Fuel Trends Report: Gasoline 1995 - 2005

United States
Environmental Protection
Agency

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Gasoline 1995 - 2005

Compliance and Innovative Strategies Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data that are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments.

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EPA420-R-08-002
January 2008

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Acknowledgments

The primary data analyst and author of this report is Stuart Romanow.

Table of Acronyms

Acronym	Definition
ASTM	ASTM International- a voluntary standards development organization (formerly, American Society for Testing and Materials)
CAA	Clean Air Act
CFR	Code of Federal Regulations
CG	Conventional Gasoline
E200	Percent evaporated at 200 degrees F
E300	Percent evaporated at 300 degrees F
EPA	US Environmental Protection Agency
ETBE	Ethyl tertiary-Butyl Ether (an oxygenate)
FR	Federal Register
MSAT	Mobile Source Air Toxics
MTBE	Methyl tertiary-Butyl Ether (an oxygenate)
NOx	Oxides of nitrogen
PADD	Petroleum Administration for Defense District (PADD I - East Coast, PADD II - Midwest, PADD III-Gulf Coast, PADD IV- Rocky Mountain, PADD V-West Coast)
RBOB	Reformulated gasoline blendstock for oxygenate blending (i.e. the RFG blendstock to which an oxygenate is added)
RFG	Federal Reformulated Gasoline
RFS	Renewable Fuels Standard
RVP	Reid Vapor Pressure
T50	50 percent evaporation temperature (degrees F)
T90	90 percent evaporation temperature (degrees F)
TAME	Tertiary-Amyl Methyl Ether (an oxygenate)
VOC	Volatile Organic Compound

Background Material

EPA has developed and implemented several regulatory programs addressing air quality and motor vehicle emissions which have significant impacts on gasoline properties and composition. Portions of these regulations imposed data-related obligations on gasoline refiners, importers and other entities, requiring that they analyze gasoline to measure certain emission-related parameters, and submit these data to EPA. Refiners and importers must also submit gasoline volume data. These data, although intended for compliance evaluation, also provide a unique source of information about trends in emission-related gasoline properties and performance. This report analyzes these data to quantify trends, and to examine how these trends relate to regulatory requirements. This chapter includes a brief description of these regulatory programs, and the data collected and analyzed in this report.

Reformulated Gasoline Program

Reformulated gasoline (RFG) is gasoline blended to burn cleaner and reduce smog-forming and toxic pollutants. In ‘211(k) of the 1990 Amendments to the Clean Air Act (CAA 1990), Congress required RFG to be sold in cities with the worst ozone non-attainment problems. In addition, other cities with significant smog problems may choose to use RFG. RFG is currently used in 17 states and the District of Columbia. About 30 percent of gasoline sold in the U.S. is reformulated.

In the 1990 Amendments, Congress also required that non-RFG, or conventional gasoline (CG), sold in the rest of the country become no more polluting than gasoline sold in 1990. This requirement ensures that refiners do not "dump" into conventional gasoline fuel components that are restricted in RFG and that cause environmentally harmful emissions.

EPA introduced the RFG program in 1995, as required by the CAA.[2] The RFG program establishes emissions performance standards for volatile organic compounds (VOCs), nitrogen oxides (NOx), and toxics. These standards are based on percent reductions from the average emissions of these pollutants in 1990 model year vehicles operated on a specified baseline gasoline. The RFG program also establishes a maximum benzene standard of 1.0 volume percent, and an oxygen minimum standard of 2.0 weight percent. (The Energy Policy Act of 2005 repealed the oxygen content requirement.) For conventional gasoline, the program establishes emissions standards for exhaust toxics and NOx designed to ensure that an individual refinery's or importer's gasoline will not have higher levels of these pollutants than the refinery's or importer's 1990 gasoline. These standards for conventional gasoline are called the anti-dumping standards.[3] EPA has implemented the RFG program in three phases; the “Simple Model” program began in 1995 and ended in 1997, the Phase I "Complex Model" RFG program began in 1998 and ended in1999, and the Phase II RFG program began in 2000. Phase II RFG is designed to result in greater reductions of VOCs, NOx, and toxics emissions.

Refiners and importers of RFG are allowed to comply with each RFG standard either on a per-gallon or annual average basis. Refiners and importers of conventional gasoline must comply with their anti-dumping standards on an annual average basis. Refiners of RFG must comply with the RFG standards separately for each refinery. Refiners of conventional gasoline may comply separately for each refinery, or they may aggregate their refineries. Importers comply with both the RFG and conventional gasoline standards for the aggregate of the gasoline they import during the year.

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[2] Regulations pertaining to the RFG program are in Subpart D-Reformulated Gasoline, 40 C.F.R. pt. 80

[3] Subpart E-Anti-Dumping, 40 C.F.R. pt. 80

The emissions performance of gasoline is calculated using a model, called the Complex Model, which predicts the emissions level of each regulated pollutant based on the measured values of certain gasoline properties. These properties are: aromatics, olefins, sulfur, Reid Vapor Pressure (RVP), benzene, oxygen and distillation points. Refiners and importers are required to measure these properties in each batch of gasoline they produce or import, using a prescribed regulatory test method, and calculate the emissions level of each pollutant in each batch of gasoline using the Complex Model. The actual emissions level of each regulated pollutant in the refiner's or importer's gasoline is compared to the emissions standard for that pollutant to determine if the gasoline is in compliance.

Content Limits for Sulfur in Gasoline

In addition to the emissions requirements for RFG and conventional gasoline under the RFG program, EPA established limits on the amount of sulfur that may be present in gasoline nationwide beginning in 2004. [4] These gasoline sulfur limits are part of a major program designed to significantly reduce the emissions from new passenger cars and light trucks. This program, called the "Tier 2" program, is a comprehensive regulatory initiative that treats vehicles and fuels as a system, combining requirements for cleaner vehicles with requirements for much lower levels of sulfur in gasoline.

The Tier 2 program phases in a single set of tailpipe emission standards that apply to all passenger cars and light trucks. To achieve these standards, very clean vehicle emission control technology is employed. Gasoline with reduced sulfur levels is required under the Tier 2 program to enable this very clean vehicle emission control technology to be effective. In addition to its beneficial effects on vehicle emission control systems, the reduction in gasoline sulfur levels required under the Tier 2 program will contribute directly to cleaner air. The Tier 2 program included an initial phase-in period in which gasoline refiners and importers were required to comply with a company-wide annual average sulfur standard of 120 parts per million (ppm) in 2004 and 90 ppm 2005. In 2005, refineries and importers began complying with a 30 ppm annual average sulfur standard. [5] The program also limited the amount of sulfur that may be present in any gallon of gasoline to 300 ppm in 2004 and 2005, and 80 ppm thereafter.

Under the Tier 2 program, refiners and importers were allowed to generate sulfur "credits" prior to 2004 for reductions from refinery sulfur baselines established under the Tier 2 regulations. Beginning with 2004, they were allowed to create sulfur credits if they over-complied with the annual average sulfur standard by producing or importing gasoline with a sulfur level that is lower than the applicable standard. Refiners and importers that create credits may use them to comply with the sulfur standard in a subsequent year or they may trade the credits to another refiner or importer who may need them to meet the sulfur standard.

Mobile Source Air Toxics Program

In addition to the RFG and sulfur programs, EPA's Mobile Source Air Toxics (MSAT) program establishes requirements for refiners and importers designed to ensure that the average level of toxic air emissions from gasoline does not increase.[6] This program requires refiners and importers to establish an individual toxics baseline, separately for RFG and conventional gasoline, based on the average toxics

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[4] 40 C.F.R. '80.195

[5] This 30 ppm standard applies to individual refineries and importers. As noted in the subsequent paragraph, the regulations allow generation and trading of sulfur credits which may be used to meet this standard.

[6] Subpart J-Gasoline Toxics, 40 C.F.R. pt 80

performance of their gasoline during the baseline period 1998 to 2000. Refiners and importers also must establish a total baseline volume based on their volume of gasoline production or imports during the baseline period. The volume of gasoline produced or imported during the year, up to the refiner's or importer's baseline volume can be no more polluting than the refiner’s or importer's MSAT baseline level for that type of gasoline (RFG or conventional). Any volume produced or imported in excess of the refiner's or importer's individual MSAT baseline volume can be no more polluting than the RFG toxics standard or the refiner's or importer's conventional gasoline anti-dumping toxics baseline level, as applicable.

Refiner/Importer Compliance Reports

EPA has required refiners and importers of RFG to submit compliance reports on a quarterly basis.[7] These reports include information on the volume, properties, and emissions performance for VOC, NOx and toxics of each individual batch of gasoline produced or imported during the quarter. In addition, refiners and importers who comply with an RFG standard for a particular pollutant on an annual average basis must submit an annual report which calculates the refinery's or importers annual average emissions for that pollutant.

In addition, refiners and importers of conventional gasoline are required to submit an annual averaging report.[8] This report includes information on the volume, properties exhaust toxics, and NOx emissions of each batch of gasoline produced or imported during the annual averaging period, and a calculation of the refinery’s or importer’s annual average for each pollutant. Refiners and importers of conventional gasoline are allowed to compile composite gasoline samples up to one month for purposes of batch reporting.

Beginning in 2004, all refiners and importers were also required to submit an annual average sulfur compliance report, which demonstrates compliance with the gasoline sulfur standards.[9] This report must include data on each batch of RFG and conventional gasoline produced or imported during the annual averaging period, including batch volume and sulfur content. The sulfur compliance report also includes information on the amount of sulfur credits that were created or received during the averaging period, used to demonstrate compliance, transferred to another party, or carried over to the next averaging period.

Since most of the information required to be reported under the MSAT program is also required under the RFG program, refiners and importers are not required to submit a separate MSAT compliance report. The only additional information required to be reported under the MSAT program relates to the toxics baseline volume and incremental volume of gasoline produced during the year by a refiner or importer. Refiners and importers are required to include this information in their RFG and conventional gasoline reports.

All refiners and importers of gasoline sold in the U.S. are required to comply with the reporting requirements described above, except for refiners and importers of gasoline produced or imported for use in California. Refiners and importers of California gasoline are exempted from the federal reporting requirements, and certain other federal enforcement requirements, based on a determination by EPA that California's emissions standards are as stringent as, or more stringent than, the federal emissions

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[7] 40 C.F.R. ‘80.75

[8] 40 C.F.R. ‘80.105

[9] 40 C.F.R. ‘80.370

standards, and California's enforcement program is sufficient to ensure that refiners and importers of California gasoline meet California's standards.

EPA's Fuel Data Base

The information provided by refiners and importers in the compliance reports described above is retained in a data base by EPA's Office of Transportation and Air Quality. This OTAQ data base is a unique repository of information regarding gasoline production and importation in the U.S. [10] Much of the information provided in the individual refiner and importer reports is deemed to be confidential business information (CBI), which the Agency may not make available to the public. However, the raw data in EPA's data base may be collectively analyzed to provide statistics on various aspects of gasoline production and importation, such as the number and distribution of refiners, refineries and importers; gasoline production and import volumes; gasoline properties; and emissions levels of various pollutants. For example, this report includes analyses of gasoline property data to show RFG and CG property averages by year and season, and property levels by gasoline volume percentile.

The information contained in this report relating to temporal and geographic trends in gasoline properties, emissions performance, and production and import volumes is based on an analysis of the collective data obtained from the refiner and importer compliance reports contained in EPA's data base. This data is not available from other sources. The information and analyses contained in this report, therefore, provides a unique picture of gasoline production and imports in the U.S.

RFG Surveys

Under the CAA, areas required to use RFG are called RFG "covered areas". Gasoline meeting RFG emissions standards is required to be sold in each covered area. The most straightforward way to meet this requirement would be to require that the contribution of each refinery to the gasoline supply of each covered area would meet the RFG standards, on average. However, such an approach is unworkable in a fungible gasoline distribution system -- one in which a refiner pumps his product into a pipeline where it mingles with other refiners product in unknown proportions before reaching the various covered areas. Gasoline is supplied to many covered areas in this manner.

As a result, the RFG program provides for a system of "refinery gate averaging", in which each refiner is responsible only for the compliance, on average, of its own product as it leaves the refinery. This approach, however, has the potential for geographical skewing, where one covered area receives very clean gasoline while another gets very dirty gasoline, or temporal skewing, where a covered area receives clean gasoline for part of the year, but gets dirty gasoline for another part of the year.

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[10] It should be noted that EPA's database does not contain information on the production of gasoline by California refiners for use in California nor on the importation of gasoline into California. Within this report, when we speak of U.S. gasoline, we refer to non-California gasoline as explained in the preceding statement

To ensure that such skewing does not occur, the RFG program requires refiners and importers to conduct surveys of gasoline quality in RFG covered areas.[11] These surveys are conducted by an industry association according to a statistical sampling plan approved by EPA and involve sampling gasoline at retail gasoline stations. If the gasoline in an area fails to meet the RFG standard for a particular RFG pollutant, the standard for that pollutant is made more stringent and the number of surveys that must be conducted in the following year is increased.

Under the RFG survey program, gasoline samples are taken at retail stations according to the statistical sampling plan, the samples are tested for the relevant gasoline properties, and the emissions performance of the gasoline is calculated to determine if the gasoline complies with the RFG standards. Therefore, the survey data provides much information regarding the quality of gasoline sold at retail gasoline stations in RFG covered areas. The information contained in this report relating to trends in gasoline properties and emissions performance at retail gasoline stations is based on the data obtained from the RFG surveys. As with the RFG and sulfur program reporting data, the RFG survey data is not available from other sources. This report, therefore, provides a unique picture of gasoline quality at retail stations in RFG covered areas. [12]

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[11] The requirement to conduct surveys is at 40 C.F.R. ‘80.67(a) and compliance survey requirements are contained in 40 C.F.R. ‘80.68

[12] In addition to the RFG survey analyses presented in this report, EPA posts survey-based summary information on RFG properties and emissions performance by area and season at http://www.epa.gov/otaq/regs/fuels/rfg/properf/rfgperf.htm

General Methodology

Certain gasoline properties affect vehicle emissions, and these properties are regulated directly through content standards or limits, and/or indirectly through standards controlling the emissions characteristics of gasoline. EPA collects data on these emission-related parameters for compliance purposes and, to verify compliance, reviews the data from individual refineries, import facilities and (for RFG only) geographic areas. In addition to their intended compliance function, these data provide a means to examine how gasoline has changed over time with respect to these emission-related parameters. This "Trends" report includes year-by-year analyses of these data, in aggregate, rather than on a facility-specific basis. EPA analyzed the "batch data" RFG and CG property information that refiners and importers submit to EPA, as well as the retail property data collected in RFG surveys that are conducted as a requirement of EPA's regulations.

While these data, in many respects, provide an unparalleled source of information about gasoline property trends, EPA's data collection is limited to information needed to evaluate compliance with its regulations. As a result, EPA lacks information about certain properties, and has only partial information on others. One important limitation of the trend analyses in this report is that, with the exception of certain oxygen and oxygenates analyses; they do not include California gasoline. EPA regulations exempted refiners, importers and oxygenate blenders from reporting requirements for this gasoline, and limited RFG compliance survey requirements to oxygen and oxygenate sampling.

Report Structure

Individual chapters are devoted to a specific emission-related parameter (e.g. gasoline sulfur content) or to groups of related parameters (e.g. distillation curve properties or Complex Model emissions calculation outputs). Each of these parameter chapters provides background information and separate RFG and CG data analyses for the pertinent parameter(s). The parameter chapters each have an appendix with further graphical and tabular data summaries. Additionally, the report contains overview chapters summarizing major trends in RFG and CG. In general, material presented in the overview chapters is expanded upon in individual parameter chapters. Some graphical analyses presented in the overview chapters are repeated in the parameter chapters and appendices for completeness and consistency.

Aggregation of Data and Limitations of Analyses

EPA separately analyzed RFG and CG data. EPA further categorized RFG and CG data from each reporting or survey year as "Summer" or "Winter", and separately analyzed these data. (The "Winter" data in each reporting or survey year includes gasoline produced or sold before and after the "Summer" season.) Although certain EPA standards and requirements apply to RFG and CG on an annual basis, emission-related regulations as well as vehicle performance needs impose seasonal requirements which substantially affect gasoline composition. RFG intended for sale during the summer ozone season must meet VOC emission performance standards and was required to meet more stringent NOx emission performance standards. CG intended for sale during the summer season must meet RVP standards intended to limit evaporative VOC emissions.

These data can be further split and/or aggregated in various other ways to provide potentially useful analyses, and, to an extent, this was done. Tabular estimates of volume-weighted annual parameter averages for each product type, and for RFG and CG combined are presented in a summary chapter following this chapter. Ideally, this "Trends" report would contain exhaustive analyses of the available data, providing the best available information to a variety of users with diverse interests and needs. However, there were some significant limitations to the scope and extent of the analysis that EPA was able to conduct and present in this report. In part, time and resource constraints limited these analyses. Additionally, the parties that submit these data to EPA have claimed that the data are confidential business information (CBI), and these data may be protected by CBI regulations. In order to avoid potential CBI issues, EPA has not included any analyses where gasoline properties or volumes could be strongly associated with individual companies, facilities or brands.

Time Span of Data for Trend Analyses

EPA analyzed "Summer" and "Winter" RFG and CG for each year in which "good" data were available, through 2005. The earliest year may be 1995, 1997 or 1998, and is dependent on the season and type of gasoline (RFG or CG), as well as the data set (reporting or surveys) and the specific gasoline property. This initial year is variable largely because the data submission requirements that EPA imposes are limited to information needed to determine compliance with regulations and standards. EPA began collecting certain data in 1995 and, for 1998 and later years, the data requirements changed. RFG surveys began in 1995, as well, and EPA's analysis includes survey-based property estimates from 1995 when data for a given property were collected. While refinery/importer reports on RFG and CG were submitted from 1995 on, only data from the more mature data management system that was in place for 1997 and later reports has been analyzed here.

Furthermore, although EPA has compared the properties and emissions qualities of conventional and reformulated gasoline within this data-analysis time span to those of 1990 baseline gasoline, it is not extrapolating backwards to extend the trend analysis back to1990. This report draws no conclusion about how well 1990 baseline gasoline represented gasoline supplied in 1990.

Although the report is not intended to forecast trends, EPA has, in various chapters, identified statutory or regulatory changes that have affected or will affect gasoline properties and emission qualities beyond 2005.

Interpretation of Results

Year-to-year changes in gasoline properties can occur for a variety of reasons; however factors associated with EPA's regulatory requirements are likely to be the dominant influences on gasoline property trends in recent years. The federal RFG program, which affected more than 25 percent of the gasoline sold outside of California, was expected to have a substantial impact on gasoline properties. Because of the scope of the RFG program, RFG requirements could potentially affect CG properties as well (and EPA's regulations include "Anti-Dumping" standards applicable to CG designed to preserve the emission-related qualities of CG after these RFG standards were implemented.) The Tier 2 Gasoline sulfur program, which affects both CG and RFG not only controls gasoline sulfur levels but could affect other gasoline property trends as well. While this report is largely devoted to providing quantitative estimates of gasoline parameters and how they changed over time, EPA also attempted to identify factors which affect these parameter values and which may be responsible for trends or changes. This latter analysis was not intended to extensively evaluate all possible reasons for trends or changes.

The analyses in this report and the interpretation of results are, for the most part, linked to EPA's regulatory perspective. Although the majority of gasoline is CG, EPA has emphasized analysis and interpretation of RFG data because it collects both production and geographic-based retail data and because the changes in RFG properties over time are likely to be the direct result of EPA regulations. EPA's analysis of RFG data pays particular attention to the changes that occurred between 1999 and 2000 with the transition from Phase I to the current Phase II standards. EPA's analysis also focuses on differences between RFG properties in 2000, the first year of Phase II standards, and 2005, the last year of data included in this report. In addition to looking at overall trends in parameter averages during this 2000 to 2005 period, EPA has also looked at differences in parameter values between 2000 and 2005 on an area-specific basis. Although differences between these two years could be due to non-regulatory factors, the Tier 2 sulfur requirements as well as changes in oxygenate use could cause or contribute to differences not only in sulfur and oxygenates, but in other parameters.

The data analysis in this report is predominantly descriptive. Quantitative results are presented in graphical and tabular format. Determinations that the data display a trend or patterns are largely based on subjective judgment and identification of a likely cause for the putative change or pattern. However, EPA has made limited use of linear regression analysis to provide a more objective means of evaluating and interpreting its estimates. For example, EPA looked at its estimates of RFG parameter averages to determine if these estimates indicate a statistically significant shift between 1999 and 2000 distinguishable from year-to-year fluctuations and any overall linear trend. EPA also looked at estimates of CG parameter averages to determine if there was evidence of any shift between 1999 and 2000. (Such shifts could, but do not necessarily indicate that CG properties changed as a result of RFG standard changes.) These regression analyses are discussed in an appendix to this report and results are cited in the body of the report.

Consistency with Other Data and Analyses

EPA based the trend analyses in this report solely on data that it collected. Furthermore, these analyses were conducted independently from other published analyses. As a result, parameter value and volume estimates in this report may not always agree perfectly with comparable values published elsewhere. Several specific consistency-related discussions are included in the report, and EPA found the trends report estimates to be in reasonably good agreement with other data and analyses. Reasons for minor differences between reporting system parameter averages published on EPA’s website and reporting system averages contained in this report are identified in the “Summary of Average Estimates” chapter. The “Oxygenates and Oxygen” chapter compares ethanol and MTBE volume estimates in this report with estimates that EPA published in support of the Renewable Fuels Standard regulations. The “PADD Level Analysis of Reporting Data” appendix includes some comparisons of EPA reporting system gasoline volume totals with publicly-available Energy Information Administration volume data.

Data Analysis Specifics

Data Screening

Regulatory requirements, such as independent sampling and testing of some samples, help to ensure the quality of the RFG and Anti-Dumping reporting data that refiners and importers submit to EPA. Instances of missing, incomplete or incorrect RFG and Anti-Dumping batch reporting data have been detected and corrected over the course of the data collection program. Furthermore, the reporting system had been in place for over three years when the 1997 data were submitted and ten years when the 2005 data were submitted, providing ample time for the industry to gain a thorough understanding of its requirements.

Based on EPA's review of the data prior to analysis for this report, data errors are believed to affect only a small proportion of the total data. Thus, data errors were not expected to have a critical effect on the analysis. However, some additional data screening was performed as part of the analyses for this report.

In general, data were eliminated from the analyses in two ways. For estimation of most seasonal average parameter values, data were excluded on a parameter-specific basis. For each parameter, a rule was established to determine if the data was missing from a batch record. This was not entirely straightforward, because, for some parameters a value of zero is possible. For these properties, a blank or null value might indicate a true "zero" value, rather than missing data. It is also possible that zeros may have been used to represent missing data. For some parameters, additional parameter-specific exclusion criteria were sometimes added to remove values that were clearly impossible (e.g. when a parameter value reported as a volume percentage substantially exceeded 100 percent). EPA applied more stringent screening for certain analyses, including estimation of average "Complex Model" emissions or emissions performance and determination of parameter value distributions by gasoline volume percentile. For this more stringent screening, in addition to the parameter-specific data screens, CG, RFG and RBOB batches were flagged if they had "outlier" values for any parameter and eliminated from an analysis even if the analysis was for a different parameter. For many parameters, the limits were set at 10% beyond the acceptable range limits for the Complex Model. For some parameters, RFG and CG have different acceptable range limits. RFG range limits are considered as standards applicable to every RFG batch. However, the intent was not to exclude non-complying or "high emissions" batches from these analyses, but to identify batches where one or more parameters were likely to have been mis-reported or a batch mis-labeled (e.g. CG identified as RFG, CG blendstock identified as CG.)

These additional screens excluded only a small proportion of the data from most of the analyses. The additional data screens for this report removed some erroneous data items, although valid data may also have been removed. The level of screening did not have much effect on the averages, suggesting that over-screening did not substantially bias the results. Removal of extreme values for certain parameters visibly affected the tails of parameter value distributions by volume for the parameters, but had little effect on median values. Removal of data on a batch basis rather than a parameter basis for some of these analyses probably removed some erroneous data values for parameters, even when the parameter value did not meet the outlier criteria for that parameter.

The RFG Survey data which were analyzed are also subject to regulatory requirements which help ensure the quality of the data submitted to EPA. Additionally, EPA has a Quality Assurance Project Plan in place for the survey program. The survey regulations provide for exclusion of samples from a specific parameter average if a sample exceeds a per gallon minimum or maximum standard for that parameter plus an enforcement tolerance. These violations are rare and do not have much effect on survey averages. EPA did not apply any further data screening criteria to the survey data for this report, although several surveys were totally excluded from the analyses.

The analyses excluded a survey conducted in St. Louis, MO beginning March 20, 2000, because a waiver issued as a result of a pipeline break allowed sale of conventional gasoline. EPA also excluded all one-week RFG surveys conducted between September 2, 2005 and September 15, 2005 from the analyses in this report since these summer surveys potentially included a mix of summer and winter gasoline. EPA allowed early use of winter gasoline in a Hurricane Katrina-related waiver issued August 31, 2005, and property averages from these surveys may not have been representative of RFG intended for sale during the summer ozone season.[13] Although hurricane-related waivers issued in September, 2005 allowed conventional gasoline use in certain RFG areas, the respective timing of these waivers and surveys made it unlikely that surveys were significantly affected. No surveys were excluded from trends report analyses in response to these waivers.

Estimation of Average Parameter Values

In order to develop estimates of property averages from these data, measurements from individual samples must be combined. These measurements represent different quantities of gasoline, consequently volume-weighting of both reporting and survey data is appropriate.

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[13] Ten surveys were excluded from 2005 averages; one in each of 10 areas (see http://epa.gov/otaq/regs/fuels/rfg/properf/rfgperf.htm)

Although the reporting system was intended to evaluate the compliance of individual facilities with standards, rather than to determine seasonal property averages for RFG and CG this is a fairly straightforward process for reporting data. The volume of each batch is reported so that volume-weighted property averages can be computed from batch reports.

Developing seasonal property average estimates for all RFG based on individual surveys conducted in different RFG areas throughout the year is more complex. The individual surveys are designed to give accurate estimates of average RFG properties in a given area during a given one-week time period. Surveys are categorized as “Summer” if they are conducted between June 1 and September 15, and “Winter” if they are conducted before or after this period. Each area surveyed is surveyed a minimum of two times during the summer and two times during the winter. EPA has determined property averages for each survey, and averaged survey averages to estimate seasonal property averages for each area.

These seasonal area averages do not represent equal volumes of gasoline so an arithmetic average of these area averages may not accurately estimate an overall seasonal RFG average. Consequently, EPA has weighted the area averages by estimates of annual gasoline sales in each of the survey areas in each of the years. These gasoline volume estimates are provided to EPA in the survey plan that the RFG Survey Association submits each year. These gasoline volume estimates are included in the survey plan for purposes other than for combining area averages, but EPA believes that they are accurate enough (even without further adjustment to estimate area-specific seasonal volumes) to ensure that areas are not substantially misrepresented in the seasonal average computations.

Individual surveys are designed to sample proportionally to gasoline grade within each area. Thus, each survey property average was expected to represent the grade mix within each area. However, this “Trends” report includes estimates of seasonal RFG averages by grade based on survey data. In order to generate these averages, EPA used area-specific estimates of grade percentages (included in the survey plans), along with gasoline volume estimates in order to estimate gasoline volumes by grade. EPA also computed individual survey averages by grade, combined them into seasonal area averages by grade, and used these estimates of gasoline volume by grade as weighting factors to compute seasonal averages by grade.

Clearly, estimation of average RFG property trends from survey data is more involved than estimation of average trends from reporting data and requires assumptions and approximations which affect the accuracy of the estimates. Also, the survey data are statistical samples while the reporting data are a census. Thus, errors inherent in statistical sampling affect the precision and accuracy of survey-based estimates. However, both estimates are included in this report because there may be real differences between retail and reporting property averages (e.g. due to certain downstream blending operations or downgrading of product) and the potential for some inaccuracies in reporting as well as retail estimates. Although both data sets were used for RFG trend analyses, in part, because there could be differences between production and retail gasoline properties, EPA expected that such differences would be small. Consequently, EPA believes that when the two estimates are in close agreement, it corroborates the quality of the data and the reliability of the estimates. (In most cases, the two estimates agree quite well. Issues pertaining to disparities between survey and reporting-based estimates are discussed in several chapters.) It is obvious that the RFG Survey data provide important geographic property information and geographic-based analysis of these retail data are included in this report. There is no comparable source of such information for CG, so CG analysis is generally limited to seasonal aggregations of reporting data and, for most properties, averages by premium or regular grade and season. Some PADD-specific analyses of 2004 and 2005 reporting data are included for both CG and RFG.

Estimation of Parameter Distributions by Volume Percentile

In addition to estimates of property averages, this report includes analysis of the distributions of property values by gasoline volume percentile for both CG and RFG, generated from batch reporting data. Graphical and tabular distribution analyses are included in the appendix to each parameter chapter and, in some chapters, in the body of the chapter, as well.

As previously noted, data used in these distribution analyses were screened for missing data and outliers. Additionally, certain CG batches were excluded from the distribution analyses because they were blendstock batches, rather than finished gasoline. These batches were included in computations of average parameter values because it was assumed that the finished gasoline that would have resulted from blending may not have also been reported. Inclusion of blendstock batches in CG average computations could reasonably be expected to improve the accuracy of parameter average estimates (and inclusion or exclusion has only minor effects on most estimates). However, inclusion of CG blendstock batches in property distributions by volume is likely to make them less representative of finished gasoline. Some properties of certain CG blendstock batches, which can be such things as oxygenates and butane, differ substantially from finished gasoline (e.g., the RVP of butane is more than 50 psi). Thus, it is probably more appropriate and useful to exclude blendstock batches from these distribution analyses.

RFG blendstock for oxygenate blending (RBOB) batches not removed for missing data or outliers were included in the distribution analyses because these batches are “hand blended” with oxygenates before properties are measured. Although these batch properties may sometimes differ from the properties of the actual blend, they are representative of finished RFG.

Estimation of Complex Model Emissions and Emissions Performance Trends

Certain RFG and CG standards are based on Complex Model emissions calculations. The gasoline property data that EPA collects are the inputs to this model, and EPA also receives certain model outputs with these data. The current standards, applicable since 2000, are based on the Phase II version of this model. Standards applicable for 1998 and 1999 were based on the Phase I version of the model. The CG and RFG reporting and RFG Survey data which EPA received for 1998 and 1999 included emissions calculations based on the Phase I model. Trend analyses based on a combination of Phase I and Phase II model calculations would provide little information on changes in the emissions qualities of gasoline since they would show the effects of the model version change as well as the effects of actual property changes on emissions. EPA based all analyses on the Phase II model. EPA calculated Phase II Complex Model results for each 1998 or 1999 batch or survey sample included in these analyses. EPA calculated average performance by averaging the performance of individual batches or survey samples. Emissions calculations using average property values for each year, season and gasoline type would probably provide good approximations of average emissions or emissions performance with significantly less computational effort. However, EPA's analysis may give slightly different and, arguably, better estimates because there are some non-linear terms in the complex model equations. Calculating the Phase II model performance of individual batches also allowed EPA to present emissions distribution by volume information for 1998 and 1999 batches that can be directly compared to distributions for later years. EPA ‘s analyses did not include calculated emissions performance for a subset of these batches representing about three percent of 1998 and 1999 reported RFG and RBOB volume because of omitted oxygenate information needed for Complex Model input. (In most cases, EPA regulations allowed these omissions.)

The gasoline data that EPA collected for years prior to 1998 did not include the full set of property inputs for the Complex Model. Consequently, this report does not include these years in emissions or emissions performance trend analyses.

Summary of Average Estimates

The tables in this chapter summarize certain gasoline parameter estimates contained in this report and aggregate Summer/Winter and RFG/CG reporting system estimates. As explained in the General Methodology Chapter:

- The primary trend analyses separated the data into Summer RFG, Winter RFG, Summer CG and Winter CG.
- Data were screened on a parameter-specific basis when calculating RFG and CG seasonal averages.

The gasoline volumes contained in the tables are the total volumes for the batches in each category, prior to data screening. In some cases, due to data-screening, these volumes differ from the total volume of the batches used to calculate the volume-weighted average for a given parameter in a given year and season. The seasonal volumes shown in the tables, rather than parameter-specific screened volumes, were used to aggregate seasonal averages into the annual and RFG + CG combined averages.

These tables are presented here without discussion. They are intended as a quick reference, as well as an aid to those who may want to examine aggregate trends. These tables do not show specific oxygenates for RFG or CG, and do not show CG oxygen content. The tables do not contain all of the information summarized in this report. The reader should refer to individual chapters for more detailed quantitative as well as qualitative information.

The reporting system parameter averages and gasoline volumes in this report, in some cases, differ from reporting system averages and volumes published on EPA's website.[14] Generally, the differences are small enough to be of no significance for most purposes. EPA believes that such differences are not due to computational error but are primarily due to the dynamic nature of the reporting system database and to slightly different assumptions regarding the inclusion or exclusion of data.

Even after reporting data for a given year have been received and entered, the reporting system data for that year may change due to resubmitted and corrected data. These changes can occur some time after the end of the reporting period. Results generated for this report and for the web posting may differ in part because they were based on "snapshots" of the data taken at different times.

Different analysts performed the computations for the trends report and web posting and used slightly different screening and analysis assumptions. For example, although California refineries report their non-California production, the web posting analyses excluded these data while the trends report analysis did not. This may well explain why the "unscreened" CG volumes given in this chapter are slightly higher than the volumes posted on the website.

The tables posted on the website include oxygen and oxygenate concentration averages for CG. These results may appear inconsistent with some of the CG oxygen and oxygenate analysis in this "trends report". However, the web analysis computed oxygen and oxygenates averages only for the batches with an oxygen value greater than zero. The "trends report" analyses included CG batches with zero or blank oxygen/oxygenate values in any CG oxygen/oxygenate averages. The report noted the uncertainty and probable error associated with any oxygen/oxygenates analysis of CG reporting data.

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[14] See http://epa.gov/otaq/regs/fuels/rfg/properf/rfg-params.htm and http://epa.gov/otaq/regs/fuels/rfg/properf/cg-params.htm

RFG Reporting - Summer

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)	2.13	2.13	2.11	2.24	2.21	2.25	2.30	2.56	2.48
Benzene (Vol%)	0.66	0.67	0.71	0.59	0.62	0.59	0.61	0.59	0.66
Olefins (Vol%)	12.0	10.9	11.4	10.6	11.8	10.8	11.0	11.3	11.9
Aromatics (Vol%)	22.4	22.8	22.1	19.3	20.1	20.4	20.1	20.1	20.9
E200 (%)		48.8	49.2	47.7	47.5	47.5	47.9	47.9	48.8
E300 (%)		82.6	82.8	84.7	84.4	84.4	84.4	83.4	84.1
RVP (psi)	7.60	7.60	7.60	6.78	6.79	6.80	6.83	6.87	6.91
Sulfur (ppm)	289	202	205	126	127	124	110	79	69
Volume (gal)	12,522,261,326	12,837,419,615	13,005,827,782	12,983,168,478	13,230,634,977	13,847,971,634	13,587,633,643	14,243,059,617	14,092,489,036

RFG Reporting - Winter

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)	2.21	2.22	2.16	2.12	2.11	2.09	2.15	2.38	2.36
Benzene (Vol%)	0.63	0.65	0.65	0.65	0.64	0.64	0.64	0.63	0.67
Olefins (Vol%)	11.3	10.8	11.3	11.8	12.3	11.2	11.0	11.1	11.0
Aromatics (Vol%)	19.2	19.9	19.5	19.0	19.2	19.4	19.4	19.1	19.6
E200 (%)		56.0	56.0	56.3	55.9	55.9	56.0	56.2	56.3
E300 (%)		84.9	84.6	86.1	85.8	85.5	85.1	84.9	85.3
RVP (psi)									
Sulfur (ppm)	251	203	214	200	185	184	164	101	80
Volume (gal)	14,942,199,473	15,091,302,974	15,085,096,147	15,831,074,709	15,792,238,105	16,494,453,697	16,679,773,135	17,194,370,899	18,046,671,196

RFG Reporting - Annualized

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)	2.17	2.18	2.14	2.18	2.15	2.16	2.22	2.46	2.41
Benzene (Vol%)	0.64	0.66	0.67	0.62	0.63	0.62	0.63	0.61	0.67
Olefins (Vol%)	11.6	10.8	11.3	11.3	12.1	11.0	11.0	11.2	11.4
Aromatics (Vol%)	20.7	21.2	20.7	19.1	19.6	19.9	19.7	19.6	20.1
E200 (%)		52.7	52.9	52.4	52.0	52.0	52.4	52.4	53.0
E300 (%)		83.8	83.8	85.5	85.1	85.0	84.8	84.3	84.8
RVP (psi)									
Sulfur (ppm)	268	203	210	167	158	156	139	91	75
Volume (gal)	27,464,460,799	27,928,722,589	28,090,923,929	28,814,243,187	29,022,873,082	30,342,425,331	30,267,406,778	31,437,430,516	32,139,160,232

Table 1

RFG Surveys - Summer

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)	2.19	2.18	2.24	2.26	2.26	2.31	2.30	2.32	2.41	2.65	2.60
Benzene (Vol%)	0.67	0.68	0.68	0.68	0.72	0.60	0.64	0.62	0.65	0.65	0.72
Olefins (Vol%)				10.3	10.8	9.4	10.3	10.8	10.9	10.9	10.8
Aromatics (Vol%)	24.3	24.8	25.5	26.0	24.9	19.5	20.2	20.5	20.1	21.2	21.1
E200 (%)				49.4	49.8	47.9	47.5	47.7	48.0	48.1	48.8
E300 (%)				82.7	83.1	84.9	84.5	84.1	84.0	83.3	84.3
RVP (psi)	7.61	7.64	7.62	7.65	7.62	6.77	6.77	6.79	6.82	6.87	6.92
Sulfur (ppm)				190	204	127	122	117	106	78	69

RFG Surveys - Winter

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)	2.42	2.28	2.38	2.42	2.32	2.31	2.24	2.24	2.35	2.61	2.62
Benzene (Vol%)	0.59	0.69	0.67	0.65	0.68	0.65	0.65	0.66	0.69	0.69	0.70
Olefins (Vol%)				9.4	10.0	10.0	10.7	10.6	10.8	10.5	9.5
Aromatics (Vol%)	20.0	20.7	20.8	21.1	21.2	18.1	18.5	19.3	19.1	19.4	18.9
E200 (%)				56.9	56.6	56.6	56.5	56.8	56.6	56.8	56.9
E300 (%)				85.1	84.6	86.1	86.1	85.7	85.6	84.9	85.6
RVP (psi)											
Sulfur (ppm)				207	215	192	182	183	167	102	80

Table 2

CG Reporting - Summer

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)									
Benzene (Vol%)	1.13	1.12	1.14	1.13	1.15	1.09	1.13	1.13	1.19
Olefins (Vol%)	12.3	11.5	11.7	11.7	12.6	12.0	11.8	11.1	11.8
Aromatics (Vol%)	27.4	27.5	27.6	28.4	28.3	28.1	27.9	28.1	27.8
E200 (%)		44.6	45.0	45.0	45.1	44.9	45.2	45.1	45.6
E300 (%)		80.8	81.1	80.5	81.1	80.6	80.7	80.6	81.6
RVP (psi)		8.31	8.29	8.26	8.25	8.25	8.29	8.29	8.29
Sulfur (ppm)	316	297	301	308	295	290	295	114	102
Volume (gal)	39,709,732,667	39,993,052,895	39,702,111,855	38,879,882,521	39,517,397,838	41,639,053,732	44,550,506,550	44,009,126,002	42,849,893,176

CG Reporting - Winter

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)									
Benzene (Vol%)	1.12	1.07	1.07	1.07	1.12	1.06	1.08	1.07	1.13
Olefins (Vol%)	12.3	11.2	11.4	12.0	12.4	11.7	11.4	11.2	11.5
Aromatics (Vol%)	25.0	24.8	25.0	24.8	25.3	25.0	24.9	24.6	24.7
E200 (%)		49.9	49.9	50.2	49.7	49.9	50.3	50.6	50.7
E300 (%)		83.2	83.0	83.4	83.2	83.1	82.8	83.3	84.1
RVP (psi)		12.13	12.04	12.01	11.91	11.99	12.11	12.17	12.06
Sulfur (ppm)	309	281	298	284	286	286	250	117	95
Volume (gal)	44,979,608,785	46,926,442,568	48,323,290,875	49,012,746,434	49,737,646,274	50,639,522,581	48,852,848,576	48,333,969,089	49,467,392,607

CG Reporting - Annualized

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)									
Benzene (Vol%)	1.12	1.09	1.10	1.10	1.14	1.08	1.11	1.10	1.16
Olefins (Vol%)	12.3	11.3	11.5	11.9	12.5	11.9	11.6	11.2	11.7
Aromatics (Vol%)	26.1	26.0	26.1	26.4	26.6	26.4	26.3	26.2	26.1
E200 (%)		47.5	47.7	47.9	47.7	47.7	47.8	48.0	48.3
E300 (%)		82.1	82.1	82.1	82.3	82.0	81.8	82.1	82.9
RVP (psi)		10.4	10.4	10.3	10.3	10.3	10.3	10.3	10.3
Sulfur (ppm)	312	288	300	295	290	288	272	116	98
Volume (gal)	84,689,341,452	86,919,495,463	88,025,402,730	87,892,628,955	89,255,044,112	92,278,576,313	93,403,355,126	92,343,095,091	92,317,285,783

Table 3

RFG & CG Combined Reporting - Summer

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)									
Benzene (Vol%)	1.02	1.01	1.03	1.00	1.02	0.97	1.01	1.00	1.06
Olefins (Vol%)	12.3	11.3	11.6	11.4	12.4	11.7	11.6	11.2	11.8
Aromatics (Vol%)	26.2	26.4	26.2	26.1	26.2	26.1	26.1	26.1	26.1
E200 (%)		45.6	46.1	45.6	45.7	45.5	45.8	45.8	46.4
E300 (%)		81.3	81.5	81.5	81.9	81.5	81.5	81.3	82.3
RVP (psi)		8.13	8.12	7.89	7.89	7.89	7.95	7.94	7.95
Sulfur (ppm)	310	274	278	262	253	248	251	106	94
Volume (gal)	52,231,993,993	52,830,472,510	52,707,939,637	51,863,050,999	52,748,032,815	55,487,025,366	58,138,140,193	58,252,185,619	56,942,382,212

RFG & CG Combined Reporting - Winter

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)									
Benzene (Vol%)	1.00	0.97	0.97	0.96	1.01	0.96	0.97	0.96	1.01
Olefins (Vol%)	12.0	11.1	11.4	11.9	12.4	11.6	11.3	11.2	11.4
Aromatics (Vol%)	23.6	23.6	23.7	23.4	23.9	23.6	23.5	23.1	23.3
E200 (%)	0	51.4	51.4	51.7	51.2	51.4	51.7	52.1	52.2
E300 (%)	0	83.6	83.4	84.1	83.8	83.7	83.4	83.8	84.4
RVP (psi)									
Sulfur (ppm)	294	262	278	264	262	261	228	113	91
Volume (gal)	59,921,808,258	62,017,745,542	63,408,387,022	64,843,821,143	65,529,884,379	67,133,976,278	65,532,621,711	65,528,339,988	67,514,063,803

RFG & CG Combined Reporting - Annualized

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Oxygen (wt%)									
Benzene (Vol%)	1.01	0.99	1.00	0.98	1.01	0.96	0.99	0.98	1.03
Olefins (Vol%)	12.1	11.2	11.5	11.7	12.4	11.7	11.5	11.2	11.6
Aromatics (Vol%)	24.8	24.9	24.8	24.6	24.9	24.7	24.7	24.5	24.6
E200 (%)		48.7	49.0	49.0	48.7	48.7	48.9	49.1	49.5
E300 (%)		82.5	82.5	82.9	83.0	82.7	82.5	82.6	83.4
RVP (psi)									
Sulfur (ppm)	302	267	278	263	258	255	239	110	92
Volume (gal)	112,153,802,251	114,848,218,052	116,116,326,659	116,706,872,142	118,277,917,194	122,621,001,644	123,670,761,904	123,780,525,607	124,456,446,015

Table 4

RFG Trends

Changes in the properties and composition of RFG have occurred since RFG was first introduced in 1995. These parameter changes were primarily due to regulatory requirements that were phased-in over time. These changes and their regulatory causes are discussed below, grouped into two time periods. The first period, from 1995 to 2000, begins with the introduction of the federal RFG program and includes two RFG standard changes; one from 1997 to 1998 and the second from 1999 to 2000. RFG standards were at their current Phase II level during the second period, from 2000 through 2005, however other regulatory factors affected RFG properties and composition.

Changes in RFG from 1995 to 2000

When RFG was introduced in 1995, it was subject to oxygen minimum and benzene maximum content standards, RVP limits for VOC-controlled (Summer ozone-season) RFG, and a toxics emission performance standard. Emission performance refers to an emission reduction, in percent, relative to a baseline gasoline, as determined by a mathematical model which estimates vehicle emissions based on certain properties of the gasoline being used. The mathematical model which provided the basis for the toxics performance standard is called the "Simple Model." The Simple Model considered the emissions effect of four parameters: aromatics, benzene, oxygen (including, for some calculations, the individual contribution of several specific oxygen-containing organic compounds called oxygenates), and RVP (Summer only). The toxics emission performance standard along with the RVP, oxygen and benzene requirements are called the Simple Model standards.

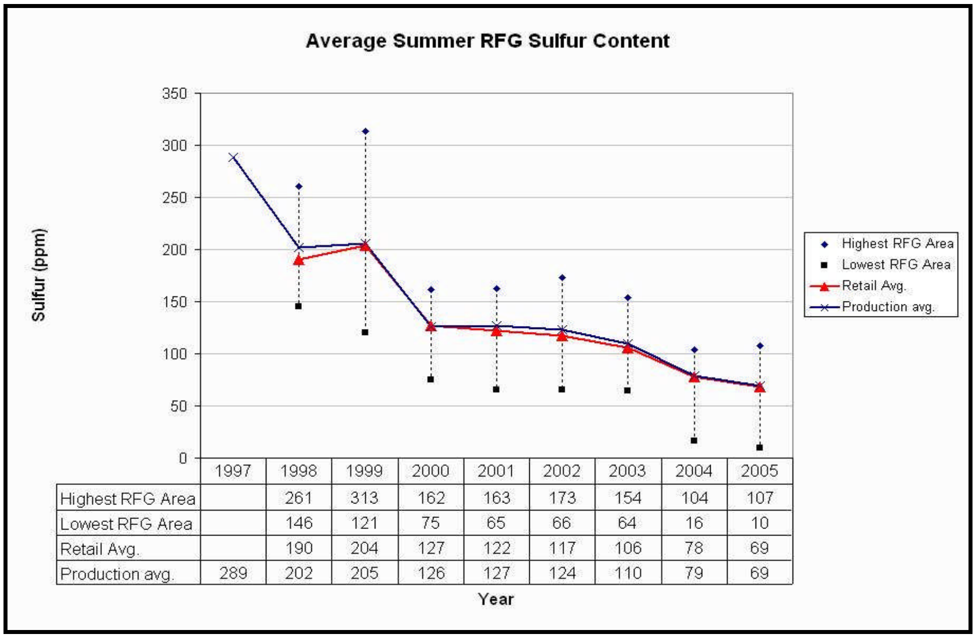
Beginning in 1998, "Complex Model" standards replaced the Simple Model standards. The Complex Model standards included the same oxygen minimum and benzene maximum content standards and, like the Simple Model standards, included a performance standard for toxics emissions. In addition, the Complex Model standards included performance standards for NOx and VOC emissions. The Complex Model considers the emissions effects of the four Simple Model parameters discussed above, and the emissions effects of several additional gasoline parameters: sulfur, olefins, and two distillation points, E200 and E300. The Complex Model standards were introduced in two phases: Phase I in 1998, and Phase II, which requires more stringent emissions reductions, beginning in 2000.

EPA's evaluation of the RFG property and emissions performance changes is based on data that it collects to determine compliance with its regulations. The gasoline parameter information that EPA needed for compliance purposes changed in 1998, and this limits EPA's ability to compare RFG from 1995 through 1997 to RFG in 1998 and later years. (EPA has also restricted its production data analysis in this report to 1997 and later years). EPA has collected data on the four Simple Model parameters (aromatics, oxygen, benzene and RVP) since 1995, and there is no evidence of substantial changes in these properties between 1997 and 1998, with the transition to the Complex Model standards. EPA also has comprehensive production data on 1997 sulfur and olefin content, two of the four additional Complex Model parameters. Based on these data, both sulfur and olefin content decreased between 1997 and 1998, and it is clear that the changes in sulfur content were substantial (figures 1 and 2). (See individual parameter chapters for detailed graphical and tabular summaries of gasoline parameter values.)

According to the Complex Model, lowering gasoline sulfur content reduces NOx, exhaust toxics and exhaust VOC emissions. Sulfur content has a substantial influence on NOx emission performance. It is likely that refiners reduced the sulfur content of RFG from 1997 levels, in part, to meet the Complex Model NOx emissions performance standard. However, it is unlikely that sulfur reductions of the magnitude seen between 1997 and 1998 were solely due to the imposition of a NOx performance standard, since Phase I Complex Model RFG was only required to have NOx emission performance equal to baseline gasoline's with sulfur levels of 338 (Winter) and 339 (Summer) ppm. In addition, the RFG regulations allowed refiners and importers to supply some RFG with NOx performance worse than baseline gasoline if they complied on average with a slightly more stringent NOx performance requirement.

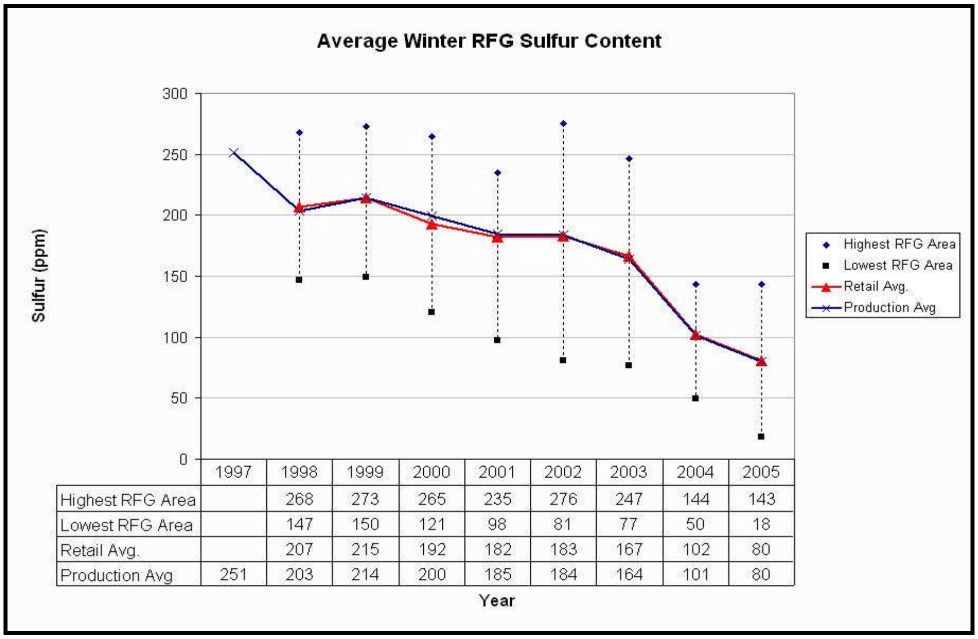
The sulfur reductions in 1998 are attributable, at least in part, to a requirement that each Complex Model input parameter be within specific range limits. These limits were intended to address the validity of the model, and EPA's regulations prohibit certification of RFG with properties outside of these model limits (*Limits of the model* 40 C.F.R. ‘80.45(f)). The limit for sulfur is 500 ppm; consequently each batch of RFG was required to have a sulfur content at or below this level beginning in 1998. Analysis of EPA's reporting data shows that about 17% of Summer and 12% of Winter RFG refined and imported in 1997 exceeded this limit (figures 3 and 4). Thus, even if 1997 RFG on average met 1998 NOx performance standards, a portion of that RFG would have required sulfur reductions to meet the Complex Model range limit imposed in 1998. EPA did not calculate the average Complex Model emission performance of its 1997 refiner/importer data since suppliers were not required to report the E200 and E300 model inputs. However, as shown later in this chapter, EPA calculated the average emission performance of 1998 and 1999 RFG. EPA found that the NOx performance of both Summer and Winter RFG was significantly better than the standard, and presumes that average NOx performance improved from 1997 to 1998. This over-compliance in 1998 and 1999 is likely partially, if not primarily, due to sulfur reductions needed to comply with the sulfur range limit.

Presumably, the NOx performance standard and the Complex Model sulfur range limit were the major factors influencing the 1997 to 1998 decrease in RFG's average sulfur content. However, since the Complex Model recognized the toxics and VOC emissions benefits of sulfur reduction, reducing sulfur levels below those needed to minimally comply with the NOx standard and sulfur range limit also may have become an economically desirable option for some producer's by 1998. (As discussed below, the more stringent standards applicable to Phase II RFG would result in additional sulfur reductions by year 2000.)



	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area		261	313	162	163	173	154	104	107
Lowest RFG Area		146	121	75	65	66	64	16	10
Retail Avg.		190	204	127	122	117	106	78	69
Production avg.	289	202	205	126	127	124	110	79	69

Figure 1



	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area		268	273	265	235	276	247	144	143
Lowest RFG Area		147	150	121	98	81	77	50	18
Retail Avg.		207	215	192	182	183	167	102	80
Production Avg	251	203	214	200	185	184	164	101	80

Figure 2

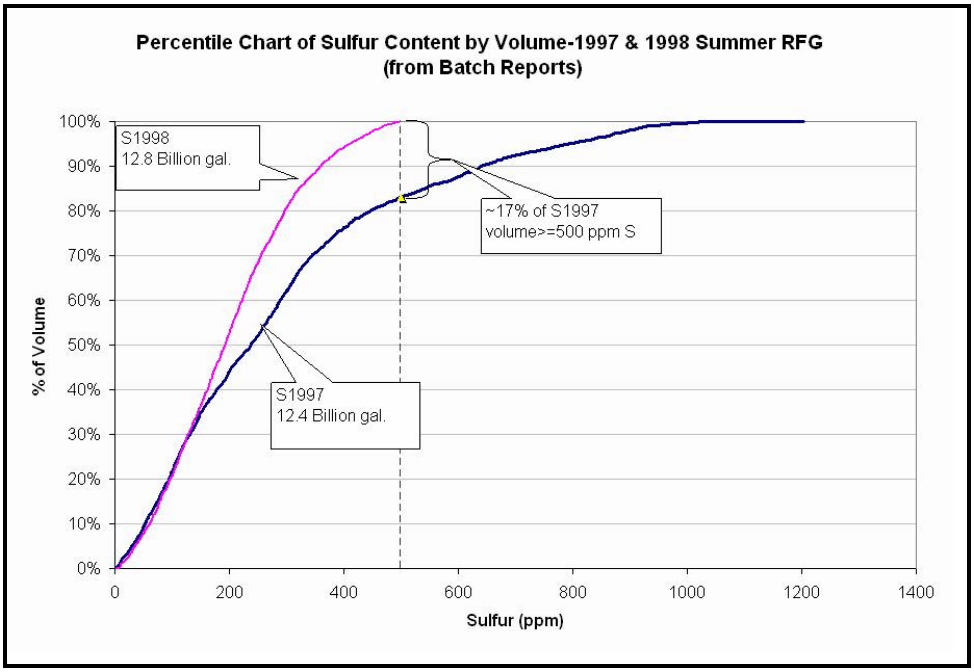


Figure 3

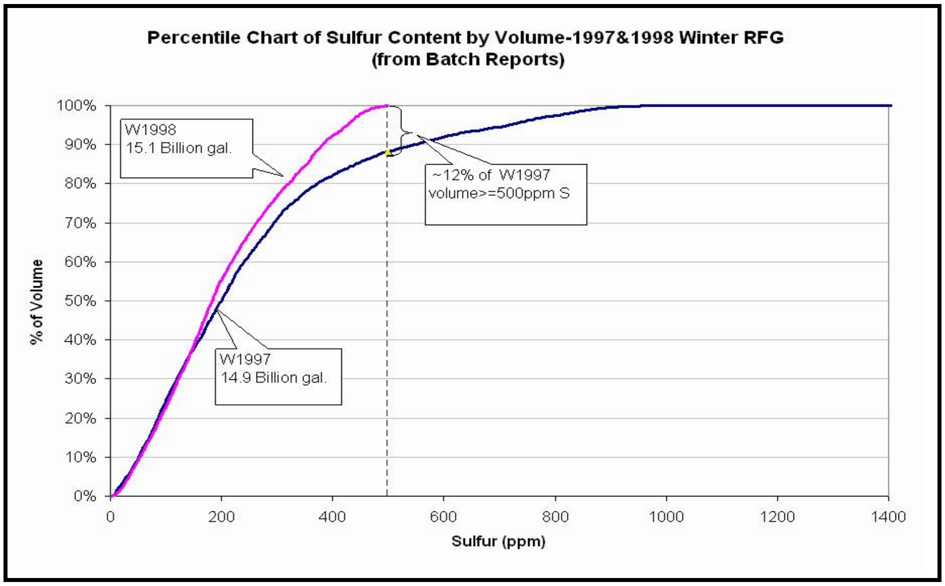
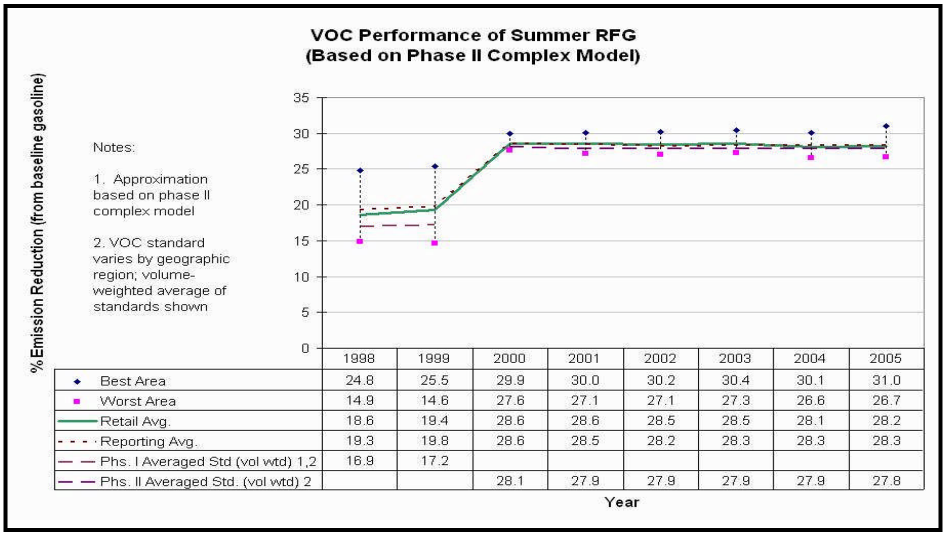


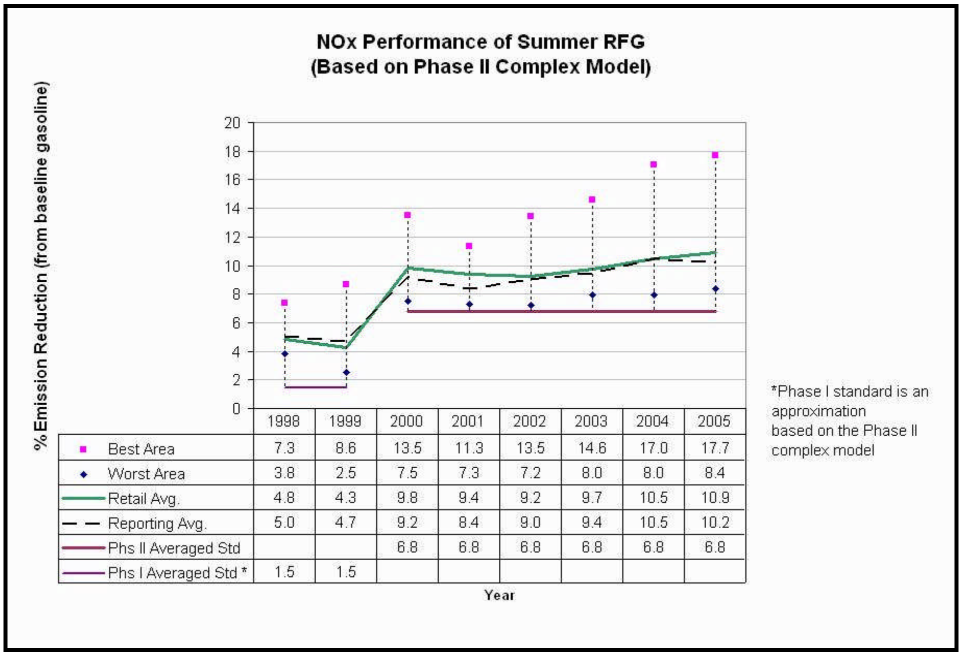
Figure 4

The transition from Phase I to Phase II Complex Model RFG occurred between 1999 and 2000. The Phase II emission performance standards, particularly the more stringent standards applicable to VOC-controlled (Summer) RFG caused significant changes in average values for most Complex Model input parameters. Phase II RFG performance standards required greater reductions of VOC and NOx emissions in VOC-controlled (Summer) RFG, and greater reductions in toxics emissions on an annual basis. Figures 5 through 9 show RFG Complex Model performance and applicable performance standards. Average Summer RFG performance improved between 1999 and 2000 even for toxics, where Phase I RFG, on average, complied with the Phase II standards. The Winter NOx standard did not become more stringent with Phase II and, on average, Phase I Winter RFG met Phase II standards for Winter NOx and annual toxics performance. EPA's two data sources disagree somewhat about the magnitude of the emissions performance changes for Winter RFG. While both data sources indicate Winter performance improvements between 1999 and 2000, only the survey estimates suggest an abrupt improvement. (The Phase II version of the Complex Model differs from the Phase I version. In this report, to facilitate comparison of Phase I and Phase II RFG, Phase I RFG performance and standards are estimated using the Phase II model.)



	1998	1999	2000	2001	2002	2003	2004	2005
◆ Best Area	24.8	25.5	29.9	30.0	30.2	30.4	30.1	31.0
■ Worst Area	14.9	14.6	27.6	27.1	27.1	27.3	26.6	26.7
—— Retail Avg.	18.6	19.4	28.6	28.6	28.5	28.5	28.1	28.2
- - - Reporting Avg.	19.3	19.8	28.6	28.5	28.2	28.3	28.3	28.3
— — Phs. I Averaged Std (vol wtd) 1,2	16.9	17.2						
— — Phs. II Averaged Std. (vol wtd) 2			28.1	27.9	27.9	27.9	27.9	27.8

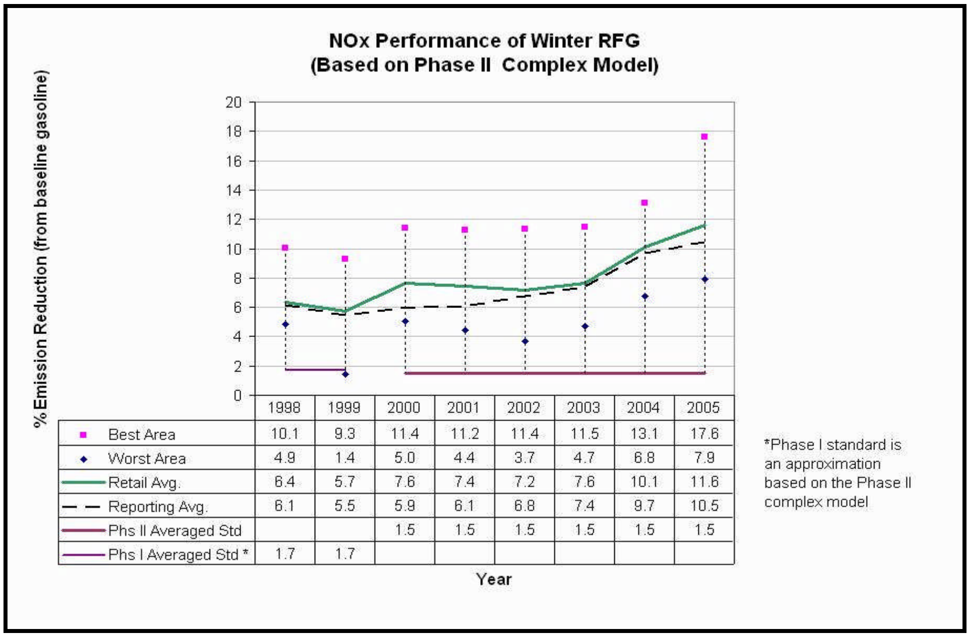
Figure 5



	1998	1999	2000	2001	2002	2003	2004	2005
■ Best Area	7.3	8.6	13.5	11.3	13.5	14.6	17.0	17.7
◆ Worst Area	3.8	2.5	7.5	7.3	7.2	8.0	8.0	8.4
Retail Avg.	4.8	4.3	9.8	9.4	9.2	9.7	10.5	10.9
Reporting Avg.	5.0	4.7	9.2	8.4	9.0	9.4	10.5	10.2
Phs II Averaged Std			6.8	6.8	6.8	6.8	6.8	6.8
Phs I Averaged Std *	1.5	1.5						

*Phase I standard is an approximation based on the Phase II complex model

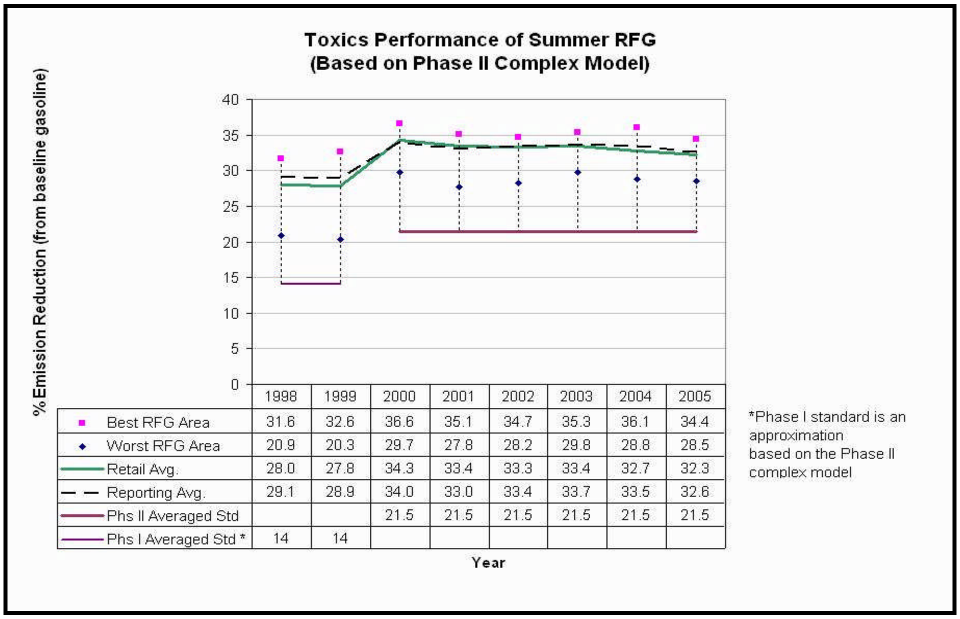
Figure 6



	1998	1999	2000	2001	2002	2003	2004	2005
■ Best Area	10.1	9.3	11.4	11.2	11.4	11.5	13.1	17.6
◆ Worst Area	4.9	1.4	5.0	4.4	3.7	4.7	6.8	7.9
Retail Avg.	6.4	5.7	7.6	7.4	7.2	7.6	10.1	11.6
Reporting Avg.	6.1	5.5	5.9	6.1	6.8	7.4	9.7	10.5
Phs II Averaged Std			1.5	1.5	1.5	1.5	1.5	1.5
Phs I Averaged Std *	1.7	1.7						

*Phase I standard is an approximation based on the Phase II complex model

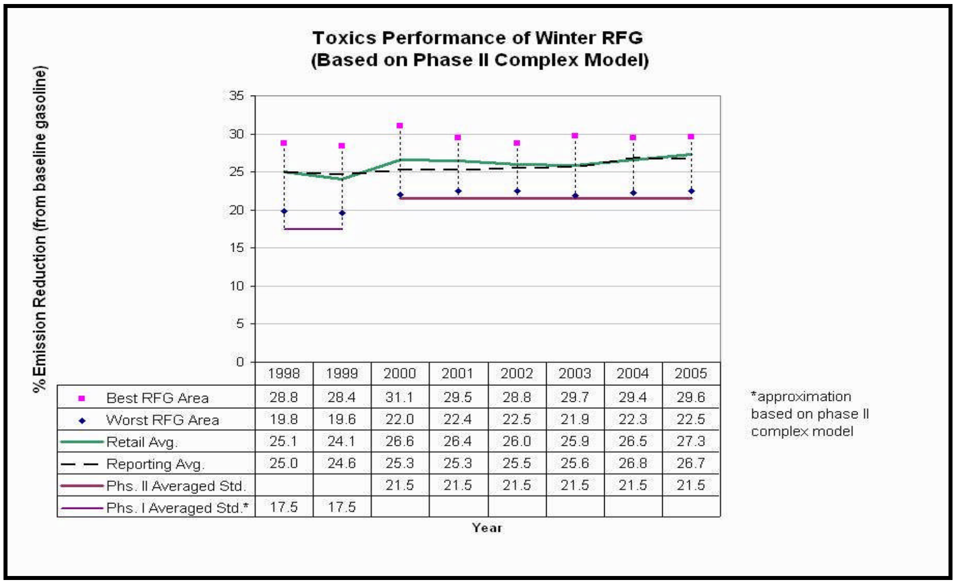
Figure 7



	1998	1999	2000	2001	2002	2003	2004	2005
■ Best RFG Area	31.6	32.6	36.6	35.1	34.7	35.3	36.1	34.4
◆ Worst RFG Area	20.9	20.3	29.7	27.8	28.2	29.8	28.8	28.5
—— Retail Avg.	28.0	27.8	34.3	33.4	33.3	33.4	32.7	32.3
— — Reporting Avg.	29.1	28.9	34.0	33.0	33.4	33.7	33.5	32.6
—— Phs II Averaged Std			21.5	21.5	21.5	21.5	21.5	21.5
—— Phs I Averaged Std *	14	14						

*Phase I standard is an approximation based on the Phase II complex model

Figure 8



	1998	1999	2000	2001	2002	2003	2004	2005
■ Best RFG Area	28.8	28.4	31.1	29.5	28.8	29.7	29.4	29.6
◆ Worst RFG Area	19.8	19.6	22.0	22.4	22.5	21.9	22.3	22.5
—— Retail Avg.	25.1	24.1	26.6	26.4	26.0	25.9	26.5	27.3
— — Reporting Avg.	25.0	24.6	25.3	25.3	25.5	25.6	26.8	26.7
—— Phs. II Averaged Std.			21.5	21.5	21.5	21.5	21.5	21.5
—— Phs. I Averaged Std.*	17.5	17.5						

*approximation based on phase II complex model

Figure 9

RFG producers adjusted several of the emission-related properties of their RFG blends to produce Phase II RFG. Figures 10 through 12 show the composite effect of all (1999) Phase I to (2000) Phase II property changes on Complex model emissions, using average property value estimates from RFG surveys, as well as the individual effects of changing one property while holding all others constant. This provides a good indication of the relative contribution of each property change to the overall Phase I to Phase II emission performance change. (Because of the non-linear mathematical structure of the Complex Model, the individual property effects do not precisely add up to the composite effect, and the emission performance of this “average RFG” is not precisely the same as the average performance of all RFG blends.) Since the performance standards, and consequentially, the emission-related properties changed more substantially for Summer RFG, only Summer graphs are presented. Each bar is labeled with the estimated average parameter values for 1999 and 2000.

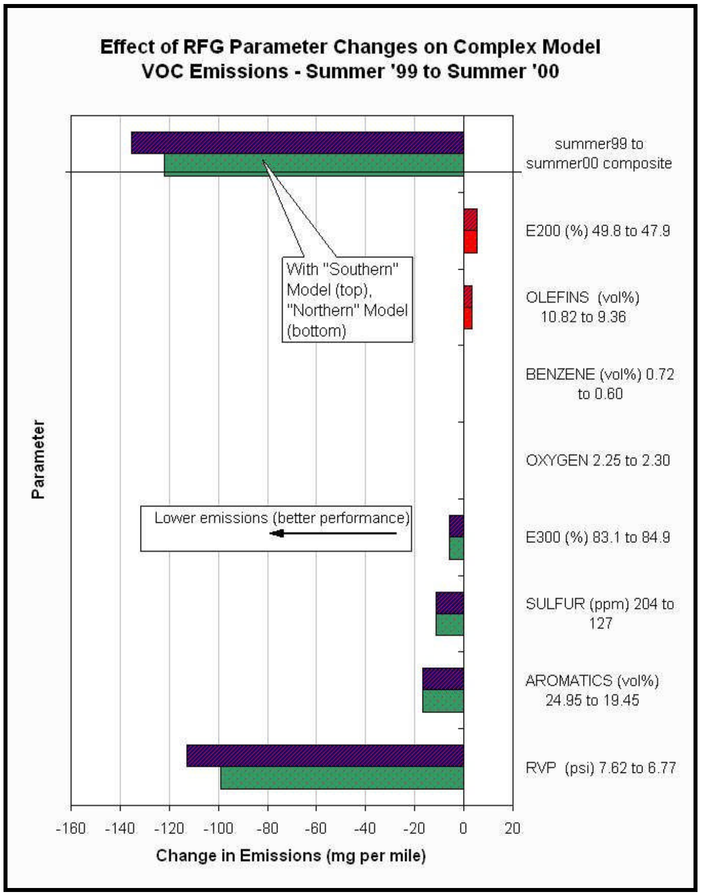


Figure 10

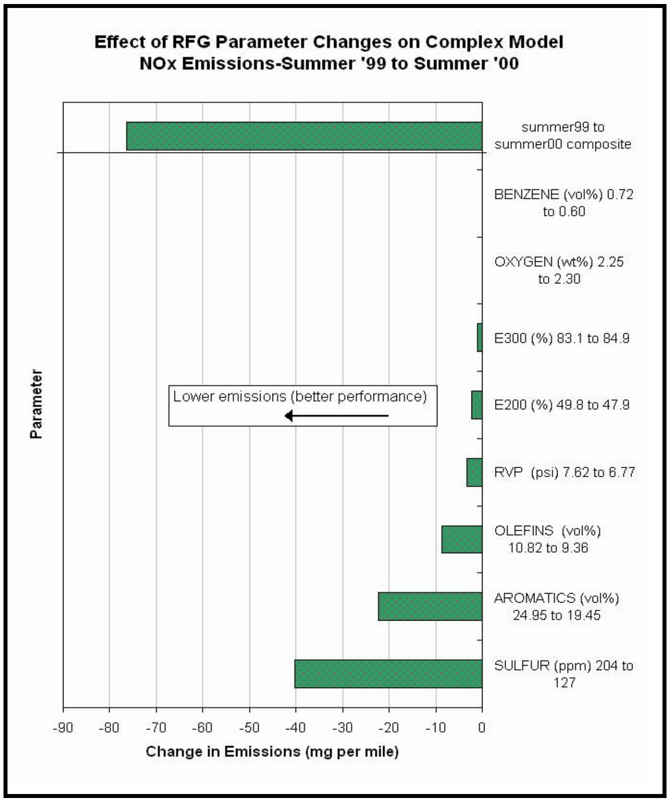


Figure 11

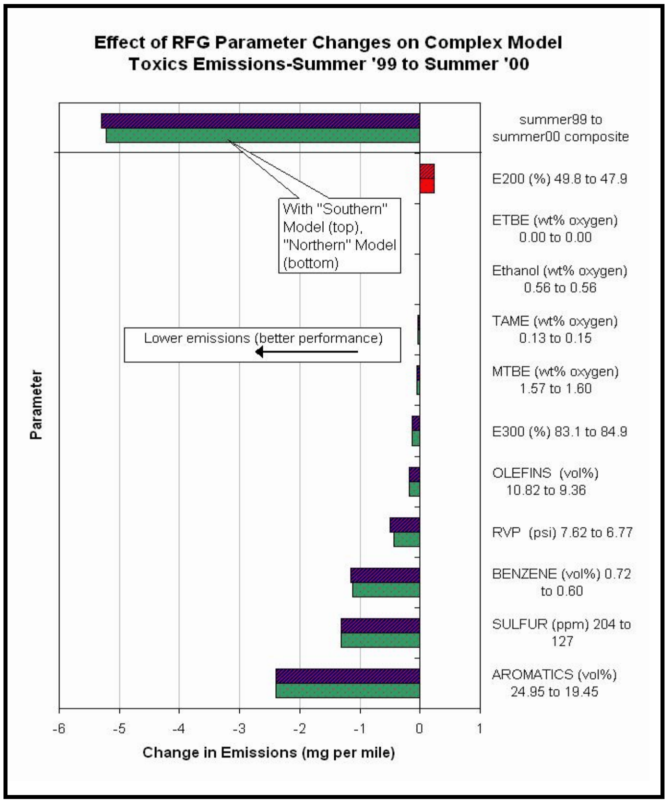


Figure 12

RVP reductions were the primary means of meeting the more stringent Phase II VOC performance standards. RVP effects on emissions are considered in the Summer version of the Complex Model only. The Complex Model estimates both exhaust and non-exhaust VOC emissions and adds them together. Although reducing RVP lowers exhaust VOC emissions, the RVP parameter primarily affects the non-exhaust (i.e. evaporative emission) portion of the Complex Model, and is the only gasoline parameter affecting its non-exhaust VOC estimates. Reductions in fuel aromatics and sulfur content, affecting exhaust VOC emissions, contributed to total VOC reductions. (Figure 10 shows two sets of bars because the non-exhaust portion of the Complex Model varies by geographic VOC Control Region. To simplify this "property effects" analysis EPA used a single set of property averages based on data from both regions.)

Sulfur and aromatics reductions were the primary changes responsible for Phase I to Phase II NOx performance improvements. Phase I to Phase II sulfur reductions were larger in Summer RFG, and this sulfur reduction appears to be the most important single parameter contributing to Summer RFG NOx performance improvement. However, it is clear that reductions in aromatics and olefin content had non-negligible effects on Summer NOx performance improvement

Several parameter changes contributed to toxics performance improvements from Phase I to Phase II. This analysis, based on property estimates from RFG Surveys indicates that reductions in aromatics content were most important, but other parameter changes, such as sulfur and benzene reductions, contributed significantly to toxics performance improvements. (Since the reporting system data estimates a smaller 1999 to 2000 change in aromatics content but almost identical sulfur and benzene changes it is possible that a similar analysis using reporting system data would conclude that the aromatics content reduction was a significant but not primary contributor to toxics performance improvement.)

The Complex Model estimates emissions of benzene, formaldehyde, acetaldehyde, 1,3-butadiene and polycyclic organic matter and adds them together to produce a toxics emission estimate. Exhaust benzene emissions are the largest component of Complex Model exhaust toxics, and exhaust benzene reductions were the largest component of the 1999 to 2000 toxics emissions reductions (see the *Emissions* chapter for this analysis.) The Summer model considers evaporative benzene emissions, as well. As one would expect, both exhaust and non-exhaust benzene emissions are directly related to gasoline benzene content, although other gasoline parameters also affect benzene emissions. There was a sharp decrease in Summer RFG benzene content between 1999 and 2000, even though the benzene content standard for RFG did not change (see the *Benzene* chapter). Additionally, RVP reductions, which were necessary to meet the more stringent Phase II VOC standards, also contributed to Summer toxics emission reductions because reducing RVP reduces evaporative benzene emissions.

The graph for parameter change effects on toxics emissions shows the oxygen contribution change from individual oxygenates because, unlike VOC and NOx Complex Model calculations, toxics calculations are a function of the type(s) of oxygenate used as well as the oxygen content of the gasoline formulation. Oxygen and oxygenate changes between 1999 and 2000, and consequentially, their effects on emissions, were very small.

Changes in RFG from 2000 to 2005

Additional regulatory requirements have been imposed on both RFG and conventional gasoline since the beginning of the Phase II program in 2000. These requirements have and will influence the properties, composition and emissions performance of RFG.

One direct change was made to the Phase II RFG performance standards. This change involved a small relaxation in the VOC performance standards applicable to certain ethanol-oxygenated RFG supplied to the Chicago and Milwaukee areas. While some decline in VOC performance in these areas was expected as a result of this change the scope and magnitude of this change was limited and influence on overall average RFG trends is small.

Figure 5, which estimates the overall VOC performance trend, suggests that RFG VOC performance may have declined very slightly from 2000 to 2005. This estimate of a slight decline could easily be attributable to imprecision or inaccuracy in the estimates. More areas declined in VOC performance than improved, but the estimated performance changes in either direction were generally small (Figure 13). However, it is apparent that the greatest performance declines occurred in the Chicago and Milwaukee areas. Since VOC performance declines in these areas were expected as a result of the standard change it is unlikely that the observed declines in VOC performance in these two areas are the result of statistical or measurement error.

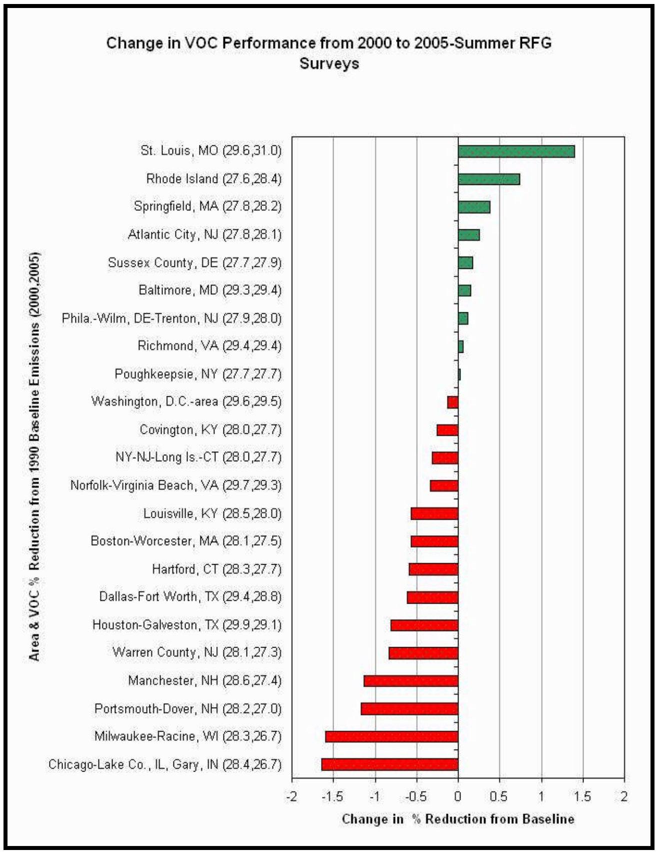


Figure 13

Perhaps the most significant post-2000 regulatory change is the Tier 2 gasoline sulfur program, applicable to both RFG and conventional gasoline, which requires refiners to reduce sulfur levels incrementally. In 2005 (with some exceptions), refiners and importers were required to comply with a 30 ppm annual average sulfur standard and a 300 ppm per gallon cap. The cap is reduced to 80 ppm for 2006 and later years. Both the RFG requirements and the Tier 2 gasoline sulfur requirements have resulted in substantial reductions in gasoline sulfur levels. However, there is an important difference between these sulfur reductions.

As indicated above, the RFG program did not mandate sulfur reductions, but set performance standards based on the Complex Model. RFG producers, through their refining and blending processes, are able to adjust various Complex Model input properties, including sulfur, in order to achieve the required emission reductions. As previously noted, lowering gasoline sulfur content reduces NOx, exhaust toxics and exhaust VOC emissions. Consequently, the more stringent Phase II performance standards for these pollutants resulted in sulfur reductions from Phase I to Phase II RFG, especially in Summer RFG (Figures 1 and 2).

The Tier 2 gasoline sulfur standards are required primarily for the purpose of enabling technology. Gasoline with reduced sulfur content is necessary to enable the emission control systems in Tier 2 vehicles to be fully effective. Phase-in of very stringent Tier 2 tailpipe emission standards, applicable to all passenger cars and light trucks, began in 2004 along with a company-wide annual average sulfur requirement of 120 ppm. The company-wide 120 ppm standard is comparable to the average sulfur content in Phase II Summer RFG in 2000 and is substantially lower than the sulfur content of Winter RFG. Thus, Tier 2 sulfur requirements have and will lower RFG sulfur content, and this trend is apparent in the retail and production data averages shown in Figures 1 and 2. (Information on CG and CG/RFG combined sulfur averages is available elsewhere in this report.)

Since the Tier 2 sulfur standards reduce sulfur levels below those needed to meet RFG performance standards, and the Complex Model predicts that emission performance improves with lower sulfur, the emissions performance of RFG could potentially improve as a result of the Tier 2 requirements. Thus, emissions of these pollutants from older vehicles, as well as "Tier 2" vehicles could be lowered by this sulfur reduction. However, RFG producers could also change their RFG formulations such that other gasoline property changes would offset the Complex Model emission benefits of the required sulfur reduction. This first effect clearly dominated RFG NOx emission performance, while the strongest evidence of this latter effect is in RFG VOC performance. More generally, the interaction between the RFG requirements and the Tier 2 sulfur reductions should be better understood as additional years of data are analyzed.

The estimates of average NOx, VOC and toxics performance shown in Figures 5 through 9 indicate clear improvements in average NOx performance between 2000 and 2005, but do not show improvements for VOCs. Summer and winter toxics changes were mixed, with a small decrease in summer performance and a small increase in winter performance. Unlike VOC (with only a summer standard) and NOx (where summer and winter standards differ), compliance with RFG toxics performance standards and other toxics-related regulatory requirements is determined on an annual average basis. Thus, improvements in Winter RFG toxics performance could have compensated for decreases in Summer RFG toxics performance, and this may have been a factor influencing the directionally opposite seasonal toxics performance trends.

EPA compared 2000 to 2005 RFG in the same manner as previously described for 1999 to 2000 RFG. Figures 14 through 18 show the composite effect of all 2000 to 2005 Phase II property changes on Complex model emissions, using average property value estimates from RFG surveys, as well as the individual effects of changing one property while holding all others constant.

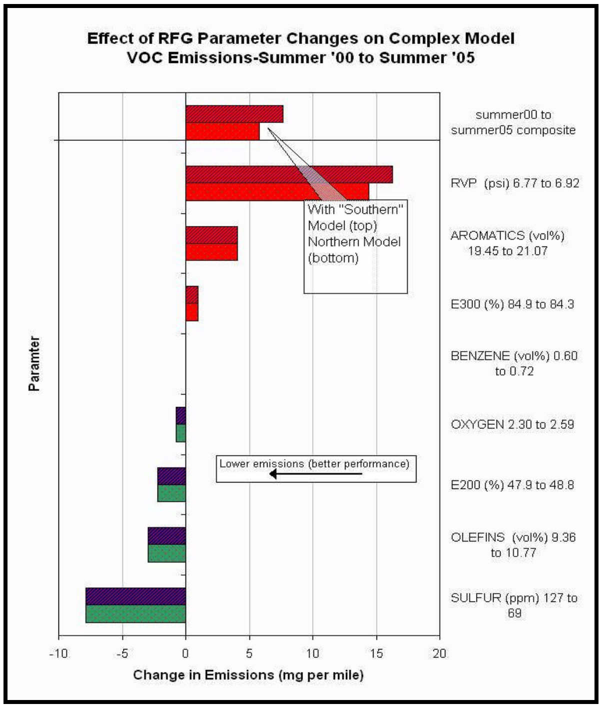


Figure 14

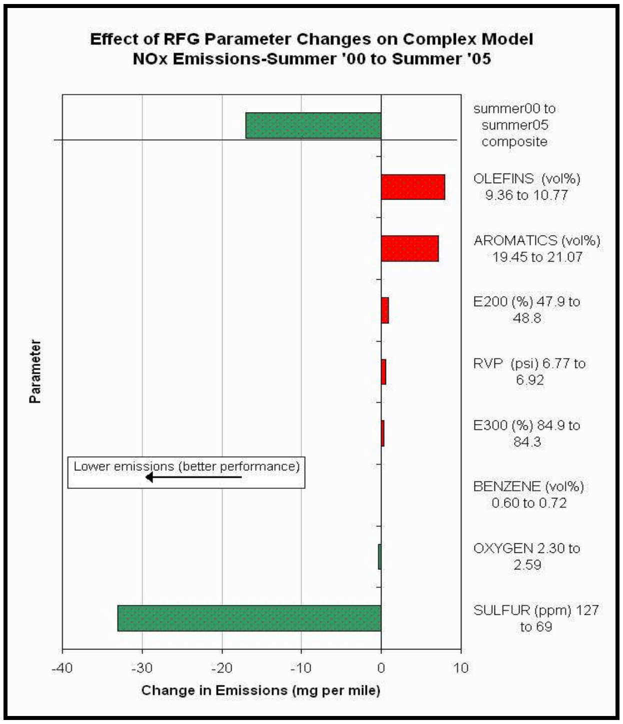


Figure 15

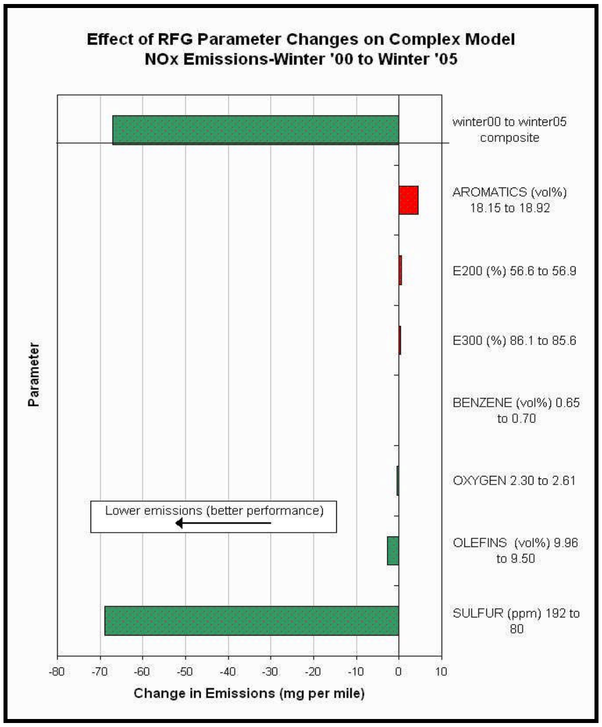


Figure 16

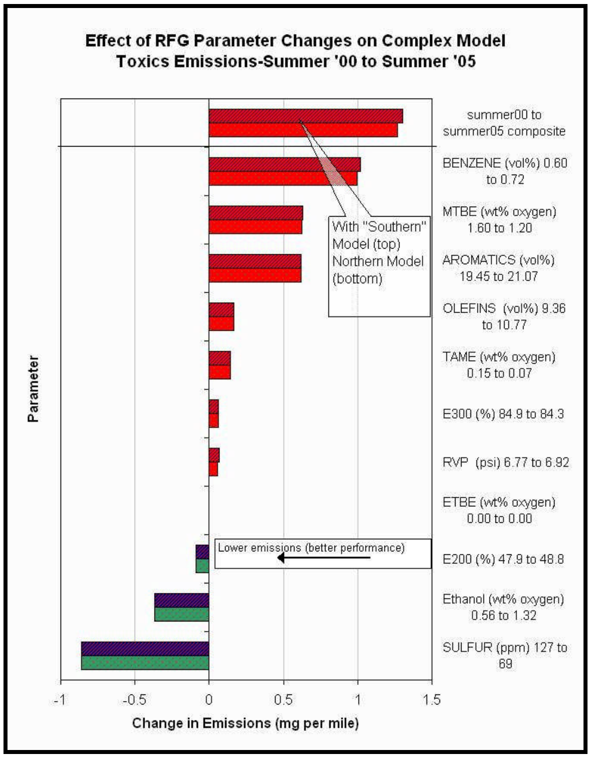


Figure 17

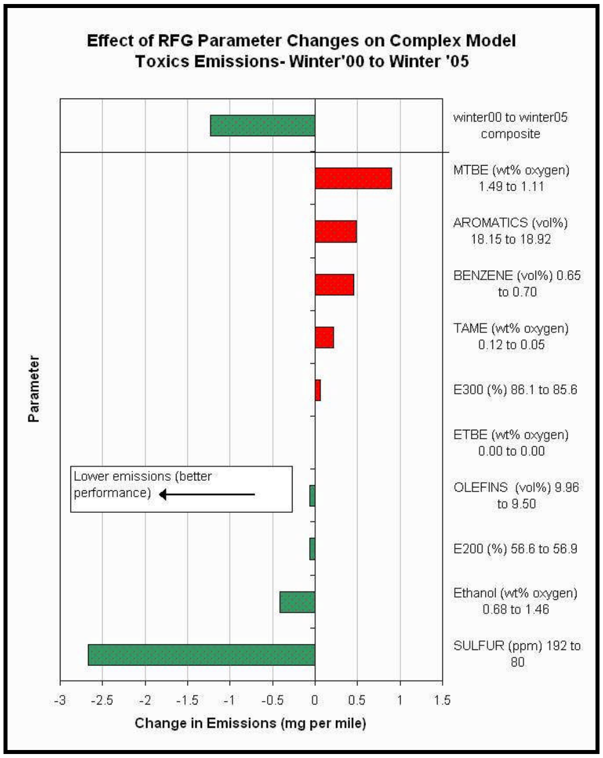


Figure 18

Figure 14 shows that the VOC emission reduction benefits of lower sulfur (from 127 to 69 ppm) and increased olefin content (which lower exhaust VOC) were offset by an increase in RVP (from 6.77 to 6.92 psi), which primarily increases evaporative VOC, and by other property changes which increase exhaust VOC. Comparison of the scale of this chart with the chart showing 1999 to 2000 property effects (figure 10) shows that, according to the Complex Model, the impact of any of the 2000 to 2005 property changes on VOC emissions is very small compared to the overall Phase I to Phase II emission change, which was primarily due to an RVP reduction (from 7.62 to 6.77 psi). The sulfur reduction between 2000 and 2005 may have facilitated some "trade off" between evaporative and exhaust VOC emission reduction, but, through 2005, the Tier 2 regulation has not had a substantial effect on overall RFG VOC performance (figure 5). Figure 14 also shows VOC reduction due to increase in RFG oxygen content. This oxygen content increase is related to an increase in ethanol use. (This is discussed later.)

Figures 15 and 16 show that the Tier 2 sulfur requirements have clearly helped RFG's NOx performance. As expected, the benefit is greater in Winter RFG because of the larger sulfur reduction (192 to 80 ppm). Summer sulfur NOx benefits have also been offset to a greater extent by other property changes. However, the overall trend shows improved NOx performance for both Summer and Winter RFG between 2000 and 2005 and a substantial improvement in Winter performance between 2003 and 2005 (Figures 6 and 7). [15]

Figures 17 and 18 show that the toxics reduction benefits of lower sulfur have been countered by emission increases due to increased aromatics and benzene content, resulting in a slight decline in

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[15] Beginning in 2007, the NOx performance standards were, with some exceptions, eliminated for RFG refiners and importers. The gasoline sulfur program will become the sole regulatory mechanism used to implement gasoline NOx requirements. See 82 FR 8427.

Summer toxics performance and a slight improvement in Winter performance. As explained earlier, the toxics graphs show oxygenate-specific effects because oxygenate type affects toxics emissions. These graphs indicate that there is a toxics emission reduction associated with an increase in oxygen coming from ethanol and a toxics emission increase associated with a decrease in oxygen coming from MTBE and TAME. It is important to remember that all oxygenates have certain toxics emission reduction benefits and that the increase in ethanol is related to the decrease in MTBE and TAME. The toxics emission benefit lost from decreased use of these ethers in RFG is at least partially offset by the benefit gained from increased use of ethanol in RFG.

Another post-2000 regulatory change affecting RFG (and conventional gasoline) is the Mobile Source Air Toxic (MSAT) rule (2001). This rule requires refiners and importers to produce or import gasoline with toxics emissions that are no greater than the toxics emissions of gasoline they produced or imported during the period 1998-2000. Data collected by EPA indicates that RFG (and conventional gasoline) often over-complied with toxics emission requirements. The MSAT rule is intended to preserve this over-compliance in order to ensure that toxics emissions do not increase above current levels. Thus, much RFG currently is subject to more stringent toxics emission performance requirements than the Phase II RFG toxics emissions performance requirements. It would be difficult to isolate the effect of the MSAT rule on changes in the properties and emission performance of RFG, but it is clear that the MSAT rule could interact with other requirements and economic factors to affect the composition and performance of RFG. [16]

An additional regulatory requirement which has significantly impacted the composition of RFG is the oxygen content requirement. The Clean Air Act (CAA) required that RFG contain 2 weight percent oxygen, until the Energy Policy Act of 2005 [in ‘1504(a)] amended the CAA to remove this requirement. [17] This requirement was effective when RFG was introduced in 1995. RFG producers satisfied this requirement by blending certain organic compounds, known as oxygenates into their gasoline. These oxygenates fall into two general categories; ethers and alcohols. The most common ether used was Methyl tertiary Butyl Ether (MTBE) although small quantities of other ethers, primarily tertiary-Amyl Methyl Ether (TAME), were sometimes used. The only alcohol used in any significant quantity was ethanol.

Although the RFG oxygen content requirement did not change during the time span considered in the report, it significantly affected composition of post-2000 RFG. A number of studies have detected MTBE in ground water throughout the country; in some instances these contaminated waters are sources of drinking water. While most of these detections have been well below levels of public health concern, low levels of MTBE can make drinking water supplies undrinkable due to its offensive taste and odor. In 1998, the EPA Administrator appointed a Blue Ribbon Panel to investigate the air quality benefits and water quality concerns associated with the use of oxygenates in gasoline. The Panel, which issued its report in September 1999, agreed broadly, but not unanimously, that in order to minimize current and future threats to drinking water, the use of MTBE should be reduced substantially (Blue Ribbon Panel, 1999). Subsequently, certain states have acted to ban or limit the use of MTBE in gasoline. This

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[16] EPA has finalized an "MSAT2" regulation to replace the current MSAT requirements with a 0.62 volume percent average benzene requirement beginning in 2011. See 72 F.R. 8427

[17] Removal of the oxygen requirement became effective with regulatory changes on April 24, 2006 for California gasoline, and May 5, 2006 for gasoline nationwide. See 71 F.R. 8965 and 71 F.R. 26419.

has resulted in a decreased use of MTBE and an increased use of ethanol in RFG. This switch from MTBE to ethanol affects the composition of RFG and potentially affects the Complex Model emissions performance of RFG. (There are a number of issues relating to the overall emissions impact of ethanol-oxygenated gasoline, and the ability of the Complex Model or other emission models to address these impacts. A discussion of these issues is beyond the scope of this report, and, unless otherwise stated, emissions performance refers to the Complex Model.)

Figures 19 through 22 show 2000 to 2005 changes in average ethanol and MTBE content (in weight %), for the various RFG areas surveyed. In some areas where large changes occurred, the change reflects a transition from all-ether to all-ethanol RFG. In other areas, the change reflects some ethanol usage in 2000 and increased ethanol usage in 2005. In the case of the NY-NJ-Long Island-CT RFG area, New York and Connecticut enacted MTBE bans, but New Jersey did not. The charts include several areas in California where RFG was required under federal law. The federal oxygen content requirement, as well as California's gasoline requirements, applied to this gasoline.

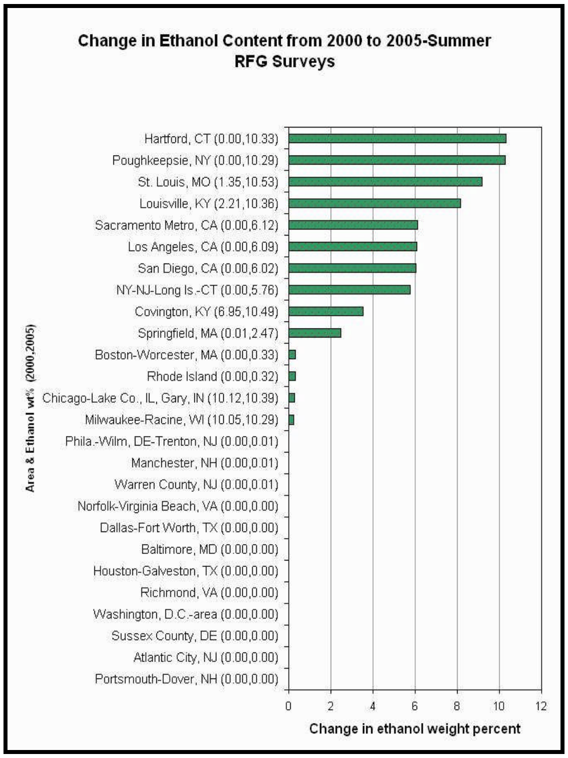


Figure 19

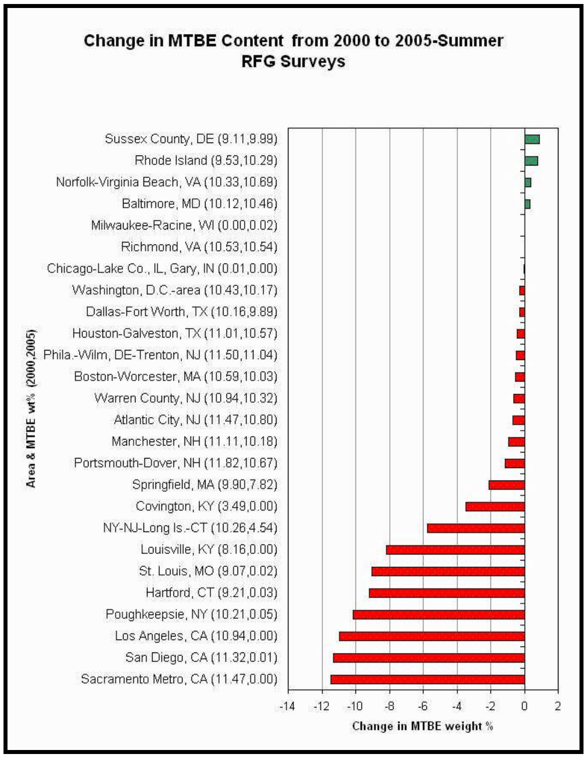
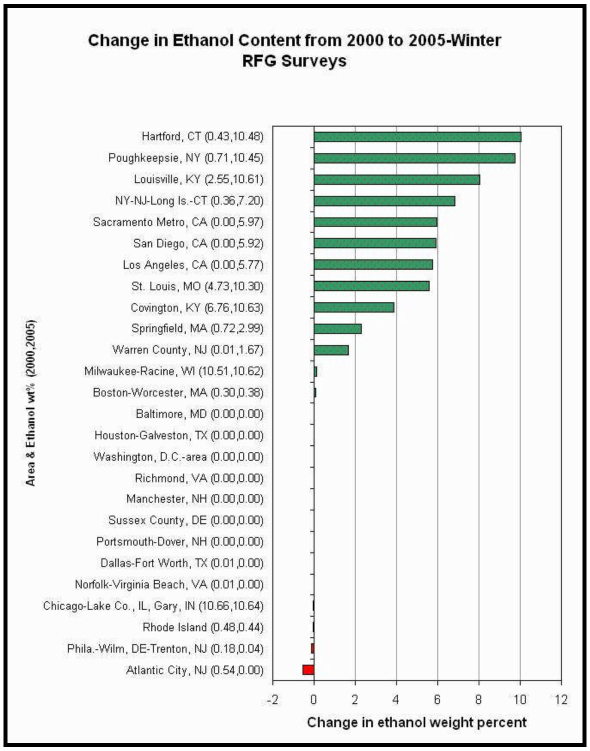


Figure 20



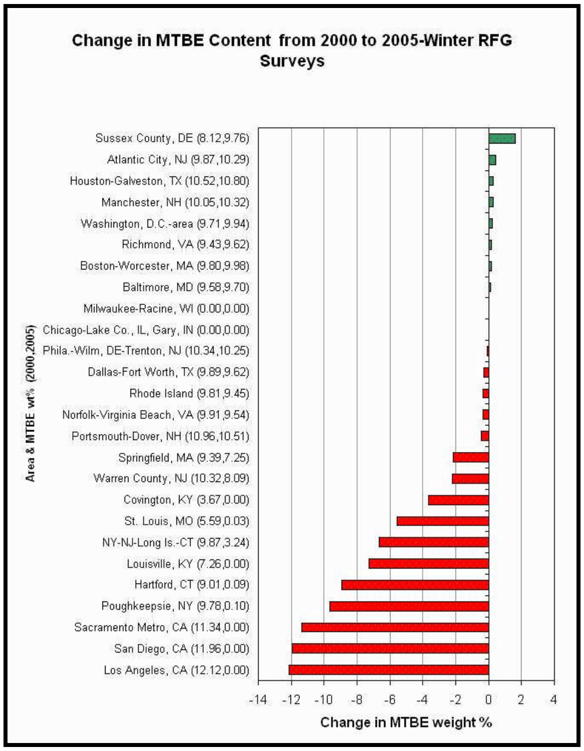
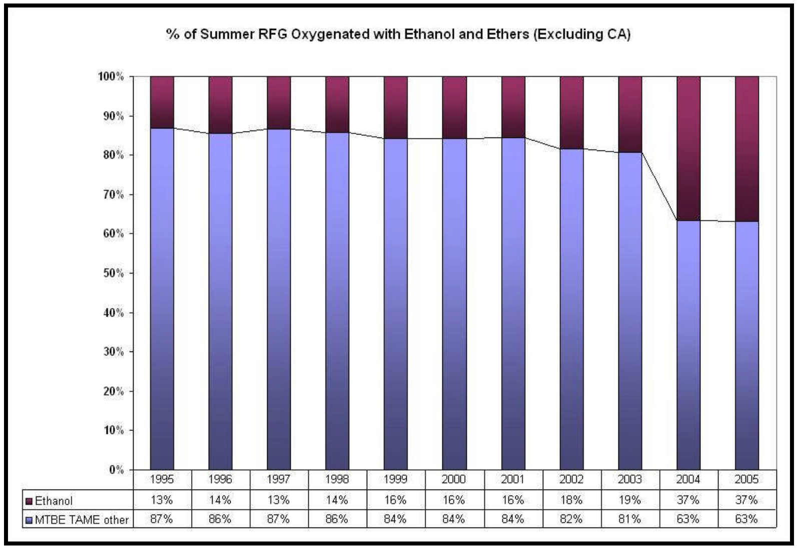


Figure 21 **Figure 22**

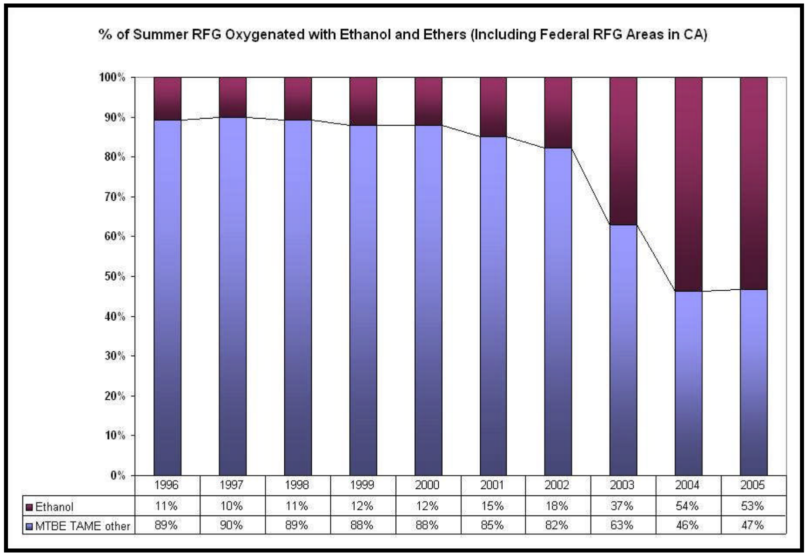
The increased use of ethanol has resulted in a higher percentage of RFG being oxygenated with ethanol, a larger fraction of total oxygen in RFG being supplied by ethanol and an increase, on average, in the total oxygen content of RFG. Figures 23 through 26 show estimates of the fraction of RFG oxygenated with ethanol, by year and season, through 2005. Figures 27 through 30 show estimates of the total oxygen (in weight %) in RFG, and the amounts of this oxygen supplied by ethanol and other oxygenates.

The total oxygen content has increased along with the ethanol share because most ethanol-oxygenated RFG supplied outside of California contains about 10 volume percent ethanol, providing about 3.5 weight percent oxygen, even though RFG was only required to have only 2 weight percent oxygen. This occurred, in part, because, until a recent legislative change (American Jobs Creation Act, 2004), a federal excise tax exemption available to ethanol was greatest when ethanol was blended at 10 volume percent and pro-rated for blending at 5.7 or 7.7 volume percent (see the Oxygenates chapter). Additionally, MTBE must be used at around 11 volume percent in order to provide the required 2 weight percent oxygen. Thus, when ethanol is used to replace MTBE, blending at 10 volume percent replaces much of the lost MTBE volume.


% of Summer RFG Oxygenated with Ethanol and Ethers (Excluding CA)

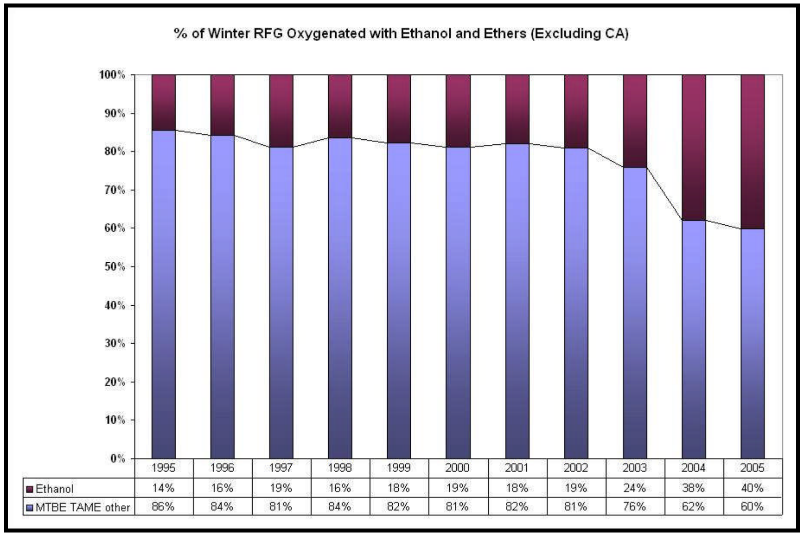
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
■ Ethanol	13%	14%	13%	14%	16%	16%	16%	18%	19%	37%	37%
■ MTBE TAME other	87%	86%	87%	86%	84%	84%	84%	82%	81%	63%	63%

Figure 23


% of Summer RFG Oxygenated with Ethanol and Ethers (Including Federal RFG Areas in CA)

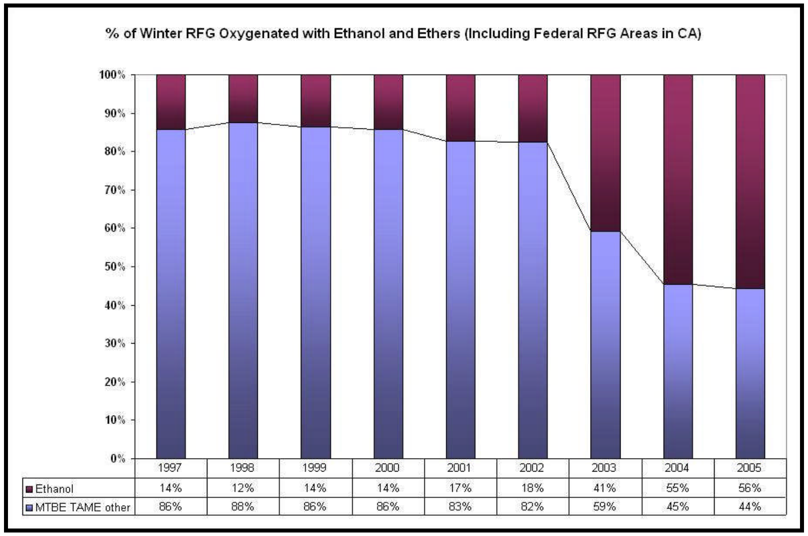
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
■ Ethanol	11%	10%	11%	12%	12%	15%	18%	37%	54%	53%
■ MTBE TAME other	89%	90%	89%	88%	88%	85%	82%	63%	46%	47%

Figure 24


% of Winter RFG Oxygenated with Ethanol and Ethers (Excluding CA)

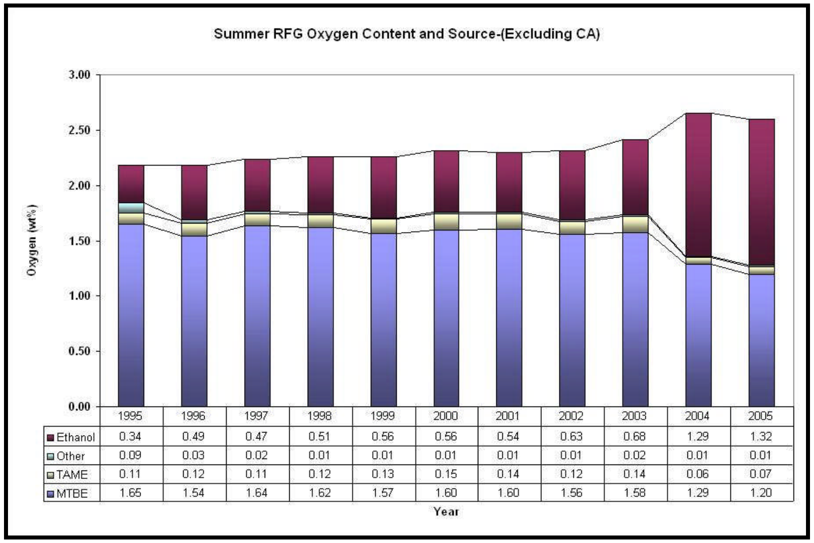
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
■ Ethanol	14%	16%	19%	16%	18%	19%	18%	19%	24%	38%	40%
■ MTBE TAME other	86%	84%	81%	84%	82%	81%	82%	81%	76%	62%	60%

Figure 25


% of Winter RFG Oxygenated with Ethanol and Ethers (Including Federal RFG Areas in CA)

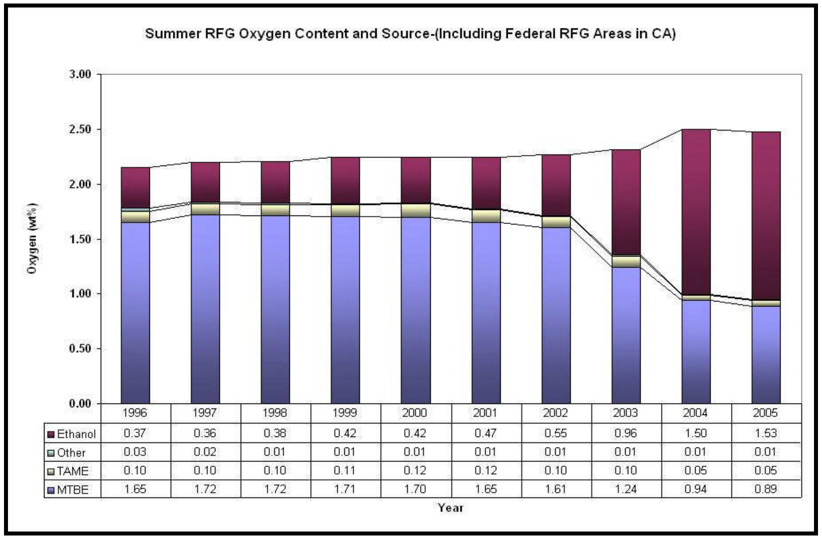
	1997	1998	1999	2000	2001	2002	2003	2004	2005
■ Ethanol	14%	12%	14%	14%	17%	18%	41%	55%	56%
■ MTBE TAME other	86%	88%	86%	86%	83%	82%	59%	45%	44%

Figure 26



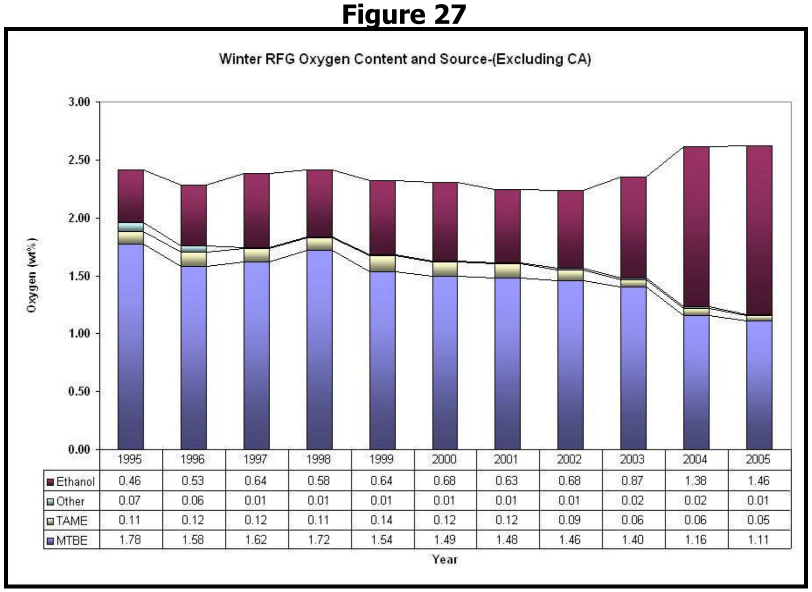
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
■ Ethanol	0.34	0.49	0.47	0.51	0.56	0.56	0.54	0.63	0.68	1.29	1.32
■ Other	0.09	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
■ TAME	0.11	0.12	0.11	0.12	0.13	0.15	0.14	0.12	0.14	0.06	0.07
■ MTBE	1.65	1.54	1.64	1.62	1.57	1.60	1.60	1.56	1.58	1.29	1.20

Figure 27



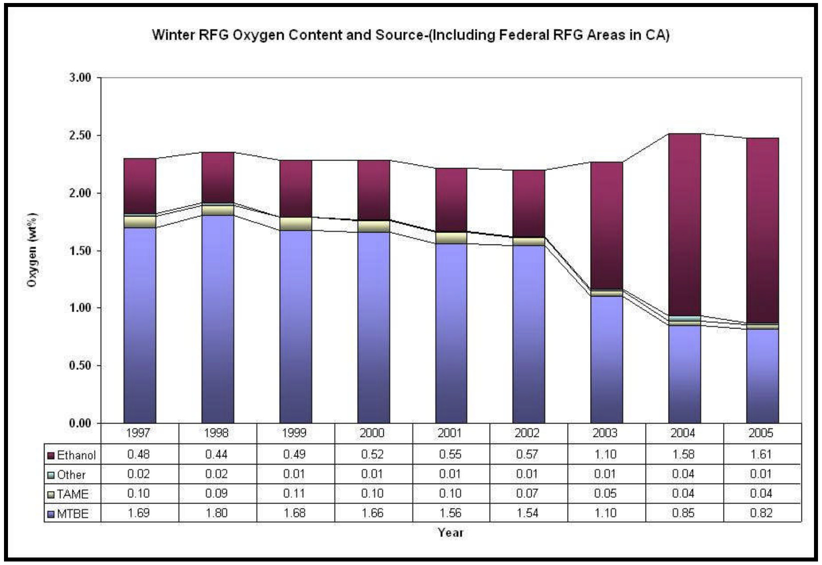
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
■ Ethanol	0.37	0.36	0.38	0.42	0.42	0.47	0.55	0.96	1.50	1.53
■ Other	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
■ TAME	0.10	0.10	0.10	0.11	0.12	0.12	0.10	0.10	0.05	0.05
■ MTBE	1.65	1.72	1.72	1.71	1.70	1.65	1.61	1.24	0.94	0.89

Figure 28



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
■ Ethanol	0.46	0.53	0.64	0.58	0.64	0.68	0.63	0.68	0.87	1.38	1.46
■ Other	0.07	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01
■ TAME	0.11	0.12	0.12	0.11	0.14	0.12	0.12	0.09	0.06	0.06	0.05
■ MTBE	1.78	1.58	1.62	1.72	1.54	1.49	1.48	1.46	1.40	1.16	1.11

Figure 29



	1997	1998	1999	2000	2001	2002	2003	2004	2005
■ Ethanol	0.48	0.44	0.49	0.52	0.55	0.57	1.10	1.58	1.61
■ Other	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.04	0.01
■ TAME	0.10	0.09	0.11	0.10	0.10	0.07	0.05	0.04	0.04
■ MTBE	1.69	1.80	1.68	1.66	1.56	1.54	1.10	0.85	0.82

Figure 30

Conventional Gasoline Trends

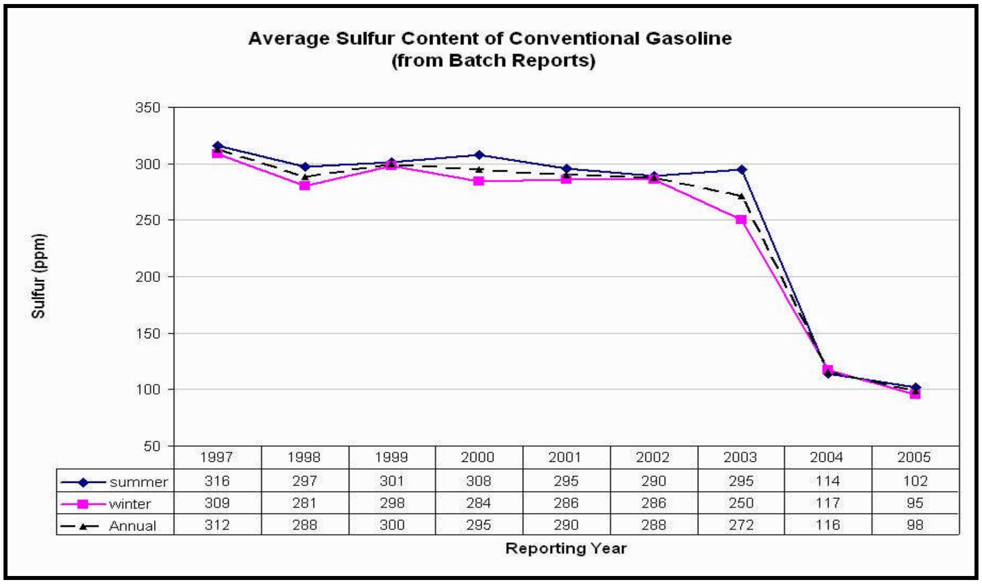
EPA used the gasoline property data that it received from conventional gasoline (CG) refiners and importers to investigate property trends. EPA's CG analysis covered the period between 1997 (or 1998 for some properties) and 2005. As noted in the General Methodology chapter, while EPA receives retail survey as well as refiner/importer data for RFG, it receives only refiner/importer data for CG. Consequently, the CG analysis in this report is less extensive than its RFG analysis.

EPA's Anti-Dumping regulations, affecting CG, and its Mobile Source Air Toxics regulations affecting both CG and RFG, limited or prevented CG deterioration, but did not necessarily force substantial changes in CG's emission-related properties or improvements in CG's emission qualities. The Anti-Dumping standards changed between 1997 and 1998, with the transition to the Complex Model, and the model for CG exhaust toxics and NOx emission calculations needed to determine CG compliance changed in 2000 with the transition to the Phase II Complex Model. However, in sharp contrast to simultaneous changes in RFG requirements that caused significant RFG composition changes, these CG changes apparently had minor impacts on CG composition. Moreover, the Anti-Dumping regulations apparently performed as intended, since CG emissions did not show significant or sustained increases when the more stringent Phase II RFG regulations took effect.

The Tier 2 gasoline sulfur regulations applicable in 2004 and later years impose the same sulfur content requirements on CG and RFG. However, CG sulfur content decreased more precipitously since other regulatory factors affecting RFG had already resulted in sulfur reductions.

To summarize, EPA's analysis shows that certain CG gasoline properties have fluctuated from year-to-year within the time period addressed in this report. These fluctuations may be linked to both regulatory and non-regulatory factors. Specific instances where regulatory factors may have influenced CG properties or emission qualities are identified in various chapters within this report. However, the sulfur reduction requirement was the only regulatory factor that clearly exerted a large influence on CG during this time period.

Figure 1 shows EPA's CG gasoline sulfur content estimates for each year between 1997 and 2005. The large change from 2003 to 2004 is due to the Tier 2 gasoline sulfur requirements and, as explained in the Sulfur chapter, these requirements may also have motivated some sulfur reductions prior to 2004.



	1997	1998	1999	2000	2001	2002	2003	2004	2005
summer	316	297	301	308	295	290	295	114	102
winter	309	281	298	284	286	286	250	117	95
Annual	312	288	300	295	290	288	272	116	98

Figure 1

Figures 2 through 5 show CG exhaust toxics and NOx average emission levels from 1998 through 2005 calculated with the Phase II Complex Model. CG must comply with Complex-model based exhaust toxics and NOx "milligram per mile" emission standards. While sulfur reductions were required to enable new technology vehicles to meet Tier 2 emission standards, the reductions also result in "cleaner" CG because these sulfur reductions result in lower Complex Model emission levels. This is evident in the 2003 to 2004 emission improvements that occurred concurrent with the large sulfur decreases. This suggests that CG sulfur reductions have and will reduce emissions in older vehicles as well.[18] These Complex Model emission calculations are not intended to be accurate estimates of the overall emissions rates or emissions changes that have occurred in each year as a result of gasoline property changes. They are indicators of changes in the emissions qualities of gasoline over time without considering changes in vehicle technology or emission standards.

Comparison with 1990 Statutory Baseline Gasoline[19]

Since the standards applicable to CG exhaust toxics and NOx are facility-specific and largely depend on individual 1990 baselines, these graphs do not show CG standards. Instead, the graphs show the Complex Model emissions rate of the seasonally-appropriate 1990 statutory baseline gasoline to provide some basis for comparison. These statutory baseline gasoline properties and emission levels were intended to be representative of the gasoline supplied in 1990. They are used to determine compliance for refiners and importers without individual baselines, and also factor into CG compliance determinations for individual refineries and importers supplying CG in excess of their 1990 gasoline volumes.

The exhaust toxics and NOx emission levels in each season and year are lower than the 1990 baseline levels. Although the 1990 statutory baseline gasoline properties were intended to be representative of the gasoline supplied in 1990, EPA does not have comprehensive data on CG properties in 1990 comparable to the data collected in its Anti-Dumping reporting system. EPA has compared properties and emission values of 1990 statutory baseline gasoline's to its CG estimates here and elsewhere in this report to provide some frame of reference. While EPA's Anti-Dumping regulations did not mandate substantial changes in CG composition or emissions characteristics these comparisons are insufficient to establish that these statutory baseline gasoline properties were or were not representative of 1990 gasoline. Regulatory changes other than the Anti-Dumping regulations, including volatility requirements and winter oxygenated gasoline program requirements certainly impacted CG composition between 1990 and 1997, the earliest year for which CG data were analyzed in this report. Various states have adopted specific gasoline requirements (e.g., low RVP, low sulfur) and these "boutique" fuels are included in EPA's CG data. Non-regulatory factors may also have caused changes in conventional gasoline during this time period.

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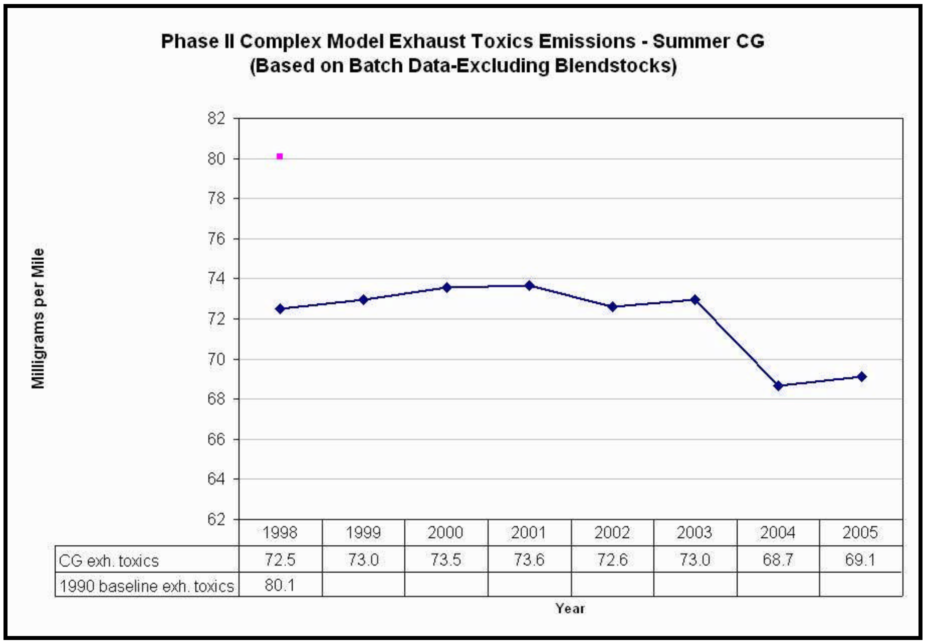
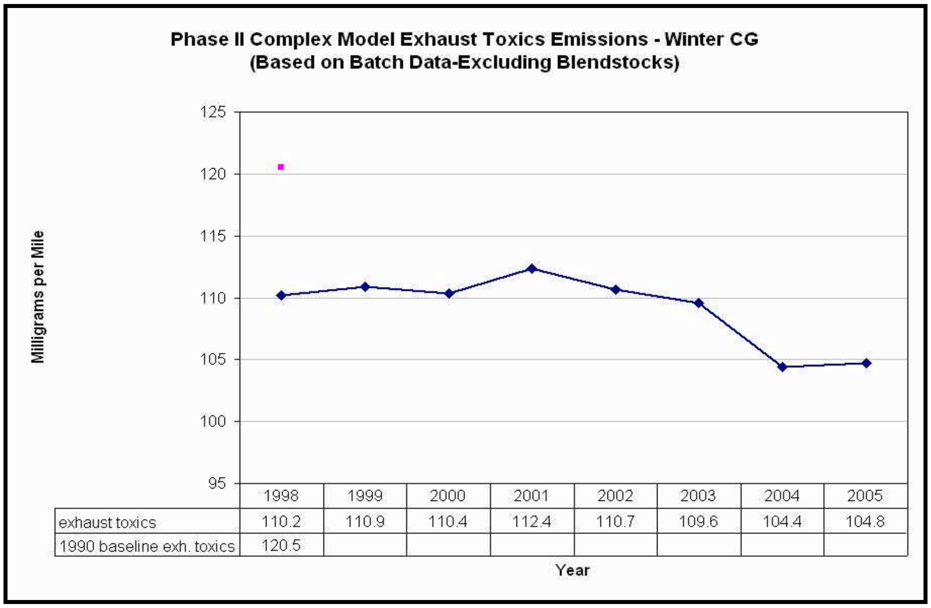
[18] Beginning in 2007, NOx emission standards were, with some exceptions, eliminated for CG refiners and importers. The gasoline sulfur program will become the sole regulatory mechanism used to implement gasoline NOx requirements. See 82 FR 8427.

[19] The properties of the Summer Baseline gasoline were specified in the Clean Air Act. EPA regulations specified the properties of Winter Baseline gasoline. The term statutory baseline gasoline is used here to refer to both the Summer and Winter .



	1998	1999	2000	2001	2002	2003	2004	2005
CG exh. toxics	72.5	73.0	73.5	73.6	72.6	73.0	68.7	69.1
1990 baseline exh. toxics	80.1							

Figure 2



	1998	1999	2000	2001	2002	2003	2004	2005
exhaust toxics	110.2	110.9	110.4	112.4	110.7	109.6	104.4	104.8
1990 baseline exh. toxics	120.5							

Figure 3

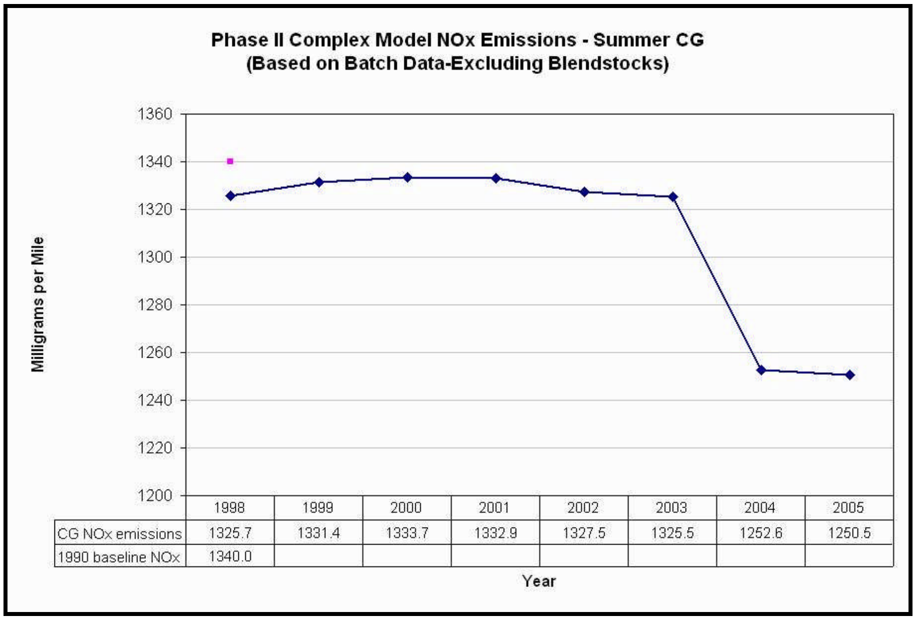


Figure 4

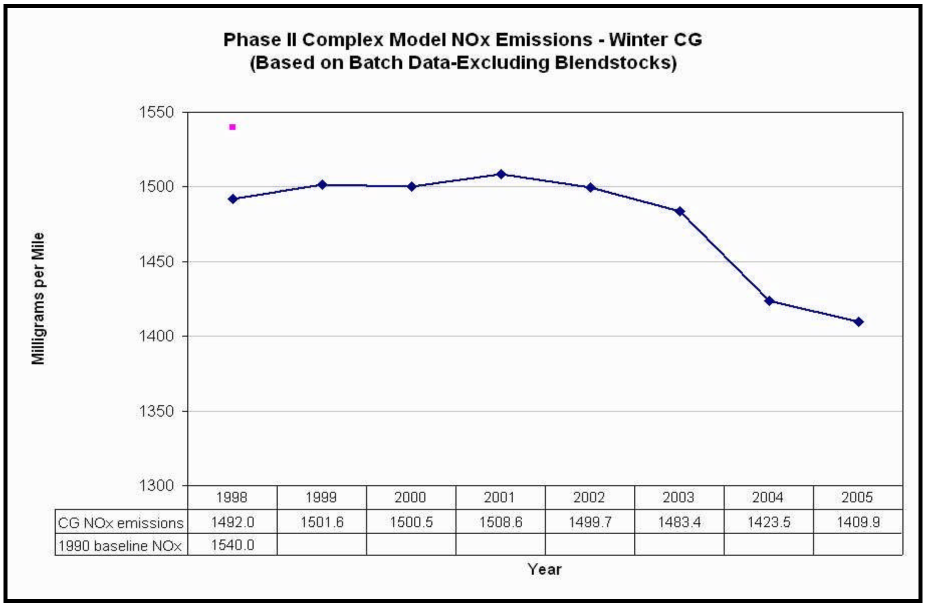


Figure 5

Comparison with RFG

The data that EPA collects allow a comparison of CG and RFG Complex Model emissions on a year-by-year basis. This is particularly interesting since CG emissions performance has improved as a result of Tier 2 sulfur reduction requirements, and the sulfur levels in CG and RFG are converging. While CG average sulfur levels in 2005 were still higher than RFG levels in that year, they were much lower than the sulfur levels typically needed to comply with Phase II RFG emissions performance standards.

Figures 6 through 10 compare RFG and CG in several ways using the "percent reduction" emission performance measures normally applied to RFG. EPA calculated both CG and RFG VOC, total toxics and NOx emission reductions from 1990 statutory baseline gasoline. CG reductions from baseline can be compared to RFG reductions from baseline and to RFG performance standards which are specified as reductions from these 1990 baselines. (Each graph shows the "averaged" RFG performance standard.) Summer VOC and Summer total toxics calculations and RFG standards depend on a geographic VOC control region specification. For these two parameters, EPA compared CG to VOC Control Region 2 (i.e. "Northern") RFG, and calculated CG emissions using the Region 2 version of Complex Model. RFG emission reductions were also calculated relative to average CG emissions in each year. These results, shown as dashed lines in each graph, allow direct comparison of RFG with its contemporary CG.

These graphs show that while CG emissions performance is improving relative to RFG, RFG emission performance remained superior for each pollutant and season combination. Summer CG's VOC performance has improved because sulfur reductions lower exhaust VOC emissions. (Sulfur reductions do not lower non-exhaust VOC's, which are directly related to the Reid Vapor Pressure (RVP) parameter.) Winter CG has met RFG's Winter NOx standard in each year analyzed. Summer CG is approaching RFG's Summer NOx standard.

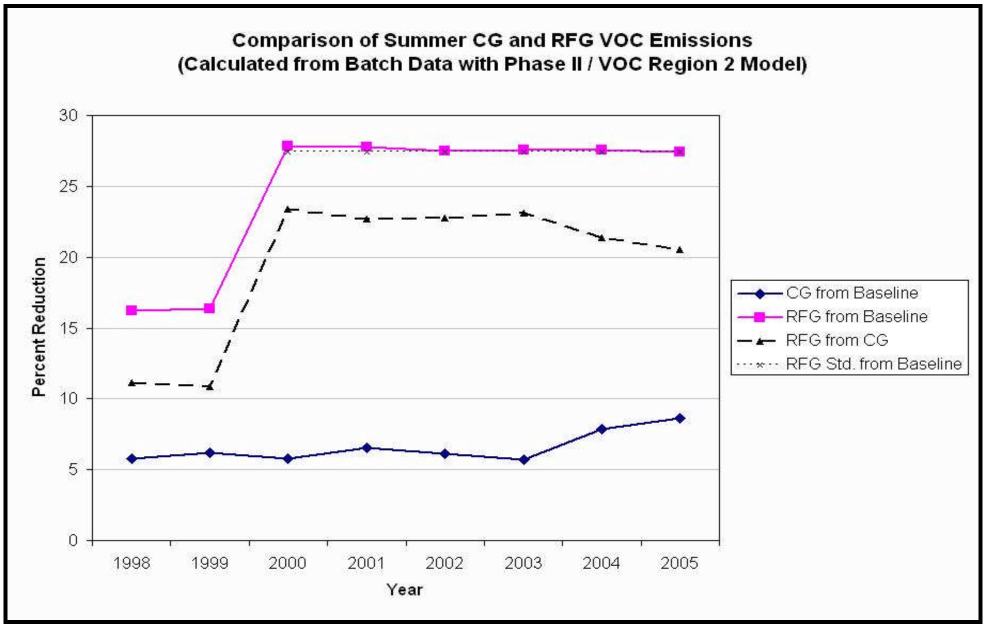


Figure 6

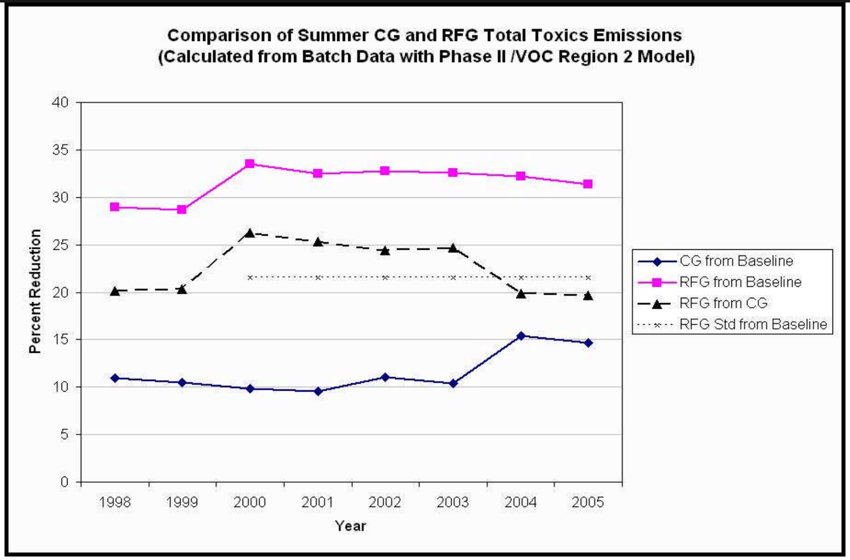


Figure 7

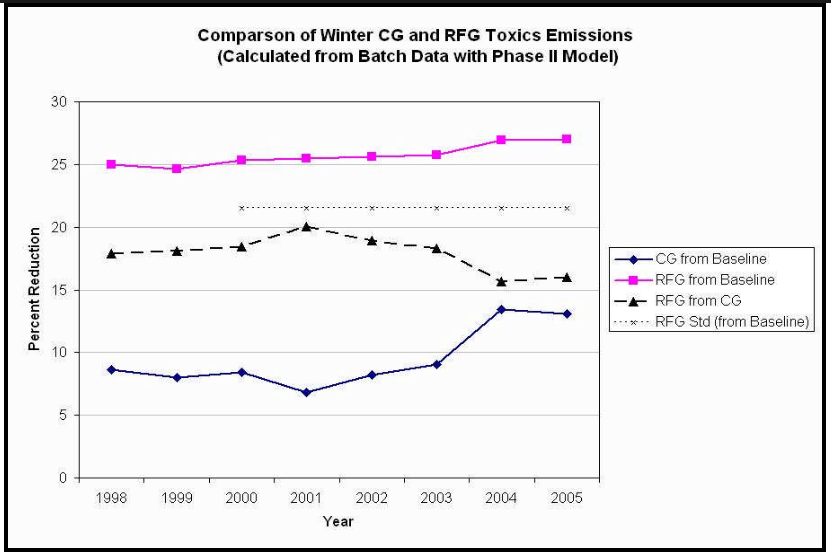


Figure 8

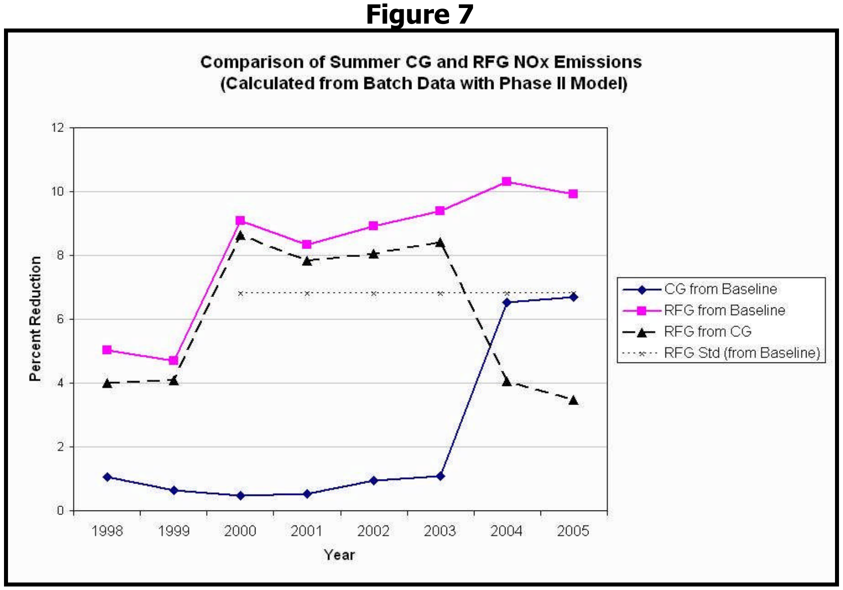


Figure 9

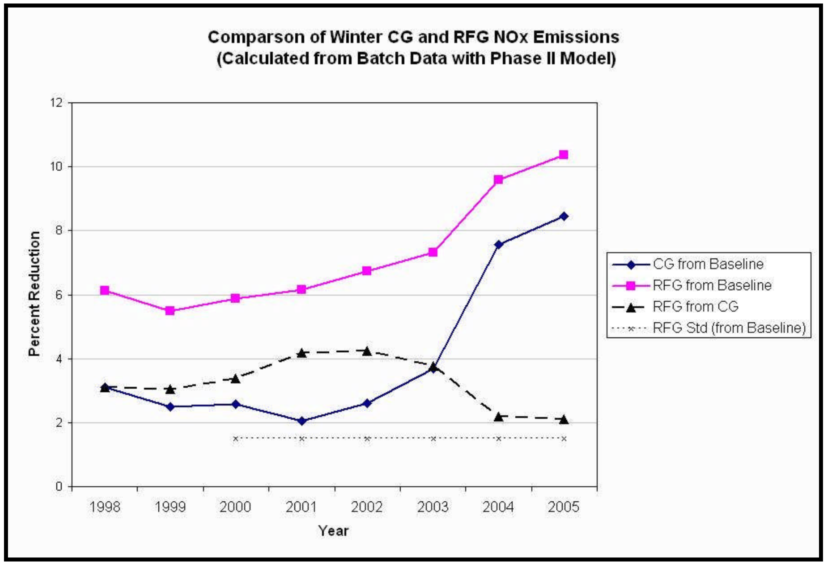


Figure 10

Sulfur

Background

Sulfur in gasoline originates in the crude oil used to produce the gasoline, and the sulfur content of crude oil varies substantially. (Crude oil with low sulfur content is classified as "sweet crude".) Historically, high sulfur content in gasoline has been considered undesirable for reasons unrelated to vehicle emissions. Sulfur oxides formed during combustion may be converted to acids that promote corrosion of engine parts and exhaust systems. ASTM Standard D4814, first published in 1988, limited sulfur content in unleaded gasoline to 0.10 mass percent (equivalent to 1000 parts per million) to protect against engine wear, deterioration of engine oil and corrosion of exhaust system parts.

More recently, gasoline sulfur content has been a concern because of emission-related effects. Sulfur affects gasoline vehicle emissions primarily because it adversely affects catalytic converters. Reductions in gasoline sulfur content can reduce NOx, exhaust toxics and exhaust VOC emissions in the "1990 technology" vehicles used to develop the Complex Model. The phase-in of stringent Tier 2 tailpipe emission standards began in 2004, along with the phase-in of the Tier 2 gasoline sulfur regulations. Vehicles designed to meet these standards are particularly sensitive to sulfur and gasoline with reduced sulfur content is necessary to enable the emission control systems in these vehicles to be fully effective. Emission-related regulatory requirements have resulted in substantial sulfur reductions.

Gasoline is produced by blending several components, produced from different processes within a refinery. The component from the Fluid Catalytic Cracking (FCC) unit typically has much higher sulfur content than other components used in gasoline blending unless it is treated to remove sulfur. In the past, refineries have largely relied on a process called hydro treating to reduce sulfur, when necessary. However, conventional hydro treating results in a substantial loss of octane in the FCC gasoline. EPA's Tier 2 sulfur reduction requirements have helped spur the development and implementation of modifications or alternatives to conventional hydro treating. These processes allow removal of sulfur while minimizing economically adverse consequences such as octane or volume loss.

Regulatory Limits on Sulfur Content

EPA's RFG and Anti-Dumping regulations have imposed both direct and indirect limits on gasoline sulfur content. The Tier 2 gasoline sulfur regulations also impose direct gasoline sulfur limits on RFG and CG. The regulatory requirements that have affected gasoline sulfur content are discussed below.

RFG Sulfur Limits

The Simple Model, which was the basis for RFG emission performance standards through 1997, did not consider the effect of sulfur on emissions, nor did it evaluate NOx emissions performance, which is sensitive to gasoline sulfur content. However, the annual average level for sulfur was not allowed to exceed a refinery's or importer's 1990 baseline level. Hence, although the RFG regulations prior to 1998 neither required nor rewarded sulfur reduction, the regulations prevented any substantial increase in sulfur levels in RFG.

Between 1997 and 1998, EPA transitioned from the Simple Model to the Phase I Complex Model for assessing the emission performance of RFG. This transition introduced several factors that affected RFG sulfur content:

- RFG was subject to NOx and VOC performance standards, as well as a toxics performance standard and the new model recognized that lowering gasoline sulfur reduced emissions of all of these pollutants.

- Each RFG batch was required to have a sulfur content at or below a 500 ppm model range limit.

Phase II RFG, introduced in 2000, required additional NOx, toxics and VOC emission reductions. EPA only required Phase I RFG to meet, on a per-gallon basis, the NOx performance of 1990 baseline gasoline's with sulfur levels of 338 (Winter) and 339 (Summer) ppm. However, for Phase II, EPA required Summer RFG to have NOx emission performance 5.5 percent better on a per gallon basis, (or 6.8 percent better on average), than this Summer baseline gasoline. It is generally accepted that this more stringent Phase II NOx performance standard necessitated a reduction in average Summer RFG sulfur levels.

CG Sulfur Limits

Prior to 1998, EPA prohibited the annual average sulfur level in CG from exceeding 125% of a refinery's or importer's 1990 baseline. For 1998 and later, EPA prohibited annual average exhaust toxics and NOx emissions from exceeding the refiner or importer's 1990 baselines for these emissions. Additionally, the annual average CG sulfur levels were not allowed to exceed the greater of 1000 ppm (the model range limit for CG) or the refiner or importer's 1990 sulfur baseline.

All Gasoline

The Tier 2 sulfur reduction standards, applicable to both RFG and CG, require a phased reduction in gasoline sulfur content beginning in 2004. The standards applying to most refiners and importers for 2004 are a 120 ppm corporate pool average and a 300 ppm per gallon cap. In 2005, the standards include a refinery or importer average of 30 ppm as well as a 90 ppm corporate pool average and a 300 ppm per gallon cap. Since 2006, the standards include a 30 ppm refinery or importer average with an 80 ppm per gallon cap. The Tier 2 requirements contain certain exceptions to the above requirements for small refiners and for “geographic phase-in “ areas, so the full impact of the regulation on gasoline sulfur levels will not be realized until later than 2006. However, the gasoline sulfur regulations also contain various Averaging Banking and Trading (ABT) provisions, including mechanisms for credit generation for sulfur reductions which occurred as early as year 2000. Thus, the Tier 2 requirements potentially impacted sulfur levels prior to the phase in of the standards.

In summary, the Tier 2 requirements will result in substantial reductions in gasoline sulfur content. The Tier 2 company-wide annual average sulfur requirement of 120 ppm, applicable in 2004, is comparable to the average sulfur content in Phase II Summer RFG in 2000, before the impact of the Tier 2 sulfur regulations, and substantially lower than the sulfur content of Winter RFG. The Tier 2 sulfur reduction requirements are more stringent than the sulfur reductions generally needed to comply with RFG emission performance standards or with Anti-Dumping program regulations applicable to CG. [20] Consequently, the Tier 2 requirements became the dominant federal constraint on gasoline sulfur levels by 2004. (California's gasoline requirements and a few other state regulatory requirements applicable to specific localities do restrict sulfur more tightly than the 2004 Tier 2 standards.)

EPA's Sulfur Data

Sulfur data for both RFG and CG are currently necessary to determine compliance with EPA's regulations. Thus, refiners and importers have been required to submit this information to EPA's RFG/Anti-Dumping reporting system for each batch of gasoline refined or imported. Additionally, since 1998, EPA has received RFG Survey data on the sulfur content of RFG sold at gasoline stations. (Since sulfur was not part of the Simple Model, Compliance was not needed with survey standards until 1998)

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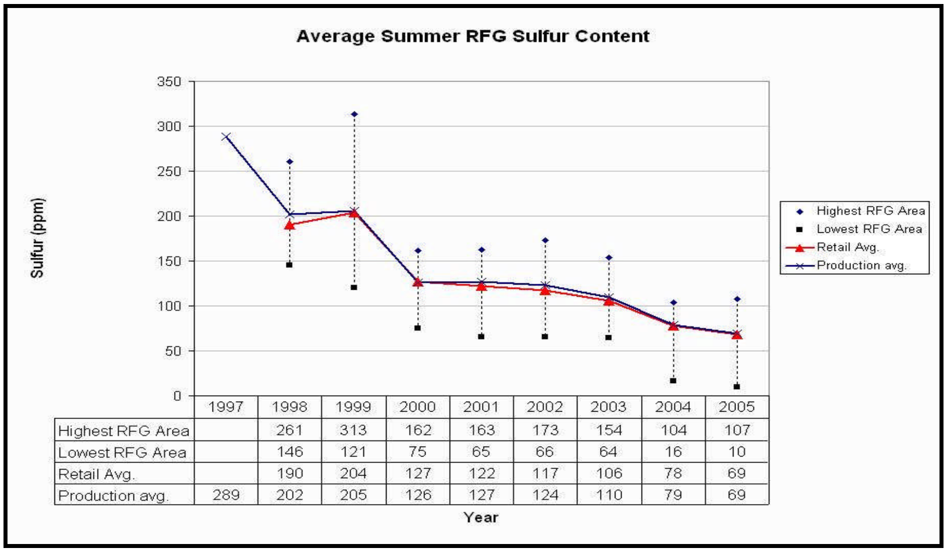
[20] In fact, beginning in 2007 the NOx emission performance and emission requirements were eliminated, with certain exceptions, for RFG and CG since the mandated sulfur reductions made them unnecessary. See 82 FR 8427.

Sulfur Trends

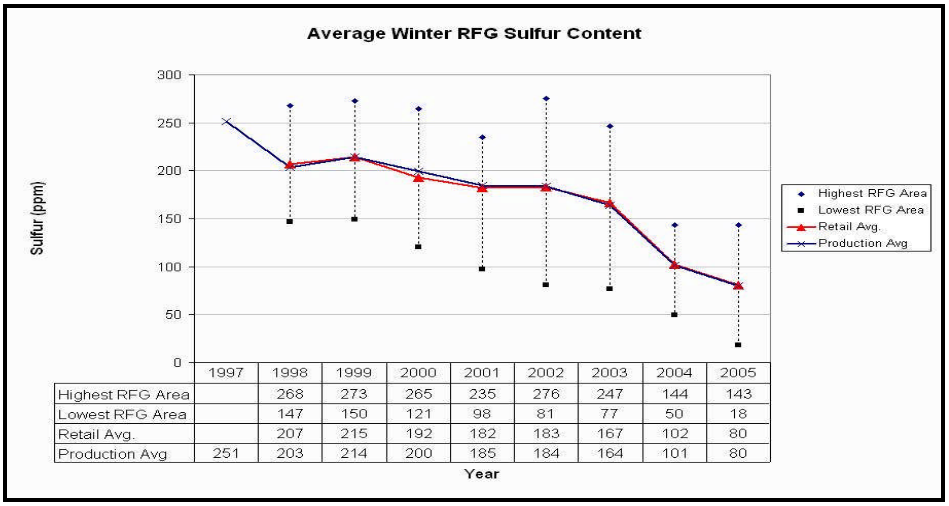
Overview-Reformulated Gasoline

Volume-weighted average RFG Sulfur levels, by year, are shown in Figures 1 (Summer) and 2 (Winter). Both reporting system estimates, by reporting year, and survey-based retail estimates, by survey year are shown. Summer and Winter RFG sulfur levels exhibit clear downward trends. Both Summer and Winter sulfur levels declined sharply between 1997 and 1998 with the transition from Simple Model to Complex Model RFG. As noted, the need to comply with a 500 ppm sulfur limit, and the introduction of new performance standards along with a model that considers the emission effect of sulfur influenced this decline. EPA determined that about 17% of Summer and 12% of Winter RFG refined and imported in 1997 exceeded the 500 ppm sulfur limit applicable in 1998 and later years, with some batches exceeding 1000 ppm. Although EPA did not quantify the extent to which 1997 RFG exceeded the NOx standard applicable to 1998 RFG, it is reasonable to assume that the 1998 NOx standard contributed to the need for these 1997 to 1998 sulfur reductions. (Since sulfur has such a strong influence on Complex Model NOx calculations, the effects of the range limit and the NOx standard on this sulfur reduction are likely hard to separate.)



	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area		261	313	162	163	173	154	104	107
Lowest RFG Area		146	121	75	65	66	64	16	10
Retail Avg.		190	204	127	122	117	106	78	69
Production avg.	289	202	205	126	127	124	110	79	69

Figure 1



	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area		268	273	265	235	276	247	144	143
Lowest RFG Area		147	150	121	98	81	77	50	18
Retail Avg.		207	215	192	182	183	167	102	80
Production Avg	251	203	214	200	185	184	164	101	80

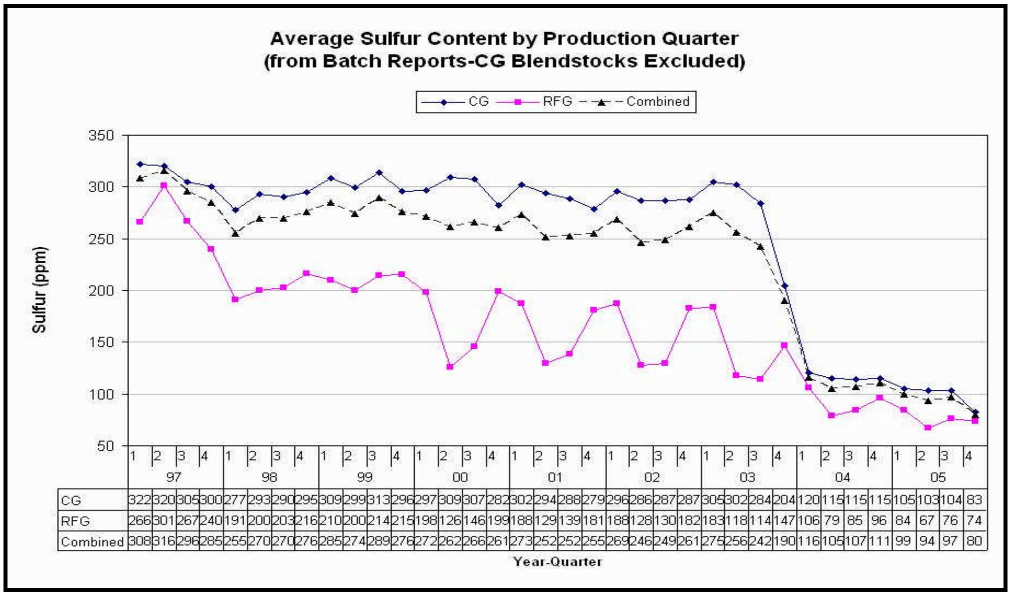
Figure 2

Summer RFG shows a second sharp sulfur decline between 1999 and 2000 with the transition from Phase I to Phase II RFG. Although Winter RFG sulfur levels declined as well, the change was much smaller. The Summer sulfur decrease is largely attributable to the more stringent NOx performance standard. Since the Winter NOx performance standard did not become more stringent, winter sulfur declines may not have been driven by the need to comply with NOx performance standards. However, NOx performance did improve, in part, as a result of these sulfur reductions (see the RFG Trends chapter.)

Both Summer and Winter RFG show decreasing sulfur levels between 2000 and 2004. The first of the phased-in Tier 2 sulfur standards necessitated sulfur reductions by 2004. Since the Tier 2 regulation, through credit generation, provided some incentive for sulfur reduction as early as 2000, it may also have affected sulfur levels in each of the interim years.

Figures 1 and 2 separately analyze changes in sulfur levels, by reporting and survey year, for Summer and Winter gasoline. Regardless of the production date reported for a batch, a batch was categorized as Summer gasoline if it was designated VOC-controlled, and Winter gasoline if it was designated non-VOC-controlled. Survey data were categorized as Summer for surveys conducted between June 1 and September 15, and Winter for surveys conducted before or after that date. Thus, for any year, the Winter RFG in this analysis is largely a mix of gasoline produced before and after each VOC season.

Quarterly averages more precisely show how sulfur levels varied with time. Figure 3 presents reporting system average sulfur levels calculated by calendar quarter based on the production date reported for each batch.



	97				98				99				00				01				02				03				04				05			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
CG	322	320	305	300	277	293	290	295	309	299	313	296	297	309	307	282	302	294	288	279	296	286	287	287	305	302	284	204	120	115	115	115	105	103	104	83
RFG	266	301	267	240	191	200	203	216	210	200	214	215	198	126	146	199	188	129	139	181	188	128	130	182	183	118	114	147	106	79	85	96	84	67	76	74
Combined	308	316	296	285	255	270	270	276	285	274	289	276	272	262	266	261	273	252	252	255	269	246	249	261	275	256	242	190	116	105	107	111	99	94	97	80

Figure 3

The lowest line, representing the RFG averages, shows that, for the years 1997 and 2003, 4th quarter sulfur averages were lower than 1st quarter, indicating that sulfur reductions needed to comply with standard changes in 1998 and 2004 were implemented, in part, during the year preceding the standard change. The timing of these sulfur reductions was likely influenced by concerns about "downstream" compliance (i.e., compliance at locations in the distribution system subsequent to the refinery or import facility). The Complex Model sulfur range limit, which drove the 1997 to 1998 sulfur reduction, was potentially enforceable as a downstream standard since it applied to every batch of RFG, although EPA exercised enforcement discretion in this matter. Since the Tier 2 regulations also included various downstream standards for sulfur, refineries and importers may have chosen to reduce sulfur levels during late 2003 to ensure compliance with these standards, as well as to generate sulfur credits. Additionally, there was uncertainty associated with the desulphurization technologies which would be needed to meet the Tier 2 standards economically. Thus, refiner's schedules for selection and implementation of new desulphurization processes, which were not fully proven technology when the Tier 2 regulations were finalized in 2000, also affected the timing of these sulfur reductions. For example, this may have made early sulfur reductions infeasible for some refineries even if the ABT program provided some incentive for such reductions. On the other hand, refineries probably had some incentive to get these processes operational earlier than needed for downstream compliance in order to ensure that there were no technical problems.

Figure 3 also shows the cyclical effect of the more stringent Summer NOx emissions performance standard on Phase II RFG sulfur levels, with quarters 2 and 3 lower than quarters 1 and 4 within each year of the Phase II RFG program. Even though the Tier 2 requirements presumably limited the rise in sulfur between the 3rd and 4th quarters of 2003, the cyclical effect is still apparent.

RFG Sulfur by PADD

Table 1 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information):

2004 & 2005 Reporting Average by PADD-RFG Sulfur (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (ppm)**	**Gasoline Volume (gal)***	**Average Value (ppm)**	**Gasoline Volume (gal)***
Summer	I	91	4,792,114,891	73	4,430,958,220
	II	78	1,740,499,436	64	1,844,913,833
	III	73	5,890,920,167	78	5,690,766,967
Winter	I	118	6,489,530,475	90	7,081,940,665
	II	93	2,436,636,058	78	2,718,751,541
	III	101	6,059,647,031	83	5,766,524,033
Annual	I	107	11,281,645,366	84	11,512,898,885
	II	87	4,177,135,494	72	4,563,665,374
	III	87	11,950,567,198	81	11,457,291,000

*Volumes exclude batches with missing values for this parameter

Table 1

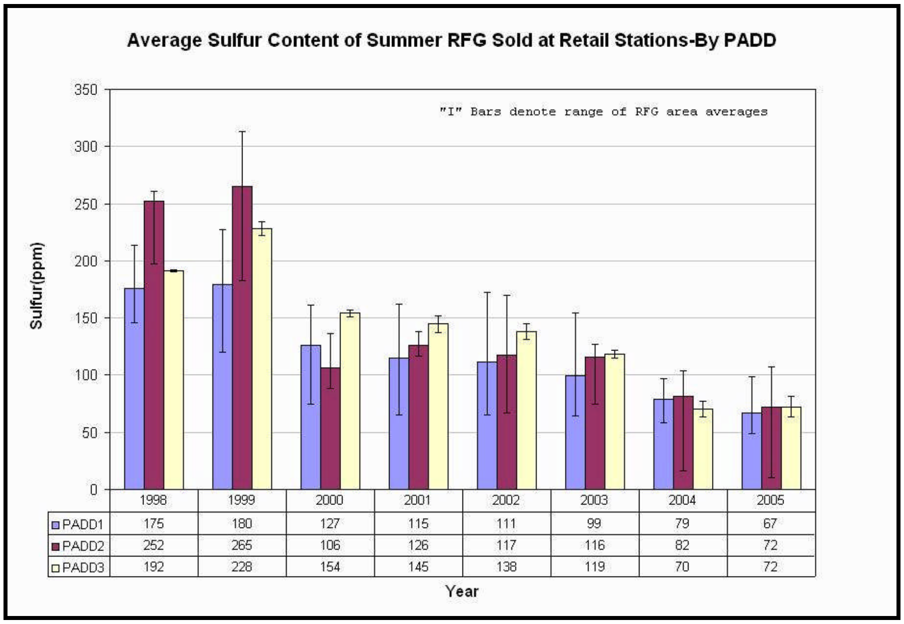


Figure 4

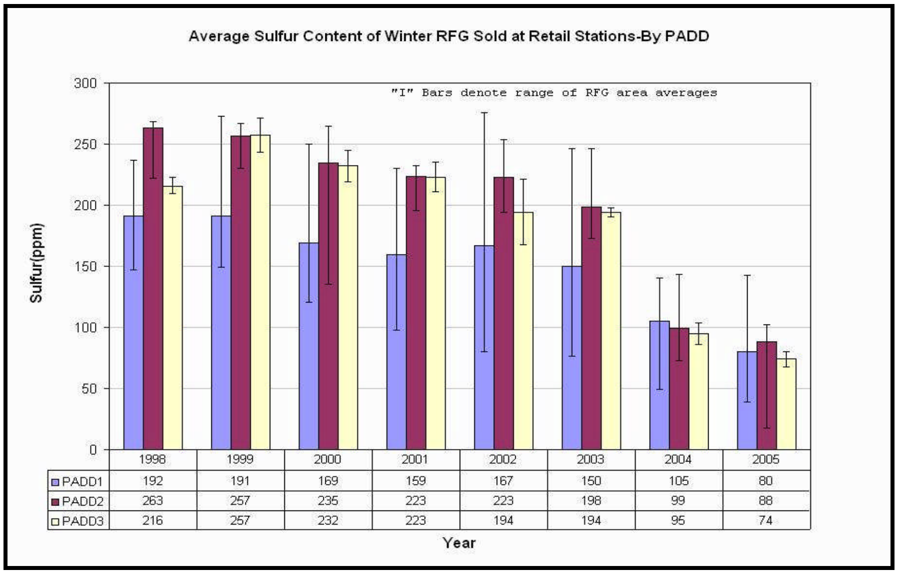


Figure 5

Additional Analysis and Observations-RFG

Data analyses pertaining to RFG sulfur are contained in the Appendix to this chapter. Several trends or patterns are highlighted below:

- Average sulfur content in premium grade RFG has been consistently lower than in regular RFG. [21]

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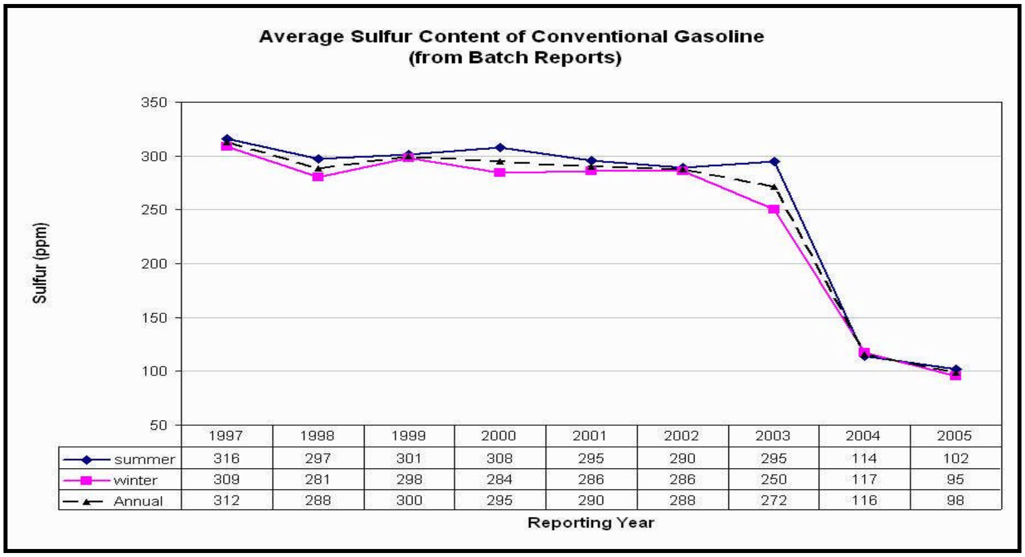
[21] As noted, removing sulfur from the FCC gasoline component could result in an octane loss. Consequently, it may seem counter-intuitive that higher octane premium RFG had lower sulfur content than regular grade. However, the lower sulfur content in premium RFG depends on the percentages of other blending components used to meet octane requirements. For example, refiners typically choose to blend more reformate, a high octane and low sulfur blending component, into premium gasoline.

- Average sulfur content of Summer and Winter RFG sold at retail outlets decreased between 2000 and 2005 in all areas surveyed in both years.

Overview-Conventional Gasoline

Volume-weighted average CG sulfur levels, by reporting year, are shown in Figure 6. Summer and Winter averages are shown separately on the same graph. Both Summer and Winter sulfur levels decreased from 1997 to 1998, with the transition from annual average sulfur content standards to Complex Model-based annual average exhaust toxics and NOx emission standards. Although both standards were derived from refinery and importer individual baselines, the 1998 standards may have acted to reduce gasoline sulfur since they required emissions equal to the refinery or importer's compliance baseline, while the 1997 standards allowed annual average sulfur content up to 125% of the refinery or importer's baseline. Additional analysis would be needed to confirm this effect.



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summer	316	297	301	308	295	290	295	114	102
winter	309	281	298	284	286	286	250	117	95
Annual	312	288	300	295	290	288	272	116	98

Figure 6

The Winter CG sulfur level decreased between 2002 and 2003, while the Summer level increased slightly. This divergence of the Summer and Winter averages is a consequence of the timing of sulfur reductions in advance of the Tier 2 standards. Similarly to RFG, the CG in this analysis was categorized as Summer gasoline, regardless of production date, if it was designated as volatility-controlled, and Winter gasoline if it was designated as non-volatility-controlled. Thus, Winter CG is largely a mix of gasoline produced before and after each volatility control season. The need to comply with downstream standards in 2004 would not have affected sulfur levels in volatility-controlled CG produced during 2003, but would likely have affected sulfur levels in non-volatility-controlled gasoline produced late in 2003. Figure 3 also shows average CG sulfur levels, by production quarter (upper line). CG sulfur content dropped during 2003 with a large decrease between the 3rd and 4th quarters of 2003. Again, this is consistent with the opportunity for sulfur credit generation, the existence of downstream standards under the Tier 2 regulation and the need to implement new sulfur reduction technology.

CG Sulfur by PADD

Table 2 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information):

2004 & 2005 Reporting Average by PADD-CG Sulfur (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (ppm)**	**Gasoline Volume (gal)***	**Average Value (ppm)**	**Gasoline Volume (gal)***
Summer	I	125	3,752,272,894	108	3,520,575,616
	II	140	11,345,514,515	121	10,460,517,681
	III	108	21,712,599,435	98	20,882,654,793
Winter	I	138	3,480,957,004	110	4,040,674,006
	II	135	13,169,031,421	117	13,447,545,074
	III	115	23,618,950,103	86	22,432,331,959
Annual	I	131	7,233,229,898	109	7,561,249,622
	II	137	24,514,545,936	119	23,908,062,755
	III	111	45,331,549,538	92	43,314,986,752

*Volumes exclude batches with missing values for this parameter

Table 2

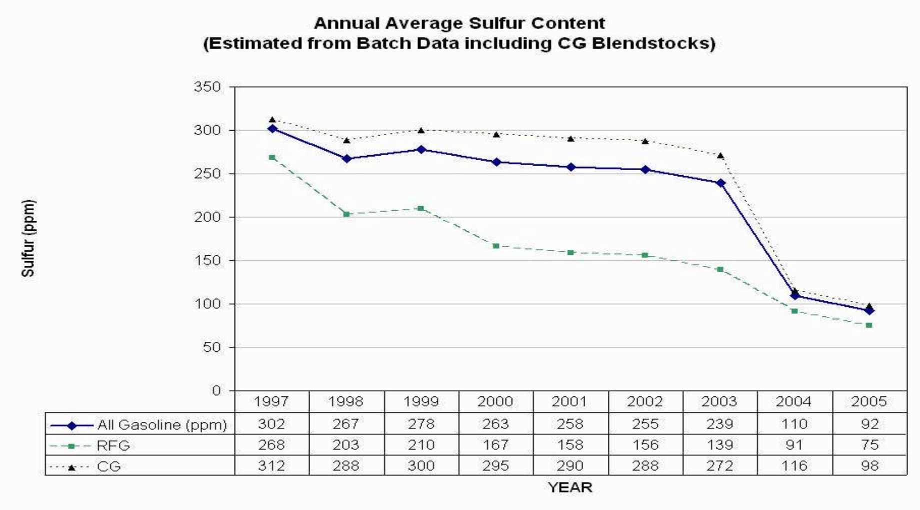
Additional Analyses and Observations-CG

The sulfur content of Summer Baseline Gasoline, as specified in the Clean Air Act, is 339 parts per million (ppm), and the sulfur content of Winter baseline gasoline, as specified by EPA's regulations, is 338 ppm. Data analyses pertaining to CG sulfur are contained in the Appendix to this chapter. These data include tabular and graphical descriptions of CG sulfur content by volume and grade which show:

- In 1997, the first year for which sulfur reporting data were analyzed, the median Summer sulfur content was 264 ppm and the 1990 baseline gasoline fell between the 60th and 65th percentile.
- In 2005, the last year for which sulfur reporting data were analyzed the median Summer sulfur content was 76 ppm and the 1990 baseline gasoline fell above the 98th percentile.
- In 1997 the median Winter sulfur content was 253 ppm and the 1990 baseline gasoline fell between the 60th and 65th percentile.
- In 2005 the median Winter sulfur content was 64 ppm and the 1990 baseline gasoline fell above the 98th percentile.
- The sulfur content of premium grade CG has been lower than that of regular grade in each year and season.

Overview-All Gasoline

For the most part, this report has separately analyzed property trends by gasoline type and season. The Tier 2 gasoline sulfur regulations do not distinguish between RFG and CG and make no seasonal distinctions, but prescribe annual average standards. Consequently, it is appropriate to look at sulfur trends in the entire gasoline pool and on an annual basis. Figure 3 shows quarterly averages for RFG and CG combined (middle line). Figure 7 shows annual average sulfur levels for CG and RFG combined. The only year-to-year increase in sulfur content occurred between 1998 and 1999, when both RFG and CG sulfur content increased. There is no apparent regulatory explanation for these increases.



	1997	1998	1999	2000	2001	2002	2003	2004	2005
All Gasoline (ppm)	302	267	278	263	258	255	239	110	92
RFG	268	203	210	167	158	156	139	91	75
CG	312	288	300	295	290	288	272	116	98

Figure 7

Aggregated sulfur content distributions by gasoline volume for 2005 are shown in Table 3, below:

2005 Sulfur Content (ppm) by Volume
(from Batch Reports excluding CG blendstocks)

Volume %tile	**CG**	**RFG/RBOB**	**ALL**
minimum	0	0	0
5%	8	9	8
10%	16	18	16
15%	21	24	22
20%	25	29	26
25%	30	35	31
30%	36	41	38
35%	44	46	45
40%	52	51	51
45%	60	56	59
50%	70	61	67
55%	80	68	76
60%	93	74	87
65%	107	82	98
70%	125	91	112
75%	147	101	130
80%	172	114	152
85%	201	127	180
90%	233	147	215
95%	264	178	254
100%	478	371	478
Volume(gal):	90,897,009,258	32,128,092,630	123,025,101,888

Table 3

Reid Vapor Pressure (RVP)

Background

RVP relates to gasoline's volatility, a gasoline's ability to change from a liquid to a vapor. More specifically, RVP is a measure of vapor pressure of gasoline at 100°F, using a prescribed test method. Gasoline volatility characteristics are important because they affect both vehicle performance and emissions. RVP affects both exhaust and evaporative emissions; however, RVP is significant from an emissions standpoint primarily because it directly relates to evaporative emissions of volatile organic compounds (VOCs). VOC emissions are involved in the atmospheric chemical reactions that form ground level ozone, an air pollutant, in the presence of sunlight and oxides of nitrogen. VOC emissions, hence RVP, are of particular significance from an air quality standpoint during the Summer season. RVP is one of the Complex Model input parameters used to calculate exhaust VOC emissions, and it is the only parameter affecting the model's evaporative VOC calculations. Since RVP is important to vehicle performance on a year-round basis, ASTM specifies RVP standards for gasoline.

Regulatory Limits on RVP

Several regulatory requirements indirectly or directly limit the RVP level in reformulated and conventional supplied during late spring and summer when ozone is likely to be a problem. Because RVP is an input parameter to the Complex Model, it is indirectly limited through Complex Model-based emission standards. RVP is also directly limited through regulations which prescribe maximum levels for RVP in gasoline (40 C.F.R. '80.27). The current volatility standards have been in effect since 1992, predating the RFG and Anti-Dumping regulations.

The RVP limits prescribed in the volatility regulations are 9.0 psi or 7.8 psi, depending on the location and specific month within the regulatory control period (May 1 to September 15 for refineries and terminals, June 1 to September 15 for retail outlets). These volatility limits do not apply to gasoline sold in Alaska, Hawaii and US territories, and gasoline containing between 9% and 10% ethanol by volume may exceed the applicable standard by 1.0 psi.

Although the volatility regulations technically apply to RFG as well as CG, RFG regulations effectively require RVP levels below those allowed under the volatility regulations. Under the RFG regulations, refiners and importers must designate RFG produced or imported for use during the VOC control period (the same period as the regulatory control period for volatility) as VOC-controlled, and all other RFG as non-VOC-controlled. Different requirements, or "standards," apply to VOC-controlled RFG depending on whether the gasoline is intended for use in VOC-Control Region 1 (VOC1), which generally includes southern RFG areas, or VOC-Control Region 2 (VOC2), which includes northern RFG areas. Refiners and importers must specify whether a VOC-controlled batch is intended for sale in VOC1 or VOC2. The RVP in VOC-controlled RFG supplied prior to 1998 was directly controlled through specific RVP standards. RFG for VOC1 was required to meet a 7.2 psi "per gallon" standard, or alternatively a 7.1 psi "averaged" standard with a 7.4 psi per gallon maximum. RFG for VOC2 was required to meet an 8.1 psi "per gallon" standard, or an 8.0 psi "averaged" standard with an 8.3 psi per gallon maximum.

Complex Model RFG requirements do not include RVP standards. However, the RVP in the "Complex Model" VOC-controlled RFG supplied since 1998 is indirectly controlled through emissions performance standards. RFG designated as VOC-controlled is required to meet certain VOC emission reduction standards relative to a "statutory baseline" gasoline, representative of gasoline supplied in 1990, with different VOC standards for VOC Control Regions 1 and 2. [22] Although other gasoline

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[22] The Energy Policy Act of 2005 requires that EPA consolidate these separate standards.

parameters also affect Complex Model VOC emission performance, RVP reduction from the statutory baseline level of 8.7 psi is the primary means to achieve these VOC reduction standards; hence these VOC standards indirectly, but tightly, limit RVP in RFG. The VOC emissions reduction standards became more stringent in 2000 with Phase II RFG. The "averaged" VOC standards specify per gallon minimum VOC reductions as well as average reductions. As a result, the RFG emissions performance standards not only constrain average RVP levels below those permitted by the volatility regulations, but generally constrain maximum RVP levels as well.

As discussed above, CG RVP levels are directly limited by EPA's volatility regulations. CG supplied since 1998 is also subject to refiner/importer baseline-specific anti-dumping exhaust toxics and NOx emission requirements calculated by the Complex Model. However, while RVP affects both exhaust toxics and NOx calculations to some extent, CG emission requirements for exhaust toxics and NOx may not have a significant limiting effect on RVP.

In addition to the federal fuel regulations affecting RVP, certain states and localities have unique gasoline specifications for RVP and/or other parameters. Such gasoline's have been referred to as “boutique” fuels, and include gasoline subject to 7.0 psi or 7.2 psi RVP standards.

EPA's RVP Data

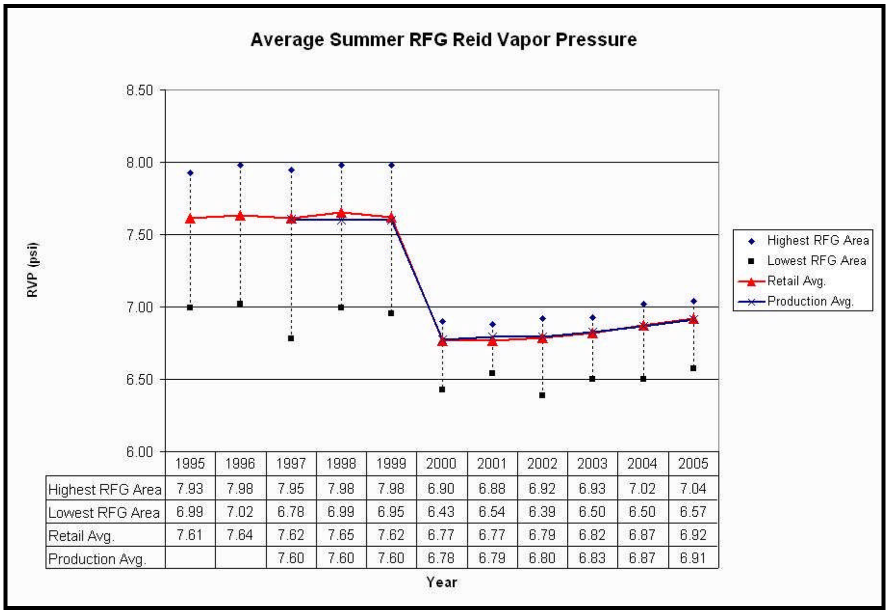
EPA collects RVP data in order to determine compliance with the RFG and Anti-Dumping regulations. RVP values are necessary for the Summer Complex Model emission calculation for VOC-controlled RFG. As a result, refiners and importers have been required, since 1995, to submit RVP data for VOC-controlled RFG to EPA's RFG/Anti-Dumping reporting system for each batch of gasoline refined or imported. Additionally, since 1995, EPA has received RFG Survey data on the RVP of RFG sold at retail outlets during the VOC control period, June 1 to September 15. Refiners and importers are not required to report the RVP for RFG designated as non-VOC-controlled. This is because the Winter version of the Complex Model, used to determine compliance for non-VOC-controlled RFG, does not require the RVP of the gasoline being evaluated as an input. As a result, EPA has only limited RVP data for Winter RFG. Winter RFG Survey data reported to EPA also do not include RVP values. Since EPA has only limited Winter RFG RVP data, this report does not include analysis of these data.

EPA's data collection requirements for CG have differed from RFG both temporally and seasonally. Whereas RVP values have been required for determining RFG compliance since 1995, they were not required for CG compliance calculations until 1998, with the introduction of Complex Model-based exhaust toxics and NOx emission standards. Although these standards are for exhaust emissions only, the RVP value is needed for the Summer Complex Model exhaust calculation. Therefore, the RVP value is needed to determine compliance for Summer CG. As discussed above, the actual RVP of the gasoline is not used in Winter Complex Model emission calculations. However, the RVP value is also needed to determine compliance for Winter CG. EPA's regulations specify that the correct model (Summer or Winter) for evaluating the emissions performance of CG depends on its RVP value. Therefore, the RVP of each batch of CG is needed to verify that the correct model was used for the batch. As a result, refiners and importers have been required, since 1998, to submit RVP data to EPA's reporting system for each CG batch, whether or not the batch was produced or imported for use during the regulatory control period specified in EPA's volatility regulations. Thus, this report includes analysis of both Summer and Winter CG RVP data.

RVP Trends

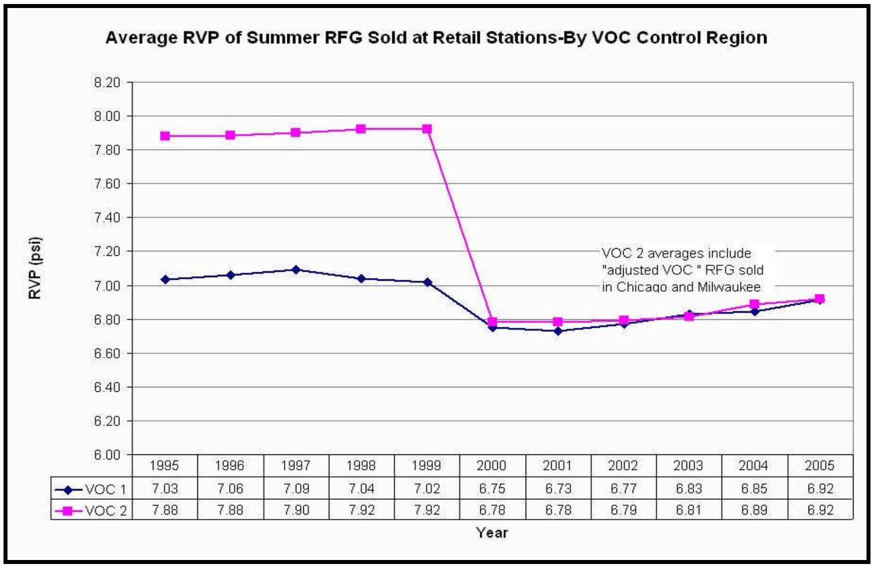
Overview-Reformulated Gasoline

Figure 1 shows volume-weighted average Summer RFG RVP levels, by year. Both reporting system estimates and survey-based estimates are shown. RVP levels were essentially unchanged with the transition from Simple Model to Phase I Complex Model RFG standards between 1997 and 1998. However, RVP decreased sharply between 1999 and 2000, with the transition from Phase I to Phase II standards. This decrease in RVP was necessary in order to meet Phase II RFG's more stringent VOC emission performance standards. Figure 2, using survey-based RVP estimates, shows that the Phase I to Phase II RVP decrease was much greater for VOC Control Region 2 RFG than for VOC Control Region RFG.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	7.93	7.98	7.95	7.98	7.98	6.90	6.88	6.92	6.93	7.02	7.04
Lowest RFG Area	6.99	7.02	6.78	6.99	6.95	6.43	6.54	6.39	6.50	6.50	6.57
Retail Avg.	7.61	7.64	7.62	7.65	7.62	6.77	6.77	6.79	6.82	6.87	6.92
Production Avg.			7.60	7.60	7.60	6.78	6.79	6.80	6.83	6.87	6.91

Figure 1

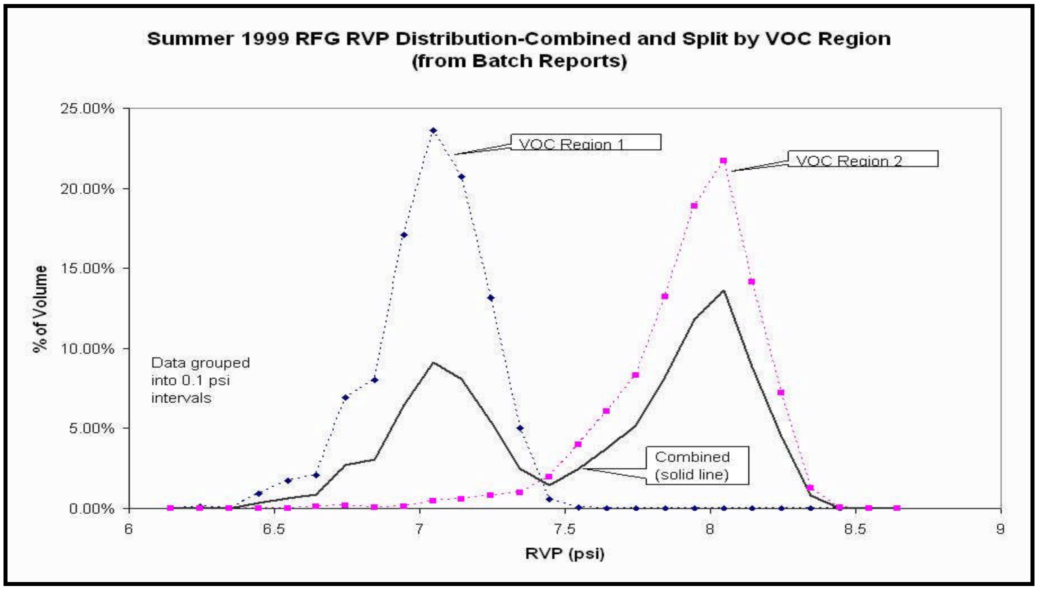


	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
VOC 1	7.03	7.06	7.09	7.04	7.02	6.75	6.73	6.77	6.83	6.85	6.92
VOC 2	7.88	7.88	7.90	7.92	7.92	6.78	6.78	6.79	6.81	6.89	6.92

Figure 2

Figure 3 shows that the frequency distribution of RVP by volume for all Summer 1999 RFG is bimodal; i.e. the “Combined” distribution has two distinct peaks. Separate frequency distributions for VOC1 and VOC2 RFG are also shown in Figure 3. They are clearly different with very little overlap in range, explaining the bimodal nature of the combined distribution. This RVP difference is a result of a more stringent VOC reduction standard applicable to VOC1 RFG during Phase I of the RFG program.

Figure 4 depicts the same analysis for Summer 2000 RFG. It is clear that there is little difference between the RVP distributions for VOC1 and VOC2. Although VOC1 RFG still has a numerically greater VOC emission reduction standard than VOC2 RFG, the difference is much smaller than in Phase I of the RFG program. Furthermore, the Complex Model evaluates VOC1 and VOC2 evaporative emissions differently. Since much of the apparent difference in VOC standards for the two regions is actually due to this model effect (See the "Emissions" Chapter), the RVP distributions for the two regions are very similar.


Summer 1999 RFG RVP Distribution-Combined and Split by VOC Region (from Batch Reports)

Data grouped into 0.1 psi intervals

Figure 3

The estimated average RVP levels in 2005 RFG are higher than in 2000 RFG. This increase is small, slightly above 0.1 psi; however both survey and reporting estimates show an upward trend in average RVP since 2000 (figure 1), and surveys show 2000 to 2005 increases in 21 of the 23 areas surveyed in both years (see appendix to this chapter.) These RVP increases do not indicate noncompliance; they are permissible as long as RFG continues to meet emissions performance standards.

The magnitude of the increase in RVP over this time period is small compared to the decrease in RVP that occurred between Phase I and Phase II. Furthermore, there is no unquestionably clear cause-effect relationship between regulatory requirements and this RVP change, as there was with the transition from Phase I to Phase II RFG where RVP reduction was the only feasible way to meet the VOC performance standard.

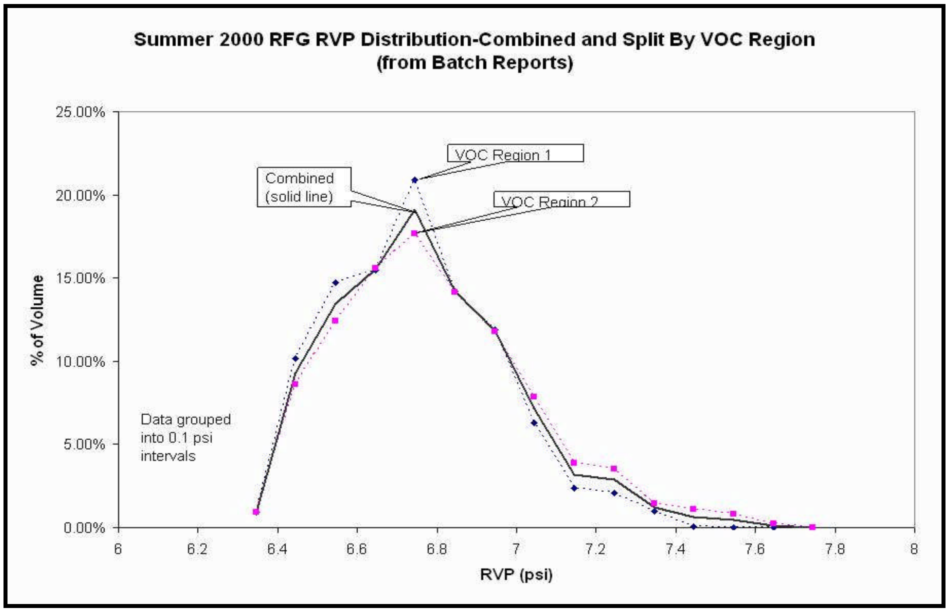


Figure 4

Nevertheless, there are indications that a cause-effect relationship may exist between the increase in RVP and the introduction of the mandated Tier 2 sulfur reduction requirements [23] A reduction in sulfur content, all else constant, would improve VOC emissions performance by reducing Complex Model exhaust VOC emissions estimates. An increase in RVP, all else constant, would hurt VOC emissions performance by increasing Complex Model evaporative and exhaust VOC emissions estimates. Thus, VOC emissions performance could remain unchanged if a sulfur decrease occurred concurrently with an RVP increase. The existence of some cause-effect relationship between sulfur decreases and RVP increases in RFG seems likely, particularly because VOC compliance margins have been small since 2000, (although there has been substantial NOx and toxics over-compliance). This likely cause-effect relationship may be due, to a large extent, to the way that refiners control gasoline RVP. It is often economically advantageous for refiners to blend as much of the lighter hydrocarbons, particularly butane, as possible into gasoline. However, butane raises RVP and, as a result, the need to comply with the VOC standard limits the amount of butane that may be blended into summer RFG., Consequently, if sulfur reductions provided additional VOC compliance margin, refiners may be motivated to offset it by raising RVP. The data indicate an increase in RVP between 2000 and 2005, which is concurrent with a decrease in sulfur content resulting from the Tier 2 sulfur requirements. As stated elsewhere in this report, these data do not reflect the final Tier 2 sulfur requirement, and the interaction between the RFG requirements and the Tier 2 sulfur reductions should be better understood as additional years of data are analyzed.

RFG RVP by PADD

Table 1 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information):

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[23] This is also discussed in the RFG Trends Chapter and in the Emissions Chapter.

2004 & 2005 Reporting Average by PADD-RFG RVP (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (psi)**	**Gasoline Volume (gal)***	**Average Value (psi)**	**Gasoline Volume (gal)***
Summer	I	6.83	4,792,114,891	6.88	4,431,080,230
	II	6.98	1,740,499,436	6.95	1,844,913,833
	III	6.88	5,890,920,167	6.93	5,690,766,967

*Volumes exclude batches with missing values for this parameter

Table 1

Figure 5 shows estimates of average levels by PADD in retail RFG. These averages are volume-weighted averages of the seasonal averages for each area, using gasoline volume estimates supplied in the survey plans. In 2005, RFG surveys were conducted in 18 PADD I areas, five PADD II areas and two PADD III areas. Prior to 2000, VOC control region was the primary factor contributing to geographic differences in RVP. PADD I is a mix of control region 1 and 2 areas. PADD 2 was entirely control region 2 areas until St. Louis (included in the 1999 surveys) opted into the RFG program. Both PADD 3 survey areas (Houston and Dallas, TX) are in control region 1. As expected, the PADD to PADD RVP differences diminished in 2000. The post-2000 upward RVP trend is apparent in each PADD.

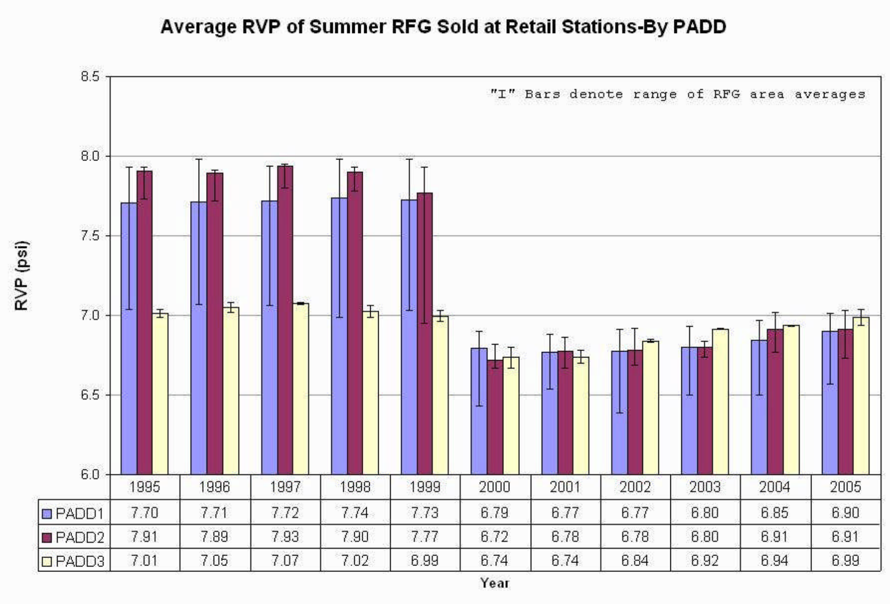

Figure 5

Additional Analyses and Observations-RFG

Data analyses pertaining to RFG RVP are contained in the Appendix to this chapter. Several trends or patterns are highlighted below:

- Twenty-one of twenty-three areas surveyed in both years had higher average RVP levels in 2005 than in 2000.

- An upward shift in RVP since 2002 can also be seen in the distribution trend graph in the appendix.

Overview-Conventional Gasoline

Volume-weighted average Summer and Winter CG RVP levels are shown in figure 6. These RVP values have varied little from year to year since 1998. These averages estimate RVP from refiner/importer sampling, and could differ from the average RVP of gasoline sold at retail outlets for various reasons, including downstream blending operations. For example, the volume-weighted CG averages reported here include batches which are blendstocks such as ethanol intended for blending downstream of refineries, as well as certain all-hydrocarbon blendstocks which do not contain oxygen. The implicit assumption in a volume-weighted property average is that the property blends linearly with volume, and this assumption is inaccurate for RVP when ethanol is blended into an all-hydrocarbon blendstock. Although inclusion of blendstocks in the RVP averages could introduce some error, exclusion of blendstocks from the average calculations does not necessarily provide a better estimate of the average RVP of all conventional gasoline. (This is less of an issue in analysis of RFG data since reporting requirements differ from CG requirements, and since retail RFG data are available as well.)

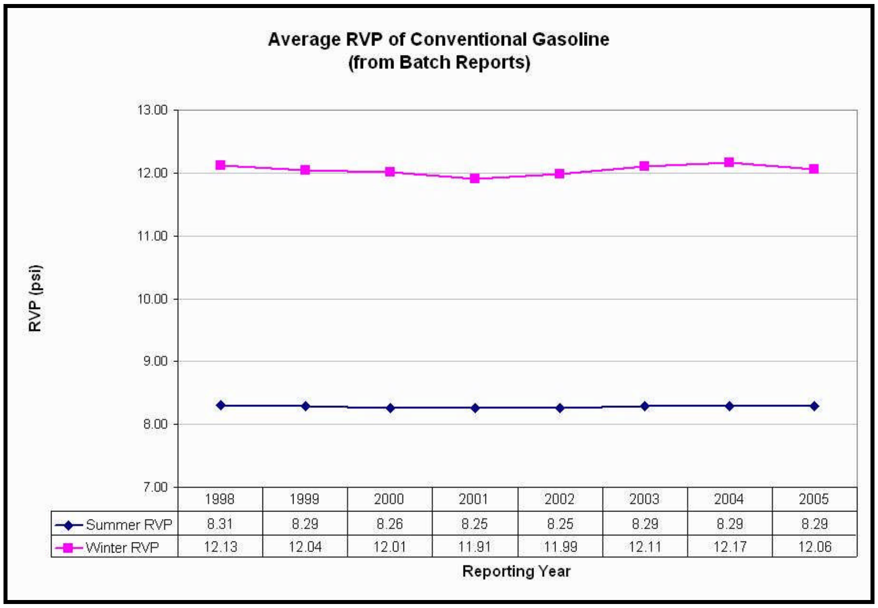

Figure 6

Figure 7 compares the RVP distributions by volume of Summer 1998 and Summer 2005 CG, showing that the distribution as well as the average has changed little. The distributions are multi-modal with peaks just to the left of the vertical lines marking 7.8 and 9.0 psi, the two federal volatility standards. The distributions drop sharply at 7.8 and 9.0 psi suggesting that CG is often blended to meet one of these two standards with only a small compliance margin. Blendstocks have been excluded from the CG distribution data.

There is an additional smaller and more rounded peak at about 6.8 RVP, probably due to certain boutique fuels. These boutique fuels are reported as CG, and EPA's reporting system does not distinguish them from other conventional gasoline. Consequently, "boutique fuel" volume share cannot be explicitly determined from EPA's data. (This "boutique fuel" portion of the distribution does not represent all gasoline with unique specifications. Notably, California gasoline has unique fuel specifications affecting RVP and other parameters, but gasoline intended for sale in California is exempt from EPA's reporting requirements.) Readers who wish to determine what portion of gasoline volume falls within a specific RVP range should refer to the percentile curves contained in the appendix to this chapter.

The distributions show a small volume of gasoline with RVP greater than 9.0 psi. This does not necessarily represent noncompliant gasoline, but could include gasoline intended for Alaska, Hawaii and US territories not subject to EPA volatility regulations. The distributions also contain some ethanol-oxygenated gasoline eligible for a 1.0 psi RVP allowance. (Ethanol is typically blended downstream of refineries, so ethanol oxygenated gasoline is under-represented in these CG distributions.) Additionally, refiners and importers did not always identify their CG batches as volatility-controlled or not. (Current instructions require that they do so.) In the absence of a designation, a batch produced or imported between April and September was assumed to be volatility-controlled, and some non-volatility-controlled CG batches may have been included in the Summer data.

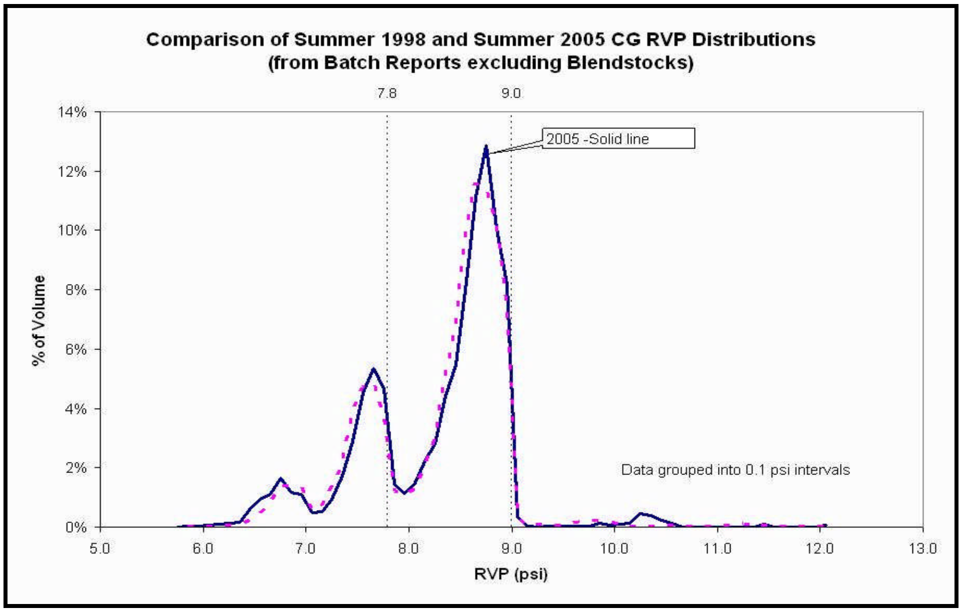

Figure 7

Figure 8 compares the RVP distributions by volume of Winter 1998 and Winter 2005 CG, again showing little difference between the two years. These distributions have a number of peaks. These multi-modal distributions occur because gasoline, even outside of the volatility control season, is produced to meet certain vapor pressure specifications. These specifications, described in ASTM Standard D 4814, define six vapor pressure classes, specifying a maximum vapor pressure for each class. The vapor pressure class limits are shown as vertical lines and labeled across the top axis. The ASTM standard also defines vapor pressure class requirements by location and month. Outside of the EPA volatility-control season these requirements are intended primarily to ensure adequate vehicle performance (e.g. a gasoline used in Maine in January would require a higher RVP than a gasoline used in Florida in January to ensure adequate cold-start performance.)

For several of the vapor pressure classes, the Winter CG distributions show a peak just to the left of the class limit, with a sharp drop at the limit. As with the Summer CG, this suggests that refiners and importers often supply gasoline which meets a vapor pressure class maximum with only a small compliance margin. The winter distributions, however, also show peaks at points other than immediately before a volatility class limit. Most notably, both distributions show a peak at about 12.5 psi, midway between two class limits.

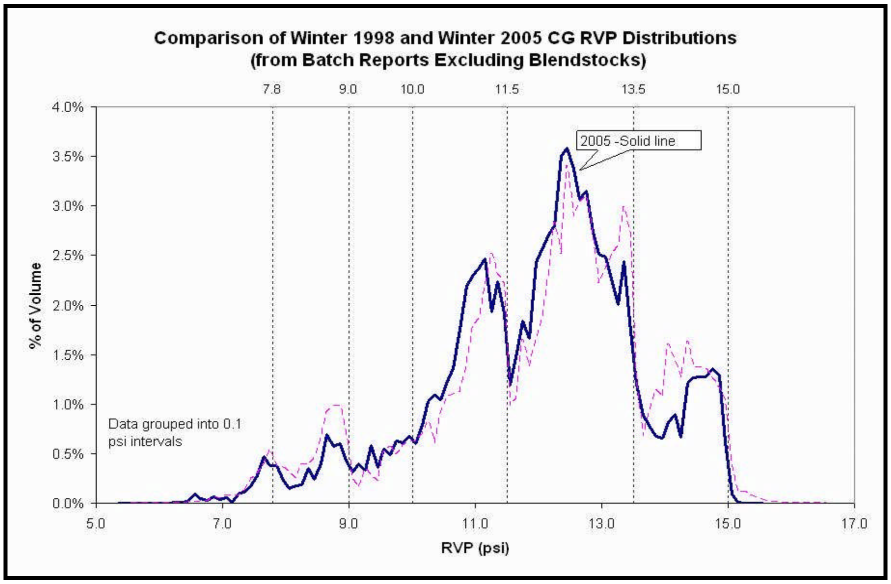

Figure 8

In summary, EPA's reporting system data indicate that both Summer and Winter CG RVP levels show little change since 1998. However, reporting system RVP data for CG may not completely and accurately reflect all downstream RVP changes. EPA's volatility regulations and ASTM standards appear to be the major factors controlling CG RVP. While Tier 2 sulfur reductions could theoretically affect Summer CG RVP levels through CG's Complex Model-based exhaust toxics and NOx standards, the significance of this effect would depend on the extent to which refiner/importer individual compliance baselines for these pollutants, rather than volatility standards, limit CG RVP.

CG RVP by PADD

Table 2 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information). As noted, the primary geographic factors limiting summer CG RVP are emission-related EPA volatility and state "boutique fuel" regulations. Winter gasoline RVP is related to location because of ambient temperature-associated drivability concerns. Thus, it is not surprising to find lower average RVP levels in PADD III production than in PADDs I and II.

2004 & 2005 Reporting Average by PADD-CG RVP (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (psi)**	**Gasoline Volume (gal)***	**Average Value (psi)**	**Gasoline Volume (gal)***
Summer	I	8.40	3,744,548,926	8.31	3,547,001,722
	II	8.46	11,453,187,269	8.46	10,554,125,517
	III	8.19	21,722,168,035	8.22	20,889,312,566
Winter	I	12.66	2,891,701,318	12.31	3,504,605,534
	II	13.31	9,805,826,594	13.25	8,565,282,585
	III	11.77	20,865,873,542	11.73	18,781,652,701
Annual	I	10.26	6,636,250,244	10.30	7,051,607,256
	II	10.70	21,259,013,863	10.61	19,119,408,102
	III	9.94	42,588,041,577	9.88	39,670,965,267

*Volumes exclude batches with missing values for this parameter

Table 2

Additional Analyses and Observations-CG

The RVP of Summer Baseline Gasoline, as specified in the Clean Air Act, is 8.7 psi, and the RVP of Winter baseline gasoline, as specified by EPA's regulations, is 11.5 psi.[24] Data analyses pertaining to CG RVP are contained in the Appendix to this chapter. These data include tabular and graphical descriptions of CG RVP by volume which show:

- In 1998, the first year for which RVP reporting data were analyzed, the median Summer RVP was 8.52 psi and the 1990 baseline gasoline fell between the 65th and 70th percentile.
- In 2005, the last year for which RVP reporting data were analyzed, the median Summer RVP was 8.55 psi and the 1990 baseline gasoline fell between the 65th and 70th percentile.
- In 1998 the median Winter RVP was 12.39 psi and the 1990 baseline gasoline fell between the 30th and 35th percentile.
- In 2005 the median Winter RVP was 12.21 psi and the 1990 baseline gasoline fell between the 35th and 40th percentile.

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[24] The 11.5 psi winter baseline value is specified in EPA's regulations even though a default value of 8.7 psi is used in Complex Model evaluations of winter gasoline in order to "zero out" the effect of RVP on Winter exhaust emissions.

Oxygenates and Oxygen

Background

Oxygenates are compounds used in gasoline blending that contain carbon, hydrogen and oxygen. There are two main classes of oxygenates; ethers and alcohols. Methyl tertiary-butyl ether (MTBE) was the predominant ether used in gasoline blending. Other ethers, primarily tertiary-Amyl methyl ether (TAME), were sometimes used, often in combination with MTBE. In the United States, ethanol is the only alcohol currently used in any significant quantity in gasoline blending, and ethers are no longer used in significant quantities.

Oxygenates have been blended into gasoline in order to comply with regulatory requirements intended to reduce air pollutant emissions from gasoline vehicles and engines. The Clean Air Act required that reformulated gasoline (RFG) contain 2.0 weight percent oxygen. RFG was intended to reduce emissions of toxics and ozone-forming pollutants. Oxygenates provided direct toxics and exhaust VOC emission reduction benefits through the effect of oxygen on combustion, as well as indirect benefits through dilution of, or partial substitution for gasoline blendstocks containing sulfur, aromatics or benzene (constituents which can adversely impact emissions). Oxygen also directly reduces carbon monoxide (CO) emissions through its effect on combustion. The Clean Air Act required that states adopt oxygenated fuel programs for carbon monoxide non-attainment areas during the portion of the year (typically winter) in which the area is prone to high ambient CO concentrations.

Oxygenates are also used in gasoline blending for reasons unrelated to emission reduction. Both ethers and alcohols have a high blending octane value, making them at times economically attractive blending component choices. Ethanol is a renewable fuel which, in the United States, is primarily produced from corn. Federal tax incentives have encouraged the use of ethanol in gasoline. These incentives included an excise tax exemption available for gasoline alcohol blends. The amount of the exemption depended on the ethanol content of the blend, with the maximum exemption available for 10% by volume ethanol blends and pro-rated amounts for 7.7% and 5.7% blends (based on 190 proof or 95% pure ethanol). Additionally, blenders receive a tax credit for blending ethanol into gasoline. The American Jobs Creation Act of 2004, signed on October 22, 2004 changed the way the excise tax exemption operates. The amount of the exemption is no longer based on these three blend levels.

The Energy Policy Act of 2005, repealed the RFG oxygen content requirement, effective immediately in California and 270 days after enactment elsewhere.[25] It added a gasoline renewable fuel content requirement of 4 billion gallons in 2006, incrementally increasing to 7.5 billion gallons in 2012.[26] These recent legislative changes will clearly impact the composition of future RFG and CG.

Regulatory Limits on Oxygen and Oxygenates

As a prelude to a discussion of this topic, it is useful to review the various units used to express gasoline oxygen and oxygenate content, and the relationship between these units. Gasoline oxygen content is expressed as a weight percentage of the gasoline-oxygenate blend. Gasoline oxygenate content may expressed as either a weight or volume percentage of the gasoline-oxygenate blend. In

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[25] Removal of the oxygen requirement became effective with regulatory changes on April 24, 2006 for California gasoline, and May 5, 2006 for gasoline nationwide. See 71 F.R. 8965 and 71 F.R. 26419.

[26] EPA finalized a regulation to implement the Renewable Fuel Standard Program on May 1, 2007. See 72 FR 23900.

order to provide gasoline meeting a specific oxygen content requirement, oxygenates such as MTBE or ethanol are blended into a hydrocarbon blendstock. As noted, oxygenates contain hydrogen and carbon as well as oxygen, and different oxygenates contain different amounts of oxygen. For example, a pound of pure MTBE contains about 0.18 pounds of oxygen, while a pound of pure ethanol contains about 0.35 pounds of oxygen. Therefore, it would be necessary to blend about 11 pounds of MTBE with 89 pounds of non-oxygenated blendstock to produce 100 pounds of 2.0 weight percent oxygenated gasoline, which would contain 11% MTBE, by weight. Alternatively, it would be necessary to blend about 5.7 pounds of pure ethanol with 94.3 pounds of non-oxygenated blendstock to produce 100 pounds of 2.0 weight percent oxygenated gasoline, which would contain 5.7% ethanol, by weight.

Since gasoline and oxygenates are liquids, oxygenate concentrations are more commonly expressed as volume percentages rather than weight percentages. There are no universal weight percent to volume percent conversion factors because each gasoline blend is a different mixture of hydrocarbons. In order to convert exactly between a weight and volume oxygenate concentration it is necessary to know the density of the gasoline-oxygenate blend, which varies from blend to blend. (There are procedures to measure the density of a gasoline-oxygenate blend and these measurements are included in the reporting system data submitted to EPA.) However, even if the density of the specific gasoline-oxygenate blend is not known, a reasonably accurate weight to volume or volume to weight conversion can be made because the densities of these blends vary over a fairly narrow range.[27] A 5.7 weight percent pure (anhydrous and 200 proof) ethanol blended gasoline would typically contain slightly less than 5.7 volume percent of pure ethanol. However, a 5.7 volume percent ethanol concentration is often nominally associated with a 2.0 weight percent oxygen concentration, 7.7 volume percent ethanol with 2.7 weight percent oxygen and 10 volume percent ethanol with 3.5 weight percent oxygen. The 2.0% and 2.7% oxygen weights and the 10 volume percent ethanol content have significance with respect to Clean Air Act requirements and EPA regulations.

As noted, (prior to the effective date of the repeal of this provision by the 2005 energy legislation) the Clean Air Act required that RFG contain 2.0 weight percent oxygen. EPA's regulations allowed refiners, importers and oxygenate blenders to meet this requirement through compliance with a 2.0 weight percent “per gallon” standard, or a 2.1 weight percent “averaged standard” and a 1.5 weight percent per gallon minimum. The per gallon minimum applicable to certain suppliers was adjusted as a consequence of RFG Survey failures for oxygen content, and for 2005 remained at 1.6 weight percent for certain suppliers and covered areas. These RFG oxygen requirements applied throughout the year. The Clean Air Act also required an oxygen credit program; i.e. parties using more than the required amount of oxygen in RFG generate credits which may be transferred to other parties for use in meeting the oxygen standard.

The Clean Air Act's oxygenated fuel requirements (Section 211(m)) are intended to address CO non-attainment. States may also have “maintenance” programs. These oxygenated fuel programs are seasonal and state-specific. The Clean Air Act specified that the oxygen content for the non-attainment areas requiring such programs be at least 2.7 weight percent. While some areas currently have winter oxygenated fuel programs a number of areas, including several areas in the RFG program, at one time had programs but no longer implement them.

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[27] EPA received RFG Survey oxygenate concentrations as weight percentages and Reporting System concentrations as volume percentages. For this report, EPA made approximate weight to volume or volume to weight conversions assuming a specific gravity of 0.745 for Summer RFG and 0.730 for Winter. The specific gravities of MTBE, ethanol and TAME published in ASTM D4814 are 0.7460, 0.7939and 0.7758, respectively. To convert a weight percent oxygenate to a volume percent oxygenate multiply the weight percent oxygenate by the gasoline blend specific gravity and divide by the oxygenate specific gravity.

In addition to the requirements for oxygen use, there are several restrictions on the maximum oxygen content and maximum amount of certain specific oxygenates that can be used. Both the Simple Model and Complex Model have valid range limits of 4.0 weight percent for oxygen. However, these range limits had little effect on the maximum oxygen content of gasoline since other requirements, in place long before the RFG and Anti-Dumping programs, were as restrictive or more restrictive.

The Clean Air Act (‘211(f)(1)) prohibits fuel and fuel additive manufacturers from first introducing into commerce, or increasing the concentration in use of any fuel or fuel additive for general use in light duty motor vehicles which is not substantially similar to that utilized in the certification of motor vehicles or engines under section 206 of the Act. A manufacturer may apply for a waiver of this provision for a fuel or fuel additive which is not substantially similar. The Act, however, does not define “substantially similar”, consequently EPA defined "substantially similar" as it applies to unleaded gasoline in an interpretive rule, last revised in 1991 (56 FR 5352). [28]

EPA's "substantially similar" definition allows certain alcohols (other than methanol) and ethers including ethanol and MTBE, provided that the oxygen content does not exceed 2.7 weight percent. This oxygen weight allows approximately 15% MTBE by volume, but the exact volume of MTBE allowed under this definition is blend-specific. However, a waiver has also been granted which, under some conditions, allows 15% MTBE by volume even if the oxygen content weight limit is exceeded. This oxygen weight percent limit would only allow ethanol blending up to about 7.7 volume percent. However, the “gasohol” waiver allows use of up to 10% by volume pure ethanol. This waiver is particularly significant since ethanol is often blended at about 10 volume percent in order to take full advantage of the tax incentives. This waiver allows approximately 3.7 weight percent oxygen, but again, this is blend-specific. The definition and several waivers also allow use of methanol as an oxygenate, but the conditions for methanol use are much more restrictive. Unless it is used with other oxygenates, methanol can only be used at 0.3% by volume (about 0.16 weight percent oxygen). Additionally, health effects testing requirements apply to methanol blends containing oxygen at 1.5 weight percent or greater. (Trace quantities of methanol were often found in MTBE-oxygenated gasoline since methanol was used to produce MTBE.) A document summarizing 211(f) waiver requests and EPA decisions is available on EPA's website (EPA, 1995).

EPA's Oxygenate and Oxygen Data

Oxygen and oxygenate content data have always been necessary to determine compliance with RFG standards. The weight percent oxygen content requirement applies to RFG for all years considered in this report. Additionally, both the Simple and Complex models require the amount of oxygen coming from specific oxygenates as inputs in order to calculate toxics emissions. Since 1995, RFG refiners and importers have been required to report weight percent oxygen as well as MTBE, ethanol, ETBE, TAME, t-butanol and methanol content. (These oxygenates are reported as volume percentages and volume to weight conversions can be made as needed since the density of each batch is also reported in units of API gravity.)

One complication with this reporting is that ethanol blending typically does not occur at refineries, but downstream at terminals. (This is necessary because gasoline is often shipped via pipeline and there are problems associated with pipeline shipment of ethanol-blended gasoline due to ethanol's affinity for water, which is present to some extent in pipelines.) Although this is less common, MTBE and other ethers may also be blended downstream of the refinery. Thus, refiners generally produce and ship reformulated blendstock for oxygenate blending (RBOB) rather than finished ethanol-oxygenated RFG.

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[28] "Substantially similar" information is available at http://www.epa.gov/otaq/additive.htm

Refiners must also designate the type(s) and amount(s) of oxygenates that may be added to the RBOB. For compliance purposes, a refiner or importer must estimate the properties of the RFG that will be produced from an RBOB batch by blending the specified type and amount of oxygenate into a sample of the RBOB and analyzing the sample. The property and volume data which are reported to EPA for RBOB batches are based on these "hand blends" rather than on analysis of the RFG produced by the actual blending operations. There are a number of regulatory requirements associated with RBOB and downstream blending of oxygenates. For example, RFG oxygenate blenders are also required to report the type and amount of oxygenate added. These regulations are intended to ensure that the RFG produced from RBOB meets all applicable standards. However, even if these requirements are precisely and rigorously adhered to, "hand blend" properties may differ from final RFG properties. In certain instances, the amount of oxygen added downstream may be greater than the amount of oxygen assumed for reporting purposes. In fact, unless a refiner or importer of RBOB meets certain contractual and quality assurance requirements addressing downstream blending, EPA's regulations require that such assumptions be made.

In addition to the reporting system data, EPA receives RFG Survey data which includes total oxygen content in weight percent as well as concentrations of specific oxygenates, including several not included in the reporting data. (These oxygenates have been reported to EPA as weight percentages. Prior to 2004, EPA did not receive density information for each sample.) Until the repeal of the RFG oxygen requirement, survey sampling for oxygen and oxygenates included RFG sold in federal RFG areas in California. This RFG is not included in EPA's reporting system data. California RFG surveys sampled for oxygen and oxygenates only and are no longer conducted. Surveys conducted outside of California continue to sample for oxygen and oxygenates because they are input parameters for the Complex Model.

The Anti-Dumping standards applicable to CG do not include an oxygen content standard. However, Complex Model CG is subject to NOx and exhaust toxics emissions standards, and oxygen and oxygenate data are necessary to calculate these emissions. Thus, since 1998, refiners and importers have been required to report CG oxygen and oxygenate data. The CG reporting procedures and requirements differ from those of RFG. CG blendstocks for oxygenate blending as well as some oxygenate batches are included. However oxygenates added downstream of the refinery or import facility may be included in compliance calculations only if the refiner can show that they were added to the gasoline or blendstock, and thus may not be reported. Additionally, refiners and importers do not create "hand blends" of blendstocks and oxygenates to determine properties, but report the pre-blend properties of the blendstocks.

In summary, downstream oxygenate blending, particularly ethanol blending, contributes to differences between gasoline leaving the refinery or import facility and gasoline sold at retail. This affects the analysis and interpretation of the data considered in this report, not only for oxygen and oxygenates, but for other properties as well since they will change with the addition of an oxygenate.

The effect on RFG data is expected to be small because of the requirement to create "hand blends", and because of other regulatory requirements. (EPA's analyses of RFG batch reporting data in this chapter and in other chapters include data for both RFG batches and RBOB batches.) Additionally, EPA has a second source of data from the RFG surveys, which directly measures retail properties. Consequently, even though ethanol is widely used in RFG, EPA believes its data provide good estimates of the oxygenate content and the other properties of the RFG that is used in vehicles. Additionally, EPA believes that it can make credible, although approximate, estimates of various measures of oxygenate "market share" (e.g. as in the RFG Trends chapter) and of the volume of oxygenates used in RFG.

It is possible that a significant amount of the ethanol added to CG is not included in the Anti-Dumping reporting data submitted to EPA. Although EPA has analyzed these data to estimate oxygen and oxygenate content, the results probably underestimate of the oxygenate content of CG sold at retail, and may not accurately reflect trends in CG oxygenate use. However, even if CG oxygenate use is significantly under-reported, the volume percentage of oxygenates in CG is believed to be small (certainly in comparison to RFG). Therefore, EPA does not believe that downstream oxygenate blending has caused estimates of other CG parameters from reporting system data to be substantially unrepresentative of CG sold at retail.

The General Methodology chapter explained that, for each parameter analysis in this report, a rule was established to determine if the data was missing from a batch record. It is worth noting that the decisions pertaining to oxygen and oxygenate data are somewhat unique. Since the RFG considered in this report was subject to an oxygen content requirement, and the oxygen could come from any of several reported oxygenates, a zero or blank value for any oxygenate was treated as a zero if there was a non-zero value for one or more of the other oxygenates; otherwise it was treated as missing data. For example, a blank ethanol value would be averaged as a zero for batches reporting MTBE, ETBE, TAME or T-Butanol content, but excluded from an average if these other oxygenates were also reported as blanks or zero. Since CG may or may not contain oxygen, a reported oxygen or oxygenate value of zero was treated as zero, and a blank value was treated as a zero if at least one other non-zero property value was reported (e.g. a blank MTBE value would be assumed zero if sulfur was greater than zero); otherwise it was treated as missing data.

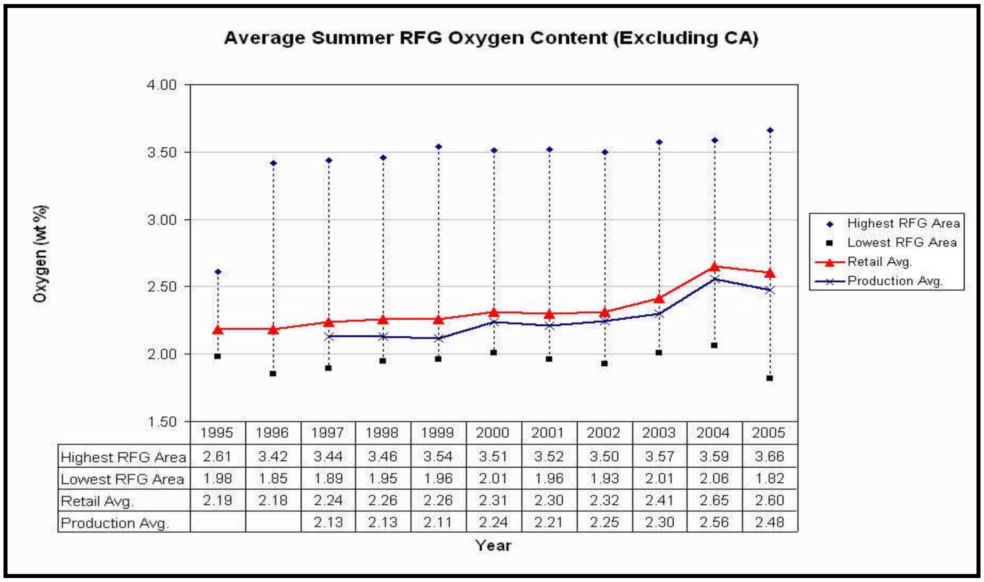
Oxygen and Oxygenate Trends

Overview-Reformulated Gasoline

Since this topic has also been discussed in the RFG Trends chapter, reference will be made to material contained therein. Readers, particularly those who are unfamiliar with the issues pertaining to oxygenate use, may wish to read the relevant portion of that chapter before continuing. (Additionally, some of the oxygen and oxygenate-related graphical and tabular data analysis in the RFG Trends chapter is not repeated here.)

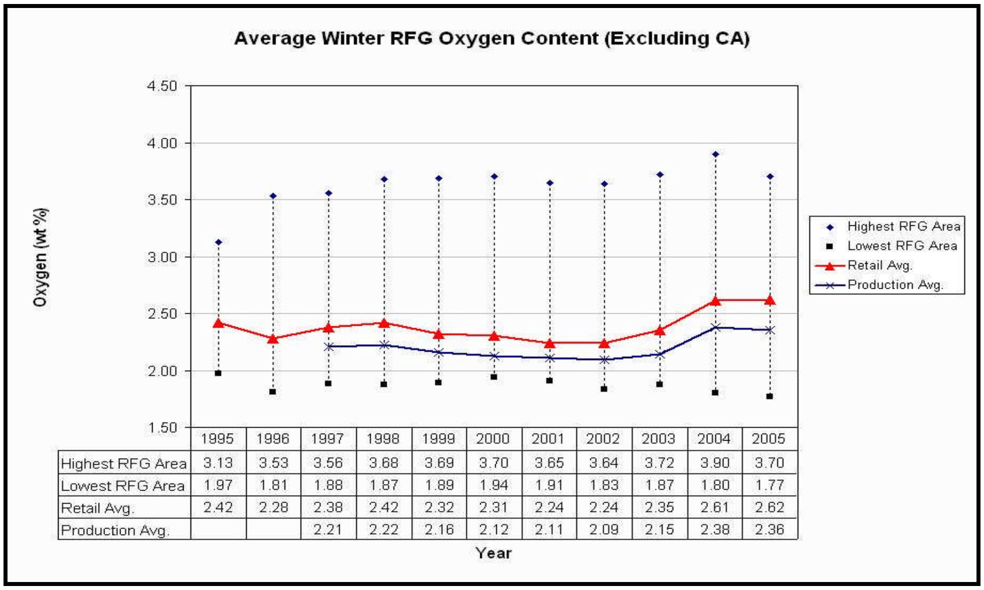
Although the RFG oxygen content requirement did not change between 1995 and 2004, average RFG oxygen content increased during that period. During this period the average ethanol content of all (i.e. ethanol and ether oxygenated) RFG increased while the average MTBE and TAME content of all RFG decreased.

Figures 1 and 2 show estimates of average RFG oxygen content in Summer and Winter RFG Both reporting system estimates, by reporting year, and survey-based retail estimates, by survey year, are shown. The survey estimates exclude California data and, as for other parameters, California gasoline is exempted from oxygen and oxygenate reporting requirements. The averages shown are volume-weighted estimates. (See also Figures 25 through 32 in the RFG Trends chapter. These graphs provide additional information and also include survey-based estimates which include federal RFG areas in California.) Figures 1 and 2 show that oxygen content estimates from reporting and survey data are close, but that survey-based estimates of oxygen content have been consistently higher by small amounts. The direction of these differences suggests that the amount of oxygen added downstream is, on average, slightly greater than that assumed for refiner and importer compliance calculations. As noted, this is allowable and consistent with EPA's regulations. EPA's data screening to exclude batches with missing oxygen or oxygenate data also contributed to lower average oxygen and ethanol content estimates from the reporting system. The majority of batches with missing data were RBOB; thus likely to be ethanol-oxygenated and also likely to be oxygenated at about 3.5 weight percent oxygen. (RBOB refiners and importers are not required to report their "hand blend" oxygen and oxygenate content. Although the majority of RBOB batch reports contained this information, a significant number in each year did not.) EPA believes that the reporting data analysis probably underestimates average oxygen (and ethanol) content. However, other factors could have caused or contributed to the differences between reporting and survey-based estimates, including statistical sampling error or errors in the estimates of gasoline volumes for individual survey areas.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	2.61	3.42	3.44	3.46	3.54	3.51	3.52	3.50	3.57	3.59	3.66
Lowest RFG Area	1.98	1.85	1.89	1.95	1.96	2.01	1.96	1.93	2.01	2.06	1.82
Retail Avg.	2.19	2.18	2.24	2.26	2.26	2.31	2.30	2.32	2.41	2.65	2.60
Production Avg.			2.13	2.13	2.11	2.24	2.21	2.25	2.30	2.56	2.48

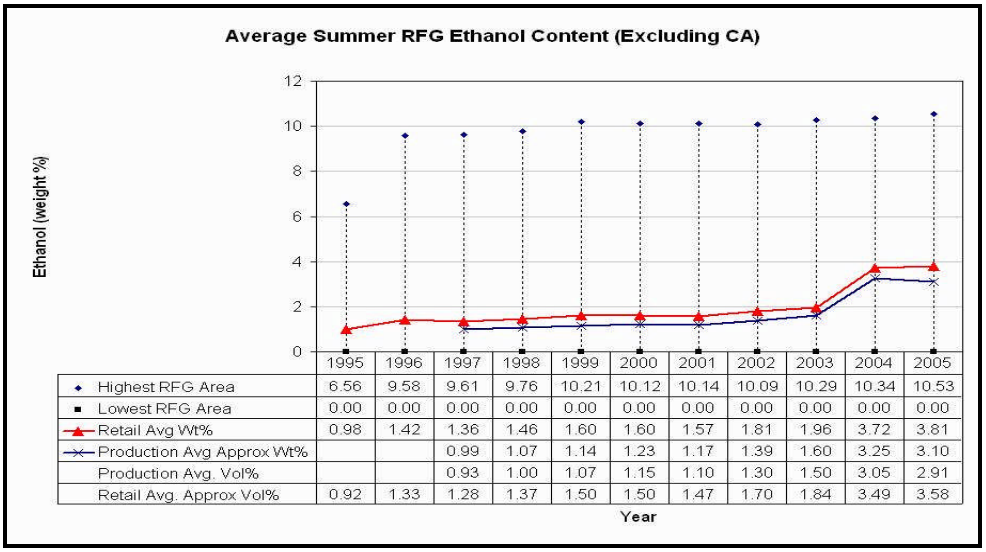
Figure 1



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	3.13	3.53	3.56	3.68	3.69	3.70	3.65	3.64	3.72	3.90	3.70
Lowest RFG Area	1.97	1.81	1.88	1.87	1.89	1.94	1.91	1.83	1.87	1.80	1.77
Retail Avg.	2.42	2.28	2.38	2.42	2.32	2.31	2.24	2.24	2.35	2.61	2.62
Production Avg.			2.21	2.22	2.16	2.12	2.11	2.09	2.15	2.38	2.36

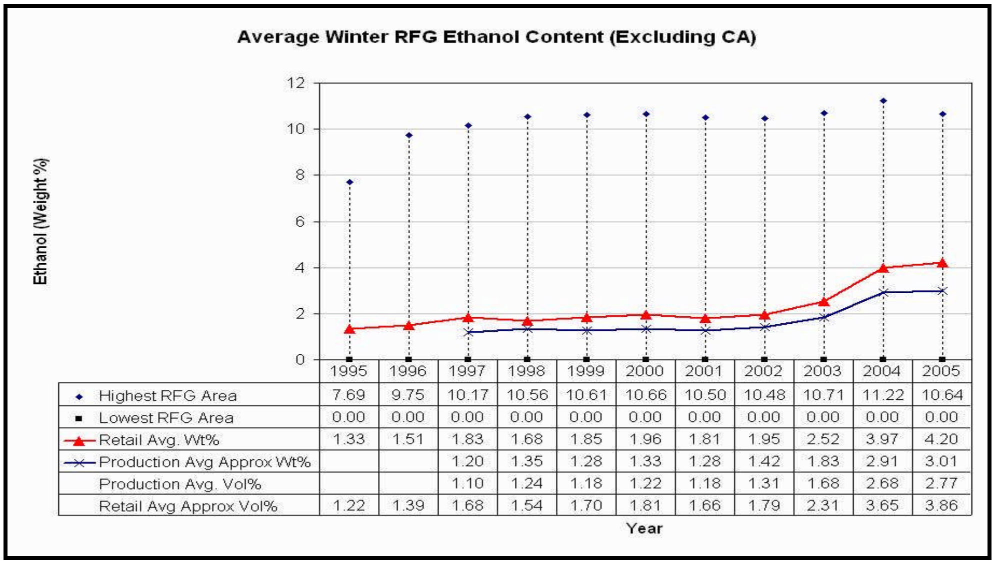
Figure 2

Both graphs show higher oxygen content in 2004 than in any of the preceding years. Average oxygen content increased due to the increased use of ethanol which, outside of California, was often blended at 10 volume % to take full advantage of tax incentives, and to replace much of the lost volume where ethanol replaced ethers as an oxygenate. Figures 3 through 8 shows that average ethanol content increased substantially from 2003 to 2004, with corresponding decreases in ether content. These changes were primarily due to MTBE bans in New York and Connecticut which took effect in 2004. Transitions from ether-oxygenated to ethanol-oxygenated RFG occurred in other areas, as well, at various times within the period covered by these trend charts. (Figures 21 through 24 in the RFG Trends Chapter identify areas where large oxygenate use changes occurred between 2000 and 2004). Ethanol content estimates from surveys are higher than reporting data estimates, and MTBE estimates lower, again consistent with downstream ethanol blending in excess of the amount assumed for compliance calculations and the probable bias resulting from screening for missing oxygenate data in batch reports. (The previously stated caveats relating to comparison of survey and reporting estimates apply. Additionally, reporting data volume concentrations were converted to weight concentrations to be directly comparable with survey estimates, and the conversion calculations were approximations using average density values.)



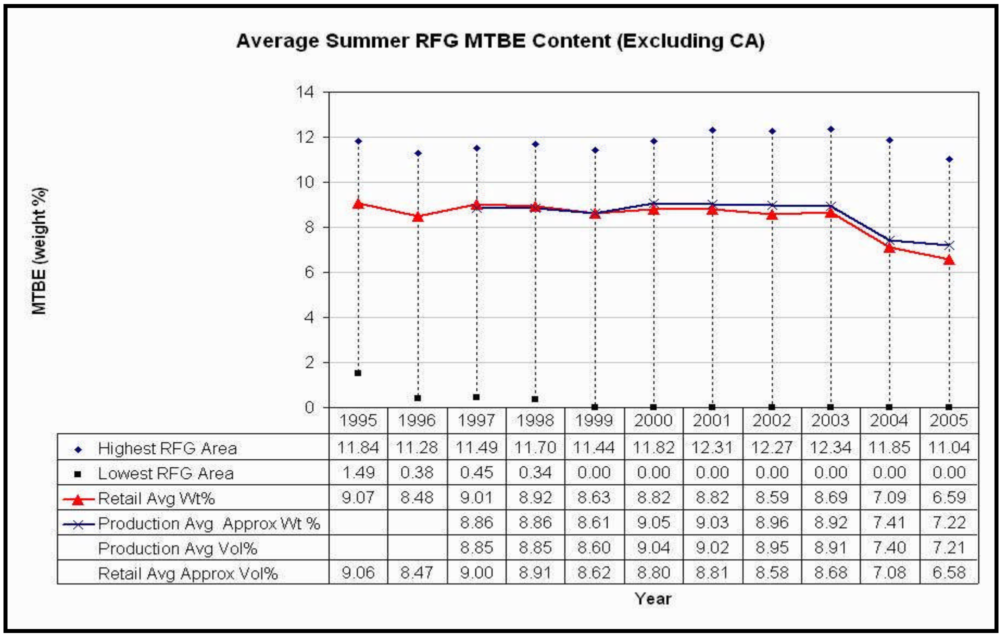
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
◆ Highest RFG Area	6.56	9.58	9.61	9.76	10.21	10.12	10.14	10.09	10.29	10.34	10.53
■ Lowest RFG Area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
▲ Retail Avg Wt%	0.98	1.42	1.36	1.46	1.60	1.60	1.57	1.81	1.96	3.72	3.81
× Production Avg Approx Wt%			0.99	1.07	1.14	1.23	1.17	1.39	1.60	3.25	3.10
Production Avg. Vol%			0.93	1.00	1.07	1.15	1.10	1.30	1.50	3.05	2.91
Retail Avg. Approx Vol%	0.92	1.33	1.28	1.37	1.50	1.50	1.47	1.70	1.84	3.49	3.58

Figure 3



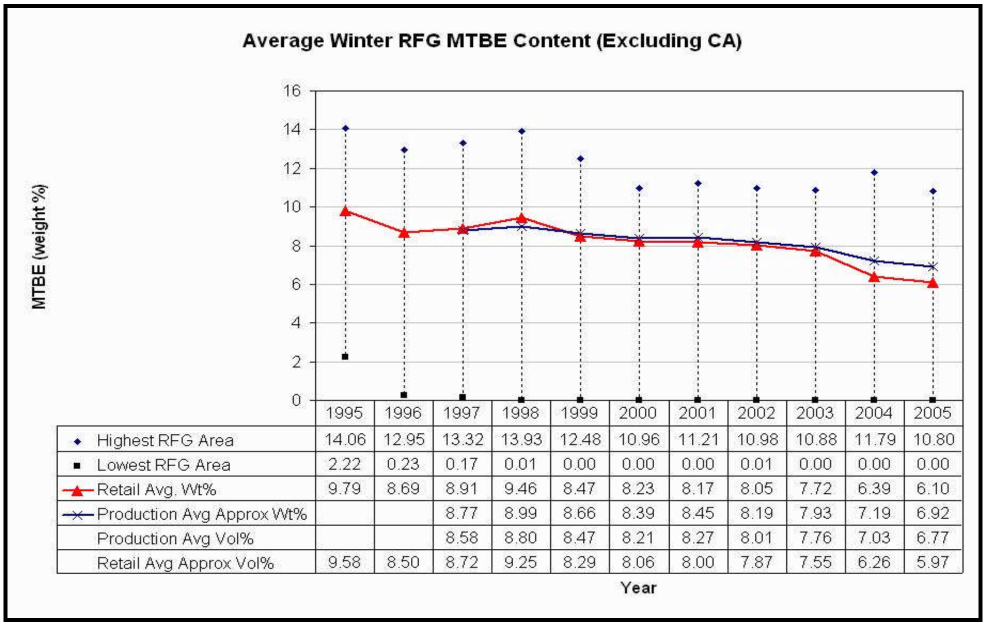
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
◆ Highest RFG Area	7.69	9.75	10.17	10.56	10.61	10.66	10.50	10.48	10.71	11.22	10.64
■ Lowest RFG Area	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
▲ Retail Avg. Wt%	1.33	1.51	1.83	1.68	1.85	1.96	1.81	1.95	2.52	3.97	4.20
× Production Avg Approx Wt%			1.20	1.35	1.28	1.33	1.28	1.42	1.83	2.91	3.01
Production Avg. Vol%			1.10	1.24	1.18	1.22	1.18	1.31	1.68	2.68	2.77
Retail Avg Approx Vol%	1.22	1.39	1.68	1.54	1.70	1.81	1.66	1.79	2.31	3.65	3.86

Figure 4



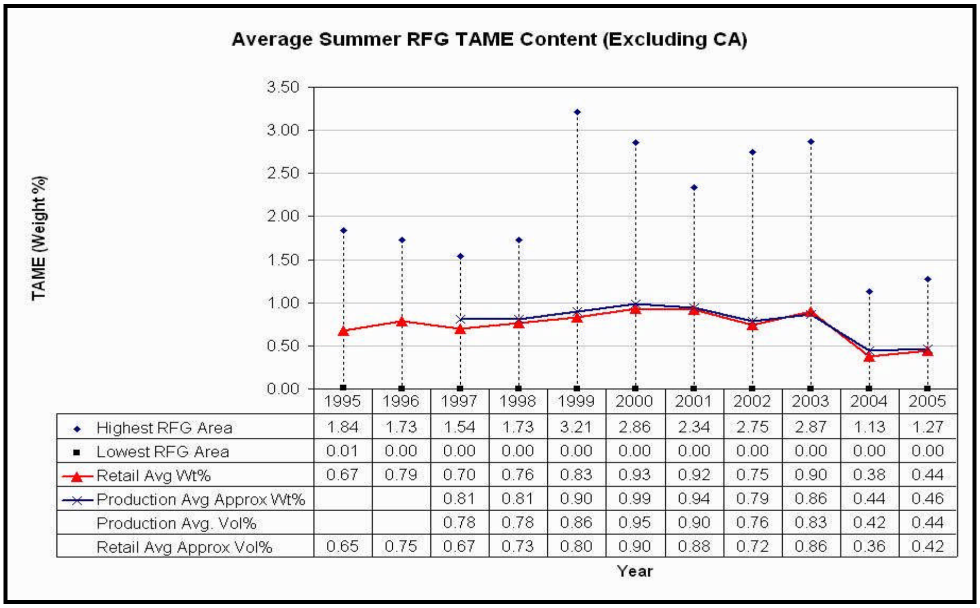
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
◆ Highest RFG Area	11.84	11.28	11.49	11.70	11.44	11.82	12.31	12.27	12.34	11.85	11.04
■ Lowest RFG Area	1.49	0.38	0.45	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
▲ Retail Avg Wt%	9.07	8.48	9.01	8.92	8.63	8.82	8.82	8.59	8.69	7.09	6.59
× Production Avg Approx Wt %			8.86	8.86	8.61	9.05	9.03	8.96	8.92	7.41	7.22
Production Avg Vol%			8.85	8.85	8.60	9.04	9.02	8.95	8.91	7.40	7.21
Retail Avg Approx Vol%	9.06	8.47	9.00	8.91	8.62	8.80	8.81	8.58	8.68	7.08	6.58

Figure 5



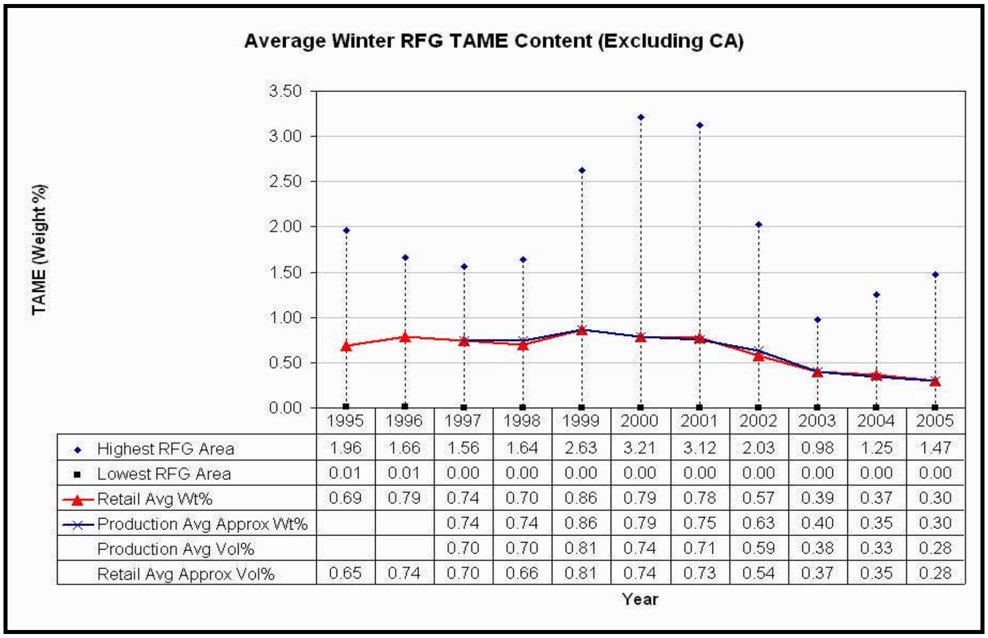
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
◆ Highest RFG Area	14.06	12.95	13.32	13.93	12.48	10.96	11.21	10.98	10.88	11.79	10.80
■ Lowest RFG Area	2.22	0.23	0.17	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
▲ Retail Avg. Wt%	9.79	8.69	8.91	9.46	8.47	8.23	8.17	8.05	7.72	6.39	6.10
× Production Avg Approx Wt%			8.77	8.99	8.66	8.39	8.45	8.19	7.93	7.19	6.92
Production Avg Vol%			8.58	8.80	8.47	8.21	8.27	8.01	7.76	7.03	6.77
Retail Avg Approx Vol%	9.58	8.50	8.72	9.25	8.29	8.06	8.00	7.87	7.55	6.26	5.97

Figure 6



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
◆ Highest RFG Area	1.84	1.73	1.54	1.73	3.21	2.86	2.34	2.75	2.87	1.13	1.27
■ Lowest RFG Area	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
▲ Retail Avg Wt%	0.67	0.79	0.70	0.76	0.83	0.93	0.92	0.75	0.90	0.38	0.44
× Production Avg Approx Wt%			0.81	0.81	0.90	0.99	0.94	0.79	0.86	0.44	0.46
Production Avg. Vol%			0.78	0.78	0.86	0.95	0.90	0.76	0.83	0.42	0.44
Retail Avg Approx Vol%	0.65	0.75	0.67	0.73	0.80	0.90	0.88	0.72	0.86	0.36	0.42

Figure 7



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
◆ Highest RFG Area	1.96	1.66	1.56	1.64	2.63	3.21	3.12	2.03	0.98	1.25	1.47
■ Lowest RFG Area	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
▲ Retail Avg Wt%	0.69	0.79	0.74	0.70	0.86	0.79	0.78	0.57	0.39	0.37	0.30
× Production Avg Approx Wt%			0.74	0.74	0.86	0.79	0.75	0.63	0.40	0.35	0.30
Production Avg Vol%			0.70	0.70	0.81	0.74	0.71	0.59	0.38	0.33	0.28
Retail Avg Approx Vol%	0.65	0.74	0.70	0.66	0.81	0.74	0.73	0.54	0.37	0.35	0.28

Figure 8

Winter oxygenated gasoline requirements were superimposed on RFG requirements in several areas including portions of Pennsylvania, New Jersey, Washington, DC, Maryland, Virginia, Massachusetts, New York and Connecticut. Consequently, the oxygen content of some of the winter RFG sold in these areas was higher than necessary to meet the federal RFG requirement. These areas were re-designated to CO attainment at various times between 1996 and 2000, and winter oxygenated programs were eliminated, except, in some cases, as contingency measures (EPA, 2005). The elimination of these programs contributed to the downward trend seen over a portion of the Winter MTBE and Winter oxygen content trend lines. Since these areas used little or no ethanol-oxygenated RFG, it is unlikely that ethanol trends were affected.

Transitions from ethers to ethanol, elimination of winter oxygenate programs in RFG areas and RFG program opt-ins/opt-outs affected specific areas at specific times. Only some RFG refiners, importers and oxygenate blenders were affected. However, some of the areas affected were major markets, so these localized changes at times materially affected overall trends. Tables contained in the appendix to this chapter show seasonal oxygen weight percent, ethanol weight percent and MTBE weight percent averages estimated from RFG surveys by area and year. The reader can determine where and when significant changes in oxygen and oxygenate usage occurred.

Although the above factors are likely to have influenced RFG oxygen and oxygenate trends, additional factors influencing oxygen and oxygenate use should be mentioned. This discussion is not intended to be an in-depth analysis of the movements of RFG oxygen and oxygenate content over time and the factors influencing these movements. Rather, it is intended to identify certain factors which could be considered in such an analysis.

Compliance with averaged standards, and the use of oxygen credits contributed to the wide range of oxygen content averages in RFG areas. The highest RFG area averages for each year-season combination with the exception of 1995 occurred in areas where the preponderance of the gasoline was ethanol blended at about 10 volume percent. The lowest area averages for each year-season combination occurred in areas where all or virtually all gasoline was ether-oxygenated, primarily MTBE-blended. Suppliers who blended this high oxygen content ethanol RFG generated credits which could be made available to producers of ether-oxygenated RFG. These producers, in turn, could use credits to help meet the 2.1 weight percent averaged oxygen content standard. This sometimes produced a situation where the average oxygen content in one or more RFG areas dropped below 2.0 weight percent, the Clean Air Act requirement for RFG. Figures 1 and 2 show that this occurred on a seasonal basis. This sometimes occurred on an annual basis, as well, triggering RFG Survey failures. EPA's regulations allowed adjustment of the per gallon minimum oxygen content standard applicable to certain suppliers and RFG areas in the event of such failures. As previously noted, EPA did, in certain instances, "ratchet" this standard. Per gallon minimum oxygen requirements became as high as 1.7 weight percent for some areas and suppliers. However, even when a small oxygen shortfall did occur, the RFG sold in the affected area met or exceeded all emissions performance requirements. Consequently, EPA elected not to adjust per gallon minimum standards in response to oxygen survey failures occurring in 1998 and later years. In accordance with EPA's regulations, a ratchet automatically became less stringent by 0.1 weight percent if a ratcheted area passes surveys in two consecutive years. As of 2005, ratchets to a 1.6% minimum were still in place in the Norfolk, VA and Washington, DC areas. Although the ratchets applied to specific areas, the effects were not as localized as transitions from ether to ethanol or elimination of winter oxygenated gasoline programs, but were likely to have applied to much of the total RFG supply (see ‘80.41(q)). However, while the ratchets applied to a significant quantity of RFG, they may well have had only a minor or negligible effect on oxygen or oxygenate content since the ratchets did not affect the average oxygen content standard.

Comparison of Figures 1 and 2 shows that winter oxygen content levels were higher than summer levels prior to 2000, but that summer levels were equal or higher in 2000 and later years. Although there may have been other seasonal influences, the winter oxygenated fuel programs in effect in several areas contributed to higher winter oxygen levels during the initial years of the RFG program. As these programs were eliminated, other factors were able to influence seasonal oxygen content differences. Since this seasonal high low reversal coincided with the transition from Phase I to Phase II RFG, it is possible that the reversal is related to differences between Phase I and Phase II RFG.

The timing of localized changes not only affected these trend lines but probably affected the variability of oxygen content within a reporting or survey year. For example, MTBE bans took effect in New York and Connecticut in 2004, but RFG Surveys indicate that the transition from MTBE to ethanol took place at the end of 2003. As noted throughout this report, the winter data for a given year include RFG produced and/or sampled both before and after the Summer VOC control season, and differences between gasoline produced before and after the Summer season may have been exacerbated by these transitions.

Figure 9 shows fluctuations in average RFG oxygen content by production quarter, based on the production date reported for each batch. Batches produced during the 1st and 4th quarters are predominantly Winter RFG, while batches produced during the 2nd and 3rd quarters are predominantly Summer RFG.

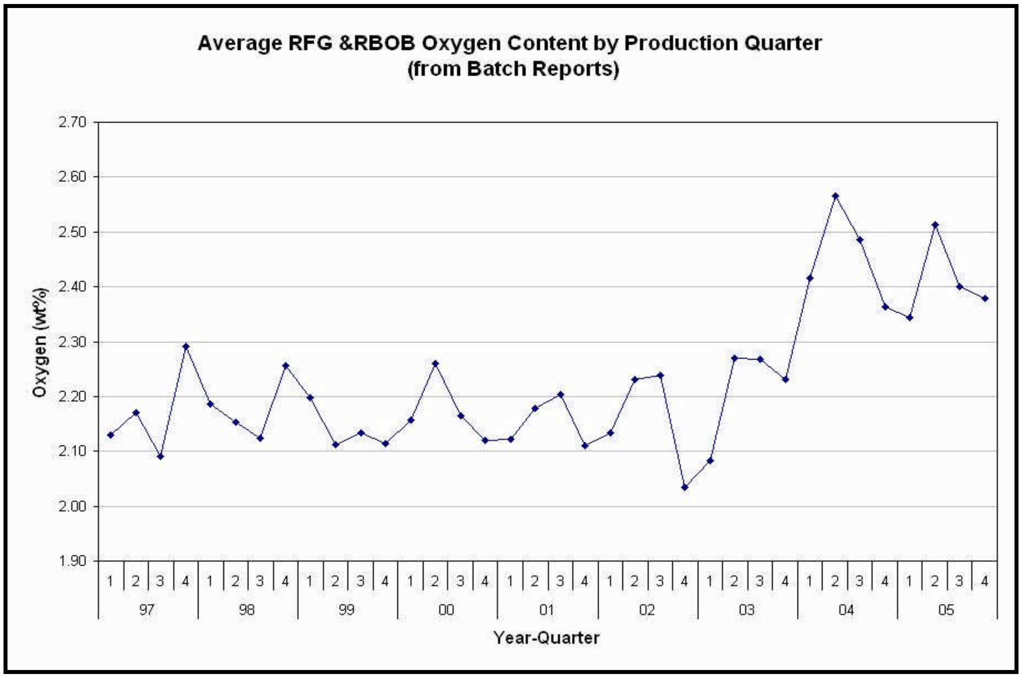


Figure 9

Figures 10 and 11 show the frequency distribution of oxygen concentrations for reporting year 2005 RFG (and RBOB) batches. For both distributions, the portion representing ethanol-oxygenated RFG and RBOB blended (or assumed blended) at about 10 volume percent is clearly evident between about 3.3 and 4 weight percent oxygen. Very little RFG or RBOB was reported with oxygen content between approximately 2.7 weight percent, the "substantially similar" upper limit exclusive of any waivers, and about 3.3 weight percent. Virtually all of the remaining volume fell between approximately 1.5 weight percent, the per gallon minimum allowed with averaged standards, and approximately 2.7 weight percent. The batches in this oxygen content range are predominantly ether-oxygenated, however some ethanol-oxygenated RBOB batches also fall within this range. Both distributions show a peak below 2.0 weight percent.

Several factors contributed to the variability of oxygen content within this 1.5 to 2.7 weight percent range. Most RFG producers chose to comply with oxygen content standards on an average rather than per gallon basis. The regulations permitting compliance on average and the use of credits to meet the oxygen standard provided flexibility in the amount of oxygen a refiner or importer might use in an individual batch as well as in total. In some cases, refiners and importers may have chosen to produce some or all of their RFG with a relatively low oxygen content, using credits, while in other cases they may have chosen to produce higher oxygen content ether-oxygenated RFG, hence not requiring or even creating credits. Additionally, refiners and importers may have chosen to blend MTBE or other oxygenates in amounts greater than needed to meet the oxygen content requirement because oxygenates are a good source of octane. Even if a producer did not, on average, exceed the oxygen content requirement, the producer may have blended premium gasoline with higher oxygen or oxygenate content than regular grade. EPA's data analyses indicate that, in aggregate, this was true for MTBE.

Table 1 shows volume-weighted average MTBE content (in volume percent), calculated for regular and premium grade RFG (and RBOB if any) batches where MTBE content was greater than zero and ethanol content equal to zero. It shows that higher levels of MTBE were used in premium RFG than in regular RFG in each year and season. These averages may not precisely represent the actual MTBE levels, by grade, found in retail MTBE-oxygenated RFG for various reasons (e.g. a portion of regular and premium production is blended at points downstream of refineries to produce mid-grade gasoline.) RFG Survey data analysis, presented in the appendix to this chapter, also estimates higher MTBE levels in premium RFG than in regular or mid-grade. Since the survey-based MTBE averages include ethanol-oxygenated RFG with no MTBE content, the averages underestimate the level of MTBE in MTBE-oxygenated RFG.

Average MTBE Content (volume %) By Grade for RFG Batches with MTBE but no Ethanol

Season	**Grade**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Summer	PRM	11.08	10.96	10.65	11.06	11.19	10.99	10.97	11.65	11.69
	REG	9.78	9.87	9.70	10.08	9.99	10.41	10.57	10.85	10.16
Winter	PRM	11.52	11.26	10.72	10.08	10.31	10.11	10.33	10.87	10.67
	REG	9.86	10.15	9.68	9.67	9.54	9.54	9.67	9.98	9.67

Table 1

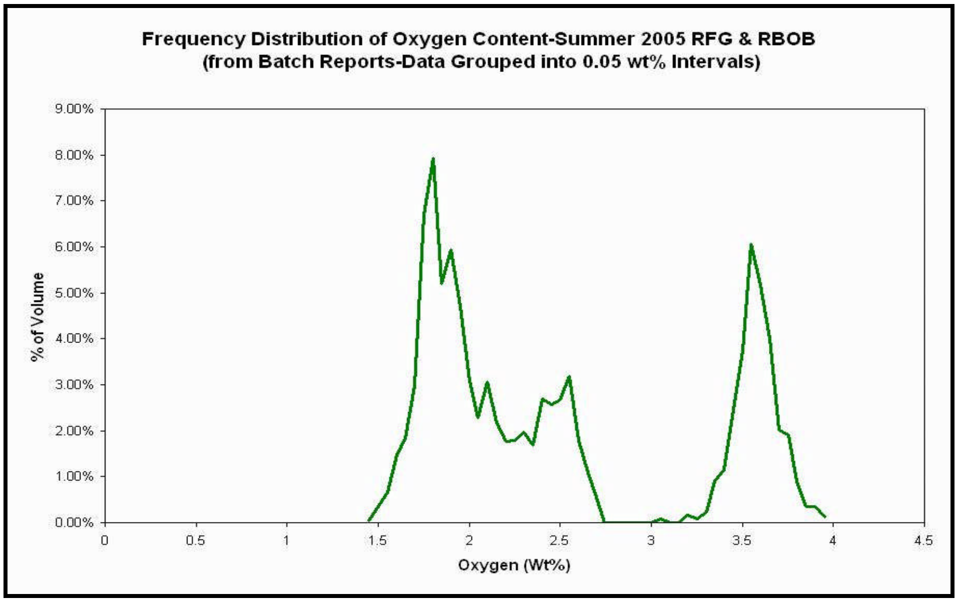


Figure 10

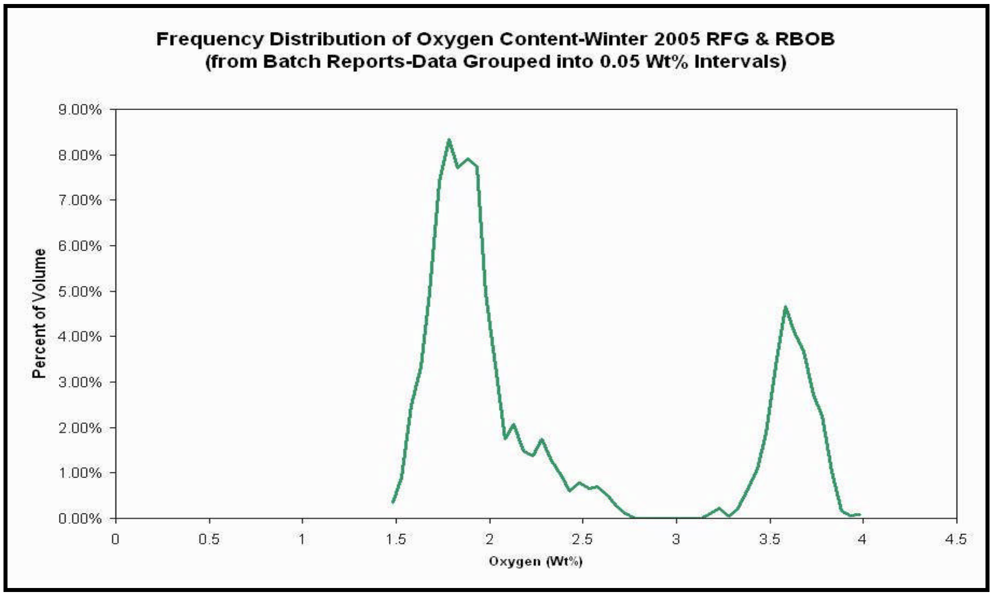


Figure 11

Since the "substantially similar" waiver for gasohol allows ethanol blending at any level up to 10 volume percent, an ethanol-oxygenated RFG batch could have contained any amount of oxygen between approximately the per-gallon minimum and approximately the 4.0 weight percent Complex model maximum. Analysis of the 2005 reporting data indicates that virtually no batches fell within a portion of this range. Although downstream oxygenate blenders may in some cases have blended and distributed RFG with oxygen content within the "empty" portion of the reporting data distribution, analysis of RFG Survey data confirms that very little of the RFG sold during that period contained oxygen greater than 2.7 weight percent and less than 3.3 weight percent. In comparison to the reporting data analysis, the survey data analysis also estimates a slightly larger fraction of the total RFG volume containing 3.3 or more weight percent oxygen, and a slightly smaller fraction containing 2.7 percent or less oxygen. This last finding is consistent with other indications that more ethanol is blended downstream than is assumed for refiner and importer RFG compliance reporting.

There are several additional factors which contribute to the shape of the distributions pictured, and in particular, explain why very little volume falls between about 2.7 and 3.3 weight percent. As noted, the excise tax incentive as structured until a recent legislative change favored 10 volume percent ethanol blending and was tied to three discrete volume concentrations (10%, 7.7% and 5.7%) with 7.7% nominally equivalent to 2.7 weight percent oxygen. EPA's RFG regulations also, in certain circumstances, provided incentives for using ethanol at 10 volume percent. These incentives included a relaxed VOC performance standard applicable to 9-10 volume percent ethanol-blended Summer RFG sold in the Chicago and Milwaukee areas and the oxygen credit program (i.e. the most credits would be generated when ethanol is blended at around 10 percent). Additionally, when ethanol is blended into a hydrocarbon blendstock to make gasoline, an RVP increase occurs which does not occur if MTBE or other ethers are blended to make gasoline. Consequently, low volatility RBOB is needed to produce ethanol-oxygenated RFG during the Summer to ensure that the finished RFG will meet VOC performance standards. Thus refining the blendstock needed to produce ethanol-oxygenated RFG is sometimes more costly than refining the blendstock needed to produce ether-oxygenated RFG. However, the blendstock needed to produce 10 percent ethanol-oxygenated RFG may not be more expensive to refine than the blendstock needed to produce 5.7 volume percent ethanol-oxygenated RFG, or RFG with any intermediate ethanol content. Lastly, EPA's RFG regulations pertaining to downstream oxygenate blending limit the amount of oxygen that refiners or importers can claim to 2.0 weight percent, and in certain circumstances requires that a refiner or importer assume that only 4.0 volume percent ethanol (about equivalent to the 1.5 weight percent oxygen per gallon minimum) will be blended downstream, unless they meet certain contractual and quality assurance requirements (see ‘80.69). While it would normally have been advantageous for refiners and importers to claim as high an oxygen content as possible in their compliance calculations, there would have been some trade-off between the benefits of claiming an oxygen content equivalent to 10 volume percent ethanol, and any costs associated with meeting these blender oversight requirements. If a refiner or importer elected not to meet these requirements, the amount of oxygen assumed would be 2 weight percent or less and if he elected to meet these requirements, he would in all likelihood have chosen to claim an oxygen content equivalent to 10 volume percent ethanol. Presumably, if refiners or importers produced RBOB for ethanol blending, there was little economic motivation to claim an ethanol content greater than that required to meet the 5.7 volume percent threshold but substantially less than 10 volume percent.

The appendix to this chapter contains tabular and graphical percentile (i.e., cumulative distribution) data for oxygen content, ethanol content and MTBE content based on reporting data. The ethanol percentile charts clearly show that ethanol content falls into discrete ranges, as would be expected from the above discussion. An additional factor contributing to the total absence of gasoline volume in a portions of this distribution is that ethanol is seldom reported as used in combination with other oxygenates. The MTBE percentile charts show that there are some batches that contain MTBE in amounts significantly greater than zero but at a concentration insufficient to meet a 1.5 weight percent per-gallon minimum oxygen standard (about 8 volume percent MTBE). This occurred because it is not unusual to find MTBE in combination with other oxygenates such as TAME in a given batch of gasoline.

Since there is interest in the absolute volume of oxygenates in gasoline, EPA has included estimates of non-oxygenated hydrocarbon and oxygenate volume for federal RFG. Table 2 shows volume estimates calculated from the batch volumes and oxygenate volume percent concentrations contained in refiner and importer batch reports.

EPA believes that these totals, in general, provide good, but imperfect, estimates of the volumes of oxygenates used in federal RFG outside of California. [29] Although some reporting errors and omissions exist, the impact on overall totals, with the exception of the ethanol volume, is likely to be small. Reliance on the refiner and importer batch data to estimate ethanol volumes is likely to be a more significant source of error in the ethanol volume estimates, for two reasons. First, as previously explained, the amount of ethanol blended downstream may exceed the amount assumed by refiners and importers. Second, although most RBOB refiners and importers report the oxygenate type and volume percent concentrations used in their "hand blends", some parties omit this data. EPA's regulations require that refiners and importers include the oxygenate volume in the volume reported for each RBOB batch but do not explicitly require that they submit the oxygenate type and volume percent concentration. Thus, EPA's oxygenate volume calculations in table 2 would not have included the oxygenate volumes for these batches. Consequently, the ethanol volumes contained in the above table are virtually certain to be lower than the actual volume of ethanol in RFG.

EPA's regulations require that RFG oxygenate blenders report oxygenate volume data. While these data provide an alternative means to develop an RFG ethanol volume estimate, blenders complying

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[29] The oxygenate volume estimates in this report are based on analysis of data and information submitted to EPA for purposes other than tracking the absolute volume of oxygenates used in gasoline. Although, in some cases, the calculated volume estimates are shown to the nearest gallon this level of precision and accuracy is not implied; these estimates are approximate. EPA has not determined that these volume estimates are the best available published information on this topic. Readers should be aware that the Department of Energy’s Energy Information Administration collects and publishes official energy statistics from the US government (see http://www.eia.doe.gov/).

with the per gallon oxygen content standard do not submit batch reports, complicating analysis of these blender data. In lieu of blender data analysis, EPA has performed other analyses which quantify the sensitivity of ethanol and total volume estimates to downstream blending.

Table 3 compares the estimates of ethanol and total RFG volume calculated directly from refiner and importer batch reports with two alternatives (shown in bold font). The first alternative assumed that each batch that did not contain oxygenate type and volume percent concentration data was oxygenated with 4.0 volume percent ethanol. (This "minimum value" assumption has a regulatory basis under certain circumstances; however in this analysis EPA applied this value to all "omitted data" batches regardless of batch type or other information.) The amount of ethanol attributed to these omitted data batches was added to the amount directly calculated from reported volumes and concentrations. The second alternative assumed that all batches containing at least 3.8 volume percent ethanol and all batches with omitted oxygenate data were oxygenated with 10 volume percent ethanol. Although this had a small effect on ethanol totals, it also assumed batches with less than 3.8 volume percent ethanol contained the directly calculated ethanol volume. The assumptions in the second alternative also have an effect on the volume for certain batches, and the table also shows the effect on the total RFG volume.

Since the “10 volume %” assumption is more consistent with survey data and other information than the “minimum value” assumption. EPA expects that the lower reporting-based estimates are virtually certain to have underestimated actual ethanol usage in RFG. However, while the higher based estimates are expected to be closer to actual usage, they may possibly overestimate ethanol volume. RFG survey sampling occasionally found samples outside of California where ethanol was present in concentrations significantly lower than 10 volume percent. Additionally, even when ethanol is blended at a nominal 10 volume percent, the actual ethanol concentration is usually slightly less than 10 percent because the ethanol blended into gasoline is denatured; i.e. it contains a small amount of an impurity making it unfit for human consumption.

Non-reporting, reporting errors and omissions as well as violation of EPA's regulatory limits on ethanol in gasoline could have resulted in RFG ethanol volume outside of the estimated ranges. However, EPA believes that the actual ethanol volume in RFG, in each year, while almost certainly above the lower reporting-based estimate, would not have significantly exceeded the higher reporting-based estimate. To further investigate this assumption, EPA also estimated ethanol volume in each year using the average RFG ethanol content estimates derived from RFG Survey data together with the annual RFG volume estimates that the RFG Survey Association provides in its survey plans. EPA assumed that 45% of this volume is VOC-controlled Summer RFG and 55% Winter RFG, since these are approximately the ratios seen in the reporting data. These survey-based estimates of RFG ethanol volume are also summarized in Table 3. In each year through 2004 the survey-based estimates fell between the high and low reporting-based estimates, closer to the higher reporting estimate. In 2005 the survey-based estimate exceeded the higher reporting-based estimate by less than three percent. These survey-based approximations, in general, indicate that the actual RFG ethanol volume in each year probably fell between the low and high reporting-based estimates. Although the 2005 survey-based estimate slightly exceeded the upper reporting-based estimate, this does not strongly indicate that actual ethanol volume exceeded the reporting-based estimate, given the approximate nature of these calculations.

As part of the process leading to the finalization of regulations to implement the renewable fuels program requirements of the Energy Policy Act of 2005, EPA published a Regulatory Impact Analysis (RIA) addressing the emissions, air quality and economic impacts of the program.[30] The RIA contained estimates of volumes for ethanol and MTBE use, based on historic data from various sources, to represent baseline conditions. EPA derived the estimates of oxygenate volume in this “trends” report independently from the analyses supporting its Renewable Fuels Standard (RFS) Regulations.

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[30] The RIA is available at http://epa.gov/otaq/renewablefuels/420r07004.pdf

Given the significance of the RFS program it is appropriate for this "trends report" to include some comparison of estimates to identify any significant disparities. Examination of comparable results indicates that they are in reasonably good agreement with respect to RFG oxygenate volumes. Specifically, estimates of oxygenate use in 2004 federal RFG contained in this report can be compared with 2004 base year estimates in the RFS RIA.

Ethanol volume totals in Table 3 of this chapter can be compared to the sum of the 2004 PADD 1, 2 and 3 RFG ethanol consumption estimates in the RFS regulatory impact analysis (1,230 million gallons).[31] The ethanol volume estimates in the trends report are intended to estimate the volume of ethanol without considering the volume of any denaturant that may be present in the ethanol. For various other purposes, including compliance with the RFS, and Internal Revenue Service excise tax regulations, the volume of denaturant is included. Assuming that 5% of the ethanol consumption estimate in the RFS RIA is denaturant, it is appropriate to compare the trends report volume estimates to 95% of the RFS estimate (1,169 million gallons). The comparable trends report ethanol volume estimates are about 78% (916 MM gallons-low reporting), 93% (1,090 MM gallons-surveys) and 96% (1,120 MM gallons - high reporting) of this volume. The upper reporting system-based estimate, which assumed that ethanol is blended into RBOB at the 10 volume % limit, agrees well with both the survey-based estimate in the trends report and the estimate in the RFS RIA.

Estimates of 2004 RFG MTBE volume shown in table 2 of this chapter can be compared with 2004 estimates in the RFS RIA. The trends report estimate (2,135 MM gallons) can be compared with the total RFG MTBE volume (1,878 MM gallons) given in the RFS RIA.[32] This latter total included 19 MM gallons used in PADD5, where Arizona's "Cleaner Burning Gasoline" fuel regulations impose requirements similar to those of federal and California RFG programs in the Phoenix area.

Refiners and importers are required to report volume percent MTBE content and batch volume for each RFG batch. MTBE was typically blended at the refinery, rather than at terminals, and there is no requirement to add a denaturant to MTBE. Consequently, calculation of MTBE volume from these batch report concentrations and volumes should provide a reasonably accurate estimate of the MTBE volume in non-California gasoline produced as RFG in a given year. California banned MTBE use after January 1, 2004, so reporting system MTBE estimates for 2004 and 2005, unlike prior year estimates, should reflect nationwide MTBE usage in RFG. The reporting system estimate exceeds the 2004 estimate in the RFS RIA by less than 14 percent. The RFS RIA noted that the Energy Information Administration reported 2004 MTBE usage in RFG as 2.0 billion gallons, but the RFS RIA analysis reduced this to 1.9 billion gallons.[33] Although the RFS RIA estimate is lower than the trends report estimate, the RIA estimate is characterized as a "consumption" estimate while the trends report estimate is a refiner/importer estimate, and MTBE consumption in RFG areas could have been smaller than the MTBE content in gasoline produced as RFG since some RFG could have been marketed outside of RFG areas. Since EPA's reporting-based MTBE volume estimates are expected to closely estimate actual MTBE use in RFG, the trends report does not include a table of survey-based MTBE volume estimates, as it does for ethanol. However, using the same basic assumptions, the survey-based MTBE use estimate for 2004 RFG is about 2.0 billion gallons.

EPA has a limited basis for estimation of oxygenate volumes in the RFG sold in federal RFG areas in California. (These are areas where RFG is mandated by the Clean Air Act and federal regulations, based on ozone air quality.) EPA's regulations (40 CFR 80.81), which exempt refiners importers and oxygenate blenders of California gasoline from many of the reporting requirements applicable to gasoline sold outside of California, provided for oxygen surveys in these areas to ensure that the federal RFG oxygen content standard was met.

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[31] See RIA table 2.2-5 page 63

[32] See RIA table 2.2-3 page 59

[33] See footnote 26 page 57 of the RIA.

Estimated Gallons of RFG Oxygenates and Hydrocarbons based on Refiner/Importer Batch Reports (Excludes California)

Season	**Data**	1997	1998	1999	2000	2001	2002	2003	2004	2005
Summer	MTBE	1,071,597,101	1,125,469,361	1,089,183,554	1,135,416,556	1,154,011,408	1,199,903,109	1,175,062,810	1,017,763,982	970,917,488
	Ethanol	116,719,792	126,671,140	135,612,567	144,765,712	140,950,792	173,837,314	186,597,775	418,865,421	392,714,925
	ETBE	163,905	57,783	76,521	529,920	550,207	211,833	777,507	124,041	1,417,282
	TAME	96,796,209	97,298,332	109,093,183	119,311,611	115,382,581	102,443,754	109,992,263	57,917,198	59,781,098
	T_butanol	1,852,929	1,662,098	2,129,311	2,306,023	2,700,257	3,191,915	2,769,361	3,302,839	2,879,387
	Methanol	2,409,022	1,842,350	1,366,976	942,867	2,006,367	939,210	950,143	1,123,509	816,929
	Hydrocarbons w/o oxygen	11,209,230,173	11,484,418,551	11,665,634,998	11,579,895,788	11,814,114,444	12,367,444,499	12,108,710,985	12,733,380,559	12,663,961,928
	Total Volume	12,498,769,130	12,837,419,615	13,003,097,110	12,983,168,478	13,229,716,057	13,847,971,634	13,584,860,845	14,232,477,549	14,092,489,036
Winter	MTBE	1,247,140,935	1,287,536,349	1,234,898,146	1,256,617,034	1,249,894,911	1,269,523,975	1,224,289,829	1,116,862,067	1,121,563,294
	Ethanol	176,044,353	182,154,056	172,692,564	188,289,969	179,198,097	207,787,969	264,607,450	425,217,760	458,144,406
	ETBE	163,829	404,759	145,423	722,267	2,353,316	1,857,791	176,153	285,687	4,288,669
	TAME	102,918,788	102,954,626	118,188,700	113,252,505	108,920,290	93,243,310	59,626,275	51,860,959	46,435,024
	T_butanol	2,525,600	2,322,076	2,740,995	2,202,582	2,538,465	2,829,843	2,839,813	2,673,376	2,788,917
	Methanol	2,165,515	1,417,924	1,861,992	1,073,472	1,915,335	1,758,366	1,469,656	798,214	1,007,389
	Hydrocarbons w/o oxygen	13,400,206,530	13,507,944,631	13,553,712,580	14,268,916,880	14,238,183,530	14,856,998,466	15,126,763,959	15,596,672,836	16,410,604,358
	Total Volume	14,931,165,550	15,084,734,421	15,084,240,402	15,831,074,709	15,783,003,943	16,433,999,720	16,679,773,135	17,194,370,899	18,044,832,058
Annual	MTBE	2,318,738,035	2,413,005,710	2,324,081,700	2,392,033,591	2,403,906,319	2,469,427,084	2,399,352,639	2,134,626,049	2,092,480,782
	Ethanol	292,764,145	308,825,195	308,305,131	333,055,681	320,148,888	381,625,284	451,205,225	844,083,182	850,859,331
	ETBE	327,734	462,542	221,944	1,252,187	2,903,523	2,069,624	953,660	409,728	5,705,951
	TAME	199,714,996	200,252,958	227,281,884	232,564,116	224,302,871	195,687,064	169,618,537	109,778,157	106,216,123
	T_butanol	4,378,529	3,984,174	4,870,306	4,508,605	5,238,723	6,021,758	5,609,175	5,976,215	5,668,304
	Methanol	4,574,536	3,260,274	3,228,969	2,016,339	3,921,702	2,697,576	2,419,800	1,921,723	1,824,318
	Hydrocarbons w/o oxygen	24,609,436,703	24,992,363,182	25,219,347,578	25,848,812,668	26,052,297,974	27,224,442,965	27,235,474,944	28,330,053,395	29,074,566,286
	Total Volume	27,429,934,680	27,922,154,036	28,087,337,512	28,814,243,187	29,012,720,000	30,281,971,354	30,264,633,980	31,426,848,448	32,137,321,094

Table 2

Reporting System Based Alternative Estimates of RFG Ethanol and Total RFG Volume

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Annual Ethanol Volumes (gallons)									
Estimated from Batch concentrations & volumes	292,764,145	308,825,195	308,305,131	333,055,681	320,148,888	381,625,284	451,205,225	844,083,182	850,859,331
All batches with unreported oxygenate data assumed 4% EtOH	332,630,715	337,543,715	343,328,264	371,560,055	361,793,029	423,492,651	504,208,308	915,998,927	935,017,799
All batches with >= 3.8% ethanol or unreported oxygenate data assumed 10% EtOH	480,033,112	471,648,802	485,801,666	501,070,555	492,370,440	592,815,198	677,741,183	1,119,661,357	1,143,158,771
Total Gallons (from batch volumes)	27,429,934,680	27,922,154,036	28,087,337,512	28,814,243,187	29,012,720,000	30,281,971,354	30,264,633,980	31,426,848,448	32,137,321,094
All batches with unreported oxygenate data assumed 4% EtOH	27,429,934,680	27,922,154,036	28,087,337,512	28,814,243,187	29,012,720,000	30,281,971,354	30,264,633,980	31,426,848,448	32,137,321,094
All batches with >=3.8% ethanol or unreported oxygenate data assumed 10% EtOH	27,517,537,221	28,013,181,344	28,177,276,214	28,885,997,127	29,080,831,200	30,388,492,850	30,358,662,231	31,522,637,261	32,219,224,365

Survey-Based Estimates Annual Ethanol Volumes (gallons)

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Estimated Average Ethanol WT% Concentration-Summer	1.36	1.46	1.60	1.60	1.57	1.81	1.96	3.72	3.81
Estimated Approximate Ethanol Vol% Concentration (assume blend sg=0.745,etoh sg=0.7939)	1.28	1.37	1.50	1.50	1.47	1.70	1.84	3.49	3.58
Estimated Average Ethanol WT% Concentration-Winter	1.83	1.68	1.85	1.96	1.81	1.95	2.52	3.97	4.20
Estimated Approximate Ethanol Vol% Concentration (assume blend sg=0.730,etoh sg=0.7939)	1.68	1.54	1.70	1.81	1.66	1.79	2.31	3.65	3.86
Estimated Annual RFG Total Gallons-except CA (From RFG Survey Plans)	28,352,970,000	28,759,802,000	29,506,498,000	28,922,480,000	29,046,358,000	29,273,367,000	29,979,353,000	30,460,161,000	31,483,686,000
Estimated Annual Ethanol Gallons (assuming 45% Summer RFG/55% Winter RFG)	424,864,889	420,987,795	475,895,074	483,112,058	458,271,047	511,926,099	629,712,996	1,090,058,001	1,175,055,482

Table 3

EPA has received both Summer and Winter oxygen survey data for three areas, Los Angeles, San Diego and Sacramento, since 1997, and for San Joaquin since 2003. These survey data provide estimates of oxygenate concentrations which can be applied to gasoline volume data to estimate oxygenate volumes. EPA does not collect such volume data, however the RFG survey plans and other survey-related documents submitted to EPA contain estimates of annual gasoline volumes for these as well as non-California RFG areas. These estimates were derived from published population and per-capita gasoline consumption data and were generated to determine the total number of RFG surveys that are required in a calendar year. EPA has used these volume estimates throughout this report as weighting factors when averaging survey data from different areas. The gasoline volume estimates for the California areas have been used with the survey oxygenate concentration averages in order to generate the oxygenate volume estimates shown in Table 4. These table values should be considered as "ballpark" estimates, and more accurate estimates of ethanol use in these California areas may be available elsewhere. The reader is also reminded that these estimates do not include oxygenate use in California gasoline sold in areas outside of the federal RFG areas. While California's regulations did not require oxygen in this gasoline, oxygenates were sometimes used.

Estimates of 2004 California RFG ethanol volume shown in table 4 of this report can also be compared with estimates in the RFS RIA.[34] However, the trends report estimate (629 MM gallons) included only the ethanol volume from RFG in the federally-mandated RFG areas in California where, in 2004, gasoline was required to contain oxygen as well as meet statewide California RFG standards. EPA, for its statewide estimate in the RFS RIA (853 MM gallons) assumed, based on discussions with California Air Resources Board staff, that all California gasoline contained 5.7% ethanol, by volume. These two estimates differ primarily because the applicable areas differed.

Estimated Oxygenate Volumes (Millions of Gallons) In California's Federal RFG Areas *

	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Estimated Ethanol Volumes									
Los Angeles, CA	0.0	0.0	0.0	0.0	57.9	55.0	364.4	404.7	397.2
Sacramento Metro, CA	0.0	0.0	0.0	0.0	5.4	8.1	45.2	70.5	59.5
San Diego, CA	0.0	0.0	0.0	0.0	5.5	6.0	55.3	68.3	68.0
San Joaquin, CA	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	42.3	85.2	85.7
Total	**0.0**	**0.0**	**0.0**	**0.0**	**68.9**	**69.2**	**507.3**	**628.7**	**610.4**
Estimated MTBE Volumes									
Los Angeles, CA	717.8	749.8	796.0	800.3	670.5	658.9	44.0	0.0	0.0
Sacramento Metro, CA	99.5	103.6	105.3	106.1	90.6	119.2	46.1	0.0	0.0
San Diego, CA	124.6	128.6	137.9	142.1	134.6	122.0	24.9	0.1	0.0
San Joaquin, CA	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	82.8	0.0	0.0
Total	**941.9**	**982.0**	**1039.2**	**1048.5**	**895.7**	**900.2**	**197.8**	**0.1**	**0.0**
Estimated TAME Volumes									
Los Angeles, CA	18.3	4.2	8.6	10.5	11.5	6.1	0.2	2.0	0.0
Sacramento Metro, CA	3.3	4.9	3.2	4.7	4.5	5.5	2.2	1.1	0.0
San Diego, CA	6.5	1.7	2.6	2.3	0.9	0.1	0.1	0.6	0.5
San Joaquin, CA	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.1	1.8	0.0
Total	**28.2**	**10.8**	**14.4**	**17.6**	**16.9**	**11.6**	**2.5**	**5.5**	**0.5**

* Estimates based on RFG Survey oxygenate measurements and survey plan estimates of gasoline volumes

Table 4

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[34] See RIA Table 2.2-3 page 59

RFG Oxygen and Oxygenates by PADD

Tables 5 through 8 show 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information):

2004 & 2005 Reporting Average by PADD-RFG Oxygen (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (wt %)**	**Gasoline Volume (gal)***	**Average Value (wt %)**	**Gasoline Volume (gal)***
Summer	I	2.59	4,726,753,777	2.50	4,224,319,396
	II	3.48	1,390,108,766	3.50	1,515,851,939
	III	2.36	5,818,619,897	2.25	5,620,100,245
Winter	I	2.45	5,896,265,229	2.41	6,230,237,499
	II	3.26	1,824,393,952	3.24	2,129,892,557
	III	2.09	5,997,046,241	2.05	5,739,092,825
Annual	I	2.51	10,623,019,006	2.45	10,454,556,895
	II	3.35	3,214,502,718	3.35	3,645,744,496
	III	2.22	11,815,666,138	2.15	11,359,193,070

*Volumes exclude batches with missing values for this parameter

Table 5

2004 & 2005 Reporting Averages by PADD-RFG Ethanol (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	3.01	4,726,753,777	3.14	4,224,319,396
	II	9.39	1,390,108,766	9.46	1,515,851,939
	III	1.75	5,827,786,523	1.31	5,620,730,455
Winter	I	3.00	5,896,265,229	3.02	6,227,516,269
	II	8.61	1,824,393,952	8.63	2,129,892,557
	III	0.98	5,997,046,241	0.91	5,739,092,825
Annual	I	3.01	10,623,019,006	3.07	10,451,835,665
	II	8.95	3,214,502,718	8.97	3,645,744,496
	III	1.36	11,824,832,764	1.11	11,359,823,280

*Volumes exclude batches with missing values for this parameter

Table 6

2004 & 2005 Reporting Averages by PADD-RFG MTBE (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	8.02	4,726,753,777	7.13	4,224,319,396
	II	0.00	1,390,108,766	0.00	1,515,851,939
	III	8.74	5,827,786,523	8.96	5,620,730,455
Winter	I	7.11	5,896,265,229	6.82	6,227,516,269
	II	0.00	1,824,393,952	0.00	2,129,892,557
	III	8.52	5,997,046,241	8.53	5,739,092,825
Annual	I	7.52	10,623,019,006	6.95	10,451,835,665
	II	0.00	3,214,502,718	0.00	3,645,744,496
	III	8.63	11,824,832,764	8.74	11,359,823,280

*Volumes exclude batches with missing values for this parameter

Table 7

2004 & 2005 Reporting Average by PADD-RFG TAME (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	0.14	4,726,753,777	0.28	4,224,319,396
	II	0.00	1,390,108,766	0.00	1,515,851,939
	III	0.55	5,827,786,523	0.59	5,620,730,455
Winter	I	0.05	5,896,265,229	0.09	6,227,516,269
	II	0.00	1,824,393,952	0.00	2,129,892,557
	III	0.68	5,997,046,241	0.53	5,739,092,825
Annual	I	0.09	10,623,019,006	0.17	10,451,835,665
	II	0.00	3,214,502,718	0.00	3,645,744,496
	III	0.62	11,824,832,764	0.56	11,359,823,280

*Volumes exclude batches with missing values for this parameter

Table 8

Figures 12 through 17 show estimates of average oxygen, ethanol and MTBE levels by PADD in retail RFG. [35] These averages are volume-weighted averages of the seasonal averages for each area, using gasoline volume estimates supplied in the survey plans. (Oxygenate concentrations for these retail data are in weight percent.) In 2005, RFG surveys were conducted in 18 PADD I areas, five PADD II areas, two PADD III areas and four PADD V areas. It is obvious that virtually all PADD II RFG in more recent years was ethanol-oxygenated. Increased ethanol use in PADDs I and V during the "trends report" time period occurred primarily as a result of state MTBE bans. The survey averages show a small amount of ethanol use in PADD I winter RFG even prior to these bans, but no ethanol use in summer RFG. EPA regulations contained prohibitions against combining VOC-controlled ethanol-oxygenated RFG with VOC controlled RFG produced using any other oxygenate during the January 1st through September 15th period. Thus, limited ethanol use in predominantly MTBE-oxygenated RFG areas would have been more feasible in winter than summer RFG.

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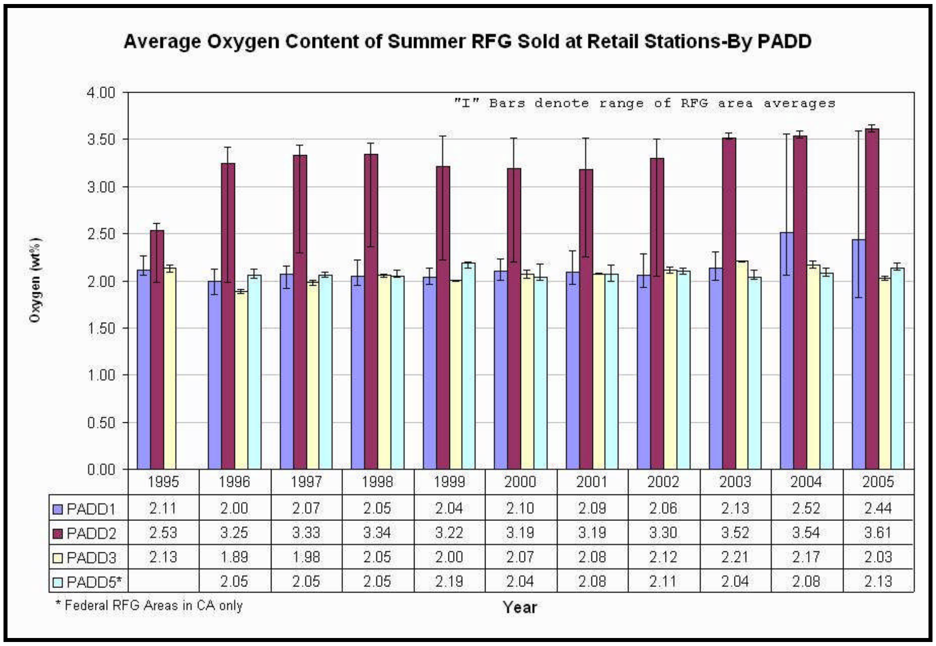
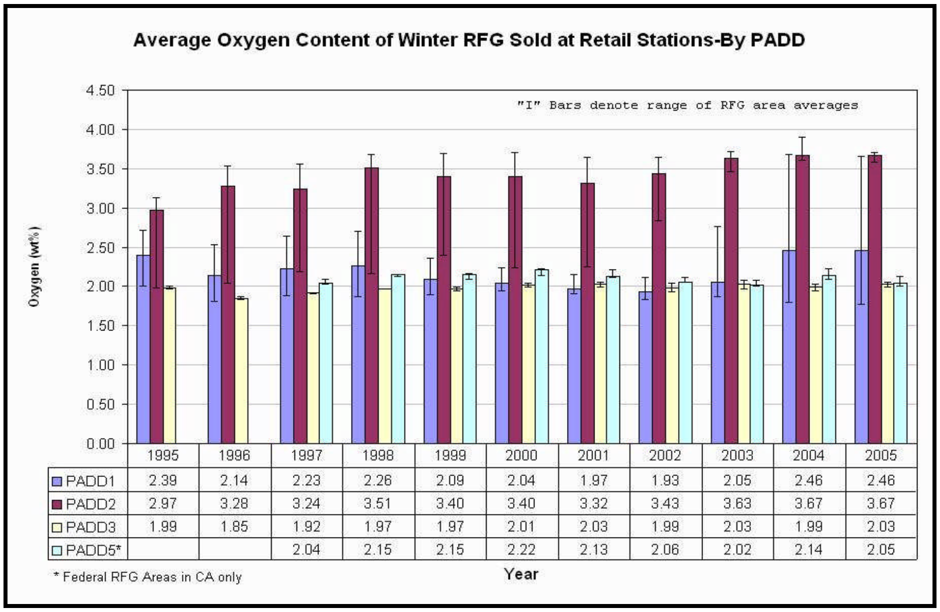
[35] Since TAME was always found in conjunction with MTBE but at much lower concentrations, PADD-specific retail averages are not shown. Area-specific RFG Survey average oxygenate concentrations for TAME and other oxygenates can be found at http://epa.gov/otaq/regs/fuels/rfg/properf/rfgperf.htm.



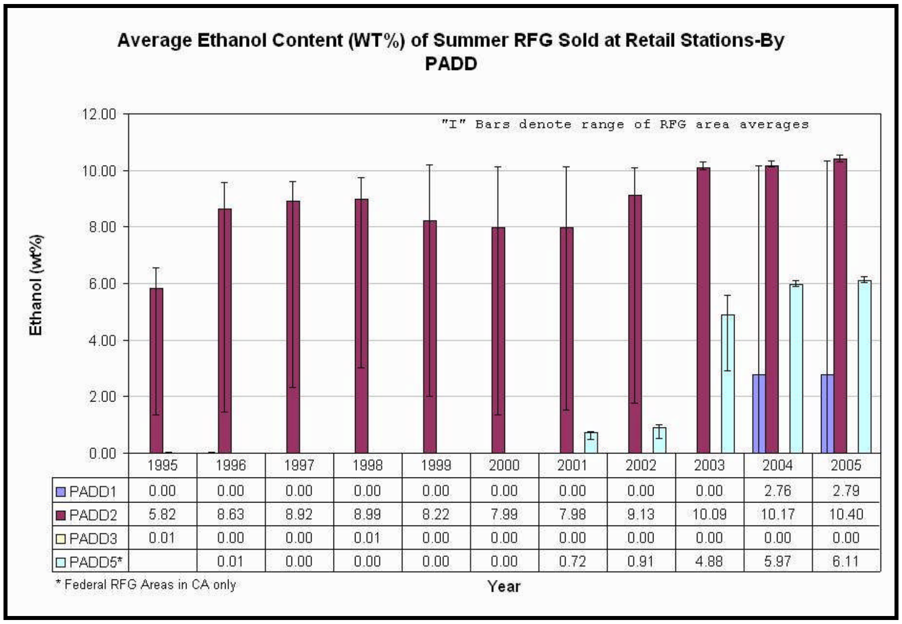
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PADD1	2.11	2.00	2.07	2.05	2.04	2.10	2.09	2.06	2.13	2.52	2.44
PADD2	2.53	3.25	3.33	3.34	3.22	3.19	3.19	3.30	3.52	3.54	3.61
PADD3	2.13	1.89	1.98	2.05	2.00	2.07	2.08	2.12	2.21	2.17	2.03
PADD5*		2.05	2.05	2.05	2.19	2.04	2.08	2.11	2.04	2.08	2.13

Figure 12



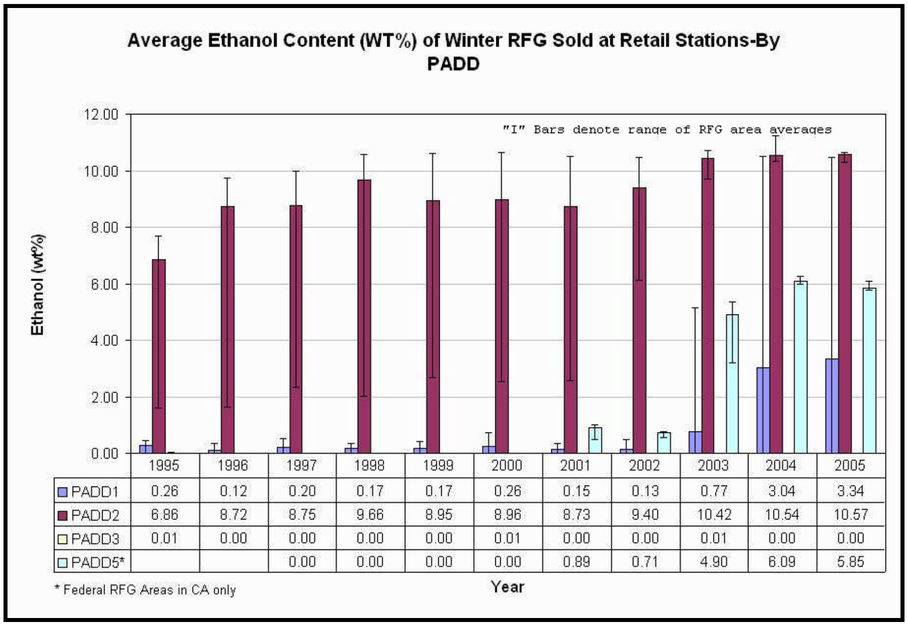
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PADD1	2.39	2.14	2.23	2.26	2.09	2.04	1.97	1.93	2.05	2.46	2.46
PADD2	2.97	3.28	3.24	3.51	3.40	3.40	3.32	3.43	3.63	3.67	3.67
PADD3	1.99	1.85	1.92	1.97	1.97	2.01	2.03	1.99	2.03	1.99	2.03
PADD5*			2.04	2.15	2.15	2.22	2.13	2.06	2.02	2.14	2.05

Figure 13



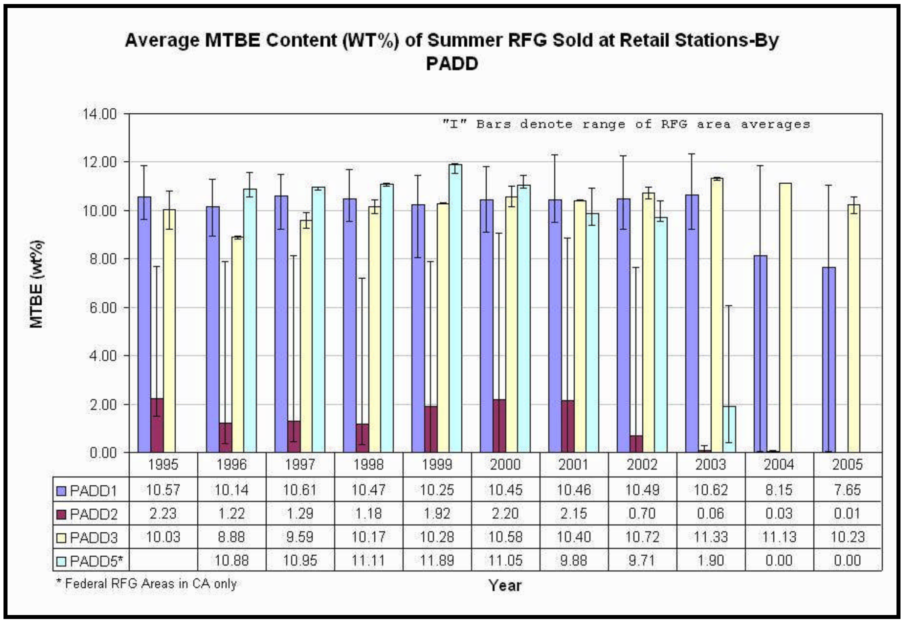
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PADD1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.76	2.79
PADD2	5.82	8.63	8.92	8.99	8.22	7.99	7.98	9.13	10.09	10.17	10.40
PADD3	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PADD5*		0.01	0.00	0.00	0.00	0.00	0.72	0.91	4.88	5.97	6.11

Figure 14



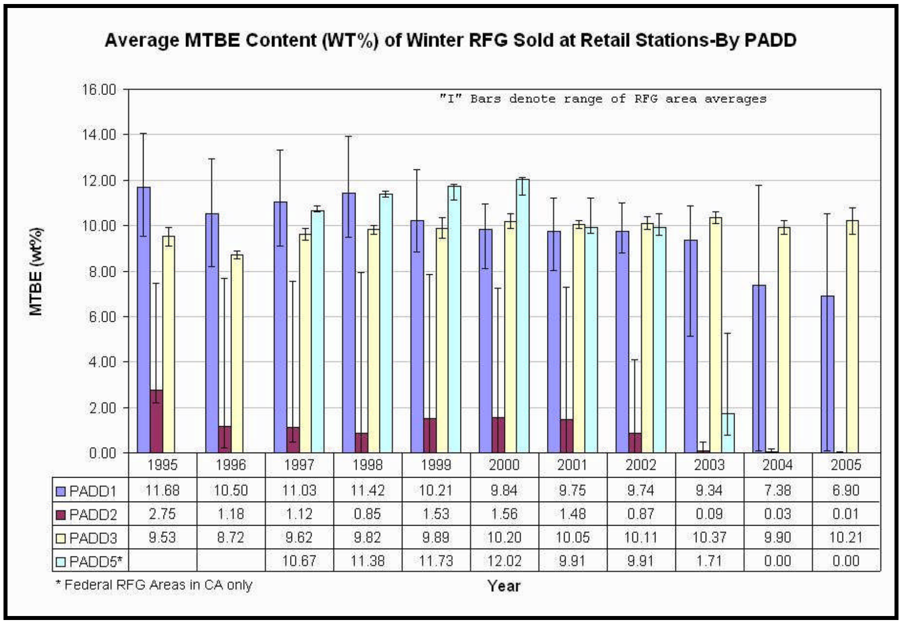
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PADD1	0.26	0.12	0.20	0.17	0.17	0.26	0.15	0.13	0.77	3.04	3.34
PADD2	6.86	8.72	8.75	9.66	8.95	8.96	8.73	9.40	10.42	10.54	10.57
PADD3	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00
PADD5*			0.00	0.00	0.00	0.00	0.89	0.71	4.90	6.09	5.85

Figure 15



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PADD1	10.57	10.14	10.61	10.47	10.25	10.45	10.46	10.49	10.62	8.15	7.65
PADD2	2.23	1.22	1.29	1.18	1.92	2.20	2.15	0.70	0.06	0.03	0.01
PADD3	10.03	8.88	9.59	10.17	10.28	10.58	10.40	10.72	11.33	11.13	10.23
PADD5*		10.88	10.95	11.11	11.89	11.05	9.88	9.71	1.90	0.00	0.00

Figure 16



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
PADD1	11.68	10.50	11.03	11.42	10.21	9.84	9.75	9.74	9.34	7.38	6.90
PADD2	2.75	1.18	1.12	0.85	1.53	1.56	1.48	0.87	0.09	0.03	0.01
PADD3	9.53	8.72	9.62	9.82	9.89	10.20	10.05	10.11	10.37	9.90	10.21
PADD5*			10.67	11.38	11.73	12.02	9.91	9.91	1.71	0.00	0.00

Figure 17

Additional Analysis and Observations-RFG

Data analyses pertaining to RFG oxygen and oxygenates are contained in the Appendix to this chapter.

Overview-Conventional Gasoline

For various reasons, analysis of EPA's CG data provides less information about oxygen and oxygenates use than analysis of EPA's RFG data. As noted, refiners and importers do not always report oxygenates added downstream of refineries and import facilities, so EPA's data are likely to underestimate ethanol use in CG, possibly to a greater extent than in RFG, and may underestimate ether use as well. Unlike downstream blenders who add oxygen to RBOB, CG oxygenate blenders are not subject to reporting requirements. Additionally, since there is no nationwide oxygen content standard applicable to CG as there was with RFG, EPA cannot determine if refiner and importer CG batch reports with blank oxygen and oxygenate data fields represent batches with zero oxygen content or batches with data omissions. Since there was no regulatory requirement for CG surveys as there was with RFG, EPA does not have retail data to compare or contrast with CG reporting data.

Nonetheless, EPA has computed estimates of CG oxygenate and hydrocarbon volumes from reporting data. These estimates are contained in Table 9. Since these data are likely to underestimate oxygenate use, and EPA lacks retail data to corroborate trends, any conclusions regarding CG oxygenate volumes or trends based on these data should be considered uncertain. Therefore, this report limits its interpretation of CG oxygenate data to a few observations.

Reporting system ethanol volume estimates for 2004 CG can also be compared with values in the RFS RIA. Based on batch reporting data, EPA estimated approximately 357 million gallons of ethanol in CG. The RFS RIA estimate (Tables 2-9) is 1,149 million gallons in CG and 193 MM gallons in winter oxygenated gasoline. This is consistent with the assumption in the trends report that EPA's Anti-Dumping reporting data significantly underestimates CG ethanol use.

In the trends report EPA estimated that about 410 MM gallons of MTBE were used in 2004 CG production. For its 2004 base case analysis, the RFS RIA assumed that MTBE use outside of RFG could be ignored. The trends report batch data analysis shows that the total MTBE volume used in 2004 CG was about 19% of that used in RFG.

Estimated Gallons of CG Oxygenates and Hydrocarbons based on Refiner/Importer Batch Reports (Excludes California)

Season	Data	1998	1999	2000	2001	2002	2003	2004	2005
Summer	MTBE	252,881,317	263,857,150	239,812,977	249,459,785	261,046,445	303,540,761	220,336,203	156,726,080
	Ethanol	68,787,726	103,158,524	104,005,119	93,305,613	122,469,291	123,138,938	151,645,217	158,885,968
	ETBE	321,936	364,469	697,051	1,203,214	445,999	4,229,741	4,600,108	1,969,397
	TAME	27,389,697	15,739,451	29,062,988	34,129,294	43,476,191	29,299,178	20,856,029	17,903,319
	T_butanol	978,010	1,025,554	1,038,110	1,151,257	1,330,605	763,296	604,433	413,913
	Methanol	1,469,751	440,993	677,409	1,051,256	1,218,595	635,660	494,447	213,725
	Hydrocarbons w/o oxygen	39,636,317,978	39,315,845,797	38,498,391,810	39,112,534,538	41,208,233,201	43,984,491,302	43,604,900,088	42,513,780,773
	Total Volume	39,988,146,413	39,700,431,939	38,873,685,463	39,492,834,956	41,638,220,326	44,446,098,876	44,003,436,524	42,849,893,176
Winter	MTBE	221,924,891	244,488,419	200,707,656	202,568,448	202,532,803	180,866,801	189,744,455	145,192,111
	Ethanol	90,932,967	140,558,756	179,725,078	171,860,389	183,660,878	179,499,685	205,465,808	231,622,489
	ETBE	232,124	82,274	724,484	1,351,462	496,032	1,034,938	1,645,897	4,744,327
	TAME	25,929,645	15,370,098	21,838,185	23,721,415	37,451,523	20,716,356	18,822,251	18,436,905
	T_butanol	679,657	680,049	685,072	837,127	958,779	656,387	555,308	262,795
	Methanol	709,534	602,052	546,135	1,155,641	1,178,733	654,325	413,736	282,911
	Hydrocarbons w/o oxygen	46,584,731,037	47,915,978,752	48,602,598,915	49,333,020,314	50,204,198,335	48,288,412,977	47,906,967,487	49,058,601,515
	Total Volume	46,925,139,854	48,317,760,399	49,006,825,526	49,734,514,796	50,630,477,083	48,671,841,470	48,323,614,941	49,459,143,051
Annual	MTBE	474,806,208	508,345,569	440,520,633	452,028,233	463,579,248	484,407,562	410,080,658	301,918,191
	Ethanol	159,720,692	243,717,280	283,730,197	265,166,002	306,130,168	302,638,623	357,111,024	390,508,457
	ETBE	554,059	446,743	1,421,534	2,554,676	942,031	5,264,680	6,246,004	6,713,724
	TAME	53,319,341	31,109,549	50,901,173	57,850,709	80,927,714	50,015,533	39,678,280	36,340,223
	T_butanol	1,657,666	1,705,602	1,723,183	1,988,384	2,289,384	1,419,683	1,159,741	676,708
	Methanol	2,179,285	1,043,045	1,223,544	2,206,898	2,397,328	1,289,985	908,183	496,635
	Hydrocarbons w/o oxygen	86,221,049,015	87,231,824,549	87,100,990,725	88,445,554,851	91,412,431,536	92,272,904,279	91,511,867,575	91,572,382,288
	Total Volume	86,913,286,267	88,018,192,338	87,880,510,989	89,227,349,752	92,268,697,409	93,117,940,346	92,327,051,465	92,309,036,227

Table 9

Figure 18 shows that reported CG oxygenate volume is less than one percent of reported CG volume. (RFG oxygenate volume has been about ten percent of RFG volume.) Based on analysis of reported volumes and concentrations, MTBE volume percentage has decreased since 1998, while ethanol volume percentage has increased. Decreases in MTBE volume share in CG may be partially attributable to MTBE bans and phase-outs, which also affected some states or portions of states using CG. (The "non-geographic" analysis presented here is insufficient to confirm a direct relationship between MTBE bans and the MTBE volume decrease.) The increase in ethanol volume share estimated from reported volumes and concentrations suggests increased use of ethanol in CG.

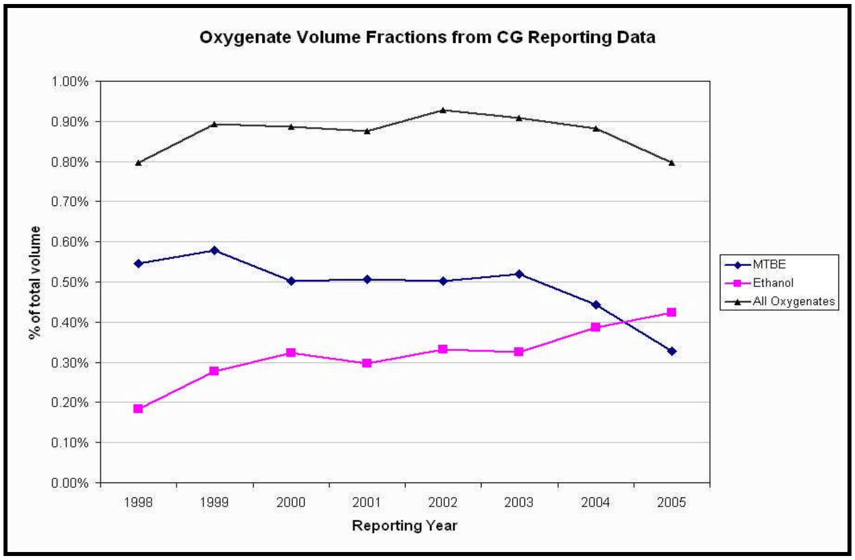


Figure 18

CG Oxygen and Oxygenates by PADD

Tables 10 through 13 show 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information).

As with aggregate CG oxygen and oxygenate data, it is likely that oxygen and ethanol are under-reported:

2004 & 2005 Reporting Average by PADD-CG Oxygen (Refiner Batches Only)

Season	PADD	2004 Average Value (wt %)	Gasoline Volume (gal)	2005 Average Value (wt %)	Gasoline Volume (gal)
Summer	I	0.44	3,752,272,894	0.34	3,547,001,722
	II	0.34	11,456,437,187	0.34	10,566,219,165
	III	0.17	21,722,608,623	0.13	20,889,546,279
Winter	I	0.37	3,484,116,076	0.30	4,064,064,814
	II	0.40	13,323,919,987	0.33	13,589,333,929
	III	0.14	23,628,091,025	0.11	22,443,420,127
Annual	I	0.41	7,236,388,970	0.32	7,611,066,536
	II	0.37	24,780,357,174	0.33	24,155,553,094
	III	0.15	45,350,699,648	0.12	43,332,966,406

Table 10

2004 & 2005 Reporting Averages by PADD-CG Ethanol (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)**	**Average Value (vol %)**	**Gasoline Volume (gal)**
Summer	I	0.82	3,752,272,894	0.74	3,547,001,722
	II	0.97	11,456,437,187	0.97	10,566,219,165
	III	0.06	21,722,608,623	0.05	20,889,546,279
Winter	I	0.83	3,484,116,076	0.68	4,064,064,814
	II	1.16	13,323,919,987	0.92	13,589,333,929
	III	0.05	23,628,091,025	0.07	22,443,420,127
Annual	I	0.82	7,236,388,970	0.71	7,611,066,536
	II	1.07	24,780,357,174	0.94	24,155,553,094
	III	0.05	45,350,699,648	0.06	43,332,966,406

Table 11

2004 & 2005 Reporting Averages by PADD-CG MTBE (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)**	**Average Value (vol %)**	**Gasoline Volume (gal)**
Summer	I	0.70	3,752,272,894	0.39	3,547,001,722
	II	0.00	11,456,437,187	0.00	10,566,219,165
	III	0.76	21,722,608,623	0.60	20,889,546,279
Winter	I	0.35	3,484,116,076	0.30	4,064,064,814
	II	0.00	13,323,919,987	0.00	13,589,333,929
	III	0.65	23,628,091,025	0.41	22,444,880,341
Annual	I	0.53	7,236,388,970	0.34	7,611,066,536
	II	0.00	24,780,357,174	0.00	24,155,553,094
	III	0.70	45,350,699,648	0.50	43,334,426,620

Table 12

2004 & 2005 Reporting Average by PADD-CG TAME (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)**	**Average Value (vol %)**	**Gasoline Volume (gal)**
Summer	I	-0.17	3,752,272,894	0.07	3,547,001,722
	II	0.00	11,456,437,187	0.00	10,566,219,165
	III	0.04	21,722,608,623	0.02	20,889,546,279
Winter	I	0.03	3,484,116,076	0.05	4,064,064,814
	II	0.00	13,323,919,987	0.00	13,589,333,929
	III	0.02	23,628,091,025	0.02	22,444,880,341
Annual	I	-0.08	7,236,388,970	0.06	7,611,066,536
	II	0.00	24,780,357,174	0.00	24,155,553,094
	III	0.03	45,350,699,648	0.02	43,334,426,620

Table 13

Benzene

Background

Benzene is an organic compound found in gasoline. It is one of a family of compounds known as aromatics. Benzene may occur in crude oil. Benzene and other aromatics are also produced in a refinery process called reforming. While gasoline aromatics content, in total, is an important parameter affecting emissions, gasoline benzene content is also considered separately because gasoline benzene content has a direct effect on exhaust and evaporative benzene emissions. Benzene emissions are of concern because benzene is a toxic air pollutant known to be carcinogenic.

Benzene is an important petrochemical. Its uses include manufacture of other compounds used to make plastics, nylon, dyes and detergents. Some refineries producing gasoline may also extract benzene. The demand for benzene as a petrochemical, as well regulatory control of gasoline benzene content for emissions purposes is likely to affect gasoline benzene content trends.

Regulatory Limits on Benzene Content

Several regulatory requirements directly or indirectly limit the benzene content in reformulated and conventional gasoline. RFG benzene content is directly limited through benzene content standards. CG benzene content is directly limited, but less strictly, through Anti-Dumping standards. RFG requirements were intended to create a gasoline that was superior, in emissions performance, to the gasoline that was supplied in 1990. CG "Anti-Dumping" requirements were intended to prevent the quality of CG from deteriorating as a result of the RFG requirements. Consequently, both RFG and CG are subject to regulations designed to limit toxics emissions. Since benzene emissions, which are the largest component of these toxics emissions, increase with increasing gasoline benzene content, limits on toxics emissions indirectly limit gasoline benzene content. These regulatory requirements are discussed in more detail below.

RFG must meet a 1.00 volume percent “per gallon” maximum benzene content standard, or alternatively, on an annual basis, a 0.95 volume percent "averaged" standard with a 1.30 volume percent per gallon maximum. These benzene content standards have been in effect since 1995. RFG benzene content has also been indirectly limited through toxics emission performance (i.e. "percent reduction") standards since 1995. However, the performance standards, unlike the benzene content standards, have not remained constant.

The Simple Model, which was the basis for the RFG toxics performance standard from 1995 through 1997, included estimates of exhaust and (for Summer) evaporative benzene emissions in its toxics performance estimate. The Phase I Complex Model determined emissions performance for RFG in 1998 and 1999. The Phase II Complex Model determines emissions performance for RFG in 2000 and beyond. While there are differences between the Phase I and Phase II Complex Models, both models include exhaust and, for Summer, evaporative benzene in their toxics estimates. Importantly, Phase II RFG is required to meet more stringent toxics reduction standards than Phase I RFG. As with the Simple Model, the Complex Model considers benzene content as one of several gasoline parameters affecting benzene emissions. The Complex Model also considers the emissions effects of several parameters, such as sulfur content, which are not included in the Simple Model. Thus, although other factors are involved, the toxics performance standard limits benzene content

CG benzene content is also both directly and indirectly limited. Annual average benzene levels may not exceed the greater of the refiner's or importer's 1990 baseline for benzene or the Complex Model's 4.9 volume percent benzene "acceptable range" maximum limit specified in EPA's regulations. CG supplied from 1995 through 1997 was required to have annual average exhaust benzene emissions, as calculated by a mathematical model, no greater than the refiner's or importer's compliance baseline for exhaust benzene emissions (i.e. refiners and importers must meet individualized standards for CG, rather than generalized standards, as for RFG.) This exhaust benzene emissions model estimated exhaust benzene as a function of gasoline benzene and aromatics content. CG supplied subsequent to 1997 is required to have exhaust toxics emissions, based on the Complex Model, which do not exceed the refiner's or importer's exhaust toxics compliance baseline. These emissions include other exhaust toxic pollutants in addition to benzene, and several gasoline parameters in addition to benzene affect the benzene portion of these Complex Model toxics emissions. Again, although other factors are involved, the emission requirement indirectly limits CG benzene content.

EPA's Mobile Source Air Toxics (MSAT) regulations have imposed additional requirements on both RFG and CG. These regulations do not regulate benzene content directly or require additional toxic emission reductions. Rather, the MSAT regulations required refiners and importers, beginning on January 1, 2002, to produce or import gasoline with toxics emissions that are no worse than the toxics emissions of gasoline they produced or imported during the period 1998 through 2000. EPA's data indicate that some refiners and importers had over-complied with toxics emissions requirements. The MSAT rule is intended to preserve this over-compliance to ensure that toxics emissions do not increase above current levels. [36]

EPA's Benzene Data

Since gasoline benzene content data has been and is currently necessary to determine RFG and CG compliance, refiners and importers have been required, since 1995, to submit this information to EPA's RFG/Anti-Dumping reporting system for each batch of gasoline refined or imported. Additionally, since 1995, EPA has received RFG Survey data on the benzene content of RFG sold at gasoline stations. EPA has analyzed reporting system benzene data from 1997 through 2005, and RFG Survey data from 1995 through 2005.

Benzene Trends

Overview-Reformulated Gasoline

Figures 1 and 2 show Summer and Winter volume-weighted average RFG benzene content levels, by year. Both the reporting system estimates, by reporting year, and the RFG Survey-based estimates, by survey year, are shown. The decrease in benzene content between Summer 1999 and Summer 2000 RFG, as estimated by both data sets, is greater in magnitude than any prior or subsequent year to year change. The change in benzene content between Summer 1999 and Summer 2000 is also obvious from the frequency distribution comparison shown in Figure 3, and in the distribution trend chart in the appendix to this chapter.

It is clear that Summer RFG benzene content changed concurrently with the transition from Phase I to Phase II RFG. (Regression analysis confirms the subjective conclusion-see "Regression Analysis" appendix). Although the RFG benzene content standard did not change from Phase I to Phase II RFG, as

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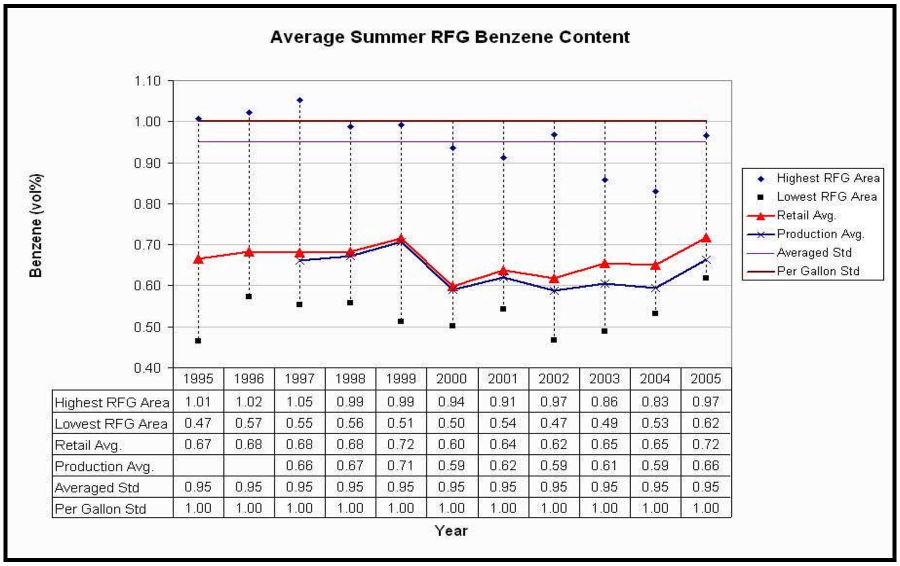
[36] EPA has finalized an "MSAT2" regulation to replace the current MSAT requirements with a 0.62 volume percent average benzene requirement beginning in 2011. See 72 F.R. 8427

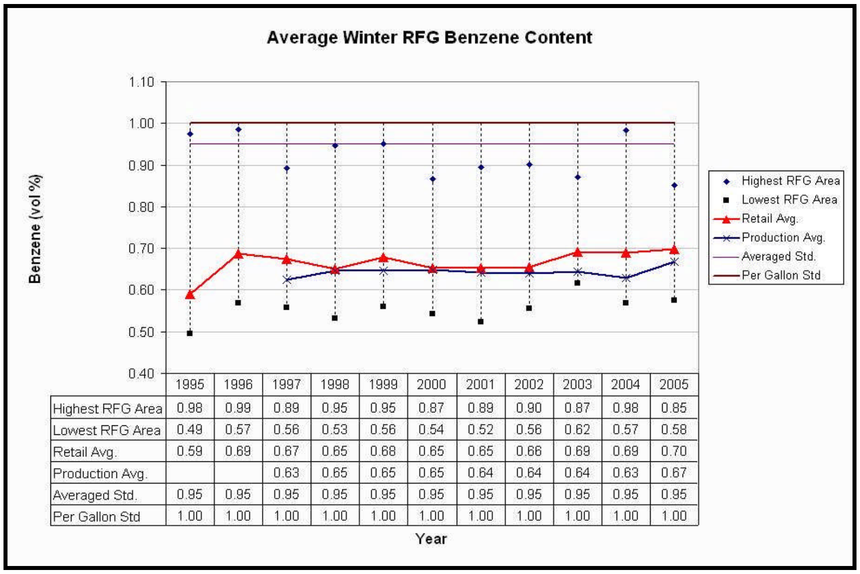
discussed above, the toxics performance requirement became more stringent with Phase II RFG. It is likely that the more stringent Phase II toxics performance requirement is partially, if not primarily responsible for the benzene content reduction, since benzene content affects Complex Model toxics emission performance calculations. Benzene content does not directly affect Complex Model NOx or VOC emission estimates, however, benzene content may also have been collaterally affected by refining and blending changes made in order to comply with Phase II NOx and VOC standards.

The timing of the benzene content shift and the relationship between benzene content and toxics emissions provide strong circumstantial evidence of a cause-effect relationship between the transition to Phase II RFG and the shift in benzene content. The analysis presented in this report is, however, more equivocal in supporting this relationship than in supporting other cause-effect relationships. Analysis presented in the RFG Trends chapter suggests that benzene reduction was not the primary reason for Phase I to Phase II toxics performance improvement and also shows that, although Summer toxics performance improved with Phase II, on average, Phase I RFG complied with Phase II toxics requirements. In contrast, similar analyses suggest that RVP reduction and sulfur reduction were, respectively, the primary reasons for VOC and NOx performance improvements, and that, on average, Phase I RFG did not comply with Phase II VOC or Summer NOx performance standards. Moreover, the demand for benzene as a petrochemical would need to be considered in any rigorous analysis to explain gasoline benzene content trends.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	1.01	1.02	1.05	0.99	0.99	0.94	0.91	0.97	0.86	0.83	0.97
Lowest RFG Area	0.47	0.57	0.55	0.56	0.51	0.50	0.54	0.47	0.49	0.53	0.62
Retail Avg.	0.67	0.68	0.68	0.68	0.72	0.60	0.64	0.62	0.65	0.65	0.72
Production Avg.			0.66	0.67	0.71	0.59	0.62	0.59	0.61	0.59	0.66
Averaged Std	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Per Gallon Std	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure 1



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	0.98	0.99	0.89	0.95	0.95	0.87	0.89	0.90	0.87	0.98	0.85
Lowest RFG Area	0.49	0.57	0.56	0.53	0.56	0.54	0.52	0.56	0.62	0.57	0.58
Retail Avg.	0.59	0.69	0.67	0.65	0.68	0.65	0.65	0.66	0.69	0.69	0.70
Production Avg.			0.63	0.65	0.65	0.65	0.64	0.64	0.64	0.63	0.67
Averaged Std.	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Per Gallon Std	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Figure 2

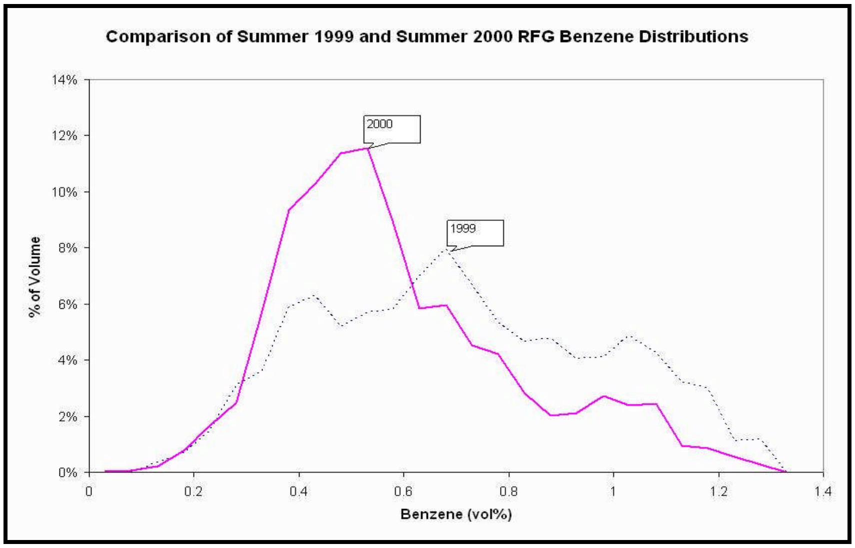


Figure 3

The RFG toxics performance standard applies to all RFG and is met on an annual average basis. However, there was little change in benzene content between Winter 1999 and Winter 2000 RFG, and pre-2000 Winter benzene content levels are comparable to those in 2000 and beyond. A possible explanation for this lack of change in Winter benzene content is that benzene reduction is more valuable as toxics emission reduction strategy when producing Summer RFG, since both exhaust and non-exhaust benzene emissions are considered in Summer toxics performance. Another hypothetical "regulatory" explanation is that, if benzene content changes were largely a collateral effect of refining and blending changes made to meet Phase II VOC and NOx standards, Winter RFG benzene content may not have been affected. VOC standards do not apply to Winter RFG and the Winter NOx standard did not become more stringent.

Comparison of Figures 1 and 2 shows that for Phase II RFG, Winter benzene levels have been consistently higher than Summer levels, while prior to 2000, Summer levels have generally been higher. The survey standard is a 1 percent annual average and, while in some years an RFG area may have approached or even exceeded this level on a seasonal basis, there have been no survey failures.

Both the survey-based and reporting estimates of average benzene concentration indicate increases between 2000 and 2005. After 2000, both summer and winter survey-based estimates have been higher than corresponding reporting estimates. It is not apparent why retail benzene concentrations would be higher than production benzene concentrations. This divergence may be the result of statistical or other errors inherent in the use of the geographic survey data to estimate overall averages.

RFG Benzene by PADD

Table 1 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information):

2004 & 2005 Reporting Averages by PADD-RFG Benzene (Refiner Batches Only)

		2004		**2005**	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	0.55	4,787,247,511	0.62	4,430,366,230
	II	0.84	1,740,499,436	0.86	1,844,913,833
	III	0.54	5,890,920,167	0.60	5,690,766,967
Winter	I	0.65	6,488,981,913	0.69	7,081,608,319
	II	0.79	2,437,732,174	0.81	2,718,751,541
	III	0.54	6,059,647,031	0.57	5,771,776,973
Annual	I	0.61	11,276,229,424	0.66	11,511,974,549
	II	0.81	4,178,231,610	0.83	4,563,665,374
	III	0.54	11,950,567,198	0.59	11,462,543,940

*Volumes exclude batches with missing values for this parameter

Table 1

Figures 4 and 5 show estimates of average levels by PADD in retail RFG. These averages are volume-weighted averages of the seasonal averages for each area, using gasoline volume estimates supplied in the survey plans. In 2005, RFG surveys were conducted in 18 PADD I areas, five PADD II areas and two PADD III areas. Survey averages show consistently higher benzene levels in PADD II, as do the reporting averages for the two years analyzed.

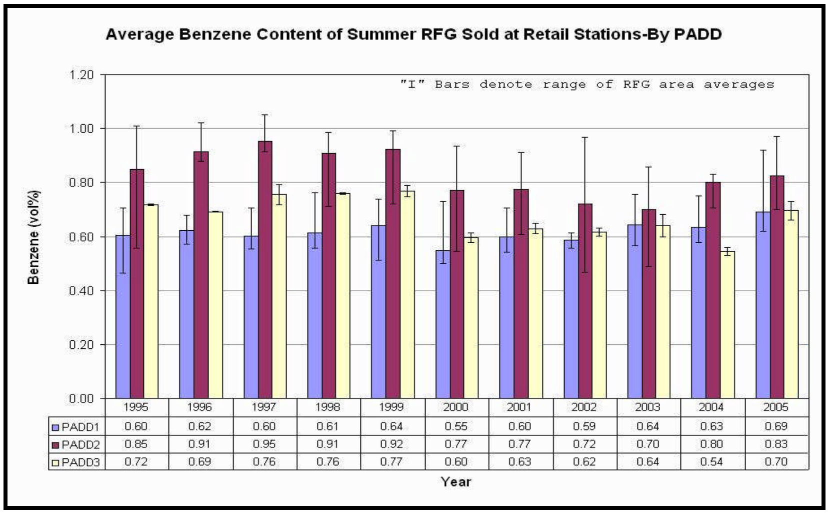


Figure 4

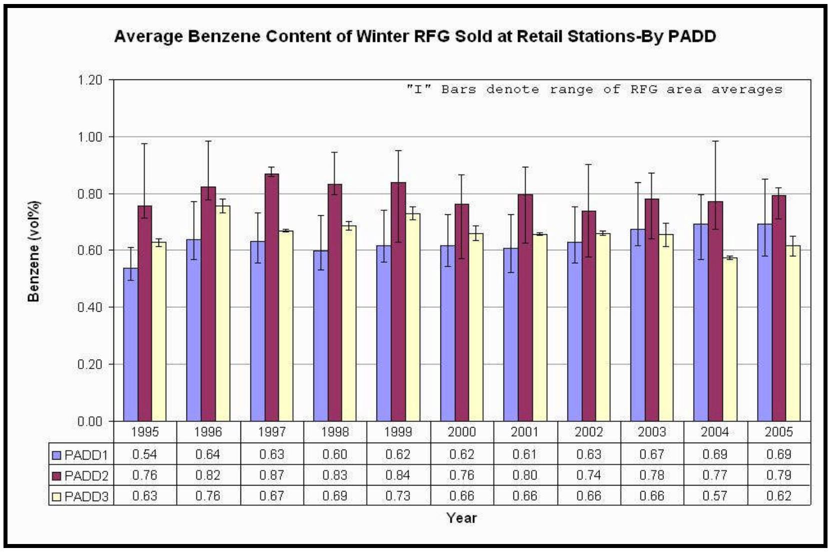


Figure 5

Additional Analysis and Observations-RFG

Data analyses pertaining to RFG benzene are contained in the Appendix to this chapter. These include estimates of grade specific averages which show that average benzene content in premium grade RFG has been consistently lower than in regular RFG.

Overview-Conventional Gasoline

Volume-weighted average CG benzene content levels, by reporting year, are shown in Figure 6. Summer and Winter averages are shown separately on the same graph. Based on inspection, these averages do not suggest a clear trend in either the Summer or Winter data, although the 2005 averages were the highest for the 1997-2005 period. Summer CG benzene content levels have been higher than winter CG benzene content levels since 1998. The direction of year to year change in Summer and Winter benzene content levels has been the same between 1999 and 2003, suggesting that the same factors might be influencing the year to year changes in both.

It is unclear whether regulatory changes have had a substantial influence on year to year changes in CG benzene content. A change in CG toxics emission requirements occurred between 1997 and 1998 with the transition to a Complex Model-based standard. CG was required to comply with the MSAT toxics requirements beginning in 2002. While reductions in average benzene content occurred concurrently with these changes, neither of these regulatory changes was explicitly intended to require a sharp reduction in toxics emissions. There was little change in CG benzene content between 1999 and 2000 even though RFG benzene declined, consistent with the intent of the Anti-Dumping regulations. Given the relatively small changes in benzene content at these transitions and the observed fluctuations in benzene content, it would be inappropriate, without further evidence and analysis, to ascribe any cause-effect relationship between these regulatory changes and changes in CG benzene content.

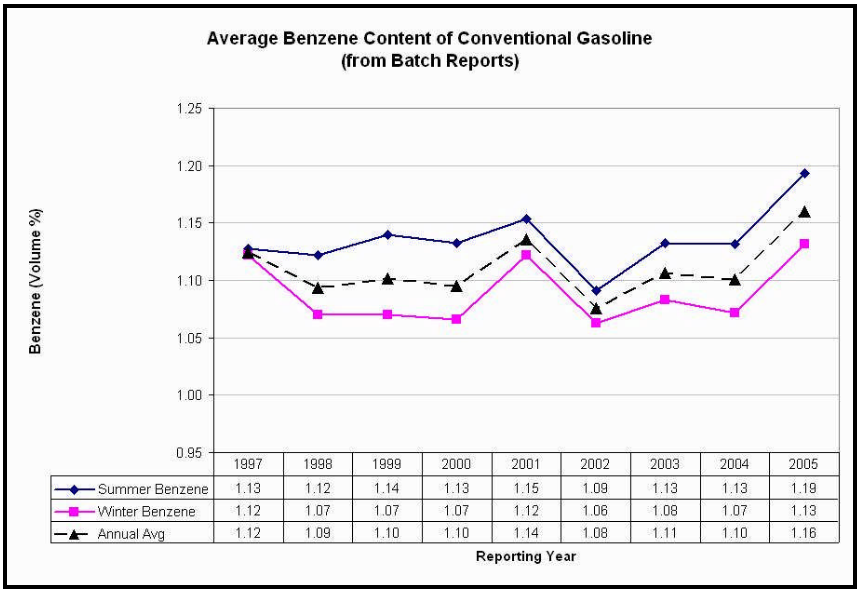


Figure 6

CG Benzene by PADD

Table 2 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see “PADD Level Analysis” appendix for additional information):

2004 & 2005 Reporting Averages by PADD-CG Benzene (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	0.96	3,721,549,054	1.12	3,517,507,894
	II	1.38	11,327,130,611	1.41	10,437,087,141
	III	0.98	21,712,599,435	1.07	20,884,656,303
Winter	I	0.93	3,451,551,536	1.18	4,025,985,850
	II	1.32	13,133,321,322	1.25	13,416,981,375
	III	0.89	23,618,108,969	1.01	22,432,331,959
Annual	I	0.95	7,173,100,590	1.15	7,543,493,744
	II	1.35	24,460,451,933	1.32	23,854,068,516
	III	0.93	45,330,708,404	1.04	43,316,988,262

*Volumes exclude batches with missing values for this parameter

Table 2

Additional Analyses and Observations-CG

The benzene content of Summer baseline gasoline, as specified in the Clean Air Act, is 1.53 volume percent, and the benzene content of Winter baseline gasoline, as specified by EPA's regulations, is 1.64 volume percent.

Data analyses pertaining to CG benzene are contained in the Appendix to this chapter. These data include tabular and graphical descriptions of CG benzene content by volume and grade which show:

- In 1997, the first year for which benzene reporting data were analyzed, the median Summer benzene content was 0.95 volume percent and the 1990 baseline gasoline fell between the 70th and 75th percentile.

- In 2005, the last year for which benzene reporting data were analyzed, the median Summer benzene content was 1.06 volume percent and the 1990 baseline gasoline fell between the 70th and 75th percentile.

- In 1997 the median Winter benzene content was 0.88 volume percent and the 1990 baseline gasoline fell between the 75th and 80th percentile.

- In 2005 the median Winter benzene content was 0.98 volume percent and the 1990 baseline gasoline fell between the 80th and 85th percentile.

- The benzene content of premium grade CG has been lower than that of regular grade in each year and season.

All Gasoline

Although this report has analyzed benzene trends separately by season and gasoline type, benzene is regulated on an annual average basis for both RFG and CG. Since the MSAT2 regulations will eventually supersede both the RFG and Anti-Dumping benzene and toxics requirements, some readers may also be interested in analyses combining RFG and CG data. Aggregated reporting data averages are available, in tabular form, in the “Summary of Average Estimates” chapter of this report. Aggregated benzene content distributions by gasoline volume for 2005 are shown in Table 3, below:

2005 Benzene Content (vol %) by Volume
(from Batch Reports excluding CG blendstocks)

Volume %	CG	RFG/RBOB	ALL
minimum	0.00	0.01	0.00
5%	0.36	0.30	0.33
10%	0.47	0.37	0.42
15%	0.53	0.41	0.48
20%	0.60	0.45	0.54
25%	0.66	0.48	0.59
30%	0.73	0.51	0.64
35%	0.79	0.54	0.69
40%	0.86	0.58	0.74
45%	0.94	0.61	0.80
50%	1.01	0.64	0.86
55%	1.10	0.67	0.92
60%	1.20	0.70	1.00
65%	1.29	0.74	1.09
70%	1.39	0.78	1.19
75%	1.49	0.82	1.32
80%	1.61	0.86	1.44
85%	1.77	0.91	1.60
90%	2.01	0.98	1.84
95%	2.43	1.07	2.25
100%	5.20	1.68	5.20
Volume (gal):	**90,872,058,197**	**32,132,421,234**	**123,004,479,431**

Table 3

Aromatics

Background

Aromatics are a family of hydrocarbon compounds with chemical properties similar to benzene. In addition to benzene, other aromatic compounds such as toluene and xylenes are found in gasoline, and aromatics other than benzene constitute the bulk of the aromatics volume in most gasoline. The main source of aromatics in gasoline is reformate, a blending component produced in a refinery process units called reformers. Reformate is a high octane, low sulfur blending component. While these are desirable characteristics, reformate, with its high aromatics content, also has some undesirable emissions characteristics. The Complex Model indicates that certain toxics, NOx and exhaust VOC increase with increasing gasoline aromatics content.

Benzene and other aromatics are petrochemicals which are used for various purposes such as in the manufacture of plastics and as solvents. Aromatics produced at refineries are sometimes extracted and marketed as petrochemicals. Thus, the demand for these aromatics as petrochemicals will, to an extent, affect the aromatics content of gasoline.

Regulatory Limits on Aromatics Content

The primary regulatory constraints on gasoline aromatics content have been and currently are indirect limits resulting from model-based emission standards. Prior to 1998, RFG was subject to a toxics emission performance standard based on the Simple Model. According to this model, exhaust benzene emissions, one of several toxic emissions incorporated in this standard, increase with gasoline aromatics content as well as gasoline benzene content. (While benzene is an aromatic compound, benzene content is also considered as a separate gasoline parameter and additional regulations address gasoline benzene content. See the Benzene Chapter in this report.) CG supplied from 1995 through 1997 was required to have annual average exhaust benzene emissions, as calculated by a formula considering both aromatics and benzene content, no greater than the refiner's or importer's compliance baseline for exhaust benzene.

In 1998 and subsequent years standards based on the Complex Model applied to both RFG and CG. Complex model RFG is subject to toxics, NOx and VOC emission performance standards. CG exhaust toxics and NOx emissions cannot exceed the refiner's or importer's compliance baseline for these emissions. Gasoline aromatics are generally associated with toxics emissions, and gasoline toxics emission requirements, including the current MSAT requirements, are expected to have a limiting effect on aromatics content. The Complex Model predicts that aromatics reduction lowers exhaust benzene emissions. Although it predicts that emissions of certain other toxics may increase slightly with reduced aromatics, the exhaust benzene emission reduction more than offsets these increases, resulting in a net toxics emission reduction with an aromatics content reduction.

Toxics emission standards may not have been the only standards limiting aromatics content Analysis presented in the RFG Trends chapter suggests that aromatics reductions may have helped significantly to meet the more stringent Phase II RFG Summer NOx performance standard, as well as to provide some additional VOC reduction. While NOx emission requirements may have, in the past, had some limiting effect on the aromatics content of RFG and CG, the Tier 2 sulfur reductions, with consequent substantial NOx emission reductions and over-compliance for both, clearly reduced the limiting effect, if any, of NOx emission requirements on aromatics content. [37]

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[37] As noted elsewhere, NOx emission requirements were generally eliminated in 2007 and toxics emission requirements will generally be eliminated in 2011, removing most of the regulatory constraints on aromatics content.

Complex Model acceptable range limits directly limit gasoline aromatics content. The acceptable range limit for RFG is 50 volume percent and the acceptable range limit for CG is 55 volume percent. For RFG, this range limit is applicable to each batch. For CG, the annual average aromatics level cannot exceed 55 volume percent or the refiner's or importer's 1990 baseline for aromatics, whichever is greater

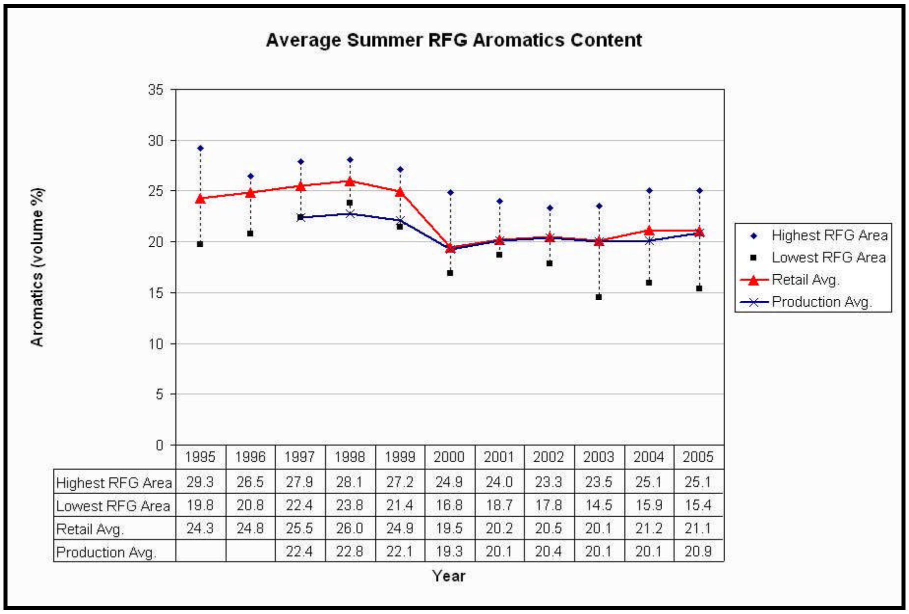
EPA's Aromatics Data

EPA collects aromatics data in order to determine compliance with the RFG and Anti-Dumping regulations. Refiners and importers have been required, since 1995, to submit aromatics content data for each batch of CG and RFG refined or imported. Additionally, since 1995, EPA has received RFG Survey data on the aromatics content of RFG sold at retail outlets.

Aromatics Trends

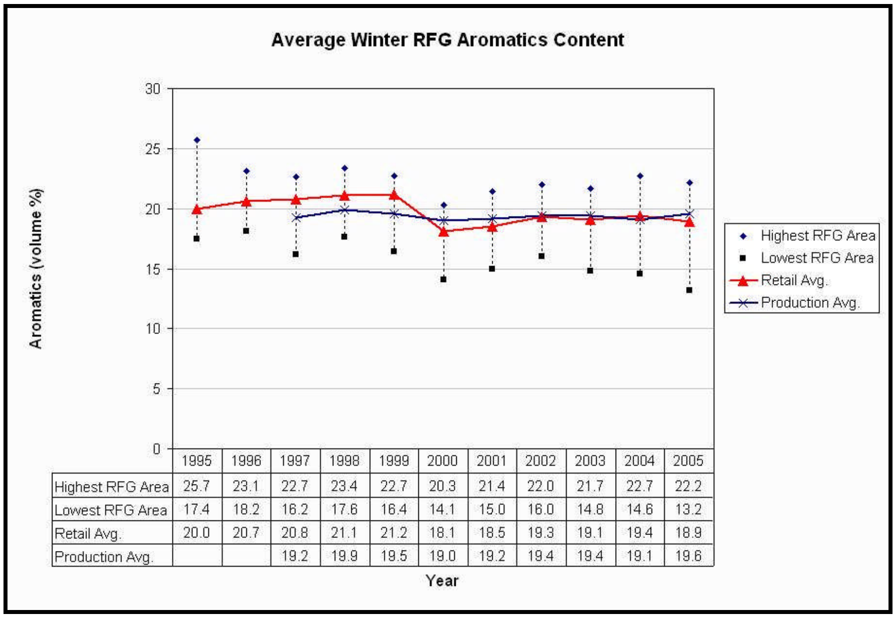
Overview-Reformulated Gasoline

Analysis of aromatics data from EPA's two data sources shows that a decrease in average aromatics content occurred with the transition from Phase I to Phase II standards. Decreases in aromatics content for both Summer and Winter RFG are consistent with a more stringent Phase II annual average toxics emission performance standard. However, estimates from these two sources have been in better agreement for most other properties, particularly in quantifying Phase I to Phase II changes. Consequently, there is additional uncertainty in any conclusions regarding aromatics trends. While it is reasonable to expect some difference in estimates from the two data sources the estimates appear to differ in a systematic fashion.



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	29.3	26.5	27.9	28.1	27.2	24.9	24.0	23.3	23.5	25.1	25.1
Lowest RFG Area	19.8	20.8	22.4	23.8	21.4	16.8	18.7	17.8	14.5	15.9	15.4
Retail Avg.	24.3	24.8	25.5	26.0	24.9	19.5	20.2	20.5	20.1	21.2	21.1
Production Avg.			22.4	22.8	22.1	19.3	20.1	20.4	20.1	20.1	20.9

Figure 1



	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	25.7	23.1	22.7	23.4	22.7	20.3	21.4	22.0	21.7	22.7	22.2
Lowest RFG Area	17.4	18.2	16.2	17.6	16.4	14.1	15.0	16.0	14.8	14.6	13.2
Retail Avg.	20.0	20.7	20.8	21.1	21.2	18.1	18.5	19.3	19.1	19.4	18.9
Production Avg.			19.2	19.9	19.5	19.0	19.2	19.4	19.4	19.1	19.6

Figure 2

Figure 1 shows Summer averages calculated from reporting system and survey data. Both data sets show a decrease in aromatics content from 1999 to 2000 greater than any of the other year to year changes, although the production data indicate a 2.9 volume percent reduction in aromatics content, while the survey data indicate a 5.4 volume percent reduction. While the survey-based and reporting system-based averages are in close agreement in 2000 and subsequent years, the survey-based estimates were higher than reporting system estimates in 1999 and in the two preceding years.

Figure 2 shows Winter averages calculated from the two data sets. While the survey data show a 1999 to 2000 decrease in aromatics content of 3.1 volume percent, clearly greater than any of the other year-to-year changes, the production data show only a 0.5 volume percent decrease in aromatics content between 1999 and 2000. As with the Summer estimates, survey-based average estimates were higher than reporting system estimates in 1999 and in the two preceding years.

Although estimates from the two data sources clearly differ, there is little doubt that an atypical change in Summer RFG aromatics content occurred concurrent with the transition from Phase I to Phase II standards. For both data sets, the 1999 to 2000 decrease in aromatics is, subjectively, large compared to other year-to- year changes. More objectively, regression analysis of both sets of estimates indicates that a statistically significant shift in aromatics content occurred (see Regression Analysis Appendix). The timing and magnitude of the decreases do not, in themselves, establish a cause-effect relationship, but toxics, NOx and VOC Summer RFG emission performance standards all became more stringent, and aromatics reductions can improve emission performance for all of these pollutants. Analysis presented in the RFG chapter, based on survey data, confirms that Summer RFG emission performance improved between 1999 and 2000, and identifies aromatics content reduction as the primary factor for toxics performance improvement, and as the secondary factor for NOx and VOC improvement.

While estimates from both data sets indicate a reduction in Winter RFG aromatics content between 1999 and 2000, only the survey-based estimates indicate that a statistically significant shift in aromatics content occurred concurrent with the transition to Phase II standards. Average toxics performance during Phase I, as estimated from both data sets substantially over-complied with the Phase II toxics performance standard. Thus, while some refineries and importers may have needed to reduce aromatics and improve winter toxics performance to meet the Phase II toxics standard (EPA's aggregate analysis did not address this), the more stringent Phase II toxics standard may not have had a large impact on average Winter RFG aromatics content. The Winter NOx performance standard did not become more stringent with Phase II, and average Phase I NOx performance substantially over-complied with the Phase II standard, so it is unlikely that this standard would have caused a change in Winter RFG aromatics content. Consequently, evidence supporting a cause-effect relationship between this transition and an aromatics content change is more equivocal.

The General Methodology Chapter explains why EPA analyzed both RFG survey and reporting data to estimate overall RFG property trends even though survey-based trend estimation required more approximations and assumptions. The analysis presented here suggests that, for aromatics, there were some systematic differences between the two estimates prior to 2000, with good agreement in 2000 and subsequent years. Consequently, the two data sets differ somewhat in their estimate of the magnitude of the change in aromatics content between Phase I and Phase II RFG. Arguably, there is some rationale for rejecting survey-based trend estimates in favor of reporting-based estimates if there is any substantial disparity. However, EPA has not identified a clear problem with either data set and believes that both sets of aromatics estimates must be considered. There are several reasons for this view:

It appears unlikely that the differences between the survey-based and reporting system estimates of average aromatics content are solely attributable to some combination of statistical sampling error and imprecise sales volume estimates. For Summer RFG, the most notable difference between the two estimates is that the reporting system averages in 1997, 1998 and 1999 fell close to or below the lowest seasonal average in any of the areas sampled. Thus, even extremely inaccurate estimates of sales volume, by themselves, would not explain the difference between the two averages. The mandatory RFG areas, which, in general, would be heavily weighted in the average calculation because of their large sales volumes were also the most frequently sampled in each survey year with multiple one week surveys during the June 1-September 15 Summer period. (e.g. In 1998 each of the non-California mandatory areas were surveyed between six and eight time during this period). Thus, the areas that most heavily influenced the volume-weighted average calculation would also likely have the most accurate seasonal area average estimates. For Winter RFG, the most notable difference is that the reporting system estimate showed only a 0.5 volume percent decrease in aromatics content between 1999 and 2000, while the survey-based estimate indicates a 3.1 volume percent decrease. Area-specific seasonal survey averages for both Summer and Winter RFG show that aromatics content decreased in each of the 23 areas surveyed in both 1999 and 2000. For Winter RFG, the area-specific survey average decreases ranged from about 1.2 to 5.9 volume percent. Since these paired area data from the surveys strongly indicate a decrease in Winter aromatics between 1999 and 2000, it is difficult to dismiss the survey data entirely, and conclude with a high degree of certainty that there was little change in Winter aromatics between 1999 and 2000.[38]

Although the reporting data are not a statistical sample, the reporting system averages are also subject to error. A number of different parties of varying capabilities collect and analyze reporting system samples and submit reports to EPA. Although EPA's regulations include mechanisms to help ensure the quality of the data, such as record keeping and independent laboratory sampling and analysis requirements, these mechanisms cannot totally eliminate reporting data errors. In addition to errors in the sense of mistakes such as incorrect reporting of data or omitting a data item, there are precision and accuracy issues associated with the measurement of any gasoline parameter (i.e., even when a gasoline

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[38] It should be noted that sample sizes in individual one-week surveys are smaller in Winter than in Summer, and in some areas fewer surveys are scheduled during the Winter season. This may result in less precision and accuracy in Winter than Summer seasonal average estimates based on survey data.

sample is carefully analyzed using the correct methods and procedures measured property values can differ from the "true" property values). A detailed discussion of these issues is beyond the scope of this report, however it is worth noting that there are some additional aromatic-specific factors that could affect the quality of the aromatics data from both data sets. EPA's regulations have allowed two methods for measurement of gasoline aromatics content; Gas Chromatography/Mass Spectrometry (GC-MS) designated as ASTM standard method D 5769, and Flourescent Indicator Adsorption (FIA), designated as ASTM standard method D 1319.[39]

EPA's regulations designated GC-MS as the method for determining aromatics content, but allowed use of D 1319 if the result is correlated with the designated method. In its "RFG Questions and Answers" guidance document (EPA 2003) EPA has characterized D 1319 as "highly operator-dependent" and having "relatively large reproducibility". "Reproducibility" is a term referring to the difference in test results from two different operators measuring the same material at two different laboratories or using two different instruments. Survey samples were analyzed for aromatics using D 1319, but in each year all or most of these analyses were done at a single laboratory (although not necessarily with the same operator and instrument), and this laboratory was used since the inception of the RFG Survey program. A larger number of laboratories analyzed reporting system samples, and the data do not identify which of these two methods was used to determine the aromatics content of each batch. (Consequently, it would be difficult to determine if measurement-related issues are important in explaining the difference between reporting system and survey aromatics estimates.)

Additionally, there may be actual differences between the average properties of gasoline sold at retail and the average of properties in the gasoline and blendstock that refiners and importers consider for compliance determination. (These differences can occur as a result of allowable practices such as downgrading of RFG to CG, downgrading of Summer RFG to Winter RFG, or blending of oxygenates in amounts greater than assumed for compliance reporting.) Differences may be even more apparent when, as in this report, gasoline properties are analyzed and compared on a seasonal basis, particularly when there are large Summer to Winter variations in a property. EPA does not know if real differences between retail and reporting properties were a major cause for differences in aromatics estimates. However, since the true retail averages could differ from the true reporting averages, and since both are of interest, it is generally appropriate to consider RFG data from both sources in trend analyses.

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[39] From time to time ASTM revises its standards and the complete standard number includes a suffix indicating the revision (e.g. D1319-02a). EPA regulations specifying test methods (40 CFR 80.46) reference specific versions of these test methods. Although EPA from time to time updates these regulations to reflect revisions to ASTM standards, these regulations do not always specify the "active" standard (see http://www.astm.org).

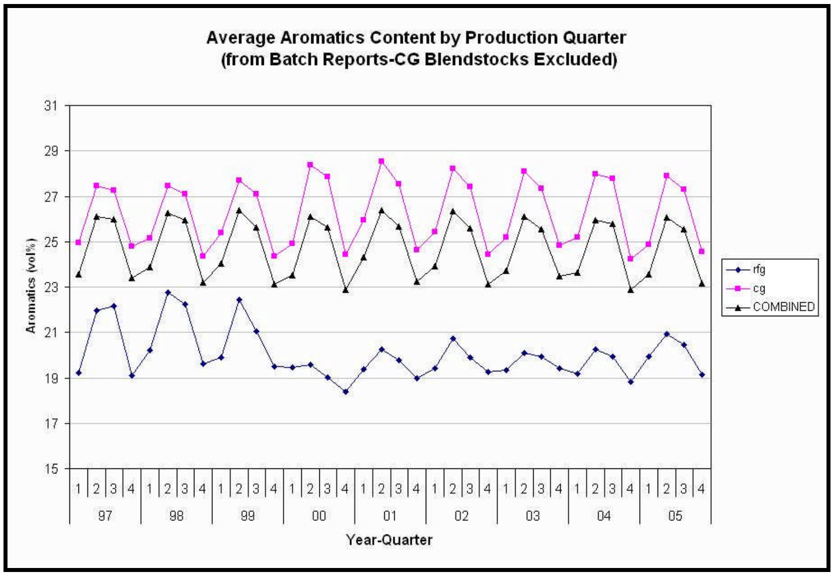

Figure 3

Regardless of which data estimates are used, comparison of Figures 1 and 2 shows that aromatics levels in Summer RFG are generally higher than aromatics levels in Winter RFG. Gasoline composition varies seasonally because of regulatory emission requirements, as well as vehicle performance ("drivability") requirements associated with gasoline's volatility and distillation characteristics. The need to meet these seasonal requirements has resulted in a clear seasonal variation in aromatics content for both RFG and CG. This variation can be seen in Figure 3, which shows average RFG and CG aromatics content, estimated from reporting system data, by production quarter. Although this yearly cyclical variation in RFG aromatics diminished with the transition to the Phase II RFG standards in 2000, it is still apparent.

RFG Aromatics by PADD

Table 1 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see “PADD Level Analysis” appendix for additional information):

2004 & 2005 Reporting Averages by PADD-RFG Aromatics (Refiner Batches Only)

		2004		**2005**	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	21.2	4,792,114,891	21.9	4,431,080,230
	II	18.9	1,740,499,436	19.1	1,844,913,833
	III	18.7	5,890,920,167	19.2	5,690,766,967
Winter	I	20.4	6,489,530,475	20.7	7,081,940,665
	II	17.3	2,438,403,544	18.4	2,718,751,541
	III	17.9	6,059,647,031	18.0	5,766,524,033
Annual	I	20.7	11,281,645,366	21.2	11,513,020,895
	II	18.0	4,178,902,980	18.7	4,563,665,374
	III	18.3	11,950,567,198	18.6	11,457,291,000

*Volumes exclude batches with missing values for this parameter

Table 1

Figures 4 and 5 show estimates of average levels by PADD in retail RFG. These averages are volume-weighted averages of the seasonal averages for each area, using gasoline volume estimates supplied in the survey plans. In 2005, RFG surveys were conducted in 18 PADD I areas, five PADD II areas and two PADD III areas. For Phase II RFG, survey data generally showed the highest aromatics concentrations in PADD I RFG, as did reporting data for the two years analyzed.

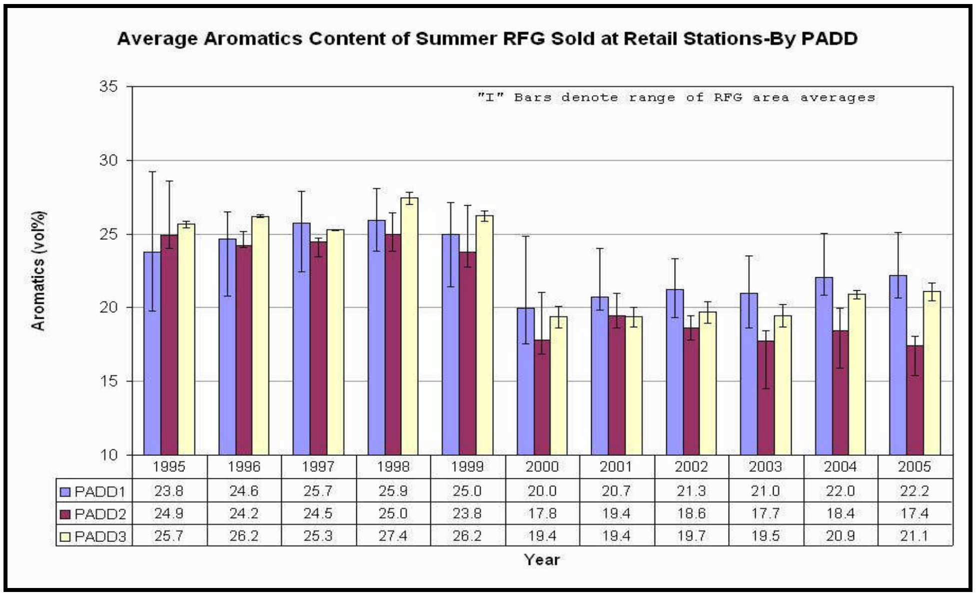

Figure 4

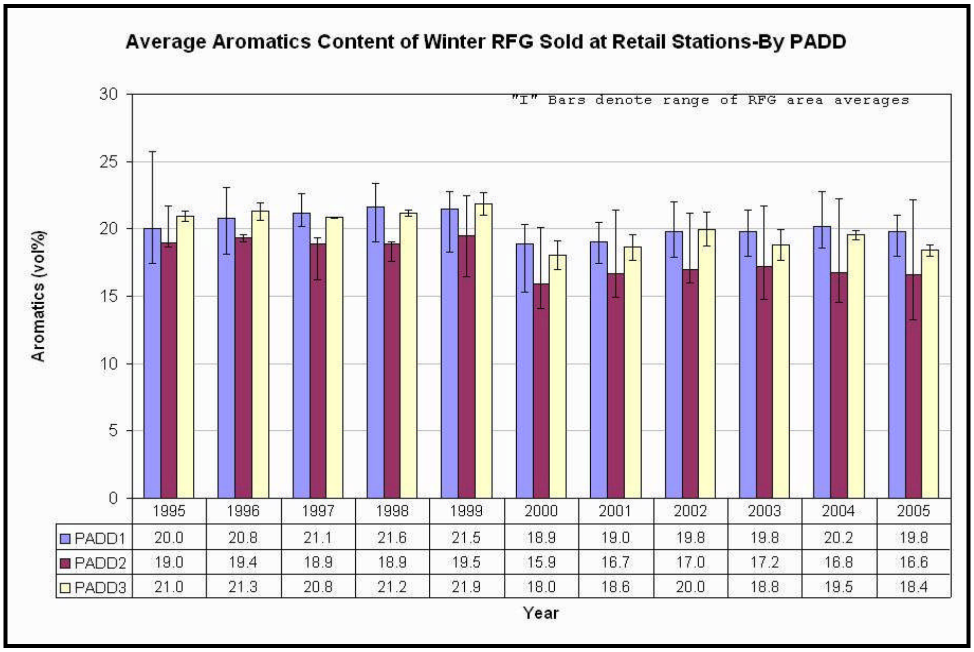

Figure 5

Additional Analyses and Observations-RFG

Data analyses pertaining to RFG aromatics content are contained in the Appendix to this chapter. Several trends or patterns are highlighted below:

- Average aromatics content of premium grade RFG has been higher than aromatics content in regular or (from survey data) mid-grade RFG in each year and season[40]

- Analysis of retail data shows that aromatics content decreased from 1999 to 2000 for each grade-season combination

Overview-Conventional Gasoline

Figure 6 shows Summer and Winter average CG aromatics levels, by reporting year. Summer and Winter average aromatics levels peaked in 2000 and 2001 respectively. The largest year-to-year change in Summer aromatics content occurred between 1999 and 2000, when average aromatics increased by more than 0.8 volume percent, and the largest Winter change occurred between 2000 and 2001, when average aromatics increased by more than 0.5 volume percent. Notably, although Summer averages decreased in each succeeding year through 2003, averages in 2000 and subsequent years were higher than averages in 1997 through 1999. Regression analysis also indicates that a shift in Summer CG aromatics content occurred between 1999 and 2000. This sustained Summer CG aromatics increase concurrent with a sustained Summer RFG Phase I to Phase II aromatics decrease suggests, but does not establish that the transition to Phase II RFG influenced CG aromatics content. Figure 3, which also shows CG aromatics averages by production quarter, illustrates that average aromatic levels have been consistently highest during the 2nd quarter of production, where the majority of production volume is Summer gasoline, and these 2nd quarter averages in 2000 and succeeding years were higher than in each year prior to 2000.

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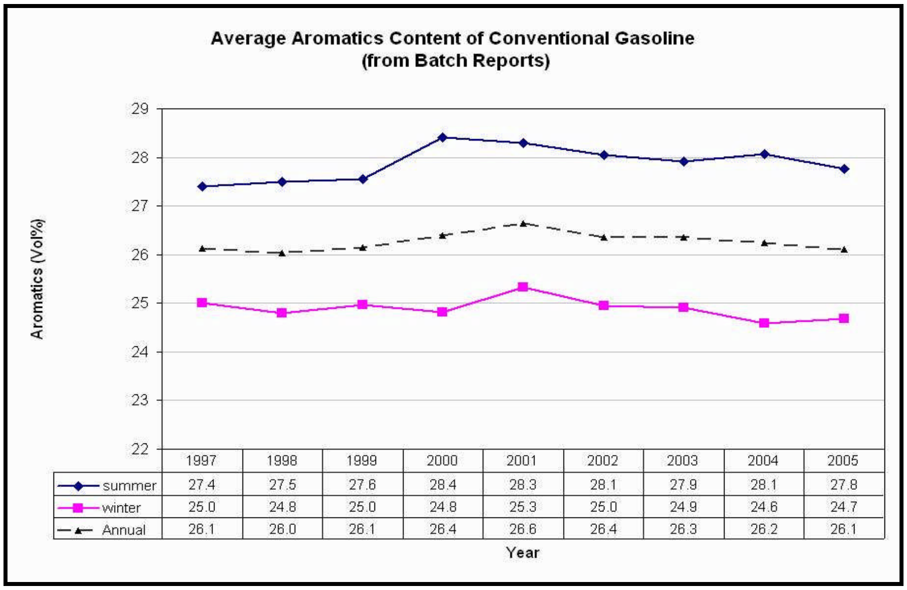
[40] The RFG Survey sampling plan estimates the grade market share in each area to ensure that grades are properly represented in each survey. Errors in estimating the grade mix may contribute to inaccuracies in individual survey estimates of property averages and, in turn, contribute to inaccuracies in survey-based estimates of overall average property values. EPA does not believe that incorrect estimates of grade mix are the major cause of differences between survey-based and reporting system based aromatics estimates, since the same directional differences are apparent when 1997 through 1999 regular and premium grade survey averages and reporting averages are compared on a grade by grade basis (see appendix).



	1997	1998	1999	2000	2001	2002	2003	2004	2005
summer	27.4	27.5	27.6	28.4	28.3	28.1	27.9	28.1	27.8
winter	25.0	24.8	25.0	24.8	25.3	25.0	24.9	24.6	24.7
Annual	26.1	26.0	26.1	26.4	26.6	26.4	26.3	26.2	26.1

Figure 6

Although EPA has no CG data from a second source comparable to the RFG Surveys, the disparity between RFG Survey and reporting system-based estimates of aromatics raises the level of uncertainty in conclusions about CG trends based on reporting system data. Since EPA cannot explain why these differences occurred, and since the differences appear to be somewhat systematic, EPA cannot rule out the possibility that this is indicative of an issue with the reporting system data that may affect both RFG and CG.

CG Aromatics by PADD

Table 2 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see “PADD Level Analysis” appendix for additional information):

2004 & 2005 Reporting Averages by PADD-CG Aromatics (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	28.4	3,721,549,054	28.9	3,520,575,616
	II	28.7	11,333,095,661	28.6	10,443,353,793
	III	27.3	21,712,599,435	27.0	20,882,654,793
Winter	I	24.0	3,455,187,610	24.6	4,011,434,950
	II	25.1	13,146,020,260	24.5	13,428,549,183
	III	24.1	23,618,763,665	24.5	22,432,331,959
Annual	I	26.2	7,176,736,664	26.6	7,532,010,566
	II	26.8	24,479,115,921	26.3	23,871,902,976
	III	25.6	45,331,363,100	25.7	43,314,986,752

*Volumes exclude batches with missing values for this parameter

Table 2

Additional Analysis and Observations-CG

The aromatic content of Summer Baseline Gasoline, as specified in the Clean Air Act, is 32.0 volume percent, and the aromatic content of Winter baseline gasoline, as specified by EPA's regulations, is 26.4 volume percent. Data analyses pertaining to CG aromatics are contained in the Appendix to this chapter. These data include tabular and graphical descriptions of CG aromatics content by volume and grade which show:

- In 1997, the first year for which aromatics reporting data were analyzed, the median Summer aromatics content was 26.9 volume percent and the 1990 baseline gasoline fell between the 75th and 80th percentile.

- In 2005, the last year for which aromatics reporting data were analyzed, the median Summer aromatics content was 27.4 volume percent and the 1990 baseline gasoline fell between the 75th and 80th percentile.

- In 1997 the median Winter aromatics content was 24.3 volume percent and the 1990 baseline gasoline fell between the 60th and 65th percentile.

- In 2005 the median Winter aromatics content was 24.2 volume percent and the 1990 baseline gasoline fell between the 65th and 70th percentile.

- The aromatics content of premium grade CG has been higher than that of regular grade in each year and season.

Olefins

Background

Olefins are a class of hydrocarbons found in gasoline. Olefins content, in volume percent, is an input parameter for the Complex Model. The gasoline blending component from the Fluid Catalytic Cracking (FCC) unit often has a high olefin concentration. Olefins are desirable gasoline constituents because of their octane characteristics but, according to the Complex Model, NOx and exhaust toxics emissions increase with olefin content. The model predicts that exhaust VOCs will decrease as olefin content increases.

Regulatory Limits on Olefin Content

EPA's RFG and Anti-Dumping regulations have imposed both direct and indirect limits on gasoline olefin content. The Simple Model, applicable to RFG through 1997, did not consider the effect of olefins on emissions. However, the annual average olefin content was not allowed to exceed a refinery's or importer's 1990 olefins baseline level. Currently, the olefin content of RFG is directly limited by a 25.0 volume percent maximum Complex Model range limit intended to ensure the validity of the model's emission performance estimates. The olefin content of RFG and CG was indirectly limited through Complex Model-based limits on RFG and CG emissions since Complex Model NOx and exhaust toxics increase with increasing gasoline olefin content. Regulatory changes eliminating these emission limits have or will remove these indirect constraints.

Prior to 1998, the annual average olefins level in CG was not allowed to exceed 125% of a refinery's or importer's 1990 baseline. For 1998 and later, CG was required to have annual average Complex Model emissions of exhaust toxics and NOx that did not exceed the refiner or importer's 1990 baselines for these emissions. Additionally, annual average CG olefins levels were not allowed to exceed the greater of the Complex Model valid range limit for CG olefins (30.0 volume %) or the refiner or importer's 1990 olefins baseline.

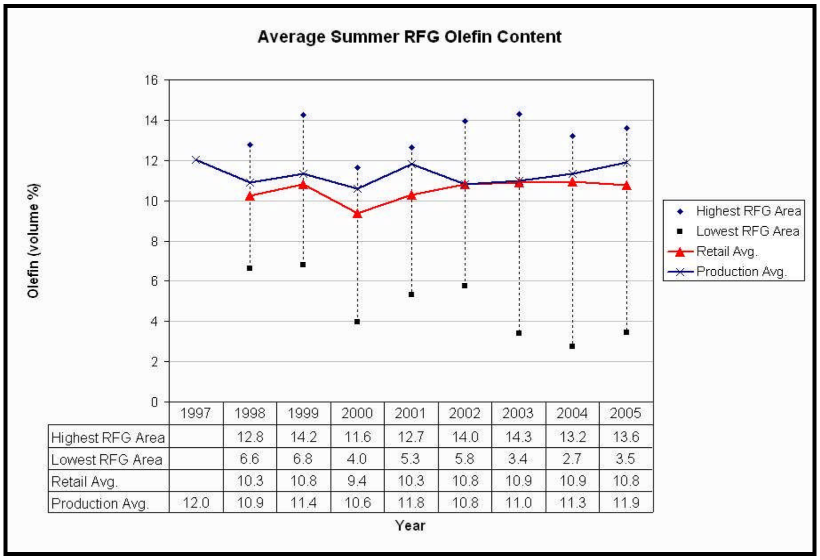
EPA's Olefins Data

Olefins data for both RFG and CG have been and are currently necessary to determine compliance with EPA's regulations. Refiners and importers have been required, since 1995, to submit this information to EPA's RFG/Anti-Dumping reporting system for each batch of gasoline refined or imported. Additionally, since 1998, EPA has received RFG Survey data on the olefins content of RFG sold at gasoline stations. (Since olefins content was not part of the Simple Model, it was not needed to determine compliance with survey standards until 1998).

Olefins Trends

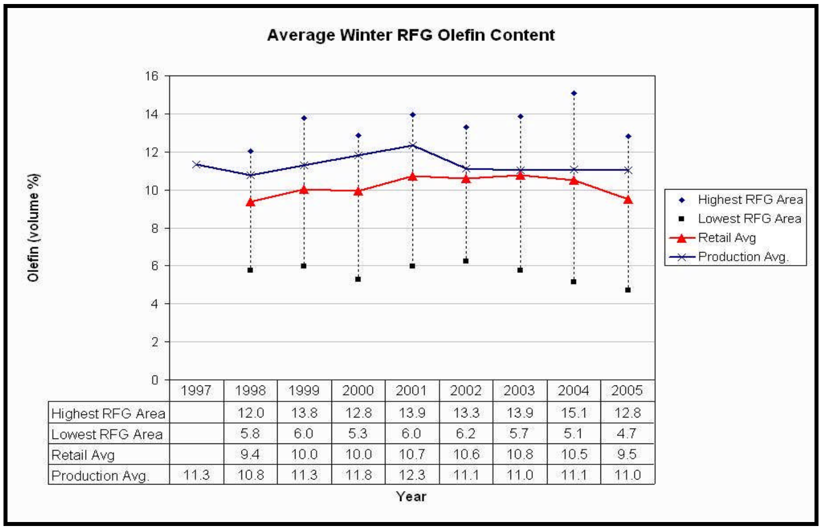
Overview-Reformulated Gasoline

Figures 1 and 2 show Summer and Winter volume-weighted average RFG olefins, by year. Although the reporting-based production and survey-based retail trendlines are somewhat different, EPA has not identified any pervasive problem with either set of olefins data. As with the aromatics estimates, EPA believes that estimates from both sets of data must be considered unless a clear problem can be identified in one or the other data sets.



	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area		12.8	14.2	11.6	12.7	14.0	14.3	13.2	13.6
Lowest RFG Area		6.6	6.8	4.0	5.3	5.8	3.4	2.7	3.5
Retail Avg.		10.3	10.8	9.4	10.3	10.8	10.9	10.9	10.8
Production Avg.	12.0	10.9	11.4	10.6	11.8	10.8	11.0	11.3	11.9

Figure 1



	1997	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area		12.0	13.8	12.8	13.9	13.3	13.9	15.1	12.8
Lowest RFG Area		5.8	6.0	5.3	6.0	6.2	5.7	5.1	4.7
Retail Avg		9.4	10.0	10.0	10.7	10.6	10.8	10.5	9.5
Production Avg.	11.3	10.8	11.3	11.8	12.3	11.1	11.0	11.1	11.0

Figure 2

The reporting system data show decreases in average olefin content between 1997 and 1998 for both Summer and Winter RFG. The 1997 Summer average is higher than in any of the succeeding years while the 1997 Winter average is not. Although EPA analyzed only a single year of Simple Model RFG olefins data, there is some basis for concluding that these decreases were in response to EPA's Complex Model requirements. Close to four percent of both Summer and Winter RFG supplied in 1997 would not have meet 1998 requirements because it did not meet the Complex Model's 25 volume percent olefin content range limit restriction, applicable to each RFG batch. (The graphical and tabular data in the appendix to this chapter show shifts in both "RFG olefins by gasoline volume" distributions between 1997 and 1998.)

Additionally, the Complex Model recognized the emission benefits of olefin reduction, and some suppliers may have reduced olefins in order to meet 1998 NOx and toxics performance standards. The transition from Simple Model to Complex Model standards affected sulfur content in a similar but much more substantial manner. (While Summer and Winter olefins content decreased by about 11% and 5%, sulfur content decreased by about 30% and 19%, respectively.) In addition to the parallel regulatory factors cited above, olefin reductions may also have occurred as a result of refining and blending processes used to reduce sulfur content. As noted in the Sulfur Chapter, refineries have, in the past, largely relied on a process called hydro treating to reduce sulfur, when necessary. In addition to lowering sulfur content, hydro treating may also have reduced olefins.

The survey-based estimates of Summer olefin content suggest that a downward shift occurred between 1999 and 2000 with the transition from Phase I to Phase II, superimposed on an upward trend. Although the reporting data also show a decrease in olefin content between 1999 and 2000, it is not distinguishable from other year to-year changes. By contrast, EPA concludes that, for Summer RFG, both data sets clearly show all other Complex Model parameters, except oxygen, shifted between 1999 and 2000. Neither of the Winter estimates suggest that olefin content changed in response to this transition.

Analysis based on RFG Survey property averages presented in the RFG Trends Chapter indicates that, even for Summer RFG, the 1999 to 2000 olefin reduction provided only a small portion of the total Phase I to Phase II RFG NOx and toxics emission reduction.

In summary, olefin content reductions apparently had a small role in meeting Phase II standards, and conversely, the transition from Phase I to Phase II RFG probably had a limited effect on RFG olefins content.

RFG Olefins by PADD

Table 1 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information):

2004 & 2005 Reporting Average by PADD-RFG Olefins (Refiner Batches Only)

		2004		**2005**	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	13.0	4,792,114,891	13.3	4,431,080,230
	II	5.3	1,740,499,436	4.7	1,844,913,833
	III	11.2	5,890,920,167	12.5	5,690,766,967
Winter	I	12.9	6,489,530,475	13.0	7,081,940,665
	II	4.9	2,438,403,544	5.3	2,718,751,541
	III	11.4	6,059,647,031	11.0	5,766,524,033
Annual	I	12.9	11,281,645,366	13.1	11,513,020,895
	II	5.0	4,178,902,980	5.1	4,563,665,374
	III	11.3	11,950,567,198	11.7	11,457,291,000

*Volumes exclude batches with missing values for this parameter

Table 1

Figures 3 and 4 show estimates of average levels by PADD in retail RFG. These averages are volume-weighted averages of the seasonal averages for each area, using gasoline volume estimates supplied in the survey plans. In 2005, RFG surveys were conducted in 18 PADD I areas, five PADD II areas and two PADD III areas. The survey data show that olefins content is consistently lowest in PADD II RFG, as do reporting data for the two years analyzed.

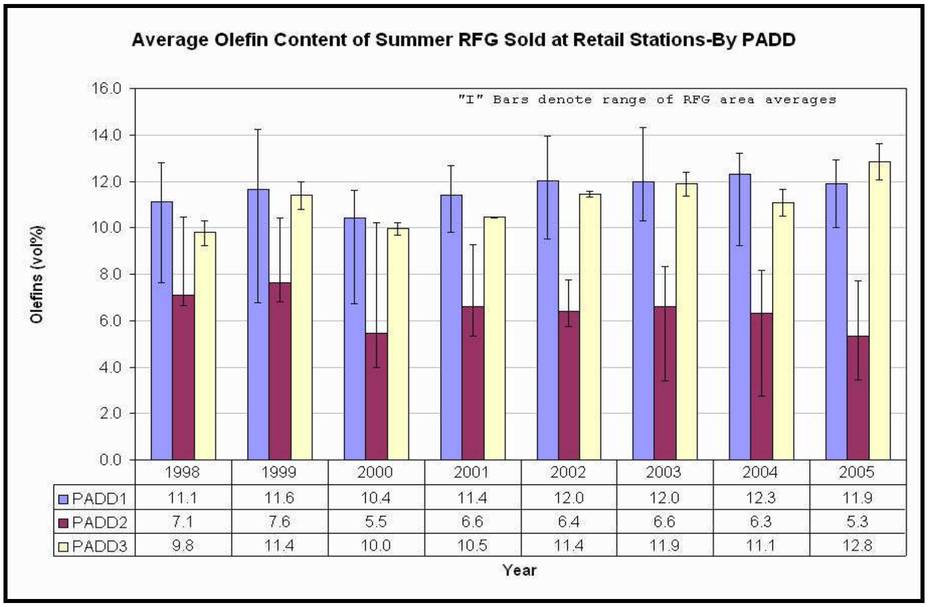


Figure 3

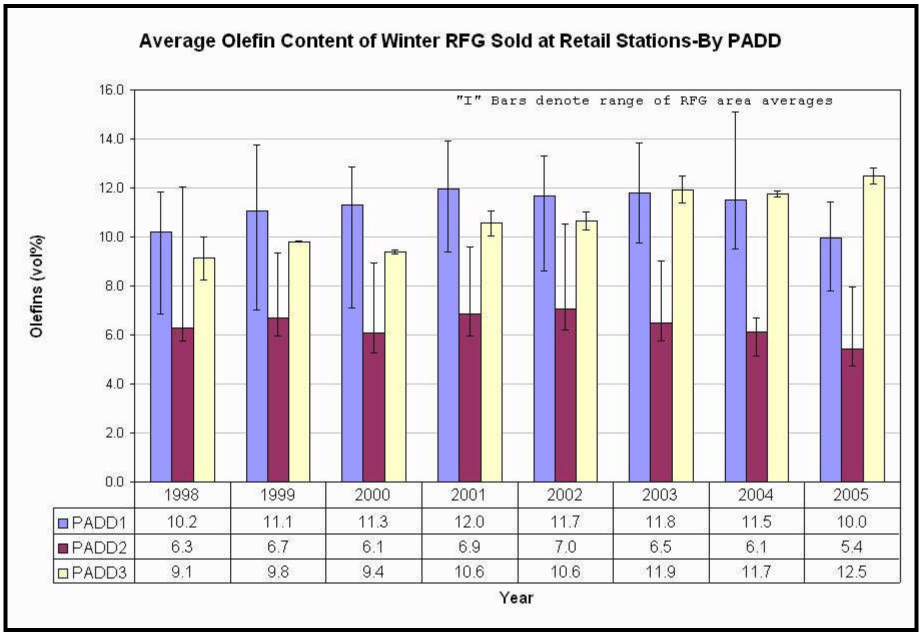


Figure 4

Additional Analysis and Observations-RFG

Data analyses pertaining to RFG olefins are contained in the Appendix to this chapter. Grade specific analyses show that average olefins content in premium grade RFG has been consistently lower than in regular RFG.

Overview-Conventional Gasoline

Figure 5 shows volume-weighted average CG olefins levels, by reporting year. These levels decreased from 1997 to 1998, concurrent with the transition from annual average olefin content standards to Complex Model-based annual average exhaust toxics and NOx emission standards. However, by 2001 both Summer and Winter olefin levels peaked above 1997 values, prior to decreasing through 2004. The standard change described earlier probably represented an increase in stringency that could have influenced the 1997 to 1998 olefin content decrease It is not readily apparent if, or how, the latter movements in CG olefin averages relate to regulatory requirements.

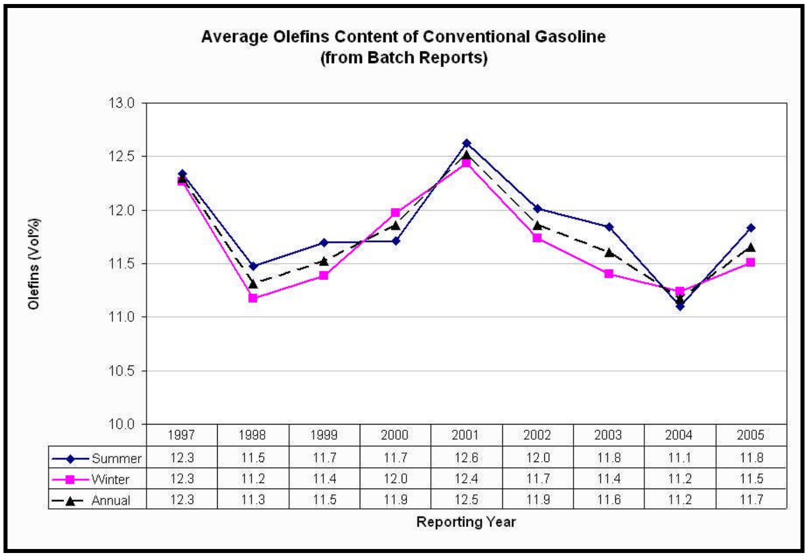


Figure 5

CG Olefins by PADD

Table 2 shows 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information):

2004 & 2005 Reporting Average by PADD-CG Olefins (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (vol %)**	**Gasoline Volume (gal)***	**Average Value (vol %)**	**Gasoline Volume (gal)***
Summer	I	12.83	3,721,549,054	12.67	3,520,575,616
	II	8.82	11,333,095,661	9.63	10,443,213,355
	III	12.20	21,712,599,435	12.80	20,882,654,793
Winter	I	15.66	3,455,187,610	14.78	4,035,235,552
	II	8.60	13,155,255,287	9.45	13,434,249,988
	III	12.18	23,618,763,665	12.07	22,432,331,959
Annual	I	14.19	7,176,736,664	13.80	7,555,811,168
	II	8.70	24,488,350,948	9.53	23,877,463,343
	III	12.19	45,331,363,100	12.42	43,314,986,752

*Volumes exclude batches with missing values for this parameter

Table 2

Additional Analysis and Observations-CG

The olefin content of Summer Baseline Gasoline, as specified in the Clean Air Act, is 9.2 volume percent, and the olefin content of Winter baseline gasoline, as specified by EPA's regulations, is 11.9 volume percent. Data analyses pertaining to CG olefins are contained in the Appendix to this chapter. These data include tabular and graphical descriptions of CG olefins content by volume and grade which show:

- In 1997, the first year for which olefins reporting data were analyzed, the median Summer olefin content was 11.8 volume percent and the 1990 baseline gasoline fell between the 30th and 35th percentile.

- In 2005, the last year for which olefins reporting data were analyzed the median Summer olefin content was 11.4 volume percent and the 1990 baseline gasoline fell at approximately the 35th percentile.

- In 1997, the median Winter olefin content was 11.7 volume percent and the 1990 baseline gasoline fell between the 50th and 55th percentile.

- In 2005, the median Winter olefin content was 10.8 volume percent and the 1990 baseline gasoline fell between the 55th and 60th percentile.

- The olefin content of premium grade CG has been lower than that of regular grade in each year and season.

Distillation Parameters

Background

Gasoline is a mixture of hydrocarbons which have different boiling points. Consequently, as gasoline is heated, portions of its volume evaporate at different temperatures. The relationship between temperature and percent of volume evaporated is referred to as a distillation curve or profile, and a test procedure (ASTM D86) is used to determine the distillation profile of a gasoline sample. Gasoline volatility characteristics are important because they affect both emissions and vehicle performance. The relationship between EPA's regulatory requirements and gasoline distillation characteristics will be discussed later in this chapter. In addition to these emission-related requirements, there are ASTM specifications that place restrictions on distillation parameters for vehicle performance purposes. ASTM standard D4814 defines specifications for six different Vapor Pressure/Distillation classes of gasoline which include limits on T10, T50 and T90 (the temperatures at which 10%, 50% and 90% of the gasoline evaporates). This standard also specifies which class of gasoline is required for each state and month of the year. In 1998 a specification was added for the “drivability index” (DI), a formula (1.5*T10+3.0*T50+1.0*T90) that combines these three distillation points into a number which, if too high, indicates that the gasoline might cause performance problems. A 2006 revision of the standard, D4814-06a, amended the formula with an upward adjustment for ethanol content (1.5*T10+3.0*T50+1.0*T90+2.4 °F*ethanol volume%).

Regulatory Limits on Distillation Parameters

Under the Simple Model standards which applied prior to 1998, the annual average T90 level for RFG could not exceed the refinery's or importer's 1990 baseline level. The Simple Model, itself, did not consider the effect of any distillation profile parameters on emissions. The Complex Model, however, included two distillation parameters, E200 and E300. These parameters are, respectively, the percent of gasoline evaporated at 200 degrees and 300 degrees Fahrenheit. There is a strong negative correlation between T50 and E200 and between T90 and E300. These "E" parameters are determined from the same distillation curve as the "T" parameters. E200 and E300, like other Complex Model parameters, have acceptable range limits (30% to 70% for E200 and 70% to 100% for E300), which are applicable to each batch of RFG. Since E200 and E300 are part of the Complex Model, RFG and CG emission requirements, in theory, could constrain these parameters.

Simple Model CG standards limited the annual average T90 level to 125% of the refiner's or importer's compliance baseline. For Complex Model CG, annual average E200 and E300 were limited to the greater of the refiner’s or importer’s 1990 baseline or the Complex Model range limit. Since gasoline's distillation characteristics depend on its composition, any changes to or limits on gasoline composition necessary for compliance with emission requirements potentially affect or constrain these distillation parameters. Changes to or trends in distillation parameters over time may indicate that such composition changes occurred.

EPA's Distillation Property Data

EPA collects data in order to determine compliance with RFG and Anti-Dumping requirements. EPA needed T90 data through reporting year 1997, and E200/E300 data in 1998 and subsequent years. EPA's RFG/Anti-Dumping batch reporting forms have provisions for reporting T50, T90, E200 and E300 for each gasoline batch, and some parties chose to report distillation parameter information beyond that needed to determine compliance with standards. EPA has restricted its analysis of batch data distillation parameters to those that were required for compliance determination. RFG Survey data prior to 1998 did not include any distillation parameter information. For 1998 and later years, the data included not only E200 and E300 but T50 and T90; consequently survey-based estimates for all four of these parameters will be included for 1998 and subsequent years.

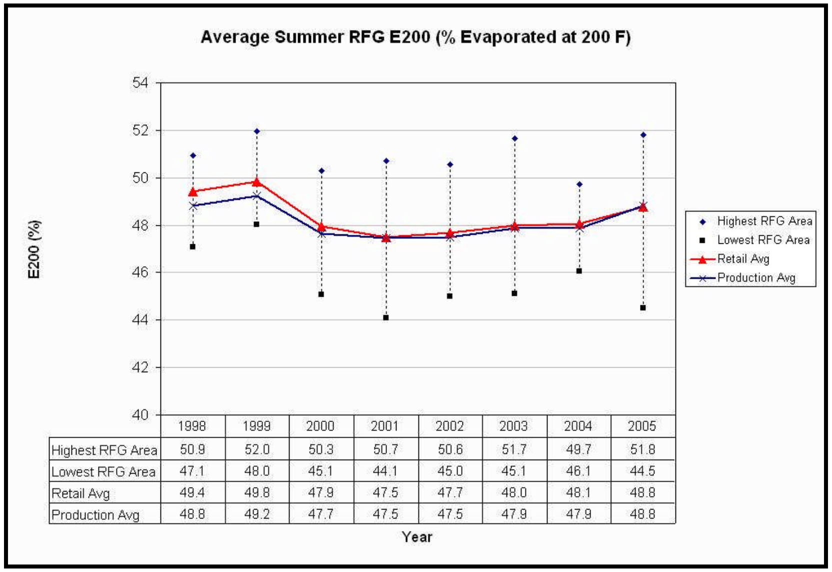
Distillation Parameter Trends

Overview-Reformulated Gasoline

Figures 1 through 4 show volume-weighted E200 and E300 averages, by year. Both the reporting system estimates, by reporting year, and the RFG Survey-based estimates, by survey year, are shown.

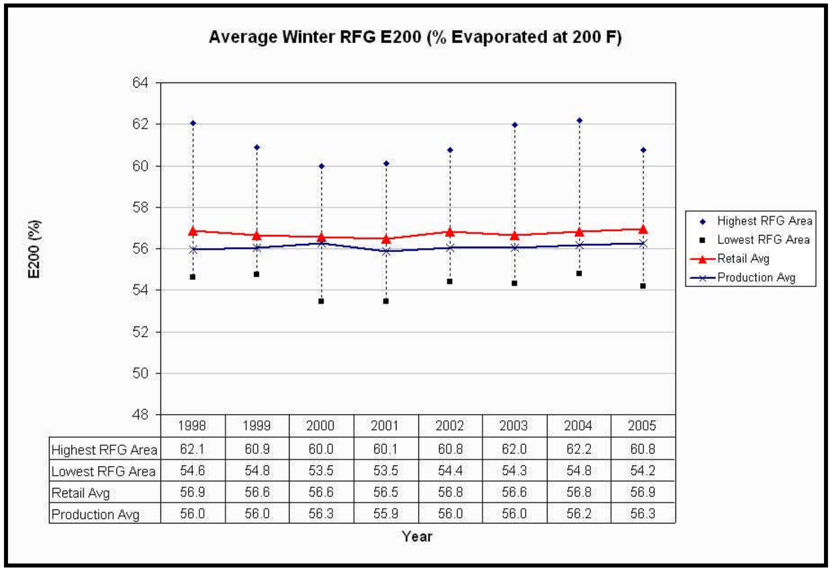
The reporting and survey based estimates both indicate that the largest year-to-year change in average Summer E200 was a decrease between 1999 and 2000, concurrent with the transition from Phase I to Phase II RFG. Regression analysis of both sets of estimates for years 1998 through 2004 indicates that a statistically significant shift in E200 occurred at that time (see Regression Analysis Appendix). There was little or no change in Winter E200 between 1999 and 2000.

The largest year-to-year changes in average Summer and Winter E300 were increases between 1999 and 2000, and regression analysis also indicates that statistically significant shifts in E300 occurred. Additionally, according to both reporting and survey-based estimates, Summer and Winter E300 were lower in 2005 than in 2000, although increases from 2004 to 2005 may indicate reversal of apparent downward trends. Regression analysis indicates statistically significant downward linear trends through 2004 in the Summer survey-based estimates, and in both Winter estimates.



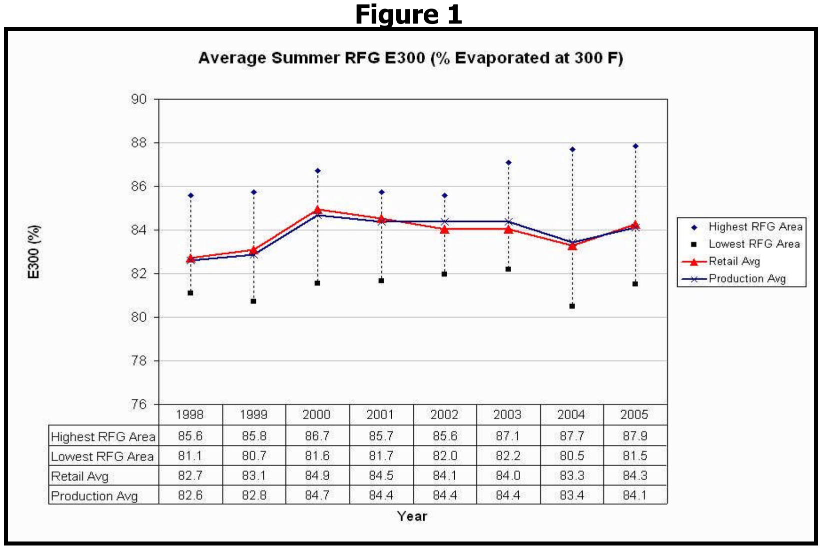
	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	50.9	52.0	50.3	50.7	50.6	51.7	49.7	51.8
Lowest RFG Area	47.1	48.0	45.1	44.1	45.0	45.1	46.1	44.5
Retail Avg	49.4	49.8	47.9	47.5	47.7	48.0	48.1	48.8
Production Avg	48.8	49.2	47.7	47.5	47.5	47.9	47.9	48.8

Figure 1



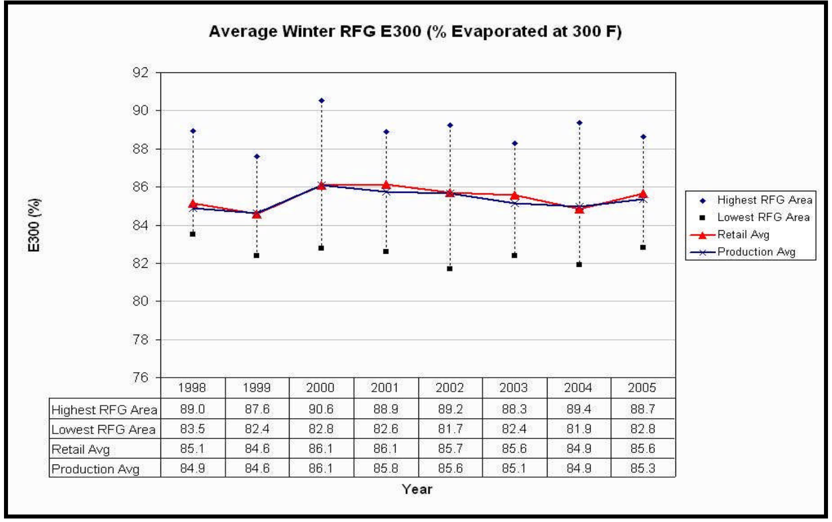
	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	62.1	60.9	60.0	60.1	60.8	62.0	62.2	60.8
Lowest RFG Area	54.6	54.8	53.5	53.5	54.4	54.3	54.8	54.2
Retail Avg	56.9	56.6	56.6	56.5	56.8	56.6	56.8	56.9
Production Avg	56.0	56.0	56.3	55.9	56.0	56.0	56.2	56.3

Figure 2



	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	85.6	85.8	86.7	85.7	85.6	87.1	87.7	87.9
Lowest RFG Area	81.1	80.7	81.6	81.7	82.0	82.2	80.5	81.5
Retail Avg	82.7	83.1	84.9	84.5	84.1	84.0	83.3	84.3
Production Avg	82.6	82.8	84.7	84.4	84.4	84.4	83.4	84.1

Figure 3



	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	89.0	87.6	90.6	88.9	89.2	88.3	89.4	88.7
Lowest RFG Area	83.5	82.4	82.8	82.6	81.7	82.4	81.9	82.8
Retail Avg	85.1	84.6	86.1	86.1	85.7	85.6	84.9	85.6
Production Avg	84.9	84.6	86.1	85.8	85.6	85.1	84.9	85.3

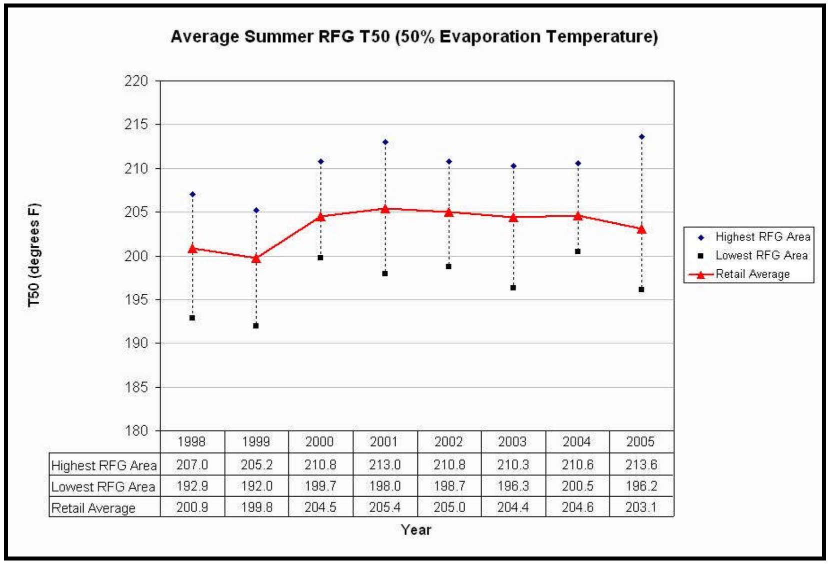
Figure 4

Figures 5 and 6 show volume-weighted T50 averages, by year, estimated from RFG Survey data.

The largest year-to-year change Summer T50 was an increase between 1999 and 2000, and regression analysis indicates that a statistically significant shift in T50 occurred. There was a much smaller increase in Winter T50 between 1999 and 2000, and regression analysis does not indicate a statistically significant shift. However, figure 6 shows that Winter T50 was lowest in 2004 and 2005, and regression analysis through 2004 indicates a statistically significant downward linear trend.

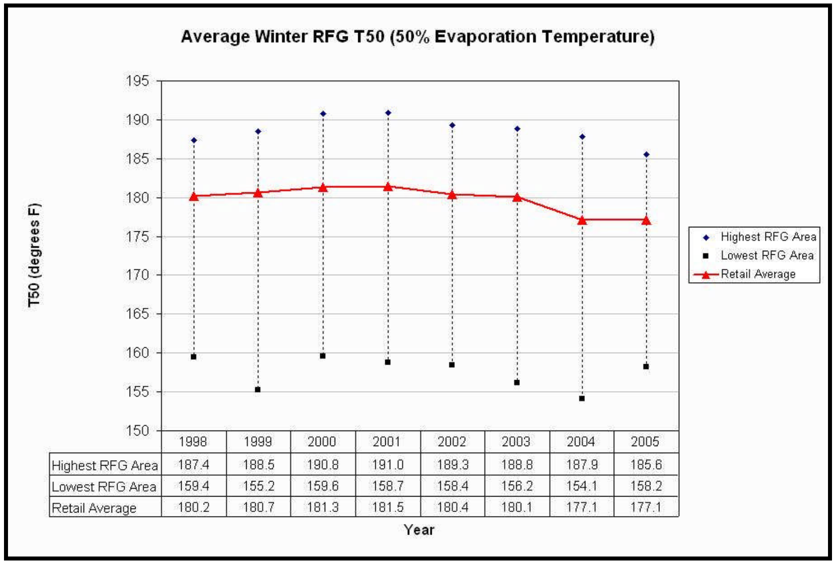
Figures 7 and 8 show volume-weighted T90 averages, by year, estimated from RFG Survey data.

The largest year-to-year changes in both Summer and Winter T90 were decreases between 1999 and 2000, and regression analysis indicates that statistically significant shifts in T90 occurred. Additionally, both Summer and Winter T90 increased between 2000 and 2004, and regression analysis indicates statistically significant upward trends through 2004. Decreases from 2004 to 2005 may indicate reversal of these upward trends.



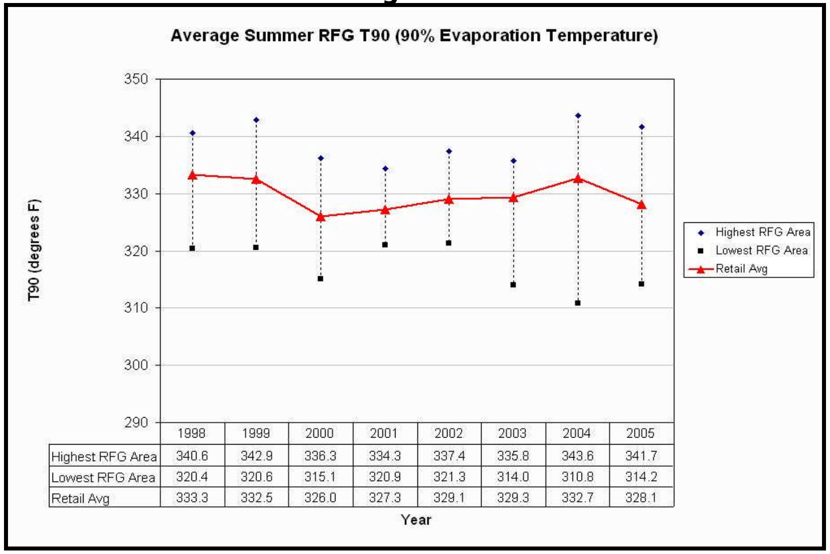
	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	207.0	205.2	210.8	213.0	210.8	210.3	210.6	213.6
Lowest RFG Area	192.9	192.0	199.7	198.0	198.7	196.3	200.5	196.2
Retail Average	200.9	199.8	204.5	205.4	205.0	204.4	204.6	203.1

Figure 5



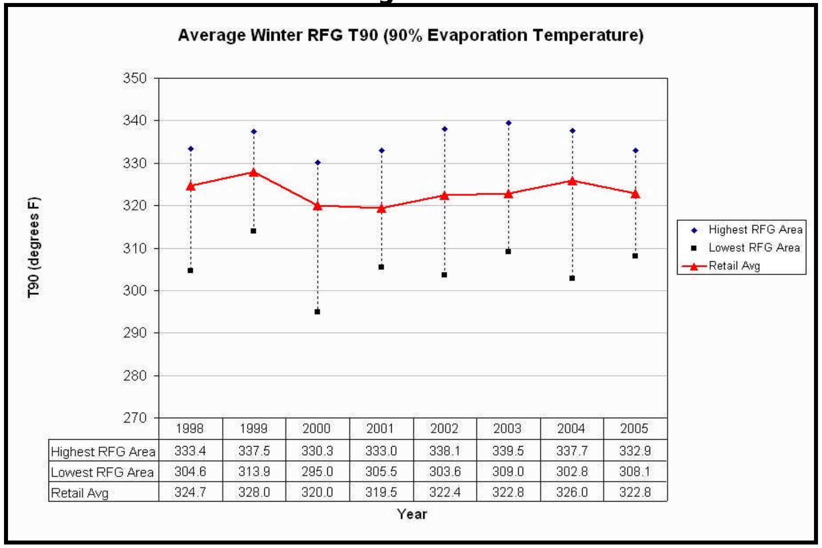
	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	187.4	188.5	190.8	191.0	189.3	188.8	187.9	185.6
Lowest RFG Area	159.4	155.2	159.6	158.7	158.4	156.2	154.1	158.2
Retail Average	180.2	180.7	181.3	181.5	180.4	180.1	177.1	177.1

Figure 6



	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	340.6	342.9	336.3	334.3	337.4	335.8	343.6	341.7
Lowest RFG Area	320.4	320.6	315.1	320.9	321.3	314.0	310.8	314.2
Retail Avg	333.3	332.5	326.0	327.3	329.1	329.3	332.7	328.1

Figure 7



	1998	1999	2000	2001	2002	2003	2004	2005
Highest RFG Area	333.4	337.5	330.3	333.0	338.1	339.5	337.7	332.9
Lowest RFG Area	304.6	313.9	295.0	305.5	303.6	309.0	302.8	308.1
Retail Avg	324.7	328.0	320.0	319.5	322.4	322.8	326.0	322.8

Figure 8

In general, it is not surprising that changes in Summer RFG distillation parameters occurred concurrent with the transition from Phase I to Phase II standards. The more stringent Phase II standards applicable to Summer RFG necessitated a number of refining and blending changes, and these changes may alter distillation profiles, even if it was not their intended purpose. In addition to the shifts in distillation parameters, analyses of Summer RFG reporting and survey data concur that statistically significant shifts in RVP, benzene, aromatics and sulfur occurred between 1999 and 2000.

Phase II requirements for Winter RFG, other than toxics performance, were not more stringent than Phase I requirements, so there was probably less regulatory pressure for changes in composition, and hence, less reason to expect significant changes in distillation properties. However, analysis of Winter survey data indicates statistically significant shifts in E300, T90 and aromatics content between 1999 and 2000. Analysis of reporting data confirms the shift in E300, but does not confirm the shift in aromatics or identify any other parameters that changed significantly between 1999 and 2000. (Reporting data were not analyzed for T90 changes.)

Since the two data sets are in agreement with respect to E300 increase, there is little doubt that a shift occurred between 1999 and 2000, possibly, but not necessarily, as a result of the transition to Phase II standards. Since there is strong evidence of an E300 change, it is reasonable to assume that there was some significant change in Winter RFG composition between 1999 and 2000, even if it was not captured in EPA's data or identified in EPA's analysis (e.g. even if aromatics or olefins content did not change, proportions of specific aromatics or olefins may have changed).

As noted, the analyses also indicate possible trends in distillation parameters between 2000 and 2004. As explained in the RFG Trends chapter, the major regulatory factors affecting RFG between 2000 and 2005 were the Tier 2 sulfur requirements, MSAT, and state bans on MTBE with consequent increased use of ethanol. EPA has not undertaken a detailed analysis to identify possible causes for these apparent trends.

RFG Distillation Parameters by PADD

Tables 1 and 2 show 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see “PADD Level Analysis” appendix for additional information):

2004 & 2005 Reporting Averages by PADD-RFG E200 (Refiner Batches Only)

		2004		**2005**	
Season	**PADD**	**Average Value (% evaporated)**	**Volume (gal)***	**Average Value (% evaporated)**	**Volume (gal)**
Summer	I	47.3	4,792,114,891	47.6	4,431,080,230
	II	46.6	1,740,499,436	46.3	1,844,913,833
	III	48.7	5,890,920,167	49.9	5,690,766,967
Winter	I	55.4	6,489,530,475	55.6	7,081,940,665
	II	58.4	2,438,403,544	56.5	2,718,751,541
	III	55.8	6,059,647,031	56.7	5,766,524,033
Annual	I	52.0	11,281,645,366	52.5	11,513,020,895
	II	53.5	4,178,902,980	52.3	4,563,665,374
	III	52.3	11,950,567,198	53.3	11,457,291,000

*Volumes exclude batches with missing values for this parameter

Table 1

2004 & 2005 Reporting Averages by PADD-RFG E300 (Refiner Batches Only)

		2004		2005	
Season	**PADD**	**Average Value (% evaporated)**	**Volume (gal)***	**Average Value (% evaporated)**	**Volume (gal)***
Summer	I	83.6	4,792,114,891	84.1	4,431,080,230
	II	84.7	1,740,499,436	84.3	1,844,913,833
	III	82.5	5,890,920,167	83.2	5,690,766,967
Winter	I	85.1	6,489,530,475	85.7	7,081,940,665
	II	85.7	2,438,403,544	84.7	2,718,751,541
	III	83.7	6,059,647,031	84.5	5,766,524,033
Annual	I	84.4	11,281,645,366	85.1	11,513,020,895
	II	85.3	4,178,902,980	84.5	4,563,665,374
	III	83.1	11,950,567,198	83.9	11,457,291,000

*Volumes exclude batches with missing values for this parameter

Table 2

Figures 9 through 12 show estimates of average E200 and E300 levels by PADD in retail RFG. These averages are volume-weighted averages of the seasonal averages for each area, using gasoline volume estimates supplied in the survey plans. In 2005, RFG surveys were conducted in 18 PADD I areas, five PADD II areas and two PADD III areas.

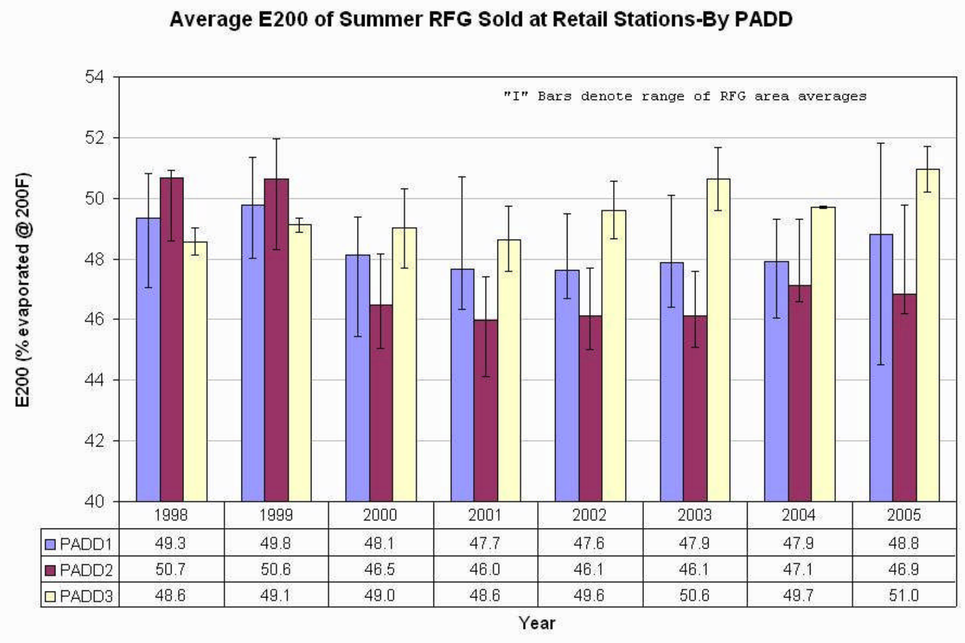
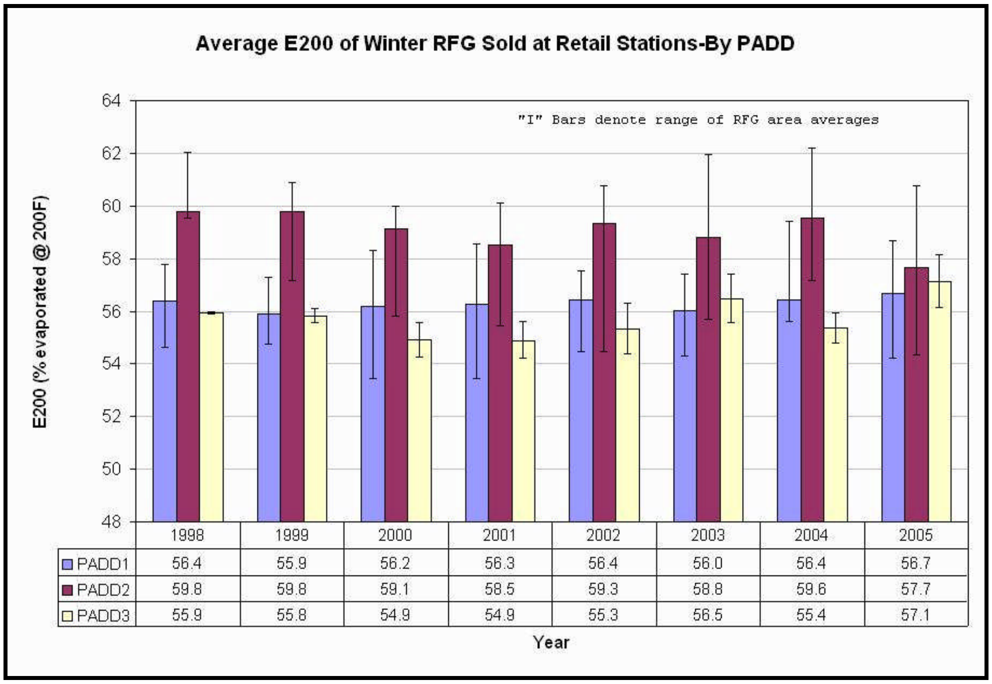
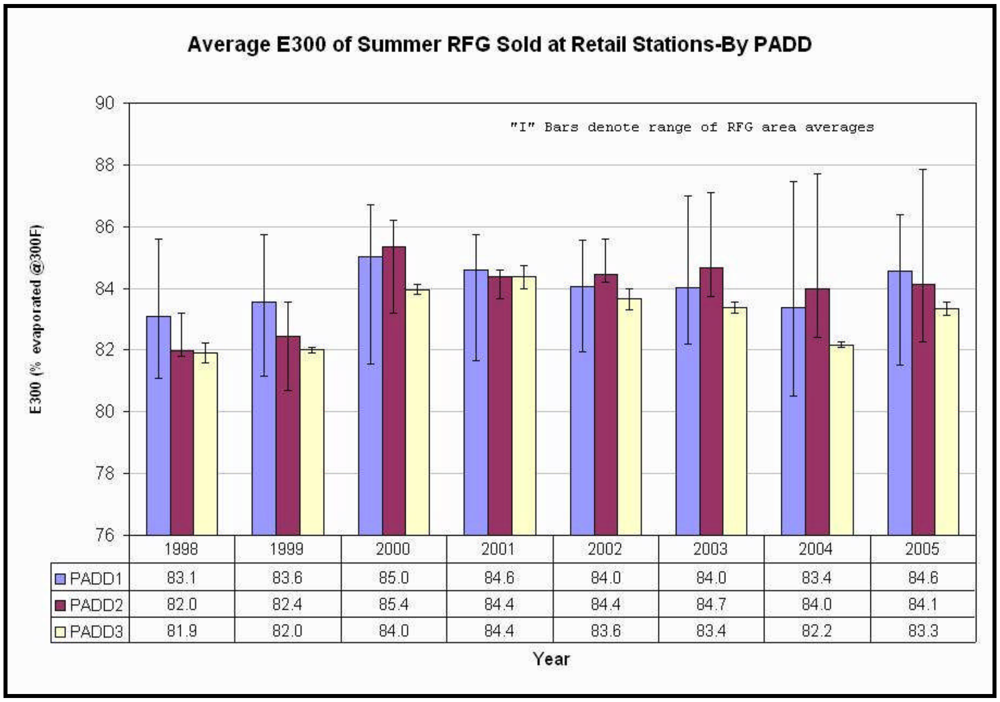


Figure 9



	1998	1999	2000	2001	2002	2003	2004	2005
▭ PADD1	56.4	55.9	56.2	56.3	56.4	56.0	56.4	56.7
■ PADD2	59.8	59.8	59.1	58.5	59.3	58.8	59.6	57.7
□ PADD3	55.9	55.8	54.9	54.9	55.3	56.5	55.4	57.1

Figure 10



	1998	1999	2000	2001	2002	2003	2004	2005
▭ PADD1	83.1	83.6	85.0	84.6	84.0	84.0	83.4	84.6
■ PADD2	82.0	82.4	85.4	84.4	84.4	84.7	84.0	84.1
□ PADD3	81.9	82.0	84.0	84.4	83.6	83.4	82.2	83.3

Figure 11

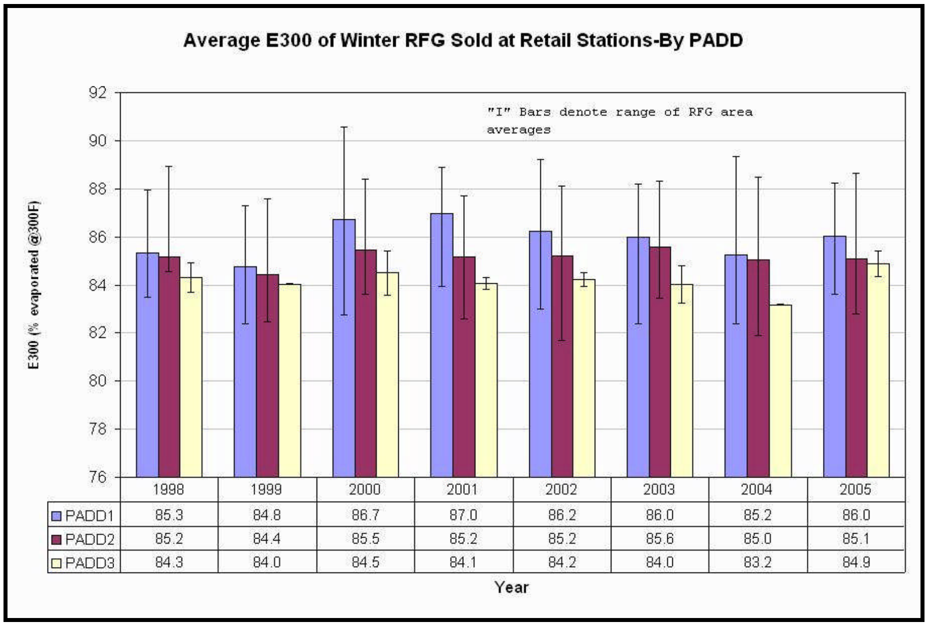


Figure 12

Additional Analysis and Observations-RFG

Data analyses pertaining to RFG distillation parameters are contained in the Appendix to this chapter.

Overview-Conventional Gasoline

Figures 13 and 14 show volume-weighted E200 and E300 averages by year. As noted, changes in distillation parameter averages are indicators of changes in gasoline composition which may or may not be reflected in the data that EPA collects. EPA's analysis for this report did not extensively look for or identify specific reasons for the observed changes in CG distillation parameters.

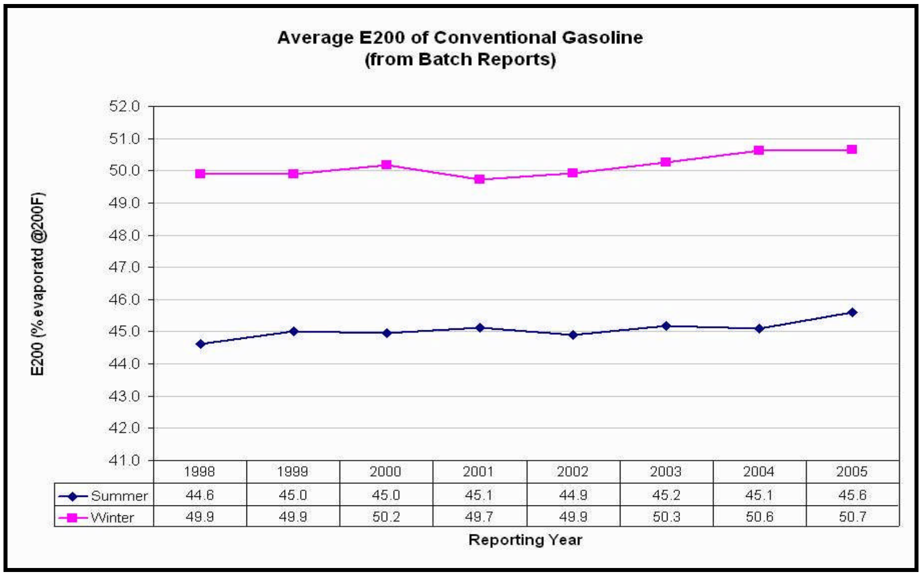


Figure 13

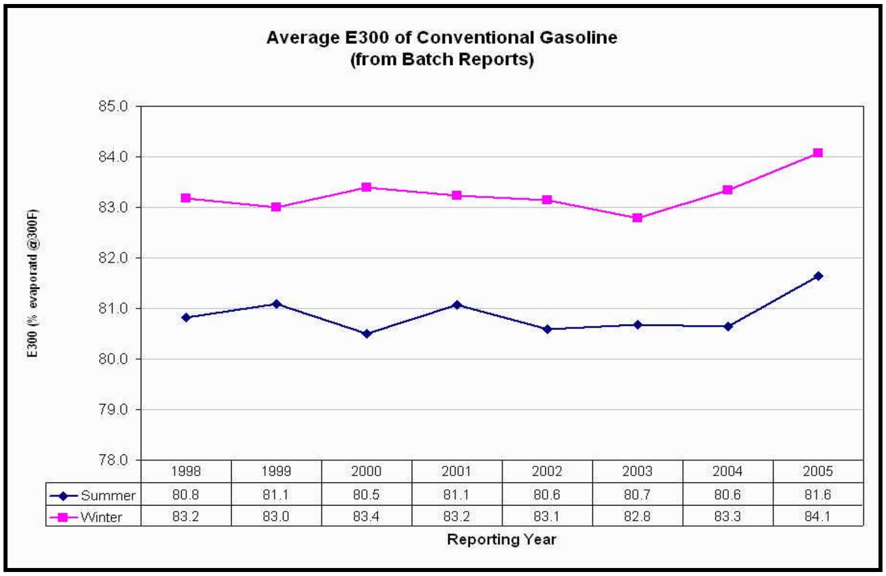


Figure 14

CG Distillation Parameters by PADD

Tables 3 and 4 show 2004 and 2005 reporting averages by PADD for PADD I, II and III refiners. These averages were calculated from batch data, excluding importer batches (see "PADD Level Analysis" appendix for additional information):

2004 & 2005 Reporting Averages by PADD-CG E200 (Refiner Batches Only)

Season	PADD	2004 Average Value (% evaporated)	Volume (gal)*	2005 Average Value (% evaporated)	Volume (gal)*
Summer	I	45.5	3,752,272,894	45.1	3,547,001,722
	II	46.6	11,456,335,295	47.5	10,565,279,667
	III	44.6	21,716,635,879	44.8	20,889,312,566
Winter	I	51.5	3,482,171,831	51.0	4,063,455,417
	II	52.6	13,313,565,716	52.7	13,578,145,833
	III	49.7	23,627,111,420	49.3	22,444,499,833
Annual	I	48.4	7,234,444,725	48.2	7,610,457,139
	II	49.8	24,769,901,011	50.4	24,143,425,500
	III	47.2	45,343,747,299	47.1	43,333,812,399

*Volumes exclude batches with missing values for this parameter

Table 3

2004 & 2005 Reporting Averages by PADD-CG E300 (Refiner Batches Only)					
		2004		2005	
Season	**PADD**	**Average Value (% evaporated)**	**Volume (gal)***	**Average Value (% evaporated)**	**Volume (gal)***
Summer	I	82.7	3,752,272,894	82.8	3,547,001,722
	II	81.4	11,456,437,187	81.9	10,566,219,165
	III	79.4	21,722,168,035	80.5	20,889,312,566
Winter	I	84.4	3,482,279,645	84.4	4,063,455,417
	II	84.1	13,313,789,786	84.6	13,583,692,059
	III	81.8	23,627,111,420	82.6	22,444,499,833
Annual	I	83.5	7,234,552,539	83.7	7,610,457,139
	II	82.9	24,770,226,973	83.4	24,149,911,224
	III	80.6	45,349,279,455	81.6	43,333,812,399

*Volumes exclude batches with missing values for this parameter

Table 4

Additional Analysis and Observations-CG

Data analyses pertaining to CG distillation parameters are contained in the Appendix to this chapter.

Emission and Emission Performance

Background

Both RFG and CG must meet certain emission-related standards tied to the Complex Model. This model produces VOC, NOx and toxics emission estimates for "1990 technology" light duty gasoline vehicles as a function of the gasoline parameters discussed throughout this report. The model is used to produce two types of estimates; "milligrams per mile" emission estimates for a given gasoline formulation and "percent reduction" emission performance estimates which compare the emissions of a given gasoline formulation to the emissions of the 1990 "statutory" baseline gasoline whose properties are specified in the Clean Air Act and/or in EPA's regulations. CG Anti-Dumping standards are intended to maintain the NOx and exhaust toxics emissions qualities of the gasoline that each individual refinery or importer produced in 1990. RFG standards require VOC (for Summer RFG), total toxics (including evaporative benzene for Summer RFG) and NOx emission reductions from the specified 1990 baseline gasoline. The "milligram per mile" Complex Model estimates are used to evaluate CG emission compliance and the “percent reduction” estimates are used to evaluate RFG compliance.

Quantitative emissions and emissions performance estimates in this report are based on the Complex Model. The standards applicable to gasoline in years 1998 and 1999 were based on the Phase I version of this model, however all analyses in this report are based on the currently applicable Phase II Complex Model. Trend analyses based on a combination of Phase I and Phase II model calculations would provide little information on changes in the emissions qualities of gasoline since they would show the effects of the model version change as well as the effects of actual property changes on emissions.

In addition to the Phase I and Phase II model difference, there are multiple versions of the Phase II model. Different versions of the model as well as different baseline gasoline properties apply to Summer and Winter gasoline. The Summer model produces different VOC and toxics estimates for VOC Control Region 1 (Southern) and VOC Control Region 2 (Northern) RFG, because its calculation of the non-exhaust portion of these emissions varies by region. As with the gasoline property analyses, EPA categorized data from each reporting or survey year as “Summer” or “Winter”, and separately analyzed these data. However, while direct comparison of seasonal or regional gasoline properties is often informative, direct comparison of emissions or emission reductions could lead to erroneous conclusions. For example, it is incorrect to conclude that the differences between Summer and Winter model milligrams per mile estimates in a given year are due solely or primarily to differences in the emissions characteristics of Summer and Winter gasoline.

EPA's Complex Model was developed from several thousand emission tests collected from studies designed to measure the effects of gasoline properties on vehicle emissions. In order to meet Clean Air Act's RFG requirements this model was based on 1990 vehicle technology, and it has not been updated to include newer technology vehicles. Although the model's developers used rigorous statistical analysis to produce a sophisticated emission model, the Complex Model was intended to be used to determine if gasoline blends complied with emission standards rather than to estimate fleet-wide emission changes resulting from changes in gasoline.

Section 1506 of The Energy Policy Act of 2005, ("Analyses of Motor Vehicle Fuel Changes") which amends Section 211 of the Clean Air Act, directs the Administrator of EPA to develop and finalize an emissions model that reflects the effects of gasoline characteristics or components on emissions from vehicles in the motor vehicle fleet during calendar year 2007. This section contains additional requirements addressing the effects of fuel changes on emissions, including a "permeation effects" study which will provide estimates of evaporative emission increases that could result from use of gasoline with ethanol content in a motor vehicle. Fulfilling the requirements in this section of the Energy Policy Act should provide analytical tools to better understand, prospectively and retrospectively, the emission impacts of gasoline property changes.

In summary, the emissions and emissions performance analyses in this chapter and elsewhere in this report provide some basis for comparing the emissions characteristics of production and retail gasoline to standards. They are also indicators of changes in the emissions qualities of gasoline over time, without considering changes in vehicles over time. Results allow some quantitative comparisons, and provide some means of judging relative emissions qualities and trends. However, the "milligram per mile" and "percent reduction" values presented here are not intended to and almost certainly do not provide an accurate estimate of the overall emissions changes that have occurred as a result of gasoline property changes.

Regulatory Limits on Emissions and Emissions Performance

As stated, RFG refineries and importers must meet VOC, total toxics and NOx emissions performance standards. These standards are specified as percent reductions from emissions with a Summer or Winter baseline gasoline (i.e. "statutory" baseline gasoline). Refiners and importers may choose to comply with "per gallon" standards or with "averaged" standards. These averaged standards require greater emission reductions than per gallon standards, but allow more batch to batch variability in emissions performance. Suppliers who comply with the averaged VOC performance standard must also meet a per-gallon minimum performance standard. There are no per-gallon minimums for toxics or NOx. VOC standards, which are applicable only to Summer RFG, vary by VOC control region and suppliers much designate the region for each batch. Slightly less stringent VOC standards apply to RFG containing10 volume percent ethanol supplied to the Chicago and Milwaukee areas.

Suppliers generally elect to comply with averaged standards. EPA's regulations required the RFG surveys that generated the retail data analyzed in this report as a condition of compliance with averaged standards. The survey regulations include requirements for VOC, toxics and NOx performance surveys, and failure criteria for each type of survey.

Current and historic emission performance standards and requirements for RFG compliance are contained in EPA's regulations (40 C.F.R. ‘80.41). Where relevant, averaged emission performance standards are displayed in the graphical and tabular analyses in this report.

CG refineries and importers must meet "milligram per mile" exhaust toxics and NOx emission standards on an annual average basis. Standards applicable to CG refineries and importers are facility-specific and largely dependent on the “individual baseline” properties and volumes of the gasoline they supplied in 1990.

The Mobile Source Air Toxics regulations impose “anti-backsliding” toxics requirements on both RFG and CG suppliers. RFG MSAT standards are total toxics performance standards and CG standards are exhaust toxics emissions standards. Both the RFG and CG requirements are facility-specific.

EPA's Emission Data

Since 1998, refiner and importer batch reports for both CG and RFG included the Complex Model outputs necessary for compliance determination, as well as the property information needed to determine the Complex Model inputs. RFG Survey data submitted since 1998 has also included both Complex Model outputs and input information. Prior to 1998 neither data source included the full set of Complex Model input properties. Consequently, although estimates of Complex Model emission performance could have been derived for earlier years with assumptions about the missing inputs, EPA has restricted the emissions analyses in this report to 1998 and later.

EPA recalculated 1998 and 1999 Complex Model outputs for each batch and survey sample using the Phase II model to provide a common basis for measurement of emissions trends. Additionally, both to provide information for further analysis and to verify the accuracy of the reported results, EPA recalculated Complex Model outputs for 2000 through 2005 CG and RFG batch data. Differences between average estimates based on reported and calculated values were small. EPA chose to rely on calculated emission values, rather than reported emission values for all CG analyses. However, EPA found that some RFG blendstock (RBOB) batch reports did not contain information on the type (presumably ethanol) and concentration of oxygenate. (While most parties report this information they are not required to do so.) These batches contained other parameter information as well as reported emission performance values. Since EPA could not correctly calculate emission performance for these batches but did not want to exclude them from trend analyses, EPA used reported emission performance values for all batches in overall RFG trend analyses. Some of the additional analyses in this chapter use calculated RFG emission or emission performance results for the batches with complete parameter information. These results are labeled "calculated from batch data".

The General Methodology chapter in this report notes that EPA screened the batch data in this report and describes, in general, the procedures used to screen gasoline property data. EPA excluded some data from the emissions analyses as well although the exclusion criteria were somewhat different. As explained in that chapter certain batches with outlier values for one or more parameters were flagged and excluded from distribution by volume analyses for all parameters, but not necessarily from average calculations. Since the Complex Model has multiple parameter inputs, flagged batches were excluded from average emission and emission performance calculations as well as distribution by volume analyses. EPA also used maximum and minimum results from its calculated RFG emissions performance results to estimate a range of reasonable values in order to flag emission outliers that are likely to be erroneous values.

For gasoline property analyses, CG blendstock batches were included in averages but excluded from property by volume distributions. CG blendstocks were excluded from all emission analyses. While EPA's regulations include an "equivalent emissions performance" (EEP) procedure for calculating Complex Model emissions for these blendstock batches, this procedure is for compliance purposes and inclusion of these EEP batches in emissions analyses would not necessarily produce better trend estimates. (Additionally, it would have been difficult for EPA to replicate these EEP calculations.)

Emission and Emission Performance Trends

Overview-Reformulated Gasoline

The VOC and NOx performance standards applicable to Summer RFG and the toxics standard applicable to both Summer and Winter RFG became more stringent in 2000 with the transition from Phase I to Phase II RFG standards. Analyses of both reporting and survey data confirmed improvements in performance concurrent with this transition. Figures 1 through 3 show the Summer RFG performance trend lines derived from both reporting and survey data. (These performance trend lines were also presented in the "RFG Trends" chapter). Since Phase I Summer RFG, on average, did not meet either the averaged or per-gallon Phase II VOC and NOx standards, an improvement in average performance was necessary. Summer toxics performance clearly improved as well, even though Phase I RFG, on average, over-complied with the Phase II standard. An analysis presented in the RFG Trends chapter illustrates one probable reason for this toxics performance improvement. This analysis shows that certain of the RFG property changes that reduced VOC and/or NOx emissions also reduced toxics emissions. Even if the toxics standard had not become more stringent with Phase II, the more stringent VOC and NOx standards would have forced certain property changes beneficial to toxics performance. RFG emission performance standards applied on a refinery or importer-specific basis and, unlike oxygen and benzene content standards, could not be met through the transfer of credits. Consequently, even though Phase I Summer RFG on average, over-complied with the Phase II toxics standard, it is probable that performance also improved because some refiners and importers did not meet Phase II toxics performance standards during Phase I and would not have met the toxics performance standard solely through property changes necessary for Phase II VOC and NOx compliance. EPA did not analyze the data on a facility-specific basis, however EPA did determine that average benzene levels dropped with the transition to Phase II. Benzene content reductions lower Complex Model toxics emissions but do not directly affect VOC or NOx emissions, suggesting that some suppliers reduced benzene content in order to improve toxics performance. (See the Benzene Chapter).

The Summer RFG trend lines also show, on average, significant over-compliance with the current NOx and toxics performance standards, but very little VOC compliance margin. The survey data shows the best NOx performance in 2005 and the reporting data in 2004, and the improvement in NOx performance since 2000 is the result of the mandated Tier 2 gasoline sulfur reductions.[41] These reductions were necessary to enable the emission control systems in "new technology" Tier 2 vehicles to be fully effective. However, the improvement in Complex Model NOx emission performance suggests that these sulfur reductions have reduced NOx emissions in older vehicles using RFG as well. Although sulfur reductions, all else constant, also lower VOC and toxics emissions, the trend lines through 2005 do not show any performance benefits. Analyses presented in the RFG Trends Chapter demonstrated that the VOC and toxics emission benefits of sulfur reductions between 2000 and 2005 were offset by changes in other properties that increased VOC and/or toxics emissions.

The data are more equivocal about Winter RFG performance. Figures 4 and 5 show that both reporting and survey average estimates indicate better Winter NOx and toxics performance in 2000 than in 1999. However only the survey estimates suggest that the transition from Phase I to Phase II RFG standards had a strong influence on Winter RFG emissions performance, since the reporting system performance improvements concurrent with this transition are not markedly different from other year-to-year performance changes. These trend lines show that Phase I Winter RFG, on average, substantially over-complied with Phase II Winter NOx and toxics emission “averaged” performance standards. Additionally, after adjusting the Phase I standards to the Phase II model, it is apparent that for Winter RFG only the toxics standard, which is applicable on an annual average basis, became more stringent in Phase II. Consequently, while EPA's aggregate data analysis did not rule out the need for Phase II performance improvements in Winter RFG, it did not indicate that emission performance improvements were necessary.

The disparity between the reporting and survey estimates leaves some question about the effect of the Phase II requirements on Winter RFG. Although there is some rationale for relying more heavily on reporting data to estimate overall averages, there are also reasons to consider survey-based estimates as well. The issue of disparity between reporting and survey estimates has been discussed in the chapter on aromatics. Since aromatics content is an important parameter in Complex Model NOx and toxics emissions calculations, differences between reporting and survey aromatics content estimates are likely to be strongly related to differences in performance estimates.

While there is some divergence in the middle, the beginning and end-points of the reporting and survey-based trend estimates are in better agreement for both NOx and toxics. Both NOx lines show approximately the same performance improvement between 1998 and 2005. The increased rate of improvement between 2003 and 2005 almost certainly resulted from the phased reduction in gasoline

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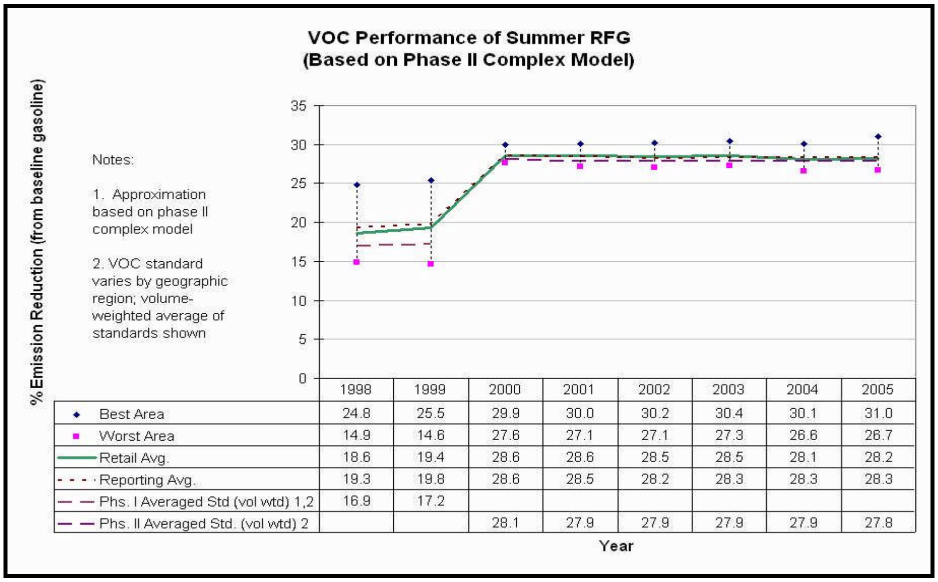
[41] A “ratchet” of the RFG NOx standards in 2002 and 2003, resulting from a 2001 NOx survey failure in Sussex County, DE may have had a minor effect on overall post-2000 NOx performance. These more stringent (by 1%) average NOx reduction standards applied to refineries that supplied RFG to this area.

sulfur standards beginning in 2004. Both toxics estimates concur that toxics performance in 2005 was better than in 1998 and 1999, and that toxics performance improved from 2003 to 2005.



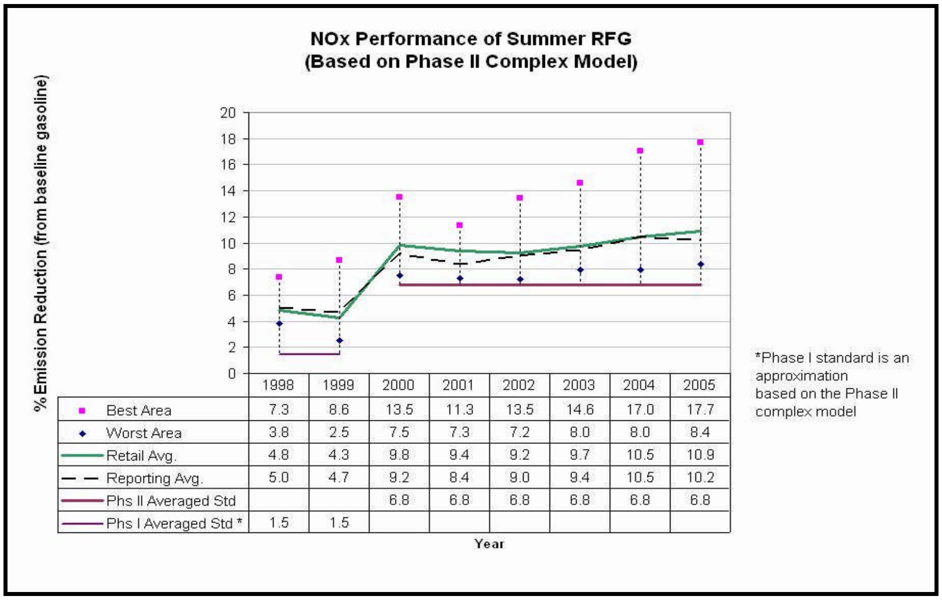
Notes:

1. Approximation based on phase II complex model

2. VOC standard varies by geographic region; volume-weighted average of standards shown

	1998	1999	2000	2001	2002	2003	2004	2005
◆ Best Area	24.8	25.5	29.9	30.0	30.2	30.4	30.1	31.0
■ Worst Area	14.9	14.6	27.6	27.1	27.1	27.3	26.6	26.7
—— Retail Avg.	18.6	19.4	28.6	28.6	28.5	28.5	28.1	28.2
- - - - Reporting Avg.	19.3	19.8	28.6	28.5	28.2	28.3	28.3	28.3
— — Phs. I Averaged Std (vol wtd) 1,2	16.9	17.2						
— — Phs. II Averaged Std. (vol wtd) 2			28.1	27.9	27.9	27.9	27.9	27.8

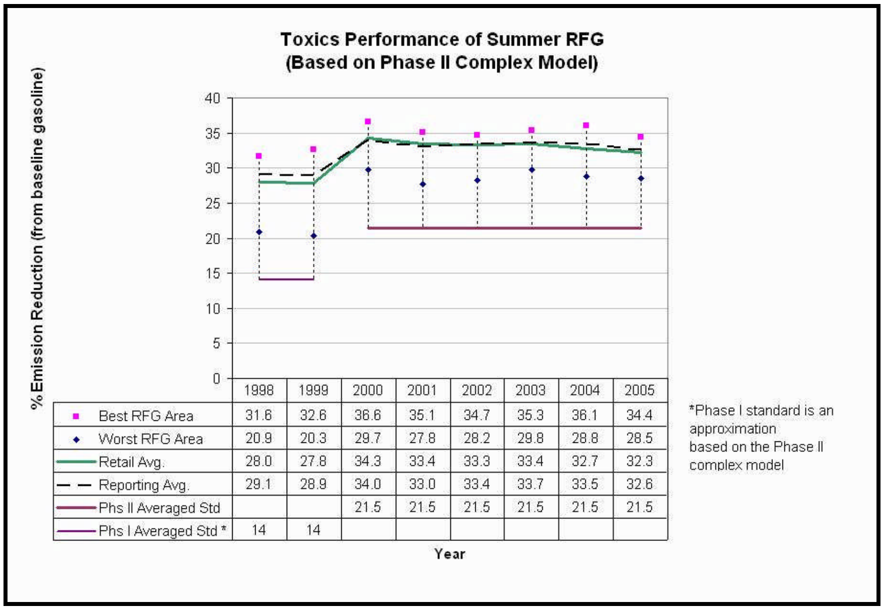
Figure 1



*Phase I standard is an approximation based on the Phase II complex model

	1998	1999	2000	2001	2002	2003	2004	2005
■ Best Area	7.3	8.6	13.5	11.3	13.5	14.6	17.0	17.7
◆ Worst Area	3.8	2.5	7.5	7.3	7.2	8.0	8.0	8.4
—— Retail Avg.	4.8	4.3	9.8	9.4	9.2	9.7	10.5	10.9
— — Reporting Avg.	5.0	4.7	9.2	8.4	9.0	9.4	10.5	10.2
—— Phs II Averaged Std			6.8	6.8	6.8	6.8	6.8	6.8
—— Phs I Averaged Std *	1.5	1.5						

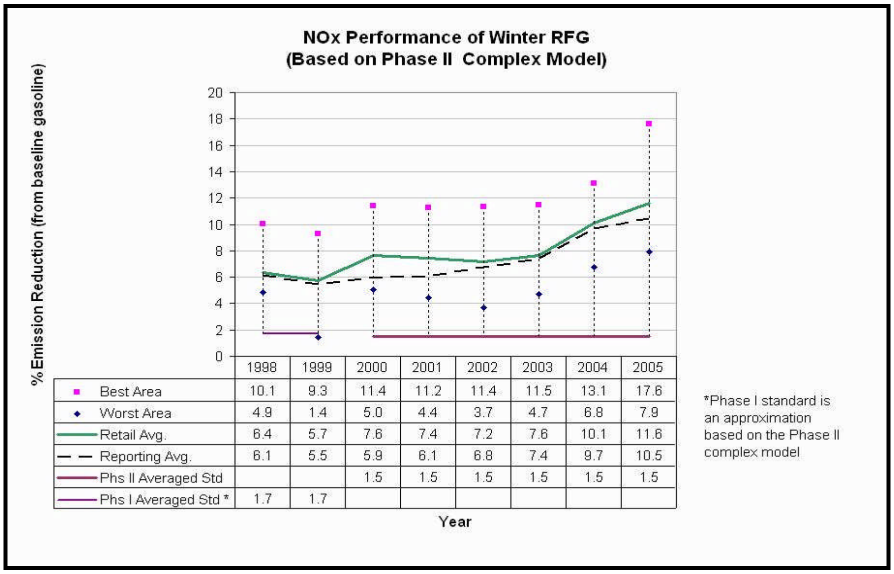
Figure 2



	1998	1999	2000	2001	2002	2003	2004	2005
■ Best RFG Area	31.6	32.6	36.6	35.1	34.7	35.3	36.1	34.4
◆ Worst RFG Area	20.9	20.3	29.7	27.8	28.2	29.8	28.8	28.5
Retail Avg.	28.0	27.8	34.3	33.4	33.3	33.4	32.7	32.3
Reporting Avg.	29.1	28.9	34.0	33.0	33.4	33.7	33.5	32.6
Phs II Averaged Std			21.5	21.5	21.5	21.5	21.5	21.5
Phs I Averaged Std *	14	14						

*Phase I standard is an approximation based on the Phase II complex model

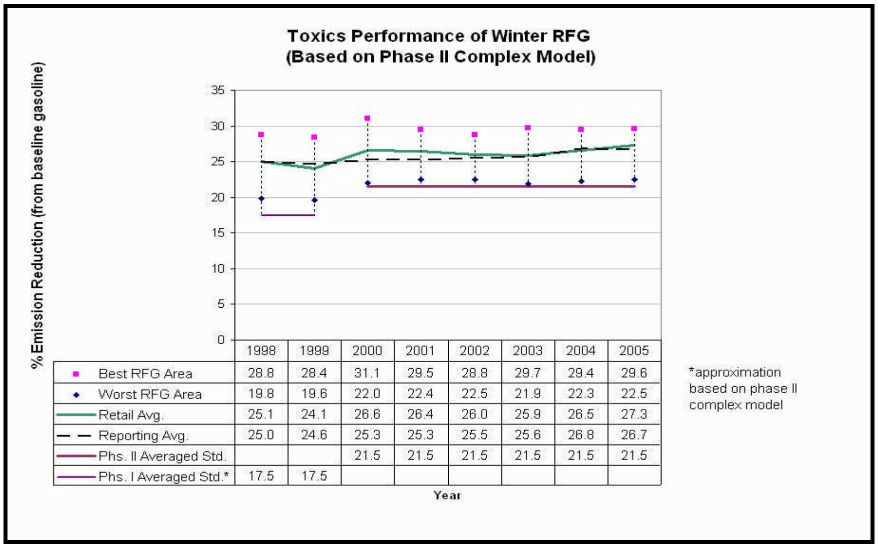
Figure 3



	1998	1999	2000	2001	2002	2003	2004	2005
■ Best Area	10.1	9.3	11.4	11.2	11.4	11.5	13.1	17.6
◆ Worst Area	4.9	1.4	5.0	4.4	3.7	4.7	6.8	7.9
Retail Avg.	6.4	5.7	7.6	7.4	7.2	7.6	10.1	11.6
Reporting Avg.	6.1	5.5	5.9	6.1	6.8	7.4	9.7	10.5
Phs II Averaged Std			1.5	1.5	1.5	1.5	1.5	1.5
Phs I Averaged Std *	1.7	1.7						

*Phase I standard is an approximation based on the Phase II complex model

Figure 4



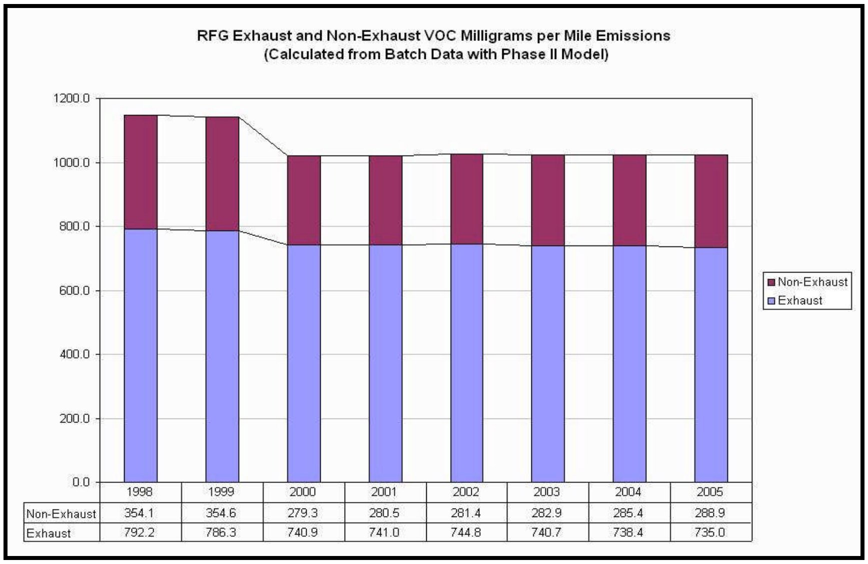
	1998	1999	2000	2001	2002	2003	2004	2005
■ Best RFG Area	28.8	28.4	31.1	29.5	28.8	29.7	29.4	29.6
◆ Worst RFG Area	19.8	19.6	22.0	22.4	22.5	21.9	22.3	22.5
Retail Avg.	25.1	24.1	26.6	26.4	26.0	25.9	26.5	27.3
Reporting Avg.	25.0	24.6	25.3	25.3	25.5	25.6	26.8	26.7
Phs. II Averaged Std.			21.5	21.5	21.5	21.5	21.5	21.5
Phs. I Averaged Std.*	17.5	17.5						

Figure 5

Additional Analyses and Observations-RFG

VOC Emissions and Emission Performance

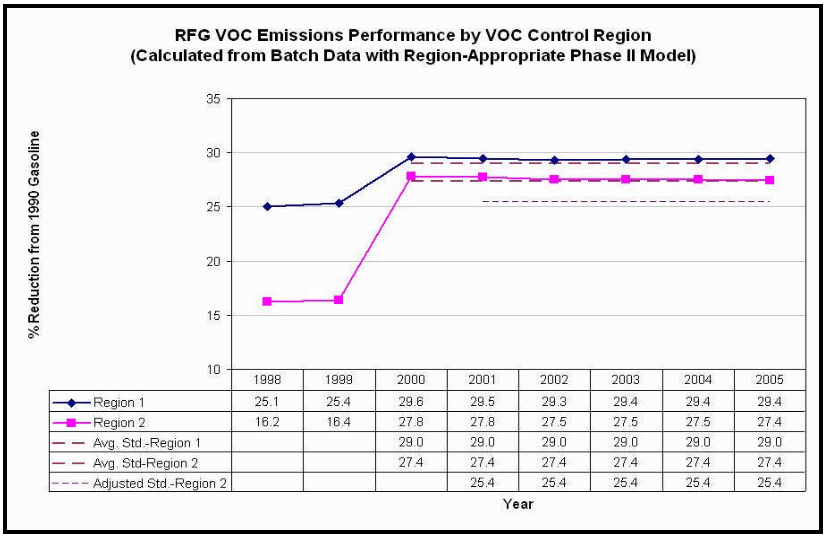
Figure 6 shows the exhaust and non-exhaust components of Complex Model VOC emissions expressed in milligrams per mile, rather than as percent reductions. The Phase II Complex Model attributes about 69 percent of Phase I and about 72 percent of Phase II Summer RFG VOC emissions to exhaust emissions. While both exhaust and non-exhaust emissions were reduced in order to meet Phase II VOC standards, non-exhaust emission reductions accounted for about 63% of the total reduction. The Complex Model estimates non-exhaust VOC emissions from gasoline RVP (and the VOC control region specification). All Complex Model input parameters except benzene affect Complex Model exhaust VOC emissions. In addition to producing the non-exhaust VOC reductions, RVP reductions contributed to exhaust VOC reductions. Consequently, RVP reduction was critical to meeting Phase II VOC reduction standards.



	1998	1999	2000	2001	2002	2003	2004	2005
Non-Exhaust	354.1	354.6	279.3	280.5	281.4	282.9	285.4	288.9
Exhaust	792.2	786.3	740.9	741.0	744.8	740.7	738.4	735.0

Figure 6

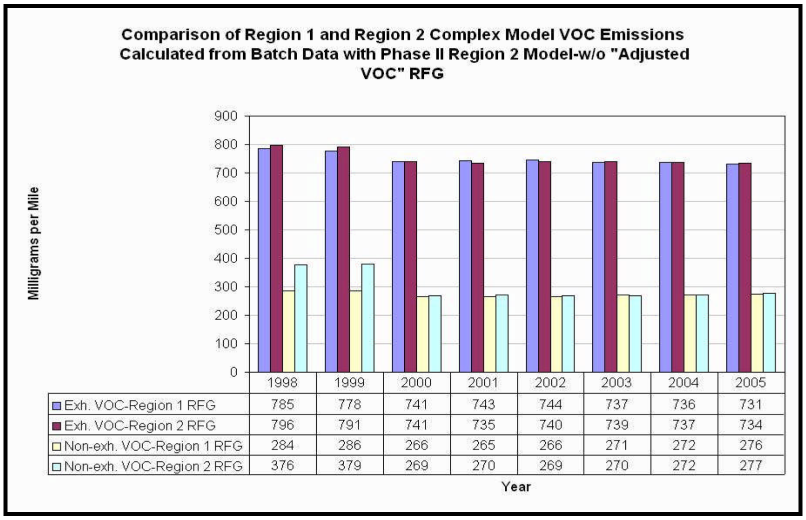
The emission estimates in Figures 1 and 6 reflect a composite of RFG designated for VOC Control Region 1 and VOC Control Region 2. Figure 7 shows VOC emission performance, based on the VOC control region specified for each batch, and calculated with the appropriate regional version of the Phase II Complex Model. The Region 2 data include some "adjusted VOC" ethanol-oxygenated RFG supplied to Chicago and Milwaukee, although this RFG may be under-represented because of data screening. This graph correctly suggests that there was a substantial difference between Region 1 and Region 2 VOC performance prior to 2000 and that both improved between 1999 and 2000, narrowing the gap. However, as explained earlier, it is important to interpret region-to region emission comparisons correctly.



	1998	1999	2000	2001	2002	2003	2004	2005
Region 1	25.1	25.4	29.6	29.5	29.3	29.4	29.4	29.4
Region 2	16.2	16.4	27.8	27.8	27.5	27.5	27.5	27.4
Avg. Std.-Region 1			29.0	29.0	29.0	29.0	29.0	29.0
Avg. Std-Region 2			27.4	27.4	27.4	27.4	27.4	27.4
Adjusted Std.-Region 2				25.4	25.4	25.4	25.4	25.4

Figure 7

Since the Complex Model evaluates the non-exhaust portion of VOC emissions differently depending on the VOC Control Region, these composite emissions reflect, to some degree, a geographic effect related to temperature, as well as the effects of the gasoline properties on emissions. In order to remove this geographic effect, non-exhaust VOC emissions for VOC Region 1 batches were recalculated using the VOC Region 2 model. This allows a side-by-side comparison of the property-related VOC emission differences between these two types of RFG. Figure 8 shows, on average, that the property-related emission characteristics of these two types of RFG, which differed during Phase I primarily because of non-exhaust emissions, became essentially the same after the Phase II standards took effect.



	1998	1999	2000	2001	2002	2003	2004	2005
Exh. VOC-Region 1 RFG	785	778	741	743	744	737	736	731
Exh. VOC-Region 2 RFG	796	791	741	735	740	739	737	734
Non-exh. VOC-Region 1 RFG	284	286	266	265	266	271	272	276
Non-exh. VOC-Region 2 RFG	376	379	269	270	269	270	272	277

Figure 8

The Energy Policy Act of 2005 requires that EPA consolidate the RFG regulations applicable to VOC Control Region 1 and VOC Control Region 2 by eliminating the less stringent requirements applicable to VOC Control Region 2 and instead applying the more stringent requirements applicable to VOC Control Region 1 (‘1504(c)). The VOC performance standard for VOC Control Region 1 (29.0 percent "averaged" reduction) is numerically more stringent than the Region 2 standard (27.4. percent except for "adjusted VOC" gasoline supplied to Chicago and Milwaukee). While there is an apparent 1.6 percent difference in stringency between the two standards, in fact, as the above analysis suggests, there is little or no real difference in stringency. To confirm this, EPA evaluated the Complex Model VOC performance of 4194 individual Summer RFG formulations reported in 2004 batch reports, using the Region 1 and Region 2 versions of the Complex Model. These batches were a mix of Region 1 and Region 2 RFG. When all formulations were evaluated with the Region 1 model the average performance was 29.2 percent, and when evaluated with the Region 2 model average performance was 27.7 percent. The 1.5 percent difference between the two performance averages is nearly the same as the difference between the Region 1 and the unadjusted Region 2 standards, demonstrating that most of this apparent difference in stringency is due to differences between the Region 1 and Region 2 models.

Figure 9 shows exhaust, non-exhaust and total VOC milligram per mile emissions plotted as differences from year 2000 emissions. Both exhaust and non-exhaust emissions changes between 2000 and 2005 are clearly very small compared to changes from 1999 to 2000. Exhaust emissions are lower in 2005 than in 2000, while non-exhaust emissions are higher in 2005 than in 2000. In particular, the exhaust emission decreases between 2002 and 2005 were nearly offset by non-exhaust emission increases.

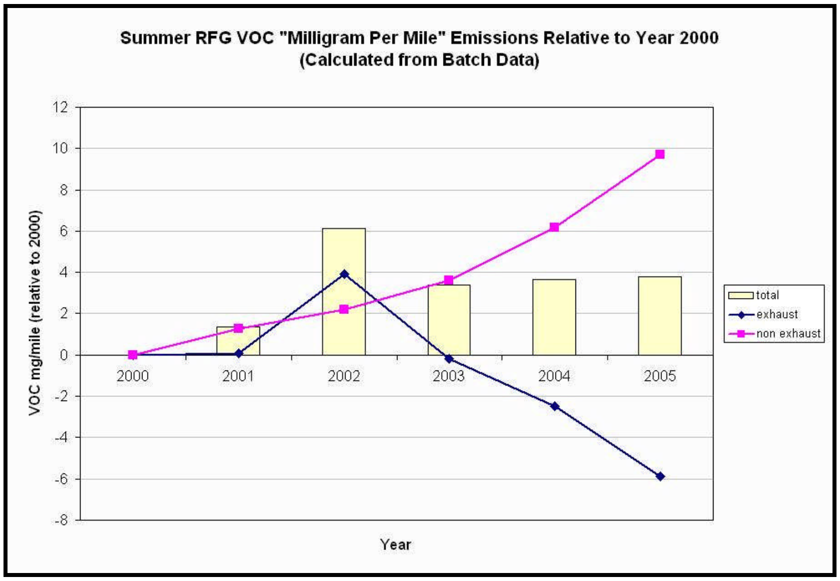


Figure 9

These opposing movements in exhaust and non-exhaust VOC emissions provide tenuous evidence of a trend because of their small magnitude and short duration. However, additional factors suggest that they may represent something other than random fluctuations. The VOC emission performance trend lines (Figures 1 and 6) show that VOC compliance margins are small especially when compared to NOx and toxics compliance margins, indicating that RFG's VOC emission performance standards are more constraining than these other RFG standards. It was suggested in the RVP chapter that suppliers would strive to increase RVP in Summer RFG, but that RVP was constrained by the VOC performance standard. Summer RFG sulfur levels decreased continuously from 2002 to 2005 as a result of the Tier 2 gasoline sulfur requirements, and these sulfur reductions were partially responsible for exhaust VOC reductions. Although these sulfur reductions could have provided additional VOC compliance margin, refiners may have chosen to take back this additional compliance margin by raising RVP. This is generally consistent with an analysis, based on 2000 and 2005 RFG Survey property estimates, presented in the RFG Trends chapter. It showed that VOC emission reductions due primarily to sulfur decreases were offset by VOC increases due primarily to RVP increases. This is also somewhat consistent with assumptions that EPA's Mobile 6.2 model makes when modeling the impact of an RFG program. This model assumed an RVP increase from 6.7 to 6.8 psi in RFG beginning in 2003 as a result of the Tier 2 gasoline sulfur program (Brzezinski, 2001).

It is important to recognize that even if the Tier 2 reductions in sulfur content do interact with RFG requirements in ways that affect how refiners meet RFG standards, the resultant property changes may be small (e.g. RVP increased by slightly more than 0.1 psi between 2000 and 2005, and other factors, such as the implementation of the Chicago/Milwaukee "adjusted VOC" standards contributed to this increase). Moreover, even if the sulfur reductions do cause changes in RFG composition, it does not necessarily follow that RFG's overall emissions impact would be adversely affected.

Toxics Emissions and Performance

The Complex Model estimates emissions of exhaust benzene, non-exhaust benzene, acetaldehyde, formaldehyde, 1, 3 Butadiene and polycyclic organic matter (POM). It sums these estimates to estimate total toxics and makes no adjustments for the different potencies of these toxic pollutants. The Winter Complex Model assumes that non-exhaust benzene emissions are zero. Figures 10 and 11 show the milligram per mile contribution of each of these toxic pollutants to RFG toxics emissions, and exhaust benzene is the major contributor to both Summer and Winter toxics emissions.

Figures 12 and 13 show each toxics component and total toxics plotted as milligram per mile changes from the 1998 estimates. The change in exhaust benzene emissions over time was the major component of the toxics emission trends for both Summer and Winter RFG. Changes in several gasoline parameters, including but not limited to gasoline benzene content, have had significant effects on RFG benzene emissions. Analysis based on RFG Survey data presented in the RFG Trends chapter showed that aromatics, sulfur, and benzene content reductions accounted for much of the Phase I to Phase II toxics reduction in Summer RFG and that sulfur reductions produced further toxics reductions between 2000 and 2005. These content changes, all else constant, lower exhaust benzene emissions.

Figures 12 and 13 also show that recent increases in acetaldehyde emissions have partially offset decreases in benzene emissions. These acetaldehyde emission increases probably resulted from increased use of ethanol in place of MTBE. RFG ethanol use increased substantially between 2002 and 2005 concurrent with these acetaldehyde increases. (See the RVP Trends and Oxygenates chapters.) The Complex Model, for toxics emissions calculations only, considers not only the amount of oxygen but the specific oxygenate(s) used. According to the Complex Model, adding any oxygenate to gasoline, all else constant, will reduce certain toxics, including exhaust benzene. Additionally, use of any oxygenate may further reduce toxics emissions because of dilution of and/or substitution for gasoline components that adversely affect toxics emissions. However, the Complex Model predicts that specific oxygenates will have different effects on certain of the constituent toxics in the total toxics calculation. It predicts that acetaldehyde emissions increase as ethanol content increases and also as MTBE content decreases. The model indicates no relationship between ethanol and formaldehyde emissions, but predicts a positive relationship between MTBE content and formaldehyde emissions. However, EPA's analysis did not find formaldehyde emission decreases concurrent with the substantial decrease in MTBE use. This lack of correlation between MTBE reduction and formaldehyde emission reduction can occur since all Complex Model toxics are functions of multiple parameters.

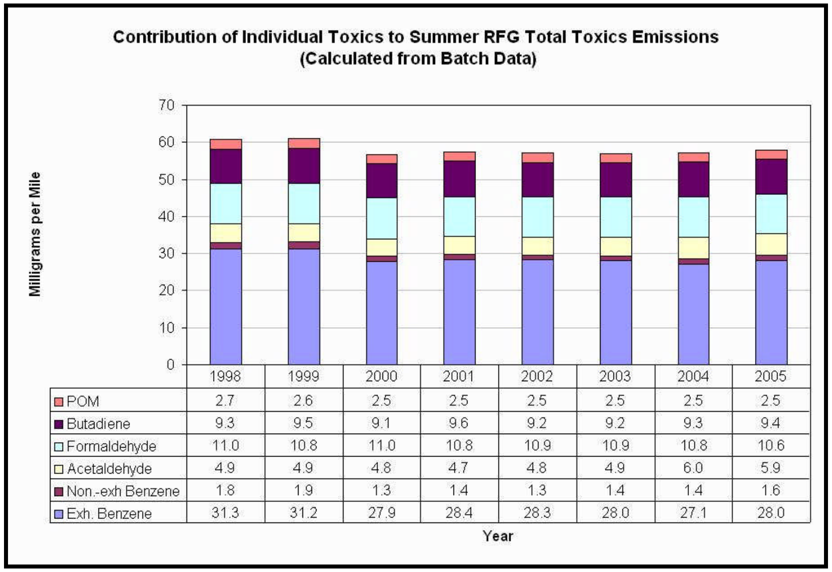
Analyses in the Chapter Appendix

The chapter appendix contains additional RFG analyses which treat the Complex Model emission performance parameters in the same manner as the gasoline property parameters addressed in other chapters, including grade-to-grade and geographic comparisons. Since these emission performance comparisons connote that some RFG is better than other RFG, some further discussion is warranted.

There are patterns in grade-to-grade emissions performance. For example, on average, premium gasoline exhibited consistently better Summer and Winter NOx performance than regular or mid-grade gasoline. This is probably largely due to lower sulfur and olefins levels in premium RFG (see the sulfur and olefins chapters). These differences were largely due to refining and blending practices needed to meet the octane requirements of each gasoline grade. Although the Complex Model may have identified premium RFG as being, in certain respects, a "cleaner" gasoline than other grades of RFG, it does not necessarily follow that significant environmental benefits would occur with increased use of premium gasoline in vehicles that do not need premium gasoline

The grade-to-grade differences may have been affected, to an extent, by some refiner decisions to market a low sulfur premium grade gasoline in advance of Tier 2 sulfur reduction standards. EPA's analysis for this report did not isolate and compare the Complex Model emissions performance of gasoline brand/grade combinations explicitly marketed as "cleaner" to that of other of the same grade. However, it is quite possible that such produced lower emissions than other of the same grade.

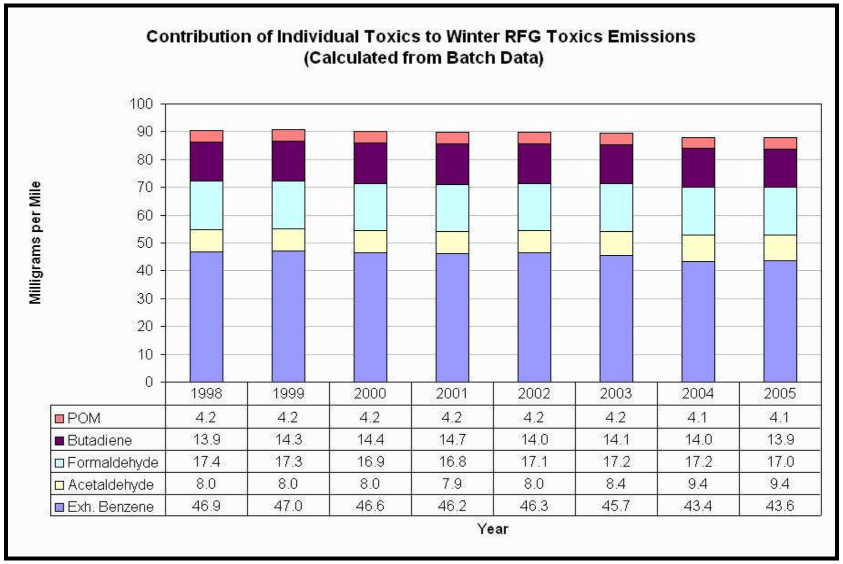
RFG emissions performance varied geographically, even for RFG covered by the same region-specific standards. Although some areas received better RFG than others, by various Complex Model emission performance measures, EPA's regulations, in particular its RFG Survey requirements, ensured that each area received “good” RFG.



Contribution of Individual Toxics to Summer RFG Total Toxics Emissions
(Calculated from Batch Data)

	1998	1999	2000	2001	2002	2003	2004	2005
🟥 POM	2.7	2.6	2.5	2.5	2.5	2.5	2.5	2.5
■ Butadiene	9.3	9.5	9.1	9.6	9.2	9.2	9.3	9.4
□ Formaldehyde	11.0	10.8	11.0	10.8	10.9	10.9	10.8	10.6
□ Acetaldehyde	4.9	4.9	4.8	4.7	4.8	4.9	6.0	5.9
■ Non.-exh Benzene	1.8	1.9	1.3	1.4	1.3	1.4	1.4	1.6
■ Exh. Benzene	31.3	31.2	27.9	28.4	28.3	28.0	27.1	28.0

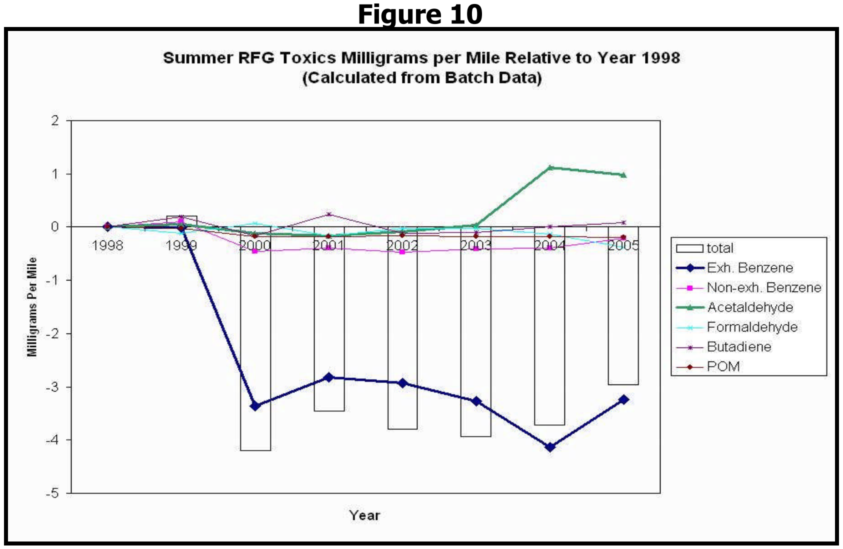
Figure 10



Contribution of Individual Toxics to Winter RFG Toxics Emissions
(Calculated from Batch Data)

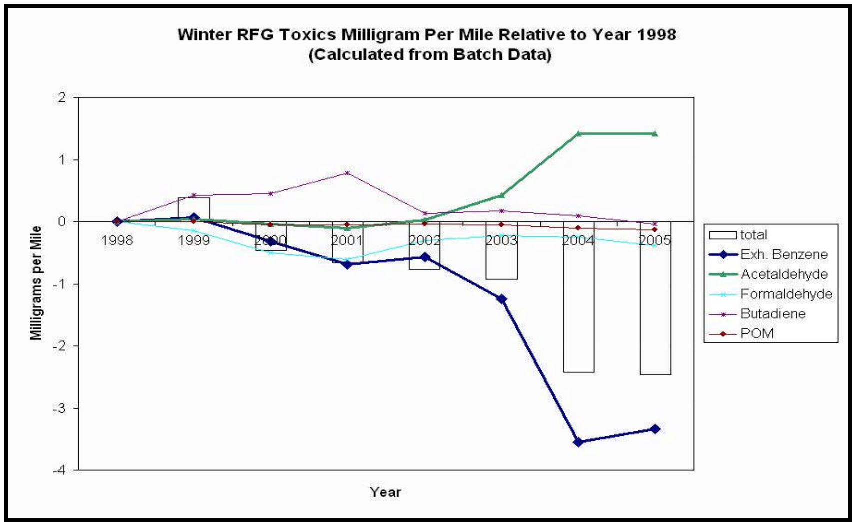
	1998	1999	2000	2001	2002	2003	2004	2005
🟥 POM	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1
■ Butadiene	13.9	14.3	14.4	14.7	14.0	14.1	14.0	13.9
□ Formaldehyde	17.4	17.3	16.9	16.8	17.1	17.2	17.2	17.0
□ Acetaldehyde	8.0	8.0	8.0	7.9	8.0	8.4	9.4	9.4
■ Exh. Benzene	46.9	47.0	46.6	46.2	46.3	45.7	43.4	43.6

Figure 11



Summer RFG Toxics Milligrams per Mile Relative to Year 1998
(Calculated from Batch Data)

Figure 12



Winter RFG Toxics Milligram Per Mile Relative to Year 1998
(Calculated from Batch Data)

Figure 13

Overview-Conventional Gasoline

Figures 14 through 17 show exhaust toxics and NOx emission trend lines for CG. Since CG standards are facility-specific these graphs, unlike the RFG trend graphs, do not show standards. However the graphs show the seasonally-appropriate 1990 baseline gasoline emission value, which provides some basis for comparison. In all cases, average emission levels have been lower than these baseline emission levels.

For each pollutant-season combination the lowest emission levels were in 2004 or 2005 and the largest year-to-year changes were emission decreases between 2003 and 2004. These changes were concurrent with the large gasoline sulfur reductions that resulted from the phase in of Tier 2 gasoline sulfur standards. EPA's analysis did not investigate the extent to which individual emission parameters influenced CG emissions, but it is virtually certain that these sulfur reductions were the primary cause of CG emission reductions.

Additional Analysis and Observations-CG

The Phase II Complex Model exhaust toxics emission rate for 1990 Summer Baseline Gasoline is 80.10 milligrams per mile and the exhaust toxics emission rate for 1990 Winter Baseline Gasoline is 120.55 milligrams per mile. The appendix to this chapter includes tabular and graphical descriptions of CG emission rates which show:

- In 1998, the first year for which Complex Model emissions were analyzed, the median Summer exhaust toxics emission rate was 70.6 mg/mi and the 1990 baseline gasoline fell between the 80th and 85th percentile.

- In 2005, the last year for which Complex Model emissions were analyzed, the median Summer exhaust toxics emission rate was 66.7 mg/mi and the 1990 baseline gasoline fell between the 85th and 90th percentile.

- In 1998, the median Winter exhaust toxics emission rate was 107.5 mg/mi and the 1990 baseline gasoline fell between the 80th and 85th percentile.

- In 2005, the median Winter exhaust toxics emission rate was 100.8 mg/mi and the 1990 baseline gasoline fell between the 85th and 90th percentile.

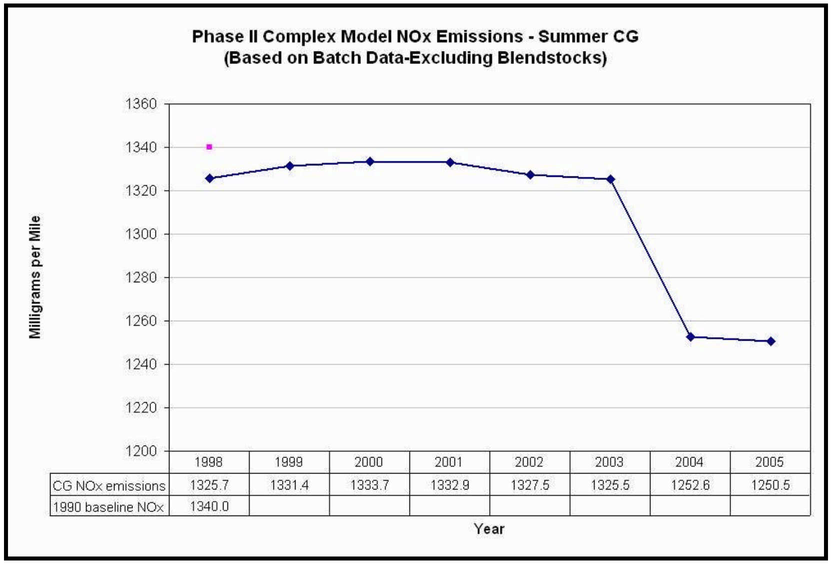
The Phase II Complex Model NOx emission rate for 1990 Summer Baseline Gasoline is 1340.0 milligrams per mile and the NOx emission rate for 1990 Winter Baseline Gasoline is 1540.0 milligrams per mile.

- In 1998, the first year for which Complex Model emissions were analyzed, the median Summer NOx emission rate was 1323.5 mg/mi and the 1990 baseline. gasoline fell between the 55th and 60th percentile.

- In 2005, the last year for which Complex Model emissions were analyzed, the median Summer NOx emission rate was 1234.0 mg/mi and the 1990 baseline gasoline fell between the 85th and 90th percentile.

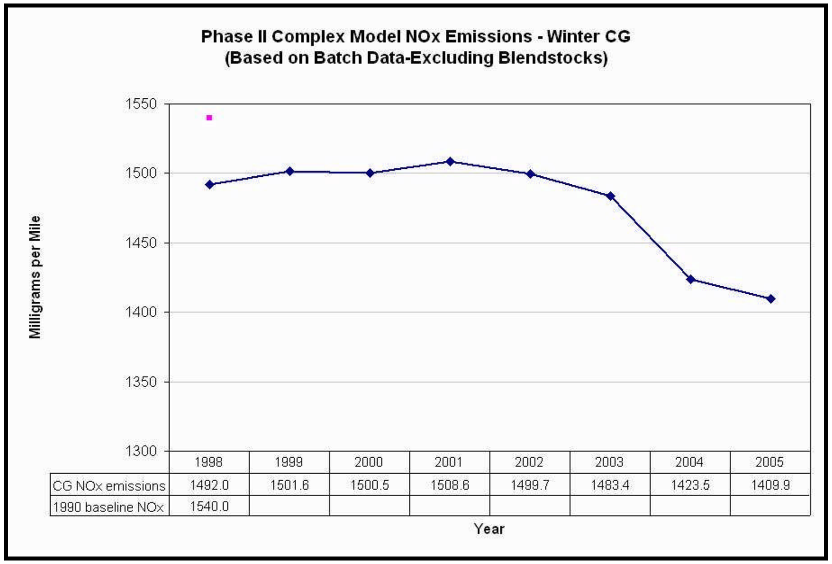
- In 1998, the median Winter NOx emission rate was 1489.4 mg/mi and the 1990 baseline gasoline fell between the 60th and 65th percentile.

- In 2005, the median Winter NOx emission rate was 1386.2 mg/mi and the 1990 baseline gasoline fell between the 90th and 95th percentile.



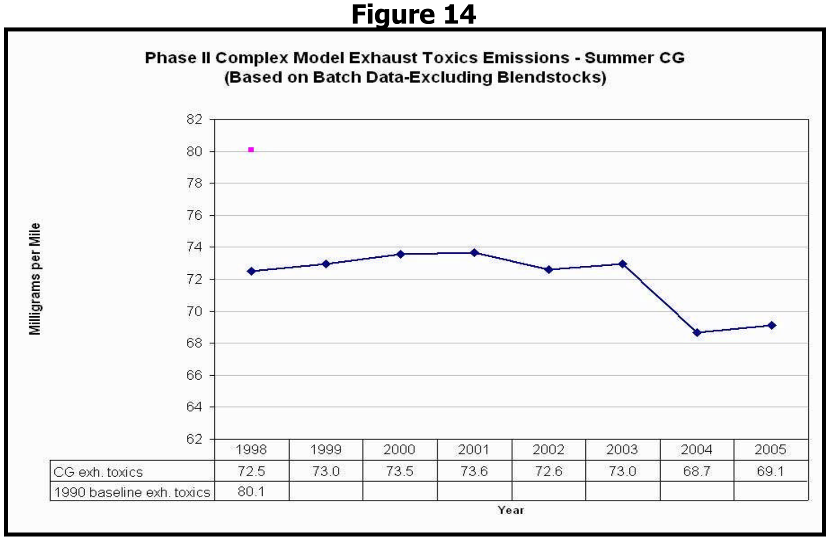
	1998	1999	2000	2001	2002	2003	2004	2005
CG NOx emissions	1325.7	1331.4	1333.7	1332.9	1327.5	1325.5	1252.6	1250.5
1990 baseline NOx	1340.0							

Figure 14



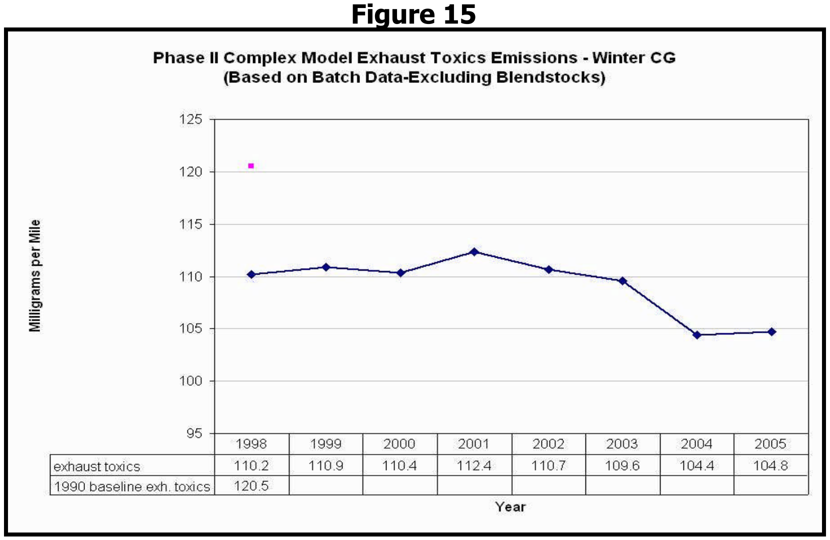
	1998	1999	2000	2001	2002	2003	2004	2005
CG NOx emissions	1492.0	1501.6	1500.5	1508.6	1499.7	1483.4	1423.5	1409.9
1990 baseline NOx	1540.0							

Figure 15



	1998	1999	2000	2001	2002	2003	2004	2005
CG exh. toxics	72.5	73.0	73.5	73.6	72.6	73.0	68.7	69.1
1990 baseline exh. toxics	80.1							

Figure 16



	1998	1999	2000	2001	2002	2003	2004	2005
exhaust toxics	110.2	110.9	110.4	112.4	110.7	109.6	104.4	104.8
1990 baseline exh. toxics	120.5							

Figure 17

Comparison of RFG and CG Emissions and Performance

To facilitate comparison of RFG and CG Complex Model emission qualities, EPA has evaluated RFG exhaust toxics and NOx "milligram per mile" emissions, and CG VOC, total toxics and NOx “percent reduction” emission performance. These results are presented in this chapter in tabular form, together with the appropriate results for comparison. Graphical comparisons of CG and RFG emissions performance are also presented in the Conventional Gasoline Trends chapter of this report. Since the VOC Control Region specification, which is not provided for CG, affects Summer VOC and Summer total toxics emissions calculations, all CG percent reduction calculations assumed VOC Control Region 2, and the control-region dependent CG results are compared to VOC Control Region 2 RFG.

It is apparent from these tables that CG, at least since 1998, has been "cleaner" than 1990 baseline gasoline. RFG has provided substantial additional emission benefits relative to CG in each year and season although improvements in CG emissions have narrowed the gap between RFG and CG

The largest improvements in Summer and Winter CG emission performance for all pollutants occurred between 2003 and 2004, concurrent with the largest sulfur reductions. NOx performance is particularly sensitive to sulfur content. However, even though CG sulfur levels in 2004 dropped to levels comparable to or below those of “pre Tier 2” RFG, the average NOx performance of 2005 Summer CG was slightly worse than the "averaged" standard for RFG. Winter CG, in each year since 1998, has met the Winter RFG NOx 1.5% averaged performance standard.

It is not the intent of this report to extrapolate these data to estimate RFG or CG emission levels when the Tier 2 sulfur reductions are fully implemented. However, CG NOx performance will likely improve and the gap between RFG and CG NOx performance may decrease, but not necessarily disappear, as further sulfur reductions occur. Although analysis or detailed discussion of the air quality benefits associated with these emission reductions is also beyond the scope of this report, it is reasonable to expect that any incremental RFG NOx reductions beyond the RFG standards or CG performance levels may translate into tangible air quality benefits. This is clearly the case for Summer RFG in areas that need to achieve additional NOx reductions in order to attain ambient ozone standards. Winter RFG over-compliance may also be important because NOx plays a role in secondary particulate formation.

Complex Model RFG and CG Exhaust Toxics and NOx Emissions in Milligrams Per Mile (Calculated from Batch Data)

	Summer RFG	Summer CG	Summer RFG	Summer CG	Winter RFG	Winter CG	Winter RFG	Winter CG
Year	**Exhaust toxics**		**NOx**		**Exhaust toxics**		**NOx**	
1998	59.0	72.5	1273	1326	90.5	110.2	1446	1492
1999	59.1	73.0	1277	1331	90.8	110.9	1456	1502
2000	55.3	73.5	1218	1334	90.0	110.4	1450	1500
2001	56.0	73.6	1228	1333	89.8	112.4	1445	1509
2002	55.7	72.6	1221	1327	89.7	110.7	1436	1500
2003	55.5	73.0	1214	1325	89.5	109.6	1427	1483
2004	55.7	68.7	1202	1253	88.0	104.4	1392	1423
2005	56.3	69.1	1207	1250	88.0	104.8	1380	1410
1990 Statutory Baseline Emissions		80.1		1340		120.5		1540

Table 1

Complex Model CG and RFG Performance in Percent Reduction from 1990 Summer Baseline (Calculated from Batch Data)

	Summer CG	Summer RFG	Summer CG	Summer RFG	Summer CG	Summer RFG
Year	VOC (VOC Region 2 Model)	VOC (VOC Region 2 Model and data)	Total toxics (VOC Region 2 Model)	Total toxics (VOC Region 2 Model and data)	NOx	NOx (all data-see note)
1998	5.8	16.2	11.0	28.9	1.1	5.0
1999	6.2	16.4	10.5	28.7	0.6	4.7
2000	5.8	27.8	9.9	33.5	0.5	9.1
2001	6.6	27.8	9.5	32.4	0.5	8.3
2002	6.2	27.5	11.0	32.8	0.9	8.9
2003	5.7	27.5	10.4	32.6	1.1	9.4
2004	7.9	27.5	15.4	32.2	6.5	10.3
2005	8.6	27.4	14.6	31.4	6.7	9.9
Phase II RFG Averaged Standards		27.4 VOC region 2		21.5 Annual Standard		6.8

Table 2

Complex Model CG and RFG Performance in Percent Reduction from 1990 Winter Baseline (Calculated from Batch Data)

	Winter CG	Winter RFG	Winter CG	Winter RFG
Year	Toxics		NOx	
1998	8.6	25.0	3.1	6.1
1999	8.0	24.6	2.5	5.5
2000	8.4	25.3	2.6	5.9
2001	6.8	25.5	2.0	6.1
2002	8.2	25.6	2.6	6.7
2003	9.1	25.7	3.7	7.3
2004	13.4	27.0	7.6	9.6
2005	13.1	27.0	8.4	10.4
Phase II RFG Averaged Standards		21.5 Annual Standard		1.5

Table 3

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