



MathPro Inc.
P.O. Box 34404
West Bethesda, MD
20827-0404

Tel: 301 951 9006
Fax: 301 652 7530
E-mail: mathpro@erols.com

Meszler Engineering Services Tel: 410 569 0599
906 Hamburg Drive Fax: 410 569 0730
Abingdon, MD E-mail: dan@meszler.com
21009

Final Report

Cost, Supply, and Emissions Impacts of Adopting the California Phase 3 Gasoline Standard for Arizona's Cleaner Burning Gasoline Program

A Technical and Economic Analysis of Cleaner Burning Gasoline Supply Under HB 2207

Prepared for

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DISCLAIMER

MathPro Inc. and Meszler Engineering Services prepared this study for the Arizona Department of Environmental Quality. The results, findings, and conclusions expressed in this report are those of MathPro Inc. and Meszler Engineering Services and do not necessarily reflect those of the Arizona Department of Environmental Quality.

MathPro Inc. and Meszler Engineering Services conducted the analysis and prepared this report using reasonable care and skill in applying methods of analysis consistent with normal industry practice. All results are based on information available at the time of presentation. Changes in factors upon which the study is based could affect the results and findings. Forecasts and projections are inherently uncertain because of events that cannot be foreseen, including the actions of governments, individuals, third parties and competitors. NO IMPLIED WARRANTY OF MERCHANTABILITY SHALL APPLY.

Executive Summary

Arizona House Bill 2207 provides for adopting the California Air Resources Board's Phase 3 gasoline standard (CARB 3) as part of the Arizona Cleaner Burning Gasoline (AZ CBG) program. One provision of the bill calls for an independent analysis of the cost, supply, and emissions impacts of adopting the CARB 3 standard. The Arizona Department of Environmental Quality (ADEQ) retained Steven Reynolds (prime contractor), MathPro Inc. (subcontractor), and Meszler Engineering Services (subcontractor) to conduct the analysis. This report is the final work product of the study.

ES.1 OBJECTIVE AND SCOPE

Consistent with the Scope of Work (SoW) document (**Appendix A**), this study assessed specified “options for modifying gasoline formulations for the purpose of providing additional supply of motor fuels to Arizona while maintaining or improving the effectiveness of the . . . CBG program being implemented in the Greater Phoenix area.” The options were:

1. Add CARB 3 as an additional standard under the CBG program for both the summer and winter seasons [retaining Arizona Type 1 CBG in the summer, as in the current program].
2. Set CARB 3 as the standard for Arizona Type 2 CBG [replacing CARB 2], as required under House Bill 2207 [again, retaining Type 1 CBG in the summer].
3. Evaluate the following regional gasoline options as possible CBG standards that will achieve the necessary emissions benefits¹ and increase the supply of CBG in the region.
 - ▶ Federal reformulated gasoline (RFG), winter season only
 - ▶ Las Vegas blend
 - ▶ Albuquerque blend
 - ▶ West Texas/El Paso blend
 - ▶ Tucson blend
 - ▶ Any other regional blend that can be delivered to the CBG area cost-effectively
4. Lift the current wintertime Reid Vapor Pressure (RVP) cap – 9 psi – in the Phoenix metropolitan area at two different oxygen content standards:
 - ▶ 11 psi, at 2.0 wt% and 3.5 wt% oxygen content
 - ▶ 13.5 psi, at 2.0 wt% and 3.5 wt% oxygen content

The study comprised four analytical tasks, as outlined in the SoW.

¹ The SoW defines “necessary emissions benefits” as emissions not more than 5% above baseline emissions of criteria pollutants and not more than 10% above baseline emissions of toxic pollutants.

➤ Task 1: Identification and Evaluation of Options

- ▶ Estimation of the current (2004) average properties – or *baseline properties* – of gasoline supplied to the CBG area in the summer and winter seasons, under the current AZ CBG program;
- ▶ Screening of the various gasoline options specified in Option 3 (above), to identify which (if any) of these would achieve the level of emissions performance specified for CBG;
- ▶ Estimation of *baseline emission inventories* for the criteria pollutants – particulate matter (PM), carbon monoxide (CO), oxides of nitrogen (NO_x), and volatile organic compounds (VOC) – and for the years of interest.

Baseline gasoline properties and emission inventories are the properties and emission inventories expected in the CBG covered area in the absence of any change in current gasoline programs. Gasoline options that did not satisfy the screening criterion were not considered in the subsequent tasks.

➤ Task 2: Analysis of Impacts on Motor Fuel Distribution

Identification and assessment of the primary implications of the various gasoline options considered on the operation of the distribution system (from the refinery to the end-use site) that supplies CBG and other refined products to the CBG covered area and its environs.

➤ Task 3: Technical and Economic Analysis of Gasoline Production

Assessment of the primary implications of the various gasoline options considered in the refining centers that produce AZ CBG, including:

- ▶ Development of approximate measures of the incremental refining costs (relative to the baseline gasoline) of producing the various gasoline options considered; and
- ▶ Estimation of other effects associated with the gasoline options considered, including possible requirements for refinery investment and effects on fuel economy.

➤ Task 4: Emissions Analysis

Assessment of the emissions effects of each gasoline option considered, including effects on

- ▶ Emissions of PM, CO, VOC, NMOC, and NO_x, on a per-vehicle basis within major vehicle technology classifications;
- ▶ Region-wide emissions of CO, PM, NMOC, and NO_x from onroad and nonroad mobile source inventories in 2005 and 2010; and

- ▶ Secondary emissions including hazardous air pollutants and emissions outside of Maricopa County.

The emissions analysis was performed for the *summer* gasoline options and some of the *winter* gasoline options considered.

ES.2 PRIMARY FINDINGS

Effects of Adopting the CARB 3 Standard

The results of the study indicate that adoption of the CARB 3 gasoline standard for the Arizona Cleaner Burning Gasoline program (AZ CBG) will have minimal effect on the cost, supply (actual and prospective), and emissions performance of Arizona CBG, in either the summer or winter gasoline seasons. This finding applies whether Arizona adopts the CARB 3 standard in place of or in addition to the CARB 2 standard (summer and winter).

Similarly, adoption of the CARB 3 gasoline standard should, in itself, have no significant effects on the operations or economics of the gasoline distribution system serving the CBG covered area (the KMP South pipeline system and the Phoenix terminal complex).

Establishing CARB 3 as an additional summer and winter standard under the CBG program (Option 1 above), rather than as a replacement for CARB 2 (Option 2), could allow the refining industry some additional flexibility in sustaining supply of Arizona CBG during temporary upsets or capacity curtailments in the logistics system.

Effects of the Other Gasoline Options Specified

For summer CBG, none of the regional gasoline options specified for consideration as possible CBG standards provide the required NO_x and VOC emissions performance. For winter CBG, none of the regional gasoline options would provide the required CO emissions performance.

Federal RFG, as it has been produced in the Midwest in the winter could offer some reduction in average refining cost of winter CBG. Relaxing the oxygen content and volatility standards of winter CBG, as specified in the SoW, could reduce slightly its average refining cost. Estimating the emissions effects of relaxing these standards was beyond the scope of the study.

ES.3 SPECIFIC RESULTS AND FINDINGS OF THE ANALYSIS

Baseline Properties of Gasoline Supplied to the CBG Covered Area

Table ES.1 shows the estimated baseline properties of Arizona CBG developed in Task 1. These properties are, with the exception of sulfur content and oxygenate content, the average properties of gasoline supplied to the CBG covered area in the 2004 summer season and the 2003-2004 winter season, determined by analysis of the Arizona Department of Weights and Measures (DWM) retail

station compliance reports for Area A for the corresponding periods. The average sulfur content is set at 30 ppm, to conform to the federal Tier 2 gasoline sulfur standard to take effect in 2006, and the ethanol content is set at 10 vol% in conformance with the CBG winter standard.

TABLE ES.1: BASELINE GASOLINE PROPERTIES: SUMMER AND WINTER

Gasoline Property	Units	Summer	Winter
Octane (R+M)/2		88.3	88.9
Oxygenate Ethanol MTBE ETBE TAME	Vol%		10.0 0
RVP	Psi	6.5	8.6
Oxygen	Wt%	0.2	3.4
Aromatics	Vol%	21.9	18.9
Benzene	Vol%	0.92	0.93
Olefins	Vol%	7.5	3.1
Sulfur	Ppm	30	30
E200	Vol% off	42.9	53.4
E300	Vol% off	85.9	90.1
T10	° F	145	127
T50	° F	212	187
T90	° F	320	300

Table ES.2 shows the emissions performance corresponding to the baseline gasoline properties, estimated by the federal Complex Model for gasoline certification. These estimated emissions reductions constitute the baseline for the initial screening of the various gasoline options.

TABLE ES.2: EMISSIONS PERFORMANCE OF BASELINE GASOLINE: SUMMER AND WINTER

Emission	Summer	Winter
	(% Reduction)	
VOCs	30.5	
NOx	14.4	15.9
Toxics	28.4	25.7
CO		23.9

Baseline Emissions Inventories for the CBG covered area

Using the source materials provided by ADEQ, along with supplemental analysis tools such as the U.S. EPA's MOBILE6.2 and NONROAD emissions models, we developed baseline emission inventories for PM, CO, NO_x, and VOC. To support evaluation of the impacts of the various gasoline options, the emission inventories were resolved sufficiently to isolate those

portions attributable to gasoline consumption (other portions of the inventory would be essentially unaffected by changes in gasoline formulation.) **Tables ES.3 and ES.4** (next page) present the inventories developed for 2005 and 2010, respectively.

TABLE ES.3: BASELINE EMISSION INVENTORIES FOR 2005 (METRIC TONS PER DAY)

Source Category	Summer								Winter
	VOC	NO _x	CO	SO ₂	Direct PM-10	Direct PM-2.5	Indirect PM-10	Indirect PM-2.5	CO
Non-Mobile Sources	162.76	60.74	60.77	3.13	190.07	66.36	4.24	3.58	41.49
Nonroad Gasoline	49.95	1.16	450.95	0.02	2.52	2.32	0.07	0.06	450.95
Nonroad Other	13.25	75.00	80.77	7.05	4.37	3.91	6.40	5.48	87.37
Onroad Gasoline	55.33	84.92	482.85	1.88	2.16	1.11	5.01	4.16	407.37
Onroad Other	4.85	33.38	34.69	1.34	1.16	1.00	2.19	1.84	36.10
Total Emissions	286.15	255.19	1110.02	13.43	200.28	74.69	17.91	15.12	1023.28
Total Gasoline Emissions	105.29	86.08	933.80	1.90	4.68	3.42	5.08	4.22	858.32

TABLE ES.4: BASELINE EMISSION INVENTORIES FOR 2010 (METRIC TONS PER DAY)

Source Category	Summer								Winter
	VOC	NO _x	CO	SO ₂	Direct PM-10	Direct PM-2.5	Indirect PM-10	Indirect PM-2.5	CO
Non-Mobile Sources	179.28	66.01	70.37	3.47	214.72	74.59	4.63	3.91	49.52
Nonroad Gasoline	17.58	1.54	466.67	0.01	3.13	2.88	0.08	0.07	466.67
Nonroad Other	11.14	73.19	78.76	4.99	4.07	3.56	5.55	4.72	86.19
Onroad Gasoline	41.93	61.23	460.38	0.76	2.34	1.12	3.40	2.80	386.60
Onroad Other	4.29	24.49	27.15	0.08	0.76	0.61	1.28	1.04	28.28
Total Emissions	254.22	226.46	1103.34	9.30	225.02	82.76	14.94	12.54	1017.25
Total Gasoline Emissions	59.51	62.77	927.05	0.77	5.46	4.00	3.48	2.87	853.27

Screening of Regional Gasoline Options

Of the regional gasoline options specified in the SoW, only one – federal RFG (winter only), as it has been produced in the Chicago-Milwaukee area – meets the emissions criterion specified in the SoW: estimated emissions not more than 5% higher for criteria pollutants and not more than 10% higher for toxic pollutants, relative to the baseline gasoline.

None of the regional gasoline options meet the screening criterion for the summer season. In particular, all the options fail on VOC, with respect to both vehicle emissions (as estimated by the Complex Model) and total Maricopa County emissions.²

Accordingly, of the regional gasoline options specified in the SoW, only federal RFG (winter only) was subjected to further emissions analysis in this study, along with all CBG options specified in the SoW.

The Gasoline Distribution System Serving the CBG covered area

The CBG covered area receives almost all of its gasoline (including AZRBOB³) and other refined products by pipeline.

In 2004, the area received by pipeline an average of about 96 K Bbl/day of AZ CBG and about 15 K Bbl/day of conventional gasoline (CG), with relatively little seasonal variation. Just over half of the CBG volume came from refineries west of Phoenix (primarily in the Los Angeles refining center); the balance came from refineries east of Phoenix (primarily in the West Texas/New Mexico refining center). In addition to the pipeline volumes, the CBG covered area received small volumes of CBG by truck and rail (from East-side sources), as well as rail shipments of ethanol for terminal blending with AZRBOB in the winter months.

The pipeline system serving the Phoenix area is a common carrier owned and operated by Kinder Morgan Energy Partners, L.P (KMP). The KMP system delivers refined products (AZ CBG, conventional gasoline (CG), jet fuel, and diesel fuels) to terminals in Phoenix and Tucson, through two pipelines.

- The West line moves refined products produced in the Los Angeles refining center, as well as lesser volumes produced in the San Francisco and Puget Sound refining centers, from Los Angeles to Phoenix and on to Tucson.⁴

At Colton (east of Los Angeles), the West line connects with KMP's CalNev pipeline, which carries refined products, including Las Vegas's special gasoline formulation, to the Las Vegas area.

- The East line moves refined products produced in the West Texas/New Mexico and Gulf Coast refining centers from El Paso, TX, to Tucson and on to Phoenix.

² Note that the fraction of Maricopa County emissions associated with gasoline combustion changes over time in accordance with national and local control programs as well as changes in source distributions, etc. For screening analysis purposes, the average of the gasoline emissions fractions for 2005 and 2010 were averaged to derive an average emission fraction for the 2005-2010 time period.

³ AZRBOB is Arizona Reformulated Blendstock for Oxygenate Blending, the base gasoline blend produced at refineries for local blending with ethanol to produce finished CBG.

⁴ However, as of October 2005, no gasoline supplies from the West will move east of Phoenix.

By virtue of this configuration, Phoenix is served by both West-side and East-side refineries.

Several proprietary pipelines deliver refined products to El Paso, for onward shipment in the East line. In addition, refined products and gasoline blendstocks from the Gulf Coast refining center move to El Paso through the new Longhorn Pipeline, which connects there with the KMP East line, and through the existing Magellan Pipeline Co. South line.

In normal operations, the East line is fully allocated (i.e., operates at full capacity), with suppliers receiving allocations, or prorated shares, of pipeline capacity. By contrast, the West line operates with spare capacity. Hence, in general, the Los Angeles refining center is the marginal supplier of gasoline to the Phoenix area.

KMP is currently expanding the capacity of the East line from El Paso to Phoenix, with completion scheduled for the second quarter of 2006. The project will increase the total capacity of the East line by about 45 K Bbl/day. KMP expects that about 25 K Bbl/day of the new capacity will be allocated to gasoline. (In August 2005, KMP announced plans for a further expansion of the East line, which will add 23 K Bbl/day of capacity from El Paso to Tucson.) After the expansion, the East line is likely to continue being fully allocated, with marginal supplies to Phoenix continuing to come from the West.

In general, the West side of the Phoenix distribution system is long on pipeline capacity and short on refining capacity to supply CBG and other refined products, whereas the East side is short on pipeline capacity but long on refining capacity.

The Phoenix terminal complex comprises five essentially contiguous bulk terminals, with an aggregate working storage capacity for CBG storage corresponding in volume to about ten days of CBG consumption. Actual gasoline stocks – as distinct from storage capacity – are not a matter of public record. However, the average volume of gasoline stocks held in the Phoenix terminal complex probably is on the order of four days of CBG consumption – several days less than the pipeline transit times to Phoenix from either Los Angeles or El Paso.

By contrast, in PADD 5,⁵ stocks of finished gasoline and gasoline blendstocks held at terminals (year-end 2004) were equal to approximately ten days of demand nation-wide and seven days of demand.

Many refineries, particularly those in PADDs 1⁶ and 5, are located close to (or indeed within) their primary market areas and have their own facilities for supplying these markets directly. Hence, some significant portion of refinery stocks (varying from PADD to PADD) is equivalent to terminal stocks, in the sense that both are “prompt stocks” – close, in distance and time, to final demand sites. Stocks of finished gasoline and gasoline blendstocks (year-end 2004) at terminals *and* refineries in PADD 5 were equal to approximately seventeen days of gasoline demand in PADD 5 – significantly higher than the prompt stocks available to the Phoenix area.

⁵ PADD 5 (Petroleum Administration for Defense District 5) comprises Arizona, California, Nevada, Oregon, and Washington.

⁶ PADD 1 comprises seventeen states along the Eastern seaboard, from Maine to Florida.

Fungibility in the Distribution System

The KMP system and the Phoenix terminal complex are configured to handle only one AZ CBG type, in two grades: regular and premium. Hence, all batches of a given grade of AZ CBG shipped via the West and East lines must be mutually fungible – that is, amenable to commingling with other batches of CBG in the pipeline, pipeline break-out tanks, and terminals.

However, AZRBOB supplied for ethanol blending and finished, non-oxygenated CBG are not mutually fungible, because of necessary differences in octane and volatility. They must be segregated from the refinery to the pump.

The refineries have dealt with the mutual fungibility requirement by limiting the CBG batches supplied to Phoenix to a single type, which changes seasonally. In the winter, the current CBG program calls for just one gasoline class: Type 2 CBG (CARB 2 standard, 9 RVP, 10 vol% ethanol). In the summer, the current CBG program requires either Type 1 CBG (federal RFG “look-alike”, with no oxygenate required) or Type 2 CBG (CARB 2 standard, with no oxygenate required). Non-oxygenated Type 1 and Type 2 CBG are fungible. The refining industry has chosen to supply only non-oxygenated summer CBG. (Prior to Arizona’s ban on MTBE use, non-oxygenated Type 1 CBG and MTBE-blended Type 2 CBG were considered fungible.)

Enabling the distribution system to handle two gasoline segregations (i.e., two non-fungible gasoline types) would require investment in additional tankage and other equipment in the pipeline and terminals. We understand that KMP has no plans for undertaking such investments.

Because the existing KMP system cannot segregate two non-fungible gasoline types, the CBG volumes supplied to the CBG covered area via both the East and West lines must be either

- All ethanol blended
- or
- All non-oxygenated.

In the winter season, the existing distribution system can accommodate any combination of ethanol-blended CARB 2, CARB 3, or federal RFG, because they would be mutually fungible and interchangeable (when properly certified) with respect to the AZ CBG program. In the summer season, the existing distribution system could accommodate either any combination of non-oxygenated federal RFG, CARB 2, or CARB 3 OR any combination of ethanol-blended federal RFG, CARB 2 or CARB 3 (all with the same ethanol content) – but not both.

Refining Sector Considerations

Gasoline production in California is not keeping pace with in-state demand in the wake of the California MTBE ban. Some refineries in the Los Angeles refining center are capable of supplying a flexible gasoline slate, including not only CARB 3 for California, but also AZ CBG (under the current program), Las Vegas gasoline, and perhaps other gasolines, in response to market driving

forces. Other refineries are configured and operated to produce primarily CARB 3 gasoline, with little or no capability to segregate additional classes for out-of-state markets.

In general, aggregate terms, the gasoline slate produced by the West Texas/New Mexico refining center (conventional gasoline, 7 RVP gasoline, and AZ CBG) is less demanding and less costly to produce than that produced by the Los Angeles refining center (mainly CARB 3, with some conventional gasoline, Las Vegas gasoline, and AZ CBG). The CBG covered area and environs is a primary gasoline market for a number of West Texas/New Mexico refineries. They have captured an increasing share of the market in recent years; since 1997, essentially all the growth in gasoline demand in the area has been met by increased supplies from East-side refineries.

As a group, the West Texas/New Mexico refineries supplying CBG have increased aggregate gasoline production capability in recent years. The planned expansion of the KMP East line suggests that West Texas/New Mexico refineries intend to continue to increase their capacity to meet increasing demand for AZ CBG. The refineries can do so either by expanding their facilities and increasing total gasoline production or by upgrading to CBG some conventional gasoline now supplied to other markets.

In summary:

- In the California refining sector, CARB 3 production predominates, Arizona CBG production represents about 5% of gasoline production, and summer CBG produced to the Type 1 standard is less costly to produce than CARB 2 or CARB 3 gasoline produced for sale in California.
- In the West Texas/New Mexico refining center, CARB 3 production is negligible, Arizona CBG production constitutes a significant share of the gasoline out-turn of the refineries supplying CBG, and CBG is more costly to produce than the balance of their gasoline production.

Estimated Refining Costs of the CBG Options Considered

Tables ES.5a and ES.5b show the refining costs estimated in the technical and economic analysis of CBG production conducted in Task 3.

TABLE ES.5A: ESTIMATED REFINING ECONOMICS OF CBG OPTIONS: SUMMER 2010

Ethanol Content (Vol%) --> Certification Option -->	Non-Oxygenated			Ethanol-Blended		
	Reference Case	Study Cases		Reference Case	Study Cases	
	0 Fed-S	0 Cal2-S	0 Cal3-S	10 Fed-S	5.7 Cal2-S	5.7 Cal3-S
Refining Cost (\$/gal of CBG)		2.4	2.2		2.9	3.5
East		2.2	2.0		1.9	2.0
West		2.7	2.5		4.2	5.5
Daily Refining Cost (\$K/d)		120	120		150	190
East		60	60		50	60
West		60	60		100	130

Summer

In the summer, Type 1 CBG (**Fed-S** in Table ES.5a) enjoys a refining cost advantage over CARB 2 (**Cal2-S**) and CARB 3 (**Cal3-S**) gasoline of about 2–2½¢/gal with no ethanol blending and about 3–3½¢/gal with ethanol blending. These cost differences are likely to lead all CBG suppliers, East and West, to continue meeting the CBG summer requirements by supplying Type 1 CBG rather than gasoline produced to the CARB 2 (if it remains in the CBG program) or CARB 3 standards, except in unusual or transient circumstances.

Because Type 1 CBG will continue to be the standard of choice for summer gasoline, the CBG covered area is likely to experience little change in the average properties of summer CBG as a consequence of HB 2207.

CBG certified to either the CARB 2 or CARB 3 standard would be more costly to produce in the West refining center than in the East. This cost difference arises from the different volume shares of CARB gasoline produced in the two refining centers. The California refining sector produces a gasoline pool that is predominately CARB 3; the West Texas/New Mexico refining center produces a gasoline pool with little or no CARB gasoline.

The difference between the costs of producing the non-oxygenated CBGs and the costs of producing their ethanol-blended counterparts would depend on the delivered price of ethanol and the relationship of the ethanol price to oil prices. Forecasting these price relationships was beyond the scope of the study.

TABLE ES.5B: ESTIMATED REFINING ECONOMICS OF CBG OPTIONS: WINTER 2010

Certification Option --> RVP (psi)--> Ethanol Content (Vol%) -->	Reference	Study Cases					
	Case						
	Cal2-W	Cal3-W					Fed-W
		8.7	11.0		13.5		12.5
			10.0	10.0	5.7	10.0	
10.0	10.0	10.0	5.7	10.0	5.7	10.0	
Refining Cost (¢/gal of CBG)		0.0	-0.8	-1.1	-1.6	-2.1	-2.0
East		0.1	-0.8	-1.2	-1.6	-2.2	-1.5
West		0.0	-0.8	-1.0	-1.6	-1.9	-2.6
Daily Refining Cost (\$K/d)		0	-40	-60	-90	-100	-100
East		0	-20	-40	-50	-60	-40
West		0	-20	-20	-40	-40	-60

Winter

In the winter, Arizona CBG would have the same average refining costs whether certified to either the CARB 2 (**Cal2-W** in Table ES.5b) and CARB 3 (**Cal3-W**) standards. Some individual refineries may have an economic incentive to continue producing to the CARB 2 standard (if it

remains part of the CBG program); others, particularly in the Los Angeles refining center, may prefer CARB 3.

The other winter CBG options specified in the SoW for consideration – federal RFG (**Fed-W**) and the CARB 3 variants with relaxed RVP or oxygen standards (**Cal3-WR**) – all have lower average refining costs than CARB 2 or CARB 3 produced to the Type 2 standard. The difference in refining costs between CARB 3 ethanol blended at 10 vol% ethanol and 5.7 vol% ethanol depends on the delivered price of ethanol and the relationship of the ethanol price to oil prices.

Emissions Effects of the CBG Options Considered

We conducted a detailed emissions analysis of six summer gasoline options:

- Non-oxygenated Type 1 (Federal) CBG and ethanol-blended Type 1 CBG.
- Non-oxygenated Type 2 (California Phase 2) CBG and ethanol-blended Type 2 CBG.
- Non-oxygenated California Phase 3 CBG and ethanol-blended California Phase 3 CBG.

The non-oxygenated Type 1 CBG and ethanol-blended Type 1 CBG, are expected to be the summer gasolines of choice on economic grounds.

We conducted a detailed emissions analysis of three winter gasoline options:

- CARB 2 and CARB 3, with 10 vol% ethanol and 9 psi RVP, as specified by the SoW.
- Federal RFG, with 10 vol% ethanol and an ASTM compliant RVP.

Given limitations in available analytical tools and the need to develop emission impact estimates on both a per-vehicle and regional basis, a hybrid analysis approach was employed to evaluate the emissions impacts of the four gasoline options. The approach included the use of EPA's MOBILE6.2, the EPA Complex Model, and the CARB Phase 3 Predictive Model. MOBILE6.2 served as the hub of the emissions analysis, producing emission factors by technology type for each fuel formulation (both the baseline formulation and associated options). However, MOBILE6.2 does not include algorithms to estimate the emissions response to changes in the full range of fuel properties. To estimate emission responses for such qualities as E200, E300, aromatic content, olefin content, and benzene content, a secondary analysis method was employed using a combination of the Complex Model and the Predictive Model.

Figures ES.1 through ES.5 summarize the estimated emissions impacts for 2010 (when not included, 2005 impacts are similar). In all cases, positive values indicate emissions increases, while negative values indicate emissions decreases.

As Figures ES.1 and ES.4 indicate, the emissions impacts of the summertime gasoline options are generally within the range of variability allowable under the existing CBG program. While significant summertime reductions of both criteria pollutant and toxic emissions could result from the sale of either CARB 2 or CARB 3 CBG relative to the Federal RFG blends that currently dominate summertime CBG sales, there is nothing in the current CBG program that

prohibits CARB 2 sales. So the actual impacts of the potential CBG program revisions are reflected solely in the emissions differences between CARB 2 and CARB 3 CBG. As indicated in Figures ES.1 and ES.4, the emissions impact differences of these blends are commensurate with the modest changes in prospective average CBG properties associated with these blends.

As indicated in Figure ES.1, the oxygenated summertime options result in significant CO reductions. However, this impact should be considered with the understanding that summertime oxygenate use is not prohibited under the current CBG program. It is simply more economical (currently) to provide non-oxygenated gasoline. Additionally, CO is not a major contributor to summertime air quality issues.

The emissions performance of the wintertime CARB 2 and CARB 3 options are also similar as indicated in Figures ES.2, ES.3, and ES.5. However, as is also indicated, there are significant emissions increases associated with the wintertime use of a federal RFG, which is not allowable under the current CBG requirement for Type 2 wintertime gasoline. These increases result from the higher aromatic, olefin, and sulfur content of the federal fuel, as well as its increased volatility. Therefore, a relaxation of the current wintertime Type 2 CBG requirement could lead to significant increases in both criteria pollutant and toxic emissions.

FIGURE ES.1: CHANGE IN TOTAL 2010 SUMMERTIME EMISSIONS

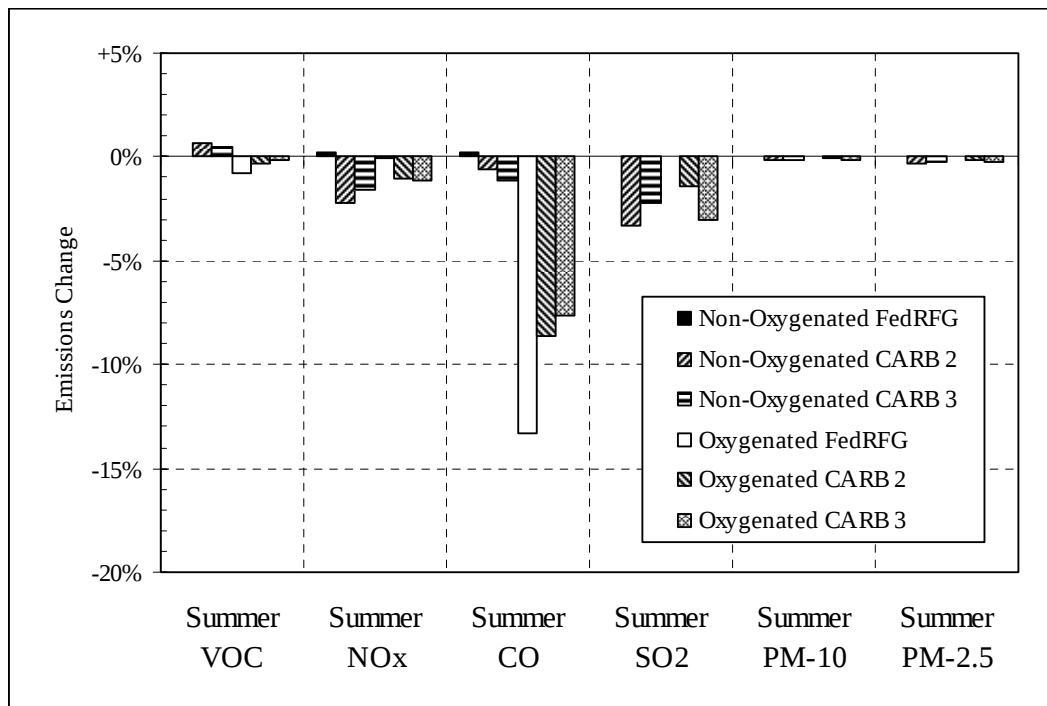


FIGURE ES.2: CHANGE IN WINTERTIME CO EMISSIONS

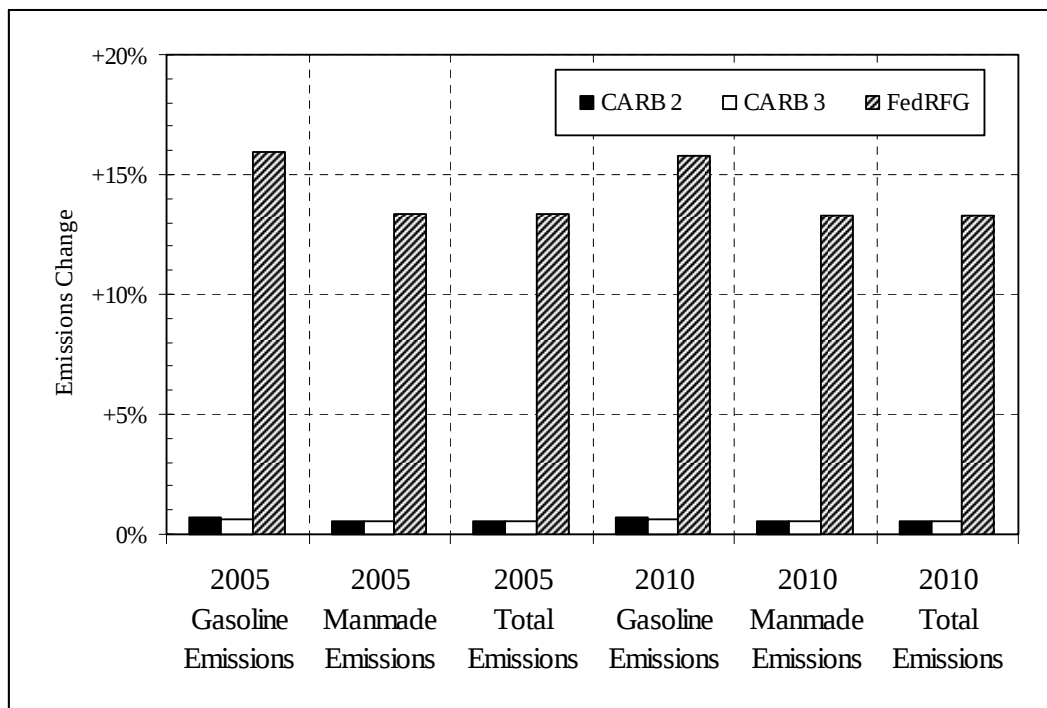


FIGURE ES.3: CHANGE IN WINTERTIME GASOLINE EXHAUST PLUS EVAPORATIVE EMISSIONS

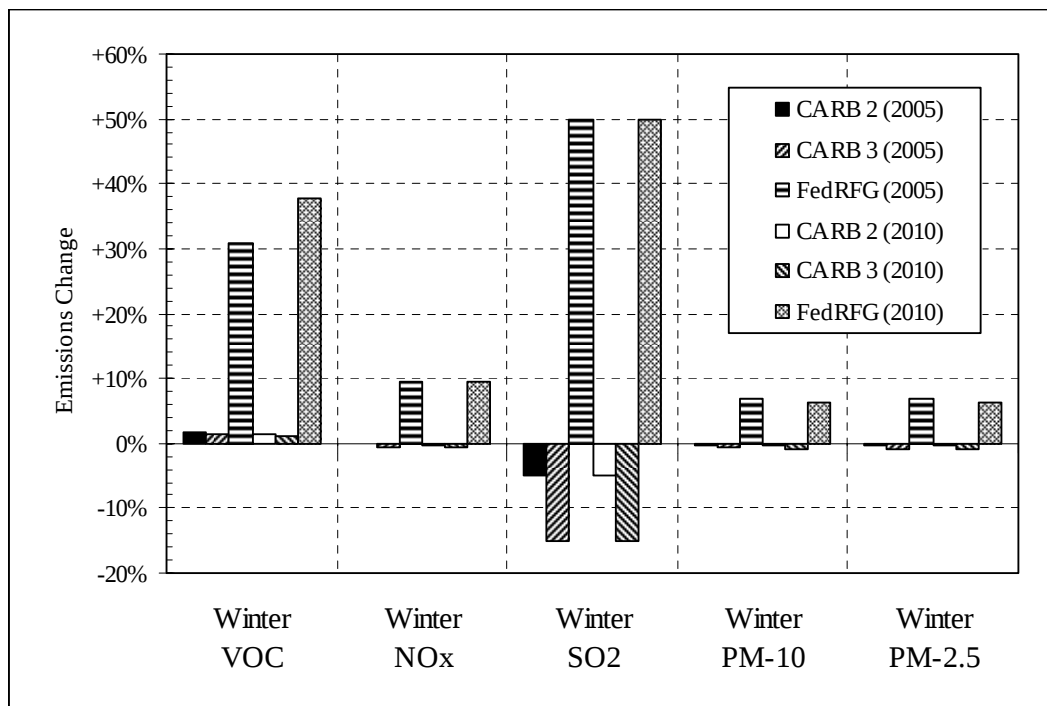


FIGURE ES.4: CHANGE IN SUMMER 2010 TOXIC EMISSIONS

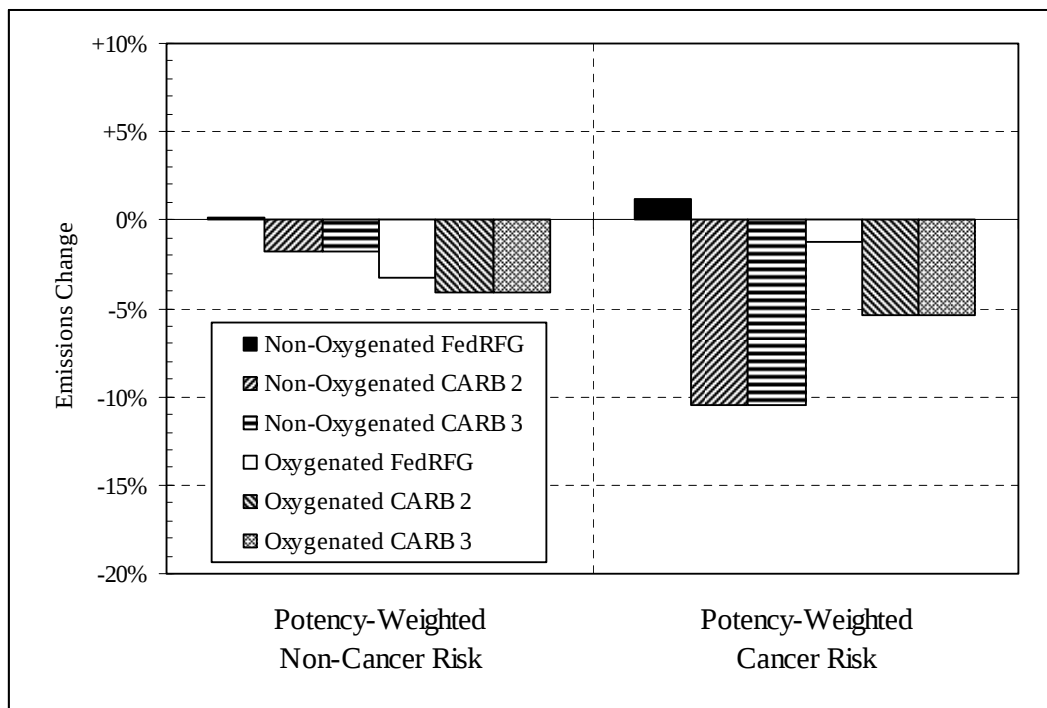
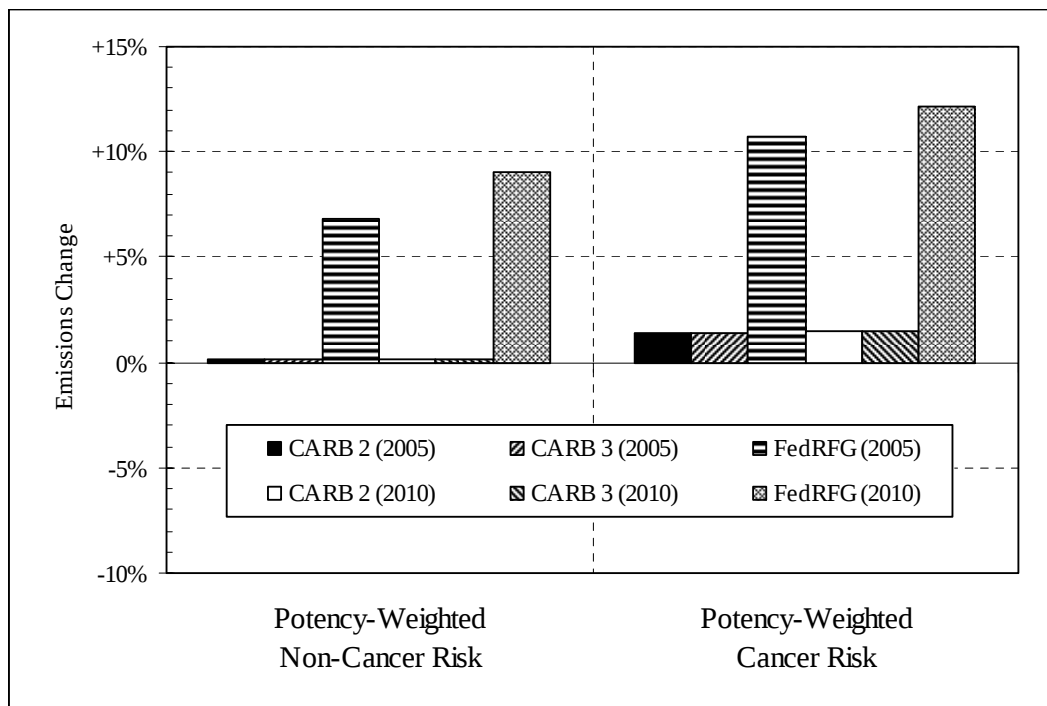


FIGURE ES.5: CHANGE IN WINTER TOXIC EMISSIONS



Cost-Effectiveness of Adopting the CARB 3 Standard

The primary findings of the study are that both the estimated costs of adopting the CARB 3 standard and the estimated emissions effects are small. Consequently, developing measures of the cost-effectiveness of adopting the CARB 3 standard was not feasible.

1. Introduction

The Arizona Department of Environmental Quality (ADEQ) retained Steven Reynolds (prime contractor), MathPro Inc. (subcontractor), and Meszler Engineering Services (subcontractor) to conduct an analysis of the cost, supply, and emissions impacts of Arizona's adopting the California Air Resources Board's Phase 3 gasoline standard (CARB 3) for the Arizona Cleaner Burning Gasoline program (AZ CBG), pursuant to Arizona House Bill 2207 [1].

MathPro Inc. conducted the analysis of refining and distribution effects of this initiative, including effects on the average properties of gasoline supplies to Arizona's the CBG covered area (Maricopa County and adjacent areas). Meszler Engineering Services conducted the analysis of emissions effects of the initiative, including effects on inventories of mobile source emissions in the Maricopa County airshed.

This report is the final work product of the project.

1.1 OBJECTIVE AND SCOPE OF THE ANALYSIS

The Scope of Work document calls for evaluation of "options for modifying gasoline formulations for the purpose of providing additional supply of motor fuels to Arizona while maintaining or improving the effectiveness of the . . . CBG program being implemented in the Greater Phoenix area."

1. Add CARB 3 as an additional standard under the CBG program for both the summer and winter seasons [retaining Arizona Type 1 CBG in the summer, as in the current program].
2. Set CARB 3 as the standard for Type 2 CBG [replacing CARB 2], as required under House Bill 2207 [again, retaining Type 1 CBG in the summer].
3. Evaluate the following regional gasoline options as possible CBG standards that will achieve the necessary emissions benefits⁷ and increase the supply of CBG in the region.
 - ▶ Federal RFG (wintertime only)
 - ▶ Las Vegas blend
 - ▶ Albuquerque blend
 - ▶ West Texas/El Paso blend
 - ▶ Tucson blend
 - ▶ Any other regional blend that can be delivered to the CBG covered area cost-effectively

⁷ As noted in the Executive Summary, the SoW defines "necessary emissions benefits" as emissions not more than 5% higher for criteria pollutants and not more than 10% higher for toxic pollutants – all of which we interpret as being relative to the baseline gasoline.

4. Lift the current wintertime cap (9 psi) on the Reid Vapor Pressure (RVP)⁸ of gasoline supplied to the Phoenix metropolitan area, at two different oxygen content standards:
 - ▶ 11 psi, at 2.0 wt% and 3.5 wt% oxygen content
 - ▶ 13.5 psi, at 2.0 wt% and 3.5 wt% oxygen content

We evaluated the primary technical, economic, and air quality effects of these options by carrying out four analytical tasks specified in the SoW:

➤ Task 1: Identification and Evaluation of Options

- ▶ Estimation of the current average properties – or *baseline properties* – of gasoline supplied to the CBG area in the summer and winter seasons, under the current CBG program;
- ▶ Screening evaluation of the various gasoline options specified in Option 3 (above) as possible alternatives to the CBG standard, to identify which (if any) of these – as alternative gasoline standards – would achieve the specified level of emissions performance;
- ▶ Estimation of baseline emission inventories for the pollutants of interest – particulate matter (PM), carbon monoxide (CO), oxides of nitrogen (NO_x), and volatile organic compounds (VOC) – for the years of interest.

Two comments are appropriate here. First, in the context of this study, *baseline* gasoline properties and emissions denote the properties and emissions expected in the CBG covered area in the absence of any change in current gasoline programs (as discussed in Section 2.1). Second, any gasoline options that did not satisfy the screening criterion in Task 1 were not considered in the subsequent tasks.

➤ Task 2: Analysis of Impacts on Motor Fuel Distribution

Identification and assessment of the primary implications of the various gasoline options considered on the operation of the distribution system (from the refinery to the end-use site) that supplies CBG and other refined products to the CBG covered area and its environs.

➤ Task 3: Technical and Economic Analysis of Gasoline Production

Assessment of the primary implications of the various gasoline options considered in the refining centers that produce the gasoline supplied to the CBG covered area, including:

- ▶ Development of approximate measures of the incremental refining costs (relative to the baseline gasoline) of producing the various gasoline options considered; and

⁸ Reid Vapor Pressure is a standard measure of gasoline volatility (i.e., propensity to evaporate).

- ▶ Estimation of other effects associated with the gasoline options considered, including possible requirements for refinery investment and effects on fuel economy.

➤ Task 4: Emissions Analysis

Assessment of the emissions effects of each gasoline option considered, including effects on

- ▶ Emissions of PM, CO, VOC, NMOC, and NO_x, on a per-vehicle basis within major vehicle technology classifications;
- ▶ Region-wide emissions of CO and for PM, NMOC, and NO_x from onroad and nonroad mobile sources in 2005 and 2010; and
- ▶ Secondary emissions, including hazardous air pollutants and effects on emissions outside of Maricopa County.

As specified in the SoW, the emissions analysis was performed for the summer gasoline options considered and for some of the winter gasoline options.

1.2 OVERVIEW OF THE REPORT

Section 2 summarizes relevant aspects of the Arizona CBG and California (CARB) RFG programs. Section 3 deals with the estimation of baseline gasoline properties and presents the estimated properties. Section 4 discusses the screening evaluation of the various regional gasoline options as possible CBG standards. Section 5 describes the distribution system through which supplies of CBG flow to the Phoenix area (Task 2). Section 6 describes the basis, methodology, and results of the technical and economic analysis of CBG production in the refining sector (Task 3). Section 7 deals with the estimation of baseline emissions inventories and presents the estimated inventories (Task 1). Section 8 describes the emissions analysis of the CBG options considered (Task 4). Section 9 briefly discusses implications of some of the key results and findings. Section 10 lists references.

Appendix A contains relevant portions of the Statement of Work. Appendix B presents a series of tables that provide detailed emissions analysis data in support of the more aggregate data presented in Section 8. Section 8 includes references to the tables in Appendix B where appropriate.

2. Overview of Applicable Gasoline Standards

All gasoline supplied to the CBG covered area must satisfy the physical property and/or emissions requirements of the Arizona Cleaner Burning Gasoline (AZ CBG) program [2, 3], Arizona's ban on the use of MTBE in gasoline, and various federal programs.

This section provides a brief overview of these standards, as well as the CARB 3 standard.

2.1 ARIZONA CBG STANDARD

For purposes of this analysis, one can summarize the current Arizona CBG standard as follows.

2.1.1 The CBG Covered Area

The AZ CBG program requires that CBG be sold in the CBG covered area, comprising all of Maricopa County plus the portions of Arizona's Area A that are in Pinal and Yavapai Counties.⁹ (In this report, we call this area "the CBG area.")

2.1.2 Summer Season

The summer season, the NOx and VOC control period, extends from May 1 to September 30.¹⁰ During this period, gasoline supplied to the CBG covered area may be either *Type 1 CBG* or *Type 2 CBG*.

Type 1 CBG is similar to federal Phase 2 reformulated gasoline (RFG 2), in that it must meet the federal Phase 2 RFG standards for NOx and VOC emission reductions (as certified by the federal Complex Model [4] for gasoline certification). However, Type 1 CBG is not subject to the existing federal RFG standards for

- Toxics emissions, because Arizona does not regulate toxic emissions;¹¹
- Benzene content¹², because CBG is not intended for toxics control; and
- Oxygen content.

⁹ The legal description of Area A is given in ARS 49-541(1).

¹⁰ The season definitions apply at the pump (i.e., at retail). Terminals and pipelines that supply CBG are not subject to formal season definitions, but are responsible for supplying the retail level with required gasoline types at all times.

¹¹ Under §211(c) of the Clean Air Act Amendments of 1990, states other than California are pre-empted from regulating toxic emissions. The federal government has no National Ambient Air Quality Standard for toxics emissions.

¹² The federal RFG limit on benzene content is 0.95 vol%, under the averaging program.

Type 1 CBG may, but need not, contain oxygen. (The Clean Air Act Amendments of 1990 specified that federal RFG contain, on average, at least 2.1 wt% oxygen. The Energy Policy Act of 2005, which became law in July 2005, has repealed this oxygen requirement; federal RFG no longer need contain oxygen.)

Ethanol-blended RFG or Type 1 CBG can be certified via the Complex Model at any ethanol concentration used in commerce – that is, at 5.7, 7.7, and 10 vol%.

Type 2 CBG is (at present) similar equivalent to California Phase 2 RFG (CARB 2), in that it must conform to the CARB 2 program’s emissions standards for NO_x and VOC, through either the averaging or “flat-limits” (non-averaging) options (as certified by the California Phase 2 Predictive Model [5]). Type 2 CBG is not subject to the CARB 2 program’s emission standard for Toxics, because Arizona does not regulate toxic emissions.

As with Type 1 CBG, Type 2 CBG may, but need not, contain oxygen. The CARB 2 standard does not include an oxygen content requirement.¹³ Ethanol-blended CARB 2 can be certified via the CARB 2 Predictive Model (PM2) at 5.7 and 7.7 vol% ethanol, but not at 10 vol%.¹⁴

2.1.3 Winter Season

The winter season, the CO control period, extends from November 1 to March 31.

(Over the past fifteen years, Maricopa County has experienced no violations in February and March of the National Ambient Air Quality Standard for CO. For this reason, Arizona intends to petition EPA to limit the winter gasoline program to November, December, and January. The ultimate duration of the winter season has no bearing on this study.)

During the winter season, all gasoline supplied to the CBG area must

- Conform to the CARB 2 standard (with oxygen content set at 2.0 wt% for certifying compliance);
- Have a Reid vapor pressure (RVP) $\leq$ 9.0 psi; and
- Contain 10 vol% ethanol (corresponding to 3.5 wt% oxygen).¹⁵

¹³ However, all CARB gasoline sold in those parts of California subject to the *federal* RFG program (as well as the CARB program) must contain oxygen, in conformance with the federal standard. About 80% of California’s gasoline consumption is in federal RFG areas.

¹⁴ Similarly, CARB 3 can be certified via the CARB 3 Predictive Model (PM3) at 5.7 and 7.7 vol%, but not at 10 vol%.

¹⁵ Because ethanol has a strong affinity for water, ethanol-blended gasolines are prepared by blending ethanol into a suitable gasoline base blend at the local terminal just before delivery to the end-use sites (e.g., retail sales sites). Base blends suitable for ethanol blending to produce AZ CBG are called AZRBOB (Arizona Reformulated Blendstock for Oxygenate Blending).

2.1.4 Transition Seasons

The gasoline calendar includes two transition periods between the primary gasoline seasons. They are necessary to accommodate practical limitations in the capability of the gasoline distribution system – pipelines and terminals – to segregate winter and summer gasolines without cross-contamination.

The spring transition extends from April 1 to April 30. The fall transition season extends from September 16 to November 1. During these periods, gasoline supplied to the CBG area must comply with the summer AZ CBG standards (Type 1 or Type 2), except for RVP. In the transition periods, CBG must meet a 9 RVP standard.

2.2 ARIZONA BAN ON MTBE IN GASOLINE

All gasoline supplied to Arizona is subject to the state's ban on MTBE in gasoline. This ban took effect 1 January 2005 (pursuant to HB 2142, Chapter 218). As a consequence, ethanol is the only practical choice as the oxygenate in AZ CBG.¹⁶ The Arizona MTBE ban affects summer CBG only, because winter CBG is already subject to an ethanol mandate (independent of the MTBE ban).

As a practical matter, essentially all AZ CBG supplied in 2004 was MTBE-free, except for small volumes of MTBE-blended premium grade Type 1 CBG produced in refineries in the West Texas/New Mexico refining center.

2.3 FEDERAL REGULATORY PROGRAMS

All gasoline consumed in the U.S. is subject to the federal Mobile Source Air Toxics (MSAT) program and the federal Tier 2 gasoline sulfur control program.

The MSAT program applies to refiners, not consuming areas, and is aimed at preventing toxics emissions from gasoline from increasing above the average levels reported by refiners in a baseline period (1998-2000).

The Tier 2 gasoline sulfur control program, setting limits on the average sulfur content of gasoline, took effect in 2004. The average sulfur standard was 120 ppm in 2004, is 90 ppm in 2005, and will be 30 ppm in 2006 and thereafter. The latter value corresponds to the CARB 2 (Type 2 CBG) sulfur standard, under averaging compliance. Hence, the Tier 2 sulfur program has had and will have little effect on the sulfur content of Type 2 CBG. However, the program has had a significant effect on the sulfur content of Type 1 CBG, particularly that produced in the West Texas/New Mexico and Gulf Coast refineries, with attendant reduction in emissions, especially NO_x emissions. (Typically, refiners can produce complying federal RFG with sulfur

¹⁶ An oxygenate is a gasoline blendstock that contains oxygen.

levels as high as 150–180 ppm). These refineries will implement some additional sulfur control in 2005 to meet the 2006 Tier 2 standard of 30 ppm.

2.4 OVERVIEW OF THE CARB 3 STANDARD

California banned the use of MTBE in gasoline sold in California, effective 1 January 2004. To facilitate the production of CARB gasoline with ethanol as the oxygenate instead of MTBE, the California Air Resources Board established the California Phase 3 RFG (CARB 3) program. The CARB 3 program supersedes the CARB 2 program. Since the advent of the CARB 3 program, all gasoline produced for sale in California must conform to the CARB 3 emissions standards and be certified with PM3.

The CARB 3 program bans the use of MTBE, includes a new set of reference gasoline properties, and has a new Predictive Model – the Phase 3 Predictive Model (PM3) [6] – that replaces the former one (PM2). The emissions reduction targets of the two standards are comparable.

Table 2.1 provides a side-by-side comparison of the CARB 2 and CARB 3 standards. The CARB 3 limits for T_{50} and T_{90} are higher than the corresponding CARB 2 limits, a technical adjustment to facilitate production of ethanol-blended CARB gasoline. To compensate for the emissions effects of these changes, the CARB 3 limits for sulfur and benzene are lower than the corresponding CARB 2 limits.

TABLE 2.1: THE CALIFORNIA REFORMULATED GASOLINE PHASE 2 AND PHASE 3 STANDARDS

Gasoline Property	Units	Flat Limits		Averaging Limits		Cap Limits	
		CARB 2	CARB 3	CARB 2	CARB 3	CARB 2	CARB 3
RVP	Psi	7.00	7.00	N.A.	N.A.	7.00	6.40 – 7.20
Oxygen	Wt%	1.8 – 2.2	1.8 – 2.2	N.A.	N.A.	0 – 3.5	0 – 3.5
Aromatics	Vol%	25.0	25.0	22.0	22.0	30.0	35.0
Benzene	Vol%	1.00	0.8	0.80	0.70	1.20	1.10
Olefins	Vol%	6.0	6.0	4.0	4.0	10.0	10.0
Sulfur	Ppm	40	20	30	15	80	30
T_{50}	° F	210	213	200	203	220	220
T_{90}	° F	300	305	290	295	330	330

Notes:

1. The indicated RVP standards do not apply in the winter months (November – February).
2. The CARB 3 RVP standard of 7.00 psi applies to the “non-evaporative” version of PM3. Most refiners use this version for certifying CARB 3 batches.
3. T_{50} and T_{90} are widely-used measures of gasoline volatility, as indicated by the gasoline “distillation curve.” T_{50} and T_{90} denote the temperatures at which 50% and 90% of the gasoline volume is vaporized.

The CARB gasoline program does not require oxygen in CARB gasoline produced for sale in California, except for gasoline sold in Southern California in the winter months (which must contain 2.7 vol.% oxygen). However, about 80% of California's gasoline consumption is in areas subject not only to the CARB program but also to the federal RFG program, year-round. In particular, essentially all of the California markets served by the Los Angeles refining center are subject to the federal RFG program. Until the passage of the Energy Policy Act of 2005 (the Act) in July 2005, the federal RFG program contained an oxygen requirement (at least 2.1 wt%, under averaging). Hence, essentially all CARB 3 gasoline produced by the Los Angeles refineries – the California refiners that supply AZ CBG to Phoenix – is now ethanol-blended, though that may change in response to the Act's repeal of the federal oxygen requirement for RFG.¹⁷

The CARB oxygen limit is 3.5 vol% (corresponding to 10 vol% ethanol). However, as a practical matter, gasoline containing more than 2.7 vol% oxygen would fail both PM2 and PM3 (on NOx emissions).

2.5 ARIZONA CBG AS A BOUTIQUE GASOLINE

A “boutique gasoline” is a special gasoline produced to local standards (usually for improving air quality) and not widely supplied throughout the area served by the gasoline supply system. Boutique gasolines are not produced by as many refineries as standard gasolines (e.g., conventional gasoline, federal RFG) and therefore can be more subject to supply interruptions than standard gasolines.

Under this definition, Arizona CBG is a boutique gasoline. The CBG area is the only area in the country that requires gasoline certified to the CARB 2 standard. The CBG winter standards calling for the combination of 9 RVP and 10 vol% ethanol are unique to the CBG area. Finally, the CBG Type 1 standard (federal RFG, but without oxygen and benzene control) also is unique to the CBG area.

The Act contains provisions intended to prevent further proliferation of boutique gasolines. In particular, Section 1541(b)(I) prohibits EPA from approving a fuel for SIP if that fuel would increase the total number of unique fuels incorporated in all SIPs nationally, as of September 1, 2004. (Section 1541(b)(II) directs EPA and the U.S. Department of Energy to develop and publish a list of the unique boutique fuels in use as of September 1, 2004.)

In summary, the act appears to allow EPA to approve a new boutique fuel for a SIP only if (1) the national list has “room” for the new fuel (because either the new fuel completely replaces a fuel already on the list or the list has an opening because some other boutique fuel has gone out of use) and (2) the fuel has 7 RVP in the summer.

One would expect Type 1 and Type 2 CBG (as they were defined as September 1, 2004), as well as CARB 3, to be on the national list.

¹⁷ Title 15 of the Energy Policy Act repeals the requirement for oxygen content in federal RFG, effective immediately for California and 270 days after enactment in the rest of the country.

2.6 THE ENERGY POLICY ACT OF 2005

The Act contains numerous provisions (some mentioned above) that will affect the production cost and supply of gasoline nation-wide and that could affect the AZ CBG program in particular.

The most significant fuels provisions of the Act include:

- A national ethanol mandate, starting at 4 billion gallons per year (bgg) in 2006 and increasing annually to 7.5 bgg in 2012

(Thereafter, the mandate volume increases in step with national gasoline use, so as to maintain ethanol's volume share of the gasoline pool at its 2012 level.)

- Repeal of the federal oxygen requirement in RFG
- Establishment of an ethanol credit trading program, to facilitate compliance with the ethanol mandate
- Limitation on the number of boutique fuels permitted in the future

In addition, the Act directs EPA to conduct studies on a number of topics, including the effects of ethanol permeation and the possible limitation on the allowable number of distinct gasoline types.

The Act could have significant effects on the AZ CBG program in the future. This study did not address the act or any its possible effects, because all analytical work had been completed before the act's passage.

2.7 NOTE ON TERMINOLOGY

As this discussion indicates, the Type 1 and Type 2 CBG standards correspond only in part to the federal RFG and CARB standards, respectively. Hence, in the context of the AZ CBG program, the terms "RFG", "CARB 2", and "CARB 3" as used in this report may denote CBG meeting (1) Arizona standards for RVP and (winter) oxygen content and (2) the federal or California reformulated gasoline standards, except for benzene content and hazardous air pollutant performance.

3. Baseline Gasoline Properties

This section defines the baseline gasoline properties for this study and presents our estimates of the baseline properties.

3.1 DEFINITION OF BASELINE PROPERTIES

For purposes of this study, the baseline gasoline properties are the average properties of the AZ CBG that would be supplied to the CBG area in the summer and winter seasons of the study's target years (2005 and 2010), if there were (1) no changes in the AZ CBG program, (2) no new federal regulatory programs affecting gasoline quality, and (3) no change from the 2004 sourcing pattern for AZ CBG.

The estimated baseline gasoline properties are a key intermediate result of the study. In subsequent tasks, the set of baseline properties are the standard of comparison for evaluating the technical and economic effects of proposed changes in the AZ CBG program.

Table 3.1 shows the set of gasoline properties for which we developed baseline values.

TABLE 3.1: BASELINE GASOLINE PROPERTY SET

Gasoline Property	Units
Octane (R+M)/2	
RVP	Psi
Oxygen	Wt%
Ethanol	Vol%
MTBE	Vol%
ETBE	Vol%
TAME	Vol%
Aromatics	Vol%
Benzene	Vol%
Olefins	Vol%
Sulfur	Ppm
E ₂₀₀	Vol% off
E ₃₀₀	Vol% off
T ₅₀	° F
T ₉₀	° F

With the exception of octane, these gasoline properties are the inputs to the federal Complex Model for RFG certification (CM) and the California Predictive Models for CARB gasoline certification (PM2 and PM3).¹⁸

¹⁸ E₂₀₀/E₃₀₀ and T₅₀/T₉₀ are alternative characterizations of a gasoline's distillation curve. The Complex Model takes E₂₀₀ and E₃₀₀ as inputs; the Predictive Model takes T₅₀ and T₉₀. The other gasoline properties shown in Table 3.1 are common inputs to both models.

These models are the prescribed tools for estimating the emissions performance of gasoline formulation and specific gasoline batches. The models compute reductions (relative to a specified baseline gasoline) in vehicle emissions of VOC, NO_x, and toxics as nonlinear functions of the gasoline properties shown in Table 3.1, for a specified mix of vehicle types.

3.2 TECHNICAL APPROACH FOR ESTIMATING BASELINE PROPERTIES

3.2.1 Sources of Data on Gasoline Properties in the CBG area

We obtained and analyzed data from three sources on the current properties of gasoline supplied to the CBG area:

- The Batch Certification Reports submitted by refineries to the Arizona Department of Weights and Measures (DWM), as required by the AZ CBG program [2].

Refiners must submit one of these reports for each gasoline batch produced in the source refinery and released for shipment to the CBG area. Each batch report lists numerous physical and chemical properties (determined by the refinery's designated analytical facilities) for the gasoline batch. DWM receives and stores these reports and records their contents in an electronic database. We examined summary reports generated by DWM from the database, not the original batch reports submitted by the refineries. The data we examined cover the period January 2003 through January 2005.

- The Station Compliance Reports for Area A, developed by DWM

These reports cover gasoline samples collected at the retail level by DWM and analyzed by a contract laboratory.

The DWM sampling program covers regular, mid-grade and premium gasolines. The gasoline property data we examined cover the period April 2003 through January 2005.

- The Alliance of Automobile Manufacturers (AAM) *North American Fuels Surveys* [7]

The AAM survey program is based on analysis of retail gasoline (and diesel fuel) samples collected in many metropolitan areas, including Phoenix. (It also covers Albuquerque, Denver, and Las Vegas.) The survey reports show the properties of retail gasoline samples in the local summer and winter gasoline seasons. The results we examined covered the 2003-2004 winter and 2004 summer seasons.

Data from each of these sources include all or most of the properties listed in **Table 3.5** (at the end of this section).

With the two sources of data provided by AZ DWM in hand, we did not consider the AAM survey as a candidate source for estimating CBG area baseline properties. However, the AAM data for Phoenix

and other Western cities were of significant value in the screening assessment of alternative gasoline formulations (discussed in Section 4).

3.2.2 Data Source of Choice

After careful assessment of the batch report data (refinery level) and the station compliance data (retail level), we chose to use the station compliance data as the basis for estimating baseline gasoline properties for the CBG area. We did so for the following reasons.

The retail-level data set comprises a large number of samples, as shown in **Table 3.2**.

TABLE 3.2: SAMPLES REPORTED IN STATION COMPLIANCE REPORTS FOR AREA A

	Summer 2004	Winter 2003-2204
Premium	142	44
Mid-grade	136	41
Regular	158	50
Total Pool	436	135

On visual inspection, the reported properties for these samples appear reasonable in magnitude and complete (i.e., no omissions).

On the other hand, the refinery-level data drawn from the batch reports appear to have several deficiencies.

- The total volume of AZ CBG covered by the batch reports for 2004 is less (by about 10%) than the total volume of CBG actually supplied in 2004, as indicated by pipeline deliveries to Phoenix (see Table 3.1). Along these lines, visual inspection of the batch report data reveals a number of temporal gaps in the batch reports submitted by several refiners that are regular suppliers of gasoline to the CBG area.
- For a number of batches, certain properties (e.g., benzene content, aromatics content) are either unreported or obviously incorrect (e.g., aromatics content > 100%).
- For a number of winter gasoline batches, the reported oxygen content is around 2.0 wt% or 2.7 wt%, rather than the 3.5 wt% required for winter CBG.

Such values probably reflect preparation by the refineries of “hand blends” of the CBG base blend (AZRBOB) actually shipped to the CBG area plus 5.7 vol% or 7.7 vol% ethanol (corresponding to in-use winter CARB 2 gasoline), rather than the required AZRBOB + 10 vol% ethanol (corresponding to in-use AZ winter CBG). Such errors affect the reported values of all relevant gasoline properties, not just oxygen content.

- Reported properties for some Type 2 CBG batches were actually “flat limit” properties (analytical artifacts used in certifying CARB gasoline supplied to California), instead of the actual in-use properties of the batches.

In summary, the retail-level data for the CBG area appear to be the more robust and reliable of the two data sources provided by DWM for the baseline period.

We understand that DWM, through its compliance audits, is aware of the errors in the batch reports and has instituted procedures to minimize such errors in the future.

3.2.3 Procedure for Calculating Baseline Properties

The SoW specifies 2005 and 2010 as the target years for the study. However, with respect to gasoline sulfur content, 2005 is a transition year, with an average sulfur limit of 90 ppm. (See Section 3.1.3.) In 2006 and later years, the average sulfur limit will go to 30 ppm.

Hence, for purposes of calculating baseline gasoline properties, we set 2006 as the baseline year.

Using the retail-level sampling data, we estimated the baseline properties for summer and winter AZ CBG for 2006 and later years using the following procedure for each season.

1. Compute three sets of average properties, covering the regular grade gasoline samples, the mid-grade samples, and the premium samples.
2. Compute the volume-weighted average of the three sets of average grade properties, using the following weighting factors:
 - Regular: 0.83
 - Mid-grade: 0.06
 - Premium: 0.11

These weighting factors are the volume shares of regular, mid-grade, and premium gasoline consumption in Arizona in 2003, estimated from the Department of Energy/Energy Information Agency’s (DOE/EIA) *Petroleum Marketing Annual 2003* [10].

The result of this step is the set of estimated baseline properties for AZ CBG for the Summer 2004 and Winter 2003-2004 seasons.

3. Project the results of Step 2 from 2004 to 2006 by setting the average sulfur level at 30 ppm, reflecting the federal Tier 2 sulfur control standard for 2006 and later years and setting the oxygenate levels to conform to the CBG oxygenate requirements.

The sulfur adjustment is minor. Step 2 yielded estimated average sulfur levels of 48 ppm in the summer and 33 ppm in the winter. These low current sulfur levels reflect (1) the 30 ppm average sulfur limit (and 40 ppm “flat limit”) in the CARB 2 gasoline program, (2) the strong

overall sulfur control capabilities in the California refineries, and (3) the progress East-side refiners have made toward coming into compliance with the 2006 Tier 2 sulfur standard.

This simple adjustment, affecting no other estimated baseline properties, reflects the assumption that refineries can accomplish the small increment of sulfur control with minimal effects on the other gasoline properties of interest.

3.3 BASELINE GASOLINE PROPERTIES: 2006

Table 3.3 shows the resulting estimated baseline gasoline properties for summer and winter. **Table 3.4** shows the corresponding emissions reductions, computed by the Complex Model from the baseline properties.

TABLE 3.3: BASELINE GASOLINE PROPERTIES: SUMMER AND WINTER

Gasoline Property	Units	Summer	Winter
Octane (R+M)/2		88.3	88.9
Oxygenate Ethanol MTBE ETBE TAME	Vol%		10.0 0
RVP	Psi	6.5	8.6
Oxygen	Wt%	0.2	3.4
Aromatics	Vol%	21.9	18.9
Benzene	Vol%	0.92	0.93
Olefins	Vol%	7.5	3.1
Sulfur	Ppm	30	30
E200	Vol% off	42.9	53.4
E300	Vol% off	85.9	90.1
T10	° F	145	127
T50	° F	212	187
T90	° F	320	300

TABLE 3.4: COMPLEX MODEL EMISSIONS OF BASELINE GASOLINE: SUMMER AND WINTER

	Summer	Winter
Emission	(% Reduction)	
VOCs	30.5	
NOx	14.4	15.9
Toxics	28.4	25.7
CO		23.9

As noted in Section 2.1.2, MTBE use is banned in Arizona, as of 2005. TAME (an ether, like MTBE) is not yet banned in Arizona, but the legislature is considering a bill (SB 1154) to ban TAME and other ethers. Nonetheless, as Table 3.3 indicates, the estimated baseline gasoline properties show small concentrations of MTBE and the ether TAME in the baseline gasolines. Examination of the batch reports, coupled with information provided by KMP, indicates that essentially all of the MTBE and TAME in the AZ CBG pool in 2004 was in premium-grade AZ CBG supplied by East-side refineries in 2004. (Apparently, these refiners had not yet completed modifications needed to enable production of premium-grade CBG without MTBE).

We did not attempt to adjust the baseline gasoline properties to reflect removal of these oxygenates by 2006, for several reasons. Even with the ether bans in place in 2006 and beyond, AZ CBG is likely to contain some de minimus, but as yet unknown, average concentration of ethers, due to commingling in refineries and pipelines supplying AZ CBG. Rigorous re-estimation of baseline properties of AZ CBG, with an assumed de minimus ether content, would not have been simple. It would have called for refinery modeling, beyond the intended scope of Task 1. The resulting estimated baseline gasoline, re-blended without MTBE and TAME, would have properties and emissions reductions only slightly different than those shown in Tables 3.3 and 3.4. We consider the estimate shown in Table 3.3 adequate for purposes of this study.

Finally, the data in the batch reports did not permit quantitative estimates of the volume shares of Type 1 and Type 2 CBG supplied to the CBG area in the summer of 2004. However, inspection of the reported properties of individual suggests that most of the CBG supplied was Type 1.

- Reported sulfur levels of East batches indicate that virtually all East volumes were Type 1.
- The set of average reported properties for all reported West batches do not pass PM-2, suggesting that most of them were certified as Type 1.

3.4 BACK-UP DATA AND CALCULATIONS

Tables 3.5, 3.6, and 3.7 show data obtained or developed in this analysis.

Table 3.5 shows estimates of the average properties (and corresponding CM emissions estimates) of Phoenix area gasoline, by season, year, and data source, derived from the various data sources described in Section 3.3: the DWM retail-level survey data, the DWM refinery-level batch report data, and the AAM fuels survey. Italicized numbers denote estimates made from a data subset, after eliminating incomplete or erroneous records.

This table indicates the three data sources lead to similar estimates of baseline gasoline properties and Complex Model emissions, lending credence to the AAM survey as the source for average properties of the various gasoline options (e.g., Denver gasoline, etc.) to be assessed in this study.

Table 3.6 shows (1) average properties of AZ CBG estimated from the *batch report* data, by season, year, and sourcing and (2) the gasoline volumes and volume shares covered by these reports.

This table shows the differences in the average properties of the AZ CBG pools supplied via the West and East lines. It also shows that essentially all of the MTBE in the Summer 2004 CBG pool was from gasoline produced by East-side refineries. Finally, comparison of the column headed *Volume & Share* with Table 5.2 indicates the shortfall in CBG volumes covered by the batch reports.

Table 3.7 shows (1) average properties of AZ CBG estimated from the *retail survey* data, by season, year, and gasoline grade and (2) the number of samples of each gasoline grade, by season and year.

TABLE 3.5: ESTIMATED AVERAGE PROPERTIES AND COMPLEX MODEL EMISSION REDUCTIONS FOR CBG, BY SEASON, DATA SOURCE, AND PERIOD

Properties & Emission Reductions	Summer					Winter				
	AAM 2004	Ariz. Retail Surveys		Batch Reports		AAM 2003-2004	Ariz. Retail Surveys		Batch Reports	
		2003	2004	2003	2004		2003-2004	2005	2003	2003-2004
Properties										
Octane ((R+M)/2))	88.4	88.7	88.3	-	-	90.0	88.9	88.9	-	-
RVP (psi)	6.7	6.8	6.5	6.7	6.6	9.0	8.6	8.7	8.7	8.7
Oxygen (wt%)	0.1	1.4	0.2	1.4	0.1	3.3	3.4	3.7	2.5	3.0
Etoh (Vol%)		0.0	0.0	-	-	9.6	8.9	9.5	7.3	8.9
MTBE (vol%)	0.6	6.3	0.5	5.8	0.5		0.2	0.0	-	-
ETBE (vol%)		0.0	0.0	-	-		0.0	0.0	-	-
TAME (vol%)	0.2	1.0	0.4	1.8	0.2		0.2	0.5	-	-
Aromatics (vol%)	20.6	22.2	21.9	22.0	20.2	17.4	18.9	18.1	17.2	21.1
Benzene (vol%)	0.90	0.97	0.92	0.98	0.84	0.94	0.93	0.70	0.97	1.11
Olefins (vol%)	6.5	4.1	7.5	4.6	8.9	1.6	3.1	4.3	3.3	1.9
Sulfur (ppm)	68	66	48	76	57	20	33	32	23	18
E200 (%off)	43.3	49.1	42.9	51.1	42.6	51.9	53.4	51.9	-	-
E300 (%off)	86.5	87.7	85.9	87.2	85.9	89.4	90.1	89.4	-	-
T10 (°F)	145	141	145	-	-	129	127	130	-	-
T50 (°F)	211	202	212	206	211	191	187	193	199	189
T90 (°F)	317	311	320	305	315	304	300	303	300	300
Complex Model Emission Reductions (%)										
VOCs	29.0	29.2	30.3	30.2	30.0					
NOx	13.2	12.8	13.6	12.1	13.3	16.9	15.7	16.2	-	-
Toxics	28.4	30.6	28.0	30.6	29.1	26.6	25.7	27.1	-	-
CO						24.5	23.8	24.6	-	-

Note: Italics indicates estimate based on a subset of refinery batch reports.

Sources:

AAM: Derived from *North American Fuels Survey*, Summer 2004, Alliance of Automobile Manufacturers.

Arizona Retail Surveys: Exhibits A.3 and B.2.

Batch Reports: Exhibit A.2.

TABLE 3.6: ESTIMATED AVERAGE PROPERTIES OF CBG IN 2003 AND 2004, FROM BATCH REPORTS SUBMITTED BY SUPPLIERS

Year & Region	Volume & Share (K b/d & %)	Properties													
		RVP (psi)	Oxygen (wt%)	Oxygenate (Vol%)				Aromatics (vol%)	Benzene (vol%)	Olefins (vol%)	Sulfur (ppm)	E200 (% off)	E300 (% off)	T50 (°F)	T90 (°F)
				EtoH	MTBE	ETBE	TAME								
Summer															
2003	89	6.7	1.4	0.0	7.0	0.0	0.8	22.0	0.98	4.6	76	51.1	87.2	206	305
East	43%	6.6	1.4	0.0	5.8	0.0	1.8	18.9	1.21	4.8	161	49.7	87.4	208	304
West	57%	6.8	1.4	0.0	7.9	0.0	0.0	24.3	0.81	4.4	12	52.2	87.1	204	306
2004	86	6.6	0.1	0.0	0.5	0.0	0.2	20.2	0.84	8.9	57	42.6	85.9	211	315
East	53%	6.6	0.2	0.0	0.9	0.0	0.3	17.1	1.02	7.6	87	41.8	86.5	212	320
West	47%	6.6	0.0	0.0	0.1	0.0	0.0	23.7	0.64	10.3	23	43.5	85.1	210	310
Winter															
2003	80	8.7	2.5	7.3	0.0	0.0	0.0	17.2	0.97	3.3	23.2	-	-	199	300
East	57%	8.7	2.7	7.9	0.0	0.0	0.0	15.9	1.13	1.3	24.6	43.0	89.8	191	291
West	43%	8.6	2.3	6.5	0.0	0.0	0.0	19.0	0.75	6.1	21.2	-	-	210	311
2003-2004	91	8.7	3.0	8.7	0.0	0.0	0.0	21.1	1.11	2.0	17.9	-	-	189	300
East	45%	8.7	2.7	7.8	0.0	0.0	0.1	16.3	0.95	1.9	30.3	-	-	197	302
West	55%	8.7	3.3	9.5	0.0	0.0	0.0	25.1	1.24	2.1	7.7	-	-	183	299

Notes: Includes gasoline shipments from April 8 through September 14

Italics indicates partial reporting by refineries, i.e. estimates reflect a subset of gasoline shipments

Source: Derived from "Refinery Batch Reports for CBG," 2003 & 2004, Arizona Department of Weights and Measures.

TABLE 3.7: AVERAGE PROPERTIES OF CBG SAMPLED AT RETAIL IN 2004, AREA A

Season & Year	Grade	No. of Samples	Octane (R+M)/2	RVP (psi)	Oxygen (wt%)	Oxygenate (vol %)				Aromatics (vol%)	Benzene (vol%)	Olefins (vol%)	Sulfur (ppm)	E200 (%off)	E300 (%off)	T10 (°F)	T50 (°F)	T90 (°F)
						EtoH	Mtbe	Etbe	Tame									
Summer																		
2003	Premium	94	91.7	6.8	2.2	0.1	10.0	0.2	1.6	20.4	0.82	4.0	91.3	46.3	86.5	143	207	318
	Intermediate	87	89.8	6.8	1.7	0.1	7.9	0.0	1.2	21.0	0.91	4.1	71.6	48.5	87.3	141	203	313
	Regular	102	88.2	6.8	1.3	0.0	5.7	0.0	0.9	22.5	0.99	4.1	62.4	49.5	87.9	140	201	310
	Pool	283	88.7	6.8	1.4	0.0	6.3	0.0	1.0	22.2	0.97	4.1	66.0	49.1	87.7	141	202	311
2004	Premium	142	91.6	6.5	0.9	0.0	3.3	0.1	1.3	21.4	0.92	5.3	44.9	41.1	87.5	148	214	314
	Intermediate	136	89.5	6.5	0.5	0.0	1.4	0.1	0.7	21.6	0.91	6.7	44.9	42.1	86.4	146	214	319
	Regular	158	87.8	6.5	0.1	0.0	0.1	0.0	0.2	22.0	0.92	7.9	48.7	43.2	85.6	145	212	321
	Pool	436	88.3	6.5	0.2	0.0	0.5	0.0	0.4	21.9	0.92	7.5	48.0	42.9	85.9	145	212	320
Winter																		
2003-2004	Premium	44	92.0	8.5	3.6	9.2	0.3	0.1	0.5	16.2	0.67	2.5	25.3	48.8	90.0	131	203	300
	Intermediate	41	90.2	8.5	3.6	9.4	0.1	0.0	0.2	17.5	0.84	2.9	30.6	51.4	90.0	129	194	301
	Regular	50	88.4	8.7	3.4	8.8	0.1	0.0	0.2	19.3	0.97	3.2	33.9	54.1	90.1	127	185	300
	Pool	135	88.9	8.6	3.4	8.9	0.2	0.0	0.2	18.9	0.93	3.1	32.8	53.4	90.1	127	187	300
2004-2005	Premium	28	92.1	8.5	3.6	9.4	0.1	0.0	0.6	13.9	0.59	2.9	36.1	47.8	89.9	134	205	301
	Intermediate	20	90.1	8.7	3.6	9.5	0.0	0.0	0.6	16.4	0.64	3.6	30.9	49.8	89.2	131	199	305
	Regular	27	88.3	8.7	3.7	9.5	0.0	0.0	0.5	18.7	0.72	4.6	31.1	52.6	89.4	129	190	303
	Pool	75	88.9	8.7	3.7	9.5	0.0	0.0	0.5	18.1	0.70	4.3	31.6	51.9	89.4	130	193	303

Notes: Gasoline shares for premium/intermediate/regular grades used to calculate gasoline pool properties are 11%/6%/83%.

Source: Derived from "Retail Gasoline Surveys," Area A, Arizona Department of Weights and Measures.

4. Screening Analysis of the Gasoline Options

The SoW calls for a screening evaluation of specified gasoline formulations as options for changing CBG standards, to identify which (if any) of these options – that is, alternative gasoline standards – would (1) achieve emissions benefits comparable to those of the current AZ CBG program *and* (2) increase the prospective supply of CBG.

This section describes the screening analysis conducted in Task 1 of the study and presents the results.

4.1 OVERVIEW

Consistent with the SoW, only those options passing the two tests cited above were considered further in this study.

As noted in Section 1, the SoW defines six alternative gasoline standards to be screened. Five are the gasoline formulations (or “blends”) currently supplied to five metropolitan areas in the Southwest – in particular, Albuquerque, Denver, El Paso, Las Vegas, and Tucson; the sixth is federal RFG, for the winter only.

We screened these options primarily by (1) estimating the average properties of these gasoline blends, using published data, (2) using these sets of average properties to estimate (with the Complex Model) the emissions of each alternative gasoline – NO_x and VOC in the summer, CO in the winter – and (3) comparing these to the corresponding estimated emissions of the baseline gasoline (shown in Table 3.4) to determine which (if any) of the specified gasoline blends would provide “necessary emissions benefits” for the CBG area (as defined in Section 1).

4.2 SPECIFIED GASOLINE OPTIONS

4.2.1 Albuquerque Gasoline

The Albuquerque area uses conventional gasoline (CG) in the summer, and oxygenated gasoline (i.e., CG containing an oxygenate in a specified concentration) in the winter (November 1 to February 28).

The winter gasoline program is part of the State Implementation Plan (SIP) for maintenance of the area’s attainment of the CO standard. Albuquerque winter gasoline must contain at least 2.7 wt% oxygen, with ethanol the oxygenate of choice.

The Albuquerque area receives its gasoline supplies from refineries in El Paso, Texas and New Mexico.

4.2.2 Denver Gasoline

Through 2004, the Denver-Boulder area used CG, but with a voluntary 8.5 RVP standard (i.e., $RVP \leq 8.5$ psi), in the summer; the area uses oxygenated gasoline in the winter (November 1 to February 7).

In 2004, EPA denied Colorado's request for a continuation of a long-standing EPA waiver allowing use of CG in the summer in the Denver-Boulder area. Absent the waiver, EPA requires the area to use 7.8 psi RVP CG in the summer. However, the AAM survey indicated the area continued to receive 8.5 RVP CG in the summer of 2004 – apparently because the waiver denial came too late to affect gasoline supplies last summer.

The winter gasoline program is part of the State Implementation Plan (SIP) for maintenance of the area's attainment of the CO standard. Denver-Boulder winter gasoline must contain 3.5 wt% oxygen, with ethanol as the oxygenate.

The Denver area receives its gasoline supplies primarily from local refineries.

4.2.3 Las Vegas Gasoline

The Las Vegas (Clark County) area uses CG in the summer, and a special ("boutique") gasoline in the winter (November thru March). The winter gasoline has a 10 psi RVP standard, oxygen content of 3.5 wt%, with ethanol (10 vol%) as the mandated oxygenate; and sulfur and aromatics content meeting CARB 2 standards.

Clark County receives the bulk of its gasoline supplies from the Los Angeles refining center, via the KMP West and CalNev pipelines.

4.2.4 Tucson Gasoline

The Tucson area (Area B) uses CG in the summer, and oxygenated gasoline in the winter (October thru March). The winter gasoline program is part of the State Implementation Plan (SIP) for maintenance of the area's attainment of the CO standard. The winter gasoline has a 13.5 psi RVP standard, oxygen content of 2.0 to 3.5 wt%, and ethanol as the mandated oxygenate.

Area B receives essentially all of its gasoline supplies from refineries in the West Texas/New Mexico refining center via the KMP East line and from the Gulf Coast refining center via the Longhorn Pipeline to El Paso and then the KMP East line. At present, the West Texas/New Mexico refining center is the primary source.

4.2.5 San Antonio Gasoline

The SoW calls for screening of El Paso gasoline, but we replaced El Paso with San Antonio.

We could find no information on the average properties of El Paso gasoline. (El Paso gasoline is not reported in either the AAM survey or the similar retail survey conducted by Southwest Research Institute.) San Antonio gasoline is reported in the AAM survey.

El Paso uses a 7 RVP CG in the summer and ethanol-blended oxygenated gasoline in the winter, similar to Albuquerque's winter gasoline. El Paso receives its gasoline supplies from local refineries, which also supply the Albuquerque area.

San Antonio uses a 7.8 RVP CG in the summer and CG in the winter. San Antonio receives its gasoline supplies from the Gulf Coast refining center, via pipeline.

4.2.6 Federal RFG (Winter Only)

We interpret this option to mean federal winter RFG, containing 10 vol% ethanol, and subject to the ASTM standard for RVP.

Ethanol-blended RFG is used (year round) in a few mid-western metropolitan areas – Chicago-Lake County-Gary, Indiana; Milwaukee-Racine, Wisconsin; St. Louis, Missouri, and Louisville and Covington, Kentucky – and, as of 1 January 2005, in the New York RFG areas and all of Connecticut. Mid-western RFG is ethanol-blended at 10 vol% (3.5 wt% oxygen), in response to state mandates and/or tax subsidies. No official data are available yet on the ethanol content of the New York and Connecticut RFG.

None of these areas impose any special RVP standards on winter RFG.

4.3 ESTIMATED AVERAGE PROPERTIES OF THE GASOLINE OPTIONS

Table 4.1 shows estimated average properties of the gasoline options described above (and CBG), for the 2004 summer and 2003-2004 winter seasons.

We developed these estimates using average gasoline property data from the following sources.

- Albuquerque, Denver, Las Vegas, San Antonio: *AAM North American Fuels Survey* [7]
- Tucson: *AZ DWM Retail Station Compliance Reports, Area B*
- Federal RFG (Winter): U.S. Environmental Protection Agency *Summary of Surveys Conducted by the RFG Survey Association* [8]

Table 4.2 shows in further detail the results drawn from the DWM retail surveys of Area B gasoline. The average properties for Area B gasoline shown in Table 4.1 are volume-weighted averages of the values shown in Table 4.2, calculated using the three-step procedure laid out in Section 3.2.3.

Table 4.3 shows average properties of ethanol-blended winter RFG in the various mid-western areas that use it, for the years 2000-2003, drawn from the retail surveys reported in the EPA publication cited above. The average properties for winter RFG shown in Table 4.3 are volume-weighted averages of the values shown in Table 4.2 for 2003. The weighting factors reflect volumes of RFG consumption in these areas in 2003, drawn from the DOE/EIA *Petroleum Marketing Annual 2003* [9].

TABLE 4.1: ESTIMATED AVERAGE PROPERTIES AND EMISSIONS PERFORMANCE OF CBG AND ALTERNATIVE GASOLINE OPTIONS

Properties & Emission Reductions	Summer 2004						Winter 2003-2004						
	Phoenix AZ	Albuquerque NM	Denver CO	Las Vegas NV	San Antonio TX	Tucson AZ	Phoenix AZ	Albuquerque NM	Denver CO	Las Vegas NV	San Antonio TX	Tucson AZ	Etoh-Blended RFG
Properties													
Octane ((R+M)/2))	88.3	87.7	86.9	88.0	88.9	88.1	88.9	89.2	87.5	89.0	88.5	89.2	-
RVP (psi)	6.5	8.3	8.3	8.2	7.4	7.8	8.6	12.6	14.1	9.1	12.9	10.7	12 to 15
Oxygen (wt%)	0.2	0.4	1.6			0.2	3.4	2.8	2.9	3.4	0.1	2.1	3.6
Etoh (Vol%)	0.0	1.3	4.5			0.1	8.9	8.0	8.3	9.8		5.4	10.5
MTBE (vol%)	0.5					0.1	0.2				0.4	0.1	0.1
ETBE (vol%)	0.0					0.2	0.0					0.3	0.0
TAME (vol%)	0.4					0.2	0.2					0.1	0.0
Aromatics (vol%)	21.9	31.8	28.6	33.2	33.7	28.3	18.9	26.0	22.7	22.3	25.6	28.2	17.0
Benzene (vol%)	0.92	1.86	1.54	0.74	0.62	1.36	0.93	1.62	1.34	0.58	0.70	1.39	0.79
Olefins (vol%)	7.5	10.2	10.3	7.1	11.6	8.1	3.1	10.1	8.7	3.9	11.1	11.8	6.3
Sulfur (ppm)	48	198	126	50	44	130	33	148	102	20	88	254	200
E200 (%off)	42.9	43.2	46.1	42.5	43.1	42.0	53.4	56.6	56.9	50.8	49.1	48.8	58.9
E300 (%off)	85.9	82.0	82.5	78.4	76.3	82.4	90.1	85.4	86.1	82.7	76.9	84.0	85.7
T10 (°F)	145	134	133	130	134	140	127	114	108	127	112	119	-
T50 (°F)	212	213	204	220	216	218	187	175	172	194	201	204	164
T90 (°F)	320	334	330	341	350	331	300	319	317	332	348	328	325
Complex Model Emission Reductions (%)													
VOCs	30.3	8.2	10.9	7.9	16.8	15.7							
NOx	13.6	3.9	7.0	10.8	9.5	8.0	15.7	7.0	10.3	15.3	9.2	2.4	8.8
Toxics	28	0.0	13.7	21.7	22.5	14.5	25.7	11.8	18.7	25.2	18.9	7.3	23.6
CO							23.8	15.1	18.6	22.3	9.3	7.8	18.7
Complex Model Emission Reductions Adjusted for 30 ppm Tier 2 Sulfur Standards (%)													
VOCs	30.5	10.0	11.9	8.2	17.0	16.7							
NOx	14.4	11.0	11.3	11.8	10.1	12.5	15.9	12.2	13.5	Same	11.9	11.5	15.8
Toxics	28.4	5.0	16.1	22.1	22.9	17.0	25.7	15.0	20.5		20.2	13.7	27.1
CO							23.9	19.5	21.2		11.7	16.7	24.7

Sources:

Phoenix: Exhibit A.3.

Albuquerque, Denver, Las Vegas, & San Antonio: Derived from *North American Fuels Survey*, 2004, Association of Automobile Manufacturers.

Tucson: Exhibit B.2

Etoh-Blended RFG: Exhibit B.3.

Complex Model Emission Reductions: Derived Using EPA's Phase 2 Complex Model with CO Enhancement.

TABLE 4.2: AVERAGE PROPERTIES OF GASOLINE SAMPLED AT RETAIL IN 2004, AREA B

Season & Year	Grade	No. of Samples	Octane (R+M)/2	RVP (psi)	Oxygen (wt%)	Oxygenate (vol %)				Aromatics (vol%)	Benzene (vol%)	Olefins (vol%)	Sulfur (ppm)	E200 (%off)	E300 (%off)	T10 (°F)	T50 (°F)	T90 (°F)
						EtoH	Mtbe	Etbe	Tame									
Summer																		
2003	Premium	25	91.3	7.8	0.3	0.1	0.3	0.6	0.2	38.3	1.93	5.8	242	33.8	82.0	144	233	326
	Intermediate	22	89.5	7.9	0.1	0.0	0.0	0.4	0.0	33.9	1.64	9.0	237	40.2	82.1	135	223	328
	Regular	25	88.0	8.1	0.2	0.0	0.3	0.3	0.1	28.6	1.32	11.6	241	46.0	83.0	132	210	328
	Pool	72	88.5	8.0	0.2	0.0	0.3	0.3	0.1	29.9	1.41	10.9	241	44.4	82.9	133	213	328
2004	Premium	4	91.0	7.3	0.2	0.1	0.0	0.3	0.4	27.8	1.33	4.2	75	31.3	83.5	151	232	327
	Intermediate	4	89.3	7.6	0.2	0.1	0.0	0.3	0.2	28.1	1.35	6.6	104	37.0	83.0	148	227	331
	Regular	4	87.6	7.9	0.2	0.1	0.1	0.2	0.1	28.4	1.36	8.7	139	43.8	82.3	138	215	332
	Pool	12	88.1	7.8	0.2	0.1	0.1	0.2	0.2	28.3	1.36	8.1	130	42.0	82.4	140	218	331
Winter																		
2002-2003	Premium	42	91.7	11.5	2.1	5.5	0.0	0.0	0.0	32.4	1.78	9.4	85	48.5	86.9	117	206	315
	Intermediate	42	90.2	11.4	2.1	5.5	0.0	0.0	0.0	27.2	1.39	10.8	100	50.8	87.1	116	199	315
	Regular	43	89.1	11.3	2.2	5.5	0.0	0.0	0.0	24.3	1.25	11.8	112	52.2	87.0	116	195	316
	Pool	127	89.5	11.3	2.2	5.5	0.0	0.0	0.0	25.3	1.31	11.4	108	51.7	87.0	116	196	316
2003-2004	Premium	65	91.2	10.6	2.1	5.2	0.1	0.3	0.2	35.4	1.88	8.9	173	43.4	82.4	122	220	331
	Intermediate	63	89.7	10.6	2.1	5.1	0.0	0.4	0.0	30.2	1.51	11.2	232	47.2	83.4	119	209	329
	Regular	63	88.9	10.7	2.1	5.4	0.1	0.3	0.1	27.2	1.31	12.2	265	49.6	84.2	118	201	327
	Pool	191	89.2	10.7	2.1	5.4	0.1	0.3	0.1	28.2	1.39	11.8	254	48.8	84.0	119	204	328
2004-2005	Premium	6	91.0	10.1	2.1	5.1	0.2	0.4	0.3	33.1	1.48	8.6	95	41.8	83.0	124	222	327
	Intermediate	3	89.3	10.2	2.3	5.7	0.3	0.0	0.5	29.6	1.47	10.5	125	44.7	83.0	121	211	328
	Regular	8	88.9	10.8	2.3	5.6	0.2	0.3	0.3	29.1	1.47	11.2	142	46.0	83.3	119	213	327
	Pool	17	89.2	10.7	2.3	5.5	0.2	0.3	0.3	29.5	1.47	10.9	136	45.5	83.2	119	214	327

Notes: Non-complying gasoline (some winter gasoline) is excluded from the tabulations

Summer 2004 has a small sample size -- only about four observations per grade. One sample for each of the premium and mid grades has very low aromatics -- none of the gasoline samples for 2003 had aromatics content as low. If these two samples are removed, aromatics levels for 2004 approximate those in 2003.

Gasoline shares for premium/intermediate/regular grades used to calculate gasoline pool properties are 11%/6%/83%.

Source: Derived from "Retail Gasoline Surveys," Area B, Arizona Department of Weights and Measures.

TABLE 4.3: ESTIMATED AVERAGE PROPERTIES OF ETHANOL-BLENDED WINTER RFG

	Illinois & Indiana				Wisconsin				Kentucky		Missouri	Wtg.
	Chicago-Lake Co.& Gary				Milwaukee-Racine, WI				Covington	Louisville	St. Louis	Average
	2000	2001	2002	2003	2000	2001	2002	2003	2003	2003	2003	2003
Properties												
RVP (psi)	-	-	-	-	-	-	-	-	-	-	-	-
Oxygen (wt %)	3.7	3.6	3.6	3.7	3.7	3.5	3.6	3.7	3.7	3.7	3.5	3.6
Ethanol (wt %)	10.7	10.5	10.5	10.5	10.5	10.1	10.4	10.6	10.7	10.7	9.7	10.5
MTBE (wt %)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1
ETBE (wt %)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TAME (wt %)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aromatics (vol %)	15.1	15.9	16.1	16.4	15.6	15.0	16.0	15.8	14.8	15.2	21.7	17.0
Benzene (vol %)	0.78	0.82	0.75	0.80	0.87	0.89	0.79	0.87	0.82	0.78	0.64	0.79
Olefins (vol %)	5.3	6.0	6.2	5.7	5.4	6.5	6.2	6.1	6.6	6.3	9.0	6.3
Sulfur (ppm)	249	232	232	199	265	228	194	197	239	247	173	200
E200 (% off)	59.8	59.0	60.5	58.8	59.9	60.1	59.9	60.7	61.0	62.0	55.7	58.9
E300 (% off)	85.5	85.2	85.6	85.8	85.8	86.3	86.0	85.7	88.3	88.1	83.5	85.7
T50 (°F)	161	162	158	164	160	159	161	157	156	157	174	164
T90 (°F)	327	327	327	326	326	324	325	327	311	310	330	325
Phase 2 Complex Model												
VOC Reduction (%)												
NOx Reduction (%)	8.3	8.5	8.1	9.2	7.8	8.7	9.5	9.4	8.2	7.7	7.5	8.8
Toxics Reduction (%)	22.9	22.4	23.4	23.3	22.0	23.0	24.1	23.5	24.0	24.0	21.9	23.6
CO Reduction (%)												18.7
Number of surveys	4	4	4	5	4	4	4	4	2	2	2	

Sources:

State/Area Data: EPA summary of surveys conducted by RFG Survey Association, EPA Website.

Wtg Average 2003:

Properties: Derived using State/Area data and weighting factors reflecting state RFG sales as reported in Petroleum Marketing Annual, 2003, EIA/DOE; and population data for Covington and Louisville from *Rand McNally Road Atlas*.

Phase 2 Complex Model Emissions: Derived using EPA's Phase 2 Complex Model with CO Enhancement.

4.4 SCREENING EVALUATIONS OF THE GASOLINE OPTIONS

As noted earlier, the SoW states the following primary criterion for screening the gasoline options.

“...eliminate those blends . . .likely to increase emissions by more than 5% for criteria pollutants [ozone, for which NO_x and VOCs are precursors, and CO] and 10% for total toxics over those of the baseline fuel [i.e., the baseline gasoline defined in Table 2.3 above] . . .”

After careful consideration, we concluded that the criterion lent itself to multiple interpretations. We decided to conduct the screening evaluation under each of two interpretations:

➤ **Complex Model Emissions**

Eliminate those gasoline options likely to increase *vehicle* emissions, *as measured by the Complex Model*, by more than 5% for criteria pollutants and 10% for total toxics, *relative to those of the baseline gasoline*.

➤ **Total Emissions**

Eliminate those gasoline options likely to increase *man-made and total emissions from all sources in Maricopa County*, by more than 5% for criteria pollutants and 10% for total toxics, *relative to the corresponding emissions with the baseline gasoline*.

The corresponding screening evaluations are discussed in Sections 4.4.1 and 4.4.2, respectively.

The evaluation based on Complex Model emissions was the simpler of the two, requiring only the prior estimation of the baseline gasoline properties for the CBG area. (See Section 3 and, in particular, Tables 3.3 and 3.4.) Accordingly, we completed this screening evaluation first and used its results to establish the scope of the subsequent refining analysis.

The evaluation based on total emissions from all Maricopa County sources was more challenging, requiring the prior estimation of the baseline emissions inventory for Maricopa County. (See Section 7 for a discussion of this effort, which proved to be complex and time-consuming.) We used the results of this screening evaluation to confirm the results of the Complex Model screening.

4.4.1 Screening for Complex Model Emissions

Table 3.4 shows the emissions reductions estimated by the Complex Model for the baseline gasoline.

Applying to these estimates of baseline emissions the 5% and 10% “discount factors” expressed in the screening criterion yields a set of target emission reduction values for screening based on Complex Model emissions. The targets are shown in **Table 4.4**.

TABLE 4.4: TARGET EMISSIONS REDUCTIONS: SUMMER AND WINTER

Emission	Summer	Winter
	(% Reduction)	
VOCs	29.0	
NOx	13.7	15.1
Toxics	25.6	23.1
CO		22.7

Table 4.1 shows two sets of estimated emissions reductions returned by the Complex Model for the specified gasolines. One set corresponds to the estimated properties shown in Table 4.1. The other set corresponds to the same properties, but with sulfur content set at 30 ppm to reflect effects of the Tier 2 sulfur control program as of 2006. (Comparison of the two sets of estimates shows the strong effect of sulfur reduction on emissions performance, especially NOx reduction, registered by the Complex Model.)

Tables 4.5a and **4.5b** show the latter (sulfur-adjusted) set of estimated emissions reduction, for the summer and winter gasolines, respectively. These estimated emissions reductions were compared with the adjusted baseline emission reductions, shown in Table 4.4.

TABLE 4.5A: ESTIMATED EMISSIONS PERFORMANCE OF AZ CBG AND GASOLINE OPTIONS: SUMMER 2006
COMPLEX MODEL EMISSIONS REDUCTIONS (%)

Emissions	Phoenix (CBG area)	Albuquerque NM	Denver CO	Las Vegas NV	San Antonio TX	Tucson (Area B)
VOCs	30.5	10.0	11.9	8.2	17.0	16.7
NOx	14.4	11.0	11.3	11.8	10.1	12.5
Toxics	28.4	5.0	16.1	22.1	22.9	17.0
CO						

TABLE 4.5B: ESTIMATED EMISSIONS PERFORMANCE OF AZ CBG AND GASOLINE OPTIONS: WINTER 2006
COMPLEX MODEL EMISSIONS REDUCTIONS (%)

Emissions	Phoenix (CBG area)	Albuquerque NM	Denver CO	Las Vegas NV	San Antonio TX	Tucson (Area B)	Federal RFG (Winter)
VOCs							
NOx	15.9	12.2	13.5	15.3	11.9	11.5	15.8
Toxics	25.7	15.0	20.5	25.2	20.2	13.7	27.1
CO	23.9	19.5	21.2	22.3	11.7	16.7	24.7

Only those gasoline formulations offering emissions reductions *greater than those shown in Table 4.4* meet the screening criterion. Clearly, under the Complex Model interpretation of the screening criterion, only one gasoline formulation does so: *federal RFG* in the *winter* season, as it is currently being produced for RFG markets in the mid-west.

Accordingly, none of the other gasoline formulations received further consideration in this study.

4.4.2 Screening for Total Emissions

The emissions performance predicted by the Complex Model is expressed as emissions changes relative to a hypothetical baseline gasoline (with properties equal to the 1990 average for U.S. summer gasoline). Hence, it is necessary to combine Complex Model predictions with emissions data applicable to Maricopa County to fully investigate the absolute emissions impacts of the various alternative formulations.

There are two constraints that should be recognized in reviewing the total emissions screening. First, as described in Section 7, available emissions inventories are limited to the summer season (with the exception of CO). Therefore, the total emissions screening analysis focused solely on the summer specifications of the alternative formulations. Second, as a screening analysis, the rigor relative to a detailed emissions analysis is necessarily constrained. The Complex Model estimates emissions changes for a 1990-era passenger car fleet; in principle, Complex Model outputs can be applied precisely only to emissions associated with the fraction of gasoline consumed by such vehicles. But not all gasoline is consumed in 1990-era passenger cars. Applying Complex Model outputs to gasoline consumed by post-1990 passenger cars as well as by other onroad vehicles and nonroad engines necessarily involves some uncertainty. Detailed adjustments designed to minimize such uncertainty are explicitly included in the detailed emissions evaluation conducted for the gasoline formulations that met the screening criterion (as presented in Section 8). However, for the screening analysis itself, Complex Model predictions are assumed to be reasonably representative of the emissions impacts that can be expected for the entire pool of gasoline consumed in the CBG area.

Note that the screening analysis does not include an estimate of PM emission impacts, because the Complex Model does not estimate PM emission impacts. Analysis of PM emissions must be conducted using other analysis tools, not easily included in a screening-level analysis. However, changes in gasoline-related PM emissions will result primarily from changes in fuel sulfur content, and to a lesser extent from changes in gasoline-related NO_x emissions. Thus, comparative fuel sulfur contents and screening analysis results for NO_x provide a reasonable surrogate for PM. Moreover, since gasoline sulfur content will be restricted to 30 ppm on average for *all* U.S. gasoline starting in 2006, it is likely that any significant differences between gasoline formulations in their PM emissions performance will decline dramatically after this year.¹⁹

¹⁹ Gasoline sulfur content limits are an integral component of the national Tier 2 motor vehicle emission standards. The 30 ppm limit on average sulfur content will take effect in 2006.

By relating Complex Model predictions for candidate gasoline formulations to Complex Model predictions for current Maricopa County gasoline, impacts on the *fraction of total Maricopa County emissions associated with gasoline combustion* can be derived directly from Complex Model outputs. In conducting this analysis, the sulfur content of the baseline Maricopa County gasoline and each of the candidate fuel formulations has been adjusted to 30 ppm to reflect the impending national sulfur limitation (as described in Section 4.4.1). **Table 4.6** presents the impacts predicted by such an approach (which is equivalent to that described in Section 4.4.1), where positive values indicate emissions increases and negative values indicate emissions decreases.

As indicated in Table 4.6, all of the candidate gasoline options violate the 5% criterion for VOC, and all are near or exceed the 10% criterion for toxic compound emissions. However, these data represent increases in gasoline-related emissions, which constitute only a fraction of total Maricopa County emissions.

Using the emission distribution data presented in Section 7, gasoline-specific impacts can be converted to overall emissions impacts. As indicated in Tables 7.11 and 7.12, the fraction of Maricopa County emissions associated with gasoline combustion changes over time in accordance with national and local control programs as well as changes in source distributions, etc. For screening analysis purposes, the gasoline emissions fractions from Tables 7.11 and 7.12 were averaged to derive an average emission fraction for the 2005-2010 time period. This average fraction was then applied to the gasoline-specific emissions impacts of Table 4.6 to derive estimates of the impact on both all man-made and total emissions. The resulting impacts are presented in **Tables 4.7 and 4.8** respectively, as well as graphically in **Figures 4.1 through 4.3** (in both the tables and the figures, positive values indicate emissions increases and negative values indicate emissions decreases).

As the tables and figures indicate, although the expanded analysis shows increasing compliance with the screening criteria, all of the candidate formulations continue to violate the 5% emissions increase criterion for VOC (albeit by a substantially diminished amount relative to the initial analysis). All candidate formulations meet the 5% criterion for NO_x and the 10% criterion for toxic compound emissions, while screening analysis impacts for CO vary across the candidate formulations.

Regardless, on the basis of estimated VOC impacts in the summer season, none of the candidate fuel formulations satisfies the screening criterion in the SoW.

TABLE 4.6: SCREENING ANALYSIS – AVERAGE 2005/2010 CHANGE IN GASOLINE EMISSIONS

Pollutant	Albuquerque Blend	Denver Blend	Las Vegas Blend	San Antonio Blend	Tucson Blend
VOC	+29.1%	+25.6%	+31.7%	+19.8%	+19.1%
CO	+3.0%	-2.4%	+7.1%	+8.4%	+2.1%
NO _x	+3.9%	+3.6%	+3.1%	+5.0%	+2.3%
Toxics	+31.6%	+18.0%	+9.5%	+8.1%	+15.9%

Only values in bold italics meet the screening criteria.

TABLE 4.7: SCREENING ANALYSIS – AVERAGE 2005/2010 CHANGE IN MANMADE EMISSIONS

Pollutant	Albuquerque Blend	Denver Blend	Las Vegas Blend	San Antonio Blend	Tucson Blend
VOC	+10.5%	+9.2%	+11.4%	+7.1%	+6.9%
CO	+2.5%	-2.0%	+6.0%	+7.0%	+1.8%
NO _x	+1.2%	+1.1%	+1.0%	+1.6%	+0.7%
Toxics	+11.4%	+6.5%	+3.4%	+2.9%	+5.8%

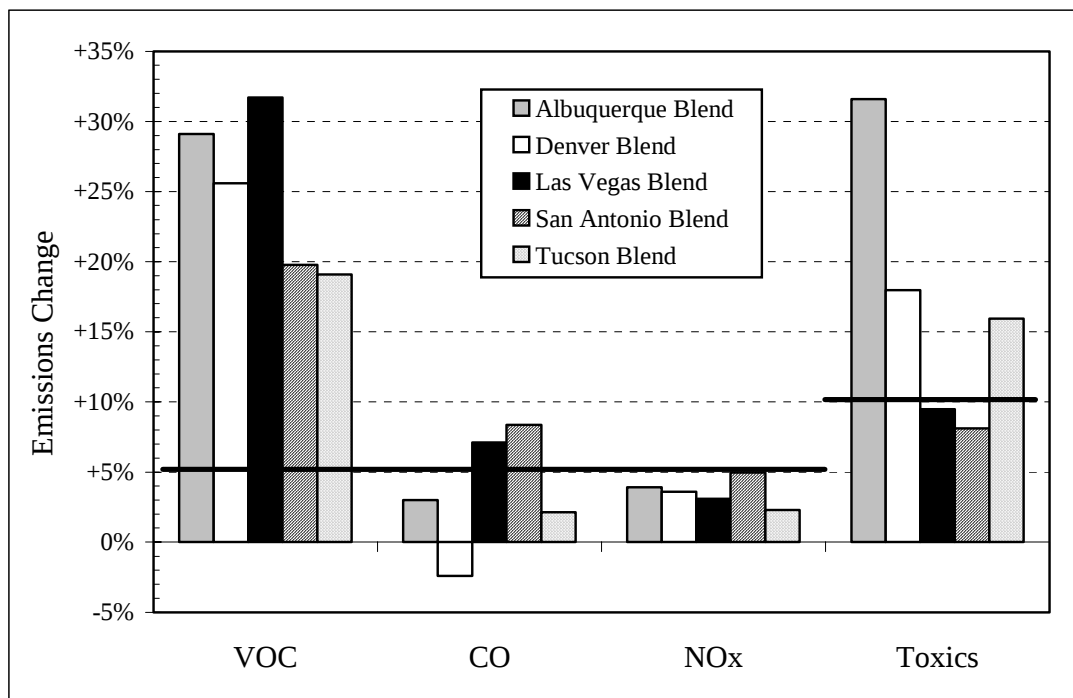
Only values in bold italics meet the screening criteria.

TABLE 4.8: SCREENING ANALYSIS – AVERAGE 2005/2010 CHANGE IN TOTAL EMISSIONS

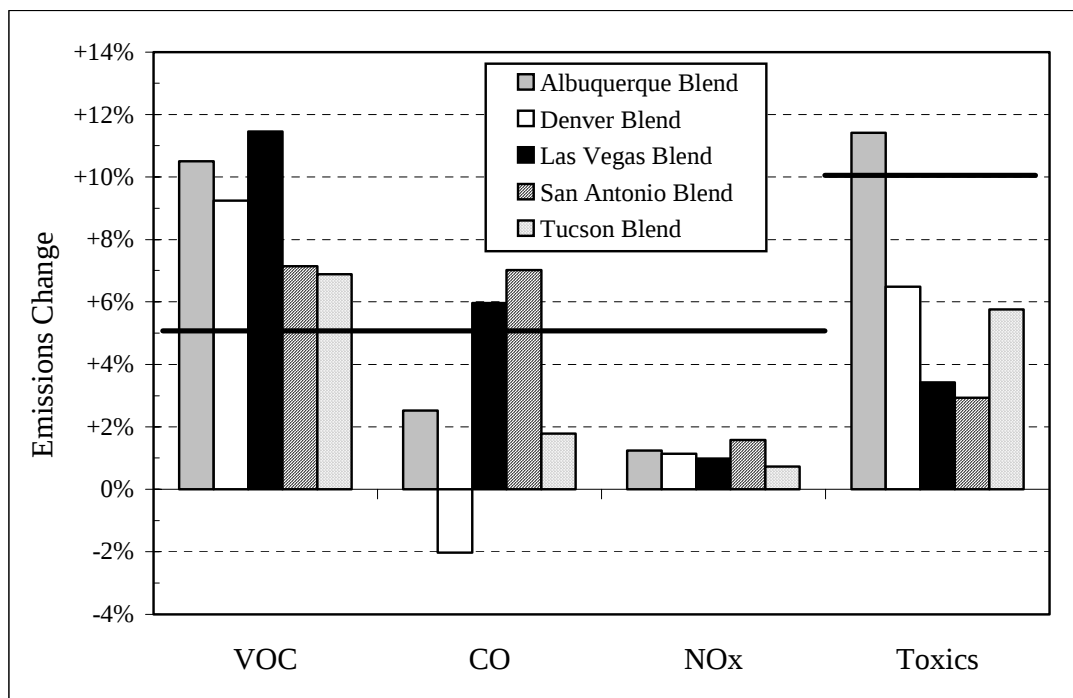
Pollutant	Albuquerque Blend	Denver Blend	Las Vegas Blend	San Antonio Blend	Tucson Blend
VOC	+8.8%	+7.7%	+9.5%	+6.0%	+5.7%
CO	+2.5%	-2.0%	+6.0%	+7.0%	+1.8%
NO _x	+1.2%	+1.1%	+0.9%	+1.5%	+0.7%
Toxics	+9.5%	+5.4%	+2.9%	+2.4%	+4.8%

Only values in bold italics meet the screening criteria.

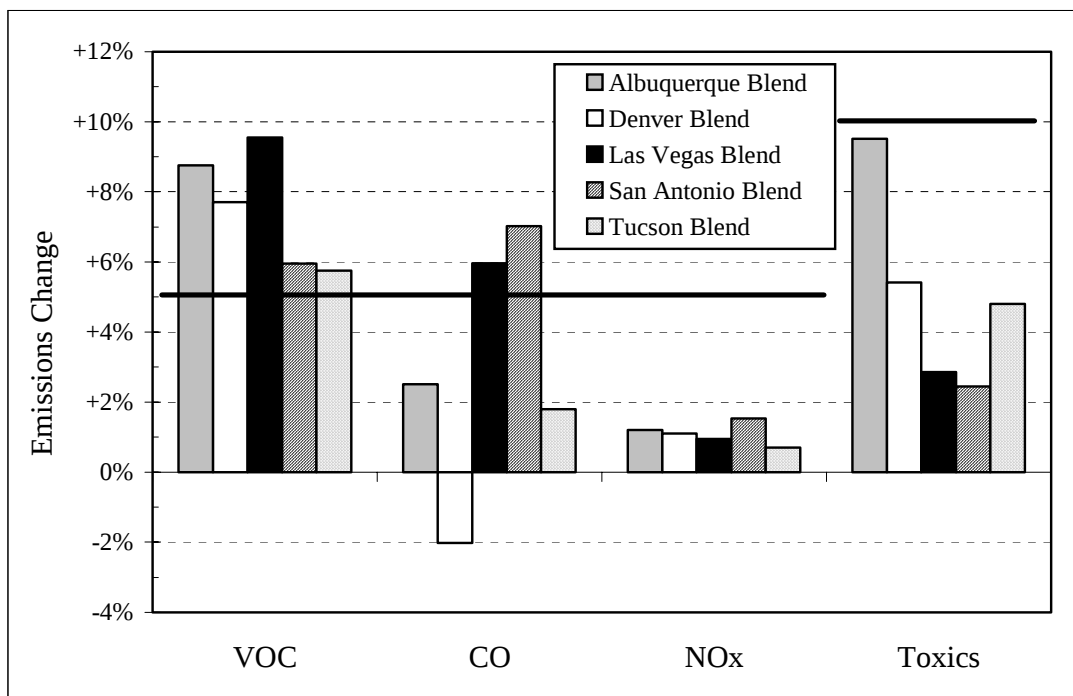
**FIGURE 4.1: CHANGE IN AVERAGE 2005/2010 GASOLINE-RELATED EMISSIONS
(SCREENING ANALYSIS – ALL FUELS AT 30 PPM SULFUR)**



**FIGURE 4.2: CHANGE IN AVERAGE 2005/2010 MANMADE EMISSIONS
(SCREENING ANALYSIS – ALL FUELS AT 30 PPM SULFUR)**



**FIGURE 4.3: CHANGE IN AVERAGE 2005/2010 TOTAL EMISSIONS
(SCREENING ANALYSIS – ALL FUELS AT 30 PPM SULFUR)**



5. Gasoline Supply to the CBG Covered Area

This section provides an overview of the distribution system supplying the CBG area, developed in Task 2, and a brief assessment of the implications for this system of the various CBG options considered in this study.

5.1 PIPELINE SYSTEM SUPPLYING THE CBG COVERED AREA AND ENVIRONS

The Phoenix area receives almost all of its gasoline (including AZRBOB) and other refined products by pipeline. Small additional volumes of CBG reach the area by truck and rail.

Figure 5.1 shows the pipeline system serving the Phoenix area.

As Figure 5.1 shows, the Phoenix area is served directly by one refined product pipeline system, owned and operated by Kinder Morgan Energy Partners, L.P (KMP). KMP's South System is a common carrier, which delivers refined products (AZ CBG, conventional gasoline, jet fuel, diesel fuels) to terminals in Phoenix, Tucson, and other locations in Arizona through two pipelines. The KMP West line moves refined products from the Los Angeles refining center to Phoenix and onward to Tucson.²⁰ The KMP East line moves refined products produced in the West Texas/New Mexico and Gulf Coast refining centers from El Paso, TX, to Tucson and onward to Phoenix. By virtue of this configuration, Phoenix is served by both West-side and East-side refineries.

The West line is a high capacity (24" and then 20") line from Carson, CA (in the Los Angeles Basin) to Phoenix, with a smaller (6") line from Phoenix to Tucson.²¹ The West line carries refined products produced in the Los Angeles refining center, as well as lesser volumes of refined products shipped into Los Angeles from other refining centers (e.g., Puget Sound, San Francisco Bay). At Colton (in Southeastern California, near the border with Arizona), the West line connects with KMP's CalNev pipeline, which carries refined products, including Las Vegas's special gasoline formulation, to the Las Vegas area. Average transit time from Carson to Phoenix is 6-7 days.

The East line is a 12" and 8" looped line from El Paso to Tucson, with an 8" line from Tucson to Phoenix. The East line carries refined products produced in the West Texas/New Mexico and Gulf Coast refining centers. Average transit time from El Paso to Phoenix is 5-6 days, to which must be added the transit times from the source refineries to El Paso.

Several proprietary pipelines deliver refined products to El Paso for onward shipment in the East line. In addition, refined products and gasoline blendstocks from the Gulf Coast refining center move to El Paso through the new Longhorn Pipeline, which connects there with the KMP East line, and through the existing Magellan Pipeline Co. South line, which supplies gasoline and gasoline blendstocks to the Western Refining Co. refinery.

²⁰ After October 2005, no gasoline shipped from the Los Angeles refining center will move east of Phoenix.

²¹ The 6" line will be shut down in October 2005.

FIGURE 5.1: PIPELINE SYSTEM SUPPLYING GASOLINE TO THE PHOENIX AREA



The Longhorn Pipeline, through its connection with the East line, makes the Phoenix area more accessible to refineries in the Gulf Coast refining center, the largest in the United States. However, average transit time to El Paso in the Longhorn line is ≈ 30 days.

5.2 PIPELINE AND OTHER TARIFFS

Table 5.1 shows the relevant tariffs for the pipelines of primary interest, as of July 1, 2005.

As the table indicates, the pipeline tariffs from the Gulf Coast to El Paso add a significant increment to the price of gasoline, CIF²² Phoenix.

TABLE 5.1: PIPELINE TARIFFS

Pipeline	Tariff		
	From	To	Rate (¢/gal)
Kinder Morgan West	Los Angeles, CA	Phoenix, AZ	3.38
Kinder Morgan East	El Paso, TX	Phoenix, AZ	1.91
Longhorn	Galena Park, TX	El Paso, TX	6.00
Magellan South	East Houston, TX	El Paso, TX	5.61

We estimate the following costs for other modes of transporting gasoline bound for Phoenix:

- Truck shipments from El Paso to Phoenix: $\approx 12\text{¢/gal}$;
- Rail shipments from West Texas to Phoenix: $\approx 6\text{¢/gal}$;
- Product tanker shipments from Puget Sound²³ to Los Angeles: $\approx 5\text{¢/gal}$.

5.3 CBG VOLUME IN 2004

Table 5.2 shows estimated average daily gasoline and AZRBOB volumes delivered to Phoenix in 2004 by the West and East lines and by other modes.

TABLE 5.2: DELIVERIES OF GASOLINE TO PHOENIX TERMINALS VIA KMP PIPELINE SYSTEM

	Average Delivery Volumes (K Bbl/day)		
	Summer (1)	Winter (2), (3)	Annual (4)
AZ CBG	97.1	94.0	96.2
West line	50.8 (52%)	49.0 (52%)	50.9 (53%)
East line	46.3 (48%)	45.0 (48%)	45.3 (47%)
Conventional (5)	16.9	13.8	15.4
West line			10.3 (67%) est.
East line			5.1 (33%) est.

1. The summer gasoline season is May 1 to September 15.
2. The winter gasoline season is November 2 to March 1.
3. Indicated winter volumes for CBG are actually AZRBOB volumes
4. The annual averages cover the full twelve months, and therefore include the two transition seasons (not shown in the table) as well the summer and winter seasons.
5. KMP did not provide a breakdown of conventional gasolines by source. The estimates are MathPro's.

²² CIF (Cargo, Insurance, Freight) denotes the price of a cargo at its destination, including shipping costs.

²³ Volumes of AZ CBG produced in the Puget Sound or San Francisco refining centers, as some were in 2004 (primarily in winter months), move by product tanker to Los Angeles and then onward by pipeline to Phoenix.

The CBG area and environs received by pipeline an average of about 96 K Bbl/day of AZ CBG and about 15 K Bbl/day of conventional gasoline (CG) in 2004, with relatively little seasonal variation. About 53% of the CBG volume came from the West line, and 47% from the East line.

We estimated these volumes from data provided by KMP on total monthly shipments and deliveries of AZ CBG through the East and West lines. Information provided by KMP indicated that (1) all gasoline shipments via the West line went to Phoenix (that is, Tucson received gasoline only from the East line) and (2) a small volume of AZ CBG was delivered to Tucson via the East line.

We assume this latter volume moved onward to Phoenix by truck.²⁴ Hence, it is included in the East line CBG delivery volumes shown in Table 4.2.

In addition to the pipeline volumes, the CBG area received small volumes – we estimate about 1 K Bbl/day – of CBG by truck and rail (direct from West Texas/New Mexico refineries), as well as ethanol for terminal blending with AZRBOB in the winter months.

5.4 WEST AND EAST LINE CAPACITY UTILIZATION AND PLANNED EXPANSION

In normal operations, the East line is fully allocated (i.e., operates at full capacity), with suppliers receiving allocations, or prorated shares, of pipeline capacity. By contrast, in normal operations, the West line operates with spare capacity. Hence, in general, the Los Angeles refining center is the marginal supplier of gasoline to the Phoenix area.

If gasoline deliveries on the East side were interrupted, as occurred in August 2003, the West line could deliver additional volumes to make up (in whole or in part) for resulting supply shortfalls in Phoenix and Tucson. But it could do so only if refineries in the Los Angeles and/or Puget Sound refining centers were to increase their production of the required gasolines on short notice. On the other hand, if gasoline supply is interrupted on the West side, resulting supply shortfalls could be made up only by trucking or railing additional gasoline from terminals in El Paso, the West Texas/New Mexico refineries, or the Los Angeles refining center (an expensive and limited-volume operation).

KMP has undertaken a project to expand the capacity of the East line from El Paso to Phoenix. The project involves increasing the throughput capacity of the East line from El Paso to Phoenix and adding a staging terminal in El Paso. KMP has stated that it plans to complete the expansion by the second quarter of 2006. The project will increase the total capacity of the East line, from El Paso to Phoenix, by 45 K Bbl/day. KMP expects about 25 K Bbl/day of the added capacity will be allocated to gasoline.²⁵ Most of this increase in gasoline carrying capacity is likely to be allocated to CBG. (In

²⁴ This truck routing was necessity by a loss in capacity in the East line between Tucson and Phoenix as a result of the August 2003 interruption incident.

²⁵ The expansion will increase total capacity of the East line to 147 K Bbl/day from El Paso to Tucson and to 99 K Bbl/day from Tucson to Phoenix. On August 4, 2005, Kinder Morgan announced an additional expansion project, which will increase East line capacity to 170 K Bbl/day.

August 2005, KMP announced another capacity expansion project, slated to add 23 K Bbl/day of capacity from El Paso to Tucson, slated for completion in the summer of 2007.)²⁶

After the expansion(s), the East line is likely to continue being fully allocated, with marginal supplies to Phoenix continuing to come from the West.

5.5 SOURCING OF CBG SUPPLIES

The planned expansion of the East line reflects not only growth in demand for refined products in Arizona markets but also a continuing change in the sourcing of AZ CBG – that is, the particular refineries supplying CBG and the volumes supplied by each. In particular, the proportion of CBG gasoline supplied by the West line has been decreasing in recent years, and the proportion supplied by the East line has been increasing correspondingly. In 1997, the West line handled about 72% of gasoline supplies to the Phoenix area; by 2004, the West line share had decreased to about 53%, as indicated above. If the expanded East line operates fully allocated, the West line share will decrease even more.

The sourcing pattern of AZ CBG is the result of a complex interplay of technical and economic factors involving

- The economics of refiners in the Los Angeles and West Texas/New Mexico refining centers;
- The economics of importing into Los Angeles gasoline and gasoline blendstocks produced in the Puget Sound refining center and foreign refining centers; and
- The carrying capacity and tariff rates of the pipelines.

On the refining and import side, these factors include refinery configurations and operations, demand for gasolines other than AZ CBG produced by the refineries, refining costs, and capabilities for segregating different gasoline types in refinery tankage. On the pipeline side, they include tariffs, total capacity, and capacity allocations.

In general, one can say the West side is long on pipeline capacity and short on refining capacity to supply CBG and other refined products, whereas the East side is short on pipeline capacity but long on refining capacity.

5.6 REGISTERED SUPPLIERS OF ARIZONA CBG

As of May 1, 2005, the list of registered suppliers of AZ CBG maintained by the AZ Department of Weights and Measures (and available on its web site) included the six sources (primarily refineries) in the Los Angeles refining center, three in San Francisco Bay, two in Puget Sound, five in West Texas/New Mexico, and two in the Gulf Coast. Not all of these are necessarily supplying AZ CBG in any given period.

²⁶ These expansions are likely to trigger increases in the Kinder Morgan East tariff shown in Table 5.1. As of the date of this report, KMP had not filed a request for a tariff increase.

5.7 LOCAL STORAGE CAPACITY AND STOCKS OF ARIZONA CBG

The Phoenix terminal complex comprises five essentially contiguous bulk terminals, operated by

- ConocoPhillips (community)
- CalJet (community)
- Kinder Morgan (community)
- BP/ARCO (proprietary)
- ChevronTexaco (proprietary)

Table 5.3 shows our estimates of (1) the aggregate *working storage capacity* and (2) the average volume of *stocks* (inventory) of all refined products and gasoline in particular in the Phoenix terminal complex.

We estimated the aggregate working storage capacities using information in the *Petroleum Terminal Encyclopedia* [16] and the results of a one-time survey of Phoenix terminal operators conducted by AZ Department of Weights and Measures in August 2003. We assumed tankage working capacity to be 90% of reported safe fill capacity (allowing 10% of safe fill capacity for tank heels – the residual volumes remaining after tanks are emptied). The resulting estimate of the aggregate working capacity of the CBG tanks in the Phoenix terminal complex, shown in Table 5.3, corresponds in volume to about ten days of CBG consumption.

TABLE 5.3: ESTIMATED STORAGE CAPACITY AND STOCKS IN PHOENIX TERMINALS

Category	Working Capacity (K Bbl)		Average Stocks (K Bbl)	
All Products		1907		
Gasoline		1366		≈ 440–480
CBG	1042		≈ 340–360	
Conventional	324		≈ 100–120	
Ethanol (winter)		101		≈ 30–35

Gasoline stocks (inventories) – as distinct from storage capacity – are not a matter of public record. However, the average volume of gasoline stocks held in the Phoenix terminal complex probably appears to be considerably less than the aggregate working capacity. The estimates in Table 5.3 reflect the August 2003 survey mentioned above and comments by various people with knowledge of refined product logistics for Phoenix.

Comparison of the estimated pipeline deliveries of CBG to Phoenix (Table 5.2) with the reported stocks of CBG and ethanol (Table 5.3) in August 2003 indicates those local stocks amounted to roughly four days of CBG consumption – several days less than the pipeline transit times to Phoenix from either Los Angeles or El Paso.

By way of comparison, consider the relationship of gasoline stocks to daily supply in the U.S. as a whole and in PADD 5²⁷ in particular. Nationwide, stocks of refined products, including gasoline and gasoline blendstocks, are held by refineries (most of which are close to at least some of their markets), pipelines, and product terminals.

All of these entities file confidential reports on refined products stocks, by region, to the U.S. Department of Energy/Energy Information Agency (EIA) weekly, monthly, and annually. EIA reports stock volumes by PADD at various intervals and in various publications, including the *Petroleum Supply Monthly* (PSM) and the *Petroleum Supply Annual* (PSA).

Table 5.4 shows, for the U.S. as a whole and for each PADD, the following information drawn from *PSA 2004*:

- Stocks of finished gasoline and gasoline blendstocks, year-end 2004, by facility type; and
- Average daily finished gasoline supply (i.e., the implicit gasoline demand) in 2004.

Table 5.4 also shows measures, computed from the *PSA 2004* data, of various gasoline stock volumes expressed in terms of average supply-days (i.e., the number days of average demand that could be met by the indicated stock volumes). For example, stocks of finished gasoline and gasoline blendstocks (year-end 2004) at terminals (only) were equal to approximately ten days of gasoline demand nationwide and seven days of demand in PADD 5.

Many refineries, particularly those in PADDs 1 and 5, are located close to (or indeed within) their primary market areas and have their own facilities for supplying these markets directly. Hence, some significant portion of refinery stocks (varying from PADD to PADD) is equivalent to terminal stocks, in the sense that they are “prompt stocks” – close, in distance and time, to final demand sites. For this reason, Table 5.4 shows the supply-day equivalents of various combinations of terminal and refinery stocks, each combination representing a possible level of prompt stocks. For example, stocks of finished gasoline and gasoline blendstocks (year-end 2004) at terminals and refineries (together) were equal to approximately fourteen days of gasoline demand in PADD 1 and seventeen days of demand in PADD 5.

These estimates suggest the Phoenix area has available, on average, significantly lower prompt stocks of gasoline (in terms of supply-days) than large metropolitan areas in PADD 5 (e.g., Los Angeles, San Francisco, San Diego) and elsewhere in the U.S. (e.g., New York, Chicago, Houston) that contain or are close to refining centers.

Phoenix is not the only large metropolitan area receiving its gasoline from remote sources. Others (e.g., Las Vegas, Washington, DC, Atlanta) are similarly situated. We have not determined whether or not any of these areas have the benefit of larger prompt supplies of gasoline than Phoenix, because information on stocks at the terminal or the metropolitan area level is not in the public domain.

²⁷ PADD denotes Petroleum Administration for Defense District, an aggregation of contiguous states established by the federal government for administrative purposes. The fifty states and the District of Columbia are grouped into five PADDs. PADD 5 encompasses Arizona, California, Nevada, Oregon, and Washington. For a map showing the states in each PADD, see any *Petroleum Supply Annual* [10].

TABLE 5.4: U.S. GASOLINE STOCKS, GASOLINE DEMAND, AND SUPPLY-DAY MEASURES

	U.S. Total	PADD				
		1	2	3	4	5
Stocks, Year-End 2004 (K Bbl)						
Refinery	69,403	9,025	12,728	27,179	4,130	16,341
Finished Gasoline	28,561	4,175	5,418	13,845	2,245	2,878
Gasoline Blendstocks	40,842	4,850	7,310	13,334	1,885	13,463
Terminal	86,670	36,541	20,866	17,154	1,065	11,044
Finished Gasoline	63,600	27,733	17,022	12,859	947	5,039
Gasoline Blendstocks	23,070	8,808	3,844	4,295	118	6,005
Pipeline	58,925	14,251	20,012	19,056	1,469	4,137
Finished Gasoline	50,961	13,165	17,239	18,084	1,469	1,004
Gasoline Blendstocks	7,964	1,086	2,773	972	-	3,133
All Finished Gasoline	143,122	45,073	39,679	44,788	4,661	8,921
All Gasoline Blendstocks	71,876	14,744	13,927	18,601	2,003	22,601
Gasoline Supplies, 2004 Average, (K Bbl/day)	9063	3207	2615	1365	284	1592
Stocks, Year-End 2004 (Days of Average Supply)						
Refinery	7.7	2.8	4.9	19.9	14.5	10.3
Terminal	9.6	11.4	8.0	12.6	3.8	6.9
Terminal + 1/2 Refinery	13.4	12.8	10.4	22.5	11.0	12.1
Terminal + Refinery	17.2	14.2	12.8	32.5	18.3	17.2
Terminal + Refinery + P/L	23.7	18.7	20.5	46.4	23.5	19.8

Notes:

1. *Gasoline Blendstocks* does not include oxygenates -- ethanol, MTBE, and others -- not yet blended into gasoline
2. *Gasoline Supplies* include imports and net inter-PADD transfers of gasoline

5.8 ARIZONA CBG CLASSES AND FUNGIBILITY

The KMP system sets monthly receipt specifications and shipping schedules for AZ CBG to ensure timely delivery to Phoenix of gasoline batches corresponding to AZ CBG standards and seasonal industry standards (e.g., the ASTM standard for Reid Vapor Pressure.)

Year-round, the KMP system recognizes one AZ CBG type, in two grades: Regular grade CBG and Premium grade CBG (pipeline product codes X and Z, respectively). This means all batches of a given grade of AZ CBG shipped via the West and East lines must be mutually fungible – that is, amenable to commingling with other batches of CBG in the pipeline, pipeline break-out tanks, and terminals.

6. Technical and Economic Assessment of the Supply of CBG Options

Task 3 involved estimating the incremental refining costs and other technical and economic implications of the various CBG options defined in the SoW. We conducted this analysis using refinery LP modeling of the California and West Texas/New Mexico refining centers.

This section lays out the framework for the refinery modeling analysis, identifies the cases analyzed, briefly discusses methodology, and presents the primary results of the analysis.

6.1 TERMINOLOGY

For clarity, we denote the various CBG options considered in the analysis in terms of the applicable certification model (Complex Model or Predictive Model) and gasoline season:

- Fed-S: Federal RFG summer, no oxygen required, no toxics control (*Type 1 CBG*)
- Fed-W: Federal RFG winter, 10 vol% ethanol blended

- Cal2-S: CARB 2 summer gasoline, ethanol blended or non-oxygenated (*Type 2 CBG*)
- Cal2-W: CARB 2 winter gasoline, 10 vol% ethanol blended, 9 RVP (*Type 2 CBG*)

- Cal3-S: CARB 3 summer gasoline, ethanol blended or non-oxygenated (*Type 2 CBG*)
- Cal3-W: CARB 3 winter gasoline, 10 vol% ethanol blended, 9 RVP (*Type 2 CBG*)

- Cal3-WR: CARB 3 winter gasoline, with relaxed RVP and oxygen standards

In this notation, Fed-S denotes Type 1 CBG. Fed-W denotes federal RFG conforming to the Type 2 CBG winter standard for oxygen content; Cal2-S and Cal2-W denote the current Type 2 CBG, summer and winter; Cal3-S and Cal3-W denote the prospective new Type 2 CBG contemplated in HB 2207, summer and winter; and Cal3-WR denotes the set of variants of the Type 2 winter standard, defined as Option 4 in the Statement of Work and Section 6.2 below.

Also for simplicity, we use the term *ethanol-blended gasoline* to denote not only finished gasoline containing ethanol, but also the base blends (e.g., CARBOB, AZRBOB, etc.) produced by refineries for ethanol blending at terminals or end-use locations.

6.2 SPECIFIED CBG OPTIONS

The SoW specified four options to be analyzed, not counting those eliminated in the screening analysis. In terms of the notation defined above, the four options are:

1. Add Cal3-S and Cal3-W as *additional* acceptable standards under the CBG program.

2. *Substitute* Cal3-S and Cal3-W for Cal2-S and Cal2-W as the Type 2 standards, as required under HB 2207.
3. *Relax* the RVP and oxygen content requirements of the winter standard:
 - ▶ 11 psi and 3.5 wt% oxygen
 - ▶ 11 psi and 2.0 wt% oxygen
 - ▶ 13.5 psi and 3.5 wt% oxygen
 - ▶ 13.5 psi and 2.0 wt% oxygen
4. *Substitute* Fed-W for Cal2-W as the CBG winter standard

Translating these options into a set of scenarios for analyzing the technical and economic effects of the options on refinery production of AZ CBG requires consideration of various technical and economic issues, some of which are discussed below.

6.3 FACTORS SHAPING THE TECHNICAL AND ECONOMIC ANALYSIS OF CBG PRODUCTION

This section briefly discusses some important factors, bearing on the distribution system and the refining centers, that shape the refinery modeling approach.

6.3.1 Fungibility in the Pipeline and Terminals

For both physical and regulatory reasons, gasoline batches that are ethanol blended and those that are not ethanol blended are non-fungible; that is, they must be segregated from the refinery to the pump.

As discussed in Section 5.8, the KMP system recognizes just one AZ CBG type, meaning all batches of a given grade (regular or premium) of AZ CBG shipped via the West and East lines must be fungible. Batches of AZRBOB for local ethanol blending to produce ethanol-blended CBG are not fungible with batches of finished, non-oxygenated CBG (due to differences in octane and RVP).

The refineries supplying the CBG area deal with the fungibility issue by restricting CBG supplies to a single type in any given season. In the summer, the current program requires either Fed-S, with ethanol permitted but not required, or Cal2-S with ethanol permitted but not required. The refining and distribution industry has elected to supply only non-oxygenated CBG, primarily Fed-S. (Non-oxygenated and MTBE-blended CBG batches are fungible, and both were supplied to the CBG area in the summer prior to Arizona's MTBE ban.) In the winter, the current CBG program calls for just one gasoline class – Type 2 CBG (Cal2-W, in the notation of this discussion), which is ethanol blended – and refiners supply Type 2 AZRBOB accordingly.

Enabling the distribution system to handle two gasoline segregations (i.e., non-fungible gasoline types) would require investment in additional tankage and other equipment in the pipeline and terminals. We understand KMP has no plans for undertaking such investments.

Adopting the CARB 3 Gasoline Standard for Arizona Cleaner Burning Gasoline

Because the existing KMP system cannot segregate two non-fungible gasoline types, the gasoline volumes supplied to the CBG area via both the East and West lines must be either

- All ethanol blended
OR
- All non-oxygenated.

In the winter, the existing distribution system can accommodate either (1) any combination of AZRBOBs for Cal2-W and Cal3-W OR any of the Cal3-WR variants. Cal2-W and Cal3-W would be mutually fungible, so long as the all batches are prepared for the same volume of ethanol blending, and would be interchangeable with respect to the AZ CBG program; the Cal3-WR variants would not be mutually fungible with Cal2-W or Cal3-W because of differences in RVP.

In the summer, the existing distribution system could accommodate either any combination of ethanol blended Fed-S, Cal2-S and Cal3-S (so long as the batches all are prepared for the same volume of ethanol blending) OR any combination of non-oxygenated Fed-S, Cal2-S, or Cal3-S – but not both.

6.3.2 Supply Capabilities of the Los Angeles Refining Center

Table 6.1 shows annual gasoline production in the California refining sector from 1996 through 2004 (excluding imported CARBOB volumes).

TABLE 6.1: AVERAGE DAILY GASOLINE PRODUCTION IN THE CALIFORNIA REFINING SECTOR: 1996-2004

Year	Crude Runs (K Bbl/day)	Average Gasoline Production (K Bbl/day)				Gasoline Yield, as % Crude Run	Comments
		Other	Oxygentd	CARB	Total		
1995	1,658	401	108	453	962	58.0%	CARB 2 program starts
1996	1,654	182	22	779	983	59.4%	
1997	1,648	124	1	869	994	60.3%	
1998	1,716	123		910	1,033	60.2%	
1999	1,672	85		943	1,028	61.5%	
2000	1,696	106	4	938	1,048	61.8%	
2001	1,703	98	3	952	1,053	61.8%	
2002	1,728	97		991	1,088	63.0%	
2003	1,789	110		978	1,088	60.8%	Transition to CARB 3 program CARB 3 program starts
2004	1,726	132		954	1,086	62.9%	

Source: Stillwater Associates LLC, private communication, May 2, 2005

These figures, compiled by Stillwater Associates LLC from weekly production data published by the California Energy Commission, show that

- During the period 1996-2202, when the California refining sector was producing CARB 2 gasoline, virtually all MTBE-blended, the sector's gasoline out-turns increased by about 1.8 percent points per year, approximately matching annual growth in gasoline consumption.

- Subsequently, in 2003 and 2004, during which the California refining sector made the transition to production of ethanol-blended CARB 3 gasoline, the sector's total gasoline out-turns remained constant.
- From 2002 to 2004, average daily production of CARB gasoline actually declined by 37 K/day, with a corresponding increase in the production of gasolines sold in Arizona, Nevada, and Oregon.

During the same period, California's imports of CARBOB and gasoline blendstocks have increased. The import volumes are included in the reported volumes of gasoline production.

These operating results suggest the California MTBE ban and the consequent introduction of the CARB 3 program have adversely affected the overall gasoline production capability of the California refining sector, such that its in-state production is not keeping pace with demand. (A number of prior analyses forecast adverse effects on gasoline production capability as well as on average costs of gasoline production.) This circumstance may limit gasoline supply from the California refining sector generally and further increase the cost of producing special gasolines with high emissions performance.

The Los Angeles refining center, source of most West-side supplies of AZ CBG, comprises refineries with differing capabilities – in terms of refining process capacity and finished product segregation capability. Several refineries are capable of supplying a flexible gasoline slate, including not only CARB 3 for California, but also AZ CBG (under the current program), Las Vegas gasoline, and perhaps other gasolines, in response to market driving forces. Other refineries are configured and operated to produce primarily CARB 3 gasoline, with little or no capability to segregate additional classes. Still others have intermediate capabilities for producing and segregating different gasoline classes.

6.3.3 Supply Capabilities of the West Texas/New Mexico Refining Center

In general, aggregate terms, the gasoline slate produced by the West Texas/New Mexico refining center (conventional gasoline, 7.8 RVP gasoline, and AZ CBG) is less demanding and less costly to produce than that produced by the Los Angeles refining center (mainly CARB 3, with some conventional gasoline, Las Vegas gasoline, and AZ CBG).

The CBG area and its environs is a primary gasoline market for a number of West Texas/New Mexico refineries. They have captured an increasing share of the market in recent years; since 1997, essentially all of the growth in gasoline demand in the CBG area has been met by increased supplies from East side refiners, primarily those in the West Texas/New Mexico refining center.

Reportedly, the West Texas/New Mexico refineries supplying CBG have, as a group, increased aggregate gasoline production capability in recent years. The planned expansion of the KMP East line suggests West Texas/New Mexico refineries intend to continue to increase their capacity to meet increasing demand for AZ CBG. The refineries can do so either by expanding their facilities and increasing total gasoline production or by upgrading to CBG some conventional gasoline now supplied to other markets. In the latter instance, compensating

volumes of CG could be brought into the area from the Gulf Coast refining center via the existing pipeline network.

6.3.4 Comparison of the Two Refining Centers With Respect to CBG Production

In the California refining sector, CARB 3 production predominates, Arizona CBG production represents about 5% of total gasoline production, and CBG produced to the Type 1 standard is less costly to produce than CARB 3 gasoline.

By contrast, in the West Texas/New Mexico refining center, CARB 3 production is negligible, Arizona CBG production constitutes a significant share of the gasoline out-turn of the refineries supplying CBG, and the CBG is more costly to produce than the balance of these refineries' gasoline production.

This means that, in general, the refineries in the West Texas/New Mexico have more flexibility than those in California to shift blendstocks among gasoline pools to facilitate production of the desired volumes of CBG.

6.4 ASSUMED EAST AND WEST VOLUME SHARES OF FUTURE CBG SUPPLY

The production limitations the MTBE ban and the CARB 3 program impose on the California refining sector, the growth in supply capability in the West Texas/New Mexico refining center, and the impending expansion of the East line imply that

- The West Texas/New Mexico refining center is likely to meet most of the future growth in gasoline demand in the CBG area and its environs;
- The East line is likely to be fully allocated, even after it expands; and
- The Los Angeles refining center is likely to remain the marginal source of supply to the area.

For purposes of this analysis, we further assumed that the volume share of CBG in total gasoline supplies from the West Texaco/New Mexico refining center would remain constant at its 2004 level.

To express these assumptions in the refinery modeling, we assigned volume shares of CBG production in 2010 to the Los Angeles and West Texas/New Mexico refining centers as follows:

$$\text{WT/NM Supply}_{2010} = \text{WT/NM Supply}_{2004} + (25,000)\text{CBG Fraction of WT/NM Supply}_{2004}$$

$$\text{LA Supply}_{2010} = \text{CBG Demand}_{2004} + \text{CBG_Dem_Growth}_{2010} - \text{WT/NM Supply}_{2010}$$

where

WT/NM Supply₂₀₁₀ is the projected year 2010 supply of CBG from West Texas/New Mexico;
LA_Supply₂₀₁₀ is the projected year 2010 supply of CBG from Los Angeles; **WT/NM_Supply₂₀₀₄** is

the reported 2004 supply of CBG from West Texas/New Mexico; **CBG_Fraction₂₀₀₄** is the volume share of CBG in total gasoline supplies to the Phoenix area in 2004; and **CBG Dem Growth₂₀₁₀** is the projected growth in CBG demand from 2004 to 2010.

6.5 CBG PRODUCTION CASES ANALYZED

Table 6.2 identifies the cases considered in the analysis, in terms of the CBG gasoline type analyzed in each case.

TABLE 6.2: CBG OPTIONS REPRESENTED IN THE REFINING ANALYSIS

Gasoline	Oxygen (wt%)	RVP (psi)
Summer		
Non-Oxygenated		
Fed-S	0	6.6 - 6.8
Cal2-S	0	6.6 - 6.8
Cal3-S	0	6.6 - 6.8
Ethanol-Blended		
Fed-S	3.5	6.6 - 6.8
Cal2-S	2.0	6.6 - 6.8
Cal3-S	2.0	6.6 - 6.8
Winter		
Fed-W	3.5	12.5
Cal2-W	3.5	9.0
Cal3-W	3.5	9.0
Cal3-WR	3.5	11.0
Cal3-WR	2.0	11.0
Cal3-WR	3.5	13.5
Cal3-WR	2.0	13.5

The *winter* cases in Table 6.2 correspond to the CBG options specified in the SoW and reflect the results of the screening analysis.

The *summer* cases in Table 6.2 are in two sets. The *non-oxygenated* cases represent the refining centers and pipeline system continuing to supply non-oxygenated CBG; the *ethanol-blended* cases represent the refining centers and pipeline system supplying ethanol-blended CBG.

In the ethanol-blended cases, Fed-S is blended to 10 vol% ethanol while PM-2S and PM-3S are blended to 5.7 vol% ethanol. Our analysis indicated these to be the least costly ethanol concentrations in each instance.

The pipeline system's capability to handle only one gasoline class means either non-oxygenated or ethanol-blended CBG batches will be supplied, but not both.

We then compared the costs of producing non-oxygenated Cal2-S and Cal3-S with the cost of producing non-oxygenated Fed-S, and similarly for the ethanol-blended CBGs. This approach produced estimates of the relative costs of producing non-oxygenated and ethanol-blended Fed-S, PM-2S, and Cal3-S.

6.6 METHODOLOGY FOR REFINING ANALYSIS OF THE SPECIFIED GBG OPTIONS

The refining analysis delineated technical and economic effects in the refining sector associated with production of the specified CBG options. The analysis employed refinery LP modeling, using aggregate representations of refining operations and associated economics, characteristic of the West (Los Angeles) and East (West Texas/New Mexico) refining centers, needed to supply the necessary volumes of each of the specified CBG options in the 2010 summer and winter gasoline seasons.

6.6.1 Regional Refining Models

To represent the East refining center, we developed an aggregate model representing the combined operations of the West Texas/New Mexico refineries that supplied CBG in 2004, according to the batch reports filed with Arizona DWM. We did not include any other West Texas/New Mexico refineries or any Gulf Coast refineries in the East model. Limiting the East model to these refineries reflected the assumption that the West Texas/New Mexico refineries now supplying CBG have some economic advantage (in terms of refining cost, production capacity, logistics costs, etc.) over the other refineries in the region with respect to supplying CBG and would retain that advantage after the new CBG standards analyzed here take effect.

To represent the West refining center, we used our existing aggregate model of the California refining sector (comprising the Los Angeles and San Francisco refining centers). The California model was already in being and was current, having been used in a number of recent studies. We did not develop a special model of the Los Angeles refining center for this study, for a number of reasons. First, for purposes of this study, the characteristics and gasoline-making capabilities of the two California refining centers are comparable. Second, not all of the gasoline supplied to the CBG area via the West line in fact came from Los Angeles refineries in 2004; some came from the San Francisco or Puget Sound refining centers, both of which contained registered suppliers of CBG (Section 5.6). Finally, the California Energy Commission publishes refining information only for the aggregate California refining sector, not for individual refineries or refining centers.

6.6.2 The ARMS Refinery Modeling System

We developed the regional models and conducted the analysis using MathPro Inc.'s proprietary refinery LP modeling system (ARMS).

ARMS is a proprietary refinery modeling system developed by MathPro Inc. It comprises a generalized linear programming (LP) model of refining operations; a library of crude oil assays; a database of techno-economic values describing refinery operations, process-by-process; and a software suite for creating, operating, and reporting on refinery LP models.

ARMS includes fully integrated representations of the EPA Complex Model, the CARB Phase 2 Predictive Model, and the CARB Phase 3 Predictive Model for certifying, respectively, federal RFG, CARB 2, and CARB 3 gasolines.

ARMS is designed expressly to support analysis of regulatory, public policy, and business planning issues dealing with technical and economic responses of the refining industry to real or prospective changes in its operating environment – such as a change in gasoline standards, as in this study.

Since coming into commercial use in 1990, ARMS has been employed to conduct analyses for dozens of private and public sector clients, dealing with the technical and economic effects on the refining sector of essentially every major regulatory initiative bearing on refined product quality and emissions performance.

6.6.3 Model Calibration

The first step in the refining analysis was to calibrate the East refining model to reported information on refining operations in the summer of 2004 and the winter of 2003-2004. The West model was already calibrated.

Calibration demonstrates the validity, for the study at hand, of the refining models and derives certain technical data elements for use in the subsequent steps of the analysis. Calibration involves adjusting technical data elements in the database of each refinery model, until the adjusted model yields solution values matching, with sufficient precision, certain key measures of refinery operations in the calibration period.²⁸ Once the model is calibrated, we “freeze” the data elements for the subsequent steps in the refining analysis.

In the model calibration, we applied the Complex Model to Arizona Type 1 CBG in the summer and the Phase 2 Predictive Model to Arizona Type 2 CBG in the winter, with 8.7 RVP and 3.5 wt% oxygen limits in place.

Most of the data needed for calibrating refinery models come from DOE/EIA publications (such as the *Petroleum Supply Annual* and the *Petroleum Marketing Annual*) and the *Oil & Gas Journal*. But before the information from these sources can be used in calibrating refinery models, it requires extensive analysis, re-organization, and summation.

6.6.4 Reference and Study Cases

The refining analysis comprised:

²⁸ The most important of the available measures for the East refining sector included refining capacity, average properties of CBG supplied from the East side, Gulf Coast prices, transportation tariffs, and information obtained in private communications.

- Winter and summer *Reference Cases* for each refining center, representing production of the baseline AZ CBG under the current CBG standard along with the other gasolines produced in the center, in volumes projected for 2010; and
- A set of winter and summer *Study Cases* for each refining center, with each case representing refining operations needed to produce one of the specified CBG options listed in Table 6.2 (along with the other gasolines), in volumes projected for 2010.

The Reference Cases delineate the baseline for the refining analysis. Comparison of the results of the Study Cases with the corresponding Reference Cases indicate the average incremental refining costs and investment requirements associated with the specified CBG option.

Solutions returned by the aggregate refinery models in each Reference Case and Study Case include average production costs, refining operations, investments in new capacity, and average gasoline properties, including properties of gasoline base blends produced for local ethanol blending.

The estimated average gasoline properties are the primary inputs from the refining analysis to the emissions analysis described in Section 8.

Developing the Reference and Study cases entailed developing various projections, most notably of (1) growth in petroleum product demand over the period 2004-2010 in the areas served by the two refining centers considered, (2) refined product out-turns of the two refining centers in 2010, based on the projections of demand growth, and (3) delivered prices of key refining inputs – imported crude oils (average), specific domestic crude oils (Alaskan North Slope, California heavy crudes, West Texas Intermediate, West Texas Sour), natural gas, electricity, and ethanol.

These projections are shown in **Tables 6.3, 6.4, and 6.5**, respectively.

The estimates of growth in refined product demand, shown in Table 6.3, are based on Department of Energy estimates of regional growth in refined product demand [14] and U.S. Census estimates of population growth [17].

The projected gasoline out-turns for the West and East refining centers in 2010, shown in Table 6.4, reflect the combined effects of (1) demand growth in the CBG area and other areas served by the refining centers and (2) the scheduled expansion of the KMP East line. With respect to CBG supplies in 2010, the net effect of the CBG area demand growth and pipeline expansion would be as follows:

- East-side supplies would increase from about 45 K Bbl/day in 2004 to 69 K Bbl/day in 2010 (and indeed earlier, as soon as the East line expansion is completed);
- West-side supplies would increase slightly, from about 52 K Bbl/day in 2004 to 56 K Bbl/day in 2010 (after an initial decline when the East line expansion is completed).

Table 6.5, which shows the projected prices of refinery inputs, also contains extensive notes regarding the publications from the projections were obtained or derived.

**TABLE 6.3: PROJECTED GROWTH IN REFINED PRODUCT CONSUMPTION AND SUPPLY,
BY AREA AND REFINING CENTER: 2004 TO 2010**

Petroleum Product	Consumption				Supply	
	West Texas	Arizona	Nevada	California	East Refining Center	West Refining Center
Total (%)	12.0%	24.5%	33.2%	16.9%	12.0%	18.3%
LPG	6.0%	18.0%	25.4%	63.0%	54.2%	0.0%
Motor Gasoline	13.9%	26.5%	37.9%	15.9%	13.9%	17.8%
Jet & Kerosene	20.6%	18.0%	25.4%	19.7%	20.6%	19.8%
Distillate	17.6%	23.6%	33.6%	19.8%	17.6%	21.2%
Residual Oil	14.3%	29.5%	29.5%	26.4%	14.3%	28.2%
Petro Feedstock	8.8%	-	-	15.4%	8.8%	15.4%
Other	5.9%	23.6%	33.6%	10.6%	5.9%	12.0%
Average Annual (%)	1.9%	3.7%	4.9%	2.6%	1.9%	2.8%
LPG	1.0%	2.8%	3.9%	8.5%	7.5%	0.0%
Motor Gasoline	2.2%	4.0%	5.5%	2.5%	2.2%	2.8%
Jet & Kerosene	3.2%	2.8%	3.9%	3.0%	3.2%	3.1%
Distillate	2.7%	3.6%	5.0%	3.1%	2.7%	3.3%
Residual Oil	2.2%	4.4%	4.4%	4.0%	2.2%	4.2%
Petro Feedstock	1.4%	-	-	2.4%	1.4%	2.4%
Other	1.0%	3.6%	5.0%	1.7%	1.0%	1.9%

- Note: i. Growth rates for West Texas correspond to the Census projections for the West South Central region (which includes Arkansas, Louisiana, Oklahoma, and Texas).
- ii. Growth rates for Arizona, Nevada, and California are estimated using DOE projections for the Mountain Region (which includes Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, & Nevada) and the Pacific Region (which includes Washington, Oregon, California, Alaska, & Hawaii) and recent changes in consumption of refined products and in population in those states.
- iii. Growth in supply for the East Refining Center is assumed to be the same as the growth in consumption estimated for West Texas.
- iv. Growth in supply for the West Refining Center is the weighted average of 50% of Arizona's projected growth and 100% of Nevada's and California's projected growth in consumption..

Sources: Derived from:

Regional Tables, *Annual Energy Outlook 2004*, DOE/IEA; Census Population Estimates and Prime Supplier Sales Tables, *Petroleum Marketing Annual 2002*, DOE/EIA.

**TABLE 6.4: REFINED PRODUCT OUT-TURNS OF EAST AND WEST REFINING CENTERS:
ESTIMATED FOR 2004 AND PROJECTED FOR 2010, BY SEASON**

Refined Product	Estimated 2004				Projected 2010			
	Arizona East Refining Center		Arizona West Refining Center		Arizona East Refining Center		Arizona West Refining Center	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Propane	8	7	49	42	9	7	58	50
Butane			35				41	
Aviation Gas			3	2			4	2
Naphthas			10	10			12	12
Gasoline								
Arizona CBG	46	45	52	52	69	68	56	55
California RFG			928	919			1076	1065
Conventional	122	118	151	102	123	118	178	120
Jet & Kerosene	47	48	258	259	57	58	309	310
Diesel Fuel								
CARB			219	195			262	234
EPA	54	56	104	93				
High Sulfur	20	21	4	4	6	6	5	5
Ultra Low Sulfur					81	84	126	113
Unfinished Oils			8	8			9	9
Residual Fuel Oil	17	16	55	66	19	18	78	91
Asphalt	4	3	41	36	5	3	45	40
Lubes & Waxes			23	20			27	24

Note: Shipments of Arizona CBG from the East Refining Center increase by about 23 K b/d in 2010 because of the expansion in pipeline capacity.

Italics for propane and butane indicate approximate production, given increase in other refined product out-turns.

Sources: CEC Refinery Reports, CEC Weekly Fuels Watch Reports, ARMS modeling results, and Table 6.1.

TABLE 6.5: PRICES OF KEY REFINERY INPUTS AND OUTPUTS: ESTIMATED FOR 2004 AND PROJECTED FOR 2010

	2004			2010		
	U.S	East Refining Center	West Refining Center	U.S	East Refining Center	West Refining Center
Crude Oil Prices (\$/b)						
World Oil Price ¹	36.7			25.5		
WTI Spot @ Cushing	41.44					
First Purchase Price						
Alaska North Slope	33.03					
California Kern River	33.42					
WTI	39.55					
WTS	37.29					
Composite Crude		41.16	36		28.60	25.01
Natural Gas²						
\$/mcf	6.52	5.60	8.27	4.59	3.94	5.82
\$/foeb	41.08	35.28	52.10	28.92	24.84	36.68
Electricity (¢/kwh)³	5.4	5.4	7.9	4.8	4.8	7.0
Ethanol		47.1	47.1	35-50	35-50	35-50

Note: All prices in year 2004 dollars.

1 Average refiner acquisition cost for imported crude oil.

2 Average delivered price to industrial customers

3 Average retail price to industrial customers

Sources:

World Oil Price: 2004 -- Landed OPEC Cost, Table 25, Petroleum Marketing Monthly, March 2005, DOE/EIA.

2010 -- Table A11, Annual Energy Outlook 2005, DOE/EIA

WTI Spot Price: Derived from daily spot prices provided on DOE/EIA's Website.

First Purchase Prices: Table 22, Petroleum Marketing Monthly, March 2005, DOE/EIA.

Composite Crude: 2004 -- Derived for each refining center based on estimated crude mix and spot and first purchase prices.

2010 -- Derived using ratio of 2004 and 2010 world oil prices.

Natural Gas Price: 2004 -- Table 23, Natural Gas Monthly, April 2005, DOE/EIA.

2010 -- U.S.: Table A13, Annual Energy Outlook 2005, DOE/EIA

Refining Centers: Derived using projected 2010 U.S. price and ratios of refining center prices to U.S. price for 2004.

Electricity Price: 2004-- Derived from Table 5.6.A, Electric Power Monthly, April 2005, DOE/EIA.

2010 -- U.S.: Table A8, Annual Energy Outlook 2005, DOE/EIA

Refining Centers: Derived using projected 2010 U.S. price and ratios of refining center prices to U.S. price for 2004.

Ethanol -- 2004: Derived from chart on California Energy Commission's website showing prices for ethanol delivered to Los Angeles by railcar.

2010: Price range estimated as 2004 ethanol price less the change in world oil prices from 2004 to 2010, and approximate full cost of ethanol production.

The regional refinery models in the Reference Cases and Study Cases incorporated the following elements.

- Gasoline emissions standards – emission limits for federal RFG, CARB gasolines, and CG imposed by the Phase 2 Complex Model, Phase 2 and Phase 3 Predictive Models, the federal Tier 2 sulfur standard (30 ppm average) on all gasoline classes.
- Refining process capacity in 2010 – composed of process capacity reported for 2004 and computed additions of new process capacity in response to the specified growth in refinery product slates.
- Investment economics for new process capacity – dependant on the nature of process capacity added
 - ▶ expansion economics (two thirds of estimated grassroots on-site investment costs and no off-site costs) for capacity added to *satisfy growth in product demand* from 2004 to 2010;
 - ▶ grassroots economics for capacity added to *meet gasoline standards*; and
 - ▶ a combination of retrofitting and grassroots economics for capacity added to meet *diesel fuel sulfur standards*.
- Investment location factors (relative to U.S. Gulf Coast)
 - ▶ West refineries: 1.35
 - ▶ East refineries: 1.15
- Oxygenate use – MTBE and other ethers allowed only in gasolines other than CARB and CBG.
- Crude oil and refined product prices – expressed in 2004 \$
- Ethanol price – set at the lower end of the ethanol price range shown in Table 6.5.

Finally, in the Study Cases, the East refining model incorporates constraints to ensure no degradation in the average emissions performance of the gasolines produced other than CBG.

6.6.5 Comments on the Reference and Study Cases

Summer Cases

In analyzing Option 2, in which Cal3-S and Cal3-W are *additional* certification options for AZ CBG, the central issue is determining whether or not, on the basis of refining economics, either West or East refineries would be likely to exercise this option. That is, would the refineries be likely to produce CARB 3 gasoline rather than Type 1 CBG or CARB 2 in the summer. To examine this issue, we analyzed study cases for the West and East refining centers as follows.

➤ Non-oxygenated CBG Cases

First, we modeled refining operations to produce a California gasoline product slate, to estimate the shadow value (marginal cost) of (1) ethanol-blended Cal3-S produced for sale in California

and (2) non-oxygenated Type 1 CBG produced for Area A. (The estimated baseline gasoline properties (Table 3.3) indicated we could assume the baseline CBG is all Type 1 CBG, certified under the Complex Model.) This is the Reference Case for non-oxygenated CBG.

Next, we developed two study cases in which Type 1 CBG was replaced by Cal2-S and Cal3-S and observed the effects of those substitutions on total refining costs.

➤ **Ethanol-blended CBG Cases**

We used the same general approach for the ethanol-blended CBG cases, analyzing a set of cases designed to delineate the relative economics of producing either ethanol-blended or non-oxygenated Cal3-S gasoline relative to producing non-oxygenated Fed-S gasoline. In these cases, we set the ethanol content of Fed-S at 10 vol%, because earlier exploratory model runs indicated this to be the lowest-cost ethanol concentration for Fed-S. We set the ethanol concentration of Cal2-S and Cal3-S at 5.7 vol% because that corresponds to the California refining sector's current practice in producing CARB 3 and because ethanol blending at 10 vol% is incompatible with both Predicative Models.

Winter Cases

For each refining center, the first study case analyzed represented a change in the Arizona winter CBG standard from Cal2-W to Cal3-W, with the same RVP and oxygen standards, to estimate the economic consequences of this shift alone.

The next step for each refining center was to analyze a set of study cases representing, in turn, each of the other winter gasoline options defined in Section 6.3 (and listed in Table 6.2).

6.7 RESULTS OF THE REFINING ANALYSIS

Tables 6.6a, 6.6b, 6.7a, 6.7b, and 6.8 summarize the results of the refining analysis for 2010.

6.7.1 Refining Economics

Tables 6.6a (summer) and 6.6b (winter) show the estimated average refining costs (relative to the corresponding reference cases), refinery investment requirements, and effects on fuel economy of the various CBG options in the East and West refining centers.

Summer CBG

Table 6.6a shows two sets of results: one for non-oxygenated CBG, the other for ethanol-blended CBG. In each set, the Reference Case denotes supply of Fed-S to Area A, and the Study Cases denote supply of Cal2-S and Cal3-S.

These results indicate that Fed-S enjoys a refining cost advantage over Cal2-S and Cal3-S of about 2–2½¢/gal with no ethanol blending and about 3–3½¢/gal with ethanol blending. These cost differences are likely to lead all CBG suppliers, East and West, to meet the CBG summer

requirements by supplying Fed-S rather than Cal2-S (if it remains in the CBG program) or PM-3S.

The costs of producing the non-oxygenated CBGs relative to the costs of producing their ethanol-blended counterparts would depend on the delivered price of ethanol and the relationship of the ethanol price to oil prices. Forecasting these price relationships was beyond the scope of the study.

Table 6.6a indicates PM-2S and Cal3-S would be somewhat more costly in the West refining center than in the East. This cost difference arises from the different volume shares of CARB gasoline produced in the two refining centers. The California refining sector produces a gasoline pool predominately CARB 3, with small volume shares of gasolines produced to less stringent standards (including CBG in the summer); the West Texas/New Mexico refining center produces a gasoline pool with little or no CARB gasoline. In general, the cost of producing a CARB gasoline increases with its volume share of the total gasoline pool; the first volume increment is the least costly to produce, and the last increment is the most costly.

Table 6.6a also indicates the estimated fuel economy effects of the CBG variants considered, relative to the corresponding reference case.

Winter CBG

Table 6.6b indicates Cal2-W and Cal3-W have essentially the same costs. Some individual refineries may have an economic incentive to continue producing Cal2-W, if it remains part of the CBG program; others, particularly in the Los Angeles refining center, may prefer to produce Cal3-W.

Table 6.6b indicates the other CBG options specified in the SoW for consideration – Fed-W and the Cal3-WR variants with relaxed RVP standards – all have somewhat lower average refining costs than Cal2-W (the current winter CBG) or Cal3-W. The costs of the Cal3-WR variants with 5.7 vol% ethanol (2.0 wt% oxygen) would depend in part on the actual delivered price of ethanol. The refining costs shown in the table reflect the low end of the ethanol price range shown on the last line of Table 6.5.

Table 6.6b also shows that the Cal3-WR variants with 5.7 vol% ethanol (2.0 wt% oxygen) would offer some fuel economy savings relative to Cal2-W, the reference gasoline, because of their lower ethanol content.

TABLE 6.6A: ESTIMATED REFINING ECONOMICS OF CBG OPTIONS: SUMMER 2010

Ethanol Content (Vol%) --> Certification Option -->	Non-Oxygenated			Ethanol-Blended		
	Reference Case	Study Cases		Reference Case	Study Cases	
	0 Fed-S	0 Cal2-S	0 Cal3-S	10 Fed-S	5.7 Cal2-S	5.7 Cal3-S
Refining Cost (¢/gal of CBG)		2.4	2.2		2.9	3.5
East		2.2	2.0		1.9	2.0
West		2.7	2.5		4.2	5.5
Daily Refining Cost (\$K/d)		120	120		150	190
East		60	60		50	60
West		60	60		100	130
Investment (\$MM)		100	100		180	200
East		50	50		70	70
West		50	50		110	130
Cost of Mileage Loss (\$K/d)		60	60		-60	-80
East		10	10		-60	-60
West		50	50		0	-20

TABLE 6.6B: ESTIMATED REFINING ECONOMICS OF CBG OPTIONS: WINTER 2010

Certification Option --> RVP (psi)--> Ethanol Content (Vol%) -->	Reference Case	Study Cases					
	Cal2-W	Cal3-W	Cal3-WR				Fed-W
	8.7	8.7	11.0		13.5		12.5
	10.0	10.0	10.0	5.7	10.0	5.7	10.0
Refining Cost (¢/gal of CBG)		0.0	-0.8	-1.1	-1.6	-2.1	-2.0
East		0.1	-0.8	-1.2	-1.6	-2.2	-1.5
West		0.0	-0.8	-1.0	-1.6	-1.9	-2.6
Daily Refining Cost (\$K/d)		0	-40	-60	-90	-100	-100
East		0	-20	-40	-50	-60	-40
West		0	-20	-20	-40	-40	-60
Investment (\$MM)		0	0	0	0	0	0
East							
West							
Cost of Mileage Loss (\$K/d)		0	30	-20	50	0	0
East		0	10	-10	20	0	0
West		0	20	-10	30	0	0

6.7.2 Average CBG Properties

Tables 6.7a and 6.7b show, for summer and winter respectively, the estimated average properties of (1) the baseline CBG and (2) the seasonal CBG options of interest.

With regard to the 2004 baseline properties, Tables 6.7a and 6.7b show three sets of average properties: one estimated in Task 1 from DWM retail survey (Table 3.3), one estimated from the batch reports submitted to DWM (discussed in Section 3.2), and the third estimated from solutions returned by the two refinery models after the calibration to 2004 baseline properties and refining operations (discussed in Section 6.6.4). The third set is the more appropriate for comparison with the estimated properties of the CBG options returned by the refinery models.

For each indicated CBG option, the estimated average properties of the CBG pool in Tables 6.7a and 6.7b are the volume-weighted averages of the estimated average properties of CBG supplied by the West and East refining centers. These average pool properties are inputs to the emissions analysis described in Section 8.

The combination of the volume shares of CBG in the West and East refining centers (discussed in Section 6.3), the overall gasoline product slate in the two refining centers, and certain characteristics of aggregate regional refining models lead to an unavoidable degree of uncertainty in the estimates of average gasoline properties. (One indication of this uncertainty is the difference between the set of estimated average baseline properties and the set of average properties estimated in the model calibration step (both shown in Tables 6.7a and 6.7b)).

As noted above, the Los Angeles refining center produces a gasoline pool that is predominately CARB 3, with small volume shares of gasolines produced to less stringent standards (including CBG in the summer). In representing this operation, the aggregate refining model has considerable flexibility to produce (in the small volumes required) various formulations that meet CBG standards with little difference in cost. But, in reality, only a sub-set of California refineries produces CBG. In these refineries, CBG constitutes a larger proportion of total gasoline out-turn than for the refining sector as a whole. Consequently, the aggregate model imputes more capability and flexibility to these refineries than any of them would actually have.

The East refining center produces a gasoline pool with about one-third CBG and about two-thirds gasolines produced to less stringent standards, such as CG or 7.8 RVP gasoline. Such an operation offers individual refineries flexibility in shifting blendstocks between gasoline pools to meet the various standards at minimum cost. Similarly, the aggregate refining model embodies considerable flexibility, but there is no way to guarantee that the solutions it returns would represent the aggregate result of the gasoline-making operations of the individual East refineries.

These comments apply specifically to the average gasoline properties returned by the refining models. Estimates of the average refining costs and investment requirements associated with the various CBG options are more robust.

TABLE 6.7A: AVERAGE CBG PROPERTIES: ESTIMATED SUMMER 2004 AND PROJECTED SUMMER 2010

Property, Octane & Volume	2004							2010 Projected ^{1, 2}					
	Retail Survey	Batch Reports			Calibration			Non-Oxy (Fed-S)			Etoh-Blnd (Fed-S)		
		East	West	Pool	East	West	Pool	East	West	Pool	East	West	Pool
Property													
RVP (psi)	6.5	6.6	6.6	6.6	6.6	6.6	6.6	6.8	6.6	6.7	6.8	6.7	6.7
Oxygen (wt%)	0.2	0.2	0.0	0.1			0.0			0.0	3.5	3.5	3.5
Aromatics (vol%)	21.9	17.1	23.7	20.6	18.0	23.5	20.9	21.0	23.9	22.3	16.7	23.2	19.6
Benzene (vol%)	0.92	1.02	0.64	0.82	0.87	0.64	0.75	0.90	0.64	0.78	0.88	0.64	0.77
Olefins (vol%)	7.5	7.6	10.3	9.1	9.0	10.0	9.5	9.0	10.0	9.4	9.0	10.0	9.4
Sulfur (ppm)	48	87	23	53	90	25	56	30	25	28	30	25	28
E200 (vol% off)	42.9	41.8	43.5	42.7	43.1	44.7	43.9	46.3	45.0	45.7	53.4	42.8	48.6
E300 (vol% off)	85.9	86.5	85.1	85.8	89.8	81.8	85.5	86.6	81.8	84.5	85.9	81.8	84.1
T50 ²	212	212	210	211	214	211	212	208	210	209	193	215	203
T90 ³	320	320	310	314	301	333	318	314	333	322	317	333	324
Octane ((R+M)/2)	88.3				87.6	87.8	87.7	87.6	87.8	87.7	87.6	87.8	87.7
Volume (K b/d)		46	52	98	46	52	98	69	56	125	69	56	125

Note: (1) Properties of CBG supplied in 2010 may differ considerably from the projections above, for reasons discussed in the report.

(2) Projected 2010 properties are for Type 1 CBG (CM-S)

Sources:

Retail Survey: Derived from Station Compliance Reports for Area A, 2004, Arizona Department of Weights and Measures.

Batch Reports: Derived from Batch Certification Reports submitted to Arizona Department of Weights and Measures, 2004.

Calibration: Results from ARMS runs for 2004.

Projected: Results from ARMS runs for 2010.

TABLE 6.7B: AVERAGE CBG PROPERTIES: ESTIMATED WINTER 2004 AND PROJECTED WINTER 2010

Property, Octane & Volume	2004							2010 Projected ¹					
	Retail Survey	Batch Reports			Calibration			Cal2-W			Cal3-W		
		East ²	West	Pool	East	West	Pool	East	West	Pool	East	West	Pool
Property													
RVP (psi)	8.6	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7
Oxygen (wt%)	3.4	2.7	3.3	3.0	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
Aromatics (vol%)	18.9	16.3	25.1	21.0	16.0	24.4	20.5	19.0	24.4	21.4	19.0	24.4	21.4
Benzene (vol%)	0.93	0.95	1.24	1.11	0.93	1.00	0.97	0.93	1.00	0.96	0.93	1.00	0.96
Olefins (vol%)	3.1	1.9	2.1	2.0	1.9	2.7	2.3	3.0	2.7	2.9	3.0	2.7	2.9
Sulfur (ppm)	33	30.3	7.7	18	30	11	20	25	11	19	21	11	17
E200 (vol% off)	53.4	-	-	0.0	58.0	58.8	58.4	54.1	54.0	54.1	54.1	54.0	54.1
E300 (vol% off)	90.1	-	-	0.0	89.9	89.0	89.4	89.1	89.0	89.1	89.1	89.0	89.1
T50	187	197	183	189	184	182	183	192	192	192	192	192	192
T90	300	302	299	300	300	304	302	304	304	304	304	304	304
Octane ((R+M)/2)	88.9				87.6	87.8	87.7	87.6	87.8	87.7	87.6	87.8	87.7
Volume (K b/d)		45	52	97	45	52	97	68	55	123	68	55	123

Note: (1) Properties of CBG supplied in 2010 may differ considerably from the projections above, for reasons discussed in the report.

(2) Batch reports from East refineries mixed "certification" gasolines at 2.0 wt% oxygen with final gasolines at 3.5 wt% oxygen.

Sources:

Retail Survey: Derived from Station Compliance Reports for Area A, 2004, Arizona Department of Weights and Measures.

Batch Reports: Derived from Batch Certification Reports submitted to Arizona Department of Weights and Measures, 2004.

Calibration: Results from ARMS runs for 2004.

Projected: Results from ARMS runs for 2010.

6.7.3 Additions to Refining Capacity

Table 6.8 shows the current and projected 2010 profiles of refining capacity, by process, for the East and West refining centers.

The projected 2010 capacity profiles returned by the refining models are determined by the requirements for producing *summer* gasoline in the required volumes and of the required emissions performance.

Table 6.8 shows indicated capacity additions, primarily to meet projected increases in demand for refined products in the various markets served by the East and West refining centers. Some capacity additions in the East refining center are for compliance with the Tier 2 gasoline sulfur standard. The capacity additions pertaining to particular CBG options in 2010 are not shown, because they are minor in comparison to those required to meet projected demand growth.

TABLE 6.8: CAPACITY PROFILES OF EAST AND WEST REFINING CENTERS: ESTIMATED FOR 2004 AND PROJECTED FOR 2010

Type of Process	Process	2004 Baseline		2010 Reference		Capacity Growth 2004 --> 2010	
		East	West	East	West	East	West
Crude Distillation	Atmospheric	314	1,827	362	2,099	15%	15%
Conversion	Fluid Cat Cracker	101	651	112	711	11%	9%
	Hydrocracker	30	401	30	459	0%	13%
	Coking		477		477		0%
	Visbreaker						
Upgrading	Alkylation	25	164	29	202	14%	23%
	Catalytic Polymerization		5		5		0%
	Dimersol		5		5		0%
	Pen/Hex Isomerization	10	100	17	100	70%	0%
	Reforming	73	388	76	388	4%	0%
Oxygenate Prod.	MTBE -- FCC-based	2		2		0%	
	TAME	2		2		0%	
Hydrotreating	Naphtha Desulfurization	96	474	96	475	0%	0%
	FCC Naphtha Desulfurization	3	60	51	60	1587%	0%
	Benzene Saturation		52		52		0%
	Distillate Desulfurization	88	347	88	404	0%	17%
	Distillate Dearomatization		135		146		8%
	FCC Feed Desulfurization		671		705		5%
	Merox (MTBE)			2			
Hydrogen	Hydrogen Plant (MM scf/d)		1,335		1,470		10%
Fractionation	Debutanization	20	201	21	225	4%	12%
	Depentanization		381		421		11%
	Lt. Naphtha Spl. (Benz. Prec.)	32	133	40	168	24%	26%
	Med. Naphtha Splt.						
	Lt FCC Naphtha Splitting		324		351		8%
	Hvy FCC Naphtha Splitting		96		96		0%
	Heavy Reformate Splitter						
Other	Aromatics Plant						
	Benzene Saturation		52		52		0%
	Butane Isomerization		52		52		0%
	Lubes & Waxes		28		28		0%
	Solvent Deasphalting	15	45	15	45	0%	0%
	Sulfur Recovery (s tons/d)						
	Electricity Gen. (K Kwh)						
	Steam Generation (K lb/hr)	1,600	10,914	1,683	12,791	5%	17%

Sources: Derived from "2004 Worldwide Refinery Survey," *Oil & Gas Journal*, Dec. 20, 2004;
DOE 2002 *Refinery Capacity Survey* (DOE website); and ARMS model runs.

7. Baseline Emissions Inventories

This section describes the development of baseline emissions inventories for Maricopa County and discusses the emissions screening of the gasoline options specified in the SoW.

In order to estimate the absolute impact of alternative gasoline formulations in Maricopa County, it is necessary to develop baseline emission inventories for the pollutants and years of interest.²⁹ For this work, both parameters have been defined by ADEQ. The years of interest have been specified as 2005 and 2010, while the pollutants of interest are defined to include particulate matter (PM), carbon monoxide (CO), oxides of nitrogen (NO_x), and volatile organic compounds (VOC). While this study evaluates the supply and distribution impacts of both changes in gasoline formulation requirements under existing RVP and oxygen requirements and changes in the current wintertime RVP cap and oxygen content requirements, ADEQ requested that emissions analysis be performed only for potential changes in CBG formulations under existing RVP and oxygen content requirements.

ADEQ provided several reference inventories for use in developing the baseline emission inventories for this work. These materials included the following:

1. “1999 Periodic Ozone Emissions Inventory for the Maricopa County, Arizona, Nonattainment Area,” Maricopa County Environmental Services Department, November 2001, Revised August 2002. [Hereafter referred to as the *1999 Ozone PEI*.]
2. “1999 Periodic Carbon Monoxide Emissions Inventory for the Maricopa County, Arizona, Nonattainment Area,” Maricopa County Environmental Services Department, November 2001, Revised August 2002. [Hereafter referred to as the *1999 CO PEI*.]
3. “One-Hour Ozone Redesignation Request and Maintenance Plan for the Maricopa County Nonattainment Area,” Maricopa Association of Governments, March 2004. [Hereafter referred to as the *MAG Ozone Redesignation Request*.]
4. “Carbon Monoxide Redesignation Request and Maintenance Plan for the Maricopa County Nonattainment Area,” Maricopa Association of Governments, May 2003. [Hereafter referred to as the *MAG CO Redesignation Request*.]
5. “Revised MAG 1999 Serious Area Particulate Plan for PM-10 for the Maricopa County Nonattainment Area,” (excerpts only), Maricopa Association of Governments, February 2000.³⁰ [Hereafter referred to as the *MAG PM Plan*.]

²⁹ In the context of this work, baseline emissions reflect the emissions expected in Maricopa County in the absence of any change to the current Arizona gasoline requirements.

³⁰ PM-10 is PM with an effective aerodynamic diameter of 10 microns or less.

6. “*Maricopa County 2002 Comprehensive Emission Inventory for the Cap and Trade Oversight Committee*,” Final Report, ENVIRON International Corporation, Maricopa County Environmental Services Department, and Arizona Department of Environmental Quality, October 9, 2003.
7. “*Development of CTAT V2 w/ENVIRON Inventory*,” Memorandum from Shawn Kendall, The Kendall Group, Inc., to Theresa Pella, Arizona Department of Environmental Quality, August 28, 2003. [Together, inventory reference documents 5 and 6 are hereafter referred to as the *C&T inventories*, where C&T is shorthand for “Cap and Trade.”]

Additional source documents were referenced and supplemental analysis tools were employed in the development of the baseline inventories, as necessary to resolve specific emissions component information. So that the specific usage of these documents and tools can be fully understood, they are referenced explicitly as appropriate in the discussion that follows.

Secondary analytical approaches were required in the development of the baseline emissions inventories for this work as none of the reference inventories were fully adequate to determine emission estimates at the level of detail required to accurately assess the impacts of changing gasoline formulations. To undertake such an assessment, emission estimates must be available at the engine and emissions type level-of-resolution (e.g., four-stroke gasoline nonroad equipment versus diesel nonroad equipment, exhaust emissions versus gasoline emissions, etc.). In most cases, the reference inventories did not provide such resolution and secondary methods, as described below, were employed to disaggregate the reference inventory estimates into more detailed emissions components.

Additionally, none of the provided reference inventories were specific to the required analysis years of 2005 and 2010, or included consistent emissions estimates for all required pollutants. The 1999 Ozone PEI included consistent emission estimates for summertime VOC, CO, and NO_x in 1999. The 1999 CO PEI included corresponding emission estimates for wintertime CO in 1999. The MAG Ozone Redesignation Request included consistent emission estimates for VOC and NO_x for a specific July Friday in 1998 and 2015 and consistent emission estimates for VOC and NO_x for a specific August Tuesday in 1999, 2006 and 2015. The MAG CO Redesignation Request included consistent emission estimates for CO for a specific December Friday in 1994, 2006, and 2015. The portions of the MAG PM Plan provided by ADEQ included complete PM-10 emission estimates only for 1994. Finally, the C&T inventories included consistent emission estimates for PM-10, PM-2.5, NO_x, SO_x (oxides of sulfur), NH₃ (ammonia) and VOC for average days in 2002 and 2018.³¹

It is also important to recognize that while the various reference inventories are internally consistent in that similar assumptions and methods are employed to generate each inventory within a specific reference document, assumptions and methods may not be consistent across reference documents. For example, the attainment and maintenance modeling inventories included in the MAG Ozone and CO Redesignation Requests are specific to conditions observed

³¹ PM-2.5 is PM with an effective aerodynamic diameter of 2.5 microns or less.

on specific days in 1994, 1998, and 1999. This is typical for a modeling inventory since the intent of the associated air quality modeling exercise is to replicate conditions that existed during a particular known air pollution episode. However, more general “planning” inventories such as those developed in the 1999 Ozone PEI and 1999 CO PEI are based on “typical” conditions that might be observed on any given day (as opposed to a specific day) during an extended period (e.g., any summertime or wintertime day). As a result, one would not expect a modeling inventory for a given year to be identical to a planning inventory for that same year. Moreover, since assumptions and methods can also vary in accordance with the information available to (as well as the inclinations of) the inventory developer, inventories from one source cannot simply be combined with those of another and assumed to provide consistent and accurate emissions estimates.

Accordingly, an explicit and detailed assessment of the provided reference inventories was undertaken to develop a set of baseline emission inventories for this work. After evaluating all available options, the 1999 Ozone PEI inventories were selected as the primary reference inventories. This decision was primarily based on the fact that the 1999 Ozone PEI included consistent VOC, CO, and NO_x inventories for a typical summer day in Maricopa County, plus the fact that the level of source resolution for the 1999 Ozone PEI inventories exceeded that of all other reference inventories. For example, onroad vehicle emissions are presented at the vehicle class level of detail, while the other reference inventories present only total onroad mobile emissions. Similarly, nonroad engine emissions are presented at the equipment type level of detail in the 1999 Ozone PEI, whereas they are presented only in total in the other reference inventories. The MAG Ozone Redesignation Request included VOC and NO_x inventories, but no CO inventory. The MAG CO Redesignation Request did include a CO inventory, but the inventory is applicable to a wintertime day and cannot be transformed into a summertime inventory consistent with the VOC and NO_x inventories from the MAG Ozone Redesignation Request. Similarly, the C&T inventories also exclude CO, and are generally less well developed than the inventories of either the 1999 Ozone PEI or the MAG Redesignation Requests.

It is also important to recognize the geographic coverage of the various inventories. The 1999 Ozone PEI, the 1999 CO PEI, and the MAG Ozone and CO Redesignation Request inventories all apply to Maricopa County ozone/CO nonattainment area geography, which essentially comprises the metropolitan Phoenix area of the county.³² The inventories from the MAG PM plan apply to Maricopa County PM nonattainment area geography, which is approximately 40 percent larger than the ozone/CO nonattainment area geography. The C&T inventories apply to the whole of Maricopa County, which is approximately 4.5 times as large as the ozone/CO nonattainment area geography and about 3 times as large as the PM nonattainment area geography. Because the inventories for this work are based on the 1999 Ozone PEI reference inventories, the associated geographic coverage area is the ozone/CO non-attainment area.

Despite the fact that the 1999 Ozone PEI inventories were well resolved, additional emissions resolution was required to facilitate accurate fuel formulation evaluation. Because changes in

³² The 1999 Ozone PEI also includes emissions from large point sources outside the ozone/CO nonattainment area, but these emissions are tabulated separately from non-attainment area emissions and have been excluded from the emission estimates used to develop the inventories presented in this report.

fuel formulations can affect exhaust and evaporative emissions differently, it is necessary to distinguish the exhaust and evaporative components of the baseline inventories. Similarly, fuel formulation changes can affect different engine and equipment technologies differently. For example, reductions in fuel sulfur will affect NO_x emissions for a three-way catalyst equipped vehicle differently than a vehicle with non-catalyst or oxidation catalyst technology. Unfortunately, none of the reference inventories (including the 1999 Ozone PEI), presented emission estimates at this requisite level of detail (although the 1999 Ozone PEI was closer than the others).

It is also important to recognize that while both summertime and wintertime impacts of potential gasoline reformulations were evaluated, wintertime impacts were limited to an evaluation of impacts on CO emissions. This limitation is an artifact of air quality planning, wherein wintertime planning is generally focused on CO emissions and inventory data for other emission species are typically not generated.³³ Since the inventories developed for this study are based on available local inventories, they are similarly restricted in their wintertime focus. This, however, is not considered to be a restriction in allowing for the full evaluating the potential gasoline reformulation impacts since, from an air quality planning standpoint, the only effective issue in regard to changing summer and wintertime formulations is their differential impact on CO due to changes in fuel oxygen content. Moreover, given that the state currently enforces specific RVP and oxygen content requirements for all wintertime gasoline, it is not expected that changes in other allowable gasoline requirements will have any significant wintertime impact.³⁴ Therefore, the wintertime gasoline reformulation emissions impact analysis is limited to CO only and the baseline 1999 wintertime CO emissions inventory is taken directly from the 1999 CO PEI.

To disaggregate the 1999 Ozone PEI VOC, CO, and NO_x inventories to the level of resolution necessary for detailed gasoline reformulation analysis, two specific modeling exercises were undertaken. First, the U.S. Environmental Protection Agency's (EPA's) NONROAD model was executed to produce estimates of Maricopa County nonroad equipment emissions in 1999. Second, the U.S. EPA's MOBILE6.2 model was executed to produce estimates of onroad vehicle emission factors for Maricopa County in 1999. Although the basic inputs for both modeling exercises were developed from information presented in the inventory reference documents cited above, it is important to recognize that the modeled emission estimates were used only in a relative fashion to disaggregate or otherwise adjust (as described further below) locally-generated emission estimates extracted from the reference inventories. In no case were emission estimates from these modeling runs used in an absolute fashion for this work.

Using the emission estimates from the NONROAD and MOBILE6.2 modeling exercises, ratios of evaporative to total emissions were developed at the vehicle and equipment type level of detail. These ratios were then applied to vehicle and equipment type emission estimates from the 1999 Ozone PEI to disaggregate evaporative and exhaust emissions.

³³ The only exception if for PM, wherein inventories generally represent an average annual day and thus are applicable to both summer and winter days.

³⁴ As previously noted, ADEQ did request a supply and distribution impact analysis for potential changes in the current wintertime RVP and oxygen content requirements, but also specifically requested that this analysis not include an emissions evaluation component.

A summary of the resulting VOC, CO, and NO_x inventories is presented in **Table 7.1**. These inventories form the basis of all VOC, CO, and NO_x impact estimates presented in this report.

TABLE 7.1: BASELINE EMISSION INVENTORIES FOR 1999 (METRIC TONS PER DAY)

Source Category	Summer								Winter
	VOC	NO _x	CO	SO ₂	Direct PM-10	Direct PM-2.5	Indirect PM-10	Indirect PM-2.5	CO
Point Sources	17.62	18.92	5.85	0.59	2.65	1.43	1.62	1.34	8.25
Area (excluding Geologic)	82.56	20.53	42.11	1.94	3.41	2.84	2.23	1.89	21.83
Area (Geologic)	0.00	0.00	0.00	0.00	39.73	14.79	0.00	0.00	0.00
Biogenic	44.15	9.09	0.00	0.00	0.00	0.00	0.67	0.55	0.00
Nonroad Equipment	76.98	83.33	515.07	6.46	8.68	7.99	8.54	7.21	520.68
Aircraft	4.53	19.94	39.88	1.67	0.90	0.64	2.09	1.77	45.49
Locomotives	1.01	26.34	3.38	1.41	0.66	0.61	2.47	2.07	3.38
All Other Nonroad	71.45	37.05	471.80	3.39	7.12	6.74	3.98	3.38	471.80
2-Stroke Gasoline	31.78	0.62	51.33	0.06	3.35	3.08	0.07	0.06	51.33
4-Stroke Gasoline	31.82	0.89	386.33	0.04	0.03	0.03	0.08	0.07	386.33
Diesel/CNG/LPG	7.86	35.54	34.15	3.28	3.73	3.62	3.84	3.25	34.15
Onroad Vehicles	82.05	133.48	575.26	6.06	3.62	2.54	12.11	10.11	490.26
Gasoline Vehicles	75.89	91.17	545.60	5.01	2.16	1.24	8.59	7.20	459.41
Diesel Vehicles	6.16	42.31	29.66	1.05	1.46	1.29	3.52	2.91	30.85
Road Dust	0.00	0.00	0.00	0.00	120.41	39.16	0.00	0.00	0.00
Total Emissions	303.37	265.35	1138.29	15.05	178.49	68.74	25.18	21.11	1041.02
Manmade Emissions	259.21	256.26	1138.29	15.05	18.36	14.79	24.50	20.56	1041.02

Since this work is designed to estimate emission impacts in 2005 and 2010, emission inventories specific to these years are required. Therefore, it is necessary to “grow” the 1999 inventory estimates to 2005 and 2010.³⁵ The 1999 Ozone PEI inventories provide no mechanism to undertake the requisite growth. However, as alluded to above, the MAG Ozone and CO Redesignation Requests include consistent summertime inventories for VOC and NO_x for 1999, 2006, and 2015 and consistent wintertime inventories for CO for 1994, 2006, and 2015. For the reasons previously described, the 1999 Ozone PEI was selected as the fundamental baseline inventory but because of the MAG Ozone and CO Redesignation Request inventories span the range of years for which inventories are required for this work, they are used as the fundamental basis for growing the 1999 inventories to 2005 and 2010.

Although the MAG CO Redesignation Request inventories reflect wintertime emissions, they are used as the growth basis for the summertime CO inventories in this work. It should be recognized that there are substantial differences between daily summertime and daily wintertime

³⁵ The term “grow” in this context is used solely to signify change, which can be either positive or negative. In this context, growth includes changes due to socioeconomic influences and the effects of emerging emissions control programs.

CO emissions. However, in no case are the MAG CO Redesignation Request inventories used in an absolute sense. They are used only in a relative sense to gauge growth rates between inventory years. Barring the advent of seasonally-specific controls during the time periods under investigation, the wintertime growth rate should be reasonably similar to the summertime growth rate. Since the oxygenated gasoline control program (the major wintertime CO control program in Maricopa County) was and will be in effect through the entire range of years covered by the MAG CO Redesignation Request inventories, it is believed that the relative growth rates implied by the inventories should be reasonably consistent with those expected for summertime CO emissions. Regardless, there is no other alternative readily available for forecasting summertime CO emissions growth.

To develop 2005 and 2010 emission inventories consistent with the 1999 Ozone PEI VOC, CO, and NO_x inventories, the following steps were undertaken. For point, area, and biogenic sources, VOC and NO_x emission estimates for 2006 and 2015 were developed by applying the growth rates implied by the MAG Ozone Redesignation Request inventories to the 1999 Ozone PEI-based inventories. Emission estimates for 2005 and 2010 were then developed through simple linear interpolation. For point, area, and biogenic source CO emissions, an additional step was required since the MAG CO Redesignation Request did not include 1999 emission estimates. Therefore, 1999 CO emission estimates were developed through simple linear interpolation of the 1994 and 2006 estimates presented in the Redesignation Request. Emission estimates for 2006 and 2015 consistent with the 1999 Ozone PEI were then developed by applying the growth rates implied by the MAG CO Redesignation Request inventories (with the interpolated 1999 inventory) to the 1999 Ozone PEI-based inventories. Emission estimates for 2005 and 2010 were then developed through simple linear interpolation.

For onroad and nonroad mobile sources a modified version of this same procedure was employed. Modification is required, because both onroad and nonroad mobile sources are subject to continuing emission control programs that take effect on a nonlinear basis as the affected vehicle and equipment fleets turnover. Thus, linear interpolation does not produce accurate emission changes over time. To account for this effect, the following approach was employed. The NONROAD and MOBILE6.2 modeling exercises previously described in the context of disaggregating 1999 evaporative emissions were also undertaken for 1994, 2005, 2006, 2010, and 2015 emissions evaluation years. Combined with the 1999 estimates developed to support the 1999 disaggregation, this results in a series of emission estimates that reflect the phase-in of applicable emission standards as well as the turnover of the affected fleet. It should be noted that both the NONROAD and MOBILE6.2 input files assembled to support this exercise include expected changes in both diesel and gasoline fuel sulfur content as well as a full set of input parameters developed from information presented in the inventory reference documents. Nevertheless, it is important to recognize that the modeled emission estimates were used only in a relative fashion to adjust locally-generated emission estimates extracted from the reference inventories. In no case were emission estimates from these modeling runs used in an absolute fashion for this work. It is also important to recognize that growth factors to account for changes in vehicle miles of travel, as presented in the MAG Ozone and CO Redesignation Request documents, are applied to the MOBILE6.2 emission factors to derive overall expected onroad vehicle emissions changes between 1994, 1999, 2005, 2006, 2010, and 2015.

The growth rates implied by the MAG Ozone and CO Redesignation Request inventories were used to estimate *total* nonroad and *total* onroad mobile source emissions in 2006 and 2015 from the baseline 1999 Ozone PEI-based estimates. The data presented in the Redesignation Request documents do not allow for a more resolved approach. For onroad vehicles, vehicle type-specific emissions were estimated from the 2006 and 2015 onroad emissions totals by applying 1999 Ozone PEI-corrected emission fractions from the MOBILE6.2 modeling exercise. The 1999 Ozone PEI correction is essentially the ratio of observed (i.e., PEI) 1999 vehicle type-specific emission fractions to the MOBILE6.2 vehicle type-specific emission fractions for 1999. This ratio effectively accounts for differences between local VMT mixes and those assumed in MOBILE6.2, and when applied to MOBILE6.2 vehicle type-specific emission fractions for 2006 and 2015 results in expected Maricopa County-specific emission fractions for those same years. These fractions are then used to disaggregate total 2006 and 2015 onroad emission estimates into eight vehicle type-specific categories.³⁶ Onroad VOC, CO, and NO_x for 2005 and 2010 are then estimated at the vehicle type level of detail by interpolating on the basis of the MOBILE6.2 emission estimates as follows:

$$\begin{aligned} \text{2005 Emissions} &= \left[\left(\frac{\text{MOBILE6.2 2005} - \text{MOBILE6.2 1999}}{\text{MOBILE6.2 2006} - \text{MOBILE6.2 1999}} \right) \times (\text{PEI Based 2006} - \text{PEI Based 1999}) \right] + \text{PEI Based 1999} \\ \text{2010 Emissions} &= \left[\left(\frac{\text{MOBILE6.2 2010} - \text{MOBILE6.2 2006}}{\text{MOBILE6.2 2015} - \text{MOBILE6.2 2006}} \right) \times (\text{PEI Based 2015} - \text{PEI Based 2006}) \right] + \text{PEI Based 2006} \end{aligned}$$

2005 and 2010 total onroad emissions are then calculated as the sum of the estimated emissions for the eight vehicle types.

For onroad CO emissions one additional step was required in that a 1999 version of the MAG CO Redesignation Request inventory had to be produced before the steps described above were possible. This inventory was developed using the same approach except that the relationships between the MOBILE6.2 inventories for 1994, 1999, and 2006 and the MAG CO Redesignation Request inventories for 1994 and 2006 were employed.

For nonroad mobile sources a similar, but somewhat modified procedure, was employed. The modifications are required because the EPA's NONROAD model does not estimate either aircraft or locomotive emissions. Therefore, emissions for these sources must be developed independently. Aircraft emissions of VOC, CO, and NO_x for 2005, 2006, 2010, and 2015 were assumed to follow the same growth rate as area source emissions. This approach was considered to be optimal given the available data since area source emissions generally grow in accordance with socioeconomic factors, and no significant changes in aircraft emissions control are expected over the evaluation timeframe. For the same reason, locomotive emissions for 2005, 2006, 2010,

³⁶ LDGV (light duty gasoline vehicles - passenger cars), LDGT1 (light duty gasoline trucks up to 6,000 pounds gross vehicle weight), LDGT2 (light duty gasoline trucks over 6,000 pounds gross vehicle weight), HDGV (heavy duty gasoline vehicles), LDDV (light duty diesel vehicles - passenger cars), LDDT (light duty diesel trucks), HDDV (heavy duty diesel vehicles), and MC (motorcycles); the standard onroad emissions vehicle classes.

and 2015 are also expected to grow at the same rate as area sources. However, since locomotive emission controls are currently undergoing a phase-in period, an additional control factor was applied to 2005, 2006, 2010, and 2015 emission estimates based on 1999, 2005, 2006, 2010, and 2015 control factors extracted from EPA's technical support document for the applicable locomotive rulemaking.³⁷ Nonroad emissions for other nonroad (i.e., non-aircraft, non-locomotive) equipment in 2006 and 2015 were then estimated by subtracting aircraft and locomotive estimates from total nonroad emission estimates for the same years (developed as described above).

Once non-aircraft, non-locomotive nonroad emission estimates for 2006 and 2015 were established, the estimates were disaggregated into 2-stroke gasoline, 4-stroke gasoline, and non-gasoline components using 1999 Ozone PEI-corrected emission fractions from the NONROAD modeling exercise described above. The 1999 Ozone PEI correction is essentially the ratio of observed (i.e., PEI) 1999 engine type-specific emission fractions to the NONROAD engine type-specific emission fractions for 1999. This ratio effectively accounts for differences between local equipment mixes and those assumed in NONROAD, and when applied to NONROAD equipment type-specific emission fractions for 2006 and 2015 results in expected Maricopa County-specific emission fractions for those same years. These fractions are then used to disaggregate total non-aircraft and non-locomotive 2006 and 2015 emission estimates into the three engine type-specific categories.³⁸ Non-aircraft and non-locomotive VOC, CO, and NO_x for 2005 and 2010 are then estimated at the engine type level of detail by interpolating on the basis of the NONROAD emission estimates as follows:

$$\begin{aligned} \text{2005 Emissions} &= \left[\left(\frac{\text{NONROAD 2005} - \text{NONROAD 1999}}{\text{NONROAD 2006} - \text{NONROAD 1999}} \right) \times (\text{PEI Based 2006} - \text{PEI Based 1999}) \right] + \text{PEI Based 1999} \\ \text{2010 Emissions} &= \left[\left(\frac{\text{NONROAD 2010} - \text{NONROAD 2006}}{\text{NONROAD 2015} - \text{NONROAD 2006}} \right) \times (\text{PEI Based 2015} - \text{PEI Based 2006}) \right] + \text{PEI Based 2006} \end{aligned}$$

2005 and 2010 total non-aircraft and non-locomotive nonroad emissions are then calculated as the sum of the estimated emissions for the three engine types. These estimates are then added to those for aircraft and locomotives to derive total 2005 and 2010 nonroad emission estimates.

As was the case with onroad vehicles, CO emission estimates require one additional step in that a 1999 version of MAG CO Redesignation Request inventory had to be produced before the steps described above were possible. This inventory was developed using the same approach except that the relationships between the NONROAD inventories for 1994, 1999, and 2006 and the MAG CO Redesignation Request inventories for 1994 and 2006 were employed, as well as identical growth assumptions for aircraft and locomotives as described above.

³⁷ Specifically, control factors were developed using relations presented in the EPA spreadsheet "locorsd.wk3," as downloaded using the link: <http://www.epa.gov/otaq/regs/nonroad/locomotv/fm/locorsd.wk3>.

³⁸ 2-stroke gasoline engines, 4-stroke gasoline engines, and non-gasoline engines.

Finally, the evaporative and exhaust emission components of both onroad vehicle and nonroad engine emissions were developed using emission estimates from the NONROAD and MOBILE6.2 modeling exercises. Ratios of evaporative to total emissions were developed at the vehicle and engine type level of detail. These ratios were then applied to the PEI-based vehicle and engine type emission estimates for 2005 and 2010 to disaggregate evaporative and exhaust emissions.

Wintertime CO inventories were developed by applying the ratio of 1999 wintertime CO emissions to 1999 summertime CO emissions to the developed 2005 and 2010 summertime CO emission estimates. This exercise was performed at the source-specific level of detail, so that source specific growth rates and control efficiencies were maintained. It is perhaps worth noting that the application of 1999 emissions ratios to 2005 and 2010 summertime emission estimates imparts no forecast error as the ratio accurately accounts for changes in seasonal activity differentials and seasonal emissions profile differentials for any forecast scenario where emissions controls are either constant across seasons or where seasonal emissions controls are constant over the forecast period, as is the case in this study.

Summaries of the resulting VOC, CO, and NO_x inventories are presented in **Tables 7.2 and 7.3**. These inventories were used to generate all VOC, CO, and NO_x impact estimates presented in this report.

To estimate fuel formulation impacts on PM, additional 2005 and 2010 inventories for PM-10 and PM-2.5, as well as 2005 and 2010 inventories for SO₂ emissions are required.³⁹ Unfortunately, none of the reference inventories provide PEI-equivalent data for these pollutants and the two reference inventories that provide PM and SO₂ data (i.e., the MAG PM Plan and the C&T inventories) indicate substantially different inventory estimates, even after differences in geographic coverage are taken into consideration. As a result, surrogate inventory generation methods are required. While, in many cases as described below, the surrogate methods rely on either the MAG PM Plan or the C&T inventories, care has been taken to ensure that the utilized methodology results in reasonably accurate inventory estimates to the maximum possible extent.

Since both the NONROAD and MOBILE6.2 models produce SO₂, PM-10, and PM-2.5 emission estimates, the generation of the required inventories for onroad and nonroad engines (other than aircraft and locomotives) is relatively straightforward. Using the outputs of the modeling exercises described above, ratios of SO₂ to NO_x, PM-10 to NO_x, and PM-2.5 to NO_x were developed at the onroad vehicle type and nonroad engine type level of detail using MOBILE6.2 and NONROAD respectively, both executed for a reasonably precise set of Maricopa County input data. These ratios were then applied to the PEI-based emission estimates for 2005 and 2010 NO_x to develop 2005 and 2010 SO₂, PM-10, and PM-2.5 emission estimates. PM-10 and PM-2.5 estimates were then disaggregated into their metallic (i.e., lead), carbon, sulfate, and

³⁹ SO₂ inventories are necessary to estimate indirect, or secondary, sulfate particulate levels.

TABLE 7.2: BASELINE EMISSION INVENTORIES FOR 2005 (METRIC TONS PER DAY)

Source Category	Summer								Winter
	VOC	NO _x	CO	SO ₂	Direct PM-10	Direct PM-2.5	Indirect PM-10	Indirect PM-2.5	CO
Point Sources	19.69	26.79	11.21	0.76	4.01	2.14	2.26	1.88	15.80
Area (excluding Geologic)	98.67	25.07	49.55	2.37	4.17	3.46	2.73	2.31	25.68
Area (Geologic)	0.00	0.00	0.00	0.00	33.80	12.58	0.00	0.00	0.00
Biogenic	44.40	8.88	0.00	0.00	0.00	0.00	0.66	0.54	0.00
Nonroad Equipment	63.20	76.16	531.72	7.08	6.89	6.23	8.23	6.98	538.32
Aircraft	5.41	24.35	46.93	2.40	1.16	0.83	2.68	2.28	53.53
Locomotives	1.16	23.32	3.98	1.47	0.62	0.57	2.26	1.90	3.98
All Other Nonroad	56.63	28.49	480.81	3.21	5.11	4.83	3.29	2.80	480.81
2-Stroke Gasoline	21.00	0.56	42.02	0.01	2.49	2.29	0.05	0.04	42.02
4-Stroke Gasoline	28.95	0.60	408.93	0.01	0.03	0.02	0.05	0.04	408.93
Diesel/CNG/LPG	6.68	27.33	29.86	3.19	2.59	2.52	3.19	2.72	29.86
Onroad Vehicles	60.18	118.29	517.54	3.22	3.32	2.11	9.95	8.24	443.47
Gasoline Vehicles	55.33	84.92	482.85	1.88	2.16	1.11	6.98	5.77	407.37
Diesel Vehicles	4.85	33.38	34.69	1.34	1.16	1.00	2.97	2.47	36.10
Road Dust	0.00	0.00	0.00	0.00	148.10	48.17	0.00	0.00	0.00
Total Emissions	286.15	255.19	1110.02	13.43	200.28	74.69	23.83	19.95	1023.28
Manmade Emissions	241.75	246.31	1110.02	13.43	18.39	13.94	23.17	19.42	1023.28

non-exhaust components using emission fractions from the NONROAD and MOBILE6.2 modeling exercises.⁴⁰

Point source SO₂, PM-10, and PM-2.5 emission estimates were developed on the basis of SO₂ to NO_x, PM-10 to NO_x, and PM-2.5 to NO_x ratios from the C&T inventories. For point sources, the PEI-based NO_x estimates are reasonably consistent with those of both the C&T inventories and the MAG PM Plan. In addition, the C&T inventory estimates for PM-10, PM-2.5, and SO₂ are reasonably close to those of the MAG PM Plan and include estimates for both 2002 and 2018. This allows for interpolation of both 2005 and 2010 inventories and development of 2005 and 2010 specific emissions ratios. These ratios were then applied to estimated PEI-based point source NO_x for both years to generate the requisite SO₂, PM-10, and PM-2.5 inventories.

⁴⁰ The NONROAD model does not explicitly provide emission estimates for the PM components, but the underlying algorithms used by the model are available in EPA technical documentation and were used to derive the required component fractions. The specific referenced technical documents are: “Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling—Compression-Ignition,” NR-009c, EPA420-P-04-009, U.S. EPA, Revised April 2004, and “Exhaust Emission Factors for Nonroad Engine Modeling – Spark-Ignition,” NR-010d, EPA420-P-04-010, U.S. EPA, Revised April 2004.

TABLE 7.3: BASELINE EMISSION INVENTORIES FOR 2010 (METRIC TONS PER DAY)

Source Category	Summer								Winter
	VOC	NO _x	CO	SO ₂	Direct PM-10	Direct PM-2.5	Indirect PM-10	Indirect PM-2.5	CO
Point Sources	21.47	29.02	14.64	0.76	4.57	2.43	2.43	2.01	20.63
Area (excluding Geologic)	111.17	28.65	55.73	2.71	4.76	3.96	3.12	2.64	28.89
Area (Geologic)	0.00	0.00	0.00	0.00	29.77	11.08	0.00	0.00	0.00
Biogenic	46.64	8.34	0.00	0.00	0.00	0.00	0.62	0.51	0.00
Nonroad Equipment	28.72	74.72	545.43	5.00	7.20	6.44	7.37	6.20	552.86
Aircraft	6.10	27.83	52.78	3.14	1.39	0.99	3.21	2.74	60.20
Locomotives	1.16	21.75	4.48	1.57	0.61	0.56	2.19	1.84	4.48
All Other Nonroad	21.46	25.15	488.18	0.29	5.20	4.89	1.97	1.62	488.18
2-Stroke Gasoline	8.15	0.66	39.69	0.01	3.08	2.84	0.05	0.04	39.69
4-Stroke Gasoline	9.43	0.88	426.98	0.01	0.04	0.04	0.07	0.06	426.98
Diesel/CNG/LPG	3.88	23.61	21.51	0.28	2.07	2.01	1.85	1.52	21.51
Onroad Vehicles	46.22	85.73	487.53	0.84	3.10	1.73	6.66	5.47	414.87
Gasoline Vehicles	41.93	61.23	460.38	0.76	2.34	1.12	4.82	3.96	386.60
Diesel Vehicles	4.29	24.49	27.15	0.08	0.76	0.61	1.84	1.51	28.28
Road Dust	0.00	0.00	0.00	0.00	175.62	57.12	0.00	0.00	0.00
Total Emissions	254.22	226.46	1103.34	9.30	225.02	82.76	20.20	16.83	1017.25
Manmade Emissions	207.58	218.12	1103.34	9.30	19.63	14.55	19.58	16.33	1017.25

Because there is a large geologic (i.e., windblown dust) component to area source PM emissions that is not dependent on combustion or economic activity (and thus has no effective relationship to VOC, CO, and NO_x emissions), area sources are treated separately for non-geologic and geologic emissions of PM. For non-geologic area sources emissions, there is little consistency between NO_x emission estimates from the PEI-based inventories, the C&T inventories, and those of the MAG PM Plan. All three sources indicate significantly different emissions, with the C&T inventories indicating the lowest level of NO_x (even though they cover the largest geographic area), and the PEI-based inventories indicating the highest level of NO_x (even though they cover the smallest geographic area). However, the C&T and MAG PM Plan do indicate more consistent PM emissions.

Given the primacy of the MAG PM Plan on a local planning basis, it was decided to utilize the MAG PM-10, PM-2.5, and SO₂ estimates directly. However, since these estimates apply to 1994, it was necessary to extrapolate the 1999 Ozone PEI-based emission estimates for NO_x back to 1994 to develop reliable PM-10 to NO_x, PM-2.5 to NO_x, and SO₂ to NO_x ratios. Application of these ratios to 1994 NO_x would effectively result in emission estimates identical to those of the MAG PM Plan, but the same ratios can then be carried forward to estimate non-geologic area source emissions for other years. This approach was used to estimate 2005 and 2010 PM-10, PM-2.5, and SO₂ emissions from PEI-based 2005 and 2010 NO_x estimates.

The approach necessarily assumes that PM and SO₂ emissions vary with NO_x and this will not be true if control programs disproportionately affect one or the other species during the forecast period. It seems reasonable to expect that such controls will have only minor, if any, impacts in the area source sector.

For geologic area source emissions, it is not possible to utilize a combustion-based emissions surrogate to derive PEI-equivalent emission estimates. Geologic area source emissions from the C&T and MAG PM Plan inventories are widely different, as one would expect given the substantial geographic differences in their scope. Since the geographic coverage of the MAG PM Plan is reasonably consistent with that of the PEI-based inventories, it was decided to use the ratio of the MAG PM Plan geologic to non-geologic area source emissions as the basis for deriving PEI-equivalent geologic area source emissions from PEI non-geologic area source emissions. Although the MAG PM Plan ratio is applicable to 1994, the Plan also provides a presentation of how geologic “emissions” change over time.⁴¹ Thus the combination of the 1994 geologic to non-geologic ratio with a ratio of MAG PM Plan future year to MAG PM Plan 1994 geologic emissions provides a robust treatment of changes in geologic emissions over time. Both ratios as applicable to 2005 and 2010 were applied to the PEI-based non-geologic area source PM emissions for those same years to derive estimates of equivalent geologic PM-10 and PM-2.5.

As with geologic area source emissions, it is not possible to utilize a combustion-based emissions surrogate to derive PEI-equivalent road dust PM emission estimates. Moreover, road dust emissions from the C&T and MAG PM Plan inventories are widely different, but not in accordance with applicable differences in geographic coverage as those of the MAG PM Plan are actually larger than those of the C&T inventories that are applicable to a much larger geographic area. Given the relative similarity in the geographic coverage of the MAG PM Plan and the PEI, it was decided to utilize the road dust emissions from the MAG PM Plan directly. Since these emissions apply to 1994, they were “grown” to 2005 and 2010 in accordance with the changes in expected vehicle miles of travel (as extracted from the MAG Ozone and CO Redesignation Request documentation).

Interpolated 2005 and 2010 C&T inventory ratios for SO₂ to NO_x, PM-10 to NO_x, and PM-2.5 to NO_x were used to estimate 2005 and 2010 aircraft SO₂, PM-10, and PM-2.5 emissions from aircraft. The MAG PM Plan provides no estimates for aircraft PM and is, therefore, not a viable option. It should be noted that the C&T NO_x emissions estimates for aircraft are substantially lower than those of the PEI-based inventories (despite its larger geographic coverage), but there is no other available reference inventory. However, the consistent C&T emission inventories for 2002 and 2018, which are used to incorporate the requisite time-sensitive emission changes between emissions evaluation years, also indicate much lower aircraft PM than the detailed 2002 emissions inventory presented in reference document 5 (listed at the beginning of this section), upon which they reportedly are based. Therefore, the application of a ratio developed from lower than expected PM and NO_x C&T inventory estimates to higher PEI-based NO_x estimates will result in more reasonable than expected PEI-equivalent aircraft PM estimates.

⁴¹ The MAG PM Plan includes estimates for 1995, 2001, and 2006. These data were extrapolated to 1994 and 2010 and interpolated to 2005 to derive a complete (in the context of this work) timeline of geologic emissions “growth.”

Locomotive SO₂, PM-10, and PM-2.5 emissions from the C&T inventories are substantially lower than corresponding emissions from the MAG PM Plan, despite the smaller geographic coverage of the latter. However, the same relationship is observed for locomotive NO_x emissions, so that the SO₂ to NO_x, PM-10 to NO_x, and PM-2.5 to NO_x emissions ratios for locomotives from the same two sources are remarkably consistent. Therefore, interpolated 2005 and 2010 C&T inventory ratios for SO₂ to NO_x, PM-10 to NO_x, and PM-2.5 to NO_x were used to estimate 2005 and 2010 locomotive SO₂, PM-10, and PM-2.5 emissions using 2005 and 2010 PEI-based NO_x emissions for locomotives.

Summaries of the resulting SO₂, PM-10, and PM-2.5 inventories are presented in the columns labeled SO₂, direct PM-10, and direct PM-2.5 in Tables 7.1 through 7.3 above. The inventories presented in Tables 7.2 and 7.3 were used to generate all impact estimates presented in this report.

In addition to being directly emitted, PM is also created in the atmosphere from directly emitted SO₂ and NO_x. Since gasoline reformulation can affect the quantity of SO₂ and NO_x emitted from combustion sources, it is important to consider the potential impacts of such changes on the post-combustion atmospheric formation of PM. Such PM is often referred to as secondary or indirect PM, and the latter terminology is employed throughout this report.

To estimate the potential impacts of gasoline reformulation on indirect PM, baseline inventories for indirect PM-10 and PM-2.5 were developed. It should be recognized that there is no standard method of developing such inventories independent of detailed air quality modeling or monitoring data analysis beyond the scope of this project, but care has been taken to ensure that the developed inventories are as reasonable as possible given existing information. The U.S. EPA PART5 emission factor model, used for regulatory purposes prior to the development of MOBILE6, assumed that 12 percent of emitted SO₂ was ultimately converted to sulfate PM in the atmosphere. Although this assumption has not been carried over to MOBILE6 to encourage the development and use of local conversion factors, the 12 percent figure essentially represents the only “regulatory” indirect PM estimation factor ever developed in the U.S. for general use. PART5 did not estimate indirect nitrate PM and no other official estimation tool independent of detailed air quality modeling or monitoring data analysis is available.

To determine the potential applicability of the 12 percent conversion rate for sulfate PM and estimate a corresponding conversion rate for nitrate PM, a previously developed report summarizing available information on indirect PM was reviewed.⁴² As expected, this report indicates indirect sulfate conversion rates that vary widely over a range from 5-50 percent of emitted SO₂. However, the report also clearly shows that the fraction of local PM associated with indirect sulfate is directly dependent on available atmospheric water, which is required to facilitate the formation of sulfuric acid, an intermediate reaction product in the formation of atmospheric sulfate PM. Areas with relatively high humidity show much greater proportions of indirect sulfate than areas such as Arizona and Nevada with relatively dry climates. Therefore, it

⁴² “A Review of Primary and Secondary Particulate Matter Associated with Light Duty Vehicles: Task 3 Draft Report,” Energy and Environmental Analysis, Inc., August 1997.

seems reasonable that indirect sulfate formation in Arizona would be on the lower end of the 5-50 percent conversion range. Since the 12 percent SO₂ conversion value previously employed by the U.S. EPA in PART5 meets such a criterion quite well, it was used without change in the development of indirect sulfate PM emission inventories for this study.

The same indirect PM report indicates conversion rates for NO_x to indirect nitrate that range from near zero to as high as 7 percent. These lower rates generally reflect the fact that NO_x participates in a wide range of atmospheric reactions and so is somewhat less “available” to participate in indirect nitrate PM reactions than simple NO_x emission rates would imply. As with indirect sulfate PM, atmospheric water plays an important role in indirect nitrate PM formation and therefore one would expect conversion rates in Arizona to be constrained relative to those observed in other areas of the U.S. Data cited in the referenced indirect PM report indicate an annual average NO_x to nitrate conversion rate for the non-coastal southwestern U.S. of about 2 percent. In the absence of specific Arizona data, this value was used for the development of indirect nitrate PM emission inventories for this study.

In addition to the SO₂ to sulfate and NO_x to nitrate conversion rates, the mass relationships between SO₂ and indirect sulfate PM, and NO_x and indirect nitrate PM must also be estimated. It is general practice to assume that indirect sulfate PM is fully neutralized ammonium sulfate ((NH₄)₂SO₄) and indirect nitrate PM is fully neutralized ammonium nitrate (NH₄NO₃). The mass numbers for both species can readily be calculated to be 132 and 80 respectively, but both species are hygroscopic and adsorb water, which further adds to the indirect PM mass. Here again, one would expect water adsorption in Arizona to be limited relative to other areas of the U.S., but such rates are not zero.

As part of their regional haze guidance, the U.S. EPA has released a document designed to assist states in tracking progress toward haze reduction goals. This document includes a set of recommended coefficients, derived from local atmospheric data, to correct the light scattering characteristics of ammonium sulfate and ammonium nitrate for adsorbed water vapor.⁴³ There are data for 12 areas in Arizona, which taken together show very little variation. From these data, an average summertime correction factor (i.e., the arithmetic average of June, July, and August data) of 1.5 was derived. Since the units of the scattering coefficients are mass based, this factor is exactly equivalent to a 1.5 percent increase in nitrate and sulfate mass, or an increase in PM mass numbers to 198 for hydrated ammonium sulfate and 120 for hydrated ammonium nitrate in Arizona. Given a mass number of 18 for water, these relations imply 3.7 moles of water for every mole of ammonium sulfate and 2.2 moles of water for every mole of ammonium nitrate.

Since the mass number of SO₂ is 64, there is a mass correction of 3.1 (198/64) for every mole of SO₂ that is converted to indirect PM. For NO_x, which is reported as NO₂, the effective mass number is 46. This produces a mass correction of 2.6 (120/46) for every mole of NO_x that is converted to indirect PM.

⁴³ “Guidance for Tracking Progress Under the Regional Haze Rule,” EPA-454/B-03-004, U.S. EPA, September 2003. See specifically, Table A-2, “Recommended Monthly Site-Specific f(RH) Values for Each Mandatory Federal Class I Area.”

Indirect sulfate and nitrate PM size distributions are taken from the same indirect PM report used to derive the SO₂ and NO_x conversion fractions discussed above.⁴⁴ That report indicates that all “but a few percent” of both indirect sulfate and indirect nitrate PM is PM-10, and that 85-95 percent of indirect sulfate particulate and 70-90 percent of indirect nitrate particulate is PM-2.5. On this basis, this study assumes that 98 percent of both species is PM-10, while assuming 90 percent of indirect sulfate and 80 percent of indirect nitrate is PM-2.5.

Using these data, emission inventories for indirect sulfate and indirect nitrate PM were developed from the SO₂ and NO_x inventories previously discussed. Summaries of the resulting PM-10 and PM-2.5 inventories are presented in the columns labeled indirect PM-10 and indirect PM-2.5 in Tables 7.1 through 7.3 above. The inventories presented in Tables 7.2 and 7.3 were used to generate all impact estimates presented in this report.

It should also be recognized that indirect organic PM also can be produced through atmospheric reactions involving emitted VOC. However, specific information of a quality necessary to develop reliable emission estimates of indirect organic PM for a given VOC inventory is not generally available and, for this reason, no emissions or emissions impacts related to indirect organic PM have been estimated in this study. It is believed that this exclusion does not impact study conclusions in any meaningful way as the data available on indirect organic PM indicate that it generally contributes only a small portion of overall PM mass. For example, a chemical mass balance study conducted in Arizona, as reported in the indirect PM report used to develop the indirect nitrate and sulfate conversion fractions discussed above, indicates that indirect organic PM constitutes a negligible fraction of local PM-2.5.⁴⁵ While this single data point cannot be assumed to definitively reflect the overall importance of indirect organic PM, it is indicative of the relative importance of organic PM mass as compared to that associated with sulfates and nitrates. Nevertheless, the impacts of specific gasoline formulations on indirect organic PM can generally be assumed to vary directly with impacts on VOC emissions, so that changes in VOC emissions can be used as a qualitative surrogate for any associated indirect organic PM impact.

Finally, because changes in fuel formulations will affect exhaust and evaporative emissions as well as PM emissions components differently, **Tables 7.4 through 7.9** present a more detailed breakdown of nonroad engine and onroad vehicle gasoline-related emissions. Tables 7.4 and 7.5 present distributions for 1999, which are included for reference purposes only since 1999 Ozone PEI emissions form the basis of the emission estimates for 2005 and 2010. Tables 7.6 and 7.7 present the corresponding distributions for 2005, while Table 7.8 and 7.9 present those for 2010. From these tables, it is possible to get a more robust indication of the absolute level of emissions that various fuel formulation changes might affect. **Tables 7.10 through 7.12** present a synopsis of the emissions distribution data expressed in terms of fraction of total and fraction of manmade emissions. As indicated in Table 7.12, gasoline-related emissions, with the

⁴⁴ “A Review of Primary and Secondary Particulate Matter Associated with Light Duty Vehicles: Task 3 Draft Report,” Energy and Environmental Analysis, Inc., August 1997.

⁴⁵ Ibid.

**TABLE 7.4: DISTRIBUTION OF 1999 NONROAD GASOLINE EQUIPMENT EMISSIONS
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
2-Stroke Engines	31.78	0.62	51.33	0.06	3.42	3.14	51.33
Exhaust	29.45	0.62	51.33	0.06	3.42	3.14	51.33
Direct Carbon	0.00	0.00	0.00	0.00	3.34	3.07	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	0.02	0.02	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	0.05	0.04	0.00
Evaporative	2.33	0.00	0.00	0.00	0.00	0.00	0.00
4-Stroke Engines	31.82	0.89	386.33	0.04	0.12	0.10	386.33
Exhaust	26.11	0.89	386.33	0.04	0.12	0.10	386.33
Direct Carbon	0.00	0.00	0.00	0.00	0.03	0.03	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	0.02	0.01	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	0.07	0.05	0.00
Evaporative	5.71	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust Total	55.56	1.51	437.66	0.10	3.54	3.24	437.66
Evaporative Total	8.04	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	63.59	1.51	437.66	0.10	3.54	3.24	437.66

**TABLE 7.5: DISTRIBUTION OF 1999 ONROAD GASOLINE VEHICLE EMISSIONS
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
Exhaust	39.53	91.17	545.60	5.01	9.48	7.99	459.41
Direct Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Direct Carbon	0.00	0.00	0.00	0.00	0.56	0.46	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.33	0.33	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	1.83	1.68	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	6.76	5.52	0.00
Evaporative	36.36	0.00	0.00	0.00	0.00	0.00	0.00
Non-Exhaust/Non-Evap	0.00	0.00	0.00	0.00	1.27	0.45	0.00
Tire Wear	0.00	0.00	0.00	0.00	0.50	0.12	0.00
Brake Wear	0.00	0.00	0.00	0.00	0.77	0.33	0.00
Total	75.89	91.17	545.60	5.01	10.75	8.45	459.41

**TABLE 7.6: DISTRIBUTION OF 2005 NONROAD GASOLINE EQUIPMENT EMISSIONS
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
2-Stroke Engines	21.00	0.56	42.02	0.01	2.54	2.33	42.02
Exhaust	18.80	0.56	42.02	0.01	2.54	2.33	42.02
Direct Carbon	0.00	0.00	0.00	0.00	2.49	2.29	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	0.04	0.03	0.00
Evaporative	2.20	0.00	0.00	0.00	0.00	0.00	0.00
4-Stroke Engines	28.95	0.60	408.93	0.01	0.07	0.06	408.93
Exhaust	23.28	0.60	408.93	0.01	0.07	0.06	408.93
Direct Carbon	0.00	0.00	0.00	0.00	0.02	0.02	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	0.04	0.04	0.00
Evaporative	5.67	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust Total	42.08	1.16	450.95	0.02	2.61	2.40	450.95
Evaporative Total	7.87	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	49.95	1.16	450.95	0.02	2.61	2.40	450.95

**TABLE 7.7: DISTRIBUTION OF 2005 ONROAD GASOLINE VEHICLE EMISSIONS
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
Exhaust	23.80	84.92	482.85	1.88	7.60	6.33	407.37
Direct Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Direct Carbon	0.00	0.00	0.00	0.00	0.51	0.46	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.10	0.10	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	0.69	0.63	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	6.30	5.14	0.00
Evaporative	31.53	0.00	0.00	0.00	0.00	0.00	0.00
Non-Exhaust/Non-Evap	0.00	0.00	0.00	0.00	1.55	0.55	0.00
Tire Wear	0.00	0.00	0.00	0.00	0.60	0.15	0.00
Brake Wear	0.00	0.00	0.00	0.00	0.94	0.40	0.00
Total	55.33	84.92	482.85	1.88	9.14	6.88	407.37

**TABLE 7.8: DISTRIBUTION OF 2010 NONROAD GASOLINE EQUIPMENT EMISSIONS
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
2-Stroke Engines	8.15	0.66	39.69	0.01	3.14	2.88	39.69
Exhaust	6.96	0.66	39.69	0.01	3.14	2.88	39.69
Direct Carbon	0.00	0.00	0.00	0.00	3.08	2.84	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	0.05	0.04	0.00
Evaporative	1.19	0.00	0.00	0.00	0.00	0.00	0.00
4-Stroke Engines	9.43	0.88	426.98	0.01	0.11	0.09	426.98
Exhaust	6.99	0.88	426.98	0.01	0.11	0.09	426.98
Direct Carbon	0.00	0.00	0.00	0.00	0.04	0.04	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	0.07	0.05	0.00
Evaporative	2.44	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust Total	13.95	1.54	466.67	0.01	3.24	2.97	466.67
Evaporative Total	3.63	0.00	0.00	0.00	0.00	0.00	0.00
Grand Total	17.58	1.54	466.67	0.01	3.24	2.97	466.67

**TABLE 7.9: DISTRIBUTION OF 2010 ONROAD GASOLINE VEHICLE EMISSIONS
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
Exhaust	16.50	61.23	460.38	0.76	5.34	4.43	386.60
Direct Lead	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Direct Carbon	0.00	0.00	0.00	0.00	0.48	0.43	0.00
Direct SO ₄	0.00	0.00	0.00	0.00	0.04	0.04	0.00
Indirect SO ₄	0.00	0.00	0.00	0.00	0.28	0.25	0.00
Indirect NO ₃	0.00	0.00	0.00	0.00	4.54	3.71	0.00
Evaporative	25.42	0.00	0.00	0.00	0.00	0.00	0.00
Non-Exhaust/Non-Evap	0.00	0.00	0.00	0.00	1.82	0.65	0.00
Tire Wear	0.00	0.00	0.00	0.00	0.71	0.18	0.00
Brake Wear	0.00	0.00	0.00	0.00	1.11	0.47	0.00
Total	41.93	61.23	460.38	0.76	7.16	5.08	386.60

TABLE 7.10: FRACTION OF 1999 EMISSIONS ASSOCIATED WITH GASOLINE COMBUSTION

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
<i>Fraction of Total Emissions</i>							
Nonroad Engines	21.0%	0.6%	38.4%	0.7%	1.7%	3.6%	42.0%
Exhaust	18.3%	0.6%	38.4%	0.7%	1.7%	3.6%	42.0%
Evaporative	2.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Onroad Vehicles	25.0%	34.4%	47.9%	33.3%	5.3%	9.4%	44.1%
Exhaust	13.0%	34.4%	47.9%	33.3%	4.7%	8.9%	44.1%
Evaporative	12.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.6%	0.5%	0.0%
Gasoline Total	46.0%	34.9%	86.4%	34.0%	7.0%	13.0%	86.2%
Exhaust	31.3%	34.9%	86.4%	34.0%	6.4%	12.5%	86.2%
Evaporative	14.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.6%	0.5%	0.0%
<i>Fraction of Manmade Emissions (i.e., Excluding Biogenic and Geologic Emissions)</i>							
Nonroad Engines	24.5%	0.6%	38.4%	0.7%	8.2%	9.2%	42.0%
Exhaust	21.4%	0.6%	38.4%	0.7%	8.2%	9.2%	42.0%
Evaporative	3.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Onroad Vehicles	29.3%	35.6%	47.9%	33.3%	25.1%	23.9%	44.1%
Exhaust	15.2%	35.6%	47.9%	33.3%	22.1%	22.6%	44.1%
Evaporative	14.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	3.0%	1.3%	0.0%
Gasoline Total	53.8%	36.2%	86.4%	34.0%	33.3%	33.1%	86.2%
Exhaust	36.7%	36.2%	86.4%	34.0%	30.4%	31.8%	86.2%
Evaporative	17.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	3.0%	1.3%	0.0%

exception of CO, are expected to comprise less than one-third of all manmade emissions in Maricopa County by 2010.

TABLE 7.11: FRACTION OF 2005 EMISSIONS ASSOCIATED WITH GASOLINE COMBUSTION

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
<i>Fraction of Total Emissions</i>							
Nonroad Engines	17.5%	0.5%	40.6%	0.2%	1.2%	2.5%	44.1%
Exhaust	14.7%	0.5%	40.6%	0.2%	1.2%	2.5%	44.1%
Evaporative	2.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Onroad Vehicles	19.3%	33.3%	43.5%	14.0%	4.1%	7.3%	39.8%
Exhaust	8.3%	33.3%	43.5%	14.0%	3.4%	6.7%	39.8%
Evaporative	11.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.7%	0.6%	0.0%
Gasoline Total	36.8%	33.7%	84.1%	14.2%	5.2%	9.8%	83.9%
Exhaust	23.0%	33.7%	84.1%	14.2%	4.6%	9.2%	83.9%
Evaporative	13.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.7%	0.6%	0.0%
<i>Fraction of Manmade Emissions (i.e., Excluding Biogenic and Geologic Emissions)</i>							
Nonroad Engines	20.7%	0.5%	40.6%	0.2%	6.3%	7.2%	44.1%
Exhaust	17.4%	0.5%	40.6%	0.2%	6.3%	7.2%	44.1%
Evaporative	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Onroad Vehicles	22.9%	34.5%	43.5%	14.0%	22.0%	20.6%	39.8%
Exhaust	9.8%	34.5%	43.5%	14.0%	18.3%	19.0%	39.8%
Evaporative	13.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	3.7%	1.7%	0.0%
Gasoline Total	43.6%	34.9%	84.1%	14.2%	28.3%	27.8%	83.9%
Exhaust	27.3%	34.9%	84.1%	14.2%	24.6%	26.1%	83.9%
Evaporative	16.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	3.7%	1.7%	0.0%

TABLE 7.12: FRACTION OF 2010 EMISSIONS ASSOCIATED WITH GASOLINE COMBUSTION

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
<i>Fraction of Total Emissions</i>							
Nonroad Engines	6.9%	0.7%	42.3%	0.1%	1.3%	3.0%	45.9%
Exhaust	5.5%	0.7%	42.3%	0.1%	1.3%	3.0%	45.9%
Evaporative	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Onroad Vehicles	16.5%	27.0%	41.7%	8.2%	2.9%	5.1%	38.0%
Exhaust	6.5%	27.0%	41.7%	8.2%	2.2%	4.5%	38.0%
Evaporative	10.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.7%	0.7%	0.0%
Gasoline Total	23.4%	27.7%	84.0%	8.3%	4.2%	8.1%	83.9%
Exhaust	12.0%	27.7%	84.0%	8.3%	3.5%	7.4%	83.9%
Evaporative	11.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.7%	0.7%	0.0%
<i>Fraction of Manmade Emissions (i.e., Excluding Biogenic and Geologic Emissions)</i>							
Nonroad Engines	8.5%	0.7%	42.3%	0.1%	8.3%	9.6%	45.9%
Exhaust	6.7%	0.7%	42.3%	0.1%	8.3%	9.6%	45.9%
Evaporative	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Onroad Vehicles	20.2%	28.1%	41.7%	8.2%	18.3%	16.5%	38.0%
Exhaust	8.0%	28.1%	41.7%	8.2%	13.6%	14.4%	38.0%
Evaporative	12.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	4.7%	2.1%	0.0%
Gasoline Total	28.7%	28.8%	84.0%	8.3%	26.5%	26.1%	83.9%
Exhaust	14.7%	28.8%	84.0%	8.3%	21.9%	24.0%	83.9%
Evaporative	14.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Exhaust/Non-Evap	0.0%	0.0%	0.0%	0.0%	4.7%	2.1%	0.0%

8. Emissions Analysis of CBG Options

8.1 FUEL FORMULATIONS SUBJECTED TO DETAILED EMISSIONS ANALYSIS

As described in the previous sections of this report, the supply and distribution impacts associated with several potential gasoline reformulation options have been considered. Among these options, in addition to the currently allowed federal (Type 1) and California Phase 2 (Type 2) RFG, were a California Phase 3 formulation, formulations based on gasoline delivered in five surrounding areas (Albuquerque, Denver, Las Vegas, San Antonio, and Tucson), and formulations based on changes to the current wintertime RVP and oxygen content requirements in Maricopa County (including a wintertime federal RFG option).

As previously discussed, none of the formulations based on gasoline delivered in the five surrounding areas passed an ADEQ-prescribed emissions screening evaluation – as a result, none of the five were subjected to further (detailed) emissions analysis. Additionally, ADEQ requested that detailed emissions analysis should not be performed for the formulations developed in response to potential changes in the current wintertime RVP and oxygen content requirements, with the exception of the wintertime federal RFG option. Therefore, only those formulations deliverable to Maricopa County under the existing CBG program as modified to allow:

- The inclusion of California Phase 3 gasoline as an additional compliance option (*i.e., allowing federal (Type 1), California Phase 2 (Type 2), or California Phase 3 RFG*),
- The replacement of the California Phase 2 (Type 2) compliance option with a California Phase 3 option (*i.e., allowing either federal (Type 1) or California Phase 3 RFG, but not California Phase 2 RFG*), or
- The replacement of the current California Phase 2 (Type 2) wintertime compliance option with a Federal RFG compliance option subject only to federal volatility requirements.

were subjected to detailed emissions analysis.

Through detailed supply and distribution analysis (as presented in the previous sections of this report), it is expected that only Type 1 CBG will be delivered to Maricopa County during the summertime CBG period. Due to the uncertainty associated with future ethanol economics, it is uncertain whether this summertime fuel will contain oxygen, so two distinct summertime options – one without oxygen and one blended with ethanol – were developed. Both formulations were subjected to detailed emissions analysis. Although neither CARB 2 nor CARB 3 gasoline is expected to be delivered to Maricopa County during the summer CBG period under any of the evaluated CBG program variants, summertime emissions analysis was performed for both non-oxygenated and ethanol-blended formulations of each to illustrate the potential emissions impacts that could accrue were either to be provided.

Conversely, it is expected that only Type 2 (i.e., California) CBG will be delivered to Maricopa County during the wintertime CBG period (as required under current Arizona rules). Given the potential revisions to the CBG program, this could be either California Phase 2 or California Phase 3 RFG, so formulations for both have been subjected to detailed wintertime emissions analysis. In response to an ADEQ request, federal RFG has also been subjected to detailed wintertime emissions analysis. It should be recognized, however, that the federal RFG formulation developed for this study does not meet current Arizona wintertime RVP requirements and is, therefore, indicative of the emissions impacts that would accrue if Arizona allowed federal RFG to be delivered without state-specific RVP restrictions.

As described in Section 7, the pollutant of concern during the wintertime CBG period is CO and wintertime emission inventories for other pollutants have not been developed. Therefore, detailed wintertime analysis on a mass emissions basis has been restricted to CO. However, relative emissions impacts for other pollutants have also been developed. So, although detailed mass emissions changes for pollutants other than CO will be uncertain, the relative impacts of the various wintertime fuel option on non-CO emissions is provided.

Tables 8.1a and 8.1b present the specific gasoline formulations subjected to detailed emissions analysis. In general, these are the specific fuel formulations developed through the refinery modeling analysis described in Section 6. The only exception is that the sulfur content of the baseline summer gasoline has been lowered to 28 ppm (from 56 ppm), a level identical to that of the summertime CARB CBG options.

The sulfur adjustment was implemented to avoid misrepresenting the impact of the potential CBG program changes. In 2006, all gasoline sold in the U.S. will have to meet a 30 ppm sulfur limit (on average), so that changes to current Maricopa County gasoline will occur regardless of any change to the CBG program. Since emissions analysis was to be conducted out to 2010, the optional CBG formulations are based on compliance with the 2006 sulfur limit. For consistency, baseline summertime CBG quality was adjusted to demonstrate similar compliance. As requested by ADEQ, emissions analysis was performed for both 2005 and 2010. Although not all gasoline will meet the 30 ppm sulfur limit in 2005, emissions analysis for both 2005 and 2010 was performed assuming compliance with the 30 ppm average sulfur limit. Again, this was primarily for consistency purposes since the only alternative would have been to develop distinct 2005 and 2010 formulations for all CBG options, even though no action could be taken in time to implement CBG program changes applicable to 2005. Thus, the 2005 emissions modeling results should be viewed in the context of illustrating changes expected over the 2005-2010 period, as opposed to emissions impacts for 2005 per se.

8.2 EMISSIONS MODELING METHODOLOGY

Ideally, all emissions analysis would be performed using a single, widely accepted, analytical tool. However, the practicalities of estimating emissions responses to changes in fuel formulation prohibit a “one-stop” approach. While a series of modeling tools have been developed to estimate emission responses, none is ideal for estimating emissions impacts on all gasoline vehicles and equipment on a regionwide inventory basis.

TABLE 8.1A: SUMMERTIME GASOLINE FORMULATIONS SUBJECTED TO DETAILED EMISSIONS ANALYSIS

Fuel Property	Baseline	Non-Oxygenated Federal Option	Oxygenated Federal Option	Non-Oxygenated CARB 2 Option	Oxygenated CARB 2 Option	Non-Oxygenated CARB 3 Option	Oxygenated CARB 3 Option
RVP (psi)	6.6	6.7	6.7	6.8	6.8	6.8	6.8
Oxygen (wt%)	0.0	0.0	3.5	0.0	2.0	0.0	2.0
Aromatics (vol%)	20.9	22.3	19.6	12.9	17.1	15.3	19.6
Benzene (vol%)	0.75	0.78	0.77	0.57	0.78	0.59	0.77
Olefins (vol%)	9.5	9.4	9.4	3.8	5.7	4.9	5.5
Sulfur (ppm)	28	28	28	16	23	20	17
E200 (vol% off)	43.9	45.7	48.6	37.9	45.5	40.5	43.1
E300 (vol% off)	85.5	84.5	84.1	88.9	86.4	87.8	87.5
T50 (°F)	212	209	203	208	206	205	208
T90 (°F)	318	322	324	305	315	309	310

Note: The summer baseline sulfur content based on refinery modeling of Arizona fuel sales for 2004 was 56 ppm. However, since all gasoline in the U.S., regardless of local activity in Arizona, will be regulated to 30 ppm sulfur beginning in 2006, all modeling for this study was performed as if that requirement were in place in all evaluation years (to avoid misrepresenting differences between alternative fuel formulations). Therefore, the summer baseline fuel sulfur content was modeled at 28 ppm, identical to the sulfur content of the expected summer fuel option (Type 1 federal RFG, as indicated in the shaded columns of the table).

TABLE 8.1B: WINTERTIME GASOLINE FORMULATIONS SUBJECTED TO DETAILED EMISSIONS ANALYSIS

Fuel Property	Baseline	CARB Phase 2 Option	CARB Phase 3 Option	Federal RFG Option
RVP (psi)	8.7	8.7	8.7	12.3
Oxygen (wt%)	3.5	3.5	3.5	3.5
Aromatics (vol%)	20.5	21.4	21.4	27.0
Benzene (vol%)	0.97	0.96	0.96	0.94
Olefins (vol%)	2.3	2.9	2.9	13.0
Sulfur (ppm)	20	19	17	30
E200 (vol% off)	58.4	54.1	54.1	54.9
E300 (vol% off)	89.4	89.1	89.1	82.8
T50 (°F)	183	192	192	190
T90 (°F)	302	304	304	329

Note: The federal RFG option is intended to reflect the impacts that would accrue if the current wintertime CBG program was modified to allow federal RFG formulations that were compliant with national (i.e., ASTM) volatility limits. Either CARB formulation (the shaded columns of the table) will meet all current Arizona CBG requirements.

MOBILE6.2 represents the current U.S. EPA-recommended modeling tool for motor vehicle emissions inventory development, while NONROAD is the corresponding modeling tool for nonroad equipment inventories. As described in Section 7, both models were used extensively in the development of the baseline emissions inventories for this study. MOBILE6.2 does include a robust set of fuel quality response algorithms, but the full set of algorithms are only utilized in the determination of toxic species emission rates. For criteria pollutants (i.e., VOC, CO, NO_x, SO₂, and PM), only responses to fuel RVP, oxygen content, and sulfur content (to a minimum of 30 ppm) are available. NONROAD includes similar criteria pollutant response algorithms, but does not estimate toxic emission rates.

The U.S. EPA has also developed a standardized analytical tool, the Complex Model, for reformulated gasoline certification purposes. This model includes a robust set of fuel quality response algorithms, but it has not been updated in the last decade and is designed to estimate emissions responses for a 1990-era vehicle fleet. Originally designed to estimate impacts on VOC, NO_x, and toxics, corresponding response algorithms for CO have been available for many years in an “unofficial” version of the model.

The California Air Resources Board has a similar analytical tool, the Predictive Model, for reformulated gasoline certification purposes in that state. Like the Complex Model, the Predictive Model includes a robust set of fuel quality response algorithms – but unlike the Complex Model, the Predictive Model includes algorithms for a wider range of vehicle technologies. Although the latest versions of the Predictive Model include fuel response algorithms for CO and evaporative VOC, neither is treated as extensively as exhaust VOC, NO_x, and toxic emissions.

Given the limitations of the available analytical tools and the need to develop emission impact estimates on both a per-vehicle and regional basis, a hybrid emissions analysis approach was employed. This approach includes the use of MOBILE6.2, the Complex Model, and the Predictive Model.⁴⁶ The NONROAD model is not used directly, but rather emission impacts on

⁴⁶ It is important to note that the officially released version of MOBILE6.2 has been used without adjustment for this analysis. The authors are aware of ongoing studies related to the wintertime effects of fuel volatility (particularly as related to CO) and the permeation effects of ethanol fuel blends. However, the potential impacts of these issues on estimated emissions have not been considered in this report for two reasons. First, since this report has been developed with the expectation that it would support any State Implementation Plan revisions that might result from potential CBG program changes, the use of official U.S. EPA planning tools was deemed essential. Second, although additional estimates could have been developed to investigate the sensitivity of emissions impacts to potential emission factor changes associated with both the wintertime volatility and permeation issues, the effect of those potential changes would not alter the relative impacts of the fuel formulations analyzed for this report. The permeation issue affects all of the wintertime options equally since all are assumed to contain 3.5 weight percent ethanol. At 3.5 weight percent ethanol, summertime federal CBG would be impacted to a larger degree than summertime California CBG, at 2.0 weight percent ethanol, but both the CARB 2 and CARB 3 options would be affected equally -- and it is this difference that distinguishes the potential CBG program revisions from the current program. The wintertime fuel volatility issue would affect the federal CBG option (at 12.3 psi RVP) to a greater extent than the CARB 2 and CARB 3 options (both at 8.7 psi RVP). However, there are significant other differences associated with the federal CBG option (e.g., higher aromatic, olefin, and sulfur content) that lead to increased wintertime emissions irrespective of the resolution of the fuel volatility issue.

nonroad equipment are estimated by applying the impacts estimated for similar technology onroad vehicles.

MOBILE6.2 served as the hub of the emissions analysis. Emission factors by technology type were estimated for each fuel formulation (both baseline and associated options) using MOBILE6.2 in conjunction with the same set of Arizona input data utilized to develop the baseline emission inventories presented previously in Section 7. ADEQ requested that emission impacts be derived both on a regional basis and on a per-vehicle basis by major technology classifications. For purposes of evaluating fuel quality impacts, major technology classifications were determined on the basis of catalyst technology since the approach to and effectiveness of emissions aftertreatment represent the principal drivers of advances in gasoline emissions control.

Five specific technology type groups were evaluated in this study:

- Non-catalyst vehicles and nonroad equipment (typical of 1974 and earlier passenger car technology),
- Oxidation catalyst vehicles and nonroad equipment (typical of 1975-1980 passenger car technology),
- Older technology (Tech 3) three-way catalyst vehicles and nonroad equipment (typical of 1981-1985 passenger car technology),
- Closed-loop (Tech 4) three-way catalyst vehicles and nonroad equipment (typical of 1986-1995 passenger car technology), and
- Adaptive learning (Tech 5) three-way catalyst vehicles and nonroad equipment (typical of 1996 and newer passenger car technology).

The fraction of 2005 and 2010 Maricopa County emissions associated with each of the five technology types within each of the five gasoline vehicle classes included in the Maricopa County emissions inventories (i.e., LDGV, LDGT1/2, LDGT3/4, HDGV, and MC) was determined on a pollutant-specific basis by evaluating MOBILE6.2 emissions estimates on a by-model year basis and weighting model year-specific emissions by the MOBILE6.2 model year-specific catalyst technology distributions. Thus, the emissions distributions are affected by both the model year-specific catalyst technology distributions and the fraction of emissions accumulated by vehicles in each model year (for example, a vehicle class with lower advanced technology penetrations than another class can have *higher* advanced technology emission fractions if a greater percentage of class travel is associated with advanced technology vehicles). **Tables 8.2 and 8.3** present the derived emission fractions for 2005 and 2010 by emission species and vehicle class.

Although the majority of nonroad equipment does not utilize aftertreatment to control emissions, the NONROAD model does assume small catalyst technology penetrations. For consistency with the treatment of onroad vehicle emissions, the NONROAD model was evaluated for 2005 and 2010 on a model year and technology specific basis and emissions were aggregated on a catalyst and non-catalyst basis. **Table 8.4** presents the derived emissions distributions.

TABLE 8.2: EMISSIONS-WEIGHTED TECHNOLOGY FRACTIONS FOR ONROAD VEHICLES IN 2005

Technology Category	Summer									Winter
	Exhaust VOC	Evap VOC	NO _x	CO	SO ₂	Direct PM-10	Direct PM-2.5	Indirect PM-10	Indirect PM-2.5	CO
Light Duty Gasoline Vehicles (LDGV)										
3WC-Tech 5	0.5015	0.1789	0.5631	0.6248	0.8039	0.7710	0.7710	See Note 5		0.5536
3WC-Tech 4	0.3711	0.6409	0.3697	0.3029	0.1747	0.1949	0.1949			0.3437
3WC-Tech 3	0.1130	0.1615	0.0601	0.0641	0.0191	0.0304	0.0304			0.0908
Oxidation Catalyst	0.0144	0.0187	0.0071	0.0082	0.0022	0.0036	0.0036			0.0118
Non-Catalyst	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Light Duty Gasoline Trucks – Up to 6,000 Pounds Gross Vehicle Weight (LDGT1/2)										
3WC-Tech 5	0.4356	0.1822	0.6581	0.5699	0.8127	0.7046	0.7046	See Note 5		0.5281
3WC-Tech 4	0.2951	0.5433	0.2802	0.2760	0.1625	0.1995	0.1995			0.3249
3WC-Tech 3	0.0268	0.0326	0.0070	0.0175	0.0031	0.0129	0.0129			0.0180
Oxidation Catalyst	0.2365	0.2368	0.0536	0.1335	0.0213	0.0814	0.0814			0.1263
Non-Catalyst	0.0060	0.0051	0.0011	0.0031	0.0004	0.0016	0.0016			0.0027
Light Duty Gasoline Trucks – Over 6,000 Pounds Gross Vehicle Weight (LDGT3/4)										
3WC-Tech 5	0.6235	0.2678	0.8052	0.6929	0.8846	0.7905	0.7905	See Note 5		0.6760
3WC-Tech 4	0.2068	0.5046	0.1589	0.2068	0.0990	0.1295	0.1295			0.2322
3WC-Tech 3	0.0160	0.0263	0.0039	0.0111	0.0020	0.0098	0.0098			0.0109
Oxidation Catalyst	0.1498	0.1969	0.0314	0.0870	0.0142	0.0687	0.0687			0.0791
Non-Catalyst	0.0039	0.0044	0.0007	0.0021	0.0003	0.0015	0.0015			0.0017
Heavy Duty Gasoline Vehicles (HDGV)										
3WC-Tech 5	0.1150	0.0322	0.1480	0.1655	0.2183	0.2128	0.2128	See Note 5		0.1245
3WC-Tech 4	0.0193	0.0487	0.0210	0.0163	0.0130	0.0170	0.0170			0.0147
3WC-Tech 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Oxidation Catalyst	0.5279	0.5559	0.6510	0.4585	0.6281	0.5881	0.5881			0.5781
Non-Catalyst	0.3378	0.3632	0.1800	0.3597	0.1407	0.1821	0.1821			0.2827
Motorcycles (MC)										
3WC-Tech 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	See Note 5		0.0000
3WC-Tech 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
3WC-Tech 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Oxidation Catalyst	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Non-Catalyst	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000			1.0000

Notes: (1) 3WC signifies a three-way (HC and CO oxidation, NO_x reduction) catalyst.

(2) Tech 5 signifies 1996 and newer 3WC with adaptive learning controls.

(3) Tech 4 signifies 1986-1995 3WC.

(4) Tech 3 signifies 1985 and older 3WC.

(5) Indirect PM is estimated on the basis of NO_x and SO₂ emissions, which are affected by the technology distributions for those emission species.

TABLE 8.3: EMISSIONS-WEIGHTED TECHNOLOGY FRACTIONS FOR ONROAD VEHICLES IN 2010

Technology Category	Summer									Winter
	Exhaust VOC	Evap VOC	NO _x	CO	SO ₂	Direct PM-10	Direct PM-2.5	Indirect PM-10	Indirect PM-2.5	CO
Light Duty Gasoline Vehicles (LDGV)										
3WC-Tech 5	0.6643	0.3190	0.6965	0.7869	0.9341	0.9237	0.9237	See Note 5		0.7777
3WC-Tech 4	0.3355	0.6804	0.3033	0.2130	0.0659	0.0762	0.0762			0.2221
3WC-Tech 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Oxidation Catalyst	0.0002	0.0005	0.0002	0.0001	0.0000	0.0001	0.0001			0.0002
Non-Catalyst	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Light Duty Gasoline Trucks – Up to 6,000 Pounds Gross Vehicle Weight (LDGT1/2)										
3WC-Tech 5	0.6101	0.2807	0.7700	0.7257	0.9385	0.8813	0.8813	See Note 5		0.7053
3WC-Tech 4	0.2973	0.5973	0.2013	0.2166	0.0552	0.0931	0.0931			0.2354
3WC-Tech 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Oxidation Catalyst	0.0926	0.1221	0.0288	0.0577	0.0063	0.0256	0.0256			0.0592
Non-Catalyst	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Light Duty Gasoline Trucks – Over 6,000 Pounds Gross Vehicle Weight (LDGT3/4)										
3WC-Tech 5	0.7692	0.4025	0.8774	0.8225	0.9639	0.9181	0.9181	See Note 5		0.8124
3WC-Tech 4	0.1763	0.4963	0.1054	0.1403	0.0318	0.0607	0.0607			0.1496
3WC-Tech 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Oxidation Catalyst	0.0545	0.1012	0.0172	0.0372	0.0043	0.0212	0.0212			0.0380
Non-Catalyst	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Heavy Duty Gasoline Vehicles (HDGV)										
3WC-Tech 5	0.2789	0.0940	0.2294	0.5248	0.5723	0.4005	0.4005	See Note 5		0.5072
3WC-Tech 4	0.0010	0.0028	0.0010	0.0007	0.0004	0.0007	0.0007			0.0005
3WC-Tech 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Oxidation Catalyst	0.6098	0.7465	0.6817	0.4040	0.3813	0.5231	0.5231			0.4317
Non-Catalyst	0.1103	0.1567	0.0878	0.0705	0.0461	0.0758	0.0758			0.0606
Motorcycles (MC)										
3WC-Tech 5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	See Note 5		0.0000
3WC-Tech 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
3WC-Tech 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Oxidation Catalyst	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000			0.0000
Non-Catalyst	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000			1.0000

Notes: (1) 3WC signifies a three-way (HC and CO oxidation, NO_x reduction) catalyst.

(2) Tech 5 signifies 1996 and newer 3WC with adaptive learning controls.

(3) Tech 4 signifies 1986-1995 3WC.

(4) Tech 3 signifies 1985 and older 3WC.

(5) Indirect PM is estimated on the basis of NO_x and SO₂ emissions, which are affected by the technology distributions for those emission species.

TABLE 8.4: EMISSIONS-WEIGHTED TECHNOLOGY FRACTIONS FOR NONROAD VEHICLES

Technology Category	Summer									Winter
	Exhaust VOC	Evap VOC	NO _x	CO	SO ₂	Direct PM-10	Direct PM-2.5	Indirect PM-10	Indirect PM-2.5	CO
Two-Stroke Gasoline Equipment in 2005										
Catalyst	0.1440	0.3324	0.3386	0.1607	0.3722	0.3428	0.3428	See Note 2		0.1607
Non-Catalyst	0.8560	0.6676	0.6614	0.8393	0.6278	0.6572	0.6572			0.8393
Four-Stroke Gasoline Equipment in 2005										
Catalyst	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	See Note 2		0.0000
Non-Catalyst	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000			1.0000
All Gasoline Equipment in 2005										
Catalyst	0.0649	0.0941	0.0195	0.0085	0.0323	0.2970	0.2970	See Note 2		0.0085
Non-Catalyst	0.9351	0.9059	0.9805	0.9915	0.9677	0.7030	0.7030			0.9915
Two-Stroke Gasoline Equipment in 2010										
Catalyst	0.2459	0.4341	0.4349	0.1987	0.4349	0.4154	0.4154	See Note 2		0.1987
Non-Catalyst	0.7541	0.5659	0.5651	0.8013	0.5651	0.5846	0.5846			0.8013
Four-Stroke Gasoline Equipment in 2010										
Catalyst	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	See Note 2		0.0000
Non-Catalyst	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000			1.0000
All Gasoline Equipment in 2010										
Catalyst	0.1087	0.1214	0.0302	0.0096	0.0387	0.3672	0.3672	See Note 2		0.0096
Non-Catalyst	0.8913	0.8786	0.9698	0.9904	0.9613	0.6328	0.6328			0.9904

Notes: (1) Nonroad catalysts in the timeframe reflected are generally low efficiency add-on components without feedback control, used on small handheld equipment. As such, they are not easily comparable to any of the automotive catalyst technologies found in the onroad sector as presented in Tables 8-2 and 8-3.

(2) Indirect PM is estimated on the basis of NO_x and SO₂ emissions, which are affected by the technology distributions for those emission species.

It is perhaps important to note that current nonroad equipment catalyst technology is generally less sophisticated than current onroad vehicle technology. That does not imply that such a relationship will continue indefinitely, but rather that the aftertreatment effectiveness currently required to meet emission standards allows for a less sophisticated approach in the nonroad sector. Future emission standards may demand more advanced technology. As a result of this situation, it is difficult to categorize current nonroad catalyst technology into any of the four catalyst technology types defined above.

For purposes of this study, nonroad equipment with catalysts has been treated as equivalent to Tech 3 three-way catalyst vehicles, the simplest three-way catalyst technology group. This may “overstate” the technology currently applied in the nonroad sector to some extent, but as shown

in Table 8.4, the emission fractions for catalyst technology in the sector are sufficiently low (i.e., 0-10 percent for all emissions except PM in both 2005 and 2010) that the net effect of any associated error will be minor.

The effect of fuel formulation changes on emissions was performed at the technology type level of detail. MOBILE6.2 emission factors, generated using the fuel quality inputs for each formulation presented in Tables 8.1a and 8.1b above, were evaluated for a series of model years with homogeneous catalyst technology. Specifically, non-catalyst technology impacts were estimated by comparing emission factors for 1974 LDGV and 1974-78 LDGT3/4, which are assumed in MOBILE6.2 to be comprised of 100 percent non-catalyst technology. Oxidation catalyst impacts were estimated by comparing emission factors for 1979-90 LDGT3/4, which are modeled as being comprised of 100 percent oxidation catalyst technology. Tech 3 impacts were estimated by comparing emission factors for 1984-85 LDGV, which are modeled as being comprised of 100 percent Tech 3 catalyst technology. Tech 4 impacts were estimated by comparing emission factors for 1986-89 and 1993-95 LDGV and 1993-95 LDGT3/4, which are modeled in MOBILE6.2 as being comprised of 100 percent Tech 4 catalyst technology. Lastly, Tech 5 impacts were estimated by comparing emission factors for 1996-98 LDGV and 1996-98 LDGT3/4, which are modeled as comprising 100 percent Tech 5 catalyst technology. Tech 5 technology impacts were restricted to 1996-98 vehicles only to allow the modeling of all five technology groups in a single execution of the MOBILE6.2 model, which is restricted to a 25 model year range.

The ratio of MOBILE6.2 emission factors for a fuel formulation option to the corresponding emission factors for the baseline fuel formulation determines the impact of that formulation option. However, as described above, MOBILE6.2 does not include algorithms to estimate the emissions response to changes in the full range of fuel quality parameters. The impacts of changes in E200, E300, aromatic content, olefin content, and benzene content are not estimated for criteria pollutants. In addition, MOBILE6.2 does not evaluate the impacts of fuel sulfur reductions below 30 ppm on either criteria pollutants or toxic emissions. To include the effects of changes in one or more of these parameters, a secondary analysis method was employed using a combination of the Complex and Predictive Models.

Both the Complex Model and the Predictive Model were also evaluated for each fuel formulation, holding constant those fuel qualities that had already been evaluated using MOBILE6.2. This allows any additional impacts due to changes in fuel qualities not considered in MOBILE6.2 to be isolated. These impacts were then incorporated into the initial impact estimates derived using MOBILE6.2.

Any additional impacts on Tech 4 three-way catalyst technology were taken directly from the Complex Model, since the model is explicitly designed to treat this technology group. Unfortunately, the Complex Model does not address other technology types. Therefore, to estimate additional impacts for other technology types, the Predictive Model results were employed on a relative basis. Impacts for both Tech 3 and Tech 5 three-way catalyst technology were estimated by adjusting Complex Model Tech 4 impacts by the ratio of Predictive Model Tech 3-to-Tech 4 and Tech 5-to-Tech 4 impacts respectively. This allows for consistency with the basic Tech 4 Complex Model estimates while addressing technology response differences.

The only exceptions are for CO and evaporative VOC, which are not fully evaluated by the Predictive Model. For these two emissions species, Complex Model Tech 4 technology impacts are applied without change to Tech 3 and Tech 5 technology.

Neither the Complex nor Predictive Models treat either oxidation catalyst or non-catalyst technology explicitly. Oxidation catalyst technology impacts are assumed to be identical to Tech 3 technology impacts except that any sulfur effects are eliminated from NO_x impacts (since sulfur is assumed to only affect catalyst performance and an oxidation catalyst does not target NO_x). Similarly, non-catalyst technology impacts are assumed to be identical to Tech 3 technology impacts except that any sulfur effects are eliminated from all emission species, except SO₂ and indirect sulfates which are obviously a function of fuel sulfur.

To estimate the impact of the potential fuel formulation options on toxic emissions, a total of seven toxic emission species were evaluated. MOBILE6.2 provides complete fuel formulation response algorithms for six species: benzene, MTBE, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein.

In addition, the Complex Model provides fuel formulation response algorithms for POM for Tech 4 technology. Since ADEQ specifically requested an impact estimate for POM, the Complex Model response was retained in this analysis and expanded to other technology types in proportion to the ratio of exhaust VOC impacts for each technology relative to Tech 4 technology. Although this is a simplistic approach to estimating POM impacts, it is consistent with the Complex Model response algorithm for Tech 4 technology since that algorithm is based on an assumed VOC fraction only. Together, these seven emission species are believed to be responsible for well over 95 percent of the toxic emissions risk from gasoline-powered vehicles and equipment.

Table 8.5 summarizes the emissions modeling methodology.

8.3 EMISSION IMPACT ESTIMATES FOR CRITERIA POLLUTANTS

Using the methodology described in Section 8.2, emission impacts for the fuel formulations summarized in Tables 8.1a and 8.1b above were estimated on both a per-vehicle basis for specific technology types and on a regional basis using the baseline emission inventories presented in Section 7. As requested by ADEQ, regional emission impacts were estimated for both 2005 and 2010 (technology-specific per-vehicle impacts are independent of time).

Tables 8.6a and 8.6b present the per-vehicle emission impact estimates by technology type (emissions increases are positive, emissions decreases negative). As indicated, the impacts of the non-oxygenated summertime formulations on emissions from newer vehicles are generally quite modest -- with the exception of the NO_x and sulfur-related impacts of the two California formulations, which result directly from the lower sulfur content of those fuels. This is to be expected since the potential changes to the CBG program are quite modest and the fuel formulation changes are more representative of evolutionary, as opposed to revolutionary, changes. In fact, emissions changes of the magnitudes observed for the non-sulfur related

TABLE 8.5: EMISSIONS IMPACT ESTIMATION METHODOLOGY

Fuel Quality	VOC, CO, NO _x , SO ₂ , and PM	Benzene, MTBE, 1,3-Butadiene, Formaldehyde, Acetaldehyde, and Acrolein	POM
RVP	MOBILE6.2 by Technology Type	MOBILE6.2 by Technology Type	EPA Complex Model, in Conjunction with MOBILE6.2
Oxygen Content		MOBILE6.2 by Technology Type	
Sulfur (to 30 ppm minimum)		MOBILE6.2 by Technology Type	
Sulfur (below 30 ppm)	EPA Complex Model, in Conjunction with California Predictive Model (CM/PM)	CM/PM	
E200/T50		MOBILE6.2 by Technology Type	
E300/T90			
Aromatic Content			
Olefin Content			
Benzene Content			

MOBILE6.2 by Technology Type. The U.S. EPA's MOBILE6.2 model was executed using the same inputs used to develop the Arizona emission inventories presented in Section 7, except that fuel quality parameters were set at the values associated with the fuel formulation being investigated. MOBILE6.2 emission factors were processed on a model year-specific basis so that impacts on non-catalyst, oxidation catalyst, Tech 3 three-way catalyst, Tech 4 three-way catalyst, and Tech 5 three-way catalyst technology were isolated. The technology-specific impacts of each fuel option were applied to the 2005 and 2010 Arizona emissions-weighted technology distributions to derive overall emission impacts for both years.

EPA Complex Model, in Conjunction with California Predictive Model (CM/PM). The U.S. EPA's Complex Model (CO Version) and the California Air Resources Board's Predictive Model were evaluated for each fuel formulation. Impacts for Tech 4 three-way catalyst technology were taken directly from the Complex Model. Impacts for Tech 3 and Tech 5 three-way catalyst technology were estimated by adjusting Complex Model Tech 4 impacts by the ratio of Predictive Model Tech 3-to-Tech 4 and Tech 5-to-Tech 4 impacts respectively. The only exceptions are for CO and evaporative VOC, which are not fully evaluated by the Predictive Model. As a result, Complex Model Tech 4 technology impacts are applied without change to Tech 3 and Tech 5 technology impacts for CO and evaporative VOC. Oxidation catalyst technology impacts are assumed to be identical to Tech 3 technology impacts except that any sulfur effects are eliminated from NO_x impacts. Similarly, non-catalyst technology impacts are assumed to be identical to Tech 3 technology impacts except that any sulfur effects are eliminated from all species except SO₂ and indirect sulfates.

EPA Complex Model, in Conjunction with MOBILE6.2. The U.S. EPA's Complex Model (CO Version) was evaluated for each fuel formulation. Impacts for Tech 4 three-way catalyst technology were taken directly from the Complex Model. Impacts for all other technology types were estimated by adjusting the Tech 4 technology impact by the ratio of the exhaust VOC impact for each technology to the exhaust VOC impact for Tech 4 technology.

impacts are likely to be within the range of uncertainty of the associated emissions analysis tools. All of oxygenated summertime formulations produce significant reductions in summertime CO and exhaust VOC due to the combustion impacts of oxygenate. However, it should be recognized that oxygenate is not prohibited from current summertime CBG, so these benefits would accrue in a competitive ethanol pricing environment regardless of CBG rules.

**TABLE 8.6A: SUMMERTIME PER-VEHICLE EMISSION IMPACTS BY TECHNOLOGY TYPE
(PERCENT CHANGE FROM BASELINE)**

Summertime Non-Oxygenated Federal RFG Option					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	-0.63%	-0.63%	-0.63%	-0.06%	-0.01%
Evaporative VOC	0.36%	0.72%	0.67%	0.52%	0.71%
CO	0.30%	0.30%	0.30%	0.30%	0.30%
NO _x	1.01%	1.01%	1.01%	0.65%	0.61%
SO ₂	0.00%	0.00%	0.00%	0.00%	0.00%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	0.00%	0.00%	0.00%	0.00%	0.00%
Summertime Oxygenated Federal RFG Option					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	-2.74%	-10.63%	-13.65%	-10.59%	-9.61%
Evaporative VOC	0.36%	0.72%	0.67%	0.52%	0.71%
CO	-24.67%	-34.42%	-17.38%	-13.79%	-2.90%
NO _x	-0.97%	-0.97%	-0.97%	0.00%	-0.08%
SO ₂	0.00%	0.00%	0.00%	0.00%	0.00%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	0.00%	0.00%	0.00%	0.00%	0.00%
Summertime Non-Oxygenated California Phase 2 RFG Option					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	6.64%	6.64%	6.64%	1.89%	0.66%
Evaporative VOC	0.73%	1.46%	1.36%	1.05%	1.43%
CO	-0.71%	-0.71%	-0.71%	-0.71%	-0.71%
NO _x	-8.97%	-8.97%	-8.97%	-5.65%	-8.50%
SO ₂	-42.86%	-42.86%	-42.86%	-42.86%	-42.86%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-42.86%	-42.86%	-42.86%	-42.86%	-42.86%
Summertime Oxygenated California Phase 2 RFG Option					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	0.71%	-5.35%	-7.68%	-7.97%	-7.68%
Evaporative VOC	0.73%	1.46%	1.36%	1.05%	1.43%
CO	-15.30%	-20.84%	-11.15%	-9.12%	-2.93%
NO _x	-4.38%	-4.38%	-4.38%	-2.67%	-3.94%
SO ₂	-17.86%	-17.86%	-17.86%	-17.86%	-17.86%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-17.86%	-17.86%	-17.86%	-17.86%	-17.86%
Summertime Non-Oxygenated California Phase 3 RFG Option					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	4.64%	4.64%	4.64%	1.03%	0.31%
Evaporative VOC	0.73%	1.46%	1.36%	1.05%	1.43%
CO	-1.30%	-1.30%	-1.30%	-1.30%	-1.30%
NO _x	-6.72%	-6.72%	-6.72%	-4.15%	-6.07%
SO ₂	-28.57%	-28.57%	-28.57%	-28.57%	-28.57%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-28.57%	-28.57%	-28.57%	-28.57%	-28.57%
Summertime Oxygenated California Phase 3 RFG Option					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	2.62%	-3.55%	-5.93%	-6.34%	-6.62%
Evaporative VOC	0.73%	1.46%	1.36%	1.05%	1.43%
CO	-14.17%	-19.78%	-9.97%	-7.91%	-1.64%
NO _x	-3.15%	-3.15%	-3.15%	-2.31%	-4.99%
SO ₂	-39.29%	-39.29%	-39.29%	-39.29%	-39.29%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-39.29%	-39.29%	-39.29%	-39.29%	-39.29%

**TABLE 8.6B: WINTERTIME PER-VEHICLE EMISSION IMPACTS BY TECHNOLOGY TYPE
(PERCENT CHANGE FROM BASELINE)**

<i>Wintertime California Phase 2 RFG Option</i>					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	2.77%	2.78%	2.78%	0.88%	0.71%
Evaporative VOC	0.00%	0.00%	0.00%	0.00%	0.00%
CO	0.71%	0.67%	0.67%	0.67%	0.67%
NO _x	0.96%	0.96%	0.92%	-0.13%	-0.48%
SO ₂	-5.00%	-5.00%	-5.00%	-5.00%	-5.00%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-5.00%	-5.00%	-5.00%	-5.00%	-5.00%
<i>Wintertime California Phase 3 RFG Option</i>					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	2.77%	2.79%	2.79%	0.84%	0.45%
Evaporative VOC	0.00%	0.00%	0.00%	0.00%	0.00%
CO	0.71%	0.58%	0.58%	0.58%	0.58%
NO _x	0.96%	0.96%	0.84%	-0.24%	-1.12%
SO ₂	-15.00%	-15.00%	-15.00%	-15.00%	-15.00%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-15.00%	-15.00%	-15.00%	-15.00%	-15.00%
<i>Wintertime Federal RFG Option</i>					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	-6.26%	-5.69%	4.54%	15.99%	16.99%
Evaporative VOC	55.99%	59.03%	65.28%	100.21%	167.05%
CO	5.68%	7.72%	27.95%	30.91%	28.66%
NO _x	9.16%	9.16%	11.50%	7.52%	10.17%
SO ₂	50.00%	50.00%	50.00%	50.00%	50.00%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	50.00%	50.00%	50.00%	50.00%	50.00%

As shown in Table 8.6b, the impacts of either of the California wintertime RFG options will also be modest -- as should be expected for an evolutionary CBG program modification. The impacts of the federal RFG option are quite significant, however, with large increases exhibited for all emissions species. This is a direct result of the substantially higher RVP of the formulation, and to a lesser extent, the increased fuel sulfur content.

To estimate associated regional emissions changes, the emissions inventories presented in Section 7 were disaggregated into their technology-specific components using the technology-specific emissions fractions presented in Tables 8.2 through 8.4 above. **Tables B.1 and B.2** (in Appendix B) summarize the resulting inventory components associated with gasoline usage in onroad vehicles and nonroad equipment. The PM estimates for gasoline usage exclude both brake and tire wear as well as road dust, since these emissions are not affected by changes in fuel formulation. Brake and tire wear PM is included in the tabulated manmade emissions totals, and road dust along with all other geologic and biogenic emissions is included in the indicated emissions grand totals. For this study, all geologic emissions have been excluded from the manmade emissions totals (regardless of whether or not they originate from manmade activity such as travel down a roadway or agricultural tillage).

To avoid misrepresenting regional emission impact estimates for both summer and wintertime fuel formulation options, it was necessary to adjust the baseline emission inventory estimates presented in Section 7 for consistency with expected future fuel sulfur contents. As previously described, all gasoline formulations sold beginning in 2006 will be required to meet a 30 ppm sulfur content limit (on average). MathPro has estimated that this will result in summertime fuel sulfur contents of about 28 ppm. The baseline Maricopa County wintertime fuel sulfur content for emission evaluation purposes is estimated to be about 20 ppm. However, the summer and winter emissions inventories presented in Section 7 were developed by local planners assuming summertime sulfur contents of 90 ppm and 30 ppm for 2005 and 2010 respectively and a wintertime sulfur content of 30 ppm for both 2005 and 2010. Therefore, it is appropriate to adjust the Section 7 inventories to the MathPro-estimated baseline fuel sulfur contents to avoid erroneously ascribing emission reductions to changes in the CBG program -- since those emissions reductions will accrue due to sulfur reductions that are independent of CBG program changes.

To accomplish the necessary adjustments, the same emissions impact estimation methodology used to evaluate fuel formulation changes (as described in Section 8.2 above) was employed to estimate the emissions changes that would accrue through a reduction in 2005 summertime baseline fuel sulfur from 90 ppm to 28 ppm, a reduction in 2010 summertime baseline fuel sulfur from 30 ppm to 28 ppm, and a reduction in 2005 and 2010 wintertime baseline fuel sulfur from 30 ppm to 20 ppm. **Table 8.7** presents the estimated emission impacts on a technology specific basis and **Table 8.8** presents a summary of the adjusted baseline emission inventories against which all fuel formulation changes were evaluated. **Tables B.3 and B.4** (in Appendix B) present more detailed (technology type-specific) versions of the adjusted baseline emission inventory estimates.

Table 8.9 presents the regional 2005 emission impact estimates for the summertime non-oxygenated gasoline options, while **Table 8.10** presents 2005 impact estimates for the summertime oxygenated gasoline options. **Tables 8.11 and 8.12** present corresponding impact estimates for 2010. **Table 8.13** presents the estimated 2005 and 2010 wintertime CO impacts for all wintertime fuel options. As described above, complete wintertime emissions inventory estimates were only available for CO, so regional wintertime impact estimates for other emission species were not developed. However, estimates for the relative (i.e., percentage change) impacts of the wintertime fuel options on *gasoline* emissions were derived, and these estimates are presented in **Table 8.14**. Without information on the relationship between gasoline and total regional emissions, it is not possible to determine the overall regional significance of the impacts, but the relative performance of the various fuel options is evident. **Tables B.5 through B.17** (in Appendix B) present the detailed technology and source-specific emissions impact estimates that underlie the summary estimates presented in Tables 8.9 through 8.13. **Figures 8.1 through 8.8** graphically summarize the estimated impacts. As with all emissions impact estimates presented in this report, positive values represent emissions increases while negative values represent emissions decreases.

As indicated, the non-oxygenated summertime fuel expected to be delivered to Maricopa County (the federal RFG option) is estimated to produce changes of less than one percent in regional

TABLE 8.7: BASELINE ADJUSTMENT OF PER-VEHICLE EMISSION IMPACTS BY TECHNOLOGY TYPE (PERCENT CHANGE FROM UNADJUSTED BASELINE)

Summertime 2005 Baseline Inventory Adjustments					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	0.00%	0.18%	-3.59%	-6.47%	-9.31%
Evaporative VOC	0.00%	0.00%	0.00%	0.00%	0.00%
CO	0.00%	1.25%	-8.88%	-11.06%	-7.75%
NO _x	0.00%	0.00%	-2.54%	-2.91%	-4.29%
SO ₂	-68.92%	-68.88%	-68.81%	-68.89%	-68.89%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-67.64%	-68.53%	-68.77%	-68.90%	-68.47%
Summertime 2010 Baseline Inventory Adjustments					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	0.00%	0.01%	0.01%	-0.04%	-0.26%
Evaporative VOC	0.00%	0.00%	0.00%	0.00%	0.00%
CO	0.00%	-0.09%	-0.09%	-0.09%	-0.09%
NO _x	0.00%	0.00%	-0.07%	-0.11%	-0.64%
SO ₂	-6.67%	-6.67%	-6.67%	-6.67%	-6.67%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-6.67%	-6.67%	-6.67%	-6.67%	-6.67%
Wintertime 2005 and 2010 Baseline Inventory Adjustments					
Emission Species	Non Cat	Oxy Cat	Tech 3	Tech 4	Tech 5
Exhaust VOC	0.00%	0.04%	0.04%	-0.17%	-1.27%
Evaporative VOC	0.00%	0.00%	0.00%	0.00%	0.00%
CO	0.00%	-0.45%	-0.45%	-0.45%	-0.45%
NO _x	0.00%	0.00%	-0.38%	-0.55%	-3.15%
SO ₂	-33.33%	-33.33%	-33.33%	-33.33%	-33.33%
Carbonaceous PM	0.00%	0.00%	0.00%	0.00%	0.00%
Direct SO ₄	-33.33%	-33.33%	-33.33%	-33.33%	-33.33%

emissions of all pollutants. The oxygenated version of this option produces larger changes for exhaust VOC and CO, but it should be noted that these impacts would be likely to decline over time if the nonroad sector is forced to implement advanced emissions control technology equivalent to that of onroad vehicles (adaptive learning, feedback controlled, catalyst systems adjust air delivery to the engine to compensate for the inherent oxygen content of oxygenated fuel). With the exception of VOC, the CARB 2 and CARB 3 summertime options (which are not expected to be delivered to Maricopa County) produce larger emission reductions, primarily due to reduced fuel sulfur contents. VOC emissions increase marginally (by about one percent) due to the slightly increased volatility of the formulations. The substantial CO reductions provided by any of the oxygenated fuel options derive almost entirely from the oxygenate. Since

TABLE 8.8: DISTRIBUTION OF ADJUSTED BASELINE GASOLINE EMISSIONS (METRIC TONS PER DAY)

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
2005 Adjusted Baseline Emissions							
Gasoline Total	103.72	83.30	896.78	0.59	7.52	6.47	856.51
Exhaust	64.32	83.30	896.78	0.59	7.52	6.47	856.51
Evaporative	39.40	0.00	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	240.18	243.53	1073.00	12.12	35.15	28.07	1021.46
Emissions Grand Total	284.58	252.41	1073.00	12.12	217.49	89.19	1021.46
Change in 2005 Emissions Relative to Baseline							
Gasoline Onroad	-2.7%	-3.3%	-7.5%	-68.9%	-12.1%	-13.1%	-0.4%
Gasoline Nonroad	-0.2%	-0.4%	-0.1%	-68.9%	-0.3%	-0.3%	-0.0%
Gasoline Total	-1.5%	-3.2%	-4.0%	-68.9%	-8.4%	-8.8%	-0.2%
Manmade Total	-0.6%	-1.1%	-3.3%	-9.8%	-1.9%	-2.2%	-0.2%
Grand Total	-0.5%	-1.1%	-3.3%	-9.8%	-0.3%	-0.7%	-0.2%
2010 Adjusted Baseline Emissions							
Gasoline Total	59.48	62.49	926.64	0.72	7.09	6.18	851.53
Exhaust	30.43	62.49	926.64	0.72	7.09	6.18	851.53
Evaporative	29.05	0.00	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	207.55	217.83	1102.92	9.25	34.10	26.71	1015.51
Emissions Grand Total	254.19	226.18	1102.92	9.25	239.92	95.26	1015.51
Change in 2010 Emissions Relative to Baseline							
Gasoline Onroad	-0.1%	-0.5%	-0.1%	-6.7%	-0.9%	-1.0%	-0.4%
Gasoline Nonroad	+0.0%	-0.0%	-0.0%	-6.7%	-0.0%	-0.0%	-0.0%
Gasoline Total	-0.0%	-0.5%	-0.0%	-6.7%	-0.5%	-0.5%	-0.2%
Manmade Total	-0.0%	-0.1%	-0.0%	-0.6%	-0.1%	-0.1%	-0.2%
Grand Total	-0.0%	-0.1%	-0.0%	-0.6%	-0.0%	-0.0%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

CO emissions only marginally participate in summertime air quality concerns (primarily ozone), the actual air quality impact of summertime CO reductions are modest.

The wintertime California fuel options expected to be delivered to Maricopa County result in virtually identical emission impacts, that are only marginally different from those associated with the baseline fuel. The marginal CO increases result from aromatic and olefin contents that are slightly higher than those of the baseline fuel, but it should be recognized that the baseline fuel represents actual 2004 fuel properties as compared to properties for the California fuel options that were estimated through refinery modeling. Since the California Phase 2 fuel option actually represents a complying fuel formulation under the current CBG program, its emissions

**TABLE 8.9: 2005 EMISSIONS FOR NON-OXYGENATED SUMMER CBG FORMULATIONS
(METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Emissions with Non-Oxygenated Federal RFG Option						
Gasoline Total	103.63	83.88	899.50	0.59	7.55	6.49
Exhaust	64.01	83.88	899.50	0.59	7.55	6.49
Evaporative	39.62	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	240.09	244.11	1075.73	12.12	35.18	28.09
Emissions Grand Total	284.49	252.99	1075.73	12.12	217.52	89.21
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+0.3%	+0.7%	+0.3%	0.0%	+0.6%	+0.6%
Gasoline Nonroad	-0.5%	+1.0%	+0.3%	0.0%	+0.0%	+0.0%
Gasoline Total	-0.1%	+0.7%	+0.3%	0.0%	+0.4%	+0.4%
Manmade Total	-0.0%	+0.2%	+0.3%	0.0%	+0.1%	+0.1%
Grand Total	-0.0%	+0.2%	+0.3%	0.0%	+0.0%	+0.0%
Emissions with Non-Oxygenated California Phase 2 RFG Option						
Gasoline Total	107.56	76.76	890.45	0.34	7.08	6.10
Exhaust	67.72	76.76	890.45	0.34	7.08	6.10
Evaporative	39.84	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	244.02	237.00	1066.68	11.87	34.71	27.70
Emissions Grand Total	288.42	245.87	1066.68	11.87	217.05	88.82
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+1.8%	-7.8%	-0.7%	-42.9%	-8.8%	-8.9%
Gasoline Nonroad	+5.7%	-9.0%	-0.7%	-42.9%	-0.3%	-0.2%
Gasoline Total	+3.7%	-7.8%	-0.7%	-42.9%	-5.8%	-5.7%
Manmade Total	+1.6%	-2.7%	-0.6%	-2.1%	-1.3%	-1.3%
Grand Total	+1.3%	-2.6%	-0.6%	-2.1%	-0.2%	-0.4%
Emissions with Non-Oxygenated California Phase 3 RFG Option						
Gasoline Total	106.50	78.56	885.09	0.42	7.21	6.20
Exhaust	66.66	78.56	885.09	0.42	7.21	6.20
Evaporative	39.84	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	242.96	238.79	1061.31	11.95	34.84	27.80
Emissions Grand Total	287.36	247.67	1061.31	11.95	217.18	88.92
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+1.4%	-5.7%	-1.3%	-28.6%	-6.2%	-6.3%
Gasoline Nonroad	+4.0%	-6.7%	-1.3%	-28.6%	-0.2%	-0.2%
Gasoline Total	+2.7%	-5.7%	-1.3%	-28.6%	-4.2%	-4.1%
Manmade Total	+1.2%	-1.9%	-1.1%	-1.4%	-0.9%	-0.9%
Grand Total	+1.0%	-1.9%	-1.1%	-1.4%	-0.1%	-0.3%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE 8.10: 2005 EMISSIONS FOR OXYGENATED SUMMER CBG FORMULATIONS
(METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Emissions with Oxygenated Federal RFG Option						
Gasoline Total	100.35	83.11	741.14	0.59	7.51	6.46
Exhaust	60.73	83.11	741.14	0.59	7.51	6.46
Evaporative	39.62	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	236.81	243.35	917.36	12.12	35.14	28.06
Emissions Grand Total	281.21	252.22	917.36	12.12	217.48	89.18
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-3.7%	-0.2%	-10.1%	0.0%	-0.2%	-0.2%
Gasoline Nonroad	-2.8%	-1.0%	-24.6%	0.0%	-0.0%	-0.0%
Gasoline Total	-3.3%	-0.2%	-17.4%	0.0%	-0.1%	-0.1%
Manmade Total	-1.4%	-0.1%	-14.5%	0.0%	-0.0%	-0.0%
Grand Total	-1.2%	-0.1%	-14.5%	0.0%	-0.0%	-0.0%
Emissions with Oxygenated California Phase 2 RFG Option						
Gasoline Total	102.75	80.22	796.87	0.49	7.32	6.30
Exhaust	62.91	80.22	796.87	0.49	7.32	6.30
Evaporative	39.84	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	239.21	240.45	973.10	12.02	34.95	27.90
Emissions Grand Total	283.61	249.33	973.10	12.02	217.29	89.02
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-2.1%	-3.7%	-7.0%	-17.9%	-4.0%	-4.1%
Gasoline Nonroad	+0.3%	-4.4%	-15.2%	-17.9%	-0.1%	-0.1%
Gasoline Total	-0.9%	-3.7%	-11.1%	-17.9%	-2.7%	-2.6%
Manmade Total	-0.4%	-1.3%	-9.3%	-0.9%	-0.6%	-0.6%
Grand Total	-0.3%	-1.2%	-9.3%	-0.9%	-0.1%	-0.2%
Emissions with Oxygenated California Phase 3 RFG Option						
Gasoline Total	103.87	80.00	807.46	0.36	7.26	6.24
Exhaust	64.03	80.00	807.46	0.36	7.26	6.24
Evaporative	39.84	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	240.33	240.24	983.69	11.89	34.88	27.84
Emissions Grand Total	284.73	249.11	983.69	11.89	217.23	88.96
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-1.5%	-4.0%	-5.8%	-39.3%	-5.3%	-5.5%
Gasoline Nonroad	+1.9%	-3.2%	-14.1%	-39.3%	-0.1%	-0.1%
Gasoline Total	+0.1%	-4.0%	-10.0%	-39.3%	-3.5%	-3.5%
Manmade Total	+0.1%	-1.4%	-8.3%	-1.9%	-0.8%	-0.8%
Grand Total	+0.1%	-1.3%	-8.3%	-1.9%	-0.1%	-0.3%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE 8.11: 2010 EMISSIONS FOR NON-OXYGENATED SUMMER CBG FORMULATIONS
(METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Emissions with Non-Oxygenated Federal RFG Option						
Gasoline Total	59.54	62.91	929.45	0.72	7.11	6.20
Exhaust	30.32	62.91	929.45	0.72	7.11	6.20
Evaporative	29.22	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	207.61	218.25	1105.74	9.25	34.13	26.73
Emissions Grand Total	254.25	226.60	1105.74	9.25	239.94	95.28
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+0.3%	+0.7%	+0.3%	0.0%	+0.5%	+0.5%
Gasoline Nonroad	-0.4%	+1.0%	+0.3%	0.0%	+0.0%	+0.0%
Gasoline Total	+0.1%	+0.7%	+0.3%	0.0%	+0.3%	+0.3%
Manmade Total	+0.0%	+0.2%	+0.3%	0.0%	+0.1%	+0.1%
Grand Total	+0.0%	+0.2%	+0.3%	0.0%	+0.0%	+0.0%
Emissions with Non-Oxygenated California Phase 2 RFG Option						
Gasoline Total	61.07	57.47	920.10	0.41	6.70	5.86
Exhaust	31.68	57.47	920.10	0.41	6.70	5.86
Evaporative	29.39	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	209.14	212.81	1096.39	8.94	33.72	26.39
Emissions Grand Total	255.78	221.16	1096.39	8.94	239.53	94.94
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+1.5%	-8.0%	-0.7%	-42.9%	-9.7%	-9.9%
Gasoline Nonroad	+5.4%	-9.0%	-0.7%	-42.9%	-0.3%	-0.3%
Gasoline Total	+2.7%	-8.0%	-0.7%	-42.9%	-5.4%	-5.3%
Manmade Total	+0.8%	-2.3%	-0.6%	-3.3%	-1.1%	-1.2%
Grand Total	+0.6%	-2.2%	-0.6%	-3.3%	-0.2%	-0.3%
Emissions with Non-Oxygenated California Phase 3 RFG Option						
Gasoline Total	60.67	58.86	914.56	0.52	6.81	5.95
Exhaust	31.28	58.86	914.56	0.52	6.81	5.95
Evaporative	29.39	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	208.74	214.21	1090.84	9.05	33.83	26.48
Emissions Grand Total	255.38	222.55	1090.84	9.05	239.65	95.03
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+1.2%	-5.8%	-1.3%	-28.6%	-6.8%	-6.9%
Gasoline Nonroad	+3.9%	-6.7%	-1.3%	-28.6%	-0.2%	-0.2%
Gasoline Total	+2.0%	-5.8%	-1.3%	-28.6%	-3.8%	-3.7%
Manmade Total	+0.6%	-1.7%	-1.1%	-2.2%	-0.8%	-0.9%
Grand Total	+0.5%	-1.6%	-1.1%	-2.2%	-0.1%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE 8.12: 2010 EMISSIONS FOR OXYGENATED SUMMER CBG FORMULATIONS
(METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Emissions with Oxygenated Federal RFG Option						
Gasoline Total	57.57	62.37	779.34	0.72	7.08	6.18
Exhaust	28.34	62.37	779.34	0.72	7.08	6.18
Evaporative	29.22	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	205.64	217.72	955.62	9.25	34.10	26.71
Emissions Grand Total	252.28	226.06	955.62	9.25	239.91	95.26
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-3.3%	-0.2%	-7.1%	0.0%	-0.1%	-0.1%
Gasoline Nonroad	-3.2%	-1.0%	-24.6%	0.0%	-0.0%	-0.0%
Gasoline Total	-3.2%	-0.2%	-15.9%	0.0%	-0.1%	-0.1%
Manmade Total	-0.9%	-0.1%	-13.4%	0.0%	-0.0%	-0.0%
Grand Total	-0.8%	-0.1%	-13.4%	0.0%	-0.0%	-0.0%
Emissions with Oxygenated California Phase 2 RFG Option						
Gasoline Total	58.67	60.13	831.09	0.59	6.91	6.04
Exhaust	29.28	60.13	831.09	0.59	6.91	6.04
Evaporative	29.39	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	206.74	215.48	1007.38	9.12	33.93	26.57
Emissions Grand Total	253.38	223.82	1007.38	9.12	239.75	95.12
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-1.9%	-3.7%	-5.3%	-17.9%	-4.4%	-4.4%
Gasoline Nonroad	-0.1%	-4.4%	-15.2%	-17.9%	-0.1%	-0.1%
Gasoline Total	-1.4%	-3.8%	-10.3%	-17.9%	-2.5%	-2.4%
Manmade Total	-0.4%	-1.1%	-8.7%	-1.4%	-0.5%	-0.6%
Grand Total	-0.3%	-1.0%	-8.7%	-1.4%	-0.1%	-0.2%
Emissions with Oxygenated California Phase 3 RFG Option						
Gasoline Total	59.15	59.83	842.14	0.44	6.83	5.96
Exhaust	29.76	59.83	842.14	0.44	6.83	5.96
Evaporative	29.39	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	207.22	215.18	1018.42	8.97	33.85	26.49
Emissions Grand Total	253.86	223.52	1018.42	8.97	239.67	95.04
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-1.4%	-4.3%	-4.1%	-39.3%	-6.4%	-6.7%
Gasoline Nonroad	+1.4%	-3.2%	-14.1%	-39.3%	-0.1%	-0.1%
Gasoline Total	-0.6%	-4.3%	-9.1%	-39.3%	-3.6%	-3.6%
Manmade Total	-0.2%	-1.2%	-7.7%	-3.1%	-0.7%	-0.8%
Grand Total	-0.1%	-1.2%	-7.7%	-3.1%	-0.1%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

TABLE 8.13: CO EMISSIONS FOR WINTER CBG FORMULATIONS (METRIC TONS PER DAY)

Source Category	Winter 2005			Winter 2010		
	CARB 2 Option	CARB 3 Option	Federal RFG	CARB 2 Option	CARB 3 Option	Federal RFG
Gasoline Total	862.43	862.07	992.88	857.43	857.08	986.20
Exhaust	862.43	862.07	992.88	857.43	857.08	986.20
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	1027.39	1027.03	1157.84	1021.41	1021.06	1150.18
Emissions Grand Total	1027.39	1027.03	1157.84	1021.41	1021.06	1150.18
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+0.7%	+0.6%	+26.9%	+0.7%	+0.6%	+27.6%
Gasoline Nonroad	+0.7%	+0.7%	+6.0%	+0.7%	+0.7%	+6.1%
Gasoline Total	+0.7%	+0.6%	+15.9%	+0.7%	+0.7%	+15.8%
Manmade Total	+0.6%	+0.5%	+13.4%	+0.6%	+0.5%	+13.3%
Grand Total	+0.6%	+0.5%	+13.4%	+0.6%	+0.5%	+13.3%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

TABLE 8.14: CHANGE IN GASOLINE (EXHAUST PLUS EVAPORATIVE) EMISSIONS FOR WINTERTIME CBG FORMULATIONS

Fuel Formulation	Year	Winter				
		VOC	NO _x	SO ₂	PM-10	PM-2.5
CARB 2	2005	+1.5%	-0.1%	-5.0%	-0.2%	-0.2%
CARB 3		+1.5%	-0.5%	-15.0%	-0.8%	-0.8%
Fed RFG		+30.8%	+9.4%	+50.0%	+6.9%	+6.8%
CARB 2	2010	+1.3%	-0.2%	-5.0%	-0.3%	-0.3%
CARB 3		+1.2%	-0.7%	-15.0%	-0.9%	-1.0%
Fed RFG		+37.8%	+9.6%	+50.0%	+6.4%	+6.3%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

FIGURE 8.1: CHANGE IN 2005 SUMMERTIME GASOLINE EXHAUST PLUS EVAPORATIVE EMISSIONS (BRAKE, TIRE WEAR, AND ROAD DUST PM ARE NOT IN THE BASELINE)

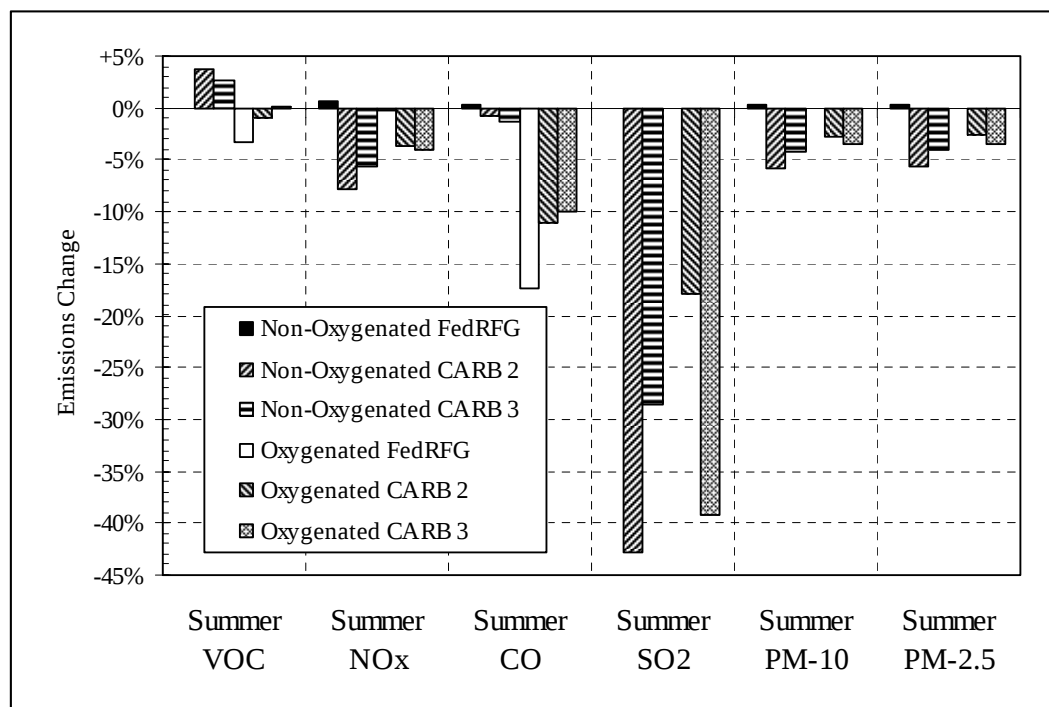


FIGURE 8.2: CHANGE IN 2010 SUMMERTIME GASOLINE EXHAUST PLUS EVAPORATIVE EMISSIONS (BRAKE, TIRE WEAR, AND ROAD DUST PM ARE NOT IN THE BASELINE)

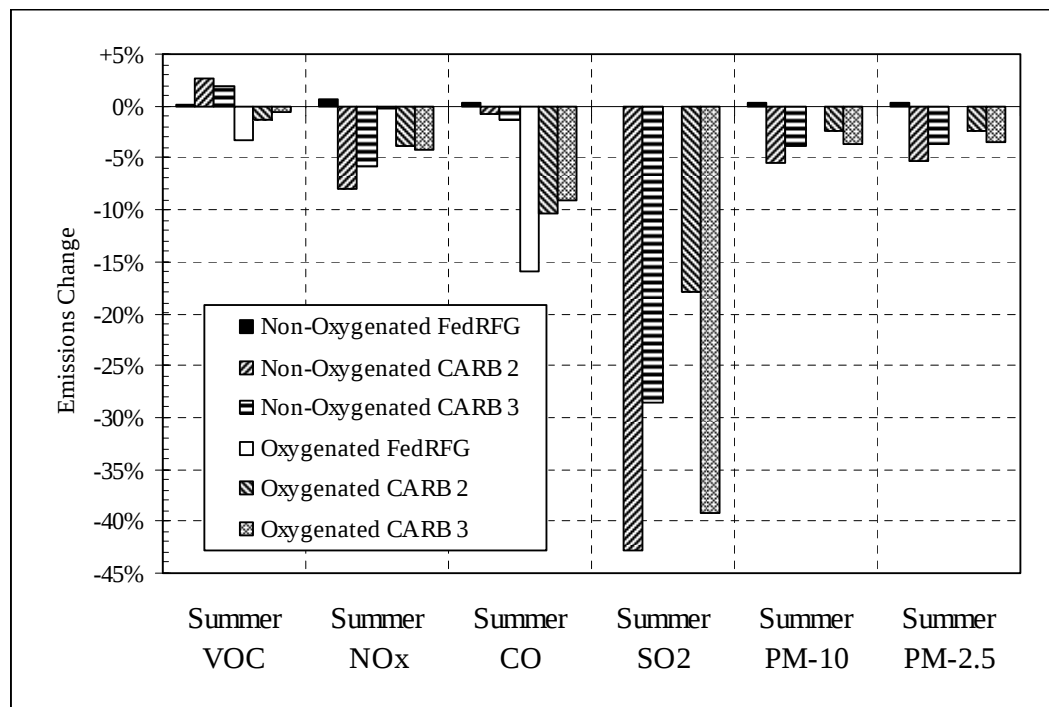


FIGURE 8.3: CHANGE IN 2005 SUMMERTIME MANMADE EMISSIONS (BIOGENIC AND GEOLOGIC EMISSIONS, INCLUDING ROAD DUST PM, ARE NOT IN THE BASELINE)

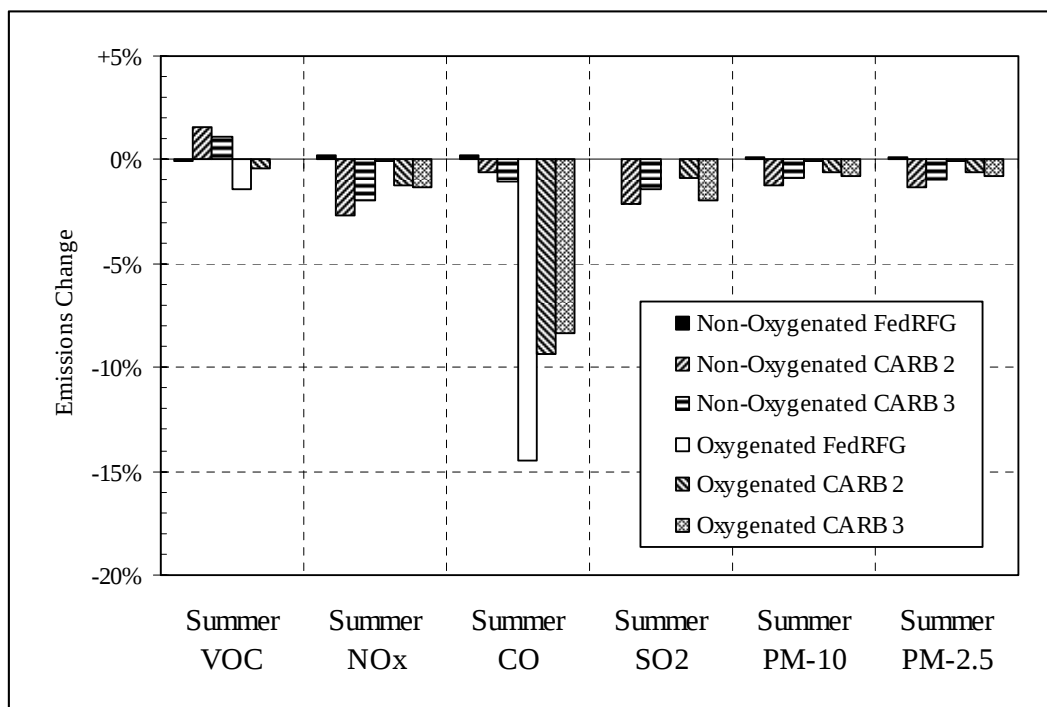


FIGURE 8.4: CHANGE IN 2010 SUMMERTIME MANMADE EMISSIONS (BIOGENIC AND GEOLOGIC EMISSIONS, INCLUDING ROAD DUST PM, ARE NOT IN THE BASELINE)

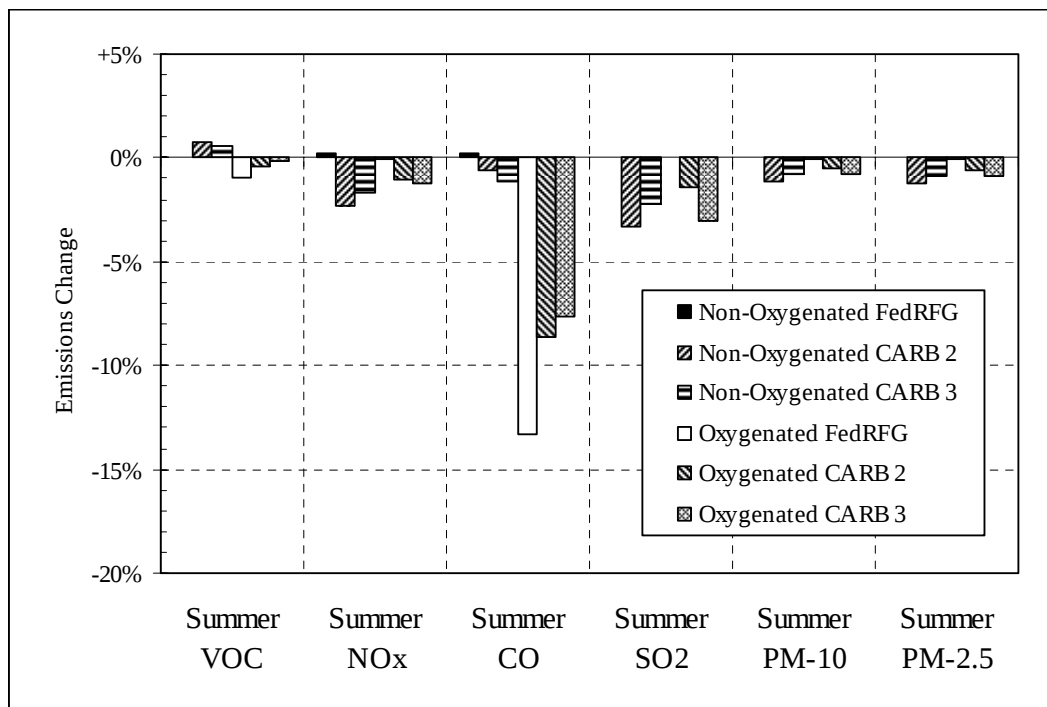


FIGURE 8.5: CHANGE IN TOTAL 2005 SUMMERTIME EMISSIONS

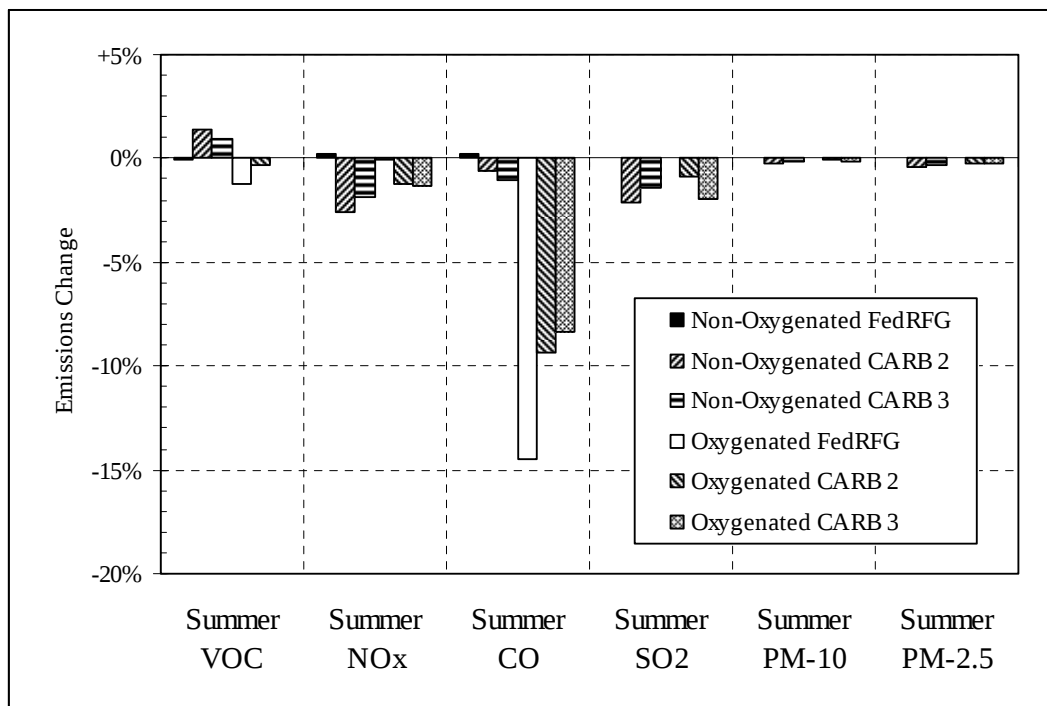


FIGURE 8.6: CHANGE IN TOTAL 2010 SUMMERTIME EMISSIONS

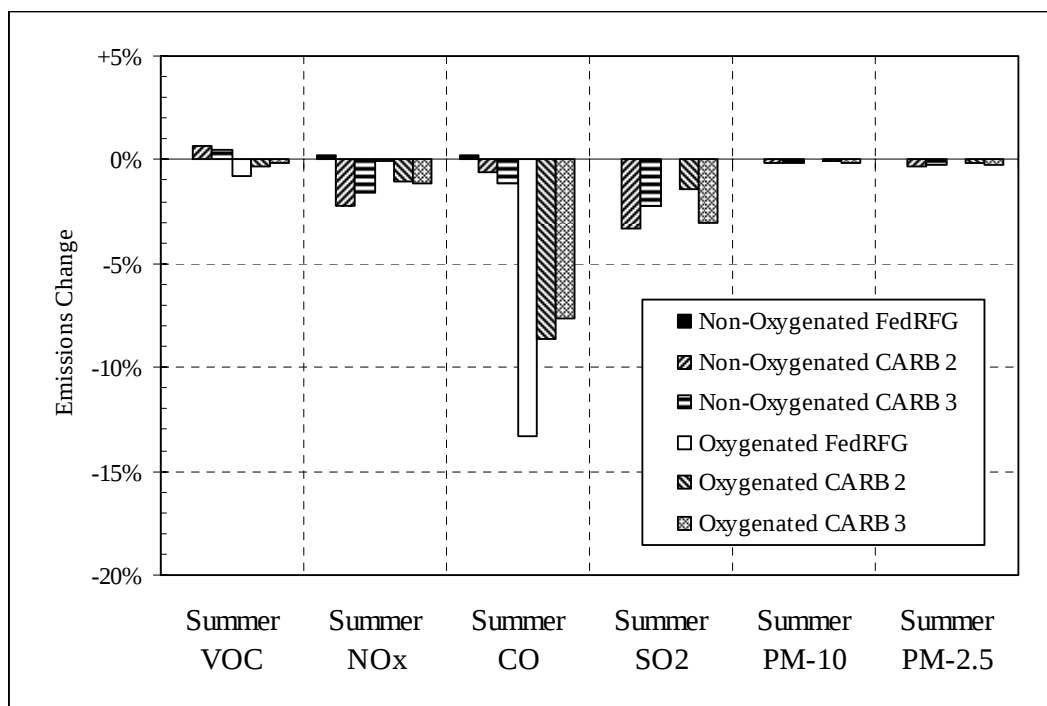


FIGURE 8.7: CHANGE IN WINTERTIME CO EMISSIONS

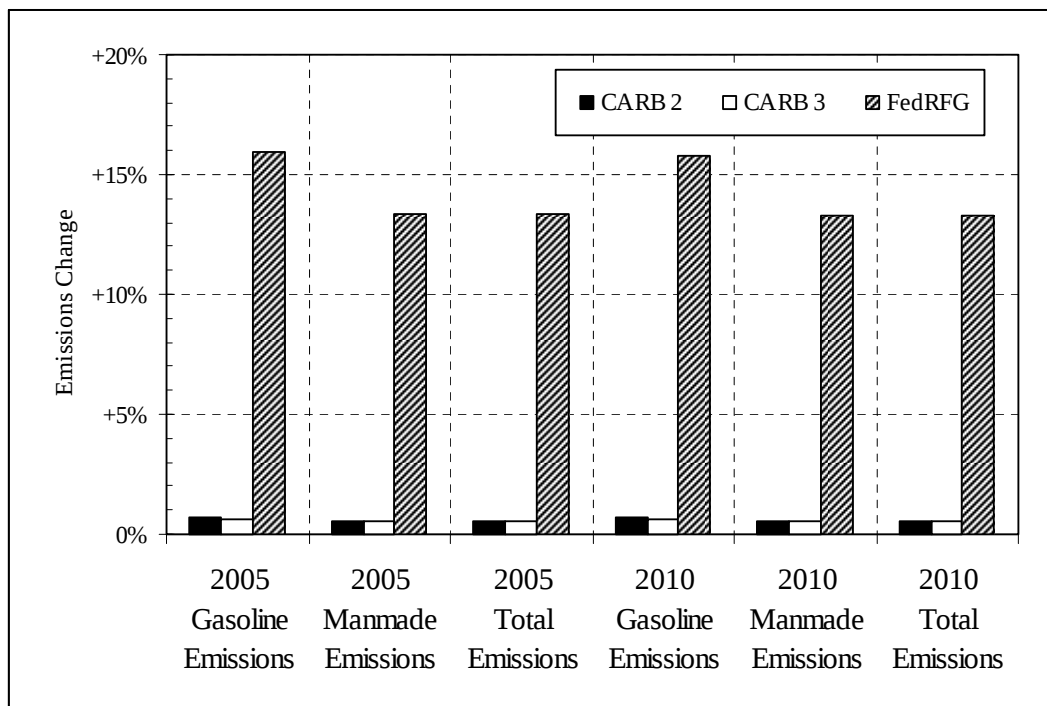
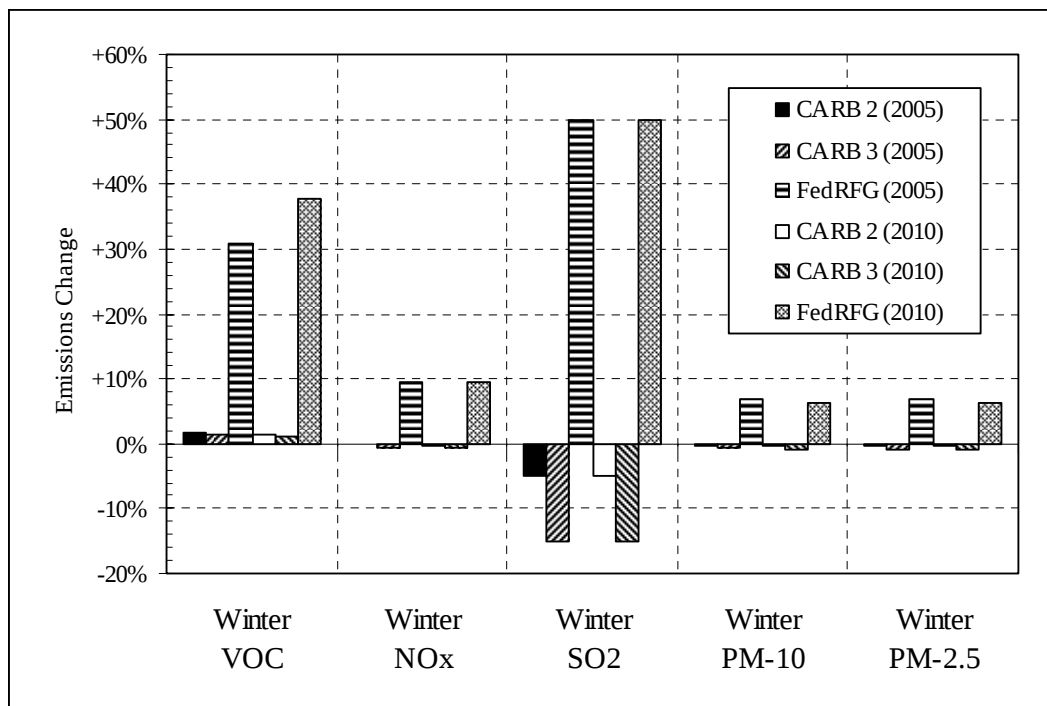


FIGURE 8.8: CHANGE IN WINTERTIME GASOLINE EXHAUST PLUS EVAPORATIVE EMISSIONS (BRAKE, TIRE WEAR, AND ROAD DUST PM ARE NOT IN THE BASELINE)



performance relative to the study baseline is an artifact of the study methodology rather than an indication of an actual expected change in overall CBG program performance.

Finally, the wintertime federal RFG option produces substantial emissions increases for all pollutants due to its increased volatility, aromatics, olefin, and sulfur content. As previously described, this formulation does not meet current Arizona wintertime volatility requirements, but is representative of a complying wintertime federal reformulated gasoline as sold outside of Arizona. It is included in the emissions analysis solely to illustrate the potential impacts of relaxing current wintertime fuel requirements.

8.4 EMISSION IMPACT ESTIMATES FOR TOXIC EMISSION SPECIES

The potential impacts of fuel reformulation on emissions of toxic species were evaluated using essentially the same methodology as employed for criteria pollutants. There were only two effective differences in the analytical methods employed for the toxics evaluation. First, since MOBILE6.2 includes fuel quality response algorithms for toxic emissions that incorporate virtually the full range of fuel quality parameters, MOBILE6.2 emission estimates play a greater role in the determination of toxic emission impacts. The Complex and Predictive Models are relegated to a correspondingly reduced role as described in Section 8.2. Second, since there are no baseline emission inventories for toxic emission species, all impacts are expressed only in terms of percentage change from baseline toxic emissions associated with gasoline combustion in onroad and nonroad vehicles and equipment. Absolute changes in emissions mass are not estimated, nor are relative changes in total toxic emissions.

As described in Section 8.2, potential fuel formulation impacts were estimated for seven toxic species. These species vary widely in terms of their inherent risk of both cancer and non-cancer effects. As a result, it can be problematic to determine whether increases in one species are more or less important than decreases in another. To allow for a reasonable evaluation of the aggregate impact on toxic emissions, this study evaluated not only the potential impact on individual emission species, but also evaluated aggregate toxic impacts by weighting individual emission species impacts according to their relative risk potential. Of course, relative risk determination is subject to considerable uncertainty, but there are “standardized” risk factors that are used by the U.S. EPA in conducting toxic emissions assessments.

For this study, aggregate toxic emission impacts were evaluated using two specific relative risk weighting schemes. The first scheme is based on the “reference concentration for non-cancer effects.” This reference concentration is an estimate of the maximum concentration to which humans might be exposed without risk of deleterious effect over a lifetime. The U.S. EPA generally places uncertainty in reference concentrations at about an order of magnitude. The second toxic emissions weighting scheme relies on “unit risk estimates,” which are defined as

upper bound estimates of the excess cancer risk that would result from a lifetime of continuous exposure to the species at a concentration of 1 microgram per cubic meter.⁴⁷

Table 8.15 summarizes the data used to develop the aggregate toxic impact estimates and presents the resulting relative risk factors. Consistent with previous toxic emissions impact analyses, the relative risk for 1,3-butadiene is arbitrarily set to unity and the risk of all other species is considered relative to that of 1,3-butadiene.

Tables 8.16 and 8.17 present the estimated aggregate toxic emission impacts of the CBG fuel options relative to baseline Maricopa County gasoline, while **Figures 8.9 through 8.11** graphically present the estimated change in overall gasoline toxics. It should be recognized that all indicated changes are relative to baseline toxic emissions associated with the combustion and evaporation of gasoline in onroad vehicles and nonroad equipment. Toxics emissions from other sources are not included – so that the indicated changes should be viewed as *maximum* impact values that will result in *lesser* changes in total toxic emissions in Maricopa County. Detailed technology-specific toxic emission impacts for individual emission species are presented in **Tables B.18 through B.26** (in Appendix B).

As indicated in Table 8.16, the federal non-oxygenated summertime option, which is expected to be delivered to Maricopa County under the CBG program, is estimated to result in a maximum one percent change in overall toxic emissions risk. However, it should be recognized that this impact is an artifact of the study methodology rather than an indication of an actual expected change in overall CBG program performance since the federal non-oxygenated summertime option is actually a complying gasoline under the current CBG program. The impacts derive solely from small differences in fuel aromatic and benzene content for the refinery modeling future formulation as compared to actual 2004 fuel properties. In effect, the estimated changes are within the margin of analysis uncertainty.

Because the federal oxygenated summertime option contains oxygen relative to a non-oxygenated baseline gasoline, it results in significant increases in acetaldehyde emissions (as shown in Table B.21 in Appendix B). However, these increases are entirely offset on both a non-cancer risk and cancer risk basis by decreases in benzene, 1,3-butadiene, and acrolein emissions – so that the aggregate toxic impacts by 2010 indicate about a three percent drop in non-cancer risk and a modest (one percent) drop in cancer risk.

⁴⁷ Ideally, there would only be one such set of unit risk estimates, but due to uncertainties in assessing cancer risk, such estimates are subject to continuous review and revision. Currently, estimates for the unit risk of formaldehyde are undergoing review and, therefore, it is not clear whether the current unit risk estimate will be retained or revised. The U.S. EPA's Integrated Risk Information System (IRIS) provides a unit risk estimate for formaldehyde of 1.3×10^{-5} , and this estimate has been used in most historic assessments of toxic emission impacts. However, recent data compiled by the Chemical Industry Institute of Technology (CIIT) indicate that the unit risk estimate may actually be over 2000 times lower, at about 5.5×10^{-9} . This recent assessment is currently under review, but has been accepted for interim use by the U.S. EPA's Office of Air Quality Planning and Standards. Nevertheless, given the uncertainty of the ongoing review, the current IRIS unit risk estimate for formaldehyde has been used in this study.

TABLE 8.15: TOXIC EMISSION SPECIES POTENCY FACTORS FOR DETERMINING AGGREGATE EMISSIONS IMPACTS

Toxic Species	Weighting Method 1		Weighting Method 2	
	Reference Concentration For Non-Cancer Effects (mg/m ³)	Risk Relative to 1,3-Butadiene	Unit Risk of Cancer Effects 1/(ug/m ³)	Risk Relative to 1,3-Butadiene
Benzene	0.03	0.0667	7.8E-06	0.2600
MTBE	3	0.0007	2.6E-07	0.0087
1,3-Butadiene	0.002	1.0000	3.0E-05	1.0000
Formaldehyde	0.0098	0.2041	1.3E-05	0.4333
Acetaldehyde	0.009	0.2222	2.2E-06	0.0733
Acrolein	0.00002	100.0000	none	0.0000
POM	none	0.0000	5.5E-05	1.8333

- Notes: (1) All data are from U.S. EPA (Office of Air Quality Planning and Standards) dose-response assessment tables as downloaded from <http://www.epa.gov/ttn/atw/toxsource/summary.html>. The only exceptions are formaldehyde under weighting method 2 and POM under both weighting methods.
- (2) The unit risk factor for formaldehyde under method 2 is taken from the U.S. EPA's Integrated Risk Information System (IRIS). The IRIS factor varies by over three orders of magnitude from the factor in the OAQPS data. Although the OAQPS factor is based on more recent risk assessment analysis than the IRIS factor, the associated data are still undergoing peer review, so that the IRIS factor continues to represent the official unit risk factor for formaldehyde.
- (3) POM represents the group of polycyclic organic species and is not treated as a group in either the EPA/OAQPS or IRIS databases. Therefore, the associated cancer risk estimates are taken from U.S. EPA's 1996 National-Scale Air Toxics Assessment (NATA), which assigned a unit risk factor for the POM composite equal to five percent of the unit risk factor for benzo[a]pyrene. Since benzo[a]pyrene has no reference concentration for non-cancer effects, POM is excluded from weighting method 1.
- (4) Acrolein is excluded from weighting method 2, as it currently has no generally accepted unit risk factor.

Both the non-oxygenated and oxygenated formulations of the California Phase 2 and California Phase 3 options produce larger summertime toxic emission reductions. The reductions associated with the non-oxygenated formulations are primarily due to reduced fuel aromatic, benzene, and olefin contents relative to the Maricopa County baseline fuel, while those of the oxygenated formulations are due to the oxygenate content in conjunction with reduced fuel aromatic and olefin contents.

As shown in Table 8.17, the aggregate toxic impacts of the two California wintertime CBG options are virtually identical, with each showing almost no change in non-cancer risk and about a 1-2 percent increase in aggregate cancer risk by 2010. The small increase in aggregate cancer risk is driven by small increases in fuel aromatic and olefin content relative to wintertime baseline gasoline. However, it should be recognized that increases of this magnitude are almost certainly within the uncertainty range of the both the fuel property and emissions estimation methodologies and should be viewed accordingly. The CARB 2 option is actually a complying fuel under the current CBG program, so that the toxic impacts are actually artifacts of the study

TABLE 8.16: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE SUMMERTIME CBG OPTIONS

Toxic Risk Metric	CBG Option	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Potency-Weighted Change in Non-Cancer Risk (1)	Non-Oxy Fed RFG	+0.05%	+0.17%	+0.13%	+0.05%	+0.16%	+0.10%
	Non-Oxy CARB 2	-2.18%	-1.22%	-1.55%	-2.14%	-1.29%	-1.73%
	Non-Oxy CARB 3	-2.18%	-1.22%	-1.55%	-2.14%	-1.29%	-1.73%
	Oxygenated Fed RFG	-6.85%	+0.65%	-2.01%	-6.36%	+0.24%	-3.28%
	Oxygenated CARB 2	-6.94%	-0.84%	-3.00%	-6.59%	-1.18%	-4.07%
	Oxygenated CARB 3	-6.94%	-0.84%	-3.00%	-6.59%	-1.18%	-4.07%
Potency-Weighted Change in Cancer Risk (2)	Non-Oxy Fed RFG	+1.00%	+1.56%	+1.35%	+0.99%	+1.51%	+1.22%
	Non-Oxy CARB 2	-11.55%	-9.21%	-9.98%	-11.54%	-9.29%	-10.42%
	Non-Oxy CARB 3	-11.55%	-9.21%	-9.98%	-11.54%	-9.29%	-10.42%
	Oxygenated Fed RFG	-5.54%	+3.17%	+0.10%	-4.56%	+2.37%	-1.28%
	Oxygenated CARB 2	-8.76%	-1.65%	-4.19%	-8.21%	-2.20%	-5.42%
	Oxygenated CARB 3	-8.76%	-1.65%	-4.19%	-8.21%	-2.20%	-5.42%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE 8.17: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE WINTERTIME CBG OPTIONS

Toxic Risk Metric	CBG Option	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Potency-Weighted Change in Non-Cancer Risk (1)	CARB 2	+0.20%	+0.09%	+0.13%	+0.19%	+0.10%	+0.15%
	CARB 3	+0.19%	+0.09%	+0.13%	+0.19%	+0.10%	+0.15%
	Federal RFG	+13.63%	+2.86%	+6.79%	+13.89%	+3.38%	+9.06%
Potency-Weighted Change in Cancer Risk (2)	CARB 2	+1.66%	+1.23%	+1.38%	+1.69%	+1.23%	+1.48%
	CARB 3	+1.60%	+1.23%	+1.36%	+1.62%	+1.23%	+1.44%
	Federal RFG	+14.92%	+8.01%	+10.76%	+15.36%	+8.16%	+12.20%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

FIGURE 8.9: CHANGE IN SUMMER 2005 TOXIC EMISSIONS ASSOCIATED WITH THE COMBUSTION AND EVAPORATION OF GASOLINE IN VEHICLES AND NONROAD EQUIPMENT

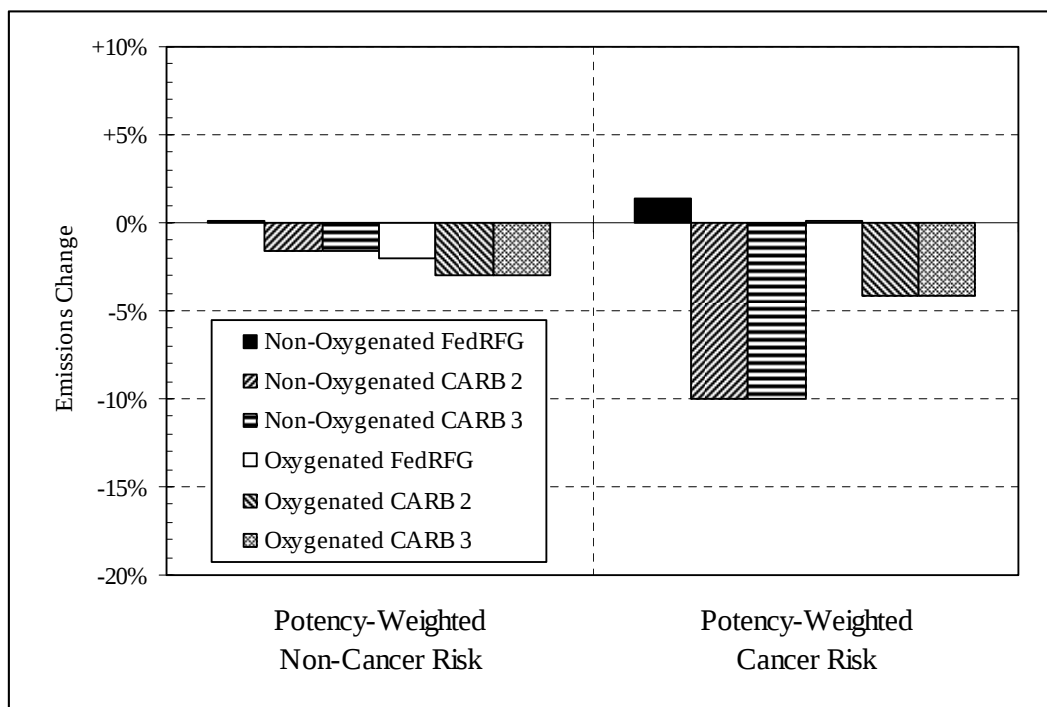


FIGURE 8.10: CHANGE IN SUMMER 2010 TOXIC EMISSIONS ASSOCIATED WITH THE COMBUSTION AND EVAPORATION OF GASOLINE IN VEHICLES AND NONROAD EQUIPMENT

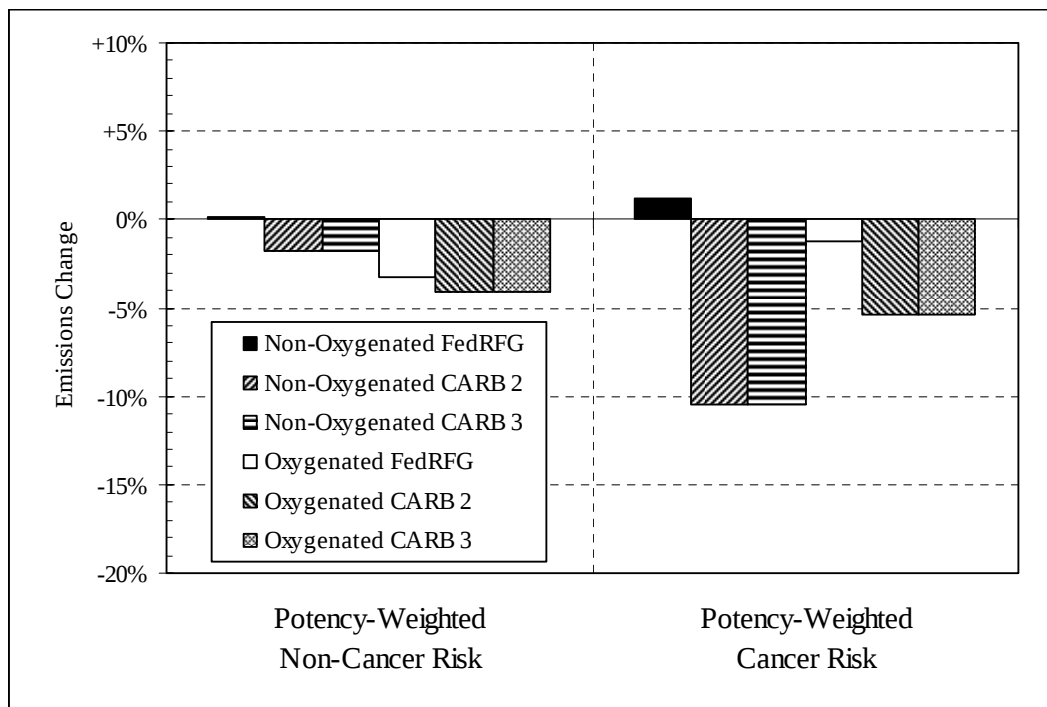
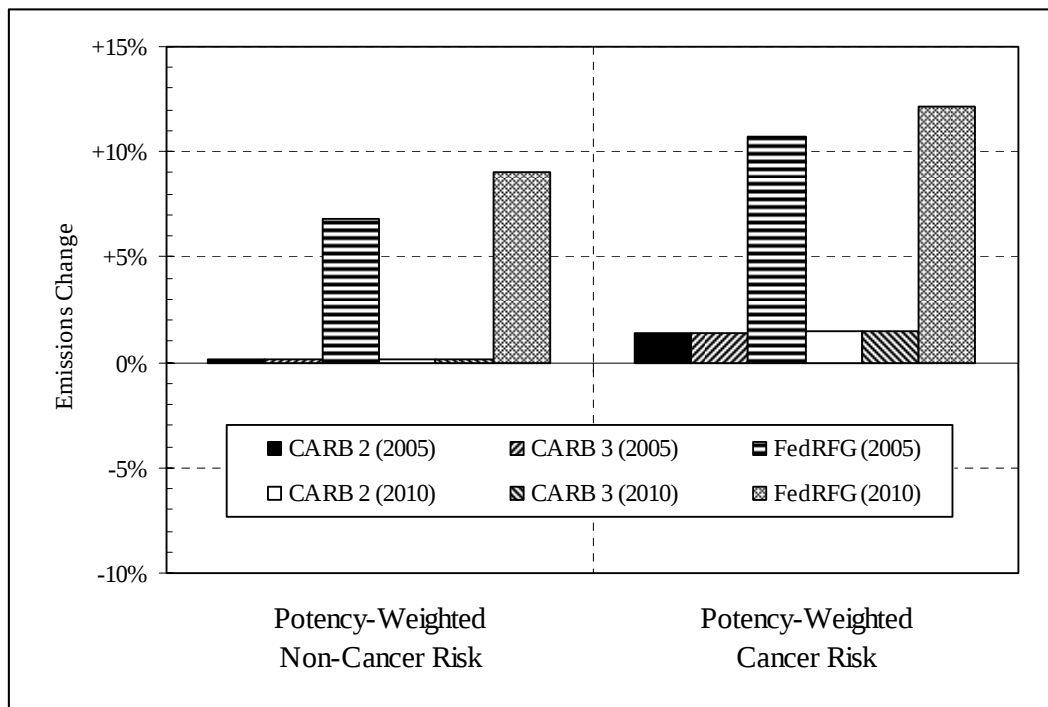


FIGURE 8.11: CHANGE IN WINTER TOXIC EMISSIONS ASSOCIATED WITH THE COMBUSTION AND EVAPORATION OF GASOLINE IN VEHICLES AND NONROAD EQUIPMENT



methodology that compares a specific refinery modeling fuel formulation to average 2004 fuel properties. By definition, the toxic impacts of a complying fuel should be nil.

In contrast, the federal wintertime option is not a complying fuel under the current CBG program and its higher volatility along with higher aromatic, olefin, and sulfur content results in substantially larger toxic emission impacts. As shown in Figure 8.11, the formulation is estimated to increase 2010 non-cancer risk by nearly ten percent and 2010 cancer risk by more than ten percent.

8.5 EMISSION IMPACT SUMMARY

As expected, the summertime non-oxygenated federal RFG option and the wintertime California Phase 2 fuel option are expected to result in few, in any, impacts on Maricopa County criteria or toxic emissions. Both represent complying fuel formulations under the current CBG program. The California Phase 3 fuel option produces impacts that are virtually identical to those of the California Phase 2 fuel option, so that revision of the CBG program to allow or require California Phase 3 fuel should not result in any significant impacts on Maricopa County air quality.

In general, the summertime California fuel options produced additional emission reduction benefits relative to the summertime federal option for all criteria pollutants but VOC, where modest increases were estimated due to the higher volatility of the California fuel. In all cases, however, the impacts were modest relative to total Maricopa County emissions. The California options did produce more significant toxic emission reductions relative to the federal option, but it should be recognized that the California Phase 2 fuel option is a complying fuel under the current CBG program.

All oxygenated summertime fuel options provide significant CO benefits relative to their non-oxygenated counterparts, but CO plays only a modest role in summertime air quality concerns. In this study, the blending or non-blending of ethanol in the summertime is treated solely as an economic decision.

The emissions impacts of the two wintertime California options are virtually identical, so that revision of the CBG program to allow or require California Phase 3 fuel should not result in any significant impacts on Maricopa County air quality. In contrast, the large emissions increases associated with the wintertime federal RFG option indicate the continuing positive effect of the current CBG requirement for Type 2 wintertime fuel.

9. Implications of Study Results and Findings

The results of the study indicate that adopting the California Air Resources Board's Phase 3 gasoline standard (CARB 3) as part of the Arizona CBG program is likely to have minor effects on the cost, supply, and emissions impacts of AZ CBG.

This section briefly discusses implications of the results and findings of the study with respect to the economics of CBG production, the prospective future supply of CBG, and the emissions inventories in the CBG Area.

9.1 COST OF CBG AND THE TYPE OF CBG LIKELY TO BE SUPPLIED

9.1.1 Summer CBG

As discussed in Section 6.7, the refining analysis indicates that Fed-S (Type 1 CBG) enjoys a significant refining cost advantage over Cal2-S (CARB 2) and PM-3S (CARB 3) gasolines, even with the low projected ethanol prices. Consequently, the gasoline supply system is likely to continue supplying Fed-S (non-oxygenated or ethanol-blended) rather than Cal2-S (if it remains in the CBG program) or Cal3-S.

The analysis indicates that Fed-S and Cal3-S would be more costly to produce in the West refining center than in the East. As discussed in Section 6.7, this cost difference arises from the different volume shares of CARB gasoline in the gasoline pools produced in the two refining centers.

Finally, the costs of producing the non-oxygenated CBGs relative to the costs of producing their ethanol-blended counterparts would depend on the delivered price of ethanol and the relationship of the ethanol price to oil prices. Opining on the relative prices of ethanol and crude oil/gasoline in the long term would be well beyond the scope of this study. Suffice it to say, the relative price issue centers more on the behavior over time of the oil exporting countries, ethanol producers (will they over-build capacity? will they organize to exert pricing power?) and the U.S. Congress and federal agencies (how will they implement the recently enacted national ethanol mandate?) than on the techno-economics of gasoline production.

9.1.2 Winter CBG

Table 6.6b indicates that Cal2-W and Cal3-W have essentially the same average refining costs. Some individual refineries may have an economic incentive to continue producing Cal2-W (CARB 2), if it remains part of the CBG program; others, particularly in the Los Angeles refining center, may prefer to produce Cal3-W (CARB 3).

If the CBG program continues to allow Cal2-W after adopting Cal3-W, the CBG area could receive either or both, in any combination, because (1) the two have essentially the same refining economics and (2) they would be fungible throughout the gasoline supply system, Area A.

Table 6.6b also indicates that the other CBG options specified in the SoW – Fed-W and the various Cal3-WR variants – all have lower average refining costs than Cal2-W (the current winter CBG) or Cal3-W. Consideration of the emissions impacts of these CBG options was beyond the scope of the study.

9.2 PROSPECTS FOR INCREASING SUPPLY OF CBG

The SoW called for further evaluation of gasoline formulations meeting the emissions criterion as well as other criteria, including “potential impacts on the volumes of CBG that may be supplied to Arizona.” This criterion merits some discussion and interpretation.

The refining and distribution facilities serving the CBG area and its environs routinely deliver supplies of CBG and conventional gasoline that meet demand (except in transient supply outages arising from unexpected upsets, equipment failures, etc., as in August 2003). Industry history and economic principles suggest that the petroleum refining and distribution industry will continue meeting Area A’s gasoline demand over time, even given the area’s rapid growth. Hence, the issue of “providing additional supply” is perhaps best interpreted as one of encouraging additional *sources* of supply to enter the AZ CBG market or encouraging existing sources to increase their capability for CBG production. A larger set of actual and potential suppliers could offer more flexibility to maintain adequate supply of CBG during periods in which one or more suppliers suffers a transient loss in production capability. Similarly, it might offer market benefits that usually follow from increased competition, real or prospective.

In practice, the most direct means of calling out additional sources of supply would be to establish a CBG standard conforming to a widely produced gasoline – i.e., not a boutique fuel, produced to a special standard. However, the results of Task 1 indicated that the primary gasoline types supplied in the Southwest (e.g., conventional gasoline and 7.8 RVP gasoline) do not meet the emissions standards of the Arizona CBG program.

Closer to home, as discussed in Section 5, the West side of the CBG area’s supply system is long on pipeline capacity and short on refining capacity to supply AZ CBG, whereas the East side is short on pipeline capacity but long on refining capacity. This situation will persist even after the completion of the East line expansion. So one has to consider East and West supply possibilities separately.

The East line currently operates at full capacity; CBG supplies from West Texaco/New Mexico and Gulf Coast refineries are limited by pipeline capacity, not refining capabilities. Completion of the East line expansion will produce a one-time step increase in East supplies, but then CBG supplies from West Texaco/New Mexico and Gulf Coast refineries will again be limited by pipeline capacity. Hence, no alternative AZ CBG standard in itself is likely to increase supply to the CBG area from refineries to the east of Phoenix, notwithstanding their gasoline production capacity. Changing the winter AZ CBG certification standard from CARB 2 (Cal2-W) to federal RFG (Fed-W) could lead to

some increase in the number of possible suppliers in the West Texas/New Mexico and Gulf Coast refining centers. But it would neither increase total supply through the East nor influence market conditions in the CBG area.

The East line is likely to continue operating fully allocated after the announced expansions, temporarily opening up more spare capacity in the West line and allowing LA refiners to produce more CARB 3 for home consumption.

Because the West line does not operate at full capacity, it could deliver additional supplies – either temporarily, during curtailments in East-side supply, or continuously, to meet demand growth in the Phoenix area – to the extent that (1) the Los Angeles and Puget Sound refining centers were able to increase CBG production or (2) more remote refining centers were to begin producing AZ CBG for delivery via Los Angeles and the West line. These prospects appear remote.

As discussed in Section 6, the California refining industry is not growing. Total gasoline production in California has been essentially unchanged for the past three years; and CARB gasoline production is declining, primarily because of California's MTBE ban and CARB 3 gasoline program. Our analysis indicates that average costs of summer CBG production are higher in the West refining center than in the East. In addition, the West refining center faces higher pipeline tariffs to Phoenix. Hence, changing the AZ CBG standard appears to offer little opportunity to increase CBG supply from the Los Angeles refining center (in terms of either volume or number of sources) over current levels, nor would such an increase (if it occurred) increase total supply of CBG.

More remote refining centers, such as the U.S. Gulf Coast, the Middle East, East Asia, etc., are likely to be capable of producing volumes of AZ CBG at competitive refining costs. But the cost of transporting these volumes to Los Angeles by waterborne shipment to Los Angeles would make these sources uncompetitive with California and Puget Sound refineries. (For example, we understand that product tanker shipments from the U.S. Gulf Coast to Los Angeles cost about 8¢/gal.)

Finally, some observers view adopting the CARB 3 standard for AZ CBG as a means of increasing CBG supply, reasoning that the CARB 3 standard would lead to increased volumes of ethanol in the CBG pool (particularly if crude oil prices move higher than current levels and remain higher). In our view, this expectation is not likely to be realized.

The AZ CBG program already requires 10% ethanol in winter CBG, so no potential exists for ethanol to provide additional volume in the winter. If refiners were to supply an AZRBOB for ethanol blending in summer CBG, it would likely be for 5.7 vol% ethanol blending. If 100% of summer CBG were so blended, the pool of CBG blendstocks in the summer would expand by about 5-6 K Bbl/day (plus a pro-rata share of the growth in CBG demand to 2010) minus the blendstock volumes that would have to be taken out to put ethanol in. In the end, the net increment in potential supply capability might be on the order of 3-4 K Bbl/day. The likelihood of realizing even that increment in supply capability depends in large measure on how California responds to the recent repeal of the federal oxygen requirement for RFG (effective immediately for California).

10. References

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Appendix A

Scope of Work

TASK ASSIGNMENT PROPOSAL SCOPE OF WORK

Overview: The Arizona Department of Environmental Quality (ADEQ) requires a consultant to provide independent expertise and analysis regarding the costs, supply and emissions impacts of adopting California Air Resources Board Phase 3 gasoline (CARB 3) standards. The primary charge of the consultant is to prepare a report, under the direction of the project officer, that will evaluate the following options for modifying gasoline formulations for the purpose providing additional supply of motor fuels to Arizona while maintaining or improving the effectiveness of the Cleaner Burning Gasoline (CBG) program being implemented in the Greater Phoenix Area:

1. Adding CARB 3 as an additional acceptable standard under the CBG program for both summer and winter seasons;
2. Setting CARB 3 as the standard for Type 2 CBG as required under House Bill 2207 (attached);
3. Evaluating the following options for changing CBG standards that will achieve the necessary emissions benefits and increase the supply of CBG in the region –
 - o Federal RFG (wintertime only)
 - o Las Vegas Blend
 - o Albuquerque Blend
 - o West Texas/El Paso Blend
 - o Denver Blend
 - o Tucson Blend
 - o Any other regional blend that can, cost-effectively, be delivered to Area A; and
4. Lifting the current wintertime RVP cap (9.0 pounds per square inch (psi)) in the Phoenix metropolitan area, assuming retention of the current CARB 2 and at two different oxygen content standards:
 - o 11 psi, at 2.0% and 3.5% weight oxygen content; and
 - o 13.5 psi, at 2.0% and 3.5% weight oxygen content.No air quality evaluation should be done for this option.

The report should take into account the unique characteristics of the Maricopa County airshed, refining and delivery system capacity and logistics, cost and to the extent feasible cost-effectiveness. The contractor shall review data and studies conducted by CARB and the California Energy Commission in support of the CARB 3 rules, and, to the extent feasible, use those data for the analyses and in the preparation of the report required in this scope of work.

Tasks:

Task 1: Identification and Evaluation of Options:

The discussion of each of these options shall:

- a) Establish baseline fuels for summer and winter seasons, vehicle mix, and other characteristics that will affect the impact of regulatory options being evaluated;
- b) Employ a screening procedure using the EPA Complex Model to eliminate those blends that are likely to increase emissions more than 5% for criteria pollutants and 10% for total toxics over those of the baseline fuel; (The purpose of the screening procedure is to narrow the

- study to fuel blends that will provide additional supply of motor fuels to Arizona while maintaining or improving the effectiveness of the CBG program being implemented in the Greater Phoenix Area.) and
- c) For the blends that fall below the screening threshold for potential emissions increases, a treatment of -
- i. Timeliness of implementation;
 - ii. Potential emissions impacts in future years;
 - iii. Regulatory issues that may affect implementation, including state and federal environmental and energy regulations, and the existence of potentially overlapping and conflicting statutes and regulations;
 - iv. Implementation issues, including adequacy of existing regulatory institutions and staffing, necessary statutory and regulatory changes, and the impact and demands on government and regulated industries;
 - v. Potential impacts on the volumes of CBG that may be supplied to Arizona;
 - vi. To the extent feasible, cost-effectiveness; and
 - vii. Other potential environmental impacts, including effects on other air pollutants, changes in risks related to fuel releases, and effects on waste oil management.

Task 2: Analysis of Impacts on Motor Fuel Distribution

The contractor shall explore the feasibility and impacts of each option identified in Task 1 passing the screening criteria with respect to:

- a) Logistics of blending, storage and delivery of gasoline;
- b) Distribution system capital improvements and any changes to distribution and storage systems that may be necessary;
- c) Added distribution costs per gallon of gasoline;
- d) Administrative and program operations costs to government and other institutions;
- e) Time frame for implementation, indicating the earliest date that each of the gasoline formulations could be implemented, including necessary lead times; and
- f) Potential supply and distribution impacts outside of Maricopa County in Arizona and outside Arizona.

Task 3: Technical and Economic Analysis of Gasoline Production

The contractor shall develop approximate measures or indicators of the incremental per-gallon refining costs associated with the options defined in Task 1 passing the screening criteria and explore the following technical and economic issues associated with the options:

- a) Existing refinery capability and anticipated changes in refineries, including output volumes, serving the Maricopa County market (including refineries having access to the Longhorn Pipeline), and modifications that may be necessary to meet new standards;
- b) Potential fuel economy impacts;
- c) Administrative and program costs to government and other institutions;
- d) Time frame for implementation, indicating the earliest date that each of the gasoline formulations could be implemented, including necessary lead times for permitting and construction; and
- e) To the extent that meaningful and consistent comparisons can be made, and for Maricopa County only, the estimated cost-effectiveness in terms of dollars per ton of PM, NMOC, NOx and CO reduced or increased.

Task 4: Emissions Analysis (not to be done for the wintertime RVP and oxygen content options)

The contractor shall assess the emissions impacts of each option identified in Task 1 that pass the screening criteria using existing models and analytical methods, to the extent available, as follows:

- a) Estimation of emissions impacts on a per-vehicle basis using an appropriate baseline, within major vehicle technology classifications (e.g. pre-pollution control, catalyst/air injection, closed loop). PM, CO, VOC, NMOC and NO_x emissions shall be assessed;
- b) Estimation of region-wide (the carbon monoxide and 1-hour ozone nonattainment areas) emissions impacts with respect to on-road and non-road mobile source inventories for CO in Maricopa County for the years 2005 and 2010, and PM, NMOC, and NO_x in the years 2005 and 2010; and
- c) Secondary emissions impacts shall be explored, including, hazardous air pollutants (primarily aldehydes, polycyclic organic compounds, benzene and butadiene), a brief literature review regarding possible health impacts of modification of fuel formulations, and effects on emissions outside of Maricopa County.
- d) ADEQ shall provide the Contractor all necessary data relating to modeling assumptions, emissions inventories, and other information needed to characterize emissions in Maricopa County.

Task 5: Conclusions

The contractor shall identify all options passing the screening criteria under Task 1 that are technically and logistically feasible, and compare them with respect to total costs, cost-effectiveness (to the extent feasible, and in accordance with Task 3, paragraph [e]), and spillover benefits and disbenefits. The study seeks all options for modifying gasoline formulations for the purpose providing additional supply of motor fuels to Arizona while maintaining or improving the effectiveness of the CBG program being implemented in the Greater Phoenix Area. Conclusions shall also identify caveats with respect to unknowns.

Appendix B

Detailed Emissions Analysis Tables

The tables presented in this appendix provide detailed data related to the emissions analysis presented in Section 8. For convenience, references to specific appendix tables are included in Section 8 -- so a proper context for the generation and use of the presented data can be derived by reviewed that section.

**TABLE B.1: DISTRIBUTION OF BASELINE 2005 GASOLINE EMISSIONS BY TECHNOLOGY TYPE
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
Onroad Vehicles – Tech 5	16.33	48.18	278.97	1.46	3.35	2.83	218.31
Exhaust	10.68	48.18	278.97	1.46	3.35	2.83	218.31
Evaporative	5.65	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	23.98	22.32	123.58	0.27	1.31	1.09	122.25
Exhaust	6.62	22.32	123.58	0.27	1.31	1.09	122.25
Evaporative	17.36	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	4.52	2.45	18.59	0.02	0.14	0.12	22.08
Exhaust	1.40	2.45	18.59	0.02	0.14	0.12	22.08
Evaporative	3.13	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	7.22	9.51	41.01	0.11	0.65	0.54	33.18
Exhaust	3.10	9.51	41.01	0.11	0.65	0.54	33.18
Evaporative	4.11	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	3.28	2.46	20.70	0.02	0.17	0.14	11.54
Exhaust	2.01	2.46	20.70	0.02	0.17	0.14	11.54
Evaporative	1.27	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	55.33	84.92	482.85	1.88	5.62	4.72	407.37
Exhaust	23.80	84.92	482.85	1.88	5.62	4.72	407.37
Evaporative	31.53	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	3.44	0.19	6.75	0.01	0.87	0.80	6.75
Exhaust	2.71	0.19	6.75	0.01	0.87	0.80	6.75
Evaporative	0.73	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	46.51	0.97	444.20	0.02	1.72	1.58	444.20
Exhaust	39.37	0.97	444.20	0.02	1.72	1.58	444.20
Evaporative	7.14	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	49.95	1.16	450.95	0.02	2.59	2.37	450.95
Exhaust	42.08	1.16	450.95	0.02	2.59	2.37	450.95
Evaporative	7.87	0.00	0.00	0.00	0.00	0.00	0.00
Gasoline Total	105.29	86.08	933.80	1.90	8.21	7.09	858.32
Exhaust	65.88	86.08	933.80	1.90	8.21	7.09	858.32
Evaporative	39.40	0.00	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	241.75	246.31	1110.02	13.43	35.84	28.69	1023.28
Emissions Grand Total	286.15	255.19	1110.02	13.43	218.18	89.81	1023.28

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.2: DISTRIBUTION OF BASELINE 2010 GASOLINE EMISSIONS BY TECHNOLOGY TYPE
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
Onroad Vehicles – Tech 5	17.33	42.87	340.05	0.70	2.84	2.39	283.80
Exhaust	9.66	42.87	340.05	0.70	2.84	2.39	283.80
Evaporative	7.67	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	18.27	11.60	83.88	0.04	0.63	0.52	76.65
Exhaust	4.04	11.60	83.88	0.04	0.63	0.52	76.65
Evaporative	14.23	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	3.81	5.77	23.90	0.02	0.37	0.31	18.15
Exhaust	1.07	5.77	23.90	0.02	0.37	0.31	18.15
Evaporative	2.74	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	2.51	0.99	12.55	0.00	0.07	0.06	8.01
Exhaust	1.73	0.99	12.55	0.00	0.07	0.06	8.01
Evaporative	0.78	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	41.93	61.23	460.38	0.76	3.91	3.27	386.60
Exhaust	16.50	61.23	460.38	0.76	3.91	3.27	386.60
Evaporative	25.42	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.23	0.29	7.89	0.00	1.30	1.19	7.89
Exhaust	1.71	0.29	7.89	0.00	1.30	1.19	7.89
Evaporative	0.52	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	15.35	1.25	458.78	0.01	1.91	1.75	458.78
Exhaust	12.24	1.25	458.78	0.01	1.91	1.75	458.78
Evaporative	3.11	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	17.58	1.54	466.67	0.01	3.21	2.94	466.67
Exhaust	13.95	1.54	466.67	0.01	3.21	2.94	466.67
Evaporative	3.63	0.00	0.00	0.00	0.00	0.00	0.00
Gasoline Total	59.51	62.77	927.05	0.77	7.12	6.22	853.27
Exhaust	30.45	62.77	927.05	0.77	7.12	6.22	853.27
Evaporative	29.05	0.00	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	207.58	218.12	1103.34	9.30	34.14	26.75	1017.25
Emissions Grand Total	254.22	226.46	1103.34	9.30	239.96	95.30	1017.25

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.3: DISTRIBUTION OF ADJUSTED BASELINE 2005 GASOLINE EMISSIONS BY TECHNOLOGY TYPE
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
Onroad Vehicles – Tech 5	15.34	46.11	257.35	0.45	2.82	2.35	217.33
Exhaust	9.69	46.11	257.35	0.45	2.82	2.35	217.33
Evaporative	5.65	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	23.55	21.67	109.91	0.08	1.20	0.99	121.70
Exhaust	6.19	21.67	109.91	0.08	1.20	0.99	121.70
Evaporative	17.36	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	4.47	2.39	16.94	0.01	0.13	0.11	21.99
Exhaust	1.35	2.39	16.94	0.01	0.13	0.11	21.99
Evaporative	3.13	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	7.22	9.51	41.52	0.03	0.62	0.51	33.03
Exhaust	3.11	9.51	41.52	0.03	0.62	0.51	33.03
Evaporative	4.11	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	3.28	2.46	20.70	0.01	0.17	0.14	11.54
Exhaust	2.01	2.46	20.70	0.01	0.17	0.14	11.54
Evaporative	1.27	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	53.87	82.14	446.43	0.58	4.94	4.10	405.59
Exhaust	22.34	82.14	446.43	0.58	4.94	4.10	405.59
Evaporative	31.53	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	3.34	0.18	6.15	0.00	0.86	0.79	6.72
Exhaust	2.61	0.18	6.15	0.00	0.86	0.79	6.72
Evaporative	0.73	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	46.51	0.97	444.20	0.01	1.71	1.57	444.20
Exhaust	39.37	0.97	444.20	0.01	1.71	1.57	444.20
Evaporative	7.14	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	49.86	1.16	450.35	0.01	2.58	2.37	450.92
Exhaust	41.98	1.16	450.35	0.01	2.58	2.37	450.92
Evaporative	7.87	0.00	0.00	0.00	0.00	0.00	0.00
Gasoline Total	103.72	83.30	896.78	0.59	7.52	6.47	856.51
Exhaust	64.32	83.30	896.78	0.59	7.52	6.47	856.51
Evaporative	39.40	0.00	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	240.18	243.53	1073.00	12.12	35.15	28.07	1021.46
Emissions Grand Total	284.58	252.41	1073.00	12.12	217.49	89.19	1021.46
Change in Emissions Relative to Baseline							
Gasoline Onroad	-2.7%	-3.3%	-7.5%	-68.9%	-12.1%	-13.1%	-0.4%
Gasoline Nonroad	-0.2%	-0.4%	-0.1%	-68.9%	-0.3%	-0.3%	-0.0%
Gasoline Total	-1.5%	-3.2%	-4.0%	-68.9%	-8.4%	-8.8%	-0.2%
Manmade Total	-0.6%	-1.1%	-3.3%	-9.8%	-1.9%	-2.2%	-0.2%
Grand Total	-0.5%	-1.1%	-3.3%	-9.8%	-0.3%	-0.7%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.4: DISTRIBUTION OF ADJUSTED BASELINE 2010 GASOLINE EMISSIONS BY TECHNOLOGY TYPE
(METRIC TONS PER DAY)**

Source Category	Summer						Winter
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5	CO
Onroad Vehicles – Tech 5	17.31	42.60	339.74	0.65	2.81	2.36	282.52
Exhaust	9.64	42.60	339.74	0.65	2.81	2.36	282.52
Evaporative	7.67	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	18.27	11.59	83.80	0.04	0.63	0.52	76.30
Exhaust	4.04	11.59	83.80	0.04	0.63	0.52	76.30
Evaporative	14.23	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	3.81	5.77	23.88	0.02	0.37	0.31	18.07
Exhaust	1.07	5.77	23.88	0.02	0.37	0.31	18.07
Evaporative	2.74	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	2.51	0.99	12.55	0.00	0.07	0.06	8.01
Exhaust	1.73	0.99	12.55	0.00	0.07	0.06	8.01
Evaporative	0.78	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	41.90	60.95	459.97	0.71	3.88	3.24	384.89
Exhaust	16.48	60.95	459.97	0.71	3.88	3.24	384.89
Evaporative	25.42	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.23	0.29	7.88	0.00	1.30	1.19	7.85
Exhaust	1.71	0.29	7.88	0.00	1.30	1.19	7.85
Evaporative	0.52	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	15.35	1.25	458.78	0.01	1.91	1.75	458.78
Exhaust	12.24	1.25	458.78	0.01	1.91	1.75	458.78
Evaporative	3.11	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	17.58	1.54	466.66	0.01	3.21	2.94	466.64
Exhaust	13.95	1.54	466.66	0.01	3.21	2.94	466.64
Evaporative	3.63	0.00	0.00	0.00	0.00	0.00	0.00
Gasoline Total	59.48	62.49	926.64	0.72	7.09	6.18	851.53
Exhaust	30.43	62.49	926.64	0.72	7.09	6.18	851.53
Evaporative	29.05	0.00	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	207.55	217.83	1102.92	9.25	34.10	26.71	1015.51
Emissions Grand Total	254.19	226.18	1102.92	9.25	239.92	95.26	1015.51
Change in Emissions Relative to Baseline							
Gasoline Onroad	-0.1%	-0.5%	-0.1%	-6.7%	-0.9%	-1.0%	-0.4%
Gasoline Nonroad	+0.0%	-0.0%	-0.0%	-6.7%	-0.0%	-0.0%	-0.0%
Gasoline Total	-0.0%	-0.5%	-0.0%	-6.7%	-0.5%	-0.5%	-0.2%
Manmade Total	-0.0%	-0.1%	-0.0%	-0.6%	-0.1%	-0.1%	-0.2%
Grand Total	-0.0%	-0.1%	-0.0%	-0.6%	-0.0%	-0.0%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.5: 2005 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR NON-OXYGENATED
SUMMER FEDERAL RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	15.38	46.39	258.13	0.45	2.84	2.36
Exhaust	9.69	46.39	258.13	0.45	2.84	2.36
Evaporative	5.69	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	23.64	21.81	110.24	0.08	1.21	1.00
Exhaust	6.18	21.81	110.24	0.08	1.21	1.00
Evaporative	17.45	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	4.49	2.42	16.99	0.01	0.13	0.11
Exhaust	1.34	2.42	16.99	0.01	0.13	0.11
Evaporative	3.15	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	7.23	9.61	41.65	0.03	0.62	0.51
Exhaust	3.09	9.61	41.65	0.03	0.62	0.51
Evaporative	4.14	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	3.27	2.48	20.76	0.01	0.17	0.14
Exhaust	2.00	2.48	20.76	0.01	0.17	0.14
Evaporative	1.28	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	54.01	82.71	447.78	0.58	4.97	4.12
Exhaust	22.29	82.71	447.78	0.58	4.97	4.12
Evaporative	31.72	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	3.33	0.19	6.17	0.00	0.86	0.79
Exhaust	2.59	0.19	6.17	0.00	0.86	0.79
Evaporative	0.74	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	46.29	0.98	445.55	0.01	1.72	1.57
Exhaust	39.13	0.98	445.55	0.01	1.72	1.57
Evaporative	7.17	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	49.62	1.17	451.72	0.01	2.58	2.37
Exhaust	41.72	1.17	451.72	0.01	2.58	2.37
Evaporative	7.90	0.00	0.00	0.00	0.00	0.00
Gasoline Total	103.63	83.88	899.50	0.59	7.55	6.49
Exhaust	64.01	83.88	899.50	0.59	7.55	6.49
Evaporative	39.62	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	240.09	244.11	1075.73	12.12	35.18	28.09
Emissions Grand Total	284.49	252.99	1075.73	12.12	217.52	89.21
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+0.3%	+0.7%	+0.3%	0.0%	+0.6%	+0.6%
Gasoline Nonroad	-0.5%	+1.0%	+0.3%	0.0%	+0.0%	+0.0%
Gasoline Total	-0.1%	+0.7%	+0.3%	0.0%	+0.4%	+0.4%
Manmade Total	-0.0%	+0.2%	+0.3%	0.0%	+0.1%	+0.1%
Grand Total	-0.0%	+0.2%	+0.3%	0.0%	+0.0%	+0.0%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

TABLE B.6: 2005 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR NON-OXYGENATED SUMMER CALIFORNIA PHASE 2 RFG OPTION (METRIC TONS PER DAY)

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	15.48	42.19	255.54	0.26	2.54	2.11
Exhaust	9.75	42.19	255.54	0.26	2.54	2.11
Evaporative	5.73	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	23.85	20.45	109.14	0.05	1.13	0.93
Exhaust	6.30	20.45	109.14	0.05	1.13	0.93
Evaporative	17.55	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	4.61	2.18	16.82	0.00	0.12	0.10
Exhaust	1.43	2.18	16.82	0.00	0.12	0.10
Evaporative	3.17	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	7.49	8.66	41.23	0.02	0.57	0.47
Exhaust	3.32	8.66	41.23	0.02	0.57	0.47
Evaporative	4.17	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	3.42	2.24	20.55	0.00	0.15	0.13
Exhaust	2.14	2.24	20.55	0.00	0.15	0.13
Evaporative	1.28	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	54.85	75.71	443.28	0.33	4.51	3.74
Exhaust	22.95	75.71	443.28	0.33	4.51	3.74
Evaporative	31.91	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	3.52	0.17	6.11	0.00	0.86	0.79
Exhaust	2.78	0.17	6.11	0.00	0.86	0.79
Evaporative	0.74	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	49.18	0.89	441.06	0.00	1.71	1.57
Exhaust	41.99	0.89	441.06	0.00	1.71	1.57
Evaporative	7.19	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	52.71	1.05	447.17	0.00	2.57	2.36
Exhaust	44.77	1.05	447.17	0.00	2.57	2.36
Evaporative	7.94	0.00	0.00	0.00	0.00	0.00
Gasoline Total	107.56	76.76	890.45	0.34	7.08	6.10
Exhaust	67.72	76.76	890.45	0.34	7.08	6.10
Evaporative	39.84	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	244.02	237.00	1066.68	11.87	34.71	27.70
Emissions Grand Total	288.42	245.87	1066.68	11.87	217.05	88.82
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+1.8%	-7.8%	-0.7%	-42.9%	-8.8%	-8.9%
Gasoline Nonroad	+5.7%	-9.0%	-0.7%	-42.9%	-0.3%	-0.2%
Gasoline Total	+3.7%	-7.8%	-0.7%	-42.9%	-5.8%	-5.7%
Manmade Total	+1.6%	-2.7%	-0.6%	-2.1%	-1.3%	-1.3%
Grand Total	+1.3%	-2.6%	-0.6%	-2.1%	-0.2%	-0.4%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.7: 2005 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR NON-OXYGENATED
SUMMER CALIFORNIA PHASE 3 RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	15.45	43.31	254.00	0.32	2.63	2.19
Exhaust	9.72	43.31	254.00	0.32	2.63	2.19
Evaporative	5.73	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	23.80	20.77	108.48	0.06	1.15	0.95
Exhaust	6.25	20.77	108.48	0.06	1.15	0.95
Evaporative	17.55	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	4.58	2.23	16.72	0.00	0.12	0.10
Exhaust	1.41	2.23	16.72	0.00	0.12	0.10
Evaporative	3.17	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	7.43	8.87	40.98	0.02	0.58	0.48
Exhaust	3.25	8.87	40.98	0.02	0.58	0.48
Evaporative	4.17	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	3.38	2.29	20.43	0.01	0.16	0.13
Exhaust	2.10	2.29	20.43	0.01	0.16	0.13
Evaporative	1.28	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	54.64	77.47	440.61	0.42	4.63	3.84
Exhaust	22.73	77.47	440.61	0.42	4.63	3.84
Evaporative	31.91	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	3.47	0.17	6.07	0.00	0.86	0.79
Exhaust	2.73	0.17	6.07	0.00	0.86	0.79
Evaporative	0.74	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	48.40	0.91	438.41	0.00	1.71	1.57
Exhaust	41.20	0.91	438.41	0.00	1.71	1.57
Evaporative	7.19	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	51.87	1.08	444.48	0.01	2.57	2.36
Exhaust	43.93	1.08	444.48	0.01	2.57	2.36
Evaporative	7.94	0.00	0.00	0.00	0.00	0.00
Gasoline Total	106.50	78.56	885.09	0.42	7.21	6.20
Exhaust	66.66	78.56	885.09	0.42	7.21	6.20
Evaporative	39.84	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	242.96	238.79	1061.31	11.95	34.84	27.80
Emissions Grand Total	287.36	247.67	1061.31	11.95	217.18	88.92
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+1.4%	-5.7%	-1.3%	-28.6%	-6.2%	-6.3%
Gasoline Nonroad	+4.0%	-6.7%	-1.3%	-28.6%	-0.2%	-0.2%
Gasoline Total	+2.7%	-5.7%	-1.3%	-28.6%	-4.2%	-4.1%
Manmade Total	+1.2%	-1.9%	-1.1%	-1.4%	-0.9%	-0.9%
Grand Total	+1.0%	-1.9%	-1.1%	-1.4%	-0.1%	-0.3%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.8: 2005 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR OXYGENATED
SUMMER FEDERAL RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	14.45	46.08	249.89	0.45	2.82	2.35
Exhaust	8.76	46.08	249.89	0.45	2.82	2.35
Evaporative	5.69	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	22.99	21.67	94.75	0.08	1.20	0.99
Exhaust	5.53	21.67	94.75	0.08	1.20	0.99
Evaporative	17.45	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	4.31	2.37	14.00	0.01	0.13	0.11
Exhaust	1.16	2.37	14.00	0.01	0.13	0.11
Evaporative	3.15	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	6.92	9.42	27.23	0.03	0.61	0.51
Exhaust	2.78	9.42	27.23	0.03	0.61	0.51
Evaporative	4.14	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	3.23	2.43	15.59	0.01	0.17	0.14
Exhaust	1.95	2.43	15.59	0.01	0.17	0.14
Evaporative	1.28	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	51.90	81.96	401.46	0.58	4.93	4.09
Exhaust	20.18	81.96	401.46	0.58	4.93	4.09
Evaporative	31.72	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.99	0.18	5.08	0.00	0.86	0.79
Exhaust	2.25	0.18	5.08	0.00	0.86	0.79
Evaporative	0.74	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	45.46	0.96	334.59	0.01	1.71	1.57
Exhaust	38.29	0.96	334.59	0.01	1.71	1.57
Evaporative	7.17	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	48.45	1.15	339.68	0.01	2.58	2.37
Exhaust	40.55	1.15	339.68	0.01	2.58	2.37
Evaporative	7.90	0.00	0.00	0.00	0.00	0.00
Gasoline Total	100.35	83.11	741.14	0.59	7.51	6.46
Exhaust	60.73	83.11	741.14	0.59	7.51	6.46
Evaporative	39.62	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	236.81	243.35	917.36	12.12	35.14	28.06
Emissions Grand Total	281.21	252.22	917.36	12.12	217.48	89.18
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-3.7%	-0.2%	-10.1%	0.0%	-0.2%	-0.2%
Gasoline Nonroad	-2.8%	-1.0%	-24.6%	0.0%	-0.0%	-0.0%
Gasoline Total	-3.3%	-0.2%	-17.4%	0.0%	-0.1%	-0.1%
Manmade Total	-1.4%	-0.1%	-14.5%	0.0%	-0.0%	-0.0%
Grand Total	-1.2%	-0.1%	-14.5%	0.0%	-0.0%	-0.0%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

TABLE B.9: 2005 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR OXYGENATED SUMMER CALIFORNIA PHASE 2 RFG OPTION (METRIC TONS PER DAY)

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	14.68	44.29	249.82	0.37	2.70	2.25
Exhaust	8.94	44.29	249.82	0.37	2.70	2.25
Evaporative	5.73	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	23.24	21.09	99.89	0.07	1.17	0.96
Exhaust	5.69	21.09	99.89	0.07	1.17	0.96
Evaporative	17.55	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	4.41	2.29	15.05	0.00	0.13	0.10
Exhaust	1.24	2.29	15.05	0.00	0.13	0.10
Evaporative	3.17	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	7.11	9.09	32.87	0.03	0.59	0.49
Exhaust	2.94	9.09	32.87	0.03	0.59	0.49
Evaporative	4.17	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	3.31	2.35	17.53	0.01	0.16	0.13
Exhaust	2.02	2.35	17.53	0.01	0.16	0.13
Evaporative	1.28	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	52.75	79.11	415.17	0.48	4.74	3.93
Exhaust	20.84	79.11	415.17	0.48	4.74	3.93
Evaporative	31.91	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	3.15	0.18	5.47	0.00	0.86	0.79
Exhaust	2.41	0.18	5.47	0.00	0.86	0.79
Evaporative	0.74	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	46.85	0.93	376.24	0.00	1.71	1.57
Exhaust	39.65	0.93	376.24	0.00	1.71	1.57
Evaporative	7.19	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	50.00	1.11	381.70	0.01	2.58	2.36
Exhaust	42.06	1.11	381.70	0.01	2.58	2.36
Evaporative	7.94	0.00	0.00	0.00	0.00	0.00
Gasoline Total	102.75	80.22	796.87	0.49	7.32	6.30
Exhaust	62.91	80.22	796.87	0.49	7.32	6.30
Evaporative	39.84	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	239.21	240.45	973.10	12.02	34.95	27.90
Emissions Grand Total	283.61	249.33	973.10	12.02	217.29	89.02
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-2.1%	-3.7%	-7.0%	-17.9%	-4.0%	-4.1%
Gasoline Nonroad	+0.3%	-4.4%	-15.2%	-17.9%	-0.1%	-0.1%
Gasoline Total	-0.9%	-3.7%	-11.1%	-17.9%	-2.7%	-2.6%
Manmade Total	-0.4%	-1.3%	-9.3%	-0.9%	-0.6%	-0.6%
Grand Total	-0.3%	-1.2%	-9.3%	-0.9%	-0.1%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.10: 2005 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR OXYGENATED
SUMMER CALIFORNIA PHASE 3 RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	14.78	43.81	253.14	0.28	2.63	2.19
Exhaust	9.04	43.81	253.14	0.28	2.63	2.19
Evaporative	5.73	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	23.34	21.17	101.22	0.05	1.16	0.96
Exhaust	5.80	21.17	101.22	0.05	1.16	0.96
Evaporative	17.55	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	4.44	2.32	15.25	0.00	0.13	0.10
Exhaust	1.27	2.32	15.25	0.00	0.13	0.10
Evaporative	3.17	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	7.17	9.21	33.31	0.02	0.60	0.49
Exhaust	3.00	9.21	33.31	0.02	0.60	0.49
Evaporative	4.17	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	3.34	2.38	17.77	0.00	0.16	0.13
Exhaust	2.06	2.38	17.77	0.00	0.16	0.13
Evaporative	1.28	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	53.07	78.88	420.69	0.35	4.68	3.88
Exhaust	21.17	78.88	420.69	0.35	4.68	3.88
Evaporative	31.91	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	3.20	0.18	5.54	0.00	0.86	0.79
Exhaust	2.45	0.18	5.54	0.00	0.86	0.79
Evaporative	0.74	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	47.60	0.94	381.24	0.00	1.71	1.57
Exhaust	40.41	0.94	381.24	0.00	1.71	1.57
Evaporative	7.19	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	50.80	1.12	386.78	0.00	2.58	2.36
Exhaust	42.86	1.12	386.78	0.00	2.58	2.36
Evaporative	7.94	0.00	0.00	0.00	0.00	0.00
Gasoline Total	103.87	80.00	807.46	0.36	7.26	6.24
Exhaust	64.03	80.00	807.46	0.36	7.26	6.24
Evaporative	39.84	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	240.33	240.24	983.69	11.89	34.88	27.84
Emissions Grand Total	284.73	249.11	983.69	11.89	217.23	88.96
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-1.5%	-4.0%	-5.8%	-39.3%	-5.3%	-5.5%
Gasoline Nonroad	+1.9%	-3.2%	-14.1%	-39.3%	-0.1%	-0.1%
Gasoline Total	+0.1%	-4.0%	-10.0%	-39.3%	-3.5%	-3.5%
Manmade Total	+0.1%	-1.4%	-8.3%	-1.9%	-0.8%	-0.8%
Grand Total	+0.1%	-1.3%	-8.3%	-1.9%	-0.1%	-0.3%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.11: 2010 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR NON-OXYGENATED
SUMMER FEDERAL RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	17.36	42.86	340.77	0.65	2.82	2.37
Exhaust	9.64	42.86	340.77	0.65	2.82	2.37
Evaporative	7.73	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	18.34	11.66	84.06	0.04	0.64	0.52
Exhaust	4.04	11.66	84.06	0.04	0.64	0.52
Evaporative	14.31	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust	0.00	0.00	0.00	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	3.82	5.83	23.95	0.02	0.38	0.31
Exhaust	1.07	5.83	23.95	0.02	0.38	0.31
Evaporative	2.76	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	2.50	1.00	12.59	0.00	0.07	0.06
Exhaust	1.72	1.00	12.59	0.00	0.07	0.06
Evaporative	0.79	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	42.03	61.35	461.37	0.71	3.90	3.26
Exhaust	16.46	61.35	461.37	0.71	3.90	3.26
Evaporative	25.57	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.22	0.29	7.90	0.00	1.30	1.19
Exhaust	1.70	0.29	7.90	0.00	1.30	1.19
Evaporative	0.52	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	15.29	1.26	460.18	0.01	1.91	1.75
Exhaust	12.16	1.26	460.18	0.01	1.91	1.75
Evaporative	3.13	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	17.51	1.55	468.08	0.01	3.21	2.94
Exhaust	13.86	1.55	468.08	0.01	3.21	2.94
Evaporative	3.65	0.00	0.00	0.00	0.00	0.00
Gasoline Total	59.54	62.91	929.45	0.72	7.11	6.20
Exhaust	30.32	62.91	929.45	0.72	7.11	6.20
Evaporative	29.22	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	207.61	218.25	1105.74	9.25	34.13	26.73
Emissions Grand Total	254.25	226.60	1105.74	9.25	239.94	95.28
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+0.3%	+0.7%	+0.3%	0.0%	+0.5%	+0.5%
Gasoline Nonroad	-0.4%	+1.0%	+0.3%	0.0%	+0.0%	+0.0%
Gasoline Total	+0.1%	+0.7%	+0.3%	0.0%	+0.3%	+0.3%
Manmade Total	+0.0%	+0.2%	+0.3%	0.0%	+0.1%	+0.1%
Grand Total	+0.0%	+0.2%	+0.3%	0.0%	+0.0%	+0.0%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.12: 2010 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR NON-OXYGENATED
SUMMER CALIFORNIA PHASE 2 RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	17.48	38.98	337.34	0.37	2.50	2.10
Exhaust	9.70	38.98	337.34	0.37	2.50	2.10
Evaporative	7.78	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	18.50	10.93	83.21	0.02	0.59	0.49
Exhaust	4.12	10.93	83.21	0.02	0.59	0.49
Evaporative	14.38	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust	0.00	0.00	0.00	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	3.92	5.25	23.71	0.01	0.34	0.28
Exhaust	1.14	5.25	23.71	0.01	0.34	0.28
Evaporative	2.78	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	2.63	0.90	12.46	0.00	0.06	0.05
Exhaust	1.84	0.90	12.46	0.00	0.06	0.05
Evaporative	0.79	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	42.53	56.07	456.73	0.41	3.50	2.92
Exhaust	16.80	56.07	456.73	0.41	3.50	2.92
Evaporative	25.73	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.35	0.26	7.82	0.00	1.30	1.19
Exhaust	1.83	0.26	7.82	0.00	1.30	1.19
Evaporative	0.52	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	16.19	1.14	455.55	0.01	1.90	1.75
Exhaust	13.05	1.14	455.55	0.01	1.90	1.75
Evaporative	3.14	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	18.54	1.40	463.37	0.01	3.20	2.94
Exhaust	14.88	1.40	463.37	0.01	3.20	2.94
Evaporative	3.66	0.00	0.00	0.00	0.00	0.00
Gasoline Total	61.07	57.47	920.10	0.41	6.70	5.86
Exhaust	31.68	57.47	920.10	0.41	6.70	5.86
Evaporative	29.39	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	209.14	212.81	1096.39	8.94	33.72	26.39
Emissions Grand Total	255.78	221.16	1096.39	8.94	239.53	94.94
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+1.5%	-8.0%	-0.7%	-42.9%	-9.7%	-9.9%
Gasoline Nonroad	+5.4%	-9.0%	-0.7%	-42.9%	-0.3%	-0.3%
Gasoline Total	+2.7%	-8.0%	-0.7%	-42.9%	-5.4%	-5.3%
Manmade Total	+0.8%	-2.3%	-0.6%	-3.3%	-1.1%	-1.2%
Grand Total	+0.6%	-2.2%	-0.6%	-3.3%	-0.2%	-0.3%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.13: 2010 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR NON-OXYGENATED
SUMMER CALIFORNIA PHASE 3 RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	17.45	40.01	335.31	0.46	2.60	2.18
Exhaust	9.67	40.01	335.31	0.46	2.60	2.18
Evaporative	7.78	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	18.46	11.10	82.71	0.03	0.60	0.50
Exhaust	4.08	11.10	82.71	0.03	0.60	0.50
Evaporative	14.38	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust	0.00	0.00	0.00	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	3.90	5.38	23.57	0.02	0.35	0.29
Exhaust	1.12	5.38	23.57	0.02	0.35	0.29
Evaporative	2.78	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	2.60	0.93	12.39	0.00	0.06	0.05
Exhaust	1.81	0.93	12.39	0.00	0.06	0.05
Evaporative	0.79	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	42.41	57.43	453.98	0.51	3.61	3.02
Exhaust	16.68	57.43	453.98	0.51	3.61	3.02
Evaporative	25.73	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.31	0.27	7.78	0.00	1.30	1.19
Exhaust	1.79	0.27	7.78	0.00	1.30	1.19
Evaporative	0.52	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	15.95	1.17	452.80	0.01	1.91	1.75
Exhaust	12.81	1.17	452.80	0.01	1.91	1.75
Evaporative	3.14	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	18.26	1.43	460.58	0.01	3.20	2.94
Exhaust	14.60	1.43	460.58	0.01	3.20	2.94
Evaporative	3.66	0.00	0.00	0.00	0.00	0.00
Gasoline Total	60.67	58.86	914.56	0.52	6.81	5.95
Exhaust	31.28	58.86	914.56	0.52	6.81	5.95
Evaporative	29.39	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	208.74	214.21	1090.84	9.05	33.83	26.48
Emissions Grand Total	255.38	222.55	1090.84	9.05	239.65	95.03
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+1.2%	-5.8%	-1.3%	-28.6%	-6.8%	-6.9%
Gasoline Nonroad	+3.9%	-6.7%	-1.3%	-28.6%	-0.2%	-0.2%
Gasoline Total	+2.0%	-5.8%	-1.3%	-28.6%	-3.8%	-3.7%
Manmade Total	+0.6%	-1.7%	-1.1%	-2.2%	-0.8%	-0.9%
Grand Total	+0.5%	-1.6%	-1.1%	-2.2%	-0.1%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.14: 2010 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR OXYGENATED
SUMMER FEDERAL RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	16.44	42.57	329.89	0.65	2.80	2.35
Exhaust	8.71	42.57	329.89	0.65	2.80	2.35
Evaporative	7.73	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	17.92	11.59	72.24	0.04	0.63	0.52
Exhaust	3.61	11.59	72.24	0.04	0.63	0.52
Evaporative	14.31	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust	0.00	0.00	0.00	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	3.71	5.71	15.66	0.02	0.37	0.31
Exhaust	0.96	5.71	15.66	0.02	0.37	0.31
Evaporative	2.76	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	2.47	0.98	9.46	0.00	0.07	0.06
Exhaust	1.68	0.98	9.46	0.00	0.07	0.06
Evaporative	0.79	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	40.54	60.85	427.24	0.71	3.87	3.24
Exhaust	14.96	60.85	427.24	0.71	3.87	3.24
Evaporative	25.57	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.00	0.28	6.51	0.00	1.30	1.19
Exhaust	1.48	0.28	6.51	0.00	1.30	1.19
Evaporative	0.52	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	15.03	1.24	345.58	0.01	1.91	1.75
Exhaust	11.90	1.24	345.58	0.01	1.91	1.75
Evaporative	3.13	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	17.03	1.52	352.09	0.01	3.21	2.94
Exhaust	13.38	1.52	352.09	0.01	3.21	2.94
Evaporative	3.65	0.00	0.00	0.00	0.00	0.00
Gasoline Total	57.57	62.37	779.34	0.72	7.08	6.18
Exhaust	28.34	62.37	779.34	0.72	7.08	6.18
Evaporative	29.22	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	205.64	217.72	955.62	9.25	34.10	26.71
Emissions Grand Total	252.28	226.06	955.62	9.25	239.91	95.26
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-3.3%	-0.2%	-7.1%	0.0%	-0.1%	-0.1%
Gasoline Nonroad	-3.2%	-1.0%	-24.6%	0.0%	-0.0%	-0.0%
Gasoline Total	-3.2%	-0.2%	-15.9%	0.0%	-0.1%	-0.1%
Manmade Total	-0.9%	-0.1%	-13.4%	0.0%	-0.0%	-0.0%
Grand Total	-0.8%	-0.1%	-13.4%	0.0%	-0.0%	-0.0%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.15: 2010 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR OXYGENATED
SUMMER CALIFORNIA PHASE 2 RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	16.68	40.92	329.80	0.53	2.67	2.24
Exhaust	8.90	40.92	329.80	0.53	2.67	2.24
Evaporative	7.78	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	18.10	11.28	76.16	0.03	0.61	0.51
Exhaust	3.72	11.28	76.16	0.03	0.61	0.51
Evaporative	14.38	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust	0.00	0.00	0.00	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	3.79	5.52	18.90	0.02	0.36	0.30
Exhaust	1.01	5.52	18.90	0.02	0.36	0.30
Evaporative	2.78	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	2.53	0.95	10.63	0.00	0.07	0.05
Exhaust	1.74	0.95	10.63	0.00	0.07	0.05
Evaporative	0.79	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	41.10	58.66	435.50	0.58	3.71	3.10
Exhaust	15.37	58.66	435.50	0.58	3.71	3.10
Evaporative	25.73	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.10	0.27	7.00	0.00	1.30	1.19
Exhaust	1.58	0.27	7.00	0.00	1.30	1.19
Evaporative	0.52	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	15.46	1.20	388.59	0.01	1.91	1.75
Exhaust	12.33	1.20	388.59	0.01	1.91	1.75
Evaporative	3.14	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	17.57	1.47	395.59	0.01	3.20	2.94
Exhaust	13.91	1.47	395.59	0.01	3.20	2.94
Evaporative	3.66	0.00	0.00	0.00	0.00	0.00
Gasoline Total	58.67	60.13	831.09	0.59	6.91	6.04
Exhaust	29.28	60.13	831.09	0.59	6.91	6.04
Evaporative	29.39	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	206.74	215.48	1007.38	9.12	33.93	26.57
Emissions Grand Total	253.38	223.82	1007.38	9.12	239.75	95.12
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-1.9%	-3.7%	-5.3%	-17.9%	-4.4%	-4.4%
Gasoline Nonroad	-0.1%	-4.4%	-15.2%	-17.9%	-0.1%	-0.1%
Gasoline Total	-1.4%	-3.8%	-10.3%	-17.9%	-2.5%	-2.4%
Manmade Total	-0.4%	-1.1%	-8.7%	-1.4%	-0.5%	-0.6%
Grand Total	-0.3%	-1.0%	-8.7%	-1.4%	-0.1%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

**TABLE B.16 2010 GASOLINE EMISSIONS BY TECHNOLOGY TYPE FOR OXYGENATED
SUMMER CALIFORNIA PHASE 3 RFG OPTION (METRIC TONS PER DAY)**

Source Category	Summer					
	VOC	NO _x	CO	SO ₂	PM-10	PM-2.5
Onroad Vehicles – Tech 5	16.78	40.47	334.18	0.39	2.59	2.17
Exhaust	9.00	40.47	334.18	0.39	2.59	2.17
Evaporative	7.78	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	18.17	11.32	77.17	0.02	0.61	0.50
Exhaust	3.78	11.32	77.17	0.02	0.61	0.50
Evaporative	14.38	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	0.00	0.00	0.00	0.00	0.00	0.00
Exhaust	0.00	0.00	0.00	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	3.81	5.59	19.15	0.01	0.36	0.30
Exhaust	1.03	5.59	19.15	0.01	0.36	0.30
Evaporative	2.78	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	2.56	0.96	10.77	0.00	0.07	0.05
Exhaust	1.78	0.96	10.77	0.00	0.07	0.05
Evaporative	0.79	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	41.32	58.34	441.29	0.43	3.63	3.02
Exhaust	15.59	58.34	441.29	0.43	3.63	3.02
Evaporative	25.73	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	2.13	0.28	7.09	0.00	1.30	1.19
Exhaust	1.61	0.28	7.09	0.00	1.30	1.19
Evaporative	0.52	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	15.70	1.21	393.76	0.01	1.91	1.75
Exhaust	12.56	1.21	393.76	0.01	1.91	1.75
Evaporative	3.14	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	17.83	1.49	400.85	0.01	3.20	2.94
Exhaust	14.17	1.49	400.85	0.01	3.20	2.94
Evaporative	3.66	0.00	0.00	0.00	0.00	0.00
Gasoline Total	59.15	59.83	842.14	0.44	6.83	5.96
Exhaust	29.76	59.83	842.14	0.44	6.83	5.96
Evaporative	29.39	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	207.22	215.18	1018.42	8.97	33.85	26.49
Emissions Grand Total	253.86	223.52	1018.42	8.97	239.67	95.04
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	-1.4%	-4.3%	-4.1%	-39.3%	-6.4%	-6.7%
Gasoline Nonroad	+1.4%	-3.2%	-14.1%	-39.3%	-0.1%	-0.1%
Gasoline Total	-0.6%	-4.3%	-9.1%	-39.3%	-3.6%	-3.6%
Manmade Total	-0.2%	-1.2%	-7.7%	-3.1%	-0.7%	-0.8%
Grand Total	-0.1%	-1.2%	-7.7%	-3.1%	-0.1%	-0.2%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

TABLE B.17: GASOLINE CO EMISSIONS BY TECHNOLOGY TYPE FOR WINTER CBG FORMULATIONS (METRIC TONS PER DAY)

Source Category	Winter 2005			Winter 2010		
	CARB 2 Option	CARB 3 Option	Federal RFG	CARB 2 Option	CARB 3 Option	Federal RFG
Onroad Vehicles – Tech 5	218.78	218.58	279.61	284.41	284.15	363.49
Exhaust	218.78	218.58	279.61	284.41	284.15	363.49
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 4	122.52	122.41	159.32	76.81	76.74	99.89
Exhaust	122.52	122.41	159.32	76.81	76.74	99.89
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Tech 3	22.13	22.11	28.13	0.00	0.00	0.00
Exhaust	22.13	22.11	28.13	0.00	0.00	0.00
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Oxy Cat	33.26	33.23	35.58	18.19	18.17	19.46
Exhaust	33.26	33.23	35.58	18.19	18.17	19.46
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles – Non Cat	11.62	11.62	12.20	8.06	8.06	8.46
Exhaust	11.62	11.62	12.20	8.06	8.06	8.46
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Onroad Vehicles - Total	408.30	407.95	514.85	387.47	387.13	491.30
Exhaust	408.30	407.95	514.85	387.47	387.13	491.30
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Catalyst	6.77	6.76	8.60	7.90	7.90	10.05
Exhaust	6.77	6.76	8.60	7.90	7.90	10.05
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Non Cat	447.36	447.36	469.43	462.05	462.05	484.85
Exhaust	447.36	447.36	469.43	462.05	462.05	484.85
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Nonroad Equipment – Total	454.13	454.12	478.04	469.96	469.95	494.90
Exhaust	454.13	454.12	478.04	469.96	469.95	494.90
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Gasoline Total	862.43	862.07	992.88	857.43	857.08	986.20
Exhaust	862.43	862.07	992.88	857.43	857.08	986.20
Evaporative	0.00	0.00	0.00	0.00	0.00	0.00
Manmade Emissions Total	1027.39	1027.03	1157.84	1021.41	1021.06	1150.18
Emissions Grand Total	1027.39	1027.03	1157.84	1021.41	1021.06	1150.18
Change in Emissions Relative to Adjusted Baseline						
Gasoline Onroad	+0.7%	+0.6%	+26.9%	+0.7%	+0.6%	+27.6%
Gasoline Nonroad	+0.7%	+0.7%	+6.0%	+0.7%	+0.7%	+6.1%
Gasoline Total	+0.7%	+0.6%	+15.9%	+0.7%	+0.7%	+15.8%
Manmade Total	+0.6%	+0.5%	+13.4%	+0.6%	+0.5%	+13.3%
Grand Total	+0.6%	+0.5%	+13.4%	+0.6%	+0.5%	+13.3%

Notes: (1) Exhaust emissions for PM-10 and PM-2.5 include both direct (carbonaceous and sulfate) and indirect (sulfate and nitrate) components. Impacts on sulfate and nitrate components are analyzed in accordance with impacts on precursor SO₂ and NO_x emissions respectively.

TABLE B.18: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE NON-OXYGENATED FEDERAL RFG SUMMERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	+2.60%	+2.54%	+1.87%	+9.68%	+9.69%	+1.87%	+9.69%
Evaporative Benzene	+3.91%	+3.73%	+3.89%	+3.95%	+3.56%	+3.89%	+3.56%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-0.98%	-1.22%	-1.57%	-0.00%	0.00%	-1.57%	0.00%
Formaldehyde	-0.34%	-0.38%	-0.30%	0.00%	0.00%	-0.30%	0.00%
Acetaldehyde	+0.06%	+0.07%	+0.03%	-0.00%	0.00%	+0.03%	0.00%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	-0.01%	-0.06%	-0.63%	-0.63%	-0.63%	-0.63%	-0.63%
Potency-Weighted Change in Non-Cancer Risk (1)	+0.03%	+0.00%	-0.07%	+0.20%	+0.19%	-0.07%	+0.19%
Potency-Weighted Change in Cancer Risk (2)	+0.84%	+0.80%	+0.49%	+2.08%	+1.64%	+0.49%	+1.64%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	+3.20%	+8.48%	+5.74%	+3.17%	+7.90%	+4.68%
Evaporative Benzene	+3.80%	+3.60%	+3.75%	+3.78%	+3.63%	+3.76%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-0.91%	-0.10%	-0.33%	-0.84%	-0.16%	-0.47%
Formaldehyde	-0.27%	-0.01%	-0.09%	-0.28%	-0.02%	-0.14%
Acetaldehyde	+0.05%	+0.00%	+0.02%	+0.05%	+0.00%	+0.03%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	-0.20%	-0.63%	-0.48%	-0.14%	-0.63%	-0.37%
Potency-Weighted Change in Non-Cancer Risk (1)	+0.05%	+0.17%	+0.13%	+0.05%	+0.16%	+0.10%
Potency-Weighted Change in Cancer Risk (2)	+1.00%	+1.56%	+1.35%	+0.99%	+1.51%	+1.22%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE B.19: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE NON-OXYGENATED CALIFORNIA PHASE 2 SUMMERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	-21.07%	-20.53%	-16.77%	-55.86%	-55.70%	-16.77%	-55.70%
Evaporative Benzene	-24.13%	-24.39%	-24.15%	-24.06%	-24.65%	-24.15%	-24.65%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-15.89%	-16.61%	-19.71%	-0.08%	0.00%	-19.71%	0.00%
Formaldehyde	-0.44%	+0.96%	+8.21%	-0.34%	0.00%	+8.21%	0.00%
Acetaldehyde	-2.90%	-2.84%	-2.88%	-0.09%	0.00%	-2.88%	0.00%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	+0.66%	+1.89%	+6.64%	+6.64%	+6.64%	+6.64%	+6.64%
Potency-Weighted Change in Non-Cancer Risk (1)	-2.30%	-2.48%	-3.17%	-1.16%	-1.09%	-3.17%	-1.09%
Potency-Weighted Change in Cancer Risk (2)	-11.83%	-11.82%	-10.99%	-11.34%	-9.07%	-10.99%	-9.07%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	-23.89%	-49.67%	-36.30%	-23.82%	-46.83%	-31.16%
Evaporative Benzene	-24.29%	-24.58%	-24.36%	-24.31%	-24.54%	-24.35%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-13.26%	-1.26%	-4.68%	-12.86%	-1.95%	-6.87%
Formaldehyde	+0.41%	+0.30%	+0.33%	-0.05%	+0.47%	+0.22%
Acetaldehyde	-2.31%	-0.16%	-0.89%	-2.37%	-0.25%	-1.34%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	+2.69%	+6.64%	+5.25%	+2.11%	+6.64%	+4.24%
Potency-Weighted Change in Non-Cancer Risk (1)	-2.18%	-1.22%	-1.55%	-2.14%	-1.29%	-1.73%
Potency-Weighted Change in Cancer Risk (2)	-11.55%	-9.21%	-9.98%	-11.54%	-9.29%	-10.42%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE B.20: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE NON-OXYGENATED CALIFORNIA PHASE 3 SUMMERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	-21.07%	-20.53%	-16.77%	-55.86%	-55.70%	-16.77%	-55.70%
Evaporative Benzene	-24.13%	-24.39%	-24.15%	-24.06%	-24.65%	-24.15%	-24.65%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-15.89%	-16.61%	-19.71%	-0.08%	0.00%	-19.71%	0.00%
Formaldehyde	-0.44%	+0.96%	+8.21%	-0.34%	0.00%	+8.21%	0.00%
Acetaldehyde	-2.90%	-2.84%	-2.88%	-0.09%	0.00%	-2.88%	0.00%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	+0.66%	+1.89%	+6.64%	+6.64%	+6.64%	+6.64%	+6.64%
Potency-Weighted Change in Non-Cancer Risk (1)	-2.30%	-2.48%	-3.17%	-1.16%	-1.09%	-3.17%	-1.09%
Potency-Weighted Change in Cancer Risk (2)	-11.83%	-11.82%	-10.99%	-11.34%	-9.07%	-10.99%	-9.07%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	-23.89%	-49.67%	-36.30%	-23.82%	-46.83%	-31.16%
Evaporative Benzene	-24.29%	-24.58%	-24.36%	-24.31%	-24.54%	-24.35%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-13.26%	-1.26%	-4.68%	-12.86%	-1.95%	-6.87%
Formaldehyde	+0.41%	+0.30%	+0.33%	-0.05%	+0.47%	+0.22%
Acetaldehyde	-2.31%	-0.16%	-0.89%	-2.37%	-0.25%	-1.34%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	+2.69%	+6.64%	+5.25%	+2.11%	+6.64%	+4.24%
Potency-Weighted Change in Non-Cancer Risk (1)	-2.18%	-1.22%	-1.55%	-2.14%	-1.29%	-1.73%
Potency-Weighted Change in Cancer Risk (2)	-11.55%	-9.21%	-9.98%	-11.54%	-9.29%	-10.42%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE B.21: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE OXYGENATED FEDERAL RFG SUMMERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	-11.51%	-14.53%	-25.76%	-16.59%	-9.28%	-25.76%	-9.28%
Evaporative Benzene	-10.02%	-10.24%	-10.09%	-9.91%	-10.33%	-10.09%	-10.33%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-6.65%	-10.52%	-20.79%	-35.77%	+9.69%	-20.79%	+9.69%
Formaldehyde	-2.40%	-3.11%	-3.66%	+20.04%	+7.72%	-3.66%	+7.72%
Acetaldehyde	+136.19%	+134.47%	+132.85%	+180.79%	+110.43%	+132.85%	+110.43%
Acrolein	-9.85%	-10.32%	-10.89%	-10.33%	-2.47%	-10.89%	-2.47%
POM	-1.84%	-2.03%	-2.61%	-2.03%	-0.53%	-2.61%	-0.53%
Potency-Weighted Change in Non-Cancer Risk (1)	-7.03%	-7.92%	-10.33%	-7.86%	+1.40%	-10.33%	+1.40%
Potency-Weighted Change in Cancer Risk (2)	-5.12%	-7.49%	-15.19%	-3.02%	+4.65%	-15.19%	+4.65%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	-13.76%	-11.83%	-12.83%	-12.38%	-13.04%	-12.59%
Evaporative Benzene	-10.16%	-10.30%	-10.19%	-10.16%	-10.28%	-10.19%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-9.33%	+7.74%	+2.87%	-6.43%	+6.67%	+0.76%
Formaldehyde	+1.09%	+7.31%	+5.51%	+0.40%	+7.08%	+3.95%
Acetaldehyde	+137.66%	+111.70%	+120.43%	+135.32%	+112.41%	+124.24%
Acrolein	-9.48%	-3.01%	-5.37%	-9.21%	-3.30%	-6.51%
POM	-1.85%	-0.65%	-1.07%	-1.75%	-0.72%	-1.27%
Potency-Weighted Change in Non-Cancer Risk (1)	-6.85%	+0.65%	-2.01%	-6.36%	+0.24%	-3.28%
Potency-Weighted Change in Cancer Risk (2)	-5.54%	+3.17%	+0.10%	-4.56%	+2.37%	-1.28%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE B.22: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE OXYGENATED CALIFORNIA PHASE 2 SUMMERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	-14.79%	-16.36%	-21.45%	-27.98%	-23.28%	-21.45%	-23.28%
Evaporative Benzene	-3.50%	-3.88%	-3.58%	-3.39%	-4.18%	-3.58%	-4.18%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-16.11%	-18.82%	-26.57%	-22.95%	+4.82%	-26.57%	+4.82%
Formaldehyde	-2.77%	-2.54%	+1.25%	+9.64%	+3.69%	+1.25%	+3.69%
Acetaldehyde	+59.30%	+58.35%	+56.88%	+103.96%	+62.57%	+56.88%	+62.57%
Acrolein	-7.48%	-7.88%	-8.48%	-8.01%	-2.15%	-8.48%	-2.15%
POM	-0.90%	-0.93%	-0.90%	-0.63%	+0.08%	-0.90%	+0.08%
Potency-Weighted Change in Non-Cancer Risk (1)	-7.21%	-7.93%	-9.90%	-6.88%	-0.22%	-9.90%	-0.22%
Potency-Weighted Change in Cancer Risk (2)	-8.91%	-10.26%	-14.32%	-6.54%	-0.63%	-14.32%	-0.63%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	-16.88%	-23.00%	-19.82%	-16.08%	-22.86%	-18.24%
Evaporative Benzene	-3.74%	-4.10%	-3.83%	-3.76%	-4.06%	-3.81%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-15.82%	+2.81%	-2.50%	-13.85%	+1.71%	-5.31%
Formaldehyde	-0.34%	+3.60%	+2.46%	-0.95%	+3.55%	+1.44%
Acetaldehyde	+63.80%	+62.25%	+62.77%	+62.12%	+62.07%	+62.10%
Acrolein	-7.27%	-2.55%	-4.27%	-7.04%	-2.77%	-5.09%
POM	-0.79%	+0.02%	-0.26%	-0.77%	-0.01%	-0.41%
Potency-Weighted Change in Non-Cancer Risk (1)	-6.94%	-0.84%	-3.00%	-6.59%	-1.18%	-4.07%
Potency-Weighted Change in Cancer Risk (2)	-8.76%	-1.65%	-4.19%	-8.21%	-2.20%	-5.42%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE B.23: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE OXYGENATED CALIFORNIA PHASE 3 SUMMERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	-14.79%	-16.36%	-21.45%	-27.98%	-23.28%	-21.45%	-23.28%
Evaporative Benzene	-3.50%	-3.88%	-3.58%	-3.39%	-4.18%	-3.58%	-4.18%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-16.11%	-18.82%	-26.57%	-22.95%	+4.82%	-26.57%	+4.82%
Formaldehyde	-2.77%	-2.54%	+1.25%	+9.64%	+3.69%	+1.25%	+3.69%
Acetaldehyde	+59.30%	+58.35%	+56.88%	+103.96%	+62.57%	+56.88%	+62.57%
Acrolein	-7.48%	-7.88%	-8.48%	-8.01%	-2.15%	-8.48%	-2.15%
POM	-0.90%	-0.93%	-0.90%	-0.63%	+0.08%	-0.90%	+0.08%
Potency-Weighted Change in Non-Cancer Risk (1)	-7.21%	-7.93%	-9.90%	-6.88%	-0.22%	-9.90%	-0.22%
Potency-Weighted Change in Cancer Risk (2)	-8.91%	-10.26%	-14.32%	-6.54%	-0.63%	-14.32%	-0.63%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	-16.88%	-23.00%	-19.82%	-16.08%	-22.86%	-18.24%
Evaporative Benzene	-3.74%	-4.10%	-3.83%	-3.76%	-4.06%	-3.81%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	-15.82%	+2.81%	-2.50%	-13.85%	+1.71%	-5.31%
Formaldehyde	-0.34%	+3.60%	+2.46%	-0.95%	+3.55%	+1.44%
Acetaldehyde	+63.80%	+62.25%	+62.77%	+62.12%	+62.07%	+62.10%
Acrolein	-7.27%	-2.55%	-4.27%	-7.04%	-2.77%	-5.09%
POM	-0.79%	+0.02%	-0.26%	-0.77%	-0.01%	-0.41%
Potency-Weighted Change in Non-Cancer Risk (1)	-6.94%	-0.84%	-3.00%	-6.59%	-1.18%	-4.07%
Potency-Weighted Change in Cancer Risk (2)	-8.76%	-1.65%	-4.19%	-8.21%	-2.20%	-5.42%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE B.24: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE CALIFORNIA PHASE 2 WINTERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	+3.94%	+3.39%	+1.14%	+4.97%	+4.67%	+1.14%	+4.67%
Evaporative Benzene	-1.17%	-1.06%	-1.03%	-1.03%	-1.03%	-1.03%	-1.03%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	+3.34%	+3.75%	+4.85%	+0.07%	0.00%	+4.85%	0.00%
Formaldehyde	-2.14%	-2.02%	-1.99%	+0.25%	0.00%	-1.99%	0.00%
Acetaldehyde	-1.67%	-1.35%	-0.84%	+0.07%	0.00%	-0.84%	0.00%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	+0.71%	+0.88%	+2.78%	+2.78%	+2.77%	+2.78%	+2.77%
Potency-Weighted Change in Non-Cancer Risk (1)	+0.20%	+0.23%	+0.24%	+0.12%	+0.08%	+0.24%	+0.08%
Potency-Weighted Change in Cancer Risk (2)	+1.79%	+1.67%	+1.28%	+1.86%	+1.23%	+1.28%	+1.23%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	+3.63%	+4.11%	+3.85%	+3.85%	+3.84%	+3.85%
Evaporative Benzene	-1.06%	-1.03%	-1.05%	-1.08%	-1.03%	-1.07%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	+2.71%	+0.18%	+0.71%	+2.51%	+0.29%	+1.09%
Formaldehyde	-1.51%	-0.08%	-0.48%	-1.58%	-0.13%	-0.77%
Acetaldehyde	-1.17%	-0.06%	-0.46%	-1.28%	-0.09%	-0.73%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	+1.29%	+2.77%	+2.23%	+1.10%	+2.77%	+1.86%
Potency-Weighted Change in Non-Cancer Risk (1)	+0.20%	+0.09%	+0.13%	+0.19%	+0.10%	+0.15%
Potency-Weighted Change in Cancer Risk (2)	+1.66%	+1.23%	+1.38%	+1.69%	+1.23%	+1.48%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE B.25: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE CALIFORNIA PHASE 3 WINTERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	+3.85%	+3.30%	+1.07%	+4.91%	+4.67%	+1.07%	+4.67%
Evaporative Benzene	-1.17%	-1.06%	-1.03%	-1.03%	-1.03%	-1.03%	-1.03%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	+3.32%	+3.74%	+4.83%	+0.05%	0.00%	+4.83%	0.00%
Formaldehyde	-2.14%	-2.02%	-2.04%	+0.20%	0.00%	-2.04%	0.00%
Acetaldehyde	-1.72%	-1.40%	-0.85%	+0.05%	0.00%	-0.85%	0.00%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	+0.45%	+0.84%	+2.79%	+2.79%	+2.77%	+2.79%	+2.77%
Potency-Weighted Change in Non-Cancer Risk (1)	+0.20%	+0.22%	+0.24%	+0.11%	+0.08%	+0.24%	+0.08%
Potency-Weighted Change in Cancer Risk (2)	+1.69%	+1.62%	+1.24%	+1.83%	+1.23%	+1.24%	+1.23%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	+3.54%	+4.09%	+3.80%	+3.76%	+3.83%	+3.78%
Evaporative Benzene	-1.06%	-1.03%	-1.05%	-1.08%	-1.03%	-1.07%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	+2.70%	+0.18%	+0.71%	+2.50%	+0.28%	+1.09%
Formaldehyde	-1.52%	-0.09%	-0.48%	-1.58%	-0.13%	-0.78%
Acetaldehyde	-1.21%	-0.06%	-0.47%	-1.33%	-0.09%	-0.75%
Acrolein	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POM	+1.17%	+2.77%	+2.18%	+0.94%	+2.77%	+1.78%
Potency-Weighted Change in Non-Cancer Risk (1)	+0.19%	+0.09%	+0.13%	+0.19%	+0.10%	+0.15%
Potency-Weighted Change in Cancer Risk (2)	+1.60%	+1.23%	+1.36%	+1.62%	+1.23%	+1.44%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).

TABLE B.26: CHANGE IN TOXIC EMISSIONS ASSOCIATED WITH THE FEDERAL RFG WINTERTIME OPTION

Emission Species	Onroad Tech 5	Onroad Tech 4	Onroad Tech 3	Onroad Oxy Cat	Onroad Non Cat	Nonroad Catalyst	Nonroad Non Cat
Exhaust Benzene	+18.30%	+16.76%	+5.16%	+38.99%	+36.91%	+5.16%	+36.91%
Evaporative Benzene	+164.46%	+97.38%	+61.10%	+57.40%	+52.56%	+61.10%	+52.56%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	+46.75%	+49.68%	+58.88%	+2.14%	+1.12%	+58.88%	+1.12%
Formaldehyde	-1.39%	-3.54%	-17.60%	+2.56%	+1.12%	-17.60%	+1.12%
Acetaldehyde	+7.51%	+8.82%	+1.83%	+2.13%	+1.12%	+1.83%	+1.12%
Acrolein	+14.90%	+15.08%	+13.32%	+1.99%	+1.12%	+13.32%	+1.12%
POM	+1.27%	+1.19%	+0.34%	-0.43%	-0.47%	+0.34%	-0.47%
Potency-Weighted Change in Non-Cancer Risk (1)	+16.07%	+16.32%	+14.62%	+2.90%	+1.88%	+14.62%	+1.88%
Potency-Weighted Change in Cancer Risk (2)	+17.14%	+16.18%	+11.43%	+11.02%	+7.74%	+11.43%	+7.74%

Emission Species	Onroad Aggregate 2005	Nonroad Aggregate 2005	Overall Aggregate 2005	Onroad Aggregate 2010	Nonroad Aggregate 2010	Overall Aggregate 2010
Exhaust Benzene	+18.49%	+31.83%	+24.74%	+19.32%	+29.45%	+22.43%
Evaporative Benzene	+91.18%	+54.16%	+83.67%	+106.77%	+54.91%	+98.94%
Exhaust MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Evaporative MTBE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
1,3-Butadiene	+36.82%	+3.28%	+10.27%	+34.90%	+4.52%	+15.50%
Formaldehyde	-2.07%	+0.33%	-0.33%	-1.16%	-0.12%	-0.58%
Acetaldehyde	+6.35%	+1.17%	+3.03%	+6.76%	+1.19%	+4.17%
Acrolein	+12.59%	+2.14%	+6.13%	+12.90%	+2.69%	+8.38%
POM	+0.86%	-0.41%	+0.06%	+0.96%	-0.37%	+0.35%
Potency-Weighted Change in Non-Cancer Risk (1)	+13.63%	+2.86%	+6.79%	+13.89%	+3.38%	+9.06%
Potency-Weighted Change in Cancer Risk (2)	+14.92%	+8.01%	+10.76%	+15.36%	+8.16%	+12.20%

Notes: (1) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA reference concentrations for non-cancer effects.

(2) Overall toxic emissions change determined by weighting individual species changes according to U.S. EPA unit risk of cancer effects (formaldehyde is treated in accordance with the current unit risk estimate from the Integrated Risk Information System).