) produced without MTBE and (2) the average refining costs associated with these variants

- Estimating the changes in vehicle emissions and air quality associated with the CBG variants – relative to (1) the baseline gasoline (average Maricopa County gasoline in Summer 1999) and (2) an estimated future baseline gasoline reflecting the effects of the federal Tier 2 program controlling the sulfur content of gasoline

- Identifying other likely effects associated with the CBG variants, such as changes in driveability index, vehicle performance, and maintenance requirements.

This report, the primary work product of the assignment, describes the methodology and conveys the results of our analysis. The report addresses ten topics, each in its own section.

1. Key elements of the Arizona Cleaner Burning Gasoline (CBG) program
2. Average properties of Arizona CBG, in the 1999 Summer season
3. Prospective CBG variants considered in this study
4. Refinery modeling: technical approach
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An earlier report [Ref. 1] conveyed estimates of the changes in Maricopa County emission inventories associated with the least-cost CBG variant (relative to the baseline gasoline). These estimates are intended to support ADEQ's analysis of the effects on the Maricopa County SIP of Arizona's MTBE phase-out.

TECHNICAL APPROACH

Average Properties of CBG in Summer 1999

We estimated the average properties of the CBG supplied in the 1999 Summer season, using confidential information provided by Arizona Department of Weights and Measures (ADWM). This information, in turn, was derived from batch-by-batch reports of CBG properties submitted to ADWM by the refineries of origin.

CBG Variants Considered

We assessed the refining economics, average properties, and emissions performance of six prospective CBG variants that the refining and distribution system could supply to the CBG area after the MTBE phase-out, singly and in certain combinations:

- Type 1 CBG (federal RFG "look-alike")
  - Blended with no oxygen
  - Ethanol blended at *2.0 wt% oxygen*
  - Ethanol blended at *2.7 wt%* oxygen
  - Ethanol blended at *3.5 wt%* oxygen

- Type 2 CBG (California RFG "look-alike")
  - Blended with no oxygen
  - Ethanol blended at *2.0 wt%* oxygen
  - Ethanol blended at *2.7 wt%* oxygen

Refining Analysis

We conducted a refinery modeling analysis to estimate the average properties of these CBG variants and the associated average refining costs. The analysis addressed the two sources of refined products supplies to the CBG area:

- The **East** refining center, comprising the West Texas and New Mexico refineries that supply the CBG area (by pipeline through El Paso and Tucson).

- The **West** refining center, comprising the California refineries that supply the CBG area (by pipeline from Los Angeles through Colton)

For each CBG variant considered, we aggregated the results obtained for each refining center to develop average properties for the total CBG supply volume. For the aggregation, we used weighting factors consistent with the West and East supply volumes in the 1999 Summer season (about 30% East/70% West). These volume shares are comparable to those in the mid- to late-90's and (given current pipeline capacities) are likely to apply in coming years as well.

The refining analysis focused on the Summer season in 2005. The MTBE phase-out will affect only Summer CBG (because Winter CBG must be ethanol-blended). 2005 will be the first year in which the properties and emissions of CBG will be influenced by both the Arizona MTBE phase-out and the federal Tier 2 sulfur standard for gasoline (30 ppm average/80 ppm cap). The Tier 2 standard takes effect in 2005.

Emissions Analysis

We conducted an emissions modeling analysis to estimate the average emissions performance of the CBG variants considered. The emissions analysis used the volume-weighted averages of the East and West gasoline properties for 2005 generated by the refining analysis for each CBG variant. The analysis focused on the Summer seasons of 2004 and 2010, as defined by projections of vehicle fleet composition and vehicle miles traveled for those years.

The emissions analysis employed established, peer-reviewed models: the EPA MOBILE6 model for estimating vehicle fleet emissions, the EPA Phase 2 Complex Model for certifying federal RFG2, and the California Phase 2 Predictive Model for certifying California RFG2.

SUMMARY OF RESULTS

Table ES-1 summarizes the estimated *average per-gallon refining costs* (in the East and West refining centers), in 2000 dollars, associated with the CBG variants considered. These are average costs, allocated to the estimated CBG out-turn of the refining centers.

Table ES-2 shows the estimated *average properties* and *reductions in vehicle emissions* associated with the CBG variants considered. The average properties are results of the refining analysis; the emissions reductions are the corresponding results returned by the Complex Model (for CBG Type 1) and the Predictive Model (for CBG Type 2).

Tables ES-3a and ES-3b and **Figures ES-1a through ES-6b** show the estimated *changes in emission inventories* (in metric tons per day (Mtpd)) associated with each of the CBG variants, for 2004 and 2010. These estimated emissions changes cover on-road and off-road vehicles and engines; they reflect estimates of baseline emissions inventories provided by ADEQ.

DISCUSSION OF RESULTS

Absent significant changes in crude oil and refined product prices, the least-cost CBG variant in both the West and East refining centers would be *CBG Type 1 blended without oxygen*. This result implies that

- Non-oxygenated CBG Type 1 oxygen likely would constitute most of the gasoline pool supplied to the CBG area in the Summer season. (Temporary conditions in West or East refineries or in the distribution system, or business considerations, might induce supply of some volumes of other CBG variants from time to time.)

- Refiners having the opportunity to produce both non-oxygenated and ethanol-blended CBG in some proportion would choose to produce 100% non-oxygenated CBG.

- Arizona's oxygen waiver for CBG, to take effect with the MTBE phase-out, will reduce significantly the refining cost of the MTBE phase-out.

Without Arizona's oxygen waiver, the least cost CBG variants would be CBG Type 1, ethanol-blended to 2.0 wt% and 2.7 wt% oxygen in the East and West refining centers, respectively.

The refining costs estimated in this study indicate the likely CBG variants of choice for the refining centers. They are not indicators of price changes that might occur as a consequence of Arizona's MTBE phase-out.

None of the CBG variants are likely to have significant effects on *ozone-related* emissions. In general, they offer estimated reductions of less than 1%, relative to average CBG in Summer 1999. Ethanol-blended CBG variants would provide the largest emission reductions. The least-cost CBG variant, non-oxygenated CBG Type 1, would lead to a marginal increase (0.2%) in ozone-related emissions. The narrow range of performance in ozone-related emissions follows from the CBG variants all meeting the emissions standards for CBG Type 1 (Complex Model) or CBG Type 2 (Predictive Model), as applicable. Given the

Estimated reductions in *toxic* emissions (potency-weighted) are small. Reductions in toxic emissions tend to increase with ethanol content and would be largest with the ethanol-blended CBG Type 2 variants. CBG Type 1, ethanol-blended to 2.7 wt% oxygen, would have virtually no impact on potency-weighted toxics. The least-cost CBG variant, non-oxygenated CBG Type 1, could produce a small increase potency-weighted toxics emissions.

By its nature, emissions modeling is subject to substantial uncertainty. Small differences in estimated emissions performance should not be viewed as robust or meaningful.

The estimates in Tables ES-3a and ES-3b include no effects of commingling (in terminals or vehicles) of ethanol-blended and non-oxygenated CBG gasolines. To the extent that it occurred, commingling would increase ozone-related emissions (but not toxic emissions). *However*, commingling is unlikely to occur in the Summer season (though it may occur in the season transition (shoulder) months, April and October) because the pipelines from the West and East refining centers can accommodate only one class of CBG gasoline – either ethanol-blended (to a uniform oxygen content) or non-oxygenated, but not both.

Finally, we did not uncover any significant effects of the CBG variants on factors such as fuel economy, vehicle performance (e.g., driveability, vapor lock), or maintenance requirements.

Table ES-1: Average Refining Costs of the CBG Variants Analyzed (¢/gal)

	CBG Type 1				CBG Type 2		
Oxygen Content →	**No oxy**	**2.0**	**2.7**	**3.5**	**No oxy**	**2.0**	**2.7**
Refining Center							
East	*0.2*	*2.5*	3.8	4.8	0.2	---	3.4
West	*5.6*	10.0	8.8	*7.4*	8.7	13.5	12.4

Table ES-2: Weighted Average Properties of the CBG Variants Analyzed

	CBG Type 1					CBG Type 2	
Oxygen Content →	**No oxy**	**2.0**	**2.7**	**3.5**	**2.0/3.5**	**No oxy**	**2.7**
Average Properties							
RVP (psi)	6.7	6.7	6.7	6.8	6.8	6.8	6.8
Oxygen (wt%)	0.0	2.0	2.7	3.5	3.1	0.0	2.7
Aromatics (vol%)	16.4	16.0	16.0	16.0	16.0	13.5	13.7
Benzene (vol%)	0.75	0.86	0.96	0.83	0.80	0.92	1.06
Olefins (vol%)	8.6	8.4	10.0	10.0	8.4	5.5	4.9
Sulfur (ppm)	22	22	25	25	22	22	22
E_{200} (vol%)	42.8	43.2	42.8	43.8	43.2	47.5	46.8
E_{300} (vol%)	84.0	83.4	83.3	83.3	83.4	83.5	84.1
T_{10} (°F)	135	128	129	129	128	134	129
T_{50} (°F)	209	210	212	216	217	207	209
T_{90} (°F)	317	319	319	319	319	318	317
Cert. Model Results (1)							
VOCs	29.9	30.2	30.3	30.4	30.1	-0.26	-0.75
NOx	15.9	16.3	15.9	15.9	16.3	-1.87	-0.21
Toxics	32.1	32.5	31.1	31.9	32.5	1.26	3.47

Notes:

1. For CBG 1, these values are Phase 2 Complex Model outputs denoting the percent reductions in emissions from 1990 vehicles fueled with the 1990 national baseline gasoline (Summer). For CBG 2, these values are Phase 2 Predictive Model outputs denoting reductions in emissions relative to the reference CARB Phase 2 RFG.

2. **CBG Type 1, 2.0/3.5 wt% Oxygen** denotes supply of CBG Type 1 with 2.0 wt% oxygen from the East refining center and 3.5 wt% oxygen from the West refining center.

Table ES-3a: Estimated Changes in Emissions Inventories, 2004 (Metric tons per day)

	CBG Type 1					CBG Type 2	
Oxygen Content →	**No oxy**	**2.0**	**2.7**	**3.5**	**2.0/3.5**	**No oxy**	**2.7**
Emissions							
VOC	+0.6	-0.6	-1.2	-0.2	+0.6	+1.0	+0.1
NOx	-1.0	-1.6	-0.3	-0.6	-2.0	-3.2	-3.9
CO	+165	-43	-112	-202	-160	+143	-132
CO_{RW} (1)	+2.0	-0.5	-1.4	-2.5	-1.9	+1.7	-1.6
VOC+CO_{RW}	+2.6	-1.1	-2.5	-2.6	-1.3	+2.8	-1.5
$Toxics_{PW}$ (2)	0.054	-0.051	-0.005	-0.071	-0.111	-0.077	-0.207

Table ES-3b: Estimated Changes in Emissions Inventories, 2010 (Metric tons per day)

	CBG Type 1					CBG Type 2	
Oxygen Content →	**No oxy**	**2.0**	**2.7**	**3.5**	**2.0/3.5**	**No oxy**	**2.7**
Emissions							
VOC	+0.4	-0.4	-0.8	-0.1	+0.5	+0.6	0
NOx	-1.1	-1.7	-0.2	-0.4	-2.1	-3.5	-4.1
CO	+168	-43	-114	-206	-162	+145	-134
CO_{RW} (1)	+2.0	-0.5	-1.4	-2.5	-2.0	+1.8	-1.6
VOC+CO_{RW}	+2.4	-1.0	-2.2	-2.6	-1.5	+2.4	-1.7
$Toxics_{PW}$ (2)	0.041	-0.039	-0.005	-0.056	-0.086	-0.056	-0.156

Notes:
1. **CO_{RW}** denotes ozone-reactivity-weighted CO emissions
2. **$Toxics_{PW}$** denotes potency-weighted toxics mass (based on factors derived from the Predictive Model).
3. The column headed **2.0/3.5** denotes the combination of the least-cost ethanol-blended CBG Type 1 gasolines from the West and East refining centers, respectively.

Figure ES-1a: Effects of CBG Variants on VOC Emissions in 2004

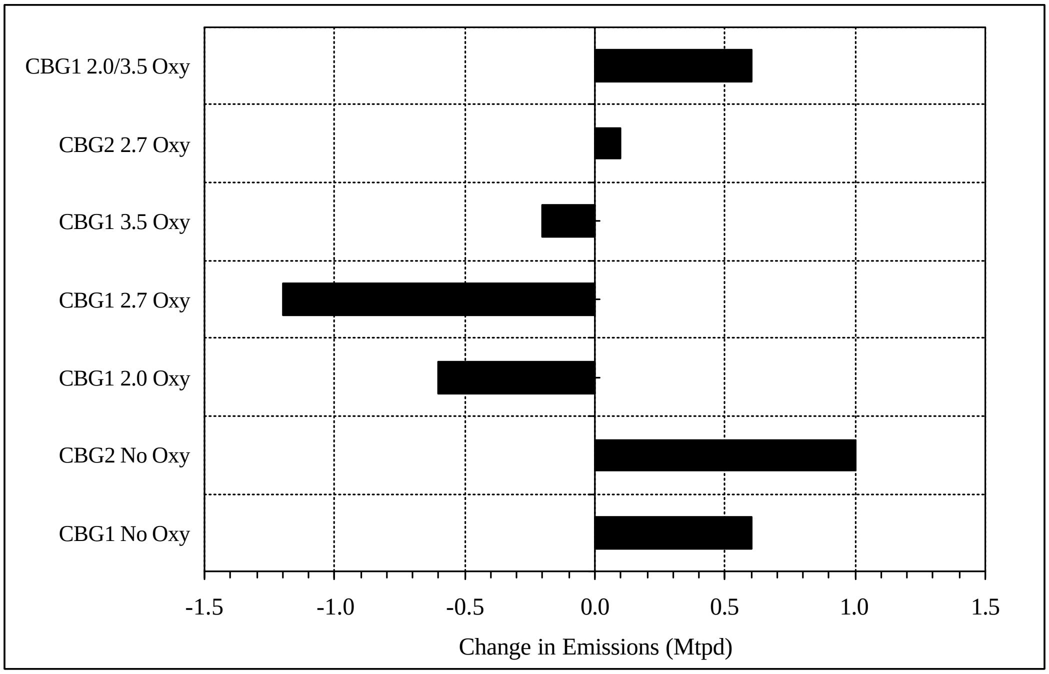


Figure ES-1b: Effects of CBG Variants on VOC Emissions in 2010

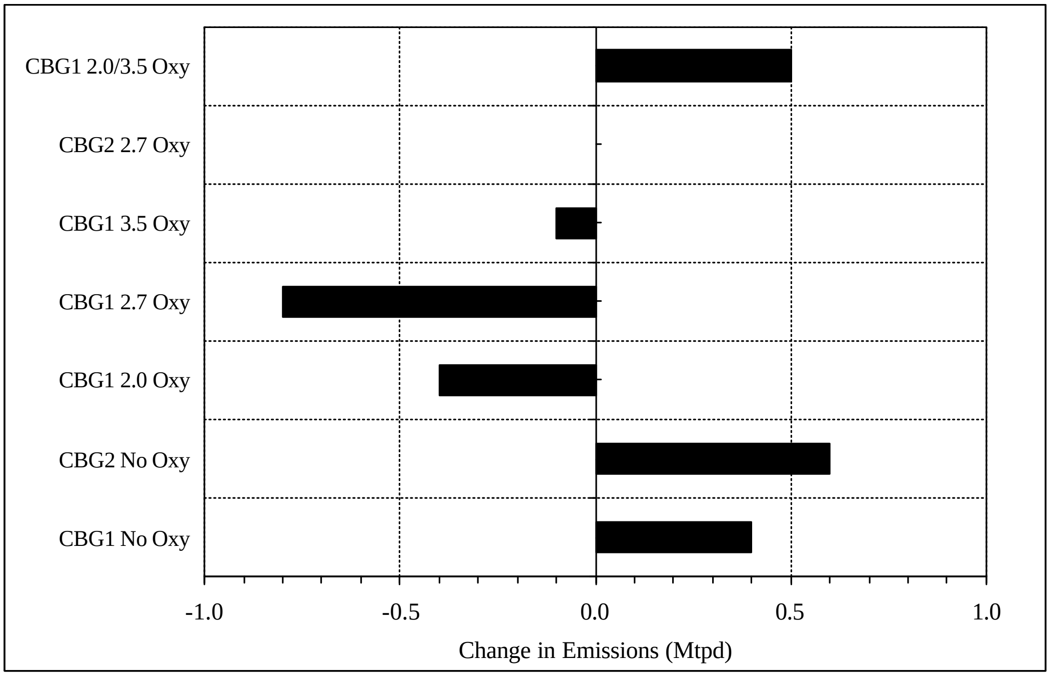


Figure ES-2a: Effects of CBG Variants on NO_x Emissions in 2004

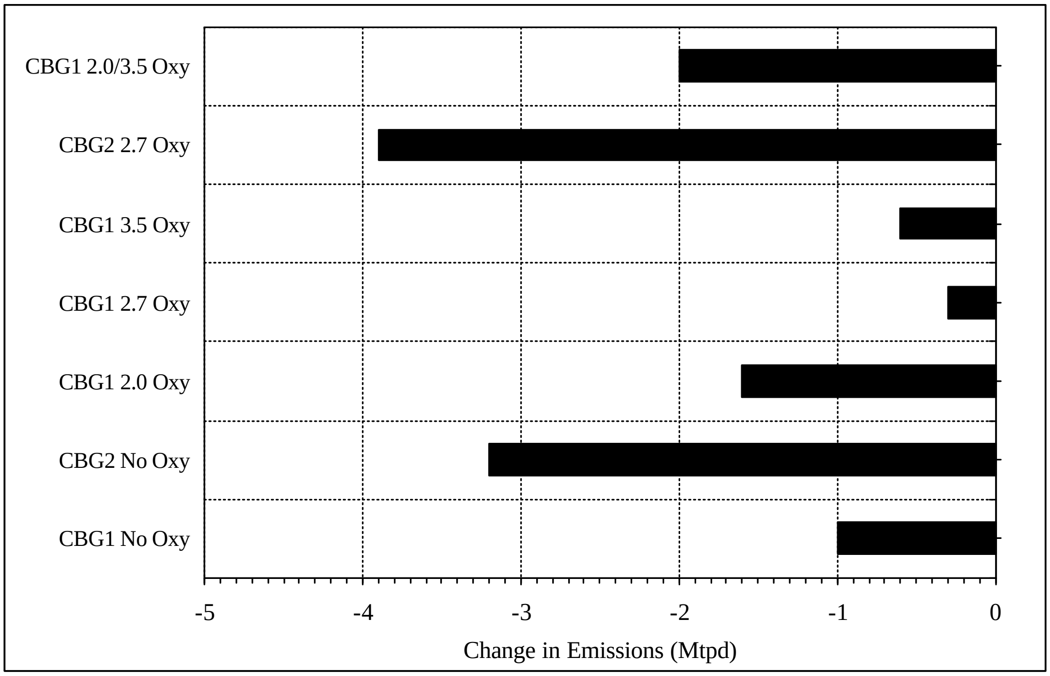


Figure ES-2b: Effects of CBG Variants on NO_x Emissions in 2010

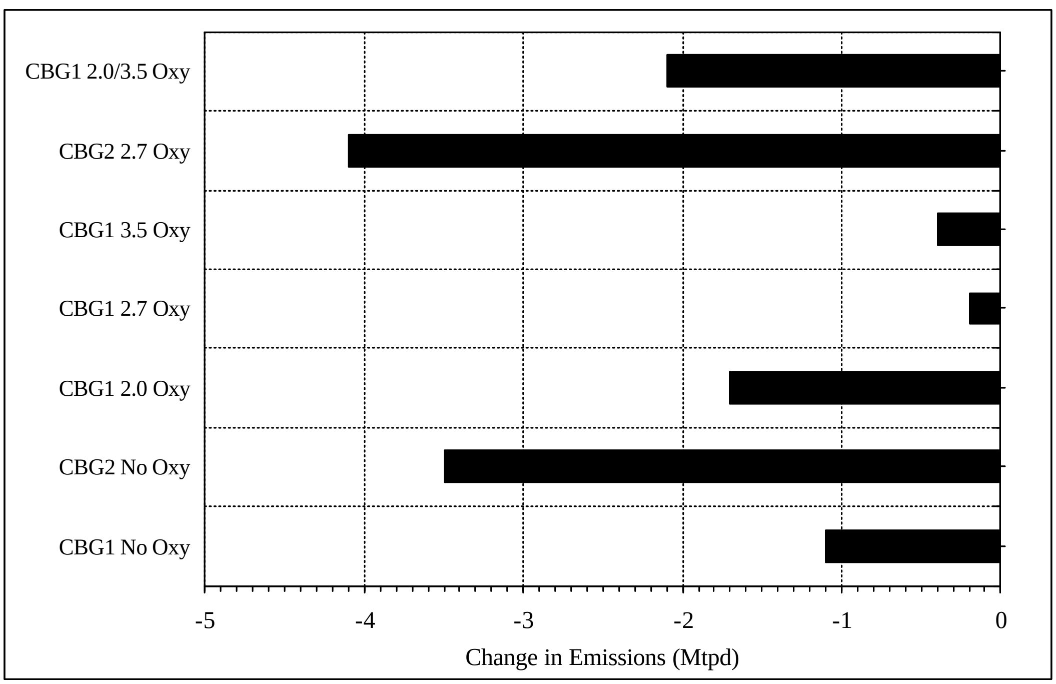


Figure ES-3a: Effects of CBG Variants on CO Emissions in 2004

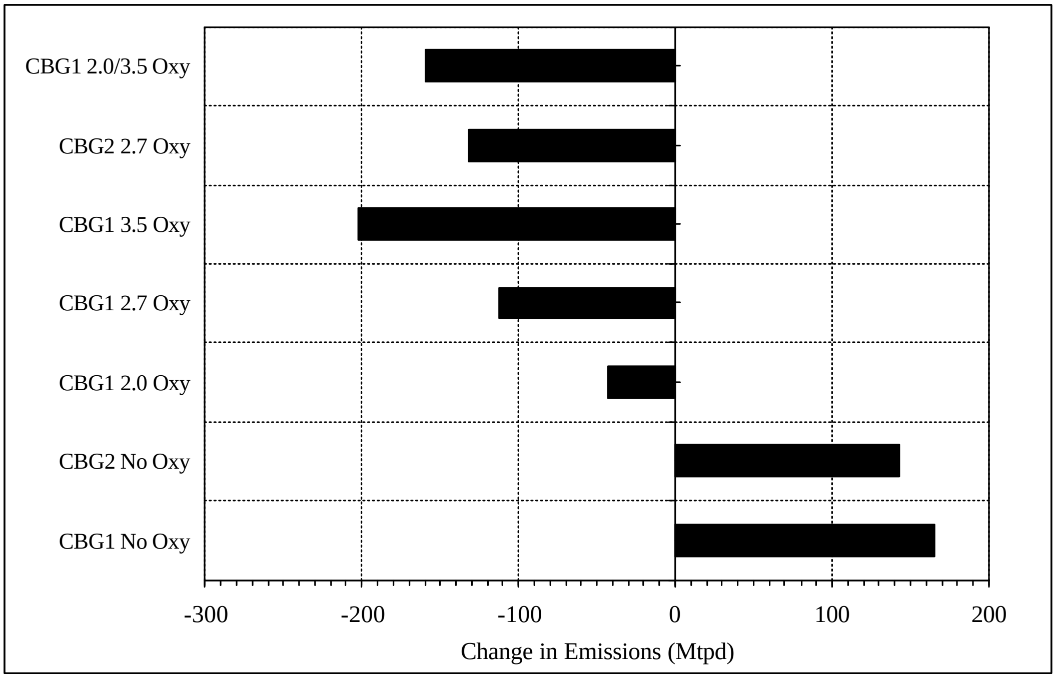


Figure ES-3b: Effects of CBG Variants on CO Emissions in 2010

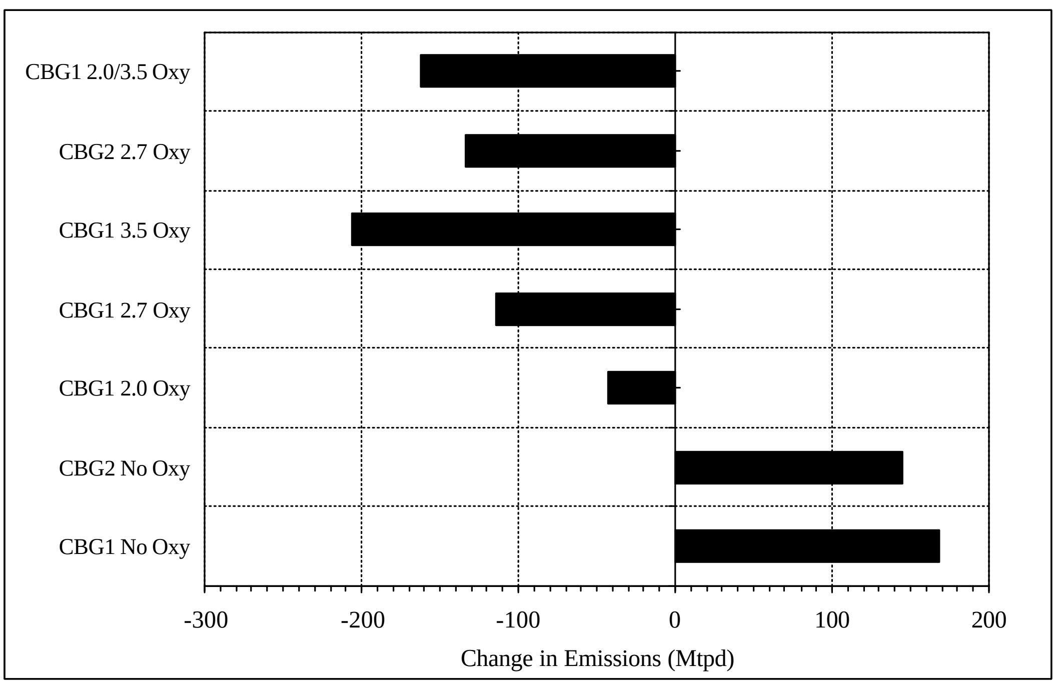


Figure ES-4a: Effects of CBG Variants on Reactivity Weighted CO in 2004

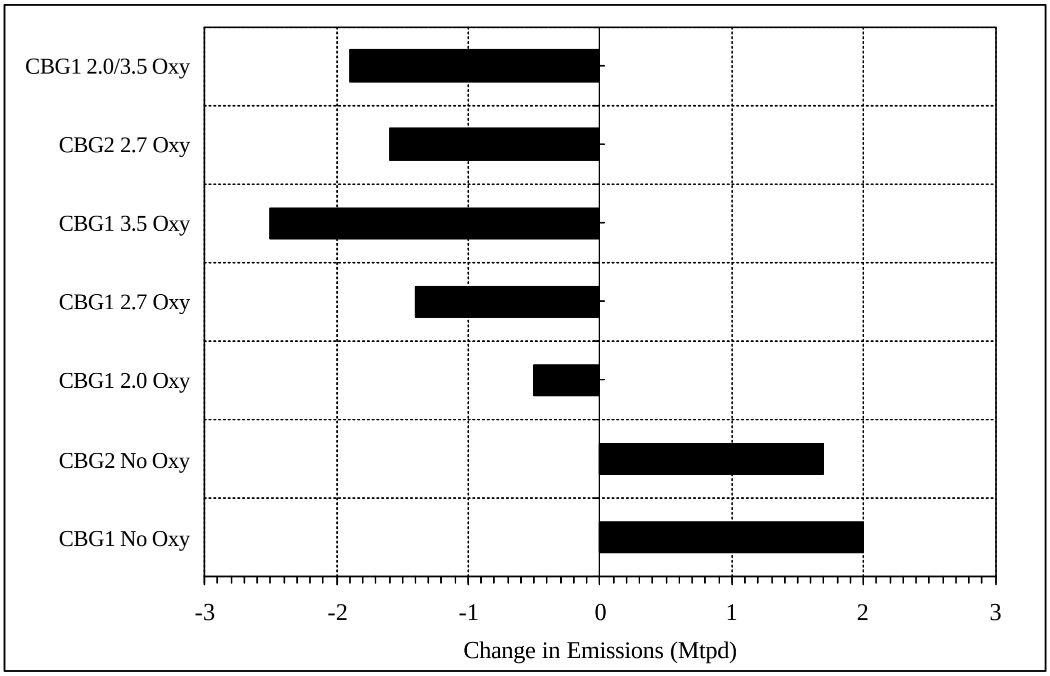


Figure ES-4b: Effects of CBG Variants on Reactivity Weighted CO in 2010

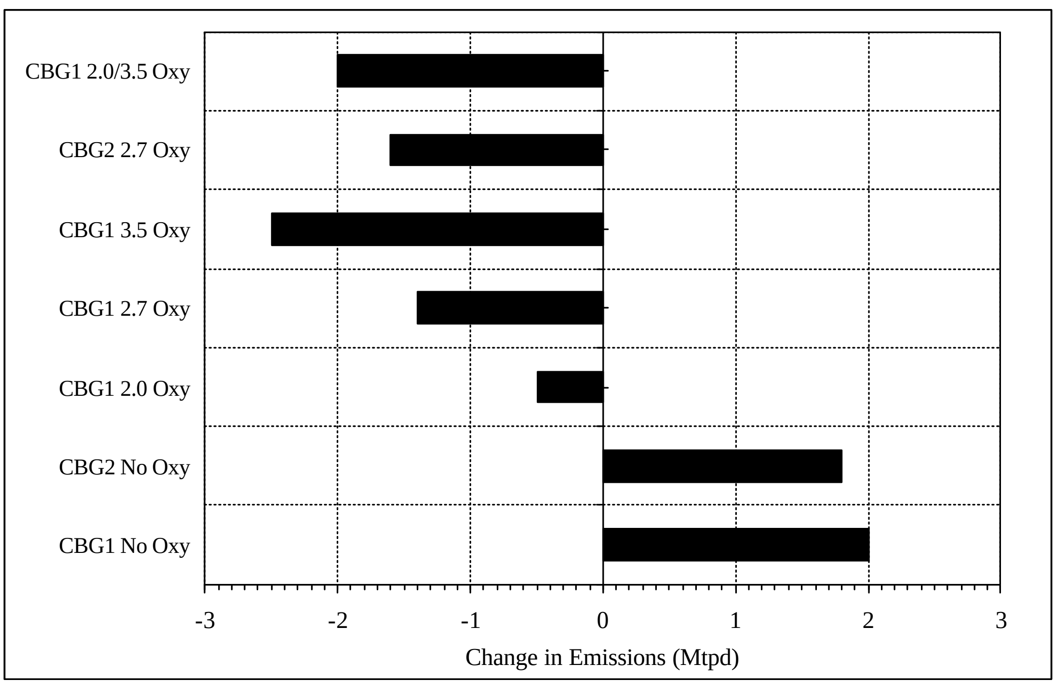


Figure ES-5a: Effects of CBG Variants on VOC + Reactivity Weighted CO in 2004

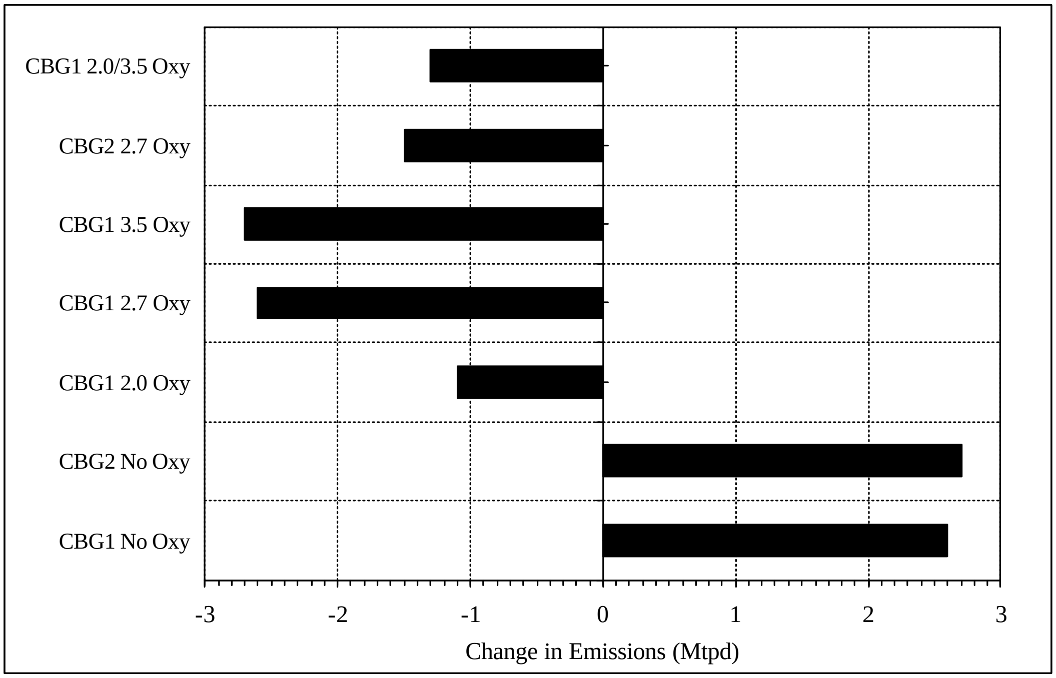


Figure ES-5b: Effects of CBG Variants on VOC + Reactivity Weighted CO in 2010

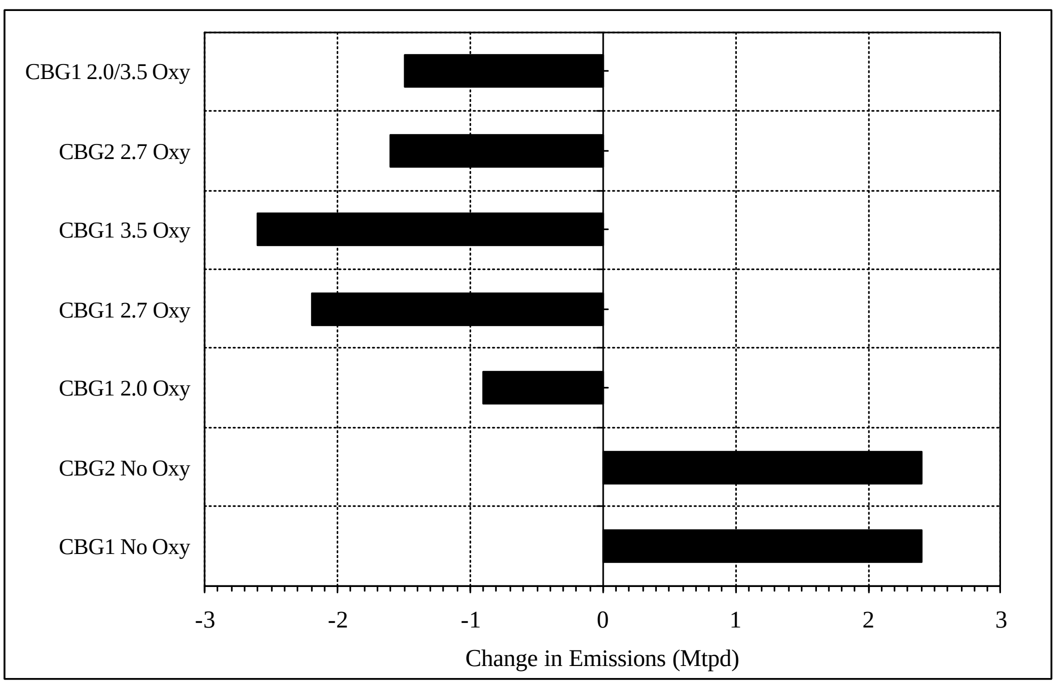


Figure ES-6a: Effects of CBG Variants on Potency Weighted Toxics in 2004

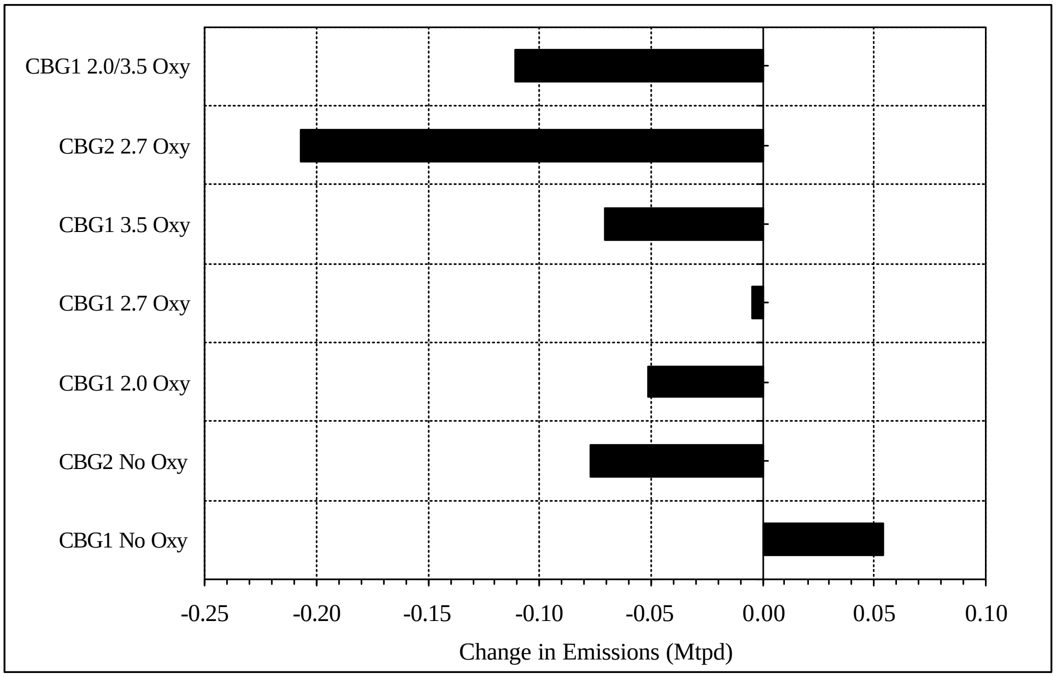
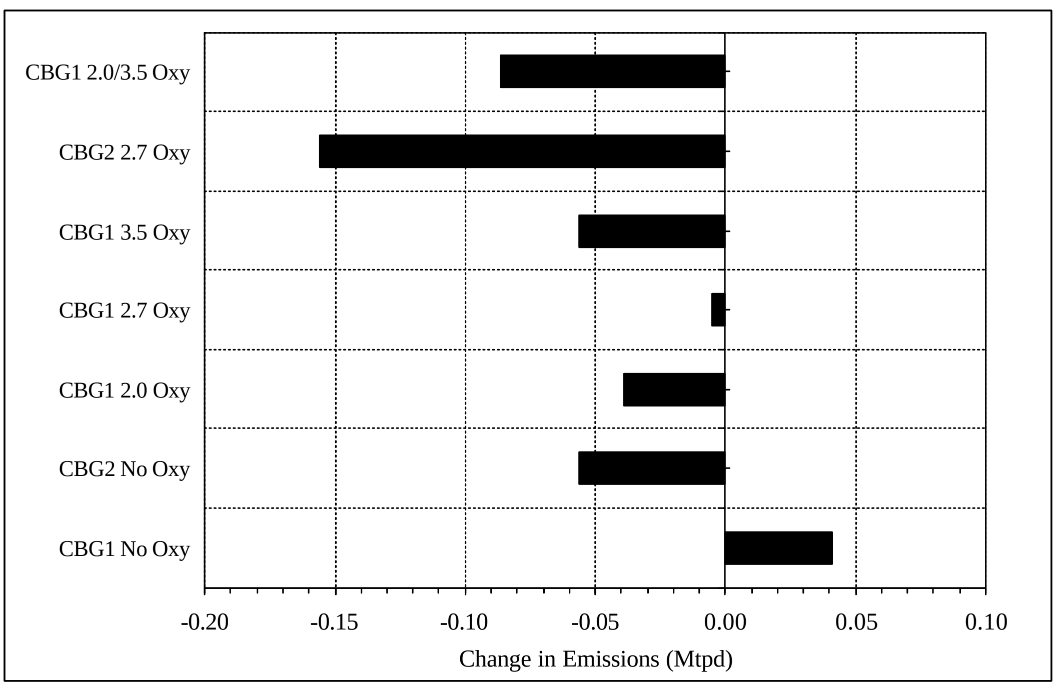


Figure ES-6b: Effects of CBG Variants on Potency Weighted Toxics in 2010



1. KEY ELEMENTS OF THE ARIZONA CBG PROGRAM

The Arizona Cleaner Burning Gasoline (CBG) program sets requirements on the emissions properties of gasoline supplied to the CBG covered area (Maricopa County plus portions of "Area A" outside of Maricopa County). Controlled emissions include oxides of nitrogen (NOx), volatile organic compounds (VOC), hazardous air pollutants (HAP), and carbon monoxide (CO).

1.1 CLEANER BURNING GASOLINE, TYPE 1 AND TYPE 2

As of 2000, the Arizona CBG program calls for the following gasoline types, by season.

In the **Summer** season – April 1 through October 31 – CBG may be either of two types.

- Type 1 (CBG 1) is a federal Phase 2 RFG "look-alike".

- Type 2 (CBG 2) is a California Phase 2 RFG (CaRFG2) "look-alike".

Summer CBG has Reid Vapor Pressure ≤ 7 psi[1] (7 RVP).

In the **Winter** season – November 1 through March 31 – CBG is Type 2 (California Phase 2 RFG "look-alike"), ethanol blended at 3.5 wt% oxygen and with 9 RVP.

Type 1 and Type 2 CBG are "look-alikes" rather than exact matches to federal and California RFG, respectively, because CBG is not subject to the federal or California standards for benzene content or toxic emissions.[2] With respect to all other relevant properties, Type 1 and Type 2 CBG correspond to federal and California RFG.

Type 1 CBG must (1) meet the emissions reduction standards imposed by EPA's Phase 2 Complex Model for VOCs and NOx (but not toxics) and (2) have an oxygen content no less than 2.0 wt%, if certified under the per-gallon standards, or that averages at least 2.1 wt%, if certified under the averaging standards. Type 2 CBG need not contain oxygen.

With respect to the federal RFG program, Arizona CBG is *conventional gasoline*, subject to the federal "anti-dumping" standards for NOx and toxics emissions.

Because the CBG program's two seasons have different RVP and oxygenate standards, practical considerations in the gasoline logistics system (pipelines and terminals) make full compliance with the RVP and oxygen standards difficult during seasonal transitions. Consequently, the state recognizes two transition months – April (Winter to Summer) and October (Summer to Winter). In

1 The abbreviation *psi* stands for *pounds per square inch.*

2 Under Section 211(c)(4) of the Clean Air Act Amendments of 1990, Arizona is pre-empted from regulating benzene content or toxic emissions of gasoline sold in the state.

the transition months, all CBG sold must meet the relevant emissions, RVP, and octane standards, but not necessarily the relevant oxygen standard.

At present, most Summer CBG – Type 1 and Type 2 – is MTBE blended to meet the oxygen content requirement in federal RFG; Winter CBG necessarily contains essentially no MTBE. Hence, most of the effects of the MTBE phase-out will bear on the Summer season.

1.2 Prospective Changes in Arizona CBG

At present, most CBG contains oxygen, from either MTBE or ethanol (although the CBG program does not require that Type 2 CBG contain oxygen). The MTBE phase-out legislation includes a concurrent waiver on the requirement for oxygen content in Type 1 CBG. Hence, from 2003, both Type 1 and Type 2 CBG may be supplied either oxygen-free or ethanol blended. Then, as now, ethanol may be blended to 2.1 wt%, 2.7 wt%, or 3.5 wt% oxygen in the Summer and must be blended to 3.5 wt% oxygen in the Winter.

Starting in 2005, Arizona CBG (indeed all gasoline supplied to Arizona) will be subject to the federal Tier 2 standard on the sulfur content of gasoline (30 ppm average/80 ppm cap).

1.3 Gasoline Standards in the Rest of Arizona

Arizona has no Summer ozone control programs outside of the CBG area. Gasoline sold in Arizona outside of the CBG area is conventional gasoline. Summer RVP ranges from 9.0 psi to 11.5 psi, depending on the month and the location within the state, in accordance with the industry-standard ASTM schedule for RVP. (The Summer RVP standard for Pima County is 9.0 psi.) Outside of the CBG area, the Summer season is April 1 to September 30.

Arizona has one Winter CO control program outside of the CBG area. Pima County has a Winter oxygenated gasoline program, with ethanol blending at 1.8-3.5 wt% oxygen. The 1 psi RVP waiver is available for ethanol blending in Pima County. Winter RVP ranges from 9.0 psi to 13.5 psi, again in accordance with the industry-standard ASTM schedule for RVP. Outside of the CBG area, the Winter season is October 1 to March 31.

1.4 Overview of the Pipeline System Supplying Maricopa County

Essentially all of Maricopa County's gasoline supplies arrive via pipeline. The Kinder Morgan Energy Partners LP South Pipeline system delivers refined products to Phoenix, Tucson, and other destinations through two lines. The West line moves refined products from the Los Angeles refining center Phoenix and on to Tucson. The East line moves refined products (coming from refineries in West Texas and New Mexico) from El Paso to Tucson and on to Phoenix. Thus, Phoenix is served by both the East and the West lines. Historically, Maricopa County receives about 70% of its gasoline supplies from the West and about 30% from the East.

The Phoenix terminal handles both CBG for Maricopa County and conventional gasoline for areas adjacent to but not including Area A. Some "spill-over" of CBG into these adjacent areas likely occurs, in the course of normal distribution operations.

The number of fungible classes, or types, of gasoline that a pipeline system can accommodate is limited by the tankage available at each terminal or off-take point. In its current configuration, the Kinder Morgan system accommodates two fungible classes of gasoline for Arizona: CBG and conventional (each with regular and premium grades). The specifications of these classes changes with the season; but at any given time the system moves only two gasoline classes. This situation is likely to prevail in the future.

Chapter 3 of [Ref. 2] provides a fuller discussion of the pipeline system serving Maricopa County.

2. AVERAGE PROPERTIES OF CBG (SUMMER 1999)

For purposes of comparison with the CBG variants considered, we computed the average properties of the total CBG pool in the 1999 Summer season.

We developed the average CBG properties for the 1999 Summer season from confidential data provided by the Arizona Department of Weights and Measures (ADWM). The ADWM data, submitted by the refiners producing CBG, shows the volumes and properties of each batch of CBG shipped to Maricopa County by refiners, from May 1, 1999 on.

We aggregated the batches of 1999 Summer gasoline by source – the East and West refining centers – and calculated the weighted average properties of the East and West gasoline supplies, shown in **Table 2.1**.

Table 2.1: Average Properties of West and East CBG (1999 Summer)

	Refining Center		Weighted Average
	East	West	
Volume (K bbl)			
Season Total (M Bbl)	3.67	7.77	11.44
Daily (K Bbl/day)	24	51	75
Property			
RVP (psi)	6.8	6.7	6.7
Oxygen (wt%)	1.4	2.1	1.9
Aromatics (vol%)	17.2	20.6	19.6
Olefins (vol%)	6.3	8.9	8.1
Sulfur (ppm)	146	42	75
E200 (%off)	49.5	46.3	47.3
E300 (%off)	88.4	80.6	83.1

The E_{200} and E_{300} estimates shown in the table incorporate our estimates of E_{200} and E_{300} for all Type 2 CBG batches (for which refiners report T_{50} and T_{90}, not E_{200} and E_{300}).[3]

The ADWM data indicate that about 70% of the gasoline supplied to the CBG area in the 1999 Summer season was Type 1 CBG; about 30% was Type 2 CBG. (These volume shares are consistent with pipeline shipments reported in prior years). The ADWM data also indicate that the East refineries shipped significant volumes of Type 2 CBG containing no oxygenate.

3 MathPro Inc. has its own proprietary correlations linking (1) E_{200} and T_{50} and (2) E_{300} and T_{90},

Table 2.2 shows the estimated average properties of the Type 1 CBG portion of the Summer 1999 CBG gasoline pool. The average properties of Type 1 CBG define the baseline gasoline for the Maricopa County SIP. Hence the average properties shown in Table 2 formed the baseline for the emissions analysis that we conducted to assess the effects on the Maricopa County SIP of the Arizona phase-out of MTBE. The results of that analysis are reported in [Ref. 1].

Table 2.2: Average Properties of Type 1 CBG (1999 Summer) – SIP Baseline

Property	Average Value
RVP (psi)	6.7
Oxygen (wt%)	2.1
Aromatics (vol%)	18.6
Benzene (vol%)	0.89
Olefins (vol%)	8.6
Sulfur (ppm)	100
E200 (%off)	47.1
E300 (%off)	82.4

The ADWM data indicate that the oxygenates of choice for Summer CBG were MTBE (predominately) and TAME (from the West only). Some CBG contained ethanol, but only in “trace” amounts. The low average oxygen content of the CBG supplied from the East reflects the volumes of oxygen-free Type 2 CBG supplied from the East.

Refineries generally shipped summer gasoline from May to the end of September (as indicated by the dates individual batches of CBG entered the pipeline system). Refiners began shipping winter gasoline (sub-grades that are terminal-blended with ethanol) in October (or late September).

3. CBG VARIANTS CONSIDERED

We analyzed eleven options, or cases. Seven involved production of a single CBG variant; four involved concurrent production of two CBG variants. The set of cases and CBG variants considered in the analysis are shown in **Table 3.1**.

Table 3.1: CBG Variants Analyzed

Case Number	CBG Type	Oxygen Content				Refining Center	
		0	2.0	2.7	3.5	East	West
*Cases Analyzing Production of **One CBG Variant at a Time***							
1	1	X				✓	✓
2	2	X				✓	✓
3	1		X			✓	✓
4				X		✓	✓
5					X	✓	✓
6	2		X				✓
7				X		✓	✓
*Cases Analyzing Concurrent Production of **Two CBG Variants***							
8	1	X		X			✓
9		X			X	✓	✓
10	2	X	X				✓
11		X		X		✓	✓

Cases 1 and 2 covered, respectively, *non-oxygenated* Type 1 and Type 2 CBG, each produced in the East and West refining centers.

Cases 3 – 7 covered *ethanol blended* Type 1 and Type 2 CBG, at different oxygen contents, as indicated, and produced in the East and West refining centers, as indicated.

> We selected these CBG options on the basis of engineering judgement and the results of recent studies [Refs. 4 and 5] of the effects of California and national MTBE bans. We did not analyze Type 2 CBG ethanol blended to 3.5 wt% oxygen because prior analyses indicated that this gasoline would be very costly (or even infeasible) to produce under the California Phase 2 Predictive Model.

Cases 8 – 11 covered *simultaneous production* of two CBG variants – one non-oxygenated and one ethanol blended. The cases cover Type 1 and Type 2 CBG, different oxygen contents for the ethanol blended variants, and production in the East and West refining centers as indicated.

We analyzed these cases because they were requested and because they yield interesting results. However, at least for the foreseeable future, they do not represent feasible operations for supplying CBG to Maricopa County. Recall that the pipeline system can accommodate only two fungible classes of gasoline (Section 1.4). One of these would continue to be conventional gasoline, for areas of Arizona other than Maricopa County; the other would be one class of CBG gasoline – either ethanol-blended (to a uniform oxygen content) or non-oxygenated, but not both. Ethanol-blended and non-oxygenated gasolines are not fungible, nor are ethanol-blended gasolines blended to different oxygen contents.

4. REFINING ANALYSIS: METHODOLOGY

This section discusses the most important elements of the refinery modeling methodology used in this analysis.

1. Aggregate refinery models
2. Three stages of refinery modeling
3. Cost accounting framework
4. Over-optimization, ratio constraints, and aggregate blendstocks
5. Complex Model and Predictive Model

4.1 EAST AND WEST AGGREGATE REFINERY MODELS

We used MathPro Inc.'s refinery LP modeling system (**ARMS**) to analyze refining operations in the East and West refining centers supplying the CBG area.

Within ARMS, we represented refining operations in those centers as *aggregate refineries*. (An *aggregate refinery* is a model representing the aggregate of all refining capacity in the category or region of interest.)

The East aggregate refinery is configured such that it (1) has the aggregate capacity of the refineries in West Texas and New Mexico that supplied CBG in the 1999 Summer season; (2) runs West Texas Intermediate (WTI) crude oil; and (3) produces a product slate with volumes, grade splits, and properties consistent with the capacity profiles of these refineries.

> The East aggregate refinery embodies essentially the same refinery process and blendstock data as the PADDs 1 & 3 refining model that we developed and applied in two recent (as yet unpublished) studies for the National Petroleum Council and the Oxygenated Fuels Association (OFA) to analyze effects of a national MTBE ban. However, we adjusted certain blendstock properties to conform to the average properties of East gasoline supplied in the 1999 Summer season (Section 2).

The West aggregate refinery is configured such that it (1) has the same capacity profile as the aggregate of refineries in California; (2) runs a crude oil slate similar to the aggregate crude oil slate run in California; and (3) produces a product slate with volumes, grade splits, and properties consistent with current or forecast aggregate production by California refineries.

> The West aggregate refinery is essentially the same as the California refining model that we developed and applied in (1) previous studies for the California Energy Commission to analyze effects of the MTBE ban in California and (2) a recent (as yet unpublished) study for the OFA to analyze effects of a national MTBE ban.

4.2 THREE STAGES OF REFINERY MODELING

As is customary in our refinery modeling work, we conducted the refinery modeling for this study in three stages.

1. Calibrate ARMS so that the refinery models conform to key aspects of refining operations in the centers or regions under consideration, for a period where adequate data are available.

2. Develop Reference cases for a baseline year representing future operations with business-as-usual – in this study, with prospective gasoline property standards in place, but no MTBE phase-out in Arizona.

   Such gasoline property standards include federal Phase 2 RFG standards, the federal 30 ppm sulfur content standard, California's Phase 3 RFG standards, and the California ban on MTBE.

3. Develop and analyze cases representing alternative policy or technical scenarios – in this study, denoting various possible formulations of Type 1 and Type 2 CBG under the Arizona phase-out of MTBE. (We refer to these cases as CBG Variant cases.)

4.2.1 Model Development and Calibration

Developing the Refinery Models

As the discussion in Section 4.1 implies, the West refinery model used in this study had already been developed and calibrated. The East refinery model was developed and calibrated for this study.

We relied primarily on publicly available data sources to establish the refining process capacities, refinery input and product slates, gasoline grade splits, crude oil slates, prices for crude oil and refined products, product specifications, and average properties of conventional gasoline and RFG for the refinery models.

Calibrating ARMS

Calibration demonstrates the validity of the ARMS refinery LP model for the study at hand and establishes certain initial conditions for subsequent steps in the analysis.

Calibration involves adjusting technical elements of ARMS and the model's "boundary conditions," so that the ARMS model yields solution values that match with sufficient precision certain key measures of refinery operations in the period for which operating data are available. The key measures include capacity utilization of various refining processes, marginal refining costs at observed product volumes, marginal costs of product specifications, volumes of purchased crude oil and other inputs, gasoline properties and composition, and jet fuel and diesel properties.

4.2.2 Reference Cases

The Reference cases (one per refining center) represent refining operations under the regulatory regime projected for the 2005 Summer season. Results of the Reference case analyses define baseline conditions for the analysis of the CBG Variant cases.

For purposes of this analysis, the regulatory regime for 2005 includes:

- The California ban on MTBE blending
- The California Phase 3 RFG program (CaRFG3) with the Phase 3 Predictive Model
- No waiver of the requirement for oxygen content in federal RFG
- The federal Phase 2 RFG program (RFG2)
- The national Tier 2 sulfur standard for gasoline (30 ppm average/80 ppm cap)[4]
- Current EPA and California standards for diesel fuel

Results of the Reference case analysis comprise estimates of baseline refinery operations, product out-turns, average product properties, and costs. Comparison of these baseline values with corresponding values generated in the CBG Variant cases provides estimates of the costs and technical implications of an MTBE phase-out in Arizona.

4.2.3 CBG Variant Cases

The CBG Variant cases (eleven in all) represent refining operations in the West and East refining centers that are consistent with the Arizona phase-out of MTBE.

For the CBG Variant cases (and the Reference case), we assumed that the West refining center could import

- Iso-octane or iso-octene – in volumes up to 12 K Bbl/day – produced by a merchant MTBE plant outside of the U.S. that has been retro-fitted for the purpose.

  Iso-octane and iso-octene are high-octane, high-quality blendstocks, desirable for producing conventional gasoline and federal RFG2.

- Special light alkylate – a C_6/C_7 heart cut, with blending properties tailored to the requirements of CaRFG3 – from inland PADD 3 refineries

4 For purposes of refinery modeling, we used set the average sulfur standard at 25 ppm (to allow for downstream effects, such as measurement tolerances and interface contamination).

In particular, we made imported special light alkylate available to the West refining center at

- Volumes up to 25 K Bbl/day, and
- A price equal to the estimated marginal cost of producing special light alkylate in PADD 3 plus 15¢/gal to account for the cost of rail transportation from those refineries in PADD 3 to California.

The estimated marginal cost (drawn from a recent MathPro Inc. study of a national MTBE ban) includes operating costs and capital charge (at a 15% rate of return) for new facilities required to produce special light alkylate and for additional tankage and rail sidings.

- C_6 isomerate and C_6 isomerate feed

  Though having only moderate octane, C_6 isomerate has high value in CaRFG3 production, because it has relatively low RVP and low T_{50} and T_{90}. (Because of their high RVP, C_5 and C_5/C_6 isomerates have less value for CaRFG3.)

4.3 Additional Premises and Assumptions

The Reference and CBG Variant cases reflected the following modeling premises, in addition to those listed in Section 4.2.

- The reference crude oil price – Saudi Light (FOB Persian Gulf) – is $25/Bbl, corresponding to about $26.50/Bbl (CIF U.S. Gulf Coast).

  This reference crude oil price leads to estimated values of $25.35/Bbl for the aggregate crude slate in California and $26.50/Bbl for WTI (the crude for the East aggregate refinery).

- Average crude slates remain the same in the Reference and CBG Variant cases. That is, the average crude slate for each refining center is unaffected by Arizona's MTBE phase-out.

- Gasoline grade splits and average pool octane remain the same in the Reference and CBG Variant cases. That is, gasoline out-turn is unaffected by Arizona's MTBE phase-out.

- Gasoline demand in the CBG area is 82 K Bbl/day in 2000 (consistent with the estimates in [Ref. 2]) and grows at about 2.4%/year.

- The volume of CBG spill-over outside the CBG area is about 20% of the volume of CBG consumed in the CBG area.

- Future demand growth is met by the West refining center, because the KMEP East pipeline is operating at capacity and the West pipeline is not.

- The East refining center uses "selective" hydrotreating processes (e.g., the CD Hydro/CD HDS® process) to achieve the federal Tier 2 sulfur standard for gasoline. (The West refining center is already in compliance with the Tier 2 standard, with respect to production of California gasoline, by virtue of the California Phase 2 RFG program).

- The hurdle rate for new capital investment is a 15% real, after-tax rate of return. In post-modeling, spreadsheet analysis of costs, capital charges are reduced to reflect a 10% real, after-tax rate of return.

  This approach imposes a 15% rate of return on investment for estimating total capital investment in new process capacity and a 10% rate of return for computing the capital charge item in the cost accounting framework (described in Section 4.4.2).

- Process unit investment costs and capital charges are specified in terms of 2000 Gulf Coast costs, adjusted by regional location factors.

- The price of ethanol is $50.40/Bbl (CIF Phoenix), or $1.20/gal, after giving effect to the federal tax subsidy granted to ethanol blenders (54¢/gal at present; 51¢/gal in 2005).

  This estimate is drawn from an ethanol supply function that MathPro Inc. developed in the recent study for OFA and corresponds to our estimate of total U.S. consumption of ethanol, given the California MTBE ban and no national MTBE ban. The estimated ethanol price includes 15¢/gal for transportation from the Midwest to Phoenix and an upward adjustment of 8¢/gal in our ethanol supply function to reflect the effect of crude oil price on ethanol price.

  All else equal, an increase in crude oil prices will increase the cost of producing ethanol, because corn and ethanol production consume oil, in the form of fuels and petrochemicals. We had estimated our ethanol supply function for a crude oil price of about $20/Bbl (CIF Gulf Coast), as opposed to the $26.50/Bbl (CIF Gulf Coast) assumed in this analysis.

  We did not adjust the ethanol price in the CBG Variant cases to reflect the additional ethanol demand induced by Arizona's phase-out of MTBE.

4.4 Cost Accounting Framework

4.4.1 Overall Framework

For each CBG Variant case, we estimated the associated refining cost for each refining center, in terms of:

- The estimated *Total Average Cost* (¢/gal)

- The estimated *Total Annual Cost* ($M/year) for the entire CBG pool

- The estimated *Investment* ($M) in new refining capacity

The estimated Total Average Cost, Total Annual Cost, and Investment values are **differences** between costs and investments in the given CBG Variant case and those in the Reference case.

4.4.2 Accounting Framework for Total Average Cost

The Total Average Cost (and, by extension, the Total Annual Cost) values are the sums of five cost elements.

- *Variable Refining Cost* is the increase in direct, or out-of-pocket, refining costs resulting from producing Type 1 or Type 2 CBG with no MTBE blending. This cost element includes incremental crude oil and refinery inputs, energy consumption, catalyst and chemical costs, royalties, etc and changes in revenue resulting from changes in product volumes.

- *Refinery Capital Charge* is the annualized per-gallon cost for capital recovery and return on investment associated with investments made by refineries to expand or add new refining process capacity.

- *Refinery Fixed Cost* is the annualized per-gallon cost of the increases in fixed costs associated with new investments in refining capacity.

- *Ancillary Refining Costs* are costs that refineries may incur in complying with an Arizona phase-out of MTBE, but that are not registered in a refinery LP model.

  Refinery LP models do not register ancillary costs not because they are imaginary, but because it is hard to express them as explicit functions of refinery operating variables. We estimate these costs outside of ARMS, on the basis of engineering analysis and information from industry experts.

  In this analysis, we identified no significant ancillary costs that would be associated with Arizona's MTBE phase-out.

- *Mileage Loss* is the cost (not including federal or state taxes) of producing the additional gasoline required because of the mileage loss incurred in producing gasoline without MTBE.

  In general, we assume that a fuel's mileage (fuel economy) is proportional to its energy density. For gasoline, we assume that energy density is the volume-weighted average of the energy densities of the individual blendstocks. ARMS contains estimated values of energy density for each gasoline blendstock (including ethanol).

4.4.3 Costs Incurred Inside the Refinery Gate

The accounting framework deals only with costs incurred inside refinery battery limits, in connection with refining operations to comply with an MTBE ban.

In general, the accounting framework does not address logistics costs, that is, costs incurred downstream of the refinery – from the refinery gate to the pump – in moving, storing, and distributing gasoline.

Arizona's MTBE phase-out is unlikely to incur significant logistics costs, mainly because facilities for ethanol blending are already in place (by virtue of the Winter CBG program) downstream.

4.5 Over-Optimization, Ratio Constraints, and Aggregate Blendstocks

The refinery models used in this study incorporate certain procedures to minimize "over-optimization" to which all refinery LP modeling is susceptible.[5] One source of over-optimization – called "cherry-picking" – has particularly important consequences when modeling refinery responses to changes in product standards, particularly sulfur standards. Cherry-picking arises from the interaction of three factors.

- Most refineries simultaneously process a number of crude oils – each with distinct price, properties, and refining value. Because refineries commingle crude oils, the intermediate streams that refineries produce also are commingled (within each boiling range, defined by distillation cut points).

- Most refinery models represent crude oils individually to (1) capture their unique physical and economic properties and (2) allow selection of an "optimal" crude slate. But, separate representation of crude oils leads naturally, almost inevitably, to separate representation of the intermediate streams produced from each crude even though these steams are actually commingled in the "real" refinery.

- As a mathematical technique, LP is a relentless optimizer; it always locates and selects the most attractive processing options represented in the model at hand.

Left to its own devices, an LP solution procedure will produce model solutions showing highly specific separations and allocations of the commingled streams in any given boiling range. This is cherry-picking. In a cherry-picking solution, each process unit receives as feed the streams that maximize the unit's economic effectiveness, and each product blending pool receives the blendstocks best suited to it. Unfortunately, cherry-picking separations from commingled, run-of-the-refinery streams are difficult or impossible to accomplish in most real refinery operations.

Cherry-picking will occur with any refinery LP model that represents individual intermediate streams within given boiling ranges without special analytical techniques to represent the commingling that actually occurs. The two most widely used techniques to address cherry-picking are *recursive pooling* and *ratio constraints*. The former is rigorous, but complicated, expensive,

5 The term "over-optimization" denotes the tendency of refinery LP modeling to indicate higher aggregate profit contributions and/or lower incremental costs of a given refining operation than could occur in practice for a given set of refinery capital stock, product specifications, and market conditions.

and time-consuming. The latter is approximate, but less difficult to implement and easier and cheaper to use.

The models used in this analysis minimize cherry-picking though the use of (1) ratio constraints to control the allocation of sulfur-bearing streams to process units; and (2) aggregate, run-of-the-refinery blendstocks, within specific boiling ranges or for certain sources of material, to control product blending. The ratio constraints prevent the notional refinery from shifting commingled streams among processes or cherry-picking blendstocks in ways actual refineries are unable to do. The use of aggregate blendstocks limits the extent to which ARMS can cherry-pick blendstocks for product blending.

4.6 COMPLEX MODEL AND PREDICTIVE MODEL

In the Reference and CBG Variant cases, we used the following emissions models to control gasoline pool properties and ensure compliance with federal and state emissions regulations.

- EPA Phase 2 Complex Model for Type 1 CBG (West and East refining centers)
- EPA Phase 2 Complex Model (“anti-dumping”) for conventional gasoline (East refining center)
- California Phase 3 Predictive Model for CaRFG3 produced for use in California (West refining center)
- California Phase 2 Predictive Model for Type 2 CBG (West and East refining centers)

The Complex Model returns percent reductions in emissions relative to those of the statutory baseline gasoline (e.g., 30.7% for CBG *1* VOCs in the Reference case for the East refining center). For compliance, the emission reductions returned by the Complex Model must be larger than those specified in the federal Phase 2 RFG progam (e.g., 28.5% for VOCs, under the averaging option). The *higher* the algebraic value returned by the Complex Model, the larger the indicated emission reduction.

The Predictive Model returns percent reductions in emissions relative to the reductions required by the CaRFG3 program (e.g., -0.52% for CBG *2* VOCs in the East Reference case). For compliance, the emission reductions returned by the Predictive Model must be less than zero (i.e., negative). The *lower* the algebraic value returned by Predictive Model, the larger the indicated emission reduction.

ARMS incorporates “reduced forms” of EPA’s Complex Model and California’s Predictive Model (both the Phase 2 and the Phase 3 versions). Both models relate certain gasoline properties to emissions or changes in emissions of VOCs, NOx, and toxics.

A *reduced-form* model attempts to capture in a simple mathematical structure the major relationships of a larger or more complicated model. The reduced forms of the Complex Model or Predictive Model in ARMS (1) calculate changes in emissions close to those calculated by the original model; (2) approximate the functional relationships between changes in emissions and specific gasoline properties, so that ARMS can identify the lowest cost blends consistent with quality and emission performance constraints; and (3) are integrated directly into the refinery LP model.

5. REFINING ANALYSIS: RESULTS
ESTIMATED AVERAGE REFINING COSTS AND CBG PROPERTIES

5.1 Presentation of Detailed Results

Appendix A, **Exhibits A-1 through A-5** present the detailed results of the refining analysis, by refining center (East and West). The exhibits cover the Reference case and all of the CBG Variant cases.

Exhibits A-1 through A-5 convey a detailed technical description of the aggregate refinery representations of regional refining operations.

- Exhibit A-1 shows computed capacity utilization, process capacity additions, and key operating indices.
- Exhibit A-2 shows refinery charges (crude oil and other feedstocks), energy use, and refined product slates.
- Exhibit A-3 shows (1) pool-average gasoline properties, by gasoline type (RFG2, CaRFG3, conventional gasoline, and Arizona CBG) and by source (East and West), and (2) estimated emissions, by gasoline type (from the Complex Model or Predictive Model, as appropriate).
- Exhibit A-4 shows pool-average gasoline compositions and pool volumes, by gasoline type.

Exhibit A-5 shows the primary economic results of the analysis: estimated costs (expressed in our cost accounting framework) and investment requirements for the various CBG Variant cases.

5.2 Discussion

5.2.1 Refining Costs

Table 5.1 summarizes the estimated *average per-gallon refining costs* (in the East and West refining centers) associated with the various CBG variants considered.

The average per gallon costs are as defined in Section 4.4.2, expressed in 2000 dollars. They are average costs, applicable only to the CBG out-turn of the refining centers.

Table 5.1: Average Refining Costs of the CBG Options Analyzed

Case Number	CBG Type	Oxygen Content				Refining Cost (¢/gal)	
		0	2.0	2.7	3.5	East	West
*Cases Analyzing Production of **One CBG Variant at a Time***							
1	1	X				0.2	5.6
2	2	X				0.2	8.7
3	1		X			2.5	10.0
4				X		3.8	8.8
5					X	4.8	7.4
6	2		X				13.5
7				X		3.4	12.4
*Cases Analyzing Concurrent Production of **Two CBG Variants***							
8	1	X		X			5.6
9		X			X	0.2	5.6
10	2	X	X				8.7
11		X		X		0.2	8.7

These results indicate that Arizona's oxygen waiver for CBG, to take effect with the MTBE phase-out, will reduce significantly the refining cost of the MTBE phase-out.

They also indicate that refiners who have the opportunity to produce either or both non-oxygenated and ethanol-blended CBG (represented in the Concurrent Production cases) are likely (on economic grounds) to produce non-oxygenated CBG exclusively.

The estimated costs of producing CBG are higher for the West refining center than for the East, especially for ethanol-blended Type 2 CBG. These costs – all relative to the Reference case – reflect the interaction of four factors:

- CBG is a small portion (< 6%) of total gasoline out-turn in California;
- Ethanol blending is more costly than MTBE blending for producing CaRFG3;
- The Reference case includes the California MTBE ban (with the ethanol use that it induces) for CaRFG3 production; and
- The Reference case allows MTBE blending for CBG production (though, in practice, California refiners probably would not do so, for reasons other than refining economics).

Refining economics dictates that the *marginal cost* of replacing MTBE (with ethanol or other blendstock) will increase progressively as the replacement progresses. The *marginal* cost of replacing MTBE will be higher than the *average* cost (the cost estimated in refinery modeling), and the last increment of MTBE replacement will be the most expensive.

Under the premises of the Reference case, that last increment in the West refining center (i.e., California refineries) would be CBG. Hence, CBG would incur higher cost than any other segment of the California refineries' gasoline out-turn.

On the other hand, if California refiners were to stop MTBE blending for CBG production when the California MTBE ban takes effect (as they well may), the incremental cost of Arizona’s MTBE phase-out would be lower than the results of this analysis indicate. Under that assumption, the cost of removing MTBE from CBG supplied by the West refining center would be recognized in the Reference case, rather than in the CBG Variant cases.

The economic situation is reversed in the East refineries. For them, CBG is a relatively small share of their total gasoline out-turn. The rest of the gasoline out-turn is conventional gasoline, which is subject to less stringent emissions standards than CBG. The East refiners can use their relatively large conventional gasoline pool as a "sink" for blendstocks that are undesirable in CBG, and thereby lower their marginal and average costs of producing CBG.

In the West refineries, CBG is a small share of a relatively *higher-quality* gasoline pool; in the East refineries it is a small share of a relatively *lower-quality* gasoline pool.

5.2.2 Average CBG Properties and Emissions Reductions

Table 5.2 summarizes the estimated *average properties* and corresponding *emissions performance* (weighted by source refining center) associated with the various CBG variants considered.

The estimated average CBG properties and corresponding emissions performance indicate that

- In general, Arizona's MTBE phase-out will have little effect on vehicle emissions of VOC and NOx in the CBG area; but

- Type 2 CBG blended without oxygen would offer a small, but perhaps significant, reduction in NOx emissions.

These emissions reductions would be relative not to the current CBG pool, but to the CBG pool that the CBG area would receive from 2005 on, absent Arizona's MTBE phase-out.

In the long term (2005 and on), the average properties of the CBG pool will be determined not only by the Arizona CBG program (including the MTBE phase-out and the oxygen waiver) and the California MTBE phase-out, but also by the federal Tier 2 sulfur standard.

The Tier 2 sulfur standard will affect the sulfur content and other properties of CBG produced in the East refineries; it will have little effect on CBG from the West refineries.

The estimated emissions, by gasoline type and source, shown in Table 5.2 and Exhibit A-3 incorporate the effects of the Tier 2 sulfur standard. Average CBG properties and emissions performance may be somewhat less desirable in 2003 and 2004.

Table 5.2: Weighted Average Properties of the CBG Variants Analyzed

	CBG Type 1					**CBG Type 2**	
Oxygen Content →	**No oxy**	**2.0**	**2.7**	**3.5**	**2.0/3.5**	**No oxy**	**2.7**
Average Properties							
RVP (psi)	6.7	6.7	6.7	6.8	6.8	6.8	6.8
Oxygen (wt%)	0.0	2.0	2.7	3.5	3.1	0.0	2.7
Aromatics (vol%)	16.4	16.0	16.0	16.0	16.0	13.5	13.7
Benzene (vol%)	0.75	0.86	0.96	0.83	0.80	0.92	1.06
Olefins (vol%)	8.6	8.4	10.0	10.0	8.4	5.5	4.9
Sulfur (ppm)	22	22	25	25	22	22	22
E_{200} (vol%)	42.8	43.2	42.8	43.8	43.2	47.5	46.8
E_{300} (vol%)	84.0	83.4	83.3	83.3	83.4	83.5	84.1
T_{10} (°F)	135	128	129	129	128	134	129
T_{50} (°F)	209	210	212	216	217	207	209
T_{90} (°F)	317	319	319	319	319	318	317
Cert. Model Results (1)							
VOCs	29.9	30.2	30.3	30.4	30.1	-0.26	-0.75
NOx	15.9	16.3	15.9	15.9	16.3	-1.87	-0.21
Toxics	32.1	32.5	31.1	31.9	32.5	1.26	3.47

Notes:

1. For CBG 1, the **Certification Model Results** are Phase 2 Complex Model outputs denoting the percent reductions in emissions from 1990 vehicles fueled with the 1990 national baseline gasoline (Summer). For CBG 2, these values are Phase 2 Predictive Model outputs denoting reductions in emissions relative to the reference CARB Phase 2 RFG.

2. **CBG Type 1, 2.0/3.5 wt% Oxygen** denotes supply of CBG Type 1 with 2.0 wt% oxygen from the East refining center and 3.5 wt% oxygen from the West refining center.

5.2.3 Average Properties of SIP Baseline and Reference Case Gasolines

Table 5.3 shows the estimated average properties of (1) the baseline gasoline for the Maricopa County SIP (also shown in Table 2.2) and (2) the reference CBG pool from the refining analysis.

Recall that the baseline gasoline for the Maricopa County SIP is the Type 1 portion of the Summer 1999 CBG pool.

The reference CBG is the CBG (weighted by source refining center) produced in the Reference case of the refining analysis (Section 4.2.2). It is the standard of comparison for the various CBG variants considered in the refining analysis.

Table 5.3: Average Properties of SIP Baseline and Reference Case CBGs

Property	Average Values	
	SIP Baseline	Reference Case
RVP (psi)	6.7	6.7
Oxygen (wt%)	2.1	1.6
Aromatics (vol%)	18.6	17.3
Benzene (vol%)	0.89	0.95
Olefins (vol%)	8.6	8.6
Sulfur (ppm)	100	24
E200 (%off)	47.1	43.2
E300 (%off)	82.4	83.1

The two sets of CBG properties differ mainly in sulfur content, E_{200}, and oxygen content. The reference CBG has lower sulfur content because the Reference case incorporates the federal Tier 2 sulfur standard for gasoline. The reference CBG has lower E_{200} and oxygen content, reflecting supply of a significant volume of non-oxygenated Type 2 CBG.

We estimate that, with respect to the SIP baseline gasoline (1) the Type 1 portion of the reference CBG would cost about 2½¢/gal more to produce, and (2) the reference CBG would produce about 5 percent points more reduction in NOx emissions.

6. EMISSIONS ANALYSIS: METHODOLOGY

Task 4 (Emissions Analysis) of the Statement of Work (SoW) requires the "…assess[ment of] the emissions impacts of each [fuel formulation] scenario developed in Task 1 using existing models and analytical methods, to the extent available …" This section discusses the tools and methodologies employed to conduct the required emissions analysis. The discussion covers:

1. The emissions of interest
2. The emissions models used to estimate fuel-driven emissions impacts
3. The baseline emission levels against which fuel driven-impacts were evaluated

6.1 EMISSIONS OF INTEREST

The emissions of interest in this analysis are those pollutants for which ongoing air quality planning efforts are in place in Maricopa County and for which the combustion of gasoline is a significant contributor. In terms of gasoline combustion, this primarily involves emissions related to the continuing ozone and carbon monoxide air quality planning efforts, including:

- *Volatile Organic Compounds (VOC)*, which are precursors of ozone;
- *Oxides of Nitrogen (NO_x)*, which also are precursors of ozone; and
- *Carbon Monoxide (CO)*, which is both a pollutant of concern in its own right as well as a participant in the ozone formation process.

The SoW also requires an assessment of *hazardous air pollutant (HAP)* impacts. In fulfillment of this requirement, each CBG variant was analyzed to estimate its impacts on benzene, 1,3-butadiene, formaldehyde, and acetaldehyde emissions. These four compounds are generally recognized as the primary HAPs associated with gasoline combustion and, therefore, should provide an accurate assessment of the overall hazardous air pollutant impacts associated with each formulation. In fact, benzene and 1,3-butadiene alone are estimated to account for about 95 percent of the estimated potential cancer risk from gasoline powered vehicles. Formaldehyde and acetaldehyde account for the bulk of the remaining 5 percent. However, ADEQ also requested that polycyclic aromatic hydrocarbon (PAH) emission impacts be estimated on at least a qualitative basis. Although there is a lack of direct empirical evidence relating changes in PAH emissions to changes in fuel formulation, we accomplished this estimation through a surrogate comparison of the fuel aromatic contents. Throughout this report, the terms *hazardous air pollutant* and *toxic* emissions are used interchangeably.

Gasoline reformulation affects two specific sources of emissions in Maricopa County:

- On-road gasoline powered passenger cars and trucks, and

- Off-road gasoline powered vehicles and engines.

The emissions impacts of specific fuel formulations can vary with vehicle or engine technology (e.g., catalyst-equipped vehicles versus non-catalyst vehicles). It is, therefore, important to consider specific technology penetrations in deriving aggregate fuel-related impacts. Section 6.2 describes the various methodologies used to ensure a *reasonable* accounting of the various vehicle and engine technologies in use.

6.2 EMISSIONS MODELING TOOLS

The SoW requires that the emissions analysis be performed using "existing models and analytical methods, to the extent available." Unfortunately, no widely accepted, peer-reviewed modeling tools are available to definitively estimate the emissions impacts of gasoline reformulation. Nevertheless, several existing models can be used to support the required emissions analysis, including:

- The EPA **MOBILE** emission factor model (VOC, CO, and NO_x),
- The CARB **EMFAC** emission factor model (VOC, CO, and NO_x),
- The EPA **Complex Model** (VOC, NO_x, HAP's) for certifying federal RFG2,
- The CARB **Predictive Model** (VOC, NO_x, HAP's) for certifying CARB RFG2, and
- The EPA reformulated gasoline **CO [Complex] Model** (CO).

MOBILE and EMFAC are "fleetwide emission factor models", designed to assist air quality planners in developing regional emission inventories similar to those required in this analysis. The strength of both models is in the scope of *vehicle* technology representations underlying their emission factor predictions. Both models have only *limited* capability to evaluate "fuel property responses" – that is, the effects on vehicle emissions of changes in gasoline properties.

MOBILE's dynamic fuel responses are currently limited to changes in gasoline vapor pressure and oxygen content. (Additionally, static responses are included for federal RFG via an on/off switch, but the activated modeling algorithms are not sensitive to user-input fuel properties). Both vapor pressure and oxygen content are properties of importance in this analysis, but so too are other fuel properties, such as olefin, aromatic, and sulfur content, for which MOBILE includes no estimation algorithms. Similar limitations apply to EMFAC. These limitations, in conjunction with the fact that EMFAC is designed to reflect the emissions performance of California-certified passenger cars and trucks, renders EMFAC inappropriate for assessing impacts on the primarily federally-certified fleet of vehicles operating in Maricopa County.

MOBILE does include a robust treatment of evaporative VOC emissions for gasoline-powered passenger cars and trucks, using fuel RVP as an indicator of evaporative emissions potential. In fact, the *basic* evaporative emissions algorithms encoded in the Complex Model are taken directly from MOBILE. However, the specific algorithms encoded in MOBILE treat 7.0 psi RVP as a local minimum for older vehicle technologies. For advanced gasoline formulations, summertime volatilities of 7.0 psi and below are not uncommon; in this study, all evaluated formulations have RVP of 6.7 or 6.8 psi. In fact, the CARB Predictive Model treats 7.2 psi as an RVP cap. Both the Predictive Model and the Complex Model allow certified fuels to demonstrate evaporative emission reductions at RVP as low as 6.4 psi. As a result, MOBILE no longer reflects the most recent emissions impacts associated with gasoline RVP control.

The Complex Model (including the supplemental CO component) and the Predictive Model were developed specifically to evaluate the effects of gasoline properties on vehicle emissions. However, these models have weaknesses complementary to those of the fleetwide emission factor models described above (i.e., MOBILE and EMFAC). Whereas the emission factor models incorporate comprehensive treatment of vehicle technologies and allow detailed fleetwide impacts to be assessed, the Complex and Predictive Models consider only limited vehicle technology impacts. The Complex Model estimates impacts specifically for a 1990 fleet of vehicles and is not sensitive to changes in fleetwide technology characteristics. The latest version of the Predictive Model (Beta 3) is considerably more sensitive to vehicle technology. It includes vehicle components explicit to 1981 through 1985 (Tech 3), 1986 through 1994 (Tech 4), and 1995 and later advanced passenger car technology (Tech 5). Though the Predictive Model lacks specific treatments for pre-1981 vehicle technologies, such technologies constitute a modest fraction of the on-road vehicle fleet in the 2004 and 2010 evaluation years of this study. However, given that similar technology continues to be prevalent in the off-road vehicle and engine sector, pre-Tech 3 technology is an important element of this analysis. Moreover, the Predictive Model has no CO component, limiting its utility to VOC, NO_x, and HAPs evaluation.

Nevertheless, given their ability to evaluate detailed gasoline property impacts on emissions, the Complex and Predictive Models are clearly the models of choice for evaluating gasoline property responses, within the context of their inherent limitations. These limitations were identified and discussed in detail during the 1996 analysis performed in support of the Maricopa County Voluntary Early Ozone Plan (VEOP) for Summer gasoline. As documented in the report summarizing that work [Ref. 2] as well as in a subsequent report addressing Winter gasoline and diesel formulation options [Ref. 3], techniques have been developed to adjust both Complex Model and Predictive Model impact estimates to account for changes in non-represented fleet technology have been developed.

By adjusting for the effects of fuel sulfur changes on NO_x emissions of oxidation catalyst vehicles and on VOC, CO, and NO_x emissions of pre-catalyst vehicle (and engine), one can use the models to estimate fuel property responses for Tech 1 and Tech 2 vehicles (and engines). The basic theory behind these adjustments is that gasoline sulfur impacts are overwhelmingly reflected in improvement (declining sulfur) or deterioration (increasing sulfur) of vehicle catalyst efficiency. Therefore, emissions from vehicles without catalysts will be unaffected by changes in fuel sulfur as will NO_x emissions from oxidation catalyst equipped vehicles. Emissions sensitivity to fuel sulfur is among the most significant of fuel formulation impacts. We made no additional adjustments for other fuel parameters.

We estimated fuel property responses for gasoline-fueled vehicles other than passenger cars (which are represented by the Complex Model and Predictive Model) by converting the specific technologies observed in each gasoline vehicle class to an equivalent passenger car technology class. For example, light duty truck technologies similar to Tech 3 passenger car technology are assigned fuel property responses equivalent to those of Tech 3 passenger cars.

For this analysis, the applicable model year breakdown for non-passenger-car classes is as follows:

LDGT1: Pre-1988 TWC technology is Tech 3
1988-1994 TWC technology is Tech 4
1995 and newer TWC technology is Tech 5

LDGT2: Pre-1988 TWC technology is Tech 3
1988-1996 TWC technology is Tech 4
1997 and newer TWC technology is Tech 5

HDGV: All TWC technology is Tech 4

In all cases, non-TWC (three-way catalyst) technology (including all motorcycles and off-road vehicles and engines) is treated as either oxidation catalyst or non-catalyst technology as applicable, and modeled using the sulfur adjusted approach described above for passenger cars.

Table 6.1 (next page) summarizes the modeling approaches used for the emissions analysis of the CBG variants.

As indicated, these approaches rely on one or more of the existing modeling tools described above. Since specific adjustments were required to estimate the emissions impacts of the CBG variants for the various vehicle (and engine) catalyst technologies found in the Maricopa County fleet, all emissions impact analysis was (1) performed at a catalyst technology level-of-detail and (2) aggregated on the basis of vehicle miles of travel (VMT)-weighted technology market penetrations to derive overall gasoline formulation impact estimates.

In other words, emissions estimates were developed separately for non-catalyst, oxidation catalyst, and three-way catalyst technologies (Tech 3, Tech 4, and Tech 5), and these individual impacts were aggregated in accordance with evaluation year-specific technology fractions. Technology fractions for each evaluation year consider penetrations within the passenger car, light truck, heavy truck, and motorcycle sectors. All gasoline powered off-road vehicle and engine impacts were assumed to be equivalent to non-catalyst on-road vehicle impacts.

The Complex Model was used as the basis for all gasoline-related VOC, CO, NO_x, and HAPs impacts. As described above, the effect of changes in gasoline sulfur content was factored out of emissions impact estimates for non-catalyst vehicles (as well as NO_x impact estimates for oxidation catalyst vehicles). The Predictive Model was used to adjust the inherent Tech 4 impacts predicted through the Complex Model for differentials observed for Tech 3 and Tech 5 vehicle technologies. In other words, to estimate Tech 5 vehicle impacts (which constitute a substantial fraction of overall impacts for the 2004 and 2010 evaluation years used in this study), basic Complex Model predictions were adjusted by the ratio of Predictive Model Tech 5 to Tech 4 impacts. Corresponding adjustments were made for Tech 3. However, in both cases, the implemented adjustments were limited to the normal emitter fraction of the fleet (as defined by the

Complex Model). High emitter impacts predicted by the Complex Model were used without change.

Table 6.1: Modeling Approach for Emissions Analysis, by Emission Type

Inventory Source	VOC	CO	NO_x	HAPs
Pre-Catalyst On-Road and All Off-Road Vehicles	**Complex Model** (adjusted to eliminate effects of fuel sulfur) plus **Predictive Model-Derived Tech 3 Adjustment Factor**	**CO Complex Model** (adjusted to eliminate effects of fuel sulfur and oxygen) plus **MOBILE6 Oxy Content Reduction Factors**	**Complex Model** (adjusted to eliminate effects of fuel sulfur) plus **Predictive Model-Derived Tech 3 Adjustment Factor**	**Complex Model** (adjusted to eliminate effects of fuel sulfur) plus **Predictive Model-Derived Tech 3 Adjustment Factor**
Oxidation Catalyst On-Road Vehicles	**Complex Model** plus **Predictive Model-Derived Tech 3 Adjustment Factor**	**CO Complex Model** (adjusted to eliminate effects of fuel oxygen) plus **MOBILE6 Oxy Content Reduction Factors**	**Complex Model** (adjusted to eliminate effects of fuel sulfur) plus **Predictive Model-Derived Tech 3 Adjustment Factor**	**Complex Model** plus **Predictive Model-Derived Tech 3 Adjustment Factor**
Tech 3 On-Road Vehicles	**Complex Model** plus **Predictive Model-Derived Tech 3 Adjustment Factor**	**CO Complex Model** (adjusted to eliminate effects of fuel oxygen) plus **MOBILE6 Oxy Content Reduction Factors**	**Complex Model** plus **Predictive Model-Derived Tech 3 Adjustment Factor**	**Complex Model** plus **Predictive Model-Derived Tech 3 Adjustment Factor**
Tech 4 On-Road Vehicles	**Complex Model** (without adjustment)	**CO Complex Model** (adjusted to eliminate effects of fuel oxygen) plus **MOBILE6 Oxy Content Reduction Factors**	**Complex Model** (without adjustment)	**Complex Model** (without adjustment)
Tech 5 On-Road Vehicles	**Complex Model** plus **Predictive Model-Derived Tech 5 Adjustment Factor**	**CO Complex Model** (adjusted to eliminate effects of fuel oxygen) plus **MOBILE6 Oxy Content Reduction Factors**	**Complex Model** plus **Predictive Model-Derived Tech 5 Adjustment Factor**	**Complex Model** plus **Predictive Model-Derived Tech 5 Adjustment Factor**

Substantial work has been done in evaluating the effects of gasoline oxygen content since the release of the CO version of the Complex Model. The MOBILE6 development document [Ref. 4] summarizes this work. In recognition, oxygen content impact estimates (on exhaust CO) presented in this EPA document were used in place of the impact estimates predicted via the CO version of the Complex Model. The CO version of the Complex Model was used to estimate the impact of other fuel properties (e.g., aromatic and sulfur content) on exhaust CO, but oxygen content impacts were estimated using the following factors (expressed as percentage change in exhaust CO per weight percent oxygen) extracted from [Ref. 4]:

	Normal Emitters	High Emitters
Tech 5 vehicles	-0.0	-5.3
Tech 4 vehicles (1)	-4.5	-5.3
Tech 3 vehicles	-4.0	-5.3
Oxidation catalyst vehicles	-9.4	-9.4
Non-catalyst vehicles	-6.6	-6.6

(1) Arithmetic average of –3.1 (1988 and newer TWC/ADL), -4.8 (1986-1987 TWC/ADL), and –5.7 (1986 and newer TWC/No ADL).

6.3 Baseline Emission Inventories

The emissions models used in this study express emission impacts in terms of percentage change from a baseline. Hence, baseline emission inventories are required to convert fuel quality responses into mass emission impacts. For this analysis, the baseline inventories should reflect the emission levels expected in Maricopa County in each evaluation year, assuming the continuation (without change) of current fuel regulations and the implementation of already adopted new fuel regulations. The SoW states that "ADEQ shall provide the Contractor all necessary data relating to modeling assumptions, emissions inventories, and other information needed to characterize emissions in Maricopa County." We interpreted this clause to imply that not only should the local inventory data be provided by ADEQ (or their designee), but that all data provided should be used without change, except as necessary to conduct the required fuel analyses.

In fulfillment of this requirement, ADEQ advised that the summer emission inventories for VOC, CO, and NO_x presented in [Ref. 3, Chapter 5] should be used as the baseline inventories for this study. [Ref. 3] presents inventories for 1999 and 2010 evaluation years. ADEQ recommended a simple interpolation between these two years to develop the necessary 2004 evaluation year emission inventories.

Table 6.2 presents the resulting baseline emission inventories for VOC, CO, and NO_x.

No Maricopa County specific summer baseline HAP inventories were available from ADEQ. Therefore, to provide mass emission impact estimates for each of the fuel formulations evaluated in this study, a baseline HAP emission inventory for on- and off-road vehicles and engines was constructed using Complex Model relations for the baseline gasoline properties. Since the Complex Model predicts both HAP and VOC emission rates, it is possible to evaluate the ratio of HAP to VOC emissions and apply the resulting ratios to the Maricopa County VOC inventories to derive expected HAP inventories. This calculation can be performed only for the on- and off-road sources considered in the Complex Model analysis, so that HAP inventories for other source categories were not derived. While the absence of complete HAP inventories prohibits a determination of total emission inventory impacts, it is possible through this approach to estimate both the mass emission impacts of each fuel formulation and the relative change in *mobile* source emissions.

Tables 6.3 and **6.4** present the resulting estimates of HAP baseline inventories.

6.4 BASELINE INVENTORY ADJUSTMENTS

As described in [Ref. 3], the baseline inventories presented in **Table 6.2** are derived from data collected in support of the Maricopa County VEOP process. Accordingly, those inventories do not reflect the imposition of the Tier 2 gasoline sulfur standard recently issued by EPA. As a result of the Tier 2 gasoline program, gasoline supplied to Maricopa County in the 2004 and 2010 evaluation years will differ from that assumed for the inventories presented in **Tables 6.2** through **6.4** (1999 summer gasoline) regardless of whether or not MTBE is phased out of Maricopa County gasoline. Therefore, to accurately evaluate the impact of Arizona's MTBE phase-out in the 2004 and 2010 evaluation years, the baseline emission inventories must first be adjusted to reflect the expected summer fuel properties in those years.

To undertake the required adjustment of the 2004 and 2010 baseline emission inventories, the properties of Maricopa County summer gasoline after the imposition of the federal low sulfur gasoline requirements was estimated, as previously presented in Chapter 2. The emission impacts of this “expected” baseline fuel were applied to the inventories presented in **Tables 6.2** through **6.4** to derive more appropriate baseline inventories for this study. The emission impacts of the expected future baseline gasoline were estimated using the exact same modeling methods described in Section 6.2 for the alternative MTBE phase out fuel options. The resulting estimated adjusted baseline inventories are presented in **Tables 6.5** through **6.7**.

It should be recognized that the emission differentials reflected across **Tables 6.2** through **5.7** represent changes expected between now and 2004/2010 regardless of the MTBE phase-out. **Table 6.8** summarizes these prospective changes in baseline emissions.

Table 6.2: Baseline VOC, CO, and NO_X Inventories

			VOC (Mtpd) Summer 2004	VOC (Mtpd) Summer 2010	NO_x (Mtpd) Summer 2004	NO_x (Mtpd) Summer 2010	CO (Mtpd) Summer 2004	CO (Mtpd) Summer 2010
Point			16.4	18.0	23.5	24.0	9.4	17.0
Area			75.1	86.0	13.8	16.0	5.9	7.0
Biogenic			57.0	57.0	14.0	14.0	0.0	0.0
On-Road			90.3	75.0	206.3	221.0	1117.9	1017.0
	Gasoline		82.7	67.1	146.8	159.2	1054.1	943.7
		Exhaust	49.3	43.0	146.8	159.2	1054.1	943.7
		Evap	33.5	24.1	0.0	0.0	0.0	0.0
	Diesel		7.5	7.9	59.5	61.8	63.8	73.3
	Other		0.0	0.0	0.0	0.0	0.0	0.0
Off-Road			77.2	63.0	102.2	118.0	921.5	1090.0
	Gasoline		55.4	36.3	5.1	6.4	797.1	934.2
		Exhaust	30.6	17.6	5.1	6.4	797.1	934.2
		Evap	24.9	18.7	0.0	0.0	0.0	0.0
	Diesel		20.1	25.0	91.0	105.0	101.6	131.6
	Other		1.7	1.7	6.1	6.6	22.8	24.1
All Sources			315.9	299.0	359.7	393.0	2054.6	2131.0

(Mtpd denotes metric tons per day.)

Table 6.3: Baseline Benzene, 1,3-Butadiene, and Formaldehyde Inventories

			Benzene (Mtpd) Summer 2004	Benzene (Mtpd) Summer 2010	1,3-But (Mtpd) Summer 2004	1,3-But (Mtpd) Summer 2010	Formald (Mtpd) Summer 2004	Formald (Mtpd) Summer 2010
Point			n/e	n/e	n/e	n/e	n/e	n/e
Area			n/e	n/e	n/e	n/e	n/e	n/e
Biogenic			n/e	n/e	n/e	n/e	n/e	n/e
On-Road			n/e	n/e	n/e	n/e	n/e	n/e
	Gasoline		2.2	1.9	0.6	0.5	0.8	0.7
		Exhaust	2.0	1.7	0.6	0.5	0.8	0.7
		Evap	0.3	0.2	0.0	0.0	0.0	0.0
	Diesel		n/e	n/e	n/e	n/e	n/e	n/e
	Other		n/e	n/e	n/e	n/e	n/e	n/e
Off-Road			n/e	n/e	n/e	n/e	n/e	n/e
	Gasoline		1.4	0.9	0.3	0.2	0.5	0.3
		Exhaust	1.2	0.7	0.3	0.2	0.5	0.3
		Evap	0.2	0.1	0.0	0.0	0.0	0.0
	Diesel		n/e	n/e	n/e	n/e	n/e	n/e
	Other		n/e	n/e	n/e	n/e	n/e	n/e
All Sources			3.7	2.8	0.9	0.7	1.3	1.0

"1,3-But" is 1,3-Butadiene
"Formald" is Formaldehyde

(Mtpd denotes metric tons per day.)
("n/e" indicates that no estimate is available for the applicable source category.)

Table 6.4: Baseline Acetaldehyde and Total Toxics Inventories

			Acetald (Mtpd) Summer 2004	Acetald (Mtpd) Summer 2010	Total Toxics (Mtpd) Summer 2004	Total Toxics (Mtpd) Summer 2010
Point			n/e	n/e	n/e	n/e
Area			n/e	n/e	n/e	n/e
Biogenic			n/e	n/e	n/e	n/e
On-Road			n/e	n/e	n/e	n/e
	Gasoline		0.3	0.2	3.9	3.3
		Exhaust	0.3	0.2	3.6	3.1
		Evap	0.0	0.0	0.3	0.2
	Diesel		n/e	n/e	n/e	n/e
	Other		n/e	n/e	n/e	n/e
Off-Road			n/e	n/e	n/e	n/e
	Gasoline		0.2	0.1	2.4	1.4
		Exhaust	0.2	0.1	2.2	1.3
		Evap	0.0	0.0	0.2	0.1
	Diesel		n/e	n/e	n/e	n/e
	Other		n/e	n/e	n/e	n/e
All Sources			0.4	0.3	6.3	4.8

"Acetald" is Acetaldehyde

(Mtpd denotes metric tons per day.)
("n/e" indicates that no estimate is available for the applicable source category.)

Table 6.5: Adjusted Baseline VOC, CO, and NO_x Inventories

			VOC (Mtpd) Summer 2004	VOC (Mtpd) Summer 2010	NO_x (Mtpd) Summer 2004	NO_x (Mtpd) Summer 2010	CO (Mtpd) Summer 2004	CO (Mtpd) Summer 2010
Point			16.4	18.0	23.5	24.0	9.4	17.0
Area			75.1	86.0	13.8	16.0	5.9	7.0
Biogenic			57.0	57.0	14.0	14.0	0.0	0.0
On-Road			89.4	74.1	191.9	203.1	1106.4	1005.4
	Gasoline		81.9	66.1	132.4	141.3	1042.6	932.1
		Exhaust	48.4	42.1	132.4	141.3	1042.6	932.1
		Evap	33.5	24.1	0.0	0.0	0.0	0.0
	Diesel		7.5	7.9	59.5	61.8	63.8	73.3
	Other		0.0	0.0	0.0	0.0	0.0	0.0
Off-Road			77.6	63.3	102.1	118.0	938.7	1110.2
	Gasoline		55.9	36.6	5.1	6.4	814.3	954.5
		Exhaust	31.0	17.8	5.1	6.4	814.3	954.5
		Evap	24.9	18.7	0.0	0.0	0.0	0.0
	Diesel		20.1	25.0	91.0	105.0	101.6	131.6
	Other		1.7	1.7	6.1	6.6	22.8	24.1
All Sources			315.5	298.3	345.3	375.0	2060.4	2139.6

(Mtpd denotes metric tons per day.)

Table 6.6: Adjusted Baseline Benzene, 1,3-Butadiene, and Formaldehyde Inventories

			Benzene (Mtpd) Summer 2004	Benzene (Mtpd) Summer 2010	1,3-But (Mtpd) Summer 2004	1,3-But (Mtpd) Summer 2010	Formald (Mtpd) Summer 2004	Formald (Mtpd) Summer 2010
Point			n/e	n/e	n/e	n/e	n/e	n/e
Area			n/e	n/e	n/e	n/e	n/e	n/e
Biogenic			n/e	n/e	n/e	n/e	n/e	n/e
On-Road			n/e	n/e	n/e	n/e	n/e	n/e
	Gasoline		2.2	1.9	0.6	0.5	0.8	0.7
		Exhaust	1.9	1.7	0.6	0.5	0.8	0.7
		Evap	0.3	0.2	0.0	0.0	0.0	0.0
	Diesel		n/e	n/e	n/e	n/e	n/e	n/e
	Other		n/e	n/e	n/e	n/e	n/e	n/e
Off-Road			n/e	n/e	n/e	n/e	n/e	n/e
	Gasoline		1.4	0.8	0.4	0.2	0.5	0.3
		Exhaust	1.2	0.7	0.4	0.2	0.5	0.3
		Evap	0.2	0.1	0.0	0.0	0.0	0.0
	Diesel		n/e	n/e	n/e	n/e	n/e	n/e
	Other		n/e	n/e	n/e	n/e	n/e	n/e
All Sources			3.6	2.7	1.0	0.7	1.3	1.0

"1,3-But" is 1,3-Butadiene
"Formald" is Formaldehyde

(Mtpd denotes metric tons per day.)
("n/e" indicates that no estimate is available for the applicable source category.)

Table 6.7: Adjusted Baseline Acetaldehyde and Total Toxics Inventories

			Acetald (Mtpd) Summer 2004	Acetald (Mtpd) Summer 2010	Total Toxics (Mtpd) Summer 2004	Total Toxics (Mtpd) Summer 2010
Point			n/e	n/e	n/e	n/e
Area			n/e	n/e	n/e	n/e
Biogenic			n/e	n/e	n/e	n/e
On-Road			n/e	n/e	n/e	n/e
	Gasoline		0.3	0.2	3.8	3.3
		Exhaust	0.3	0.2	3.6	3.1
		Evap	0.0	0.0	0.3	0.2
	Diesel		n/e	n/e	n/e	n/e
	Other		n/e	n/e	n/e	n/e
Off-Road			n/e	n/e	n/e	n/e
	Gasoline		0.2	0.1	2.4	1.4
		Exhaust	0.2	0.1	2.2	1.3
		Evap	0.0	0.0	0.2	0.1
	Diesel		n/e	n/e	n/e	n/e
	Other		n/e	n/e	n/e	n/e
All Sources			0.4	0.3	6.3	4.7

"Acetald" is Acetaldehyde

(Mtpd denotes metric tons per day.)
("n/e" indicates that no estimate is available for the applicable source category.)

Table 6.8: Adjusted Baseline Emission Inventory Impacts

Emission Species	Absolute Emission Change (Mtpd)	Percent Change in Total Inventory	Percent Change in On-Road Inventory	Percent Change in Off-Road Inventory	Percent Change in Mobile Inventory
2004 Evaluation Year					
VOC	-0.4	-0.1%	-0.9%	+0.6%	-0.2%
NO_x	-14.4	-4.0%	-7.0%	0.0%	-4.7%
CO	+5.8	+0.3%	-1.0%	+1.9%	+0.3%
Benzene (1)	-0.090	-2.5%	-3.2%	-1.3%	-2.5%
1,3-Butadiene (1)	+0.068	+7.6%	+6.9%	+8.6%	+7.6%
Formaldehyde (1)	-0.011	-0.9%	-0.7%	-1.2%	-0.9%
Acetaldehyde (1)	+0.006	+1.4%	+1.2%	+1.8%	+1.4%
Total Toxics (1)	-0.027	-0.4%	-0.9%	+0.4%	-0.4%
2010 Evaluation Year					
VOC	-0.7	-0.2%	-1.2%	+0.4%	-0.5%
NO_x	-18.0	-4.6%	-8.1%	0.0%	-5.3%
CO	+8.6	+0.4%	-1.1%	+1.9%	+0.4%
Benzene (1)	-0.074	-2.7%	-3.4%	-1.2%	-2.7%
1,3-Butadiene (1)	+0.050	+7.4%	+6.9%	+8.6%	+7.4%
Formaldehyde (1)	-0.007	-0.8%	-0.6%	-1.2%	-0.8%
Acetaldehyde (1)	+0.004	+1.4%	+1.2%	+1.8%	+1.4%
Total Toxics (1)	-0.027	-0.6%	-1.0%	+0.4%	-0.6%

(1) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change impacts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

7. EMISSIONS ANALYSIS: RESULTS ESTIMATED CHANGES IN EMISSIONS INVENTORIES

7.1 VEHICLE AND OFF-ROAD EMISSION IMPACTS OF CBG VARIANTS.

Using the methodology described in Section 6, we estimated emission impacts for each of the CBG variants considered. As also described in Section 6, the baseline against which emission impacts are estimated is not the CBG currently delivered to Maricopa County, but rather the Reference fuel from the refining analysis. This means that the impacts of the Tier 2 gasoline sulfur standard recently adopted by the EPA have been incorporated into the 2004 and 2010 emissions baselines used for the MTBE phase-out analysis, as described in Section 6.4. **Table 7.1** summarizes the impacts of this incorporation relative to the Maricopa County emissions inventories expected in the absence of the EPA Tier 2 standard (i.e., the inventories that would be applicable if the baseline gasoline continued to be delivered through 2004 and 2010). As indicated in **Table 7.1**, most of the differences between the baseline CBG and the Reference CBG are modest, the exception being a significant decrease in baseline NO_x emissions.

Tables 7.2 and 7**.3** summarize the results of the emissions analysis, presenting the combined on-road and off-road vehicle and engine effects, in terms of both mass emissions and percentage emissions change in 2004 and 2010. CO emission impacts are presented both in terms of total and reactivity weighted mass. Reactivity weighting is important when considering CO impacts on ozone since, while CO does contribute to the ozone formation process, it does not do so with the same level of significance as VOC emissions. Previous modeling studies performed in Maricopa County by ADEQ have indicated that CO participates in the ozone formation process at a rate about 1/82nd that of VOC. Therefore, the emissions analysis includes estimates for both total and reactivity weighted CO, with the latter determined as 1/82nd of the former. A similar adjustment for the significance of NO_x in the ozone formation process would allow for an aggregate determination of overall ozone forming potential, but efforts to quantify the significance of NO_x emissions relative to VOC in Maricopa County are ongoing and no specific equivalency factor is available at this time.

Toxic emissions are treated on a basis analogous to that of ozone-related CO. Not all toxic compounds pose the same level of risk. For example, one milligram of benzene is generally considered to pose a greater risk than one milligram of acetaldehyde. While increasing benzene emissions by one milligram and decreasing acetaldehyde emissions by one milligram will keep the total toxic mass emissions the same, the associated risk of that mass has increased. Therefore, potency weighting factors have been derived to adjust toxic compound mass in accordance with the relative potency of individual compounds. For this analysis, weighting factors were taken from the CARB Predictive Model, which normalizes all toxic emissions to 1,3-butadiene equivalent risk. The associated weighting factors are 1.0 for 1,3-butadiene, 0.17 for benzene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Figures 7.1 through **7.6** present a graphical depiction of the mass emission impacts in 2004, drawn from **Table 7.2**. Given the similarity in 2004 and 2010 impacts (when viewed on a relative basis across alternative formulations), corresponding graphic depictions of 2010 impacts have not been included, but are quite similar to those of 2004.

Appendix B presents additional detail for each CBG variant, including both total unweighted toxic mass and individual toxic compound emission impacts, as well as percentage change estimates for the total mobile, on-road mobile, and off-road mobile components of the overall Maricopa County inventory.

Appendix C presents results for each CBG variant regarding emission impacts for specific vehicle and engine technologies, as well as technology-weighted impacts for each evaluation year.

Tables 7.2 and 7.3 reflect assumptions of no commingling and full commingling of ethanol-blended and non-ethanol-blended CBG.

The SoW called for evaluation of the potential impacts of commingling of ethanol- and non-ethanol-containing fuel blends. It has been demonstrated that commingling of otherwise similar ethanol-containing and non-ethanol-containing gasolines results in an increase in the RVP of the resulting blend, even when the two gasolines have the same RVP to begin with. Five of the seven CBG variants contain ethanol in quantities of at least 2.0 wt% oxygen (on average). It is possible that ethanol-containing CBG could be commingled with non-oxygenated CBG upon delivery to Maricopa County, although the extent to which such commingling might occur is difficult to foresee.

To estimate the *worst case* potential impacts of commingling, we conducted the emissions analysis independently under two alternative commingling scenarios. In the first scenario, no commingling occurs, and all emission impacts are evaluated at the pool average gasoline properties. In the other scenario, worst case commingling occurs – that is, 50 percent of the CBG volume is ethanol-blended at the pool average oxygen level and the other 50 percent is non-oxygenated, but with properties (most specifically RVP) similar to the ethanol-blended portion. Based on data collected in support of the CARB Phase 3 Reformulated Gasoline rulemaking process, it has been estimated that the effective RVP boost under such a scenario is 0.2 psi for 2.0 weight percent ethanol blends, 0.3 psi for 2.7 weight percent ethanol blends, and 0.5 psi for 3.5 weight percent ethanol blends. An effective 0.4 psi RVP boost was assumed for the combined 2.0 and 3.5 weight percent ethanol gasoline option. We performed the emissions analysis for the second scenario using these estimated *worst case* RVP boosts.

As noted in Section 1.4, we expect that the worst case – corresponding to commingling – will be unlikely to occur in practice, because of the limited number of gasoline grades that the pipeline system can handle.

Table 7.1: Summary of Baseline Emission Adjustments

	VOC	NO_x	CO	CO_{RW} (1)	VOC + CO_{RW}	Toxics $_{PW}$ (2)
2004 Maricopa County Inventory Adjustments						
Pre-Adjustment Baseline (Mtpd)	315.9	359.7	2054.6	25.1	341.0	1.576
Adjusted Baseline (Mtpd)	315.5	345.3	2060.4	25.1	340.6	1.628
Emissions Adjustment (Mtpd)	-0.4	-14.4	+5.8	+0.1	-0.3	+0.052
Emissions Adjustment (%)	-0.1	-4.0	+0.3	+0.3	-0.1	+3.3
2010 Maricopa County Inventory Adjustments						
Pre-Adjustment Baseline (Mtpd)	299.0	393.0	2131.0	26.0	325.0	1.194
Adjusted Baseline (Mtpd)	298.3	375.0	2139.6	26.1	324.4	1.231
Emissions Adjustment (Mtpd)	-0.7	-18.0	+8.6	+0.1	-0.6	+0.038
Emissions Adjustment (%)	-0.2	-4.6	+0.4	+0.4	-0.2	+3.2

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Table 7.2: Gasoline Formulation Emission Impact Summary for 2004 (1)

Case	Type	Oxygen (wt%)	VOC		NO_x		CO		CO_{RW} (2)		VOC + CO_{RW}		Toxics $_{PW}$ (3)	
Absolute Change in Maricopa County Inventory (Mtpd)														
1	CBG1	0.0	+0.6		-1.0		+165		+2.0		+2.6		+0.054	
2	CBG2	0.0	+1.0		-3.2		+143		+1.7		+2.8		-0.077	
3	CBG1	2.0	-0.6	+3.3	-1.6	-1.5	-43	-51	-0.5	-0.6	-1.1	+2.6	-0.051	-0.048
4	CBG1	2.7	-1.2	+4.7	-0.3	-0.2	-112	-123	-1.4	-1.5	-2.5	+3.2	-0.005	+0.000
5	CBG1	3.5	-0.2	+11.0	-0.6	-0.4	-202	-217	-2.5	-2.6	-2.6	+8.3	-0.071	-0.063
6	CBG2	2.7	+0.1	+6.4	-3.9	-3.8	-132	-142	-1.6	-1.7	-1.5	+4.6	-0.207	-0.201
7	CBG1	2.0 & 3.5	+0.6	+9.3	-2.0	-1.8	-160	-172	-1.9	-2.1	-1.3	+7.2	-0.111	-0.105
Percentage Change in Maricopa County Inventory														
1	CBG1	0.0	+0.2		-0.3		+8.0		+8.0		+0.8		+3.3	
2	CBG2	0.0	+0.3		-0.9		+6.9		+6.9		+0.8		-4.7	
3	CBG1	2.0	-0.2	+1.0	-0.5	-0.4	-2.1	-2.5	-2.1	-2.5	-0.3	+0.8	-3.1	-3.0
4	CBG1	2.7	-0.4	+1.5	-0.1	-0.1	-5.4	-6.0	-5.4	-6.0	-0.7	+1.0	-0.3	+0.0
5	CBG1	3.5	-0.1	+3.5	-0.2	-0.1	-9.8	-10.5	-9.8	-10.5	-0.8	+2.4	-4.4	-3.9
6	CBG2	2.7	+0.0	+2.0	-1.1	-1.1	-6.4	-6.9	-6.4	-6.9	-0.4	+1.4	-12.7	-12.4
7	CBG1	2.0 & 3.5	+0.2	+2.9	-0.6	-0.5	-7.8	-8.4	-7.8	-8.4	-0.4	+2.1	-6.8	-6.4

(1) For non-zero oxygen content formulations: the leftmost value indicates emission impacts for a homogenous fuel market at average fuel properties, the rightmost value indicates "worst case" impacts if commingling occurs between zero oxygen and fuel at average (with oxygen) properties.

(2) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Table 7.3: Gasoline Formulation Emission Impact Summary for 2010 (1)

Case	Type	Oxygen (wt%)	VOC		NO_x		CO		CO_{RW} (2)		VOC + CO_{RW}		Toxics $_{PW}$ (3)	
Absolute Change in Maricopa County Inventory (Mtpd)														
1	CBG1	0.0	+0.4		-1.1		+168		+2.0		+2.4		+0.041	
2	CBG2	0.0	+0.6		-3.5		+145		+1.8		+2.4		-0.056	
3	CBG1	2.0	-0.4	+2.4	-1.7	-1.6	-43	-51	-0.5	-0.6	-1.0	+1.8	-0.039	-0.037
4	CBG1	2.7	-0.8	+3.5	-0.2	-0.0	-114	-125	-1.4	-1.5	-2.2	+2.0	-0.005	-0.001
5	CBG1	3.5	-0.1	+8.1	-0.4	-0.2	-206	-221	-2.5	-2.7	-2.6	+5.4	-0.056	-0.050
6	CBG2	2.7	-0.0	+4.6	-4.1	-4.0	-134	-144	-1.6	-1.8	-1.7	+2.9	-0.156	-0.151
7	CBG1	2.0 & 3.5	+0.5	+6.8	-2.1	-1.9	-162	-175	-2.0	-2.1	-1.5	+4.7	-0.086	-0.081
Percentage Change in Maricopa County Inventory														
1	CBG1	0.0	+0.1		-0.3		+7.8		+7.8		+0.7		+3.3	
2	CBG2	0.0	+0.2		-0.9		+6.8		+6.8		+0.7		-4.6	
3	CBG1	2.0	-0.1	+0.8	-0.5	-0.4	-2.0	-2.4	-2.0	-2.4	-0.3	+0.5	-3.1	-3.0
4	CBG1	2.7	-0.3	+1.2	-0.0	-0.0	-5.3	-5.9	-5.3	-5.9	-0.7	+0.6	-0.4	-0.1
5	CBG1	3.5	-0.0	+2.7	-0.1	-0.0	-9.6	-10.3	-9.6	-10.3	-0.8	+1.7	-4.6	-4.1
6	CBG2	2.7	-0.0	+1.5	-1.1	-1.1	-6.3	-6.7	-6.3	-6.7	-0.5	+0.9	-12.6	-12.3
7	CBG1	2.0 & 3.5	+0.2	+2.3	-0.6	-0.5	-7.6	-8.2	-7.6	-8.2	-0.5	+1.4	-6.9	-6.6

(1) For non-zero oxygen content formulations: the leftmost value indicates emission impacts for a homogenous fuel market at average fuel properties, the rightmost value indicates "worst case" impacts if commingling occurs between zero oxygen and fuel at average (with oxygen) properties.

(2) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

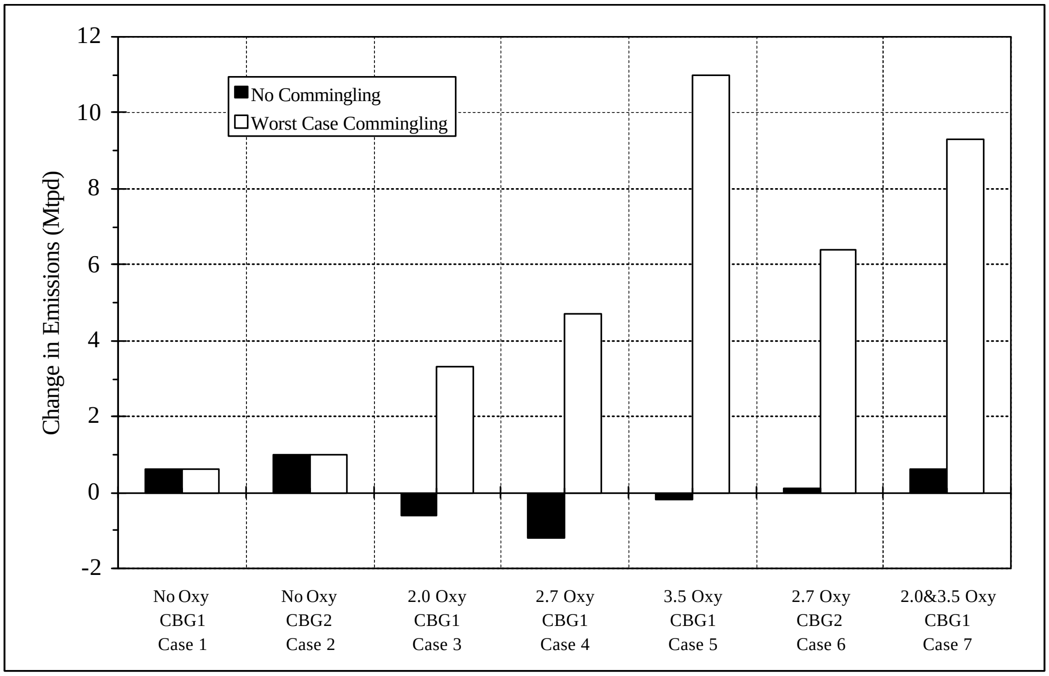
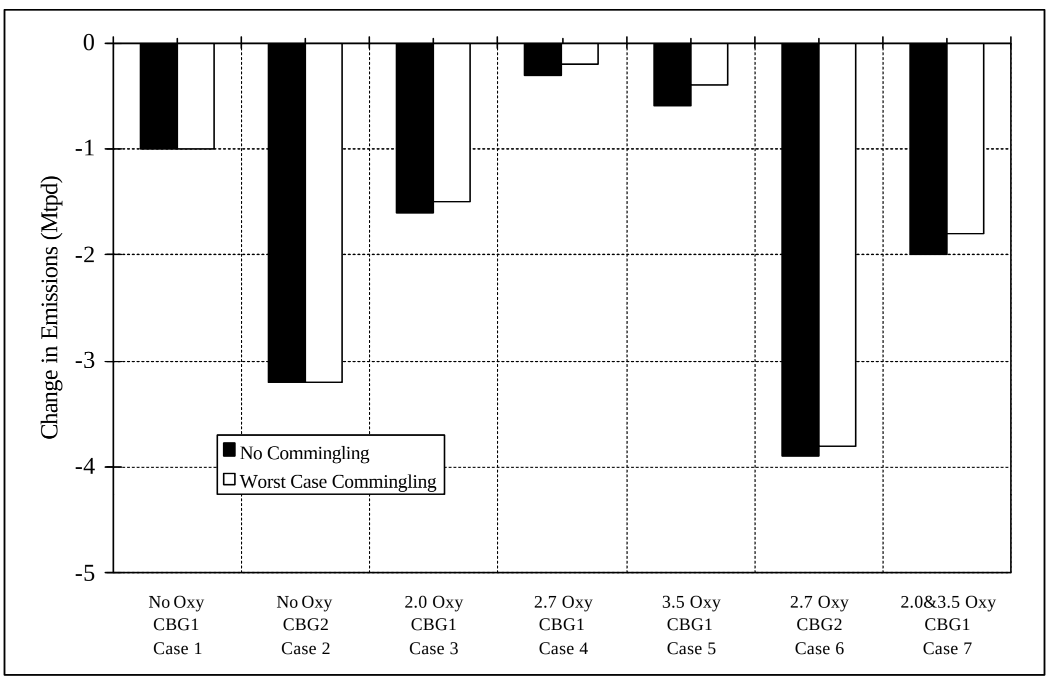


Figure 7.1: Effects of CBG Variants on VOC Emissions in 2004

Figure 7.2: Effects of CBG Variants on NO_X Emissions in 2004



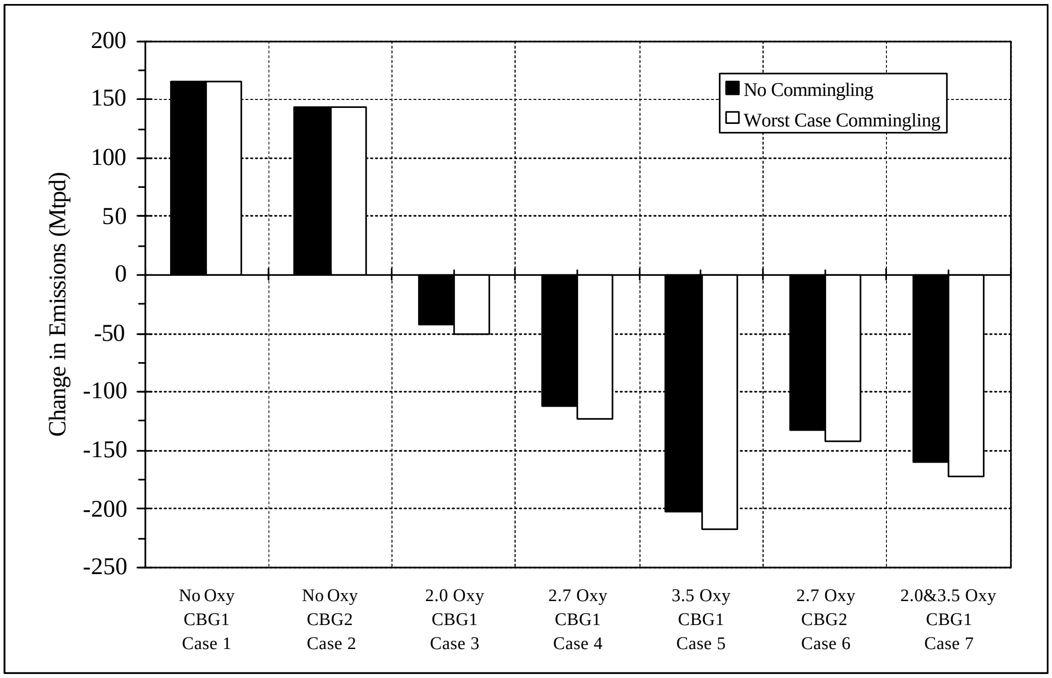
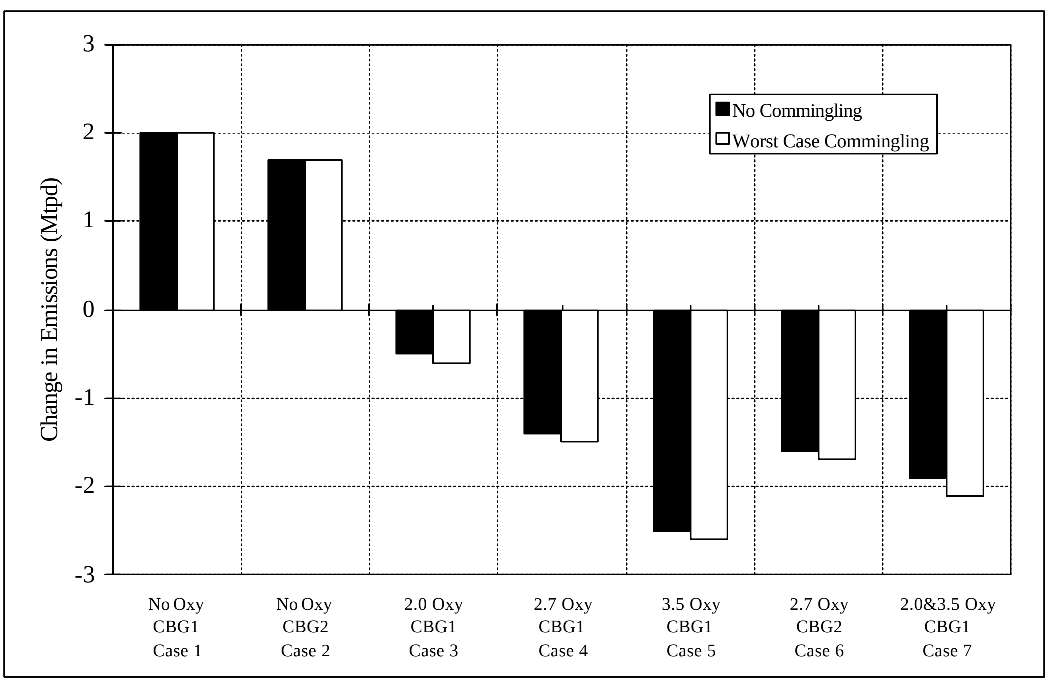


Figure 7.3: Effects of CBG Variants on CO Emissions in 2004

Figure 7.4: Effects of CBG Variants on Reactivity Weighted CO in 2004



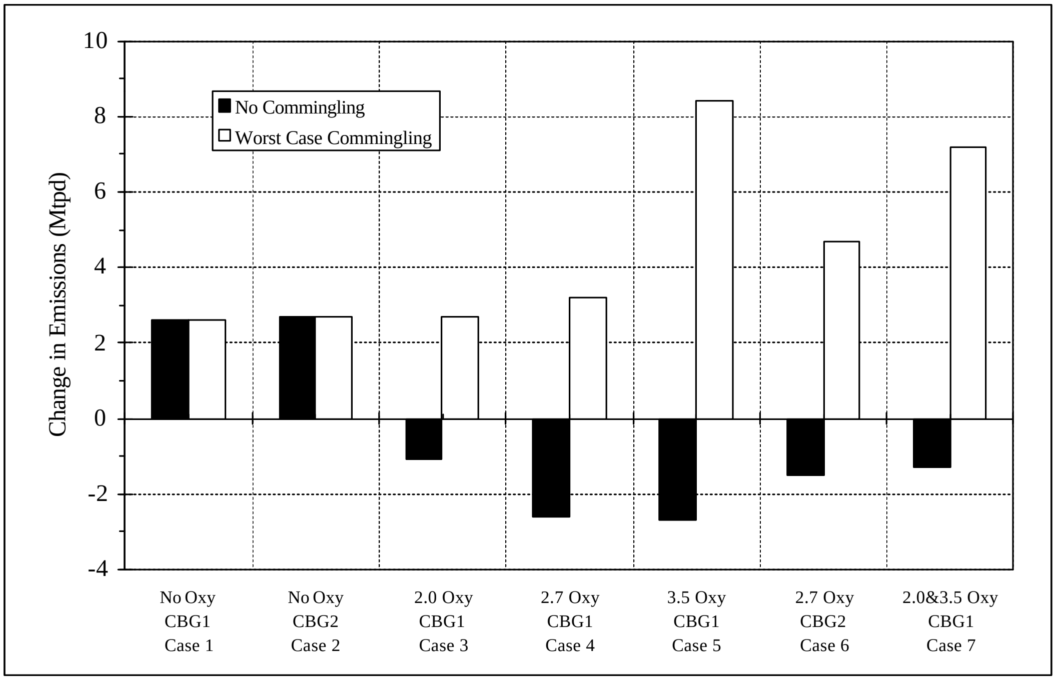
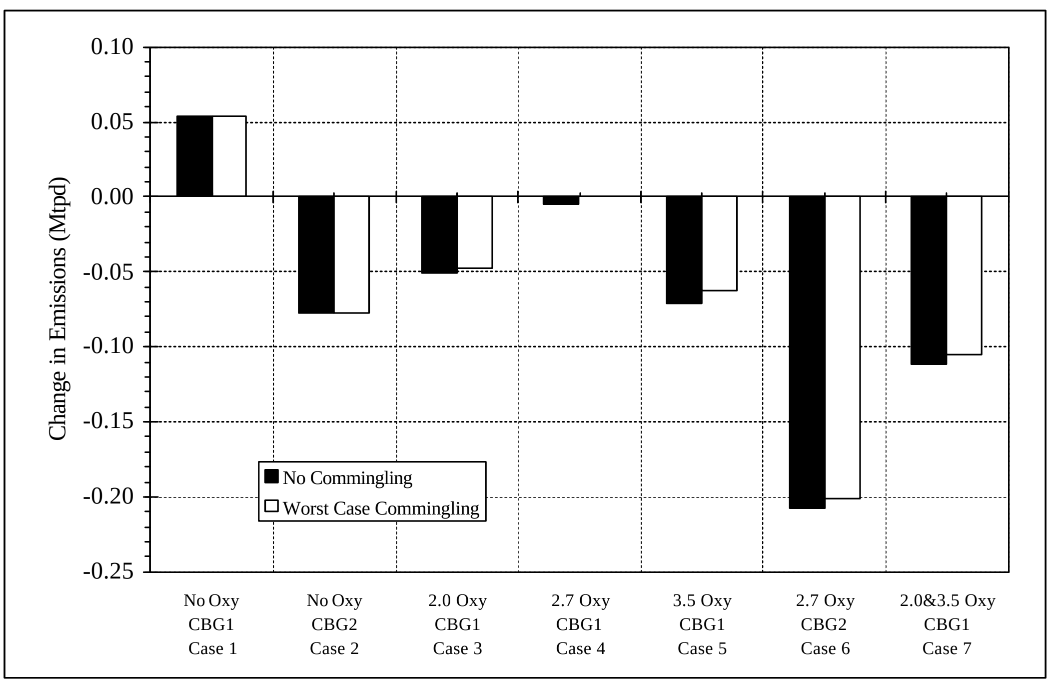


Figure 7.5: Effects of CBG Variants on VOC + Reactivity Weighted CO in 2004

Figure 7.6: Effects of CBG Variants on Potency Weighted Toxics in 2004



7.2 IMPLICATIONS OF THE EMISSIONS ANALYSIS

The results shown in **Tables 7.2** and 7**.3** and **Figures 7.1** through **7.6** lead to several conclusions regarding the emission impacts of the CBG variants considered.

- In the absence of commingling, there are only modest ozone-related differences between the CBG variants. VOC plus reactivity weighted CO impacts range from small decreases (less than 0.5 percent) to small increases (less than 1 percent). NO_x impacts range from no change to small decreases (about 1 percent).

- For the oxygenated variants, commingling will result in some degree of ozone-related emissions degradation relative to no commingling impacts. The upper end of the VOC plus reactivity weighted CO impact range extends to as far as a 2 percent increase, essentially doubling the upper limit of the impact range from a no commingling scenario.

- Six of the seven CBG variants produce reductions in gasoline-related toxic emissions (reactivity weighted) of up to 12 percent. Only the non-oxygenated CBG1 variant results in a toxic emissions increase (of about 3 percent).

Sections 7.2.1 and 7.2.2 provide additional discussion related to these conclusions.

7.2.1 Ozone-Related Emissions Impacts

In the *absence* of commingling, the range of ozone related (i.e., VOC, NO_x, and reactivity weighted CO) emission impacts is dominated by oxygenate influences on CO emissions. Changes in VOC for all formulations are modest at ±0.4 percent. All CBG1 formulations produce modest NO_x reductions of 0.1-0.6 percent, while the CBG2 formulations reduce NO_x by about 1 percent. However, the oxygenated gasoline formulations produce CO reductions of between 2 and 10 percent, while their nonoxygenated counterparts result in CO emissions increases of 7 to 8 percent. This 9 to 18 percentage point swing in CO emissions effectively dominates the ozone related impacts of the alternative formulations..

The 2.7 wt% oxygen CBG Type 1 formulation produces the largest VOC emission reduction – 0.3 to 0.4 percent. The 2.7 wt% oxygen CBG Type 2 formulation produces the largest NO_x emission reduction – 1.1 percent. CO reductions are directly related to fuel oxygen so that the 3.5 wt% oxygen CBG Type 1 formulation produces the largest CO emission reduction – about 10 percent. In the aggregate, the 2.7 wt% oxygen CBG Type 2 formulation produces the largest net ozone related emission reduction – just under 1 percent. But, the variability in ozone impacts across fuels is small so that consideration of NO_x versus VOC versus CO might be important.

When commingling *is* considered, the relative ozone impacts of the CBG variants can change dramatically. While NO_x and CO impacts are essentially unchanged with commingling, VOC *increases* of between 1 and 3.5 per cent could accrue for all of the various oxygenated formulations under worst case commingling scenarios. This magnitude of change in VOC emission impacts completely offsets the ozone effects of the CO reductions of the oxygenated formulations. Net ozone-related VOC plus reactivity weighted CO impacts range from *increases* of 0.5 to 2 percent (as opposed to *decreases* of 0.3 to 0.8 percent under a no commingling scenario). For the CBG2 oxygenated variant, this increase is offset to an unknown extent by numerically larger decreases in NO_x emissions.

Since the actual degree of commingling that will occur is unknown, it is not possible to pinpoint exactly where ozone related impacts for the oxygenated formulations will end up. In fact, the impacts could vary over time between the ranges indicated. Short of implementing requirements that minimize commingling, there will always be uncertainty in the effective ozone impacts of ethanol-blended gasolines. Nevertheless, for three of the oxygenated gasoline formulations (those with oxygenate contents less than 3.5 wt%), the magnitude of the worst case commingling emissions increase (when VOC, NO_x, and reactivity weighted CO are considered) is no greater than the magnitude of the no commingling emissions reduction, so that it would be unlikely that ozone-related emissions increases would occur over an extended timeframe such as an entire ozone season. The two 3.5 wt% oxygen formulations exhibit worst-case commingling impacts that are larger in magnitude than the no commingling emission reductions and, as such, pose greater risks of both short and long term emission increases.

7.2.2 Toxic Emission Impacts

In terms of total toxic mass, all oxygenated CBG variants lead to increases in toxic emissions due to significant increases in emissions of acetaldehyde (see **Appendix B** for impacts on individual toxic species). The non-oxygenated CBG variants lead to modest toxic mass emission increases, primarily due to increases in benzene emissions. Commingling has only a modest influence on the estimated mass of toxic emissions, so that the trends across CBG variants are similar regardless of the degree of commingling assumed.

Since the risk associated with toxic emissions species varies considerably, it is more appropriate to evaluate toxic emission impacts through a potency weighted metric. For example, the potency of 1,3-butadiene is nearly 6 times that of benzene, which in turn is nearly 5 times that of formaldehyde. As acetaldehyde potency is only about half that of formaldehyde, increases in acetaldehyde emissions, such as those produced by the ethanol-blended CBG variants, can be more than offset by smaller reductions in the more toxic emission species. This is, in fact, exactly what is expected to occur. On a potency-weighted basis, as shown in **Tables 7.2** and 7**.3** and **Figure 7.6**, all but one of the CBG variants (non-oxygenated CBG Type 1) result in toxic emission reductions. The range of reductions extends from 0 to almost 13 percent, with the 2.7 wt% oxygen CBG Type 2 option producing the largest reductions (nearly twice those of any other option).

The potency weighted emission impact estimates presented here include impacts on 1,3-butadiene, benzene, formaldehyde, and acetaldehyde. As discussed in Chapter 6, the four toxic compounds covered in these tables have been estimated to account for over 97 percent of the toxic risk from gasoline powered motor vehicles and engines. Nevertheless, ADEQ also requested a qualitative estimate of impacts on PAH emissions. However, as described in Section 6, no models are available to relate changes in PAH emissions to changes in gasoline properties. As an alternative, gasoline aromatic content has been used as surrogate indicator of the relative PAH emissions potential of each of the gasoline options. The resulting relations are included in **Appendix C**. However, these relationships should be viewed as directional indicators only and should not be accorded the same degree of significance ascribed to the toxic emission impact estimates presented in **Tables 7.2** and **7.3,** or those presented in **Appendix B**. Given the relatively small contribution of PAH emissions to total gasoline combustion related toxic risk, the inability to accurately account for changes PAH emissions should not fundamentally alter the toxic emissions performance impacts of the various gasoline options as discussed above.

8. ADDITIONAL CONSIDERATIONS

This section briefly discusses other possible effects of Arizona's MTBE phase-out.

As evidenced by the ongoing testimony presented in support of the California Phase 3 Reformulated Gasoline rulemaking and program review process, there is considerable debate on the impact of an MTBE ban on vehicle performance. In general, vehicle performance concerns can be traced directly to the degree to which ethanol is used to replace MTBE. In many respects such concerns are not new, as similar debate has surrounded ethanol blended gasolines since the initial widespread introduction of such fuels in the early 1980s. At that time, issues such as vehicle driveability, vapor lock, fuel economy, and fuel system deposits were considered to be potentially significant impediments to the use of ethanol blended gasolines.

All of these issues have been addressed in numerous test programs over the years and diminished in potential impact through improvements in both vehicle and fuel technology. Nonetheless, several aspects of ethanol blending have the *potential* for negative vehicle performance impacts. Hence, the effects discussed here bear on the ethanol-blended CBG variants.

8.1 Fueling System Deposits

Concerns regarding the impact of fueling system deposits on vehicle performance with the use of ethanol-blended fuels derive primarily from the tendency of those fuels to dislodge accumulated deposits and rust, resulting in fuel filter plugging and diminished performance. This problem has been resolved by the universal introduction of effective corrosion and deposit inhibitors and detergents. Effective fuel additives are required in all gasoline sold in the U.S. to ensure optimal emissions performance throughout a vehicle life cycle, as well as to facilitate problem-free operation of the sophisticated fuel injection systems currently used on vehicles. Moreover, Maricopa County's use of ethanol-blended gasoline for Winter CO control ensures that such fuels have already been introduced to the area's vehicle fleet and that any transient effects related to fueling system deposits have already taken place.

8.2 Fuel Economy

At a given combustion efficiency, a vehicle's fuel economy (miles/gal) is proportional to its fuel's energy content. Ethanol blended gasolines have somewhat lower energy density (BTU/gal), and hence lower fuel economy, than their non-ethanol counterparts. Other gasoline properties, notably aromatics content, also affect energy density and fuel economy.

Table 8.1 shows the energy densities of the baseline CBG pool and the CBG variants (as estimated in the refining analysis), as well as the differences between them. As indicated, the estimated differences in energy density are small – ranging from an increase of 0.7 percent (for non-oxygenated CBG Type 1) to a decrease of 1.8 percent (for ethanol-blended CBG Type 2, with 2.7wt% oxygen).

Table 8.1: Energy Contents of CBG Variants

Gasoline Formulation	Energy Content (MMBtu/bbl)	Change from Baseline
Reference Case (Baseline)	5.145	n/a
Case 1: No Oxy CBG1	5.179	+0.7%
Case 2: No Oxy CBG2	5.139	-0.1%
Case 3: 2.0 wt% Oxy CBG1	5.112	-0.6%
Case 4: 2.7 wt% Oxy CBG1	5.093	-1.0%
Case 5: 3.5 wt% Oxy CBG1	5.066	-1.5%
Case 6: 2.7 wt% Oxy CBG2	5.053	-1.8%
Case 7: 2.0 & 3.5 wt% Oxy CBG1	5.070	-1.4%

For a vehicle with a fuel efficiency of 20 miles per gallon (mpg), these estimated energy contents correspond to fuel economy changes ranging from an increase of 0.13 mpg to a decrease of 0.36 mpg. At a fuel price of $1.50 per gallon and an annual mileage accumulation of 10,000 miles, these fuel economy changes would lead to changes in *annual* fuel purchase costs ranging from a savings of $4.92 to an increased cost of $13.66. For a 40 mpg vehicle, similar calculations yield fuel economy impacts ranging from an increase of 0.26 mpg to a decrease of 0.72 mpg and annual fuel cost impacts ranging from a savings $2.46 to an increased cost of $6.83. Clearly, the impact on vehicle fuel economy and fuel purchase costs due to *fuel economy* differentials across the CBG variants is minimal, especially considering that the fuel economy effect will be felt only in the Summer season (i.e., actual costs will only be half those estimated).

Note that the average refining costs reported in Section 6 include this fuel economy effect. As discussed in Section 5, fuel economy is a line item in the cost accounting framework used in the refining analysis.

8.3 Driveability

The *Driveability Index* (DI), established through cooperative research between vehicle and fuel manufacturers, provides an indication of the effect on vehicle performance of a gasoline's distillation characteristics. It may also correlate with vehicle emissions performance.

The accepted formula for DI as a function of measured T_{10}, T_{50}, and T_{90} temperatures is:

$$DI = 1.5 (T_{10}) + 3 (T_{50}) + T_{90}$$

The automobile industry has proposed an alternative expression, as follows:

$$DI = 1.5 (T_{10}) + 3 (T_{50}) + T_{90} + 20 \text{ (wt.\% oxygen from ethanol blending)}$$

In this formula, for example, ethanol blending at 2.7 wt% oxygen adds 54 numbers to the DI, all else equal.

Given the high average temperatures in Maricopa County, the first of these DI expressions is probably the more appropriate one for estimating the driveability of Arizona CBG.

It is generally accepted that a DI < 1200 indicates good performance characteristics, while a DI > 1250 indicates poor performance. In Maricopa County, again because of its high average temperatures, gasoline with DI between 1200 and 1250 is likely to have satisfactory driveability.

ASTM has established a maximum standard DI of 1250 (at the pump) and the refining industry is honoring that standard on a voluntary basis (at the refinery gate).

The estimates of DI that one can obtain from the refining analysis are average values, at the *refinery gate* (not at the pump). For any average DI, the actual DIs of individual gasoline batches would be distributed over a range that encompasses the average. This effect is caused by normal fluctuations in refinery operations and normal commingling of batches in the distribution system.

Ensuring that at least 95% of all gasoline batches have DI $\leq$ 1200 at the pump is likely to require a pool average DI at the refinery gate in the range of 1150-1170 – assuming that the refining industry monitored and controlled DI as closely as it does other regulated properties.

Table 8.2 shows the estimated average DI values at the refinery gate for the various CBG variants (drawn from the refining analysis) and the corresponding estimated range of maximum DI values at the pump (occurring say at least 5% of the time).

These estimates suggest that

- The Arizona MTBE phase-out would yield little change in the average DI of CBG, at least relative to the average DI in Summer 1999;

- The average DI of the CBG pool under the MTBE phase-out should be satisfactory with respect to vehicle performance.

- CBG Type 1 gasoline is likely to have higher average DI than CBG Type 2 gasoline. This is a consequence of the differences between the California CaRFG3 program (and the Predictive Model) and the federal RFG2 program (and the Complex Model).

Table 8.2: Estimated Driveability Indices for CBG Variants Under MTBE Phase-Out

		Estimated DI Values	
Gasoline	**Oxygen Content (wt%)**	**Weighted Average at Refinery Gate**	**Maximum Value at Pump**
Baseline (1999)	0--2.1	1141	1170-1190
Reference	0--2.1	1167	1195-1215
CBG Type 1	Zero	1156	1185-1205
	2.0	1153	1185-1205
	2.7	1156	1185-1205
	3.5	1176	1205-1225
CBG Type 2	Zero	1135	1155-1175
	2.0		1170-1190
	2.7	1135	1165-1185

8.4 Vapor Lock

Vapor lock has probably received more attention regarding potential problems with ethanol blended fuels than any other aspect of vehicle performance. Vapor lock can occur when fuel is too volatile, and concentrations of compressible fuel vapor in fuel lines and fueling system components become excessive relative to concentrations of incompressible liquid fuel. This situation leads to problems in fuel delivery as fuel pump operation results not only in the desired fuel pressurization and, thus, movement through the fueling system, but also in fuel compression in lieu of fuel movement. Generally, this phenomenon has been controlled in automotive applications through an ASTM vapor-to-liquid ratio (or V/L) standard, which sets upper limits on the temperature at which V/L equals 20.

When ethanol blended gasolines were first introduced into widespread commerce in the U.S. in the early 1980s, there was specific concern regarding the potential for increased vapor lock as a result of ethanol's propensity to increase fuel volatility over the lower half of the distillation curve (i.e., up to about 200°F). However, less often cited was a potentially offsetting characteristic of ethanol blending; ethanol's heat of vaporization is about three times greater than that of gasoline. This higher heat of vaporization effectively results in fuel system cooling that reduces fueling system vapor generation. Considerable testing was performed during the 1980s, some of which indicated increased vapor lock occurrence with ethanol blending, some of which did not. Interestingly, laboratory studies tended to indicate the increased potential, while in-use studies generally found no problems, including tests performed in temperatures as high as 100°F.

The CBG variants considered in this study are unlikely to increase the incidence of vapor lock in the CBG area. First, the distillation characteristics of the base gasolines that would be used for ethanol blended CBG variants will account for ethanol's effects on the distillation curve. In fact, the estimated DI values for the ethanol blended CBG variants indicate lower volatility than the non-oxygenated CBG variants. Second, earlier studies showing potential vapor lock propensity generally compared ethanol splash blends to the base fuels from which they were created; no adjustments to offset ethanol's fuel distillation impacts were considered. Even under such test conditions, in-use vehicle studies at temperatures as high as 110°F did not indicate increased vapor lock occurrence with ethanol blends. Third, fueling system design has been improved since those early studies to reduce vapor lock potential regardless of the fuel considered. Design advances such as moving fuel pumps to vehicle fuel tanks have resulted in both cooler and more effective fuel delivery systems. We consider it unlikely that Arizona's MTBE phase-out will lead to an increased incidence of vapor lock, regardless of which CBG variants are ultimately delivered to the CBG area.

8.5 Non-Quantified Potential Emission Impacts

The permeation of fuel through fueling system components contributes to overall vehicle HC emissions performance. Small quantities of fuel permeate through fueling system components – including fuel tanks, lines, and gaskets – and subsequently evaporate. Both running and resting evaporative emissions are affected by the degree to which such permeation occurs.

Specific testing on the degree to which such permeation may be a function of the oxygenate used is ongoing. Preliminary work indicates that ethanol blends exhibit a much higher permeation rate for many existing fueling system components. Data showing permeation rates through nitrile butadiene rubber, a material used for fueling system gaskets, nearly seven times higher for an ethanol blend as compared to an MTBE blend were presented during the deliberation process for California CaRFG3. Similarly, multiples of 18 and 20 have been shown for in-use plastic fuel lines (constructed of polyamid 11) and in-use plastic fuel tanks (layered high density polyethylene, polyamid 6, and high density polyethylene). It has also been shown that these multiples can be reduced for fuel lines and fuel tanks to at least levels of two and six, respectively, with existing alternative materials. Nonetheless, ethanol blending increases the potential for increased evaporative emissions, for both current and future vehicles.

The initial detailed test program to investigate the significance of this potential emissions impact is currently ongoing under the California CaRFG3 adoption process. Neither the federal Complex Model nor the California Predictive Model currently accounts for permeability effects. Accordingly, the emissions estimates developed in this study exclude consideration of permeability differences.

A rough range of the potential impact can be estimated by recognizing that about 16-18 percent of gasoline vehicle HC emissions are estimated to be associated with resting and running losses. Not all of these emissions are due to permeation losses, but perhaps half are, implying a net permeation contribution of about 8 percent. At this level of permeation loss, a doubling of permeation-related emissions would increase overall HC emissions by about 8 percent. However, a fifteen-fold increase in permeation rate would more than double overall gasoline vehicle HC emissions.

If replacement components or fuel additives are not developed to effectively control permeation, it appears likely that the ozone-related emissions performance of the ethanol-blended CBG variants evaluated in this study could be significantly worse that presented in this report. Close monitoring of the on-going California permeation study is advised, so that appropriate response can be implemented as more data become available.

8.6 Vehicle Maintenance Impacts

When oxygenated gasolines were first introduced on a widespread basis in the early 1980s, there was considerable concern regarding materials compatibility issues. Issues such as fuel tank and fuel system corrosion, fuel system elastomer deterioration, fuel system deposits, and fuel filter clogging were cited as potential problems. However, even during that period, most studies indicated that such problems were minor and could be adequately controlled through the use of corrosion inhibitors and deposit control and detergent additives. Since that time, not only has the use of such fuel additives become universal, but fuel system components have been upgraded to handle oxygenated gasolines and gasolines with high aromatics content. Moreover, all vehicle manufacturers warranted their systems for use with oxygenated gasoline formulations for the last fifteen years. Finally, ethanol-blended gasolines similar to those considered in this study have been used in Maricopa County for many years during the Winter season.

Consequently, we expect that none of the CBG variants considered in this study will call for special vehicle maintenance requirements.

9. ESTIMATING MTBE USAGE OUTSIDE OF MARICOPA COUNTY

We conducted a brief analysis to delineate the extent of current usage of MTBE-blended gasoline outside of the CBG area. Such usage can arise from

- Spill-over of MTBE-blended CBG distributed from the Phoenix terminal; and
- Supply of MTBE-blended conventional gasoline to the rest of Arizona.

We obtained information on gasoline supply in Arizona from (1) Kinder Morgan Energy Partners LP on deliveries of CBG and conventional gasoline to he Phoenix terminal and (2) other suppliers of conventional gasoline to non-CBG areas of Arizona.

9.1 CURRENT PATTERN OF GASOLINE SUPPLY

Table 9.1 summarizes the pattern of gasoline supply in Arizona, by county. (Table 9.1 is drawn from a description of the gasoline distribution system serving Maricopa County in [Ref. 2].

Table 9.1: Arizona's Gasoline Supply Pattern

SOURCE OF SUPPLY	County
IN-STATE	
Phoenix terminal	Maricopa
	Coconino
	La Paz
	Pinal
	Yavapai
Tucson terminal	Cochise
	Graham
	Greenlee
	Pima
	Santa Cruz
OUT OF STATE	
Imperial, CA terminal	Yuma
Gallup, NM refinery }	Apache, Navajo
Bloomfield, NM terminal }	Gila, Yavapai
Las Vegas, NV terminal	Mohave

We understand that Coconino, Gila, and Yavapai Counties also receives some gasoline volumes from New Mexico and (occasionally) from the Salt Lake City refining center. A few transmix operators supply may small volumes of gasoline in the northern and western parts of the state.

The Phoenix terminal is by far the largest source of supply, handling roughly 70% of Arizona's gasoline supply.

9.2 Spill-Over of CBG

Some of the CBG delivered to Phoenix likely "spills over" into the counties indicated in Table 9.1, via tankwagon deliveries. We could not determine the volume of CBG spill-over. However, the volumes of CBG and conventional gasoline flowing through Phoenix suggest that the spill-over could be on the order of 5–10 K Bbl/day. To the extent that it occurs, the spill-over could extend throughout the counties served by the Phoenix terminal.

Once Arizona's MTBE phase-out takes effect, spill-over from the Phoenix terminal should cease to be a source of MTBE-blended gasoline throughout the state.

9.3 Supply of MTBE-blended conventional gasoline

Suppliers routinely use MTBE for octane enhancement in some conventional gasoline supplied to Arizona. For example, the primary supplier to northern Arizona (Apache, Navajo, and Coconino counties) blends MTBE in all of its premium gasoline and some regular and mid-grade gasoline. The company maintains the MTBE concentration at ≤ 9 vol%, the threshold for labeling gasoline at the pump as oxygenated. Similarly, transmix operators who sell premium gasoline may use MTBE for octane enhancement. Gasoline suppliers in New Mexico and Utah may practice MTBE blending, in part because these states have an 85 ((R+M)/2) octane standard for regular gasoline, versus Arizona's standard of 87 octane.

Conventional gasoline supplied to Mohave County from Las Vegas is likely to have been produced in the Los Angeles refining center. Our analyses of the California refining sector consistently indicate that such gasoline is unlikely to be MTBE blended.

10. REFERENCES

1. *Supplemental Emissions Impact Analysis*, memorandum to ADEQ, EEA, Inc., October 10, 2000

2. *Assessment of Fuel Formulation Options for Maricopa County*, report to ADEQ, MathPro Inc., November 7, 1996

3. *Evaluation of Gasoline and Diesel Fuel Options for Maricopa County*, report to ADEQ, MathPro Inc., February 16, 1998

4. *Fuel Oxygen Effects on Exhaust CO Emissions, Recommendations for MOBILE6*, March 16, 1998, EPA 420-P-98-006

5. *Evaluating the Cost and Supply of Alternatives to MTBE in California's Reformulated Gasoline, Final Report: Refinery Modeling, Task 3: Supply Scenario Modeling Runs*, report to California Energy Commission, MathPro Inc., December 9, 1998

6. *Analysis of the Refining Economics of California Phase 3 RFG*, report to California Energy Commission, MathPro Inc., January 5, 2000

APPENDIX A

RESULTS OF THE REFINING ANALYSIS

FOR

THE WEST AND EAST REFINING CENTERS

SERVING THE ARIZONA CBG AREA

Exhibit A-1: Process Unit Utilization, Additions, and Operations
(K bbl/d)

		East Refining Center						
			Arizona MTBE Phase-out					
			CBG 1	CBG 2	CBG 1			CBG 2
Type of		Reference	No Oxy	No Oxy	2.0 wt%	2.7 wt%	3.5 wt%	2.7 wt%
Process	Process	Case	Case 1	Case 2	Case 3	Case 4	Case 5	Case 7
USE OF EXISTING CAP.								
Crude Distillation	Atmospheric	189.6	189.6	189.6	189.6	189.6	189.6	189.6
Conversion	Fluid Cat Cracker	66.5	66.5	66.5	66.5	66.5	66.5	66.5
	Hydrocracker - Distillate Feed							
	Hydrocracker - Gas Oil Feed							
	Coking - Delayed							
	Coking - Fluid & Flexi							
Upgrading	Alkylation	16.8	16.8	16.8	16.8	16.8	16.8	16.8
	Dimersol							
	Pen/Hex Isom. (Once Thru)	9.9	9.7	9.7	7.4	7.0	6.3	7.0
	Pen/Hex Isom. (Recycle)							
	Polymerization							
	Reforming (150-350 psi)	42.1	42.3	42.3	40.4	40.3	39.4	40.3
Oxygenate Prod.	MTBE Plant -- Captive	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Tame Plant	0.9	0.7	0.7	0.7	0.7	0.7	0.7
Hydrotreating	Naphtha & Isom Feed Desulf.	16.7	16.0	16.0	15.8	15.2	15.7	15.2
	Reformer Feed Desulfurization	42.1	42.6	42.6	40.5	40.7	39.4	40.7
	Distillate Desulfurization	49.2	49.2	49.2	49.2	49.2	49.2	49.2
	Distillate Dearomatization							
	FCC Feed Desulf. -- Conv.							
	FCC Feed Desulf. -- Deep							
	FCC Naphtha Desulfurization	33.6	34.0	34.0	34.0	34.0	34.0	34.0
	FCC Naphtha Desulfurization (Calif)							
	Benzene Saturation							
Hydrogen (MM scf/d)	Hydrogen Plant							
Other	Aromatics Plant							
	Butane Isomerization	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Lubes & Waxes							
	Merox Treatment of MTBE/IsoOctene	1.8	1.8	1.8	1.8	1.8	1.8	1.8
	Solvent Deasphalting	16.5	16.5	16.5	16.5	16.5	16.5	16.5
	Sulfur Recovery (tons/d)	38	38	38	38	38	38	38
Fractionation	Debutanization	11.7	11.7	11.7	11.7	11.7	11.7	11.7
	Depentanization	39.1	34.7	34.7	34.7	34.7	34.7	34.7
	Lt. Naphtha Spl. (Benz. Prec.)							
	FCC Naphtha Splitter							
	FCC Naphtha T90 Control							
RETROFIT CAPACITY								
IsoOctane/Octene*	From Captive MTBE							
NEW CAPACITY								
Crude Distillation	Atmospheric							
Upgrading	Alkylation							
Hydrotreating	Naphtha Desulfurization							
	FCC Naphtha Desulfurization							
	FCC Naphtha Desulfurization (Calif)							
	Benzene Saturation							
Hydrogen (foeb)	Hydrogen Plant (MM scf/d)							
Other	Benzene Extraction							
	FCC Gas Processing							
	Merox Treatment of MTBE							
	Butane Isomerization							
	Sulfur Recovery (tons/d)							
Fractionation	Alkylate Fractionation (Lt. Alkylate)							
	Debutanization							
	Depentanization							
	Lt. Naphtha Spl. (Benz. Prec.)							
	Naphtha Splitter (T90 Control)							
	FCC Naphtha Splitter							
	FCC Naphtha (T90 Control)							
OPERATIONS								
Operating Indices	FCC Conversion (Vol %)	77.6	77.6	77.6	77.6	77.6	77.6	77.6
	Reformer Severity (RON)	99.2	98.6	98.6	99.2	98.3	99.2	98.3
Charge Rates	Fluid Cat Cracker	61.9	61.9	61.9	61.9	61.9	61.9	61.9
	Reformer (150-350 psi)	42.4	42.9	42.9	40.8	41.0	39.7	41.0
FCC Olefin Max Cat. (%)								

Exhibit A-1: Process Unit Utilization, Additions, and Operations

(K bbl/d)

		West Refining Center							
			Arizona MTBE Phase-out						
			CBG 1	CBG 2	CBG 1			CBG 2	CBG 2
Type of		Reference	No Oxy	No Oxy	2.0 wt%	2.7 wt%	3.5 wt%	2.0 wt%	2.7 wt%
Process	Process	Case	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
USE OF EXISTING CAP.									
Crude Distillation	Atmospheric	2019	2018	2017	2018	2018	2018	2017	2016
Conversion	Fluid Cat Cracker	732	732	732	732	732	732	732	731
	Hydrocracker - Distillate Feed	291	291	291	291	291	291	291	291
	Hydrocracker - Gas Oil Feed	143	143	143	143	143	143	143	143
	Coking - Delayed	391	391	391	391	391	391	391	390
	Coking - Fluid & Flexi	106	106	106	106	106	106	106	106
Upgrading	Alkylation	161	161	161	161	161	161	161	161
	Dimersol	5	4	3	4	4	4	3	3
	Pen/Hex Isom. (Once Thru)								
	Pen/Hex Isom. (Recycle)	86	86	86	86	86	86	86	86
	Polymerization	5	5	5	5	5	5	5	5
	Reforming (150-350 psi)	378	386	387	381	378	375	383	379
Oxygenate Prod.	MTBE Plant -- Captive	7							
	Tame Plant								
Hydrotreating	Naphtha & Isom Feed Desulf.	74	82	80	85	88	84	81	87
	Reformer Feed Desulfurization	330	325	314	318	317	318	308	310
	Distillate Desulfurization	366	367	366	367	366	367	366	366
	Distillate Dearomatization	112	113	113	113	113	113	113	113
	FCC Feed Desulf. -- Conv.	349	349	349	349	349	349	349	349
	FCC Feed Desulf. -- Deep	379	379	378	379	379	379	378	378
	FCC Naphtha Desulfurization								
	FCC Naphtha Desulfurization (Calif)	101	101	101	101	101	101	101	101
	Benzene Saturation	20	28	36	29	28	24	37	33
Hydrogen (MM scf/d)	Hydrogen Plant	1344	1349	1355	1351	1351	1351	1357	1355
Other	Aromatics Plant								
	Butane Isomerization	18	18	18	18	18	18	18	18
	Lubes & Waxes	25	25	25	25	25	25	25	25
	Merox Treatment of MTBE/IsoOctene								
	Solvent Deasphalting	50	50	50	50	50	50	50	50
	Sulfur Recovery (tons/d)	6000	6000	6000	6000	6000	6000	6000	6000
Fractionation	Debutanization	197	197	197	197	197	197	197	197
	Depentanization	64	64	64	64	64	64	64	64
	Lt. Naphtha Spl. (Benz. Prec.)	114	114	114	114	114	114	114	114
	FCC Naphtha Splitter	178	178	178	178	178	178	178	178
	FCC Naphtha T90 Control	29	29	29	29	29	29	29	29
RETROFIT CAPACITY									
IsoOctane/Octene*	From Captive MTBE		6	6	6	6	6	6	6
NEW CAPACITY									
Crude Distillation	Atmospheric								
Upgrading	Alkylation	16	17	17	17	17	17	17	17
Hydrotreating	Naphtha Desulfurization								
	FCC Naphtha Desulfurization	24	19	22	19	19	19	19	22
	FCC Naphtha Desulfurization (Calif)	61	61	58	61	61	61	59	57
	Benzene Saturation								
Hydrogen (foeb)	Hydrogen Plant (MM scf/d)								
Other	Benzene Extraction								
	FCC Gas Processing	6							
	Merox Treatment of MTBE	9	7	7	7	7	7	7	7
	Butane Isomerization								
	Sulfur Recovery (tons/d)	99	99	94	99	99	98	94	89
Fractionation	Alkylate Fractionation (Lt. Alkylate)								
	Debutanization	28	28	28	28	28	28	28	28
	Depentanization	24	15	20	26	23	21	32	27
	Lt. Naphtha Spl. (Benz. Prec.)	98	94	94	86	85	89	88	84
	Naphtha Splitter (T90 Control)								
	FCC Naphtha Splitter	121	105	121	105	105	104	107	119
	FCC Naphtha (T90 Control)	231	252	252	252	250	252	252	252
OPERATIONS									
Operating Indices	FCC Conversion (Vol %)	75	75	75	75	75	75	75	75
	Reformer Severity (RON)	100	100	100	100	100	100	100	100
Charge Rates	Fluid Cat Cracker	732	732	732	732	732	732	732	731
	Reformer (150-350 psi)	378	386	387	381	378	375	383	379
FCC Olefin Max Cat. (%)									

Exhibit A-2: Crude Oil, Other Inputs, and Refined Product Outputs

(K barrels/day)

	East Refining Center						
		Arizona MTBE Phase-out					
		CBG 1	CBG 2	CBG 1			CBG 2
Inputs/ Outputs	**Reference Case**	**No Oxy Case 1**	**No Oxy Case 2**	**2.0 wt% Case 3**	**2.7 wt% Case 4**	**3.5 wt% Case 5**	**2.7 wt% Case 7**
Crude Oil							
Composite	189.6	189.6	189.6	189.6	189.6	189.6	189.6
Other Inputs							
Isobutane	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Butane -- Refinery				0.2	0.2		
Butane -- Merchant PC							
Mixed Butylenes -- Refinery	0.2	0.2	0.2			0.2	0.2
Mixed Butylenes -- M PetCh							
Natural Gas Liquids	5.3	5.1	5.1	2.8	2.4	1.7	2.4
C6 Isomerate Feed							
C6 Isomerate							
Full Range Alkylate							
Light Alkylate							
IsoOctane							
IsoOctene							
Reformate							
Heavy Gas Oil							
Residual Oil							
MTBE							
Ethanol				1.7	2.3	2.9	2.3
Methanol	0.9	0.8	0.8	0.8	0.8	0.8	0.8
Energy Use							
Electricity (K Kwh)	827.6	827.9	827.9	815.7	815.4	809.9	815.4
Fuel (foeb)	14.2	14.2	14.2	14.0	14.0	13.9	14.0
Refined Products							
BTX							
MTBE							
C6 Isomerate Feed							
C6 Isomerate							
Light Alkylate							
IsoOctane							
IsoOctene							
Propane	6.7	6.5	6.5	6.6	6.3	6.5	6.3
Propylene							
Butane	1.8	1.8	1.8	1.3	1.8	1.6	1.8
Mixed Butylenes							
Naphtha							
Gasoline:							
Calif. RFG3 (Oxy)							
Calif. RFG3 (No Oxy)							
Arizona CBG	29.0	29.0	29.0	29.0	29.0	29.0	29.0
Conventional	78.0	78.0	78.0	78.0	78.0	78.0	78.0
Aviation Gasoline							
Jet Fuel	19.7	19.7	19.7	19.7	19.7	19.7	19.7
CARB Diesel							
On-road Diesel (< 0.05% Sulf)	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Other Diesel/Heating Oil							
Carbon Black Feed							
Residual Oil	11.6	11.6	11.6	11.6	11.6	11.6	11.6
Asphalt							
Lubes & Waxes							
Coke							
Sulfur (tons/d)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rejected Blendstocks							

Exhibit A-2: Crude Oil, Other Inputs, and Refined Product Outputs

(K barrels/day)

Inputs/ Outputs	West Refining Center							
		Arizona MTBE Phase-out						
		CBG 1	CBG 2	CBG 1			CBG 2	CBG 2
	Reference Case	No Oxy Case 1	No Oxy Case 2	2.0 wt% Case 3	2.7 wt% Case 4	3.5 wt% Case 5	2.0 wt% Case 6	2.7 wt% Case 7
Crude Oil								
Composite	2018	2018	2017	2018	2018	2018	2017	2015
Other Inputs								
Isobutane								
Butane -- Refinery								
Butane -- Merchant PC								
Mixed Butylenes -- Refinery								
Mixed Butylenes -- M PetCh								
Natural Gas Liquids								
C6 Isomerate Feed								
C6 Isomerate	26	35	38	34	31	28	38	36
Full Range Alkylate	11	11	11	11	11	11	11	11
Light Alkylate	25	25	25	25	25	25	25	25
IsoOctane	12	12	12	12	12	12	12	12
IsoOctene								
Reformate								
Heavy Gas Oil	19	19	19	19	19	19	19	19
Residual Oil	38	38	38	38	38	38	38	38
MTBE	0							
Ethanol	79	79	79	83	85	86	83	85
Methanol	2							
Energy Use								
Electricity (K Kwh)	17835	17880	17879	17844	17827	17826	17835	17816
Fuel (foeb)	254	255	255	255	254	254	255	255
Refined Products								
BTX								
MTBE								
C6 Isomerate Feed								
C6 Isomerate								
Light Alkylate								
IsoOctane								
IsoOctene								
Propane	37	37	37	37	37	37	37	37
Propylene	2	2	2	2	2	2	2	2
Butane	30	30	30	30	30	30	30	30
Mixed Butylenes	4	4	4	4	4	4	4	4
Naphtha	3	3	3	3	3	3	3	3
Gasoline:								
Calif. RFG3 (Oxy)	1022	1022	1022	1022	1022	1022	1022	1022
Calif. RFG3 (No Oxy)								
Arizona CBG	68	68	68	68	68	68	68	68
Conventional	161	161	161	161	161	161	161	161
Aviation Gasoline	5	5	5	5	5	5	5	5
Jet Fuel	333	333	333	333	333	333	333	333
CARB Diesel	204	204	204	204	204	204	204	204
On-road Diesel (< 0.05% Sulf)	122	122	122	122	122	122	122	122
Other Diesel/Heating Oil	18	18	18	18	18	18	18	18
Carbon Black Feed								
Residual Oil	57	57	57	57	57	57	57	57
Asphalt								
Lubes & Waxes	25	25	25	25	25	25	25	25
Coke	147	147	147	147	147	147	147	146
Sulfur (tons/d)	6	6	6	6	6	6	6	6
Rejected Blendstocks	40	44	46	48	47	45	51	49

Exhibit A-3: Gasoline Properties and Emissions, by Gasoline Type

Property & Emissions	East Refining Center									
	Reference Case				Arizona MTBE Phase-out					
					CBG 1, No Oxy Case 1			CBG 2, No Oxy Case 2		
	Arizona CM	Arizona PM	Conv.	Pool	Ariz	Conv.	Pool	Ariz	Conv.	Pool
Property										
RVP (psi)*	6.8	6.8	7.6	7.4	6.8	7.6	7.4	6.8	7.6	7.4
Oxygen (wt%)	2.1	0.0	0.0	0.4	0.0	0.6	0.4	0.0	0.6	0.4
Aromatics (vol%)	16.3	21.6	36.3	31.2	17.4	36.6	31.4	21.6	35.0	31.4
Benzene (vol%)	1.12	1.23	2.40	2.06	0.95	2.50	2.08	1.68	2.23	2.08
Olefins (vol%)	4.3	5.7	10.3	8.8	5.2	10.2	8.8	4.9	10.3	8.8
Sulfur (ppm)	13	25	25	22	16	25	22	16	25	22
E200 (vol% off)	49.2	51.0	42.4	44.4	49.2	42.3	44.1	49.8	42.0	44.1
E300 (vol% off)	88.4	85.5	79.7	81.9	86.7	79.9	81.7	87.2	79.7	81.7
T10**	133	132	132	132	132	132	132	135	131	132
T50**	202	197	216	212	201	218	213	201	219	214
T90**	305	313	329	323	309	329	323	308	329	323
Estimated DI***	1,109	1,104	1,176	1,158	1,112	1,179	1,161	1,113	1,182	1,163
En. Den. (MM Btu/bbl)	5.071	5.174	5.243	5.203	5.127	5.233	5.205	5.153	5.224	5.205
Emission Reduct. (%)										
VOCs	30.7	-0.40	16.1		30.2	16.2		-0.31	16.5	
NOx	17.2	-0.52	11.1		16.3	11.2		-1.08	11.2	
Toxics	34.2	6.82	-7.7		31.0	-7.6		11.93	-1.1	
Volume (K bbl/d)	22	7	78	107	29	78	107	29	78	107

* Final blended RVP (ethanol blending adds 1.3 psi to Arizona CBG and CaRFG3).

** Linear interpolations for T10 and T50, except that when emissions are calculated by the Predictive Model T50 = (125.3846 - E200)/0.3769. T90 is calculated as (196.1538 - E300)/.3538 in all cases.

*** Calculated as follows: 1.5*T10 + 3.0*T50 + 1.0*T90 + 20*(wt% oxygen from ethanol).

Note: Emissions calculations based on: Phase II Complex Model for conventional gasoline and CBG 1; Phase 2 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CBG 2; and Phase 3 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG3.

Exhibit A-3: Gasoline Properties and Emissions, by Gasoline Type

Property & Emissions	East Refining Center — Arizona MTBE Phase-out — CBG 1, 2.0 wt% Case 3 Ariz	Case 3 Conv.	Case 3 Pool	CBG 1, 2.7 wt% Case 4 Ariz	Case 4 Conv.	Case 4 Pool	CBG 1, 3.5 wt% Case 5 Ariz	Case 5 Conv.	Case 5 Pool	CBG 2, 2.7 wt% Case 7 Ariz	Case 7 Conv.	Case 7 Pool
Property												
RVP (psi)*	6.8	7.6	7.4	6.8	7.6	7.4	6.8	7.6	7.4	6.8	7.6	7.4
Oxygen (wt%)	2.0	0.6	1.0	2.7	0.6	1.1	3.5	0.6	1.4	2.7	0.6	1.1
Aromatics (vol%)	16.0	35.9	30.5	16.0	35.9	30.5	16.0	35.3	30.1	21.6	33.8	30.5
Benzene (vol%)	0.78	2.43	1.98	0.95	2.38	1.99	0.87	2.33	1.94	1.30	2.25	1.99
Olefins (vol%)	4.8	10.4	8.9	10.0	8.4	8.9	10.0	8.5	8.9	4.0	10.7	8.9
Sulfur (ppm)	16	25	22	25	21	22	25	21	22	16	25	22
E200 (vol% off)	50.6	42.0	44.3	49.2	42.4	44.3	52.7	42.0	44.9	49.9	42.2	44.3
E300 (vol% off)	87.1	80.1	82.0	86.7	80.0	81.8	86.7	80.3	82.0	85.5	80.5	81.8
T10**	120	133	129	125	132	130	124	132	130	130	130	130
T50**	198	218	213	201	218	214	194	219	212	200	218	213
T90**	308	328	323	309	328	323	309	327	323	313	327	323
Estimated DI***	1,121	1,183	1,166	1,154	1,181	1,174	1,147	1,182	1,173	1,163	1,175	1,172
En. Den. (MM Btu/bbl)	5.047	5.234	5.183	5.060	5.225	5.180	5.032	5.222	5.170	5.085	5.215	5.180
Emission Reduct. (%)												
VOCs	31.0	16.4		31.5	16.2		32.2	16.5		-1.74	17.3	
NOx	16.9	11.1		15.5	12.0		15.3	12.0		-0.25	11.1	
Toxics	35.2	-5.7		32.6	-4.2		33.3	-2.9		7.83	-0.3	
Volume (K bbl/d)	29	78	107	29	78	107	29	78	107	29	78	107

* Final blended RVP (ethanol blending adds 1.3 psi to Arizona CBG and CaRFG3).

** Linear interpolations for T10 and T50, except that when emissions are calculated by the Predictive Model T50 = (125.3846 - E200)/0.3769. T90 is calculated as (196.1538 - E300)/.3538 in all cases.

*** Calculated as follows: 1.5*T10 + 3.0*T50 + 1.0*T90 + 20*(wt% oxygen from ethanol).

Note: Emissions calculations based on: Phase II Complex Model for conventional gasoline and CBG 1; Phase 2 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CBG 2; and Phase 3 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG3.

Exhibit A-3: Gasoline Properties and Emissions, by Gasoline Type

Property & Emissions	West Refining Center															
					Arizona MTBE Phase-out											
	Reference Case				CBG 1, No Oxy Case 1				CBG 2, No Oxy Case 2				CBG 1, 2.0 wt% Case 3			
	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool
Property																
RVP (psi)*	6.8	6.7	8.1	7.0	6.8	6.7	8.1	7.0	6.8	6.8	8.1	7.0	6.8	6.7	8.1	7.0
Oxygen (wt%)	2.7	2.1	0.0	2.3	2.7	0.0	0.0	2.2	2.7	0.0	0.0	2.2	2.7	2.0	0.0	2.3
Aromatics (vol%)	25.8	16.0	34.4	26.4	25.8	16.0	34.4	26.4	26.1	10.1	34.4	26.3	25.6	16.0	34.4	26.2
Benzene (vol%)	0.58	0.84	1.24	0.68	0.57	0.66	1.33	0.68	0.58	0.59	1.32	0.68	0.58	0.89	1.35	0.69
Olefins (vol%)	1.6	10.0	10.0	3.1	1.6	10.0	10.0	3.1	1.4	5.7	10.0	2.8	1.7	10.0	10.0	3.2
Sulfur (ppm)	8	25	25	11	8	25	25	11	8	25	25	11	8	25	25	11
E200 (vol% off)	47.7	40.0	38.9	46.2	47.7	40.0	38.9	46.2	47.5	46.6	38.9	46.4	47.7	40.0	38.9	46.1
E300 (vol% off)	87.4	81.8	78.5	86.0	87.4	82.8	78.5	86.0	87.9	81.9	78.5	86.4	87.5	81.8	78.5	86.0
T10**	129	137	139	131	130	136	139	131	130	133	139	131	129	132	139	131
T50**	206	217	224	209	206	212	226	209	207	209	228	209	206	216	223	209
T90**	307	323	333	311	307	320	333	311	306	323	333	310	307	323	333	311
Estimated DI***	1,174	1,179	1,213	1,179	1,174	1,160	1,218	1,179	1,175	1,150	1,226	1,180	1,174	1,208	1,212	1,181
En. Den. (MM Btu/bbl)	5.104	5.143	5.315	5.133	5.102	5.201	5.315	5.134	5.103	5.133	5.313	5.132	5.101	5.139	5.315	5.130
Emission Reduct. (%)																
VOCs	-0.17	29.8	-		-0.17	29.8	-		-0.19	-0.24	-		-0.18	29.8	-	
NOx	-0.25	16.0	-		-0.26	15.8	-		-0.25	-2.21	-		-0.25	16.0	-	
Toxics	-0.22	34.6	-		-0.23	32.6	-		-0.15	-3.29	-		-0.27	31.4	-	
Volume (K bbl/d)	1,022	68	161	1,251	1,022	68	161	1,251	1,022	68	161	1,251	1,022	68	161	1,251

* Final blended RVP (ethanol blending adds 1.3 psi to Arizona CBG and CaRFG3).

** Linear interpolations for T10 and T50, except that when emissions are calculated by the Predictive Model T50 = (125.3846 - E200)/0.3769. T90 is calculated as (196.1538 - E300)/.3538 in all cases.

*** Calculated as follows: 1.5*T10 + 3.0*T50 + 1.0*T90 + 20*(wt% oxygen from ethanol).

Note: Emissions calculations based on: Phase II Complex Model for conventional gasoline and CBG 1; Phase 2 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CBG 2; and Phase 3 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG3.

Exhibit A-3: Gasoline Properties and Emissions, by Gasoline Type

Property & Emissions	West Refining Center															
	Arizona MTBE Phase-out															
	CBG 1, 2.7 wt% Case 4				CBG 1, 3.5 wt% Case 5				CBG 2, 2.0 wt% Case 6				CBG 2, 2.7 wt% Case 7			
	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool
Property																
RVP (psi)*	6.8	6.7	8.1	7.0	6.8	6.7	8.1	7.0	6.8	6.8	8.1	7.0	6.8	6.8	8.1	7.0
Oxygen (wt%)	2.7	2.7	0.0	2.4	2.7	3.5	0.0	2.4	2.7	2.0	0.0	2.3	2.7	2.7	0.0	2.4
Aromatics (vol%)	25.5	16.0	34.4	26.1	25.4	16.0	34.4	26.1	25.8	11.7	34.4	26.1	25.8	10.3	34.4	26.1
Benzene (vol%)	0.58	0.96	1.35	0.70	0.58	0.81	1.33	0.69	0.59	0.72	1.35	0.70	0.59	0.96	1.34	0.70
Olefins (vol%)	1.7	10.0	10.0	3.2	1.7	10.0	10.0	3.2	1.4	5.7	10.0	2.8	1.5	5.3	10.0	2.8
Sulfur (ppm)	8	25	25	11	8	25	25	11	8	25	25	11	8	25	25	11
E200 (vol% off)	47.7	40.0	38.9	46.1	47.6	40.0	38.9	46.1	47.6	47.0	38.9	46.4	47.6	45.5	38.9	46.4
E300 (vol% off)	87.5	81.8	78.5	86.0	87.6	81.8	78.5	86.1	87.9	81.9	78.5	86.4	87.7	83.6	78.5	86.3
T10**	129	130	139	131	129	131	139	131	130	129	139	131	130	128	139	131
T50**	206	217	223	209	206	226	224	210	207	208	224	209	206	212	224	209
T90**	307	323	333	311	307	323	333	311	306	323	333	310	307	318	333	311
Estimated DI***	1,174	1,223	1,212	1,182	1,174	1,268	1,214	1,184	1,175	1,181	1,213	1,180	1,174	1,201	1,212	1,180
En. Den. (MM Btu/bbl)	5.101	5.108	5.315	5.129	5.100	5.080	5.315	5.127	5.101	5.078	5.314	5.127	5.102	5.040	5.314	5.126
Emission Reduct. (%)																
VOCs	-0.19	29.8	-		-0.21	29.7	-		-0.20	-0.28	-		-0.19	-0.33	-	
NOx	-0.25	16.1	-		-0.25	16.1	-		-0.25	-1.17	-		-0.25	-0.20	-	
Toxics	-0.28	30.5	-		-0.29	31.3	-		-0.20	0.08	-		-0.22	1.61	-	
Volume (K bbl/d)	1,022	68	161	1,251	1,022	68	161	1,251	1,022	68	161	1,251	1,022	68	161	1,251

* Final blended RVP (ethanol blending adds 1.3 psi to Arizona CBG and CaRFG3).

** Linear interpolations for T10 and T50, except that when emissions are calculated by the Predictive Model T50 = (125.3846 - E200)/0.3769. T90 is calculated as (196.1538 - E300)/.3538 in all cases.

*** Calculated as follows: 1.5*T10 + 3.0*T50 + 1.0*T90 + 20*(wt% oxygen from ethanol).

Note: Emissions calculations based on: Phase II Complex Model for conventional gasoline and CBG 1; Phase 2 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CBG 2; and Phase 3 Predictive Model in Flat Limits Mode, with "Property Compliance Margins" specified by ARB, for CaRFG3.

Exhibit A-4: Gasoline Composition and Volume, by Gasoline Type

Composition & Volume	East Refining Center									
	Reference Case				Arizona MTBE Phase-out					
					CBG 1, No Oxy Case 1			CBG 2, No Oxy Case 2		
	Arizona									
	CM	PM	Conv.	Pool	Ariz	Conv.	Pool	Ariz	Conv.	Pool
Composition (vol%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C4s:	4.0	2.4	3.4	3.5	2.0	3.9	3.4	2.0	3.9	3.4
Butenes										
I-Butane	0.2		0.3	0.3	0.6	0.1	0.3	0.3	0.3	0.3
N-Butane	3.8	2.4	3.1	3.2	1.4	3.8	3.1	1.7	3.6	3.1
C5s & Isomerate	15.5	16.5	14.3	14.7	27.3	9.5	14.3	22.5	11.2	14.3
Raffinate										
Natural Gas Liquids										
Naphtha	9.2	7.7	2.6	4.3	0.0	5.1	3.8	1.2	4.7	3.8
C5-160		7.7	1.6	1.7		2.3	1.7	1.2	1.9	1.7
Coker Naphtha										
160-250	9.2	0.0	0.9	2.5	0.0	2.8	2.1		2.8	2.1
Alkylate	31.6	36.8	8.3	14.9	40.7	5.4	14.9	35.6	7.3	14.9
Hydrocrackate										
Poly Gasoline										
FCC Gasoline:	9.9	12.2	37.0	29.8	11.4	37.2	30.2	13.8	36.3	30.2
Full Range										
Full Range - Desulf.	9.9	12.2	37.0	29.8	11.4	37.2	30.2	13.8	36.3	30.2
Light										
Light - Desulf.										
Medium										
Medum - Desulf.										
Heavy										
Heavy - Desulf.										
Reformate	17.8	24.4	34.5	30.4	18.6	35.7	31.1	24.9	33.3	31.1
Light	3.1	4.8	15.5	12.2	3.5	16.0	12.6	11.0	13.2	12.6
Medium										
Heavy	14.7	19.6	19.0	18.2	15.1	19.7	18.5	13.9	20.2	18.5
Oxygenate	12.1	0.0	0.0	2.5	0.0	3.2	2.4	0.0	3.2	2.4
MTBE	8.2			1.7		2.3	1.7		2.3	1.7
TAME	3.9			0.8		0.9	0.7		0.9	0.7
Ethanol										
Gasoline Volume (K Bbl/day)	22	7	78	107	29	78	107	29	78	107

Exhibit A-4: Gasoline Composition and Volume, by Gasoline Type

Composition & Volume	East Refining Center											
	Arizona MTBE Phase-out											
	CBG 1, 2.0 wt% Case 3			CBG 1, 2.7 wt% Case 4			CBG 1, 3.5 wt% Case 5			CBG 2, 2.7 wt% Case 7		
	Ariz	**Conv.**	**Pool**	**Ariz**	**Conv.**	**Pool**	**Ariz**	**Conv.**	**Pool**	**Ariz**	**Conv.**	**Pool**
Composition (vol%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C4s:	2.0	4.5	3.8	2.0	3.7	3.3	2.0	3.9	3.4	2.0	3.7	3.3
Butenes												
I-Butane		0.3	0.2	0.8		0.2	0.2	0.2	0.2		0.3	0.2
N-Butane	2.0	4.2	3.6	1.2	3.7	3.0	1.8	3.7	3.2	2.0	3.4	3.0
C5s & Isomerate	18.2	9.9	12.1	10.2	12.4	11.8	5.2	13.3	11.1	14.1	10.9	11.8
Raffinate												
Natural Gas Liquids												
Naphtha	8.6	4.7	5.8	5.9	5.4	5.5	9.2	5.8	6.7	8.6	4.4	5.5
C5-160	2.3	1.5	1.7	0.7	2.1	1.7	1.9	1.6	1.7	2.1	1.6	1.7
Coker Naphtha												
160-250	6.4	3.2	4.1	5.3	3.3	3.8	7.3	4.1	5.0	6.5	2.8	3.8
Alkylate	39.2	5.9	14.9	34.3	7.7	14.9	32.0	8.6	14.9	30.4	9.2	14.9
Hydrocrackate												
Poly Gasoline												
FCC Gasoline:	9.3	38.0	30.2	31.5	29.7	30.2	34.3	28.7	30.2	14.2	36.1	30.2
Full Range												
Full Range - Desulf.	9.3	38.0	30.2	31.5	29.7	30.2	34.3	28.7	30.2	14.2	36.1	30.2
Light												
Light - Desulf.												
Medium												
Medum - Desulf.												
Heavy												
Heavy - Desulf.												
Reformate	16.9	33.8	29.3	8.2	37.8	29.8	7.3	36.4	28.5	22.9	32.4	29.8
Light		15.2	11.1	2.2	14.6	11.3	0.7	14.0	10.4	4.0	14.0	11.3
Medium												
Heavy	16.9	18.6	18.2	6.0	23.2	18.6	6.6	22.5	18.2	18.9	18.4	18.6
Oxygenate	5.7	3.2	3.9	7.8	3.2	4.5	10.1	3.2	5.1	7.8	3.2	4.5
MTBE		2.3	1.7		2.3	1.7		2.3	1.7		2.3	1.7
TAME		0.9	0.7		0.9	0.7		0.9	0.7		0.9	0.7
Ethanol	5.7		1.6	7.8		2.1	10.1		2.7	7.8		2.1
Gasoline Volume (K Bbl/day)	29	78	107	29	78	107	29	78	107	29	78	107

Exhibit A-4: Gasoline Composition and Volume, by Gasoline Type

Composition & Volume	West Refining Center															
					Arizona MTBE Phase-out											
	Reference Case				CBG 1, No Oxy Case 1				CBG 2, No Oxy Case 2				CBG 1, 2.0 wt% Case 3			
	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool	CARB	Ariz	Conv.	Pool
Composition (vol%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C4s:	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Butenes																
I-Butane																
N-Butane	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
C5s & Isomerate	10.8		1.5	9.0	11.6		1.5	9.7	11.9		1.5	9.9	11.5		1.5	9.6
Raffinate																
Natural Gas Liquids																
Naphtha	1.4	0.0	0.0	1.1	1.6	0.0	2.7	1.7	1.5	0.0	2.6	1.5	1.1	9.6	3.1	1.8
C5-160	1.4			1.1	1.6			1.3	1.5			1.2	1.1			0.9
Coker Naphtha														9.6	3.1	0.9
160-250							2.7	0.4			2.6	0.3				
Alkylate	18.9	22.8	4.6	17.2	18.9	30.3	4.8	17.7	18.4	38.5	4.8	17.8	19.1	29.8	4.3	17.8
Hydrocrackate	14.8	14.3	4.4	13.4	13.7	24.4	0.1	12.6	13.2	31.3		12.5	14.6	10.8	0.0	12.5
Poly Gasoline	0.4	0.2	0.2	0.4	0.4			0.3	0.2	2.6		0.3	0.3			0.3
FCC Gasoline:	19.8	47.9	63.7	27.0	19.0	44.3	64.8	26.3	20.1	27.1	64.9	26.2	19.1	43.5	64.7	26.3
Full Range		17.7	50.5	7.5		38.8	50.9	8.7	0.9	1.5	51.2	7.4	0.2	35.8	50.7	8.6
Full Range - Desulf.																
Light		17.5	11.6	2.4			13.4	1.7		5.1	13.6	2.0			13.5	1.7
Light - Desulf.			1.5	0.2			0.5	0.1		0.6		0.0			0.5	0.1
Medium	5.6			4.6	4.8			3.9	5.7	3.3		4.8	4.8			4.0
Medum - Desulf.	9.5			7.8	9.6			7.8	9.4			7.7	9.6			7.8
Heavy																
Heavy - Desulf.	4.7	12.8		4.5	4.6	5.5		4.1	4.2	16.6		4.3	4.5	7.7		4.1
Reformate	25.7	2.7	25.1	24.4	26.4	0.5	25.6	24.9	26.5	0.0	25.8	25.0	26.0	0.0	25.9	24.6
Light	9.5		5.2	8.5	10.0		6.0	9.0	10.9		6.7	9.7	9.6		6.0	8.6
Medium																
Heavy	16.2	2.7	19.9	15.9	16.4	0.5	19.5	15.9	15.6		19.1	15.2	16.4		19.9	15.9
Oxygenate	7.8	11.5	0.0	7.0	7.8	0.0	0.0	6.3	7.8	0.0	0.0	6.3	7.8	5.7	0.0	6.7
MTBE		11.5		0.6												
TAME																
Ethanol	7.8			6.3	7.8			6.3	7.8			6.3	7.8	5.7		6.7
Gasoline Volume (K Bbl/day)	1,022	68	161	1,251	1,022	68	161	1,251	1,022	68	161	1,251	1,022	68	161	1,251

Exhibit A-4: Gasoline Composition and Volume, by Gasoline Type

Composition & Volume	West Refining Center															
	Arizona MTBE Phase-out															
	CBG 1, 2.7 wt% Case 4				CBG 1, 3.5 wt% Case 5				CBG 2, 2.0 wt% Case 6				CBG 2, 2.7 wt% Case 7			
	CARB	**Ariz**	**Conv.**	**Pool**	**CARB**	**Ariz**	**Conv.**	**Pool**	**CARB**	**Ariz**	**Conv.**	**Pool**	**CARB**	**Ariz**	**Conv.**	**Pool**
Composition (vol%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
C4s:	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Butenes																
I-Butane																
N-Butane	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
C5s & Isomerate	11.3		1.5	9.4	10.9		1.5	9.1	11.9		1.5	9.9	11.7		1.5	9.7
Raffinate																
Natural Gas Liquids																
Naphtha	1.2	11.6	3.1	2.0	1.3	6.5	2.5	1.8	0.9	7.3	3.0	1.5	1.0	12.4	3.1	1.9
C5-160	1.2			1.0	1.3			1.1	0.9			0.7	1.0			0.8
Coker Naphtha																
160-250		11.6	3.1	1.0		6.5	2.5	0.7		7.3	3.0	0.8		12.4	3.1	1.1
Alkylate	19.4	25.4	4.2	17.8	19.5	24.1	3.7	17.8	18.7	35.7	4.0	17.8	18.8	34.3	4.1	17.8
Hydrocrackate	14.6	11.7	0.0	12.6	15.4	9.3	0.5	13.2	13.8	20.8	0.1	12.4	13.9	18.7	0.1	12.4
Poly Gasoline	0.4			0.3	0.3			0.3	0.1	3.3		0.3	0.2	2.4		0.3
FCC Gasoline:	19.2	42.9	64.7	26.3	18.9	49.4	63.9	26.4	20.2	26.7	64.6	26.3	20.3	24.0	64.6	26.2
Full Range	0.3	34.9	50.7	8.6		40.9	50.3	8.7	1.8	8.8	50.8	8.5	1.2		50.8	7.6
Full Range - Desulf.																
Light			13.5	1.7		0.9	13.4	1.8			13.8	1.8		3.9	13.8	2.0
Light - Desulf.			0.5	0.1		0.9	0.1	0.1		0.7		0.0		0.5		0.0
Medium	4.8			3.9	4.8			3.9	4.9	2.5		4.2	5.5	4.1		4.7
Medum - Desulf.	9.6			7.8	9.6			7.8	9.4			7.7	9.3			7.6
Heavy																
Heavy - Desulf.	4.5	8.0		4.1	4.6	6.8		4.1	4.1	14.6		4.1	4.2	15.6		4.3
Reformate	25.8	0.0	26.0	24.4	25.3	0.0	27.4	24.2	26.1	0.0	26.1	24.7	25.9	0.0	26.0	24.5
Light	9.4		6.1	8.5	9.2		7.3	8.5	10.7		6.3	9.5	10.0		6.2	9.0
Medium																
Heavy	16.4		19.9	15.9	16.1		20.1	15.7	15.5		19.8	15.2	15.9		19.8	15.5
Oxygenate	7.8	7.8	0.0	6.8	7.8	10.1	0.0	6.9	7.8	5.7	0.0	6.7	7.8	7.8	0.0	6.8
MTBE																
TAME																
Ethanol	7.8	7.8		6.8	7.8	10.1		6.9	7.8	5.7		6.7	7.8	7.8		6.8
Gasoline Volume (K Bbl/day)	1,022	68	161	1,251	1,022	68	161	1,251	1,022	68	161	1,251	1,022	68	161	1,251

Exhibit A-5: Estimated Refining Costs of Arizona MTBE Phase-out (1)
Summer Season

	East Refining Center						West Refining Center						
	CBG 1	CBG 2	CBG 1			CBG 2	CBG 1	CBG 2	CBG 1			CBG 2	CBG 2
	No Oxy	No Oxy	2.0 wt%	2.7 wt%	3.5 wt%	2.7 wt%	No Oxy	No Oxy	2.0 wt%	2.7 wt%	3.5 wt%	2.0 wt%	2.7 wt%
Measure	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 7**	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Total Average Cost (¢/gal) (2)	**0.0**	**0.0**	**2.3**	**3.5**	**4.5**	**3.5**	**5.7**	**8.8**	**10.1**	**8.9**	**7.5**	**13.6**	**12.5**
Variable Refining Cost (3)	0.0	0.0	1.9	3.1	3.9	3.1	5.4	8.1	9.7	8.6	7.1	13.3	12.0
Cost of Inputs	-0.3	-0.3	0.9	2.6	3.6	2.6	8.3	12.1	14.9	13.1	10.8	20.1	17.7
Processing Cost	0.0	0.0	-0.1	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2
Product Revenues	0.3	0.3	1.1	0.6	0.5	0.6	-2.8	-3.9	-5.0	-4.3	-3.4	-6.6	-5.5
Capital Charge	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.2	0.1	0.2	0.1	0.2
Fixed Cost	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.1	0.1
Ancillary Refining Cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mileage Loss	0.0	0.0	0.3	0.4	0.6	0.4	0.0	0.0	0.1	0.1	0.1	0.1	0.2
Refining Sector Seasonal Cost ($ million)	**0**	**0**	**6**	**8**	**10**	**8**	**29**	**45**	**52**	**46**	**39**	**72**	**66**
Variable Refining Cost	0	0	5	7	9	7	28	42	51	45	37	70	63
Capital Charge	0	0	0	0	0	0	1	2	1	1	1	1	1
Fixed Cost	0	0	0	0	0	0	0	1	0	0	0	0	1
Ancillary Refining Cost	0	0	0	0	0	0	0	0	0	0	0	0	0
Mileage Loss	0	0	1	1	1	1	0	0	0	0	1	1	1
Refinery Investment ($ million) (6)	**0**	**0**	**0**	**0**	**0**	**0**	**29**	**41**	**29**	**27**	**28**	**25**	**31**

(1) In year 2000 dollars.

APPENDIX B

EMISSION IMPACTS BY INDIVIDUAL SOURCE COMPONENT

EMISSION IMPACTS BY INDIVIDUAL SOURCE COMPONENT

The aggregate (i.e., combined on-road vehicle and off-road engine) emission impacts of the alternative gasoline formulations were presented in Chapter 6. This appendix presents a more detailed listing of those impacts, expressed in terms of both mass emissions and percentage change in the 2004 and 2010 evaluation years. The presented exhibits also breakdown the estimated impacts into the specific changes expected for various components of the overall Maricopa County inventories, allowing for a comparison of the relative contributions of each component to the overall emissions impact associated with each gasoline formulation. Mass emission and percentage change impacts are presented for the following Maricopa County inventory components.

Exhibits B.1 - B.4 .... Total Maricopa County Inventory

Exhibits B.5 - B.8 .... Maricopa County Mobile Source Inventory

Exhibits B.9 - B.12 .... Maricopa County On-Road Inventory

Exhibits B.13 - B.16 .... Maricopa County Off-Road Inventory

Exhibits B.17 - B.20 .... Maricopa County On-Road Gasoline Inventory

Exhibits B.21 - B.24 .... Maricopa County Off-Road Gasoline Inventory

Exhibits B.25 - B.28 .... Maricopa County On-Road Gasoline Exhaust Inventory

Exhibits B.29 - B.32 .... Maricopa County On-Road Gasoline Evaporative Inventory

Exhibits B.33 - B.36 .... Maricopa County Off-Road Gasoline Exhaust Inventory

Exhibits B.37 - B.40 .... Maricopa County Off-Road Gasoline Evaporative Inventory

Exhibit B.1: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.6	+1.0	-0.6	-1.2	-0.2	+0.1	+0.6
NO_x	-1.0	-3.2	-1.6	-0.3	-0.6	-3.9	-2.0
CO	+164.7	+142.6	-42.6	-112.2	-202.4	-131.9	-159.7
CO_{RW} (1)	+2.0	+1.7	-0.5	-1.4	-2.5	-1.6	-1.9
VOC + CO_{RW}	+2.6	+2.8	-1.1	-2.5	-2.6	-1.5	-1.3
Benzene	+0.062	+0.101	-0.213	-0.207	-0.487	-0.203	-0.466
1,3-Butadiene	+0.046	-0.095	-0.018	+0.026	+0.003	-0.181	-0.040
Formaldehyde	-0.095	-0.009	-0.081	-0.116	-0.100	-0.002	-0.069
Acetaldehyde	+0.029	+0.040	+0.374	+0.533	+0.761	+0.541	+0.642
Total Toxics	+0.043	+0.038	+0.062	+0.236	+0.177	+0.154	+0.067
Total $Toxics_{PW}$ (2)	+0.054	-0.077	-0.051	-0.005	-0.071	-0.207	-0.111
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.6	+1.0	+3.3	+4.7	+11.0	+6.4	+9.3
NO_x	-1.0	-3.2	-1.5	-0.2	-0.4	-3.8	-1.8
CO	+164.7	+142.6	-50.5	-123.2	-217.0	-142.0	-172.3
CO_{RW} (1)	+2.0	+1.7	-0.6	-1.5	-2.6	-1.7	-2.1
VOC + CO_{RW}	+2.6	+2.8	+2.6	+3.2	+8.3	+4.6	+7.2
Benzene	+0.062	+0.101	-0.197	-0.178	-0.439	-0.169	-0.430
1,3-Butadiene	+0.046	-0.095	-0.018	+0.026	+0.003	-0.181	-0.040
Formaldehyde	-0.095	-0.009	-0.081	-0.116	-0.100	-0.002	-0.069
Acetaldehyde	+0.029	+0.040	+0.377	+0.538	+0.772	+0.546	+0.649
Total Toxics	+0.043	+0.038	+0.081	+0.270	+0.235	+0.194	+0.110
Total $Toxics_{PW}$ (2)	+0.054	-0.077	-0.048	+0.000	-0.063	-0.201	-0.105

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.2: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.4	+0.6	-0.4	-0.8	-0.1	-0.0	+0.5
NO_x	-1.1	-3.5	-1.7	-0.2	-0.4	-4.1	-2.1
CO	+167.7	+145.2	-43.2	-114.2	-205.9	-134.1	-162.3
CO_{RW} (1)	+2.0	+1.8	-0.5	-1.4	-2.5	-1.6	-2.0
VOC + CO_{RW}	+2.4	+2.4	-1.0	-2.2	-2.6	-1.7	-1.5
Benzene	+0.043	+0.067	-0.161	-0.155	-0.361	-0.156	-0.345
1,3-Butadiene	+0.036	-0.068	-0.014	+0.019	-0.001	-0.135	-0.033
Formaldehyde	-0.072	-0.004	-0.061	-0.087	-0.078	+0.001	-0.054
Acetaldehyde	+0.021	+0.029	+0.275	+0.393	+0.562	+0.399	+0.473
Total Toxics	+0.028	+0.024	+0.040	+0.170	+0.122	+0.108	+0.042
Total $Toxics_{PW}$ (2)	+0.041	-0.056	-0.039	-0.005	-0.056	-0.156	-0.086
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.4	+0.6	+2.4	+3.5	+8.1	+4.6	+6.8
NO_x	-1.1	-3.5	-1.6	-0.0	-0.2	-4.0	-1.9
CO	+167.7	+145.2	-51.3	-125.4	-220.8	-144.3	-175.2
CO_{RW} (1)	+2.0	+1.8	-0.6	-1.5	-2.7	-1.8	-2.1
VOC + CO_{RW}	+2.4	+2.4	+1.8	+2.0	+5.4	+2.9	+4.7
Benzene	+0.043	+0.067	-0.149	-0.134	-0.326	-0.131	-0.319
1,3-Butadiene	+0.036	-0.068	-0.014	+0.019	-0.001	-0.135	-0.033
Formaldehyde	-0.072	-0.004	-0.061	-0.087	-0.078	+0.001	-0.054
Acetaldehyde	+0.021	+0.029	+0.277	+0.397	+0.570	+0.402	+0.479
Total Toxics	+0.028	+0.024	+0.054	+0.194	+0.164	+0.137	+0.073
Total $Toxics_{PW}$ (2)	+0.041	-0.056	-0.037	-0.001	-0.050	-0.151	-0.081

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.3: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Total Maricopa County Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.2%	+0.3%	-0.2%	-0.4%	-0.1%	+0.0%	+0.2%
NO_x	-0.3%	-0.9%	-0.5%	-0.1%	-0.2%	-1.1%	-0.6%
CO	+8.0%	+6.9%	-2.1%	-5.4%	-9.8%	-6.4%	-7.8%
CO_{RW} (1)	+8.0%	+6.9%	-2.1%	-5.4%	-9.8%	-6.4%	-7.8%
VOC + CO_{RW}	+0.8%	+0.8%	-0.3%	-0.7%	-0.8%	-0.4%	-0.4%
Benzene (2)	+1.7%	+2.8%	-6.0%	-5.8%	-13.6%	-5.7%	-13.0%
1,3-Butadiene (2)	+4.8%	-9.8%	-1.8%	+2.7%	+0.3%	-18.7%	-4.1%
Formaldehyde (2)	-7.5%	-0.7%	-6.4%	-9.1%	-7.9%	-0.2%	-5.4%
Acetaldehyde (2)	+6.6%	+9.2%	+85.1%	+121.4%	+173.4%	+123.2%	+146.2%
Total Toxics (2)	+0.7%	+0.6%	+1.0%	+3.8%	+2.8%	+2.5%	+1.1%
Total $Toxics_{PW}$ (2,3)	+3.3%	-4.7%	-3.1%	-0.3%	-4.4%	-12.7%	-6.8%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.2%	+0.3%	+1.0%	+1.5%	+3.5%	+2.0%	+2.9%
NO_x	-0.3%	-0.9%	-0.4%	-0.1%	-0.1%	-1.1%	-0.5%
CO	+8.0%	+6.9%	-2.5%	-6.0%	-10.5%	-6.9%	-8.4%
CO_{RW} (1)	+8.0%	+6.9%	-2.5%	-6.0%	-10.5%	-6.9%	-8.4%
VOC + CO_{RW}	+0.8%	+0.8%	+0.8%	+1.0%	+2.4%	+1.4%	+2.1%
Benzene (2)	+1.7%	+2.8%	-5.5%	-5.0%	-12.3%	-4.7%	-12.0%
1,3-Butadiene (2)	+4.8%	-9.8%	-1.8%	+2.7%	+0.3%	-18.7%	-4.1%
Formaldehyde (2)	-7.5%	-0.7%	-6.4%	-9.1%	-7.9%	-0.2%	-5.4%
Acetaldehyde (2)	+6.6%	+9.2%	+85.8%	+122.5%	+175.7%	+124.4%	+147.9%
Total Toxics (2)	+0.7%	+0.6%	+1.3%	+4.3%	+3.8%	+3.1%	+1.8%
Total $Toxics_{PW}$ (2,3)	+3.3%	-4.7%	-3.0%	+0.0%	-3.9%	-12.4%	-6.4%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change impacts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.4: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Total Maricopa County Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.1%	+0.2%	-0.1%	-0.3%	-0.0%	-0.0%	+0.2%
NO_x	-0.3%	-0.9%	-0.5%	-0.0%	-0.1%	-1.1%	-0.6%
CO	+7.8%	+6.8%	-2.0%	-5.3%	-9.6%	-6.3%	-7.6%
CO_{RW} (1)	+7.8%	+6.8%	-2.0%	-5.3%	-9.6%	-6.3%	-7.6%
VOC + CO_{RW}	+0.7%	+0.7%	-0.3%	-0.7%	-0.8%	-0.5%	-0.5%
Benzene (2)	+1.6%	+2.5%	-6.0%	-5.8%	-13.4%	-5.8%	-12.8%
1,3-Butadiene (2)	+4.9%	-9.3%	-1.9%	+2.5%	-0.1%	-18.5%	-4.4%
Formaldehyde (2)	-7.5%	-0.4%	-6.3%	-9.0%	-8.1%	+0.1%	-5.6%
Acetaldehyde (2)	+6.3%	+8.9%	+82.6%	+118.2%	+168.8%	+119.8%	+142.2%
Total Toxics (2)	+0.6%	+0.5%	+0.8%	+3.6%	+2.6%	+2.3%	+0.9%
Total $Toxics_{PW}$ (2,3)	+3.3%	-4.6%	-3.1%	-0.4%	-4.6%	-12.6%	-6.9%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.1%	+0.2%	+0.8%	+1.2%	+2.7%	+1.5%	+2.3%
NO_x	-0.3%	-0.9%	-0.4%	-0.0%	-0.0%	-1.1%	-0.5%
CO	+7.8%	+6.8%	-2.4%	-5.9%	-10.3%	-6.7%	-8.2%
CO_{RW} (1)	+7.8%	+6.8%	-2.4%	-5.9%	-10.3%	-6.7%	-8.2%
VOC + CO_{RW}	+0.7%	+0.7%	+0.5%	+0.6%	+1.7%	+0.9%	+1.4%
Benzene (2)	+1.6%	+2.5%	-5.5%	-5.0%	-12.1%	-4.8%	-11.8%
1,3-Butadiene (2)	+4.9%	-9.3%	-1.9%	+2.5%	-0.1%	-18.5%	-4.4%
Formaldehyde (2)	-7.5%	-0.4%	-6.3%	-9.0%	-8.1%	+0.1%	-5.6%
Acetaldehyde (2)	+6.3%	+8.9%	+83.2%	+119.3%	+171.1%	+120.9%	+143.9%
Total Toxics (2)	+0.6%	+0.5%	+1.1%	+4.1%	+3.5%	+2.9%	+1.5%
Total $Toxics_{PW}$ (2,3)	+3.3%	-4.6%	-3.0%	-0.1%	-4.1%	-12.3%	-6.6%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change imp acts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.5: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County Mobile Source Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.6	+1.0	-0.6	-1.2	-0.2	+0.1	+0.6
NO_x	-1.0	-3.2	-1.6	-0.3	-0.6	-3.9	-2.0
CO	+164.7	+142.6	-42.6	-112.2	-202.4	-131.9	-159.7
CO_{RW} (1)	+2.0	+1.7	-0.5	-1.4	-2.5	-1.6	-1.9
VOC + CO_{RW}	+2.6	+2.8	-1.1	-2.5	-2.6	-1.5	-1.3
Benzene	+0.062	+0.101	-0.213	-0.207	-0.487	-0.203	-0.466
1,3-Butadiene	+0.046	-0.095	-0.018	+0.026	+0.003	-0.181	-0.040
Formaldehyde	-0.095	-0.009	-0.081	-0.116	-0.100	-0.002	-0.069
Acetaldehyde	+0.029	+0.040	+0.374	+0.533	+0.761	+0.541	+0.642
Total Toxics	+0.043	+0.038	+0.062	+0.236	+0.177	+0.154	+0.067
Total $Toxics_{PW}$ (2)	+0.054	-0.077	-0.051	-0.005	-0.071	-0.207	-0.111
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.6	+1.0	+3.3	+4.7	+11.0	+6.4	+9.3
NO_x	-1.0	-3.2	-1.5	-0.2	-0.4	-3.8	-1.8
CO	+164.7	+142.6	-50.5	-123.2	-217.0	-142.0	-172.3
CO_{RW} (1)	+2.0	+1.7	-0.6	-1.5	-2.6	-1.7	-2.1
VOC + CO_{RW}	+2.6	+2.8	+2.6	+3.2	+8.3	+4.6	+7.2
Benzene	+0.062	+0.101	-0.197	-0.178	-0.439	-0.169	-0.430
1,3-Butadiene	+0.046	-0.095	-0.018	+0.026	+0.003	-0.181	-0.040
Formaldehyde	-0.095	-0.009	-0.081	-0.116	-0.100	-0.002	-0.069
Acetaldehyde	+0.029	+0.040	+0.377	+0.538	+0.772	+0.546	+0.649
Total Toxics	+0.043	+0.038	+0.081	+0.270	+0.235	+0.194	+0.110
Total $Toxics_{PW}$ (2)	+0.054	-0.077	-0.048	+0.000	-0.063	-0.201	-0.105

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.6: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County Mobile Source Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.4	+0.6	-0.4	-0.8	-0.1	-0.0	+0.5
NO_x	-1.1	-3.5	-1.7	-0.2	-0.4	-4.1	-2.1
CO	+167.7	+145.2	-43.2	-114.2	-205.9	-134.1	-162.3
CO_{RW} (1)	+2.0	+1.8	-0.5	-1.4	-2.5	-1.6	-2.0
VOC + CO_{RW}	+2.4	+2.4	-1.0	-2.2	-2.6	-1.7	-1.5
Benzene	+0.043	+0.067	-0.161	-0.155	-0.361	-0.156	-0.345
1,3-Butadiene	+0.036	-0.068	-0.014	+0.019	-0.001	-0.135	-0.033
Formaldehyde	-0.072	-0.004	-0.061	-0.087	-0.078	+0.001	-0.054
Acetaldehyde	+0.021	+0.029	+0.275	+0.393	+0.562	+0.399	+0.473
Total Toxics	+0.028	+0.024	+0.040	+0.170	+0.122	+0.108	+0.042
Total $Toxics_{PW}$ (2)	+0.041	-0.056	-0.039	-0.005	-0.056	-0.156	-0.086
Impacts with “worst case” commingling between zero oxy and average property gasoline …							
VOC	+0.4	+0.6	+2.4	+3.5	+8.1	+4.6	+6.8
NO_x	-1.1	-3.5	-1.6	-0.0	-0.2	-4.0	-1.9
CO	+167.7	+145.2	-51.3	-125.4	-220.8	-144.3	-175.2
CO_{RW} (1)	+2.0	+1.8	-0.6	-1.5	-2.7	-1.8	-2.1
VOC + CO_{RW}	+2.4	+2.4	+1.8	+2.0	+5.4	+2.9	+4.7
Benzene	+0.043	+0.067	-0.149	-0.134	-0.326	-0.131	-0.319
1,3-Butadiene	+0.036	-0.068	-0.014	+0.019	-0.001	-0.135	-0.033
Formaldehyde	-0.072	-0.004	-0.061	-0.087	-0.078	+0.001	-0.054
Acetaldehyde	+0.021	+0.029	+0.277	+0.397	+0.570	+0.402	+0.479
Total Toxics	+0.028	+0.024	+0.054	+0.194	+0.164	+0.137	+0.073
Total $Toxics_{PW}$ (2)	+0.041	-0.056	-0.037	-0.001	-0.050	-0.151	-0.081

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.7: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County Mobile Source Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.4%	+0.6%	-0.3%	-0.7%	-0.1%	+0.0%	+0.4%
NO_x	-0.3%	-1.1%	-0.5%	-0.1%	-0.2%	-1.3%	-0.7%
CO	+8.1%	+7.0%	-2.1%	-5.5%	-9.9%	-6.5%	-7.8%
CO_{RW} (1)	+8.1%	+7.0%	-2.1%	-5.5%	-9.9%	-6.5%	-7.8%
VOC + CO_{RW}	+1.4%	+1.4%	-0.6%	-1.3%	-1.4%	-0.8%	-0.7%
Benzene (2)	+1.7%	+2.8%	-6.0%	-5.8%	-13.6%	-5.7%	-13.0%
1,3-Butadiene (2)	+4.8%	-9.8%	-1.8%	+2.7%	+0.3%	-18.7%	-4.1%
Formaldehyde (2)	-7.5%	-0.7%	-6.4%	-9.1%	-7.9%	-0.2%	-5.4%
Acetaldehyde (2)	+6.6%	+9.2%	+85.1%	+121.4%	+173.4%	+123.2%	+146.2%
Total Toxics (2)	+0.7%	+0.6%	+1.0%	+3.8%	+2.8%	+2.5%	+1.1%
Total $Toxics_{PW}$ (2,3)	+3.3%	-4.7%	-3.1%	-0.3%	-4.4%	-12.7%	-6.8%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.4%	+0.6%	+2.0%	+2.8%	+6.6%	+3.8%	+5.6%
NO_x	-0.3%	-1.1%	-0.5%	-0.1%	-0.1%	-1.3%	-0.6%
CO	+8.1%	+7.0%	-2.5%	-6.0%	-10.6%	-6.9%	-8.4%
CO_{RW} (1)	+8.1%	+7.0%	-2.5%	-6.0%	-10.6%	-6.9%	-8.4%
VOC + CO_{RW}	+1.4%	+1.4%	+1.4%	+1.7%	+4.3%	+2.4%	+3.7%
Benzene (2)	+1.7%	+2.8%	-5.5%	-5.0%	-12.3%	-4.7%	-12.0%
1,3-Butadiene (2)	+4.8%	-9.8%	-1.8%	+2.7%	+0.3%	-18.7%	-4.1%
Formaldehyde (2)	-7.5%	-0.7%	-6.4%	-9.1%	-7.9%	-0.2%	-5.4%
Acetaldehyde (2)	+6.6%	+9.2%	+85.8%	+122.5%	+175.7%	+124.4%	+147.9%
Total Toxics (2)	+0.7%	+0.6%	+1.3%	+4.3%	+3.8%	+3.1%	+1.8%
Total $Toxics_{PW}$ (2,3)	+3.3%	-4.7%	-3.0%	+0.0%	-3.9%	-12.4%	-6.4%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change impacts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.8: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County Mobile Source Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.3%	+0.4%	-0.3%	-0.6%	-0.1%	-0.0%	+0.3%
NO_x	-0.4%	-1.1%	-0.5%	-0.1%	-0.1%	-1.3%	-0.7%
CO	+7.9%	+6.9%	-2.0%	-5.4%	-9.7%	-6.3%	-7.7%
CO_{RW} (1)	+7.9%	+6.9%	-2.0%	-5.4%	-9.7%	-6.3%	-7.7%
VOC + CO_{RW}	+1.5%	+1.5%	-0.6%	-1.4%	-1.6%	-1.0%	-0.9%
Benzene (2)	+1.6%	+2.5%	-6.0%	-5.8%	-13.4%	-5.8%	-12.8%
1,3-Butadiene (2)	+4.9%	-9.3%	-1.9%	+2.5%	-0.1%	-18.5%	-4.4%
Formaldehyde (2)	-7.5%	-0.4%	-6.3%	-9.0%	-8.1%	+0.1%	-5.6%
Acetaldehyde (2)	+6.3%	+8.9%	+82.6%	+118.2%	+168.8%	+119.8%	+142.2%
Total Toxics (2)	+0.6%	+0.5%	+0.8%	+3.6%	+2.6%	+2.3%	+0.9%
Total $Toxics_{PW}$ (2,3)	+3.3%	-4.6%	-3.1%	-0.4%	-4.6%	-12.6%	-6.9%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.3%	+0.4%	+1.7%	+2.6%	+5.9%	+3.4%	+5.0%
NO_x	-0.4%	-1.1%	-0.5%	-0.0%	-0.1%	-1.3%	-0.6%
CO	+7.9%	+6.9%	-2.4%	-5.9%	-10.4%	-6.8%	-8.3%
CO_{RW} (1)	+7.9%	+6.9%	-2.4%	-5.9%	-10.4%	-6.8%	-8.3%
VOC + CO_{RW}	+1.5%	+1.5%	+1.1%	+1.2%	+3.3%	+1.7%	+2.9%
Benzene (2)	+1.6%	+2.5%	-5.5%	-5.0%	-12.1%	-4.8%	-11.8%
1,3-Butadiene (2)	+4.9%	-9.3%	-1.9%	+2.5%	-0.1%	-18.5%	-4.4%
Formaldehyde (2)	-7.5%	-0.4%	-6.3%	-9.0%	-8.1%	+0.1%	-5.6%
Acetaldehyde (2)	+6.3%	+8.9%	+83.2%	+119.3%	+171.1%	+120.9%	+143.9%
Total Toxics (2)	+0.6%	+0.5%	+1.1%	+4.1%	+3.5%	+2.9%	+1.5%
Total $Toxics_{PW}$ (2,3)	+3.3%	-4.6%	-3.0%	-0.1%	-4.1%	-12.3%	-6.6%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change impacts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.9: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County On-Road Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.16	+0.23	-0.37	-0.59	+0.05	-0.12	+0.42
NO_x	-0.96	-3.04	-1.49	-0.19	-0.38	-3.67	-1.84
CO	+68.0	+55.9	-18.3	-46.3	-85.1	-58.1	-67.6
CO_{RW} (1)	+0.83	+0.68	-0.22	-0.56	-1.04	-0.71	-0.82
VOC + CO_{RW}	+0.99	+0.91	-0.59	-1.16	-0.98	-0.83	-0.41
Benzene	+0.029	+0.042	-0.129	-0.124	-0.284	-0.128	-0.270
1,3-Butadiene	+0.031	-0.049	-0.011	+0.013	-0.005	-0.107	-0.030
Formaldehyde	-0.058	+0.001	-0.049	-0.069	-0.066	+0.004	-0.047
Acetaldehyde	+0.015	+0.022	+0.209	+0.302	+0.431	+0.305	+0.363
Total Toxics	+0.017	+0.016	+0.020	+0.122	+0.076	+0.075	+0.016
Total $Toxics_{PW}$ (2)	+0.034	-0.041	-0.031	-0.005	-0.049	-0.123	-0.072
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.16	+0.23	+1.84	+2.83	+6.50	+3.52	+5.43
NO_x	-0.96	-3.04	-1.42	-0.08	-0.20	-3.56	-1.70
CO	+68.0	+55.9	-22.8	-52.6	-93.6	-63.9	-74.8
CO_{RW} (1)	+0.83	+0.68	-0.28	-0.64	-1.14	-0.78	-0.91
VOC + CO_{RW}	+0.99	+0.91	+1.56	+2.19	+5.36	+2.74	+4.52
Benzene	+0.029	+0.042	-0.120	-0.108	-0.256	-0.108	-0.250
1,3-Butadiene	+0.031	-0.049	-0.011	+0.013	-0.005	-0.107	-0.030
Formaldehyde	-0.058	+0.001	-0.049	-0.069	-0.066	+0.004	-0.047
Acetaldehyde	+0.015	+0.022	+0.211	+0.305	+0.437	+0.308	+0.367
Total Toxics	+0.017	+0.016	+0.031	+0.141	+0.109	+0.097	+0.041
Total $Toxics_{PW}$ (2)	+0.034	-0.041	-0.030	-0.003	-0.044	-0.120	-0.068

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.10: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County On-Road Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.11	+0.03	-0.33	-0.50	-0.07	-0.26	+0.23
NO_x	-1.06	-3.23	-1.62	-0.05	-0.17	-3.82	-1.92
CO	+54.4	+43.6	-14.7	-37.0	-68.4	-47.6	-54.4
CO_{RW} (1)	+0.66	+0.53	-0.18	-0.45	-0.83	-0.58	-0.66
VOC + CO_{RW}	+0.78	+0.56	-0.51	-0.95	-0.90	-0.84	-0.43
Benzene	+0.029	+0.031	-0.111	-0.111	-0.243	-0.120	-0.230
1,3-Butadiene	+0.027	-0.042	-0.010	+0.011	-0.005	-0.093	-0.027
Formaldehyde	-0.051	+0.002	-0.043	-0.060	-0.059	+0.004	-0.042
Acetaldehyde	+0.013	+0.019	+0.180	+0.261	+0.372	+0.263	+0.313
Total Toxics	+0.018	+0.010	+0.017	+0.102	+0.066	+0.055	+0.015
Total $Toxics_{PW}$ (2)	+0.030	-0.036	-0.027	-0.005	-0.043	-0.109	-0.062
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.11	+0.03	+1.31	+2.04	+4.70	+2.44	+3.94
NO_x	-1.06	-3.23	-1.55	+0.06	+0.03	-3.70	-1.77
CO	+54.4	+43.6	-18.8	-42.6	-76.1	-52.8	-60.9
CO_{RW} (1)	+0.66	+0.53	-0.23	-0.52	-0.93	-0.64	-0.74
VOC + CO_{RW}	+0.78	+0.56	+1.08	+1.52	+3.77	+1.80	+3.20
Benzene	+0.029	+0.031	-0.104	-0.099	-0.223	-0.106	-0.215
1,3-Butadiene	+0.027	-0.042	-0.010	+0.011	-0.005	-0.093	-0.027
Formaldehyde	-0.051	+0.002	-0.043	-0.060	-0.059	+0.004	-0.042
Acetaldehyde	+0.013	+0.019	+0.182	+0.263	+0.378	+0.266	+0.317
Total Toxics	+0.018	+0.010	+0.025	+0.116	+0.091	+0.072	+0.034
Total $Toxics_{PW}$ (2)	+0.030	-0.036	-0.026	-0.003	-0.039	-0.106	-0.060

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.11: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County On-Road Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.2%	+0.3%	-0.4%	-0.7%	+0.1%	-0.1%	+0.5%
NO_x	-0.5%	-1.6%	-0.8%	-0.1%	-0.2%	-1.9%	-1.0%
CO	+6.1%	+5.0%	-1.7%	-4.2%	-7.7%	-5.3%	-6.1%
CO_{RW} (1)	+6.1%	+5.0%	-1.7%	-4.2%	-7.7%	-5.3%	-6.1%
VOC + CO_{RW}	+1.0%	+0.9%	-0.6%	-1.1%	-1.0%	-0.8%	-0.4%
Benzene (2)	+1.3%	+1.9%	-6.0%	-5.7%	-13.1%	-5.9%	-12.4%
1,3-Butadiene (2)	+5.1%	-8.2%	-1.9%	+2.2%	-0.9%	-17.9%	-5.0%
Formaldehyde (2)	-7.4%	+0.2%	-6.3%	-8.8%	-8.5%	+0.6%	-6.0%
Acetaldehyde (2)	+5.6%	+8.1%	+77.4%	+111.8%	+159.6%	+112.8%	+134.3%
Total Toxics (2)	+0.4%	+0.4%	+0.5%	+3.2%	+2.0%	+2.0%	+0.4%
Total $Toxics_{PW}$ (2,3)	+3.4%	-4.2%	-3.2%	-0.5%	-4.9%	-12.4%	-7.2%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.2%	+0.3%	+2.1%	+3.2%	+7.3%	+3.9%	+6.1%
NO_x	-0.5%	-1.6%	-0.7%	-0.0%	-0.1%	-1.9%	-0.9%
CO	+6.1%	+5.0%	-2.1%	-4.8%	-8.5%	-5.8%	-6.8%
CO_{RW} (1)	+6.1%	+5.0%	-2.1%	-4.8%	-8.5%	-5.8%	-6.8%
VOC + CO_{RW}	+1.0%	+0.9%	+1.5%	+2.1%	+5.2%	+2.7%	+4.4%
Benzene (2)	+1.3%	+1.9%	-5.5%	-5.0%	-11.8%	-5.0%	-11.5%
1,3-Butadiene (2)	+5.1%	-8.2%	-1.9%	+2.2%	-0.9%	-17.9%	-5.0%
Formaldehyde (2)	-7.4%	+0.2%	-6.3%	-8.8%	-8.5%	+0.6%	-6.0%
Acetaldehyde (2)	+5.6%	+8.1%	+78.0%	+112.9%	+161.8%	+113.9%	+135.9%
Total Toxics (2)	+0.4%	+0.4%	+0.8%	+3.7%	+2.9%	+2.5%	+1.1%
Total $Toxics_{PW}$ (2,3)	+3.4%	-4.2%	-3.0%	-0.3%	-4.4%	-12.0%	-6.9%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change impacts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.12: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County On-Road Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.2%	+0.0%	-0.4%	-0.7%	-0.1%	-0.3%	+0.3%
NO_x	-0.5%	-1.6%	-0.8%	-0.0%	-0.1%	-1.9%	-0.9%
CO	+5.4%	+4.3%	-1.5%	-3.7%	-6.8%	-4.7%	-5.4%
CO_{RW} (1)	+5.4%	+4.3%	-1.5%	-3.7%	-6.8%	-4.7%	-5.4%
VOC + CO_{RW}	+0.9%	+0.7%	-0.6%	-1.1%	-1.0%	-1.0%	-0.5%
Benzene (2)	+1.6%	+1.7%	-6.0%	-6.0%	-13.1%	-6.5%	-12.4%
1,3-Butadiene (2)	+5.2%	-8.0%	-1.9%	+2.2%	-1.0%	-17.8%	-5.2%
Formaldehyde (2)	-7.4%	+0.3%	-6.2%	-8.8%	-8.6%	+0.6%	-6.1%
Acetaldehyde (2)	+5.4%	+8.0%	+76.4%	+110.5%	+157.8%	+111.5%	+132.8%
Total Toxics (2)	+0.6%	+0.3%	+0.5%	+3.1%	+2.0%	+1.7%	+0.5%
Total $Toxics_{PW}$ (2,3)	+3.5%	-4.2%	-3.2%	-0.6%	-5.0%	-12.6%	-7.2%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.2%	+0.0%	+1.8%	+2.8%	+6.3%	+3.3%	+5.3%
NO_x	-0.5%	-1.6%	-0.8%	+0.0%	+0.0%	-1.8%	-0.9%
CO	+5.4%	+4.3%	-1.9%	-4.2%	-7.6%	-5.2%	-6.1%
CO_{RW} (1)	+5.4%	+4.3%	-1.9%	-4.2%	-7.6%	-5.2%	-6.1%
VOC + CO_{RW}	+0.9%	+0.7%	+1.3%	+1.8%	+4.4%	+2.1%	+3.7%
Benzene (2)	+1.6%	+1.7%	-5.6%	-5.3%	-12.0%	-5.7%	-11.6%
1,3-Butadiene (2)	+5.2%	-8.0%	-1.9%	+2.2%	-1.0%	-17.8%	-5.2%
Formaldehyde (2)	-7.4%	+0.3%	-6.2%	-8.8%	-8.6%	+0.6%	-6.1%
Acetaldehyde (2)	+5.4%	+8.0%	+77.0%	+111.6%	+160.0%	+112.6%	+134.4%
Total Toxics (2)	+0.6%	+0.3%	+0.8%	+3.5%	+2.8%	+2.2%	+1.0%
Total $Toxics_{PW}$ (2,3)	+3.5%	-4.2%	-3.0%	-0.4%	-4.6%	-12.3%	-6.9%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change impacts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.13: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County Off-Road Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.45	+0.78	-0.18	-0.57	-0.22	+0.20	+0.19
NO_x	-0.06	-0.18	-0.08	-0.09	-0.17	-0.26	-0.15
CO	+96.7	+86.8	-24.3	-65.9	-117.3	-73.8	-92.1
CO_{RW} (1)	+1.18	+1.06	-0.30	-0.80	-1.43	-0.90	-1.12
VOC + CO_{RW}	+1.63	+1.84	-0.48	-1.38	-1.65	-0.70	-0.93
Benzene	+0.034	+0.059	-0.084	-0.082	-0.203	-0.075	-0.196
1,3-Butadiene	+0.015	-0.046	-0.007	+0.013	+0.008	-0.075	-0.010
Formaldehyde	-0.037	-0.010	-0.032	-0.047	-0.034	-0.006	-0.021
Acetaldehyde	+0.014	+0.019	+0.165	+0.231	+0.330	+0.236	+0.279
Total Toxics	+0.026	+0.022	+0.042	+0.114	+0.101	+0.080	+0.052
Total $Toxics_{PW}$ (2)	+0.020	-0.036	-0.019	+0.001	-0.023	-0.084	-0.039
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.45	+0.78	+1.42	+1.91	+4.47	+2.86	+3.84
NO_x	-0.06	-0.18	-0.08	-0.09	-0.16	-0.25	-0.14
CO	+96.7	+86.8	-27.7	-70.6	-123.5	-78.1	-97.5
CO_{RW} (1)	+1.18	+1.06	-0.34	-0.86	-1.51	-0.95	-1.19
VOC + CO_{RW}	+1.63	+1.84	+1.08	+1.05	+2.96	+1.90	+2.65
Benzene	+0.034	+0.059	-0.077	-0.070	-0.183	-0.061	-0.181
1,3-Butadiene	+0.015	-0.046	-0.007	+0.013	+0.008	-0.075	-0.010
Formaldehyde	-0.037	-0.010	-0.032	-0.047	-0.034	-0.006	-0.021
Acetaldehyde	+0.014	+0.019	+0.166	+0.233	+0.334	+0.238	+0.282
Total Toxics	+0.026	+0.022	+0.050	+0.128	+0.125	+0.096	+0.070
Total $Toxics_{PW}$ (2)	+0.020	-0.036	-0.018	+0.003	-0.019	-0.082	-0.037

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.14: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County Off-Road Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.26	+0.57	-0.10	-0.33	-0.01	+0.23	+0.23
NO_x	-0.07	-0.23	-0.10	-0.12	-0.21	-0.32	-0.19
CO	+113.3	+101.7	-28.4	-77.2	-137.5	-86.5	-107.9
CO_{RW} (1)	+1.38	+1.24	-0.35	-0.94	-1.68	-1.05	-1.32
VOC + CO_{RW}	+1.64	+1.81	-0.45	-1.27	-1.69	-0.82	-1.09
Benzene	+0.014	+0.036	-0.049	-0.045	-0.119	-0.036	-0.116
1,3-Butadiene	+0.009	-0.026	-0.004	+0.007	+0.005	-0.043	-0.006
Formaldehyde	-0.021	-0.006	-0.018	-0.027	-0.019	-0.004	-0.012
Acetaldehyde	+0.008	+0.011	+0.095	+0.133	+0.190	+0.136	+0.160
Total Toxics	+0.009	+0.014	+0.023	+0.068	+0.056	+0.053	+0.027
Total $Toxics_{PW}$ (2)	+0.011	-0.020	-0.011	+0.001	-0.013	-0.047	-0.023
Impacts with “worst case” commingling between zero oxy and average property gasoline …							
VOC	+0.26	+0.57	+1.06	+1.48	+3.42	+2.17	+2.89
NO_x	-0.07	-0.23	-0.09	-0.11	-0.20	-0.31	-0.18
CO	+113.3	+101.7	-32.5	-82.8	-144.7	-91.5	-114.2
CO_{RW} (1)	+1.38	+1.24	-0.40	-1.01	-1.76	-1.12	-1.39
VOC + CO_{RW}	+1.64	+1.81	+0.67	+0.47	+1.66	+1.06	+1.50
Benzene	+0.014	+0.036	-0.044	-0.036	-0.103	-0.025	-0.104
1,3-Butadiene	+0.009	-0.026	-0.004	+0.007	+0.005	-0.043	-0.006
Formaldehyde	-0.021	-0.006	-0.018	-0.027	-0.019	-0.004	-0.012
Acetaldehyde	+0.008	+0.011	+0.095	+0.134	+0.192	+0.137	+0.162
Total Toxics	+0.009	+0.014	+0.029	+0.079	+0.074	+0.065	+0.040
Total $Toxics_{PW}$ (2)	+0.011	-0.020	-0.010	+0.002	-0.011	-0.045	-0.021

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.15: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County Off-Road Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.6%	+1.0%	-0.2%	-0.7%	-0.3%	+0.3%	+0.2%
NO_x	-0.1%	-0.2%	-0.1%	-0.1%	-0.2%	-0.3%	-0.1%
CO	+10.3%	+9.2%	-2.6%	-7.0%	-12.5%	-7.9%	-9.8%
CO_{RW} (1)	+10.3%	+9.2%	-2.6%	-7.0%	-12.5%	-7.9%	-9.8%
VOC + CO_{RW}	+1.8%	+2.1%	-0.5%	-1.5%	-1.9%	-0.8%	-1.0%
Benzene (2)	+2.4%	+4.2%	-6.0%	-5.9%	-14.5%	-5.4%	-13.9%
1,3-Butadiene (2)	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde (2)	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde (2)	+8.4%	+11.0%	+97.5%	+136.8%	+195.5%	+139.9%	+165.3%
Total Toxics (2)	+1.1%	+0.9%	+1.7%	+4.7%	+4.1%	+3.3%	+2.1%
Total $Toxics_{PW}$ (2,3)	+3.2%	-5.6%	-3.1%	+0.1%	-3.6%	-13.3%	-6.2%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.6%	+1.0%	+1.8%	+2.5%	+5.8%	+3.7%	+4.9%
NO_x	-0.1%	-0.2%	-0.1%	-0.1%	-0.2%	-0.2%	-0.1%
CO	+10.3%	+9.2%	-3.0%	-7.5%	-13.2%	-8.3%	-10.4%
CO_{RW} (1)	+10.3%	+9.2%	-3.0%	-7.5%	-13.2%	-8.3%	-10.4%
VOC + CO_{RW}	+1.8%	+2.1%	+1.2%	+1.2%	+3.3%	+2.1%	+3.0%
Benzene (2)	+2.4%	+4.2%	-5.5%	-5.0%	-13.0%	-4.3%	-12.9%
1,3-Butadiene (2)	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde (2)	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde (2)	+8.4%	+11.0%	+98.2%	+138.0%	+198.0%	+141.1%	+167.1%
Total Toxics (2)	+1.1%	+0.9%	+2.1%	+5.3%	+5.2%	+4.0%	+2.9%
Total $Toxics_{PW}$ (2,3)	+3.2%	-5.6%	-2.9%	+0.4%	-3.0%	-12.9%	-5.8%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change impacts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.16: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County Off-Road Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.4%	+0.9%	-0.2%	-0.5%	-0.0%	+0.4%	+0.4%
NO_x	-0.1%	-0.2%	-0.1%	-0.1%	-0.2%	-0.3%	-0.2%
CO	+10.2%	+9.2%	-2.6%	-7.0%	-12.4%	-7.8%	-9.7%
CO_{RW} (1)	+10.2%	+9.2%	-2.6%	-7.0%	-12.4%	-7.8%	-9.7%
VOC + CO_{RW}	+2.1%	+2.4%	-0.6%	-1.7%	-2.2%	-1.1%	-1.4%
Benzene (2)	+1.6%	+4.2%	-5.9%	-5.3%	-14.1%	-4.3%	-13.7%
1,3-Butadiene (2)	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde (2)	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde (2)	+8.4%	+11.0%	+97.5%	+136.8%	+195.5%	+139.9%	+165.3%
Total Toxics (2)	+0.7%	+1.0%	+1.6%	+4.8%	+3.9%	+3.7%	+1.9%
Total $Toxics_{PW}$ (2,3)	+2.9%	-5.5%	-3.1%	+0.2%	-3.6%	-12.7%	-6.3%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.4%	+0.9%	+1.7%	+2.3%	+5.4%	+3.4%	+4.6%
NO_x	-0.1%	-0.2%	-0.1%	-0.1%	-0.2%	-0.3%	-0.2%
CO	+10.2%	+9.2%	-2.9%	-7.5%	-13.0%	-8.2%	-10.3%
CO_{RW} (1)	+10.2%	+9.2%	-2.9%	-7.5%	-13.0%	-8.2%	-10.3%
VOC + CO_{RW}	+2.1%	+2.4%	+0.9%	+0.6%	+2.2%	+1.4%	+2.0%
Benzene (2)	+1.6%	+4.2%	-5.2%	-4.2%	-12.3%	-3.0%	-12.4%
1,3-Butadiene (2)	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde (2)	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde (2)	+8.4%	+11.0%	+98.2%	+138.0%	+198.0%	+141.1%	+167.1%
Total Toxics (2)	+0.7%	+1.0%	+2.0%	+5.5%	+5.1%	+4.6%	+2.8%
Total $Toxics_{PW}$ (2,3)	+2.9%	-5.5%	-2.8%	+0.6%	-2.9%	-12.2%	-5.7%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) For toxic emissions, only on- and off-road gasoline inventories have been estimated, so percent change impacts exclude emissions from point, area, biogenic, and non-gasoline mobile sources.

(3) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.17: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County On-Road Gasoline Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.16	+0.23	-0.37	-0.59	+0.05	-0.12	+0.42
NO_x	-0.96	-3.04	-1.49	-0.19	-0.38	-3.67	-1.84
CO	+68.0	+55.9	-18.3	-46.3	-85.1	-58.1	-67.6
CO_{RW} (1)	+0.83	+0.68	-0.22	-0.56	-1.04	-0.71	-0.82
VOC + CO_{RW}	+0.99	+0.91	-0.59	-1.16	-0.98	-0.83	-0.41
Benzene	+0.029	+0.042	-0.129	-0.124	-0.284	-0.128	-0.270
1,3-Butadiene	+0.031	-0.049	-0.011	+0.013	-0.005	-0.107	-0.030
Formaldehyde	-0.058	+0.001	-0.049	-0.069	-0.066	+0.004	-0.047
Acetaldehyde	+0.015	+0.022	+0.209	+0.302	+0.431	+0.305	+0.363
Total Toxics	+0.017	+0.016	+0.020	+0.122	+0.076	+0.075	+0.016
Total $Toxics_{PW}$ (2)	+0.034	-0.041	-0.031	-0.005	-0.049	-0.123	-0.072
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.16	+0.23	+1.84	+2.83	+6.50	+3.52	+5.43
NO_x	-0.96	-3.04	-1.42	-0.08	-0.20	-3.56	-1.70
CO	+68.0	+55.9	-22.8	-52.6	-93.6	-63.9	-74.8
CO_{RW} (1)	+0.83	+0.68	-0.28	-0.64	-1.14	-0.78	-0.91
VOC + CO_{RW}	+0.99	+0.91	+1.56	+2.19	+5.36	+2.74	+4.52
Benzene	+0.029	+0.042	-0.120	-0.108	-0.256	-0.108	-0.250
1,3-Butadiene	+0.031	-0.049	-0.011	+0.013	-0.005	-0.107	-0.030
Formaldehyde	-0.058	+0.001	-0.049	-0.069	-0.066	+0.004	-0.047
Acetaldehyde	+0.015	+0.022	+0.211	+0.305	+0.437	+0.308	+0.367
Total Toxics	+0.017	+0.016	+0.031	+0.141	+0.109	+0.097	+0.041
Total $Toxics_{PW}$ (2)	+0.034	-0.041	-0.030	-0.003	-0.044	-0.120	-0.068

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.18: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County On-Road Gasoline Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.11	+0.03	-0.33	-0.50	-0.07	-0.26	+0.23
NO_x	-1.06	-3.23	-1.62	-0.05	-0.17	-3.82	-1.92
CO	+54.4	+43.6	-14.7	-37.0	-68.4	-47.6	-54.4
CO_{RW} (1)	+0.66	+0.53	-0.18	-0.45	-0.83	-0.58	-0.66
VOC + CO_{RW}	+0.78	+0.56	-0.51	-0.95	-0.90	-0.84	-0.43
Benzene	+0.029	+0.031	-0.111	-0.111	-0.243	-0.120	-0.230
1,3-Butadiene	+0.027	-0.042	-0.010	+0.011	-0.005	-0.093	-0.027
Formaldehyde	-0.051	+0.002	-0.043	-0.060	-0.059	+0.004	-0.042
Acetaldehyde	+0.013	+0.019	+0.180	+0.261	+0.372	+0.263	+0.313
Total Toxics	+0.018	+0.010	+0.017	+0.102	+0.066	+0.055	+0.015
Total $Toxics_{PW}$ (2)	+0.030	-0.036	-0.027	-0.005	-0.043	-0.109	-0.062
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.11	+0.03	+1.31	+2.04	+4.70	+2.44	+3.94
NO_x	-1.06	-3.23	-1.55	+0.06	+0.03	-3.70	-1.77
CO	+54.4	+43.6	-18.8	-42.6	-76.1	-52.8	-60.9
CO_{RW} (1)	+0.66	+0.53	-0.23	-0.52	-0.93	-0.64	-0.74
VOC + CO_{RW}	+0.78	+0.56	+1.08	+1.52	+3.77	+1.80	+3.20
Benzene	+0.029	+0.031	-0.104	-0.099	-0.223	-0.106	-0.215
1,3-Butadiene	+0.027	-0.042	-0.010	+0.011	-0.005	-0.093	-0.027
Formaldehyde	-0.051	+0.002	-0.043	-0.060	-0.059	+0.004	-0.042
Acetaldehyde	+0.013	+0.019	+0.182	+0.263	+0.378	+0.266	+0.317
Total Toxics	+0.018	+0.010	+0.025	+0.116	+0.091	+0.072	+0.034
Total $Toxics_{PW}$ (2)	+0.030	-0.036	-0.026	-0.003	-0.039	-0.106	-0.060

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.19: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County On-Road Gasoline Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.2%	+0.3%	-0.5%	-0.7%	+0.1%	-0.1%	+0.5%
NO_x	-0.7%	-2.3%	-1.1%	-0.1%	-0.3%	-2.8%	-1.4%
CO	+6.5%	+5.4%	-1.8%	-4.4%	-8.2%	-5.6%	-6.5%
CO_{RW} (1)	+6.5%	+5.4%	-1.8%	-4.4%	-8.2%	-5.6%	-6.5%
VOC + CO_{RW}	+1.0%	+1.0%	-0.6%	-1.2%	-1.0%	-0.9%	-0.4%
Benzene	+1.3%	+1.9%	-6.0%	-5.7%	-13.1%	-5.9%	-12.4%
1,3-Butadiene	+5.1%	-8.2%	-1.9%	+2.2%	-0.9%	-17.9%	-5.0%
Formaldehyde	-7.4%	+0.2%	-6.3%	-8.8%	-8.5%	+0.6%	-6.0%
Acetaldehyde	+5.6%	+8.1%	+77.4%	+111.8%	+159.6%	+112.8%	+134.3%
Total Toxics	+0.4%	+0.4%	+0.5%	+3.2%	+2.0%	+2.0%	+0.4%
Total $Toxics_{PW}$ (2)	+3.4%	-4.2%	-3.2%	-0.5%	-4.9%	-12.4%	-7.2%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.2%	+0.3%	+2.2%	+3.5%	+7.9%	+4.3%	+6.6%
NO_x	-0.7%	-2.3%	-1.1%	-0.1%	-0.2%	-2.7%	-1.3%
CO	+6.5%	+5.4%	-2.2%	-5.0%	-9.0%	-6.1%	-7.2%
CO_{RW} (1)	+6.5%	+5.4%	-2.2%	-5.0%	-9.0%	-6.1%	-7.2%
VOC + CO_{RW}	+1.0%	+1.0%	+1.7%	+2.3%	+5.7%	+2.9%	+4.8%
Benzene	+1.3%	+1.9%	-5.5%	-5.0%	-11.8%	-5.0%	-11.5%
1,3-Butadiene	+5.1%	-8.2%	-1.9%	+2.2%	-0.9%	-17.9%	-5.0%
Formaldehyde	-7.4%	+0.2%	-6.3%	-8.8%	-8.5%	+0.6%	-6.0%
Acetaldehyde	+5.6%	+8.1%	+78.0%	+112.9%	+161.8%	+113.9%	+135.9%
Total Toxics	+0.4%	+0.4%	+0.8%	+3.7%	+2.9%	+2.5%	+1.1%
Total $Toxics_{PW}$ (2)	+3.4%	-4.2%	-3.0%	-0.3%	-4.4%	-12.0%	-6.9%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.20: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County On-Road Gasoline Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.2%	+0.0%	-0.5%	-0.8%	-0.1%	-0.4%	+0.3%
NO_x	-0.8%	-2.3%	-1.1%	-0.0%	-0.1%	-2.7%	-1.4%
CO	+5.8%	+4.7%	-1.6%	-4.0%	-7.3%	-5.1%	-5.8%
CO_{RW} (1)	+5.8%	+4.7%	-1.6%	-4.0%	-7.3%	-5.1%	-5.8%
VOC + CO_{RW}	+1.0%	+0.7%	-0.7%	-1.2%	-1.2%	-1.1%	-0.6%
Benzene	+1.6%	+1.7%	-6.0%	-6.0%	-13.1%	-6.5%	-12.4%
1,3-Butadiene	+5.2%	-8.0%	-1.9%	+2.2%	-1.0%	-17.8%	-5.2%
Formaldehyde	-7.4%	+0.3%	-6.2%	-8.8%	-8.6%	+0.6%	-6.1%
Acetaldehyde	+5.4%	+8.0%	+76.4%	+110.5%	+157.8%	+111.5%	+132.8%
Total Toxics	+0.6%	+0.3%	+0.5%	+3.1%	+2.0%	+1.7%	+0.5%
Total $Toxics_{PW}$ (2)	+3.5%	-4.2%	-3.2%	-0.6%	-5.0%	-12.6%	-7.2%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.2%	+0.0%	+2.0%	+3.1%	+7.1%	+3.7%	+6.0%
NO_x	-0.8%	-2.3%	-1.1%	+0.0%	+0.0%	-2.6%	-1.3%
CO	+5.8%	+4.7%	-2.0%	-4.6%	-8.2%	-5.7%	-6.5%
CO_{RW} (1)	+5.8%	+4.7%	-2.0%	-4.6%	-8.2%	-5.7%	-6.5%
VOC + CO_{RW}	+1.0%	+0.7%	+1.4%	+2.0%	+4.9%	+2.3%	+4.1%
Benzene	+1.6%	+1.7%	-5.6%	-5.3%	-12.0%	-5.7%	-11.6%
1,3-Butadiene	+5.2%	-8.0%	-1.9%	+2.2%	-1.0%	-17.8%	-5.2%
Formaldehyde	-7.4%	+0.3%	-6.2%	-8.8%	-8.6%	+0.6%	-6.1%
Acetaldehyde	+5.4%	+8.0%	+77.0%	+111.6%	+160.0%	+112.6%	+134.4%
Total Toxics	+0.6%	+0.3%	+0.8%	+3.5%	+2.8%	+2.2%	+1.0%
Total $Toxics_{PW}$ (2)	+3.5%	-4.2%	-3.0%	-0.4%	-4.6%	-12.3%	-6.9%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.21: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County Off-Road Gasoline Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.45	+0.78	-0.18	-0.57	-0.22	+0.20	+0.19
NO_x	-0.06	-0.18	-0.08	-0.09	-0.17	-0.26	-0.15
CO	+96.7	+86.8	-24.3	-65.9	-117.3	-73.8	-92.1
CO_{RW} (1)	+1.18	+1.06	-0.30	-0.80	-1.43	-0.90	-1.12
VOC + CO_{RW}	+1.63	+1.84	-0.48	-1.38	-1.65	-0.70	-0.93
Benzene	+0.034	+0.059	-0.084	-0.082	-0.203	-0.075	-0.196
1,3-Butadiene	+0.015	-0.046	-0.007	+0.013	+0.008	-0.075	-0.010
Formaldehyde	-0.037	-0.010	-0.032	-0.047	-0.034	-0.006	-0.021
Acetaldehyde	+0.014	+0.019	+0.165	+0.231	+0.330	+0.236	+0.279
Total Toxics	+0.026	+0.022	+0.042	+0.114	+0.101	+0.080	+0.052
Total $Toxics_{PW}$ (2)	+0.020	-0.036	-0.019	+0.001	-0.023	-0.084	-0.039
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.45	+0.78	+1.42	+1.91	+4.47	+2.86	+3.84
NO_x	-0.06	-0.18	-0.08	-0.09	-0.16	-0.25	-0.14
CO	+96.7	+86.8	-27.7	-70.6	-123.5	-78.1	-97.5
CO_{RW} (1)	+1.18	+1.06	-0.34	-0.86	-1.51	-0.95	-1.19
VOC + CO_{RW}	+1.63	+1.84	+1.08	+1.05	+2.96	+1.90	+2.65
Benzene	+0.034	+0.059	-0.077	-0.070	-0.183	-0.061	-0.181
1,3-Butadiene	+0.015	-0.046	-0.007	+0.013	+0.008	-0.075	-0.010
Formaldehyde	-0.037	-0.010	-0.032	-0.047	-0.034	-0.006	-0.021
Acetaldehyde	+0.014	+0.019	+0.166	+0.233	+0.334	+0.238	+0.282
Total Toxics	+0.026	+0.022	+0.050	+0.128	+0.125	+0.096	+0.070
Total $Toxics_{PW}$ (2)	+0.020	-0.036	-0.018	+0.003	-0.019	-0.082	-0.037

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.22: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County Off-Road Gasoline Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.26	+0.57	-0.10	-0.33	-0.01	+0.23	+0.23
NO_x	-0.07	-0.23	-0.10	-0.12	-0.21	-0.32	-0.19
CO	+113.3	+101.7	-28.4	-77.2	-137.5	-86.5	-107.9
CO_{RW} (1)	+1.38	+1.24	-0.35	-0.94	-1.68	-1.05	-1.32
VOC + CO_{RW}	+1.64	+1.81	-0.45	-1.27	-1.69	-0.82	-1.09
Benzene	+0.014	+0.036	-0.049	-0.045	-0.119	-0.036	-0.116
1,3-Butadiene	+0.009	-0.026	-0.004	+0.007	+0.005	-0.043	-0.006
Formaldehyde	-0.021	-0.006	-0.018	-0.027	-0.019	-0.004	-0.012
Acetaldehyde	+0.008	+0.011	+0.095	+0.133	+0.190	+0.136	+0.160
Total Toxics	+0.009	+0.014	+0.023	+0.068	+0.056	+0.053	+0.027
Total $Toxics_{PW}$ (2)	+0.011	-0.020	-0.011	+0.001	-0.013	-0.047	-0.023
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.26	+0.57	+1.06	+1.48	+3.42	+2.17	+2.89
NO_x	-0.07	-0.23	-0.09	-0.11	-0.20	-0.31	-0.18
CO	+113.3	+101.7	-32.5	-82.8	-144.7	-91.5	-114.2
CO_{RW} (1)	+1.38	+1.24	-0.40	-1.01	-1.76	-1.12	-1.39
VOC + CO_{RW}	+1.64	+1.81	+0.67	+0.47	+1.66	+1.06	+1.50
Benzene	+0.014	+0.036	-0.044	-0.036	-0.103	-0.025	-0.104
1,3-Butadiene	+0.009	-0.026	-0.004	+0.007	+0.005	-0.043	-0.006
Formaldehyde	-0.021	-0.006	-0.018	-0.027	-0.019	-0.004	-0.012
Acetaldehyde	+0.008	+0.011	+0.095	+0.134	+0.192	+0.137	+0.162
Total Toxics	+0.009	+0.014	+0.029	+0.079	+0.074	+0.065	+0.040
Total $Toxics_{PW}$ (2)	+0.011	-0.020	-0.010	+0.002	-0.011	-0.045	-0.021

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.23: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County Off-Road Gasoline Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.8%	+1.4%	-0.3%	-1.0%	-0.4%	+0.4%	+0.3%
NO_x	-1.1%	-3.5%	-1.5%	-1.9%	-3.3%	-5.0%	-2.9%
CO	+11.9%	+10.7%	-3.0%	-8.1%	-14.4%	-9.1%	-11.3%
CO_{RW} (1)	+11.9%	+10.7%	-3.0%	-8.1%	-14.4%	-9.1%	-11.3%
VOC + CO_{RW}	+2.5%	+2.8%	-0.7%	-2.1%	-2.5%	-1.1%	-1.4%
Benzene	+2.4%	+4.2%	-6.0%	-5.9%	-14.5%	-5.4%	-13.9%
1,3-Butadiene	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde	+8.4%	+11.0%	+97.5%	+136.8%	+195.5%	+139.9%	+165.3%
Total Toxics	+1.1%	+0.9%	+1.7%	+4.7%	+4.1%	+3.3%	+2.1%
Total $Toxics_{PW}$ (2)	+3.2%	-5.6%	-3.1%	+0.1%	-3.6%	-13.3%	-6.2%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.8%	+1.4%	+2.5%	+3.4%	+8.0%	+5.1%	+6.9%
NO_x	-1.1%	-3.5%	-1.5%	-1.8%	-3.1%	-4.9%	-2.8%
CO	+11.9%	+10.7%	-3.4%	-8.7%	-15.2%	-9.6%	-12.0%
CO_{RW} (1)	+11.9%	+10.7%	-3.4%	-8.7%	-15.2%	-9.6%	-12.0%
VOC + CO_{RW}	+2.5%	+2.8%	+1.6%	+1.6%	+4.5%	+2.9%	+4.0%
Benzene	+2.4%	+4.2%	-5.5%	-5.0%	-13.0%	-4.3%	-12.9%
1,3-Butadiene	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde	+8.4%	+11.0%	+98.2%	+138.0%	+198.0%	+141.1%	+167.1%
Total Toxics	+1.1%	+0.9%	+2.1%	+5.3%	+5.2%	+4.0%	+2.9%
Total $Toxics_{PW}$ (2)	+3.2%	-5.6%	-2.9%	+0.4%	-3.0%	-12.9%	-5.8%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.24: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County Off-Road Gasoline Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.7%	+1.6%	-0.3%	-0.9%	-0.0%	+0.6%	+0.6%
NO_x	-1.1%	-3.5%	-1.5%	-1.9%	-3.3%	-5.0%	-2.9%
CO	+11.9%	+10.7%	-3.0%	-8.1%	-14.4%	-9.1%	-11.3%
CO_{RW} (1)	+11.9%	+10.7%	-3.0%	-8.1%	-14.4%	-9.1%	-11.3%
VOC + CO_{RW}	+3.4%	+3.8%	-0.9%	-2.6%	-3.5%	-1.7%	-2.3%
Benzene	+1.6%	+4.2%	-5.9%	-5.3%	-14.1%	-4.3%	-13.7%
1,3-Butadiene	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde	+8.4%	+11.0%	+97.5%	+136.8%	+195.5%	+139.9%	+165.3%
Total Toxics	+0.7%	+1.0%	+1.6%	+4.8%	+3.9%	+3.7%	+1.9%
Total $Toxics_{PW}$ (2)	+2.9%	-5.5%	-3.1%	+0.2%	-3.6%	-12.7%	-6.3%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.7%	+1.6%	+2.9%	+4.1%	+9.4%	+5.9%	+7.9%
NO_x	-1.1%	-3.5%	-1.5%	-1.8%	-3.1%	-4.9%	-2.8%
CO	+11.9%	+10.7%	-3.4%	-8.7%	-15.2%	-9.6%	-12.0%
CO_{RW} (1)	+11.9%	+10.7%	-3.4%	-8.7%	-15.2%	-9.6%	-12.0%
VOC + CO_{RW}	+3.4%	+3.8%	+1.4%	+1.0%	+3.4%	+2.2%	+3.1%
Benzene	+1.6%	+4.2%	-5.2%	-4.2%	-12.3%	-3.0%	-12.4%
1,3-Butadiene	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde	+8.4%	+11.0%	+98.2%	+138.0%	+198.0%	+141.1%	+167.1%
Total Toxics	+0.7%	+1.0%	+2.0%	+5.5%	+5.1%	+4.6%	+2.8%
Total $Toxics_{PW}$ (2)	+2.9%	-5.5%	-2.8%	+0.6%	-2.9%	-12.2%	-5.7%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.25: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County On-Road Gasoline Exhaust Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.16	-0.66	-0.37	-0.59	-0.83	-1.01	-0.47
NO_x	-0.96	-3.04	-1.49	-0.19	-0.38	-3.67	-1.84
CO	+68.0	+55.9	-18.3	-46.3	-85.1	-58.1	-67.6
CO_{RW} (1)	+0.83	+0.68	-0.22	-0.56	-1.04	-0.71	-0.82
VOC + CO_{RW}	+0.99	+0.03	-0.59	-1.16	-1.87	-1.72	-1.29
Benzene	+0.072	+0.030	-0.119	-0.144	-0.269	-0.183	-0.246
1,3-Butadiene	+0.031	-0.049	-0.011	+0.013	-0.005	-0.107	-0.030
Formaldehyde	-0.058	+0.001	-0.049	-0.069	-0.066	+0.004	-0.047
Acetaldehyde	+0.015	+0.022	+0.209	+0.302	+0.431	+0.305	+0.363
Total Toxics	+0.059	+0.004	+0.030	+0.103	+0.091	+0.020	+0.040
Total $Toxics_{PW}$ (2)	+0.041	-0.044	-0.030	-0.009	-0.046	-0.133	-0.068
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.16	-0.66	-0.01	-0.05	+0.07	-0.47	+0.26
NO_x	-0.96	-3.04	-1.42	-0.08	-0.20	-3.56	-1.70
CO	+68.0	+55.9	-22.8	-52.6	-93.6	-63.9	-74.8
CO_{RW} (1)	+0.83	+0.68	-0.28	-0.64	-1.14	-0.78	-0.91
VOC + CO_{RW}	+0.99	+0.03	-0.29	-0.69	-1.08	-1.25	-0.66
Benzene	+0.072	+0.030	-0.119	-0.144	-0.269	-0.183	-0.246
1,3-Butadiene	+0.031	-0.049	-0.011	+0.013	-0.005	-0.107	-0.030
Formaldehyde	-0.058	+0.001	-0.049	-0.069	-0.066	+0.004	-0.047
Acetaldehyde	+0.015	+0.022	+0.211	+0.305	+0.437	+0.308	+0.367
Total Toxics	+0.059	+0.004	+0.031	+0.105	+0.097	+0.023	+0.044
Total $Toxics_{PW}$ (2)	+0.041	-0.044	-0.030	-0.009	-0.046	-0.133	-0.068

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.26: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County On-Road Gasoline Exhaust Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.11	-0.61	-0.33	-0.50	-0.71	-0.89	-0.41
NO_x	-1.06	-3.23	-1.62	-0.05	-0.17	-3.82	-1.92
CO	+54.4	+43.6	-14.7	-37.0	-68.4	-47.6	-54.4
CO_{RW} (1)	+0.66	+0.53	-0.18	-0.45	-0.83	-0.58	-0.66
VOC + CO_{RW}	+0.78	-0.07	-0.51	-0.95	-1.54	-1.47	-1.07
Benzene	+0.060	+0.022	-0.104	-0.125	-0.232	-0.159	-0.212
1,3-Butadiene	+0.027	-0.042	-0.010	+0.011	-0.005	-0.093	-0.027
Formaldehyde	-0.051	+0.002	-0.043	-0.060	-0.059	+0.004	-0.042
Acetaldehyde	+0.013	+0.019	+0.180	+0.261	+0.372	+0.263	+0.313
Total Toxics	+0.049	+0.001	+0.024	+0.088	+0.076	+0.016	+0.032
Total $Toxics_{PW}$ (2)	+0.036	-0.038	-0.026	-0.008	-0.041	-0.115	-0.059
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.11	-0.61	-0.02	-0.03	+0.08	-0.43	+0.22
NO_x	-1.06	-3.23	-1.55	+0.06	+0.03	-3.70	-1.77
CO	+54.4	+43.6	-18.8	-42.6	-76.1	-52.8	-60.9
CO_{RW} (1)	+0.66	+0.53	-0.23	-0.52	-0.93	-0.64	-0.74
VOC + CO_{RW}	+0.78	-0.07	-0.24	-0.55	-0.85	-1.07	-0.52
Benzene	+0.060	+0.022	-0.104	-0.125	-0.232	-0.159	-0.212
1,3-Butadiene	+0.027	-0.042	-0.010	+0.011	-0.005	-0.093	-0.027
Formaldehyde	-0.051	+0.002	-0.043	-0.060	-0.059	+0.004	-0.042
Acetaldehyde	+0.013	+0.019	+0.182	+0.263	+0.378	+0.266	+0.317
Total Toxics	+0.049	+0.001	+0.025	+0.090	+0.081	+0.018	+0.036
Total $Toxics_{PW}$ (2)	+0.036	-0.038	-0.026	-0.008	-0.041	-0.115	-0.059

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.27: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County On-Road Gasoline Exhaust Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.3%	-1.4%	-0.8%	-1.2%	-1.7%	-2.1%	-1.0%
NO_x	-0.7%	-2.3%	-1.1%	-0.1%	-0.3%	-2.8%	-1.4%
CO	+6.5%	+5.4%	-1.8%	-4.4%	-8.2%	-5.6%	-6.5%
CO_{RW} (1)	+6.5%	+5.4%	-1.8%	-4.4%	-8.2%	-5.6%	-6.5%
VOC + CO_{RW}	+1.6%	+0.0%	-1.0%	-1.9%	-3.1%	-2.8%	-2.1%
Benzene	+3.8%	+1.6%	-6.3%	-7.6%	-14.1%	-9.6%	-12.9%
1,3-Butadiene	+5.1%	-8.2%	-1.9%	+2.2%	-0.9%	-17.9%	-5.0%
Formaldehyde	-7.4%	+0.2%	-6.3%	-8.8%	-8.5%	+0.6%	-6.0%
Acetaldehyde	+5.6%	+8.1%	+77.4%	+111.8%	+159.6%	+112.8%	+134.3%
Total Toxics	+1.7%	+0.1%	+0.8%	+2.9%	+2.6%	+0.6%	+1.1%
Total $Toxics_{PW}$ (2)	+4.3%	-4.6%	-3.1%	-0.9%	-4.9%	-14.0%	-7.1%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.3%	-1.4%	-0.0%	-0.1%	+0.1%	-1.0%	+0.5%
NO_x	-0.7%	-2.3%	-1.1%	-0.1%	-0.2%	-2.7%	-1.3%
CO	+6.5%	+5.4%	-2.2%	-5.0%	-9.0%	-6.1%	-7.2%
CO_{RW} (1)	+6.5%	+5.4%	-2.2%	-5.0%	-9.0%	-6.1%	-7.2%
VOC + CO_{RW}	+1.6%	+0.0%	-0.5%	-1.1%	-1.8%	-2.0%	-1.1%
Benzene	+3.8%	+1.6%	-6.3%	-7.6%	-14.1%	-9.6%	-12.9%
1,3-Butadiene	+5.1%	-8.2%	-1.9%	+2.2%	-0.9%	-17.9%	-5.0%
Formaldehyde	-7.4%	+0.2%	-6.3%	-8.8%	-8.5%	+0.6%	-6.0%
Acetaldehyde	+5.6%	+8.1%	+78.0%	+112.9%	+161.8%	+113.9%	+135.9%
Total Toxics	+1.7%	+0.1%	+0.9%	+3.0%	+2.7%	+0.6%	+1.2%
Total $Toxics_{PW}$ (2)	+4.3%	-4.6%	-3.1%	-0.9%	-4.9%	-13.9%	-7.1%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.28: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County On-Road Gasoline Exhaust Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.3%	-1.4%	-0.8%	-1.2%	-1.7%	-2.1%	-1.0%
NO_x	-0.8%	-2.3%	-1.1%	-0.0%	-0.1%	-2.7%	-1.4%
CO	+5.8%	+4.7%	-1.6%	-4.0%	-7.3%	-5.1%	-5.8%
CO_{RW} (1)	+5.8%	+4.7%	-1.6%	-4.0%	-7.3%	-5.1%	-5.8%
VOC + CO_{RW}	+1.5%	-0.1%	-1.0%	-1.8%	-2.9%	-2.8%	-2.0%
Benzene	+3.6%	+1.3%	-6.2%	-7.5%	-13.9%	-9.6%	-12.8%
1,3-Butadiene	+5.2%	-8.0%	-1.9%	+2.2%	-1.0%	-17.8%	-5.2%
Formaldehyde	-7.4%	+0.3%	-6.2%	-8.8%	-8.6%	+0.6%	-6.1%
Acetaldehyde	+5.4%	+8.0%	+76.4%	+110.5%	+157.8%	+111.5%	+132.8%
Total Toxics	+1.6%	+0.0%	+0.8%	+2.8%	+2.5%	+0.5%	+1.0%
Total $Toxics_{PW}$ (2)	+4.3%	-4.5%	-3.1%	-0.9%	-4.9%	-13.9%	-7.2%
Impacts with “worst case” commingling between zero oxy and average property gasoline …							
VOC	+0.3%	-1.4%	-0.0%	-0.1%	+0.2%	-1.0%	+0.5%
NO_x	-0.8%	-2.3%	-1.1%	+0.0%	+0.0%	-2.6%	-1.3%
CO	+5.8%	+4.7%	-2.0%	-4.6%	-8.2%	-5.7%	-6.5%
CO_{RW} (1)	+5.8%	+4.7%	-2.0%	-4.6%	-8.2%	-5.7%	-6.5%
VOC + CO_{RW}	+1.5%	-0.1%	-0.5%	-1.0%	-1.6%	-2.0%	-1.0%
Benzene	+3.6%	+1.3%	-6.2%	-7.5%	-13.9%	-9.6%	-12.8%
1,3-Butadiene	+5.2%	-8.0%	-1.9%	+2.2%	-1.0%	-17.8%	-5.2%
Formaldehyde	-7.4%	+0.3%	-6.2%	-8.8%	-8.6%	+0.6%	-6.1%
Acetaldehyde	+5.4%	+8.0%	+77.0%	+111.6%	+160.0%	+112.6%	+134.4%
Total Toxics	+1.6%	+0.0%	+0.8%	+2.9%	+2.6%	+0.6%	+1.2%
Total $Toxics_{PW}$ (2)	+4.3%	-4.5%	-3.1%	-0.9%	-4.9%	-13.9%	-7.2%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.29: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County On-Road Gasoline Evaporative Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	0.00	+0.89	0.00	0.00	+0.89	+0.89	+0.89
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.00	+0.89	0.00	0.00	+0.89	+0.89	+0.89
Benzene	-0.043	+0.012	-0.010	+0.020	-0.015	+0.055	-0.024
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-0.043	+0.012	-0.010	+0.020	-0.015	+0.055	-0.024
Total $Toxics_{PW}$ (2)	-0.007	+0.002	-0.002	+0.003	-0.003	+0.009	-0.004
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	0.00	+0.89	+1.85	+2.88	+6.44	+3.99	+5.18
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.00	+0.89	+1.85	+2.88	+6.44	+3.99	+5.18
Benzene	-0.043	+0.012	-0.001	+0.036	+0.013	+0.074	-0.003
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-0.043	+0.012	-0.001	+0.036	+0.013	+0.074	-0.003
Total $Toxics_{PW}$ (2)	-0.007	+0.002	-0.000	+0.006	+0.002	+0.013	-0.001

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.30: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County On-Road Gasoline Evaporative Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	0.00	+0.64	0.00	0.00	+0.64	+0.64	+0.64
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.00	+0.64	0.00	0.00	+0.64	+0.64	+0.64
Benzene	-0.031	+0.009	-0.007	+0.014	-0.011	+0.039	-0.017
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-0.031	+0.009	-0.007	+0.014	-0.011	+0.039	-0.017
Total $Toxics_{PW}$ (2)	-0.005	+0.002	-0.001	+0.002	-0.002	+0.007	-0.003
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	0.00	+0.64	+1.33	+2.07	+4.63	+2.87	+3.72
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.00	+0.64	+1.33	+2.07	+4.63	+2.87	+3.72
Benzene	-0.031	+0.009	-0.001	+0.026	+0.009	+0.053	-0.002
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-0.031	+0.009	-0.001	+0.026	+0.009	+0.053	-0.002
Total $Toxics_{PW}$ (2)	-0.005	+0.002	-0.000	+0.004	+0.002	+0.009	-0.000

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.31: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County On-Road Gasoline Evaporative Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	0.0%	+2.7%	0.0%	0.0%	+2.7%	+2.7%	+2.7%
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.0%	+2.7%	0.0%	0.0%	+2.7%	+2.7%	+2.7%
Benzene	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
Total $Toxics_{PW}$ (2)	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	0.0%	+2.7%	+5.5%	+8.6%	+19.2%	+11.9%	+15.5%
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.0%	+2.7%	+5.5%	+8.6%	+19.2%	+11.9%	+15.5%
Benzene	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%
Total $Toxics_{PW}$ (2)	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.32: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County On-Road Gasoline Evaporative Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	0.0%	+2.7%	0.0%	0.0%	+2.7%	+2.7%	+2.7%
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.0%	+2.7%	0.0%	0.0%	+2.7%	+2.7%	+2.7%
Benzene	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
Total $Toxics_{PW}$ (2)	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	0.0%	+2.7%	+5.5%	+8.6%	+19.2%	+11.9%	+15.5%
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.0%	+2.7%	+5.5%	+8.6%	+19.2%	+11.9%	+15.5%
Benzene	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%
Total $Toxics_{PW}$ (2)	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.33: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County Off-Road Gasoline Exhaust Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.45	+0.13	-0.18	-0.57	-0.88	-0.46	-0.47
NO_x	-0.06	-0.18	-0.08	-0.09	-0.17	-0.26	-0.15
CO	+96.7	+86.8	-24.3	-65.9	-117.3	-73.8	-92.1
CO_{RW} (1)	+1.18	+1.06	-0.30	-0.80	-1.43	-0.90	-1.12
VOC + CO_{RW}	+1.63	+1.18	-0.48	-1.38	-2.31	-1.36	-1.59
Benzene	+0.065	+0.050	-0.076	-0.097	-0.192	-0.116	-0.178
1,3-Butadiene	+0.015	-0.046	-0.007	+0.013	+0.008	-0.075	-0.010
Formaldehyde	-0.037	-0.010	-0.032	-0.047	-0.034	-0.006	-0.021
Acetaldehyde	+0.014	+0.019	+0.165	+0.231	+0.330	+0.236	+0.279
Total Toxics	+0.058	+0.013	+0.050	+0.100	+0.112	+0.039	+0.069
Total $Toxics_{PW}$ (2)	+0.025	-0.037	-0.018	-0.002	-0.021	-0.091	-0.036
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.45	+0.13	+0.05	-0.23	-0.31	-0.11	-0.01
NO_x	-0.06	-0.18	-0.08	-0.09	-0.16	-0.25	-0.14
CO	+96.7	+86.8	-27.7	-70.6	-123.5	-78.1	-97.5
CO_{RW} (1)	+1.18	+1.06	-0.34	-0.86	-1.51	-0.95	-1.19
VOC + CO_{RW}	+1.63	+1.18	-0.29	-1.09	-1.82	-1.06	-1.20
Benzene	+0.065	+0.050	-0.076	-0.097	-0.192	-0.116	-0.178
1,3-Butadiene	+0.015	-0.046	-0.007	+0.013	+0.008	-0.075	-0.010
Formaldehyde	-0.037	-0.010	-0.032	-0.047	-0.034	-0.006	-0.021
Acetaldehyde	+0.014	+0.019	+0.166	+0.233	+0.334	+0.238	+0.282
Total Toxics	+0.058	+0.013	+0.051	+0.102	+0.116	+0.041	+0.072
Total $Toxics_{PW}$ (2)	+0.025	-0.037	-0.018	-0.002	-0.021	-0.091	-0.036

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.34: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County Off-Road Gasoline Exhaust Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+0.26	+0.07	-0.10	-0.33	-0.51	-0.26	-0.27
NO_x	-0.07	-0.23	-0.10	-0.12	-0.21	-0.32	-0.19
CO	+113.3	+101.7	-28.4	-77.2	-137.5	-86.5	-107.9
CO_{RW} (1)	+1.38	+1.24	-0.35	-0.94	-1.68	-1.05	-1.32
VOC + CO_{RW}	+1.64	+1.31	-0.45	-1.27	-2.18	-1.32	-1.59
Benzene	+0.038	+0.029	-0.044	-0.056	-0.111	-0.067	-0.102
1,3-Butadiene	+0.009	-0.026	-0.004	+0.007	+0.005	-0.043	-0.006
Formaldehyde	-0.021	-0.006	-0.018	-0.027	-0.019	-0.004	-0.012
Acetaldehyde	+0.008	+0.011	+0.095	+0.133	+0.190	+0.136	+0.160
Total Toxics	+0.033	+0.007	+0.029	+0.057	+0.064	+0.022	+0.040
Total $Toxics_{PW}$ (2)	+0.015	-0.021	-0.010	-0.001	-0.012	-0.052	-0.021
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+0.26	+0.07	+0.03	-0.13	-0.18	-0.06	-0.01
NO_x	-0.07	-0.23	-0.09	-0.11	-0.20	-0.31	-0.18
CO	+113.3	+101.7	-32.5	-82.8	-144.7	-91.5	-114.2
CO_{RW} (1)	+1.38	+1.24	-0.40	-1.01	-1.76	-1.12	-1.39
VOC + CO_{RW}	+1.64	+1.31	-0.37	-1.14	-1.95	-1.18	-1.40
Benzene	+0.038	+0.029	-0.044	-0.056	-0.111	-0.067	-0.102
1,3-Butadiene	+0.009	-0.026	-0.004	+0.007	+0.005	-0.043	-0.006
Formaldehyde	-0.021	-0.006	-0.018	-0.027	-0.019	-0.004	-0.012
Acetaldehyde	+0.008	+0.011	+0.095	+0.134	+0.192	+0.137	+0.162
Total Toxics	+0.033	+0.007	+0.029	+0.058	+0.067	+0.024	+0.042
Total $Toxics_{PW}$ (2)	+0.015	-0.021	-0.010	-0.001	-0.012	-0.052	-0.021

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.35: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County Off-Road Gasoline Exhaust Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+1.5%	+0.4%	-0.6%	-1.8%	-2.8%	-1.5%	-1.5%
NO_x	-1.1%	-3.5%	-1.5%	-1.9%	-3.3%	-5.0%	-2.9%
CO	+11.9%	+10.7%	-3.0%	-8.1%	-14.4%	-9.1%	-11.3%
CO_{RW} (1)	+11.9%	+10.7%	-3.0%	-8.1%	-14.4%	-9.1%	-11.3%
VOC + CO_{RW}	+4.0%	+2.9%	-1.2%	-3.4%	-5.7%	-3.3%	-3.9%
Benzene	+5.4%	+4.2%	-6.3%	-8.0%	-15.9%	-9.6%	-14.8%
1,3-Butadiene	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde	+8.4%	+11.0%	+97.5%	+136.8%	+195.5%	+139.9%	+165.3%
Total Toxics	+2.6%	+0.6%	+2.2%	+4.5%	+5.0%	+1.7%	+3.1%
Total $Toxics_{PW}$ (2)	+4.2%	-6.2%	-3.0%	-0.3%	-3.5%	-15.2%	-6.1%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+1.5%	+0.4%	+0.2%	-0.7%	-1.0%	-0.4%	-0.0%
NO_x	-1.1%	-3.5%	-1.5%	-1.8%	-3.1%	-4.9%	-2.8%
CO	+11.9%	+10.7%	-3.4%	-8.7%	-15.2%	-9.6%	-12.0%
CO_{RW} (1)	+11.9%	+10.7%	-3.4%	-8.7%	-15.2%	-9.6%	-12.0%
VOC + CO_{RW}	+4.0%	+2.9%	-0.7%	-2.7%	-4.4%	-2.6%	-2.9%
Benzene	+5.4%	+4.2%	-6.3%	-8.0%	-15.9%	-9.6%	-14.8%
1,3-Butadiene	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde	+8.4%	+11.0%	+98.2%	+138.0%	+198.0%	+141.1%	+167.1%
Total Toxics	+2.6%	+0.6%	+2.3%	+4.6%	+5.2%	+1.8%	+3.2%
Total $Toxics_{PW}$ (2)	+4.2%	-6.2%	-3.0%	-0.3%	-3.4%	-15.2%	-6.1%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.36: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County Off-Road Gasoline Exhaust Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	+1.5%	+0.4%	-0.6%	-1.8%	-2.8%	-1.5%	-1.5%
NO_x	-1.1%	-3.5%	-1.5%	-1.9%	-3.3%	-5.0%	-2.9%
CO	+11.9%	+10.7%	-3.0%	-8.1%	-14.4%	-9.1%	-11.3%
CO_{RW} (1)	+11.9%	+10.7%	-3.0%	-8.1%	-14.4%	-9.1%	-11.3%
VOC + CO_{RW}	+5.6%	+4.5%	-1.5%	-4.3%	-7.4%	-4.5%	-5.4%
Benzene	+5.4%	+4.2%	-6.3%	-8.0%	-15.9%	-9.6%	-14.8%
1,3-Butadiene	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde	+8.4%	+11.0%	+97.5%	+136.8%	+195.5%	+139.9%	+165.3%
Total Toxics	+2.6%	+0.6%	+2.2%	+4.5%	+5.0%	+1.7%	+3.1%
Total $Toxics_{PW}$ (2)	+4.2%	-6.2%	-3.0%	-0.3%	-3.5%	-15.2%	-6.1%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	+1.5%	+0.4%	+0.2%	-0.7%	-1.0%	-0.4%	-0.0%
NO_x	-1.1%	-3.5%	-1.5%	-1.8%	-3.1%	-4.9%	-2.8%
CO	+11.9%	+10.7%	-3.4%	-8.7%	-15.2%	-9.6%	-12.0%
CO_{RW} (1)	+11.9%	+10.7%	-3.4%	-8.7%	-15.2%	-9.6%	-12.0%
VOC + CO_{RW}	+5.6%	+4.5%	-1.2%	-3.9%	-6.6%	-4.0%	-4.7%
Benzene	+5.4%	+4.2%	-6.3%	-8.0%	-15.9%	-9.6%	-14.8%
1,3-Butadiene	+4.1%	-12.2%	-1.8%	+3.4%	+2.1%	-20.0%	-2.6%
Formaldehyde	-7.6%	-2.1%	-6.6%	-9.7%	-7.0%	-1.3%	-4.5%
Acetaldehyde	+8.4%	+11.0%	+98.2%	+138.0%	+198.0%	+141.1%	+167.1%
Total Toxics	+2.6%	+0.6%	+2.3%	+4.6%	+5.2%	+1.8%	+3.2%
Total $Toxics_{PW}$ (2)	+4.2%	-6.2%	-3.0%	-0.3%	-3.4%	-15.2%	-6.1%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.37: Emission Impacts of Alternative Gasoline Formulations in 2004
(Change in Maricopa County Off-Road Gasoline Evaporative Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	0.00	+0.66	0.00	0.00	+0.66	+0.66	+0.66
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.00	+0.66	0.00	0.00	+0.66	+0.66	+0.66
Benzene	-0.032	+0.009	-0.008	+0.015	-0.011	+0.041	-0.018
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-0.032	+0.009	-0.008	+0.015	-0.011	+0.041	-0.018
Total $Toxics_{PW}$ (2)	-0.005	+0.002	-0.001	+0.002	-0.002	+0.007	-0.003
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	0.00	+0.66	+1.37	+2.14	+4.78	+2.97	+3.85
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.00	+0.66	+1.37	+2.14	+4.78	+2.97	+3.85
Benzene	-0.032	+0.009	-0.001	+0.027	+0.009	+0.055	-0.002
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-0.032	+0.009	-0.001	+0.027	+0.009	+0.055	-0.002
Total $Toxics_{PW}$ (2)	-0.005	+0.002	-0.000	+0.005	+0.002	+0.009	-0.000

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.38: Emission Impacts of Alternative Gasoline Formulations in 2010
(Change in Maricopa County Off-Road Gasoline Evaporative Inventory, Mtpd)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	0.00	+0.50	0.00	0.00	+0.50	+0.50	+0.50
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.00	+0.50	0.00	0.00	+0.50	+0.50	+0.50
Benzene	-0.024	+0.007	-0.006	+0.011	-0.008	+0.031	-0.013
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-0.024	+0.007	-0.006	+0.011	-0.008	+0.031	-0.013
Total $Toxics_{PW}$ (2)	-0.004	+0.001	-0.001	+0.002	-0.001	+0.005	-0.002
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	0.00	+0.50	+1.03	+1.61	+3.60	+2.24	+2.90
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.00	+0.50	+1.03	+1.61	+3.60	+2.24	+2.90
Benzene	-0.024	+0.007	-0.000	+0.020	+0.007	+0.042	-0.002
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-0.024	+0.007	-0.000	+0.020	+0.007	+0.042	-0.002
Total $Toxics_{PW}$ (2)	-0.004	+0.001	-0.000	+0.003	+0.001	+0.007	-0.000

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.39: Emission Impacts of Alternative Gasoline Formulations in 2004
(Percent Change in Maricopa County Off-Road Gasoline Evaporative Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	0.0%	+2.7%	0.0%	0.0%	+2.7%	+2.7%	+2.7%
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.0%	+2.7%	0.0%	0.0%	+2.7%	+2.7%	+2.7%
Benzene	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
Total $Toxics_{PW}$ (2)	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	0.0%	+2.7%	+5.5%	+8.6%	+19.2%	+11.9%	+15.5%
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.0%	+2.7%	+5.5%	+8.6%	+19.2%	+11.9%	+15.5%
Benzene	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%
Total $Toxics_{PW}$ (2)	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

Exhibit B.40: Emission Impacts of Alternative Gasoline Formulations in 2010
(Percent Change in Maricopa County Off-Road Gasoline Evaporative Inventory)

Emission Species	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …							
VOC	0.0%	+2.7%	0.0%	0.0%	+2.7%	+2.7%	+2.7%
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.0%	+2.7%	0.0%	0.0%	+2.7%	+2.7%	+2.7%
Benzene	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
Total $Toxics_{PW}$ (2)	-16.1%	+4.7%	-3.8%	+7.4%	-5.5%	+20.6%	-9.0%
Impacts with "worst case" commingling between zero oxy and average property gasoline …							
VOC	0.0%	+2.7%	+5.5%	+8.6%	+19.2%	+11.9%	+15.5%
NO_x	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO	n/a	n/a	n/a	n/a	n/a	n/a	n/a
CO_{RW} (1)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
VOC + CO_{RW}	0.0%	+2.7%	+5.5%	+8.6%	+19.2%	+11.9%	+15.5%
Benzene	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%
1,3-Butadiene	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Formaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Acetaldehyde	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total Toxics	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%
Total $Toxics_{PW}$ (2)	-16.1%	+4.7%	-0.3%	+13.5%	+4.8%	+28.0%	-1.3%

(1) Ozone reactivity weighted CO. Based on a reactivity adjustment factor of 1/82, as reported for Maricopa County by ADEQ.

(2) Potency weighted toxic mass. Based on weighting factors derived from the CARB Predictive Model as follows: 0.17 for benzene, 1.0 for 1,3-butadiene, 0.035 for formaldehyde, and 0.016 for acetaldehyde.

APPENDIX C

TECHNOLOGY-SPECIFIC GASOLINE OPTION IMPACTS

TECHNOLOGY-SPECIFIC GASOLINE OPTION IMPACTS

As described in Chapter 5, alternative gasoline formulation analysis must be conducted at a vehicle and catalyst technology level-of-detail. This approach to estimating both on- and off-road vehicle and engine impacts is required because advanced technology vehicles can be expected to respond differently to fuel quality changes than their less advanced counterparts. **Exhibits C.1** through **C.5** present the technology-specific impacts estimated for each of the alternative gasoline formulations (as well as the estimated impact between the gasoline quality assumed for Maricopa County baseline emissions inventory modeling and actual gasoline qualities expected in the years evaluated for this analysis; see Section 5.4 for a detailed discussion of this adjustment). The non-catalyst technology impacts (**Exhibit C.5**) are used without further adjustment to estimate all gasoline formulation impacts in the gasoline-powered off-road vehicle and engine sector. For on-road vehicles, the impacts presented in **Exhibits C.1** through **C.5** are aggregated in accordance with the market penetrations of each of the individual technologies in the applicable evaluation year.

Exhibit C.6 presents the technology weighting factors derived for each of the gasoline evaluation years. These technology fractions reflect both: (1) the market penetration of three-way catalyst vehicles (Tech 3, Tech 4, and Tech 5), oxidation catalyst vehicles, and non-catalyst vehicles in the gasoline-powered passenger car, truck, and motorcycle fleets and (2) the VMT-weighted emissions performance of those vehicles. In short, the tabulated values represent the fraction of total on-road gasoline vehicle *emissions* accumulated by vehicles of the various technologies. These technology fractions are applied to the individual technology impacts presented in **Exhibits C.1** through **C.5** to derive aggregate evaluation year impacts. **Exhibits C.7** and **C.8** present the resulting aggregate impacts.

As indicated in Chapter 5, the exhibits presented in this appendix also include a qualitative assessment of PAH impacts. This assessment is reflected in the *potential* PAH reduction relationships listed in each of the exhibits. It must, however, be recognized that the tabulated impact values are based solely on the relationship between fuel aromatic contents and do *not* reflect any additional emissions impact factors. As such, these values are only indicative of *possible* PAH impacts.

Exhibit C.1: Tech 5 Three-Way Catalyst Emission Impacts (percent change)

Baseline Gasoline	Current Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline
Alternative Gasoline	Expected Baseline Gasoline	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …								
Exhaust VOC	-2.57%	+0.18%	-1.57%	-0.80%	-1.14%	-1.60%	-2.18%	-0.94%
Evaporative VOC	0.00%	0.00%	+2.65%	0.00%	0.00%	+2.65%	+2.65%	+2.65%
NO_x	-12.70%	-0.75%	-2.22%	-1.15%	+0.11%	+0.12%	-2.56%	-1.28%
CO	-1.46%	+4.89%	+3.74%	-1.35%	-3.32%	-6.23%	-4.47%	-4.96%
Exhaust Benzene	-4.07%	+3.41%	+1.05%	-6.23%	-7.43%	-13.76%	-9.56%	-12.59%
Evap Benzene	+2.26%	-16.11%	+4.69%	-3.81%	+7.37%	-5.55%	+20.62%	-8.96%
Acetaldehyde	+1.13%	+5.21%	+7.75%	+74.9%	+108.6%	+155.1%	+109.5%	+130.4%
Formaldehyde	-0.50%	-7.38%	+0.44%	-6.22%	-8.68%	-8.68%	+0.78%	-6.22%
1,3-Butadiene	+6.83%	+5.32%	-7.73%	-1.89%	+2.08%	-1.28%	-17.70%	-5.38%
PAH (1)	-11.73%	-5.20%	-21.97%	-7.51%	-7.51%	-7.51%	-20.81%	-7.51%
Impacts with "worst case" commingling between zero oxy and average property gasoline …								
Exhaust VOC	-2.57%	+0.18%	-1.57%	-0.06%	-0.03%	+0.26%	-1.07%	+0.55%
Evaporative VOC	0.00%	0.00%	+2.65%	+5.52%	+8.62%	+19.23%	+11.93%	+15.47%
NO_x	-12.70%	-0.75%	-2.22%	-1.09%	+0.19%	+0.26%	-2.48%	-1.17%
CO	-1.46%	+4.89%	+3.74%	-1.78%	-3.93%	-7.06%	-5.03%	-5.67%
Exhaust Benzene	-4.07%	+3.41%	+1.05%	-6.23%	-7.43%	-13.76%	-9.56%	-12.59%
Evap Benzene	+2.26%	-16.11%	+4.69%	-0.30%	+13.53%	+4.80%	+28.00%	-1.26%
Acetaldehyde	+1.13%	+5.21%	+7.75%	+75.5%	+109.7%	+157.3%	+110.5%	+132.0%
Formaldehyde	-0.50%	-7.38%	+0.44%	-6.22%	-8.68%	-8.68%	+0.78%	-6.22%
1,3-Butadiene	+6.83%	+5.32%	-7.73%	-1.89%	+2.08%	-1.28%	-17.70%	-5.38%

(1) Impact not quantified, tabulated values are relative differences in the fuel aromatic contents and should be only be used as a qualitative indicator of PAH impact potential. Exhaust VOC emission impacts can be used as a secondary PAH impact estimate since the EPA Complex Model assumes that polycyclic organic material (POM) emissions are a constant fraction of exhaust VOC emissions.

Exhibit C.2: Tech 4 Three-Way Catalyst Emission Impacts (percent change)

Baseline Gasoline	Current Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline
Alternative Gasoline	Expected Baseline Gasoline	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …								
Exhaust VOC	-0.07%	+0.21%	-1.58%	-0.70%	-1.14%	-1.52%	-2.07%	-0.72%
Evaporative VOC	0.00%	0.00%	+2.65%	0.00%	0.00%	+2.65%	+2.65%	+2.65%
NO_x	-3.70%	-0.37%	-1.82%	-0.78%	-0.09%	-0.07%	-2.20%	-0.88%
CO	-0.77%	+8.56%	+7.37%	-2.27%	-5.85%	-10.58%	-6.97%	-8.39%
Exhaust Benzene	-3.92%	+4.11%	+1.93%	-6.28%	-7.74%	-14.30%	-9.66%	-13.01%
Evap Benzene	+2.26%	-16.11%	+4.69%	-3.81%	+7.37%	-5.55%	+20.62%	-8.96%
Acetaldehyde	+1.12%	+5.22%	+7.76%	+74.9%	+108.7%	+155.1%	+109.5%	+130.5%
Formaldehyde	-0.52%	-7.38%	+0.49%	-6.22%	-8.70%	-8.70%	+0.83%	-6.22%
1,3-Butadiene	+6.75%	+5.16%	-7.80%	-1.85%	+2.15%	-1.15%	-17.56%	-5.25%
PAH (1)	-11.73%	-5.20%	-21.97%	-7.51%	-7.51%	-7.51%	-20.81%	-7.51%
Impacts with "worst case" commingling between zero oxy and average property gasoline …								
Exhaust VOC	-0.07%	+0.21%	-1.58%	+0.05%	-0.03%	+0.34%	-0.97%	+0.77%
Evaporative VOC	0.00%	0.00%	+2.65%	+5.52%	+8.62%	+19.23%	+11.93%	+15.47%
NO_x	-3.70%	-0.37%	-1.82%	-0.72%	-0.01%	+0.07%	-2.12%	-0.77%
CO	-0.77%	+8.56%	+7.37%	-2.69%	-6.44%	-11.37%	-7.51%	-9.08%
Exhaust Benzene	-3.92%	+4.11%	+1.93%	-6.28%	-7.74%	-14.30%	-9.66%	-13.01%
Evap Benzene	+2.26%	-16.11%	+4.69%	-0.30%	+13.53%	+4.80%	+28.00%	-1.26%
Acetaldehyde	+1.12%	+5.22%	+7.76%	+75.5%	+109.7%	+157.3%	+110.5%	+132.0%
Formaldehyde	-0.52%	-7.38%	+0.49%	-6.22%	-8.70%	-8.70%	+0.83%	-6.22%
1,3-Butadiene	+6.75%	+5.16%	-7.80%	-1.85%	+2.15%	-1.15%	-17.56%	-5.25%

(1) Impact not quantified, tabulated values are relative differences in the fuel aromatic contents and should be only be used as a qualitative indicator of PAH impact potential. Exhaust VOC emission impacts can be used as a secondary PAH impact estimate since the EPA Complex Model assumes that polycyclic organic material (POM) emissions are a constant fraction of exhaust VOC emissions.

Exhibit C.3: Tech 3 Three-Way Catalyst Emission Impacts (percent change)

Baseline Gasoline	Current Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline
Alternative Gasoline	Expected Baseline Gasoline	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …								
Exhaust VOC	+0.56%	+1.42%	+0.37%	-0.62%	-1.83%	-2.83%	-1.50%	-1.55%
Evaporative VOC	0.00%	0.00%	+2.65%	0.00%	0.00%	+2.65%	+2.65%	+2.65%
NO_x	-3.27%	-1.19%	-3.65%	-1.65%	-1.81%	-3.22%	-5.12%	-3.05%
CO	-0.85%	+8.12%	+6.93%	-2.16%	-5.54%	-10.05%	-6.67%	-7.98%
Exhaust Benzene	-3.17%	+5.35%	+4.10%	-6.35%	-8.00%	-15.91%	-9.65%	-14.80%
Evap Benzene	+2.26%	-16.11%	+4.69%	-3.81%	+7.37%	-5.55%	+20.62%	-8.96%
Acetaldehyde	+1.46%	+8.37%	+10.99%	+97.5%	+136.8%	+195.5%	+139.8%	+165.2%
Formaldehyde	-2.09%	-7.62%	-2.15%	-6.61%	-9.68%	-6.97%	-1.34%	-4.48%
1,3-Butadiene	+7.15%	+4.07%	-12.24%	-1.84%	+3.40%	+2.15%	-19.99%	-2.65%
PAH (1)	-11.73%	-5.20%	-21.97%	-7.51%	-7.51%	-7.51%	-20.81%	-7.51%
Impacts with "worst case" commingling between zero oxy and average property gasoline …								
Exhaust VOC	+0.56%	+1.42%	+0.37%	+0.12%	-0.72%	-0.99%	-0.39%	-0.06%
Evaporative VOC	0.00%	0.00%	+2.65%	+5.52%	+8.62%	+19.23%	+11.93%	+15.47%
NO_x	-3.27%	-1.19%	-3.65%	-1.59%	-1.73%	-3.08%	-5.04%	-2.94%
CO	-0.85%	+8.12%	+6.93%	-2.58%	-6.14%	-10.85%	-7.21%	-8.66%
Exhaust Benzene	-3.17%	+5.35%	+4.10%	-6.35%	-8.00%	-15.91%	-9.65%	-14.80%
Evap Benzene	+2.26%	-16.11%	+4.69%	-0.30%	+13.53%	+4.80%	+28.00%	-1.26%
Acetaldehyde	+1.46%	+8.37%	+10.99%	+98.2%	+138.0%	+198.0%	+141.0%	+167.0%
Formaldehyde	-2.09%	-7.62%	-2.15%	-6.61%	-9.68%	-6.97%	-1.34%	-4.48%
1,3-Butadiene	+7.15%	+4.07%	-12.24%	-1.84%	+3.40%	+2.15%	-19.99%	-2.65%

(1) Impact not quantified, tabulated values are relative differences in the fuel aromatic contents and should be only be used as a qualitative indicator of PAH impact potential. Exhaust VOC emission impacts can be used as a secondary PAH impact estimate since the EPA Complex Model assumes that polycyclic organic material (POM) emissions are a constant fraction of exhaust VOC emissions.

Exhibit C.4: Oxidation Catalyst Emission Impacts (percent change)

Baseline Gasoline	Current Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline
Alternative Gasoline	Expected Baseline Gasoline	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …								
Exhaust VOC	+0.56%	+1.42%	+0.37%	-0.62%	-1.83%	-2.83%	-1.50%	-1.55%
Evaporative VOC	0.00%	0.00%	+2.65%	0.00%	0.00%	+2.65%	+2.65%	+2.65%
NO_x	-0.65%	-1.09%	-3.55%	-1.54%	-1.86%	-3.26%	-5.01%	-2.94%
CO	+0.98%	+17.64%	+16.35%	-4.54%	-12.10%	-21.32%	-13.14%	-16.88%
Exhaust Benzene	-3.17%	+5.35%	+4.10%	-6.35%	-8.00%	-15.91%	-9.65%	-14.80%
Evap Benzene	+2.26%	-16.11%	+4.69%	-3.81%	+7.37%	-5.55%	+20.62%	-8.96%
Acetaldehyde	+1.46%	+8.37%	+10.99%	+97.5%	+136.8%	+195.5%	+139.8%	+165.2%
Formaldehyde	-2.09%	-7.62%	-2.15%	-6.61%	-9.68%	-6.97%	-1.34%	-4.48%
1,3-Butadiene	+7.15%	+4.07%	-12.24%	-1.84%	+3.40%	+2.15%	-19.99%	-2.65%
PAH (1)	-11.73%	-5.20%	-21.97%	-7.51%	-7.51%	-7.51%	-20.81%	-7.51%
Impacts with “worst case” commingling between zero oxy and average property gasoline …								
Exhaust VOC	+0.56%	+1.42%	+0.37%	+0.12%	-0.72%	-0.99%	-0.39%	-0.06%
Evaporative VOC	0.00%	0.00%	+2.65%	+5.52%	+8.62%	+19.23%	+11.93%	+15.47%
NO_x	-0.65%	-1.09%	-3.55%	-1.48%	-1.78%	-3.12%	-4.93%	-2.83%
CO	+0.98%	+17.64%	+16.35%	-4.95%	-12.65%	-22.02%	-13.65%	-17.50%
Exhaust Benzene	-3.17%	+5.35%	+4.10%	-6.35%	-8.00%	-15.91%	-9.65%	-14.80%
Evap Benzene	+2.26%	-16.11%	+4.69%	-0.30%	+13.53%	+4.80%	+28.00%	-1.26%
Acetaldehyde	+1.46%	+8.37%	+10.99%	+98.2%	+138.0%	+198.0%	+141.0%	+167.0%
Formaldehyde	-2.09%	-7.62%	-2.15%	-6.61%	-9.68%	-6.97%	-1.34%	-4.48%
1,3-Butadiene	+7.15%	+4.07%	-12.24%	-1.84%	+3.40%	+2.15%	-19.99%	-2.65%

(1) Impact not quantified, tabulated values are relative differences in the fuel aromatic contents and should be only be used as a qualitative indicator of PAH impact potential. Exhaust VOC emission impacts can be used as a secondary PAH impact estimate since the EPA Complex Model assumes that polycyclic organic material (POM) emissions are a constant fraction of exhaust VOC emissions.

Exhibit C.5: Non-Catalyst Vehicle and Off-Road Emission Impacts (percent change)

Baseline Gasoline	Current Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline
Alternative Gasoline	Expected Baseline Gasoline	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …								
Exhaust VOC	+1.50%	+1.45%	+0.40%	-0.59%	-1.84%	-2.85%	-1.47%	-1.52%
Evaporative VOC	0.00%	0.00%	+2.65%	0.00%	0.00%	+2.65%	+2.65%	+2.65%
NO_x	-0.65%	-1.09%	-3.55%	-1.54%	-1.86%	-3.26%	-5.01%	-2.94%
CO	+2.17%	+11.87%	+10.65%	-2.98%	-8.09%	-14.40%	-9.06%	-11.31%
Exhaust Benzene	-1.86%	+5.40%	+4.15%	-6.31%	-8.03%	-15.93%	-9.60%	-14.75%
Evap Benzene	+2.26%	-16.11%	+4.69%	-3.81%	+7.37%	-5.55%	+20.62%	-8.96%
Acetaldehyde	+1.83%	+8.36%	+11.00%	+97.5%	+136.8%	+195.5%	+139.9%	+165.3%
Formaldehyde	-1.17%	-7.59%	-2.12%	-6.58%	-9.70%	-6.99%	-1.31%	-4.45%
1,3-Butadiene	+8.64%	+4.12%	-12.21%	-1.80%	+3.37%	+2.10%	-19.96%	-2.61%
PAH (1)	-11.73%	-5.20%	-21.97%	-7.51%	-7.51%	-7.51%	-20.81%	-7.51%
Impacts with "worst case" commingling between zero oxy and average property gasoline …								
Exhaust VOC	+1.50%	+1.45%	+0.40%	+0.16%	-0.73%	-1.01%	-0.36%	-0.03%
Evaporative VOC	0.00%	0.00%	+2.65%	+5.52%	+8.62%	+19.23%	+11.93%	+15.47%
NO_x	-0.65%	-1.09%	-3.55%	-1.48%	-1.78%	-3.12%	-4.93%	-2.83%
CO	+2.17%	+11.87%	+10.65%	-3.40%	-8.67%	-15.16%	-9.59%	-11.97%
Exhaust Benzene	-1.86%	+5.40%	+4.15%	-6.31%	-8.03%	-15.93%	-9.60%	-14.75%
Evap Benzene	+2.26%	-16.11%	+4.69%	-0.30%	+13.53%	+4.80%	+28.00%	-1.26%
Acetaldehyde	+1.83%	+8.36%	+11.00%	+98.2%	+138.0%	+198.0%	+141.1%	+167.1%
Formaldehyde	-1.17%	-7.59%	-2.12%	-6.58%	-9.70%	-6.99%	-1.31%	-4.45%
1,3-Butadiene	+8.64%	+4.12%	-12.21%	-1.80%	+3.37%	+2.10%	-19.96%	-2.61%

(1) Impact not quantified, tabulated values are relative differences in the fuel aromatic contents and should be only be used as a qualitative indicator of PAH impact potential. Exhaust VOC emission impacts can be used as a secondary PAH impact estimate since the EPA Complex Model assumes that polycyclic organic material (POM) emissions are a constant fraction of exhaust VOC emissions.

Exhibit C.6: On-Road Gasoline Vehicle VMT and Emission Rate Weighted Technology Fractions

Evaluation Year	No Catalyst	Oxidation Catalyst	Tech 3 3-Way Cat	Tech 4 3-Way Cat	Tech 5 3-Way Cat
2004	0.0247	0.0524	0.0341	0.1852	0.7036
2010	0.0214	0.0400	0.0056	0.0711	0.8619

Consolidates LDGV, LDGT1, LDGT2, HDGV, and MC technologies.

Exhibit C.7: Aggregate 2004 On-Road Vehicle Emission Impacts (percent change)

Baseline Gasoline	Current Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline
Alternative Gasoline	Expected Baseline Gasoline	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …								
Exhaust VOC	-1.74%	+0.33%	-1.35%	-0.76%	-1.22%	-1.72%	-2.08%	-0.97%
Evaporative VOC	0.00%	0.00%	+2.65%	0.00%	0.00%	+2.65%	+2.65%	+2.65%
NO_x	-9.78%	-0.72%	-2.30%	-1.13%	-0.15%	-0.29%	-2.77%	-1.39%
CO	-1.09%	+6.52%	+5.36%	-1.75%	-4.44%	-8.16%	-5.58%	-6.48%
Exhaust Benzene	-3.91%	+3.76%	+1.55%	-6.25%	-7.55%	-14.10%	-9.59%	-12.91%
Evap Benzene	+2.26%	-16.11%	+4.69%	-3.81%	+7.37%	-5.55%	+20.62%	-8.96%
Acetaldehyde	+1.17%	+5.56%	+8.11%	+77.40%	+111.8%	+159.6%	+112.8%	+134.3%
Formaldehyde	-0.66%	-7.41%	+0.16%	-6.26%	-8.80%	-8.50%	+0.56%	-6.02%
1,3-Butadiene	+6.89%	+5.15%	-8.24%	-1.88%	+2.24%	-0.88%	-17.93%	-5.05%
PAH (1)	-11.73%	-5.20%	-21.97%	-7.51%	-7.51%	-7.51%	-20.81%	-7.51%
Impacts with "worst case" commingling between zero oxy and average property gasoline …								
Exhaust VOC	-1.74%	+0.33%	-1.35%	-0.02%	-0.11%	+0.13%	-0.98%	+0.53%
Evaporative VOC	0.00%	0.00%	+2.65%	+5.52%	+8.62%	+19.23%	+11.93%	+15.47%
NO_x	-9.78%	-0.72%	-2.30%	-1.07%	-0.06%	-0.15%	-2.69%	-1.28%
CO	-1.09%	+6.52%	+5.36%	-2.18%	-5.05%	-8.97%	-6.13%	-7.18%
Exhaust Benzene	-3.91%	+3.76%	+1.55%	-6.25%	-7.55%	-14.10%	-9.59%	-12.91%
Evap Benzene	+2.26%	-16.11%	+4.69%	-0.30%	+13.53%	+4.80%	+28.00%	-1.26%
Acetaldehyde	+1.17%	+5.56%	+8.11%	+78.00%	+112.9%	+161.8%	+113.9%	+135.9%
Formaldehyde	-0.66%	-7.41%	+0.16%	-6.26%	-8.80%	-8.50%	+0.56%	-6.02%
1,3-Butadiene	+6.89%	+5.15%	-8.24%	-1.88%	+2.24%	-0.88%	-17.93%	-5.05%

(1) Impact not quantified, tabulated values are relative differences in the fuel aromatic contents and should be only be used as a qualitative indicator of PAH impact potential. Exhaust VOC emission impacts can be used as a secondary PAH impact estimate since the EPA Complex Model assumes that polycyclic organic material (POM) emissions are a constant fraction of exhaust VOC emissions.

Exhibit C.8: Aggregate 2010 On-Road Vehicle Emission Impacts (percent change)

Baseline Gasoline	Current Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline	Expected Baseline Gasoline
Alternative Gasoline	Expected Baseline Gasoline	CBG1 No Oxy Case 1	CBG2 No Oxy Case 2	CBG1 2% Oxy Case 3	CBG1 2.7% Oxy Case 4	CBG1 3.5% Oxy Case 5	CBG2 2.7% Oxy Case 6	CBG1 2.0 & 3.5% Case 7
Impacts for a homogeneous fuel market at average gasoline properties …								
Exhaust VOC	-2.17%	+0.27%	-1.44%	-0.78%	-1.19%	-1.68%	-2.13%	-0.97%
Evaporative VOC	0.00%	0.00%	+2.65%	0.00%	0.00%	+2.65%	+2.65%	+2.65%
NO_x	-11.26%	-0.75%	-2.28%	-1.15%	-0.04%	-0.12%	-2.70%	-1.36%
CO	-1.23%	+5.83%	+4.67%	-1.58%	-3.97%	-7.34%	-5.11%	-5.84%
Exhaust Benzene	-3.97%	+3.59%	+1.32%	-6.24%	-7.49%	-13.95%	-9.57%	-12.77%
Evap Benzene	+2.26%	-16.11%	+4.69%	-3.81%	+7.37%	-5.55%	+20.62%	-8.96%
Acetaldehyde	+1.16%	+5.42%	+7.97%	+76.39%	+110.5%	+157.8%	+111.5%	+132.8%
Formaldehyde	-0.59%	-7.40%	+0.27%	-6.24%	-8.75%	-8.57%	+0.64%	-6.10%
1,3-Butadiene	+6.88%	+5.22%	-8.04%	-1.88%	+2.17%	-1.04%	-17.84%	-5.18%
PAH (1)	-11.73%	-5.20%	-21.97%	-7.51%	-7.51%	-7.51%	-20.81%	-7.51%
Impacts with "worst case" commingling between zero oxy and average property gasoline …								
Exhaust VOC	-2.17%	+0.27%	-1.44%	-0.04%	-0.07%	+0.18%	-1.02%	+0.53%
Evaporative VOC	0.00%	0.00%	+2.65%	+5.52%	+8.62%	+19.23%	+11.93%	+15.47%
NO_x	-11.26%	-0.75%	-2.28%	-1.09%	+0.04%	+0.02%	-2.62%	-1.25%
CO	-1.23%	+5.83%	+4.67%	-2.01%	-4.57%	-8.16%	-5.66%	-6.54%
Exhaust Benzene	-3.97%	+3.59%	+1.32%	-6.24%	-7.49%	-13.95%	-9.57%	-12.77%
Evap Benzene	+2.26%	-16.11%	+4.69%	-0.30%	+13.53%	+4.80%	+28.00%	-1.26%
Acetaldehyde	+1.16%	+5.42%	+7.97%	+76.99%	+111.6%	+160.0%	+112.6%	+134.4%
Formaldehyde	-0.59%	-7.40%	+0.27%	-6.24%	-8.75%	-8.57%	+0.64%	-6.10%
1,3-Butadiene	+6.88%	+5.22%	-8.04%	-1.88%	+2.17%	-1.04%	-17.84%	-5.18%

(1) Impact not quantified, tabulated values are relative differences in the fuel aromatic contents and should be only be used as a qualitative indicator of PAH impact potential. Exhaust VOC emission impacts can be used as a secondary PAH impact estimate since the EPA Complex Model assumes that polycyclic organic material (POM) emissions are a constant fraction of exhaust VOC emissions.