Regulatory Impact Analysis: Renewable Fuel Standard Program

Chapter 4
National Emission Inventory Impacts

Assessment and Standards 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 an exchange of technical information and to inform the public of technical developments.

EPA United States Environmental Protection Agency

EPA420-R-07-004
April 2007

Chapter 4: National Emission Inventory Impacts

This chapter describes the methods used to develop national emissions inventories under the Renewable Fuel Standard (RFS) program. These inventories account for impacts from ethanol use, the removal of MTBE, and the resulting changes to gasoline. These inventories also account for the impacts of ethanol and biodiesel production and distribution. This chapter also presents and discusses these inventories.

4.1 Impact of Ethanol Use

This section describes the methods used to develop national emissions inventories with respect to ethanol consumption. This section also presents and discusses these inventories. These inventories reflect only emissions from vehicles and equipment operating on ethanol-blend gasoline, from both onroad and off-road sources. The off-road sources do not include nonroad diesel, locomotive, or marine applications.

4.1.1 Overview of Cases

As described in Section 2.1, we consider three cases for the future use of ethanol-blend gasoline: a Reference Case, an RFS Case, and an EIA Case. The main difference between the cases is our assumption about how much ethanol will be used and where it will go. The Reference case represents our estimate of fuel quality by county which existed in 2004 when approximately 3.5 billion gallons of ethanol were consumed nationwide. In terms of 2012 fuel consumption, about 4.0 billion gallons of ethanol is consumed nationwide in the Reference case. The RFS case assumes 6.7 billion gallons of ethanol consumption in 2012, in accordance with the requirements of the RFS mandate. The EIA case assumes 9.6 billion gallons of ethanol is used nationwide in 2012, based on projections made in the Energy Information Agency's 2006 Annual Energy Outlook. We evaluate each case by predicting fuel quality in each county of the U.S. in 2012. This 2012 fuel matrix is then used for all inventory and air quality assessments.

While Chapter 2 discusses our methods for determining how much ethanol will go to each state in each case and how fuel properties will be affected, this section of the RIA uses those distributions to derive estimates of the impact on national emissions inventories.

4.1.2 National Emissions Inventory Estimation Procedure

Having approximated the effects of adding ethanol and removing MTBE on fuel properties (see Chapter 2), the next step was to use the EPA's National Mobile Inventory Model (NMIM)[VVV] to calculate emissions inventories for gasoline fueled motor vehicles and nonroad equipment in years 2012, 2015, and 2020. For all three years, we ran NMIM for January and July, assuming that each was representative of winter and summer conditions, respectively. We estimate annual emission inventories by summing the two monthly inventories and multiplying by six. This was done in order to reduce the amount of time needed to actually run the model.

One additional simplification was made to shorten the time required to run NMIM for the three years, three fuel cases, two months and roughly 3100 counties in the U.S. Counties within a state with identical fuels and inspection-maintenance programs and similar temperatures were grouped together and run through NMIM as a single geographical area. The temperatures used for this area were those of the county with the highest VMT in the group. As the specific counties within a state with identical fuels sometimes changed across the three fuel cases, the groupings of counties sometimes changed across the NMIM runs of the three fuel cases. This occasionally introduced a change in the temperatures estimated for a county between fuel cases. This in turn produced a change in emissions independent of changes in fuel quality.

We evaluated the potential for this simplification to bias the projected emission impacts of the various fuel cases. Counties where RFG is sold were always modeled consistently across all three fuel cases and so are unaffected by this simplification. Counties with low RVP and 9 RVP fuel were sometimes affected. On average, the changes in emissions occurring due to a change in temperature appear to be unbiased (i.e., emissions increase as often as they decrease). Also, many of the emission impacts of changing fuel quality (e.g., exhaust VOC and NOx impact) were applied outside of the NMIM model and so are unaffected by this simplification. Since we do not present or use the emission impacts for individual counties, we believe that this simplification does not significantly impact the emission impacts presented below.

We chose 2012 as the first projection year, because it is the year of full RFS program implementation. We also chose 2015 and 2020 to illustrate how the emissions will change over time as the fleet changes. We increased ethanol consumption beyond 2012 only by volumes required to maintain the same proportion to gasoline that existed in 2012, and not by growth predicted in EIA estimates. By restricting ethanol growth in this way, the same fuel quality that existed in 2012 would apply to 2015 and 2020, which would better highlight the effects of fleet turnover.

NMIM's estimates of both onroad and nonroad emissions were "post-processed" to reflect factors not yet included in the model. For onroad emissions, the effect of fuel quality on exhaust VOC and NOx emissions contained in the model (i.e., those in MOBILE6.2) were replaced with those from the EPA Predictive Model. We further adjusted the NMIM estimates of exhaust VOC, CO and NOx emissions from onroad vehicles in a "sensitivity" analysis in order to reflect the significant degree of uncertainty which currently exists with respect to these effects. Air toxic emissions were adjusted in order to reflect changes in total exhaust VOC emissions,. Finally, the effect of ethanol on permeation VOC and benzene emissions also were added to the onroad emission estimates. This series of post-processing steps are further described in the sections below.

For nonroad emissions, the only adjustment to the NMIM estimates was to adjust air toxic emissions in the two control cases to reflect the change in the toxic fraction of VOC emissions to that estimated for onroad vehicles, as opposed to that estimated for nonroad equipment. These steps for calculating emissions inventories are described in the following sections. A summary of the models used and fundamental post-processing steps are shown in Table 4.1-1 below.

Table 4.1-1. Estimation of National Emissions Inventories: Models Used and Fundamental Post-Processing Steps

	Exhaust Emissions	Non-Exhaust Emissions
Onroad	Model: NMIM which runs MOBILE6.2. Post-processing: 1. Replace VOC and NOx fuel effects for Tier 0 vehicles from MOBILE6.2 with fuel effects from EPA Predictive Model; 2. Conduct sensitivity analysis by applying fuel effects for Tier 0 vehicles to all vehicles. 3. Adjust exhaust air toxics emissions to reflect adjustment to exhaust VOC emissions.	Model: NMIM which runs MOBILE6.2. Post-processing: 1. Add effect of ethanol on permeation emissions of VOC and benzene.
Nonroad	Model: NMIM which runs NONROAD2005 (modified to account for hose permeation). Post-processing: 1. Changes in toxic fraction of VOC emissions in two fuel control cases based on onroad estimates instead of nonroad estimates.	Model: NMIM which runs NONROAD2005 (modified to account for hose permeation). Post-processing: 1. Changes in toxic fraction of VOC emissions in two fuel control cases based on onroad estimates instead of nonroad estimates.

4.1.2.1 Onroad Emission Estimation Procedures

We ran NMIM to estimate county-specific emissions from gasoline motor vehicles for January and July in years 2012, 2015, and 2020. For each month and year combination, we ran the three onroad cases (Reference, RFS, and EIA). The NMIM model utilizes the MOBILE6.2[WWW] model to estimate motor vehicle emissions, as well as the effect of fuel quality on emissions. As discussed in Chapter 3, the EPA Predictive Model contains more recent estimates of the impact of fuel quality on exhaust VOC and NOx emissions. Therefore, we removed the impact of fuel quality on exhaust VOC and NOx emissions as estimated by MOBILE6.2 and replaced these impacts with those of the EPA Predictive Model. As also discussed in Chapter 3, MOBILE6.2 does not include the impact of ethanol on permeation emissions. Therefore, we added these emissions to those estimated by NMIM. Finally, we arrived at annual emissions estimates by summing the January and July results, then multiplying by six. The procedures for making these changes are discussed below.

4.1.2.1.1 Onroad Exhaust Emissions

MOBILE6.2 performs most of its emission estimation procedures for a non-oxygenated 8.7 RVP gasoline. The effect of differing fuel quality is represented by a set of adjustment factors, which can vary by vehicle type, model year, and whether the vehicle is properly operating or not (i.e., is a low or high emitter). Because the mix of vehicle types, model years, and low and high emitters varies by county and calendar year, it is infeasible to estimate the net impact of each fuel parameter on emissions outside of the model. In Section 3.1.1.1.2 of Chapter 3, we describe a process whereby we performed linear regressions on the exhaust emissions estimated by NMIM in order to determine the average effect of RVP, ethanol content and MTBE content on exhaust VOC and NOx emissions. Also in Section 3.1.1.1.2, we describe these same impacts using the EPA Predictive Model. We combined these fuel-emission effects with the fuel quality expected to exist in each county under each ethanol use case to estimate the adjustment which NMIM had applied to exhaust VOC and NOx emissions. This NMIM adjustment for fuel quality was removed and replaced by one based on the EPA Predictive Models. In our primary analysis, the fuel-emission effects from the EPA Predictive Models were only applied to the fraction of exhaust VOC and NOx emissions which are emitted by Tier 0 vehicles. In our sensitivity analysis, the fuel-emission effects from the EPA Predictive Models were applied to all exhaust VOC and NOx emissions.

Table 4.1-2 shows the values for "Tier 0 Fraction"; i.e., the fraction of VOC and NOx emissions from vehicles with Tier 0 emissions characteristics. Note that the fraction drops as time progress, reflecting the attrition of such vehicles in the national fleet. In the sensitivity analysis, the Tier 0 vehicle emission fraction is 1.0 for all years and pollutants.

Table 4.1-2. Fraction of In-Use Exhaust Emissions Attributable to Vehicles with Tier 0 Emissions Characteristics

Calendar Year	VOC	NOx
2012	0.339	0.162
2015	0.183	0.065
2020	0	0

After adjusting exhaust VOC and NOx according to the methods described above, we adjusted the four exhaust toxic emissions: benzene, 1,3-butadiene, formaldehyde, and acetaldehyde. MOBILE6.2 estimates exhaust toxic emissions by first estimating the fraction of exhaust VOC emissions represented by each toxic based on fuel quality. The model then applies this fraction to exhaust VOC emissions to estimate absolute emissions of air toxics. Since we adjusted exhaust VOC emissions, it was necessary to adjust exhaust toxic emissions, as well, by the ratio of the change in exhaust VOC emissions.

As described in Section 3.1.1.1.2 of Chapter 3, carbon monoxide emissions were also adjusted. The following equation illustrates the CO adjustment:

$$\begin{matrix}\text{Adj.}\\ \text{CO}\end{matrix} = \begin{matrix}\text{NMIM}\\ \text{CO}\end{matrix} \times \left(1+(\text{Etoh Vol\% x Etoh Mkt Shr + MTBE Vol\% x MTBE Mkt Shr x 0.5454}) \times \text{CO Adj. Factor}\right)$$

4.1.2.1.2 Onroad Non-Exhaust Emissions

The only adjustment to the non-exhaust emission estimates from NMIM was to add county-specific estimates of the increase in permeation emissions due to ethanol use. In Section 3.1.1.3 of Chapter 3, we determined that a 10 vol% ethanol blend increased permeation emissions by 0.8 grams per day at 95 F. We also concluded there that permeation emissions double with every increase in temperature of 18 °F. Because of this temperature relationship, permeation effects were only accounted for in the July emission estimate since emissions during the winter months could be at least four times lower, and thus negligible.

Permeation emissions occur whether a vehicle is being used or is parked. Therefore, the average hourly emission factor in each county in July is determined by adjusting the 0.8 gram per day emission rate for the average fuel tank temperature occurring in that hour of the day in each county in July and multiplying by the market share of E10 fuel in that county. Total monthly emissions in each county were determined by summing across hours of the day, multiplying by 31 days and multiplying by the number of vehicles estimated to reside in that county.

The average fuel tank temperature is a function of the average ambient temperature at that hour of the day, adjusted to account for the increase in fuel tank temperature for those vehicles which are operating or which are still cooling down from operating. We obtain estimates of these latter two factors from EPA's Draft MOVES2006 model.[XXX] These are shown in Table 4.1-3. The fuel tank temperature of vehicles which have been parked some time tend to lag the ambient temperature both when the latter is rising and falling. We assume here that the fuel tank temperature of these parked vehicles is equal to the ambient temperature, which is true on average for the day.

Table 4.1-3. Increase in Fuel Tank Temperature Relative to Ambient

Hour of the Day	Vehicles Operating or in Hot Soak	Average Tank Temperature Rise (F)
Midnight	2.6%	10.0
1:00 AM	2.8%	6.9
2:00 AM	1.2%	6.1
3:00 AM	0.9%	4.9
4:00 AM	0.8%	3.1
5:00 AM	2.6%	3.0
6:00 AM	6.6%	3.7
7:00 AM	12.3%	4.6
8:00 AM	14.0%	3.5
9:00 AM	10.0%	3.8
10:00 AM	11.1%	3.8
11:00 AM	12.5%	4.9
Noon	15.6%	4.8
1:00 PM	16.0%	5.5
2:00 PM	17.2%	6.6
3:00 PM	21.0%	7.7
4:00 PM	23.7%	8.6
5:00 PM	28.5%	8.3
6:00 PM	30.0%	8.8
7:00 PM	25.7%	9.2
8:00 PM	18.7%	8.3
9:00 PM	13.5%	7.6
10:00 PM	10.6%	8.0
11:00 PM	7.8%	8.4

The total number of gasoline vehicles in the U.S. in 2004 is estimated to be 228 million.[YYY] We increased this figure by 1.9% per year[53] to derive estimates of the gasoline vehicle fleet in 2012, 2015 and 2020. This produced estimates for the fleet of gasoline vehicles in the U.S. of 265, 281 and 308 million vehicles in 2012, 2015 and 2020, respectively. These vehicles were allocated to each county based on the county-specific distribution of national VMT by gasoline vehicles contained in NMIM.

As described in Section 3.1.1.3 of Chapter 3, we estimate that benzene represents 3% of the increased VOC permeation emissions due to ethanol use. Thus, we added this 3% to the non-exhaust emissions of benzene estimated by NMIM.

4.1.2.2 Nonroad Emissions

NMIM is capable of utilizing any one of a series of EPA's NONROAD emission models. We chose to use the NONROAD2005[ZZZ] model to estimate emissions from nonroad equipment here, as it reflects EPA's latest estimates of emission factors for nonroad equipment. EPA has also recently developed a set of emission factor inputs for the NONROAD model which include the effect of ethanol on permeation emissions from a number of types of nonroad equipment (see Chapter 3).

For the proposed rule inventories, the NONROAD model was not able to select ethanol related emission factors based on the fuel quality inputs to the model. It was therefore necessary to run NMIM for two extreme ethanol use cases (no ethanol use and 100% ethanol use) and use those results to estimate emissions for the five ethanol use cases which were the focus of the proposed rule.

For the final rule, NONROAD model capabilities were updated to account for oxygenate effects. Therefore, we were able to run NMIM (which runs NONROAD) using the same fuel property inputs that were used for onroad emissions inventories. This eliminated the need to interpolate between the "No Oxygen" and "All Oxygen" NONROAD runs that were needed for the proposal.

For nonroad toxic exhaust emissions, the toxic emissions factors for nonroad equipment are based on very limited data. In EPA's recent final rule which implemented new Mobile Source Air Toxic (MSAT) standards, we adjusted the fraction of nonroad VOC emissions represented by the various air toxics contained in NMIM for a reduction in fuel benzene content with those estimated for the same fuel change by MOBILE6.2 for onroad motor vehicles. This was done because of the very limited amount of nonroad emission test data which both varied fuel quality and measured toxics emissions. We take the same approach here. We begin with the estimate of nonroad toxic emissions from NMIM for the Reference Case. Then, any change in the toxics fraction of nonroad VOC emissions due to a change in fuel quality predicted by NMIM is replaced by the change in the toxics fraction of onroad VOC emissions due to the same

---

53 Annual growth rate in gasoline consumption on an energy basis per EIA Annual Energy Outlook, 2006 (therefore it applies regardless of future ethanol use scenario). Assumes constant annual mileage per vehicle over this timeframe.

change in fuel quality predicted by MOBILE6.2. This adjustment is illustrated in the following equation:

$$\text{Adjusted Nonroad Toxic Emissions} = \text{NMIM Toxic Emissions} \times \frac{\text{NMIM VOC Emissions (RFS or EIA case)}}{\text{NMIM VOC Emissions (Reference case)}} \times \frac{\dfrac{\text{MOBILE6.2 Toxic Emissions (RFS or EIA Case)}}{\text{MOBILE6.2 VOC Emissions (RFS or EIA Case}}}{\dfrac{\text{MOBILE6.2 Toxic Emissions (Reference Case)}}{\text{MOBILE6.2 VOC Emissions (Reference Case)}}}$$

4.1.3 National Emissions Inventory Projections

4.1.3.1 Emission Inventories: Primary Analysis

This section provides the national emissions inventories for the primary case analyses. Criteria pollutant inventories are included, along with a brief discussion of the trends. A short discussion of air toxics inventories is also included. See Tables 4A-1 through 4A-7 in the Chapter 4 Appendix for complete primary-case inventories on air toxics and criteria pollutants, as well as the percent changes in inventories from the Reference case.

Table 4.1-4 shows ethanol impacts on VOC inventories for each of the three cases of renewable fuel use in years 2012, 2015, and 2020. In any given year, the data suggest that total VOC emissions will increase as ethanol use increases. The largest increase is seen in the EIA case, where the increase is about 1% of the Reference case inventory.

Our analysis indicates that this increase is a result of VOC non-exhaust emissions, such as those from evaporation or permeation. While VOC exhaust emissions decrease, they do not decrease enough to counteract the increase from non-exhaust emissions.

Table 4.1-4.
National VOC Emissions from Gasoline Vehicles and Equipment:
Reference Case Inventory and Change in Inventory for Control Cases (Tons/Year)

Primary Case	Tons/Year		
Total	**2012**	**2015**	**2020**
Reference	5,882,000	5,569,000	5,356,000
RFS Case (Change)	18,000	25,000	34,000
EIA Case (Change)	43,000	49,000	58,000
On-Road	**2012**	**2015**	**2020**
Reference	3,417,000	3,269,000	3,244,000
RFS Case (Change)	10,000	16,000	23,000
EIA Case (Change)	32,000	36,000	42,000
Non-Road	**2012**	**2015**	**2020**
Reference	2,465,000	2,300,000	2,112,000
RFS Case (Change)	8,000	9,000	11,000
EIA Case (Change)	11,000	13,000	16,000

Table 4.1-5 shows ethanol impacts on CO inventories for each of the three cases of renewable fuel use in years 2012, 2015, and 2020. In any given year, data suggest that total CO emissions will decrease as ethanol use increases. The largest reduction is seen in the EIA case; this decrease is still less than 3% of the Reference inventory.

Table 4.1-5.
National CO Emissions from Gasoline Vehicles and Equipment:
Reference Case Inventory and Change in Inventory for Control Cases (Tons/Year)

Primary Case	Tons/Year		
Total	**2012**	**2015**	**2020**
Reference	55,022,000	53,702,000	53,949,000
RFS Case (Change)	-483,000	-473,000	-460,000
EIA Case (Change)	-1,366,000	-1,329,000	-1,286,000
On-Road	**2012**	**2015**	**2020**
Reference	37,656,000	36,171,000	35,723,000
RFS Case (Change)	-45,000	-39,000	-19,000
EIA Case (Change)	-359,000	-321,000	-252,000
Non-Road	**2012**	**2015**	**2020**
Reference	17,366,000	17,531,000	18,226,000
RFS Case (Change)	-438,000	-434,000	-441,000
EIA Case (Change)	-1,007,000	-1,008,000	-1,034,000

Table 4.1-6 shows ethanol impacts on NOx inventories for each of the three cases of renewable fuel use in years 2012, 2015, and 2020. In any given year, the data suggest that total NOx emissions will increase as ethanol use increases. The largest increase is seen in the EIA case, which is around 2% of the Reference inventory.

Our analysis also indicates that nonroad NOx emissions increase much greater than onroad emissions. While onroad inventories increase less than one percent in control cases, nonroad inventories increase up to 11% in the EIA case.

Table 4.1-6.
National NOx Emissions from Gasoline Vehicles and Equipment:
Reference Case Inventory and Change in Inventory for Control Cases (Tons/Year)

Primary Case	Tons/Year		
Total	**2012**	**2015**	**2020**
Reference	2,487,000	2,059,000	1,695,000
RFS Case (Change)	23,000	18,000	17,000
EIA Case (Change)	40,000	33,000	32,000
On-Road	**2012**	**2015**	**2020**
Reference	2,240,000	1,797,000	1,407,000
RFS Case (Change)	9,000	3,000	0
EIA Case (Change)	13,000	4,000	0
Non-Road	**2012**	**2015**	**2020**
Reference	247,000	262,000	288,000
RFS Case (Change)	14,000	15,000	17,000
EIA Case (Change)	27,000	29,000	32,000

Table 4.1-7 shows ethanol impacts on air toxic emissions for each of the three cases of renewable fuel use in 2012.

For all air toxics shown, the most extreme changes occur in the EIA case. The data suggest that, in 2012, total benzene emissions will decrease by about 4% due to decreases in both onroad and nonroad emissions. Total 1,3-butadiene emissions decrease by less than 2% due to decreases in both onroad and nonroad emissions. Total formaldehyde emissions decrease by up to 1.5%. Total acetaldehyde emissions increase by as much as 36% due to increases in both onroad and nonroad emissions.

Generally, the trends in 2015 and 2020 parallel those of 2012 and are shown in the appendix to this chapter. Benzene maintains a drop of up to about 6% with increased ethanol use. Formaldehyde remains fairly flat, ranging from a 0.5% increase to a 1.2% decrease. Acetaldehyde maintains an increase of as much as 36.5%. Finally, 1,3-butadiene remains fairly flat, ranging from no change to a 0.5% increase.

Again, we emphasize that the toxics inventories are based on very limited data, especially when it comes to emissions from nonroad equipment.

Table 4.1-7.
National Toxic Emissions from Gasoline Vehicles and Equipment in 2012: Reference Case Inventory and Change in Inventory for Control (Tons/Year)

Primary Case	Benzene	1,3-Butadiene	Formaldehyde	Acetaldehyde
Total				
Reference	178,000	18,900	40,400	19,900
RFS Case (Change)	-3,200	-200	-600	3,400
EIA Case (Change)	-7,200	-300	-200	7,100
Onroad				
Reference	124,100	12,000	29,900	15,500
RFS Case (Change)	-2,300	-200	-600	2,400
EIA Case (Change)	-5,400	-200	-300	5,400
Nonroad				
Reference	53,900	6,900	10,500	4,400
RFS Case (Change)	-900	0	0	1,000
EIA Case (Change)	-1,800	-100	100	1,700

4.1.3.2 Emission Inventories: Sensitivity Analyses

This section provides the national emissions inventories for the sensitivity case analyses. Criteria pollutant inventories are included, along with a brief discussion of the trends. See Tables 4A-1 through 4A-7 in the Chapter 4 Appendix for complete sensitivity-case inventories on air toxics and criteria pollutants, as well as the percent changes in inventories from the reference case.

Table 4.1-8 shows ethanol impacts on VOC inventories for each of the three cases of renewable fuel use in years 2012, 2015, and 2020. Where the primary analysis showed total VOC emissions increasing with ethanol use in all cases, the sensitivity analysis shows that total VOC emissions decrease. Onroad emissions decrease in all cases, while nonroad emissions increase to the same extent as under the primary analysis.

Table 4.1-8.
National VOC Emissions from Gasoline Vehicles and Equipment:
Reference Case Inventory and Change in Inventory for Control Cases (Tons/Year)

Sensitivity Case	Tons/Year		
Total	**2012**	**2015**	**2020**
Reference	5,834,000	5,510,000	5,281,000
RFS Case (Change)	-20,000	-23,000	-27,000
EIA Case (Change)	-4,000	-10,000	-17,000
On-Road	**2012**	**2015**	**2020**
Reference	3,369,000	3,210,000	3,169,000
RFS Case (Change)	-28,000	-32,000	-38,000
EIA Case (Change)	-15,000	-23,000	-33,000
Non-Road	**2012**	**2015**	**2020**
Reference	2,465,000	2,300,000	2,112,000
RFS Case (Change)	8,000	9,000	11,000
EIA Case (Change)	11,000	13,000	16,000

Table 4.1-9 shows ethanol impacts on CO inventories for each of the three cases of renewable fuel use in years 2012, 2015, and 2020. In any given year, the data suggest that total CO emissions will decrease as ethanol use increases. The onroad vehicle CO emission reductions increase by roughly a factor of three compared to the primary analysis. This increases the overall CO emissions reduction from about 3% in the primary case to 4% in the sensitivity case.

Table 4.1-9.
National CO Emissions from Gasoline Vehicles and Equipment:
Reference Case Inventory and Change in Inventory for Control Cases (Tons/Year)

Sensitivity Case	Tons/Year		
Total	**2012**	**2015**	**2020**
Reference	54,315,000	52,998,000	53,183,000
RFS Case (Change)	-692,000	-676,000	-676,000
EIA Case (Change)	-1,975,000	-1,929,000	-1,937,000
On-Road	**2012**	**2015**	**2020**
Reference	36,949,000	35,467,000	34,957,000
RFS Case (Change)	-254,000	-242,000	-235,000
EIA Case (Change)	-968,000	-921,000	-903,000
Non-Road	**2012**	**2015**	**2020**
Reference	17,366,000	17,531,000	18,226,000
RFS Case (Change)	-438,000	-434,000	-441,000
EIA Case (Change)	-1,007,000	-1,008,000	-1,034,000

Table 4.1-10 shows ethanol impacts on NOx inventories for each of the three cases of renewable fuel use in years 2012, 2015, and 2020. In any given year, the data suggest that total NOx emissions will increase as ethanol use increases. The largest increase is seen in the EIA case, where the increase in total emissions is as high as 4.6% of the reference inventory. As in

the primary analysis, nonroad NOx emissions increase much greater than onroad emissions. While onroad inventories increase up to 3.5%, nonroad inventories increase upwards of 11.1% in the EIA case.

Table 4.1-10.
National NOx Emissions from Gasoline Vehicles and Equipment:
Reference Case Inventory and Change in Inventory for Control Cases (Tons/Year)

Sensitivity Case	Tons/Year		
Total	**2012**	**2015**	**2020**
Reference	2,519,000	2,087,000	1,717,000
RFS Case (Change)	68,000	57,000	48,000
EIA Case (Change)	106,000	91,000	79,000
On-Road	**2012**	**2015**	**2020**
Reference	2,272,000	1,825,000	1,429,000
RFS Case (Change)	54,000	42,000	31,000
EIA Case (Change)	79,000	62,000	47,000
Non-Road	**2012**	**2015**	**2020**
Reference	247,000	262,000	288,000
RFS Case (Change)	14,000	15,000	17,000
EIA Case (Change)	27,000	29,000	32,000

Table 4.1-11 shows ethanol impacts on air toxic emissions for each of the five cases of renewable fuel use in 2012. The impacts in 2015 and 2020 are shown in the Appendix to this chapter.

Table 4.1-11.
National Toxic Emissions from Gasoline Vehicles and Equipment in 2012:
Reference Case Inventory and Change in Inventory for Control (Tons/Year)

Sensitivity Case	**Benzene**	**1,3-Butadiene**	**Formaldehyde**	**Acetaldehyde**
Total				
Reference Case	175,700	18,600	39,600	19,500
RFS Case (Change)	-5,000	-400	-1,100	3,000
EIA Case (Change)	-9,400	-600	-700	6,600
Onroad				
Reference Case	121,800	11,700	29,100	15,100
RFS Case (Change)	-4,100	-400	-1,100	2,000
EIA Case (Change)	-7,600	-500	-800	4,900
Nonroad				
Reference Case	53,900	6,900	10,500	4,400
RFS Case (Change)	-900	0	0	1,000
EIA Case (Change)	-1,800	-100	100	1,700

As in the primary analysis, the most extreme changes in the sensitivity analysis tend to occur in the EIA case.

The data suggest that, in 2012, total benzene emissions will decrease by as much as 5.4% due to decreases in both onroad and nonroad emissions. Total formaldehyde emissions decrease by up to 2.8%. Nonroad formaldehyde emissions tend to remain relatively flat, while onroad emissions decrease. Total acetaldehyde emissions increase by as much as 34% due to increases in both onroad and nonroad emissions. Total 1,3-butadiene emissions decrease by about 3%.

4.1.3.3 Local and Regional VOC and NOx Emissions (Summer 2015)

We also estimate the percentage change in VOC, NOx, and CO emissions from gasoline fueled motor vehicles and equipment in those areas which actually experienced a significant change in ethanol use. Specifically, we focused on areas where the market share of ethanol blends was projected to change by 50 percent or more. We also focused on summertime emissions, as these are most relevant to ozone formation as discussed in Chapter 5. We modeled 2015 because the ozone Response Surface Model (RSM) used for air quality modeling (also discussed in Chapter 5) is based upon a 2015 emissions inventory, though we would expect similar results in 2012. Finally, we developed separately estimates for: 1) RFG areas, including the state of California and the portions of Arizona where their CBG fuel programs apply, 2) low RVP areas (i.e., RVP standards less than 9.0 RVP, and 3) areas with a 9.0 RVP standard. This set of groupings helps to highlight the emissions impact of increased ethanol use in those areas where emission control is most important.

Table 4.1-12 presents our primary analysis estimates of the percentage change in VOC, NOx, and CO emission inventories for these three types of areas when compared to the 2015 reference case. Note that the analyses here is very similar to that described in Section 5.1, with the exception that Table 4.1-12 below reflects 50-state emissions (instead of 37 eastern states) and excludes diesel emissions.

Table 4.1-12.
Change in July 2015 Emissions from Gasoline Vehicles and Equipment in Counties Where Ethanol Use Changed Significantly – Primary Analysis

Ethanol Use	RFS Case	EIA Case
	RFG Areas	
Ethanol Use	Down	Up
VOC	0.8%	2.3%
NOx	-3.4%	1.6%
CO	6.1%	-2.6%
	Low RVP Areas	
Ethanol Use	Up	Up
VOC	4.2%	4.6%
NOx	6.2%	5.7%
CO	-12.5%	-13.7%
	Other Areas (9.0 RVP)	
Ethanol Use	Up	Up
VOC	3.6%	4.6%
NOx	7.3%	7.0%
CO	-6.4%	-6.0%

As expected, increased ethanol use tends to increase NOx emissions. The increase in low RVP and other areas is greater than in RFG areas, since the RFG in the RFG areas included in this analysis all contained MTBE. Also, increased ethanol use tends to increase VOC emissions, indicating that the increase in non-exhaust VOC emissions exceeds the reduction in exhaust VOC emissions. This effect is muted with RFG due to the absence of an RVP waiver for ethanol blends. See Chapter 2 for a discussion of how ethanol levels will change at the state-level.

Table 4.1-13 presents the percentage change in VOC, NOx, and CO emission inventories under our sensitivity analysis (i.e., when we apply the emission effects of the EPA Predictive Models to all motor vehicles).

Table 4.1-13.
Change in July 2015 Emissions from Gasoline Vehicles and Equipment in Counties Where Ethanol Use Changed Significantly – Sensitivity Analysis

Ethanol Use	RFS Case	EIA Case
	RFG Areas	
Ethanol Use	Down	Up
VOC	-1.0%	1.0%
NOx	-0.9%	5.6%
CO	7.3%	-3.0%
	Low RVP Areas	
Ethanol Use	Up	Up
VOC	3.4%	3.7%
NOx	10.4%	10.8%
CO	-15.0%	-16.4%
	Other Areas (9.0 RVP)	
Ethanol Use	Up	Up
VOC	3.0%	3.9%
NOx	10.8%	11.0%
CO	-9.0%	-8.9%

Directionally, the changes in VOC and NOx emissions in the various areas are consistent with those from our primary analysis. The main difference is that the increases in VOC emissions are smaller, due to more vehicles experiencing a reduction in exhaust VOC emissions, and the increases in NOx emissions are larger.

4.2 Impact of Biodiesel Use

As discussed in Chapter 1, biodiesel use totaled 25 million gallons in 2004 and is projected to increase to 300 million gallons in 2012. Total diesel fuel use in onroad diesels in 2004 was roughly 39.4 billion gallons and is expected to grow to 47.5 billion gallons per year by 2012.[54] The volumes of biodiesel produced thus represent 0.06% and 0.6% of onroad diesel fuel

[54] Based on linear interpolation between estimate for 2001 from Table 7.1.2-1 and that for 2014 from Table 7.1.3-4, both from the 2010 Nonroad FRM Final RIA, EPA420-R-04-007, May 2004, available in EPA Docket OAR-2003-0012.

consumption in 2004 and 2012, respectively. Given the very small contribution of biodiesel to the pool of diesel fuel, the nationwide emission impacts of biodiesel are expected to be similarly small for the foreseeable future. As a result, we have not included biodiesel emission impacts in our emission inventory estimates for this rule.

We do intend to investigate these impacts in the future, however. As stated in Chapter 3, the 2002 EPA report entitled "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions" concluded that biodiesel fuels improved PM, CO and HC emissions of diesel engines while slightly increasing their NOx emissions. Nevertheless, these conclusions remain controversial due to conflicting results from different studies. As a result, preparations are being made to launch a test program with stakeholder participation to further investigate the emission impacts of biodiesel.

4.3 Impact of Renewable Fuel Production and Distribution

4.3.1 Ethanol

In Chapter 2, we estimated that 3.5 billion gallons of ethanol was produced for use in motor fuel in 2004, which comprises our estimate of fuel quality for the base case . Maintaining fuel quality, but increasing fuel volume to that expected in 2012,[55] ethanol use would increase to 3.9 billion gallons. The increases in emissions associated with ethanol production and distribution under the RFS and EIA cases are, thus, determined relative to the emissions associated with producing and distributing 3.9 billion gallons of ethanol.

We describe the emissions associated with producing and distributing ethanol on a per gallon basis in Chapter 3.4.1. There, we compare emissions factors from DOE's GREET model, versions 1.6 and 1.7, as well as estimates of ethanol plant emissions obtained from the States. We decided there to use two emission estimates here, one from GREET1.7, and the other from GREET1.7 augmented by the State estimates for ethanol plant emissions. Here, we simply multiply those emission factors by the volume of ethanol being used in each scenario. Table 4.3-1 shows estimates of annual emissions expected to occur nationwide due to increased production of ethanol. It should be noted that emissions in the base case assume a 80/20 mix of dry mill and wet mill facilities. New plants (and thus, the emission increases) assume 100% dry mil facilities.

---

[55] EIA projects gasoline demand of 16.93 and 18.84 quadrillion Btu in 2004 and 2012, respectively. This represents overall growth between these two years of 11.3%.

Table 4.3-1.
Annual Emissions Nationwide from Ethanol Production and Transportation: 2012
(tons per year)

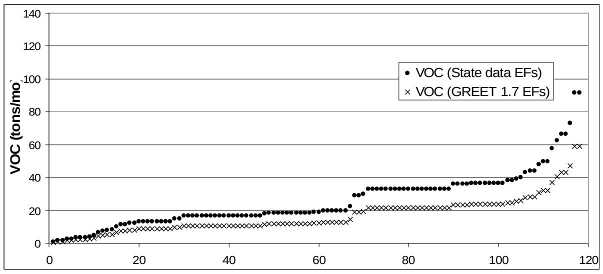
	GREET1.7			GREET1.7 + State Data		
	Base Case	RFS Case	EIA Case	Base Case	RFS Case	EIA Case
	Emissions	Increase in Emissions		Emissions	Increase in Emissions	
VOC	8,000	5,000	11,000	14,000	10,000	20,000
NOx	17,000	13,000	26,000	18,000	14,000	27,000
CO	49,000	35,000	72,000	56,000	40,000	81,000
PM10	21,000	15,000	30,000	12,000	9,000	18,000
SOx	27,000	20,000	41,000	42,000	30,000	61,000

As can be seen, the potential increases in VOC and NOx emissions from ethanol production and transportation are of the same order of magnitude as those from ethanol use. Generally, ethanol plants are not located in ozone non-attainment areas, so the ozone impact of the increased VOC and NOx emissions should be minimal.

According to our estimates, almost 120 counties throughout the nation are constructing new ethanol plants, expanding existing plants, or planning construction for future plants. The increases in ethanol production across these counties range from as low as 2 million gallons per year for modest expansions, to over 270 million gallons per year due to the construction of entirely new facilities. To estimate the potential increase in VOC and NOx emissions associated with these plants, whether construction is planned or underway, we apply the ethanol production emission factors (EFs) derived from state data as well as those found in GREET 1.7. See Chapter 3.4 for a discussion of the emission factors related to ethanol production and plant emissions.

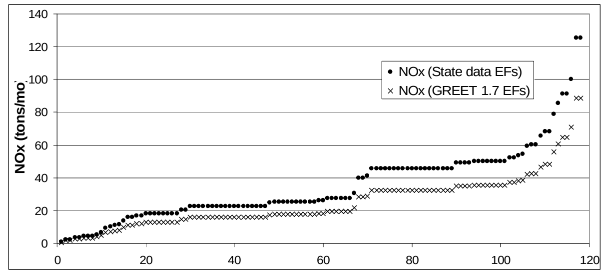
The ethanol production emission factors are applied to the increase in the volume of ethanol production expected in each of the counties. Figures 4.3-1 and 4.3-2 illustrate potential increases in future monthly VOC and NOx emissions, respectively, in counties that can expect a growth in ethanol production. The emissions reflect plants operating for one month at 90% capacity. In each figure, the distribution of counties is presented in order from the lowest-to-highest increase in ethanol production volume. The figures show results based upon both state-based emission factors and GREET 1.7 emission factors.

**Figure 4.3-1.
Monthly VOC Emissions in Counties Expecting an Increase in Ethanol Production**



Distribution of Counties
(in order of increasing ethanol production)

**Figure 4.3-2.
Monthly NOx Emissions in Counties Expecting an Increase in Ethanol Production**



Distribution of Counties
(in order of increasing ethanol production)

As the figures indicate, most counties will see an increase of less than 40 tons/month VOC and less than 60 tons/month NOx, according to the distribution based upon the state data emission factors. The average emissions are about 26 tons/month VOC and 35 tons/month NOx using state data, and about 17 tons/month VOC and 25 tons/month NOx using GREET 1.7 emission factors. However, average VOC and NOx emissions increase to about 61 tons/month and 83 tons/month, respectively, in the 10% of counties expecting largest increases in ethanol production. The average emissions for the remaining 90% of counties is about 21 tons/month VOC and 29 tons/month NOx. For both VOC and NOx, emissions estimates are about 35% less when using the GREET 1.7 emission factors.

4.3.2 Biodiesel

In Chapter 1, we estimated that 25 million gallons of biodiesel were produced for use in motor fuel in 2004. Based on growth in overall diesel fuel demand between 2004 and 2012,[56] this would represent the equivalent of 30 million gallons of biodiesel in 2012 for our reference case. Here, we estimate the increase in emissions which will occur with an increase in biodiesel production and distribution from 30 million gallons to 300 million gallons per year.

We describe the emissions associated with producing and distributing biodiesel on a per gallon basis in Chapter 3. Here, we simply multiply those emission factors by the volume of biodiesel being used in each scenario. Table 4.3-2 shows estimates of annual emissions expected to occur nationwide due to increased production of biodiesel.

[56] EIA projects gasoline demand of 16.93 and 18.84 quadrillion Btu in 2004 and 2012, respectively. This represents overall growth between these two years of 11.3%. Source: Annual Energy Outlook 2006, DOE/EIA-0383(2006), Reference Case Table 2, available in docket EPA-HQ-OAR-2005-0161.

Table 4.3-2.
Annual Emissions Nationwide from Biodiesel Production and Transportation: 2012 (tons per year)

	Reference Inventory: 28 mill gal biodiesel per year	Increase in Emissions: 300 mill gal biodiesel per year
VOC	1,400	14,000
NOx	1,500	15,000
CO	800	8,000
PM10	50	500
SOx	250	2,500

As can be seen, the potential increases in emissions from biodiesel production and transportation are of the same order of magnitude as those from biodiesel use, with the exception of CO emissions. Generally, biodiesel plants are not located in ozone non-attainment areas, so the ozone impact of the increased VOC and NOx emissions should be minimal.

4.4 Total Emission Impacts of Renewable Fuel Production and Use

Tables 4.4-1 and 4.4-2 combine the VOC, CO and NOx emission impacts for ethanol use from Section 4.1 and renewable fuel production and distribution from Section 4.3. Table 4.4-1 includes the emission impacts from gasoline vehicles and equipment under our primary analysis and renewable fuel production and distribution from GREET1.7. Table 4.4-2 includes the emission impacts from gasoline vehicles and equipment under our sensitivity analysis and renewable fuel production and distribution from GREET1.7 augmented with the State data for ethanol production plants. Emissions from renewable fuel production and distribution in 2012 were increased by 1.9% per year to account for growth in gasoline and diesel fuel demand.

Table 4.4-1.
National Emissions from Gasoline Vehicles and Equipment and Renewable Fuel Production and Distribution: Primary Case and GREET1.7 (Tons/Year)

	Tons/Year		
VOC Emissions	**2012**	**2015**	**2020**
Reference	5,891,000	5,578,513	5,366,368
RFS Case (Change)	33,000	41,969	51,584
EIA Case (Change)	63,000	71,311	83,496
CO Emissions	**2012**	**2015**	**2020**
Reference	3,467,000	3,321,850	3,301,600
RFS Case (Change)	50,000	58,337	69,232
EIA Case (Change)	108,000	116,446	130,856
NOx Emissions	**2012**	**2015**	**2020**
Reference	2,483,000	2,319,026	2,132,736
RFS Case (Change)	33,000	36,482	39,952
EIA Case (Change)	38,000	42,596	48,256

Table 4.4-2.
National Emissions from Gasoline Vehicles and Equipment and Renewable Fuel Production and Distribution: Sensitivity Case and GREET1.7/State Data (Tons/Year)

	Tons/Year		
VOC Emissions	**2012**	**2015**	**2020**
Reference	5,849,000	5,525,855	5,298,280
RFS Case (Change)	-1,000	-746	-3,656
EIA Case (Change)	25,000	22,824	18,864
CO Emissions	**2012**	**2015**	**2020**
Reference	3,426,000	3,270,249	3,234,664
RFS Case (Change)	16,000	15,622	13,992
EIA Case (Change)	70,000	67,959	66,224
NOx Emissions	**2012**	**2015**	**2020**
Reference	2,484,000	2,320,083	2,133,888
RFS Case (Change)	34,000	37,539	41,104
EIA Case (Change)	50,000	55,280	62,080

Chapter 4: Appendix

Table 4A-1. VOC Emission Inventories under Various Ethanol Use Cases

Primary	Tons/Year			Change from Reference (tons)			% Change from Reference		
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	5,882,000	5,569,000	5,356,000	--	--	--	--	--	--
RFS Case	5,900,000	5,594,000	5,390,000	18,000	25,000	34,000	0.3%	0.4%	0.6%
EIA Case	5,925,000	5,618,000	5,414,000	43,000	49,000	58,000	0.7%	0.9%	1.1%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	3,417,000	3,269,000	3,244,000	--	--	--	--	--	--
RFS Case	3,427,000	3,285,000	3,267,000	10,000	16,000	23,000	0.3%	0.5%	0.7%
EIA Case	3,449,000	3,305,000	3,286,000	32,000	36,000	42,000	0.9%	1.1%	1.3%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	2,465,000	2,300,000	2,112,000	--	--	--	--	--	--
RFS Case	2,473,000	2,309,000	2,123,000	8,000	9,000	11,000	0.3%	0.4%	0.5%
EIA Case	2,476,000	2,313,000	2,128,000	11,000	13,000	16,000	0.4%	0.6%	0.8%

Sensitivity	Tons/Year								
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	5,834,000	5,510,000	5,281,000	--	--	--	--	--	--
RFS Case	5,814,000	5,487,000	5,254,000	-20,000	-23,000	-27,000	-0.3%	-0.4%	-0.5%
EIA Case	5,830,000	5,500,000	5,264,000	-4,000	-10,000	-17,000	-0.1%	-0.2%	-0.3%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	3,369,000	3,210,000	3,169,000	--	--	--	--	--	--
RFS Case	3,341,000	3,178,000	3,131,000	-28,000	-32,000	-38,000	-0.8%	-1.0%	-1.2%
EIA Case	3,354,000	3,187,000	3,136,000	-15,000	-23,000	-33,000	-0.4%	-0.7%	-1.0%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	2,465,000	2,300,000	2,112,000	--	--	--	--	--	--
RFS Case	2,473,000	2,309,000	2,123,000	8,000	9,000	11,000	0.3%	0.4%	0.5%
EIA Case	2,476,000	2,313,000	2,128,000	11,000	13,000	16,000	0.4%	0.6%	0.8%

Table 4A-2. CO Emission Inventories under Various Ethanol Use Cases

Primary	Tons/Year			Change from Reference (tons)			% Change from Reference		
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	55,022,000	53,702,000	53,949,000	--	--	--	--	--	--
RFS Case	54,539,000	53,229,000	53,489,000	-483,000	-473,000	-460,000	-0.9%	-0.9%	-0.9%
EIA Case	53,656,000	52,373,000	52,663,000	-1,366,000	-1,329,000	-1,286,000	-2.5%	-2.5%	-2.4%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	37,656,000	36,171,000	35,723,000	--	--	--	--	--	--
RFS Case	37,611,000	36,132,000	35,704,000	-45,000	-39,000	-19,000	-0.1%	-0.1%	-0.1%
EIA Case	37,297,000	35,850,000	35,471,000	-359,000	-321,000	-252,000	-1.0%	-0.9%	-0.7%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	17,366,000	17,531,000	18,226,000	--	--	--	--	--	--
RFS Case	16,928,000	17,097,000	17,785,000	-438,000	-434,000	-441,000	-2.5%	-2.5%	-2.4%
EIA Case	16,359,000	16,523,000	17,192,000	-1,007,000	-1,008,000	-1,034,000	-5.8%	-5.7%	-5.7%

Sensitivity	Tons/Year								
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	54,315,000	52,998,000	53,183,000	--	--	--	--	--	--
RFS Case	53,623,000	52,322,000	52,507,000	-692,000	-676,000	-676,000	-1.3%	-1.3%	-1.3%
EIA Case	52,340,000	51,069,000	51,246,000	-1,975,000	-1,929,000	-1,937,000	-3.6%	-3.6%	-3.6%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	36,949,000	35,467,000	34,957,000	--	--	--	--	--	--
RFS Case	36,695,000	35,225,000	34,722,000	-254,000	-242,000	-235,000	-0.7%	-0.7%	-0.7%
EIA Case	35,981,000	34,546,000	34,054,000	-968,000	-921,000	-903,000	-2.6%	-2.6%	-2.6%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	17,366,000	17,531,000	18,226,000	--	--	--	--	--	--
RFS Case	16,928,000	17,097,000	17,785,000	-438,000	-434,000	-441,000	-2.5%	-2.5%	-2.4%
EIA Case	16,359,000	16,523,000	17,192,000	-1,007,000	-1,008,000	-1,034,000	-5.8%	-5.7%	-5.7%

Table 4A-3. NOx Emission Inventories under Various Ethanol Use Cases

Primary	Tons/Year			Change from Reference (tons)			% Change from Reference		
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	2,487,000	2,059,000	1,695,000	--	--	--	--	--	--
RFS Case	2,510,000	2,077,000	1,712,000	23,000	18,000	17,000	0.9%	0.9%	1.0%
EIA Case	2,527,000	2,092,000	1,727,000	40,000	33,000	32,000	1.6%	1.6%	1.9%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	2,240,000	1,797,000	1,407,000	--	--	--	--	--	--
RFS Case	2,249,000	1,800,000	1,407,000	9,000	3,000	0	0.4%	0.2%	0.0%
EIA Case	2,253,000	1,801,000	1,407,000	13,000	4,000	0	0.6%	0.2%	0.0%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	247,000	262,000	288,000	--	--	--	--	--	--
RFS Case	261,000	277,000	305,000	14,000	15,000	17,000	5.7%	5.7%	5.9%
EIA Case	274,000	291,000	320,000	27,000	29,000	32,000	10.9%	11.1%	11.1%

Sensitivity	Tons/Year			Change from Reference (tons)			% Change from Reference		
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	2,519,000	2,087,000	1,717,000	--	--	--	--	--	--
RFS Case	2,587,000	2,144,000	1,765,000	68,000	57,000	48,000	2.7%	2.7%	2.8%
EIA Case	2,625,000	2,178,000	1,796,000	106,000	91,000	79,000	4.2%	4.4%	4.6%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	2,272,000	1,825,000	1,429,000	--	--	--	--	--	--
RFS Case	2,326,000	1,867,000	1,460,000	54,000	42,000	31,000	2.4%	2.3%	2.2%
EIA Case	2,351,000	1,887,000	1,476,000	79,000	62,000	47,000	3.5%	3.4%	3.3%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	247,000	262,000	288,000	--	--	--	--	--	--
RFS Case	261,000	277,000	305,000	14,000	15,000	17,000	5.7%	5.7%	5.9%
EIA Case	274,000	291,000	320,000	27,000	29,000	32,000	10.9%	11.1%	11.1%

Table 4A-4. Benzene Emission Inventories under Various Ethanol Use Cases

Primary	Tons/Year			Change from Reference (tons)			% Change from Reference		
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	178,000	175,400	179,900	--	--	--	--	--	--
RFS Case	174,800	164,800	178,200	-3,200	-10,600	-1,700	-1.8%	-6.0%	-0.9%
EIA Case	170,800	169,100	174,200	-7,200	-6,300	-5,700	-4.0%	-3.6%	-3.2%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	124,100	124,200	130,600	--	--	--	--	--	--
RFS Case	121,800	122,600	129,400	-2,300	-1,600	-1,200	-1.9%	-1.3%	-0.9%
EIA Case	118,700	119,400	126,100	-5,400	-4,800	-4,500	-4.4%	-3.9%	-3.4%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	53,900	51,200	49,300	--	--	--	--	--	--
RFS Case	53,000	42,200	48,800	-900	-9,000	-500	-1.7%	-17.6%	-1.0%
EIA Case	52,100	49,700	48,100	-1,800	-1,500	-1,200	-3.3%	-2.9%	-2.4%

Sensitivity	Tons/Year								
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	175,700	172,700	176,500	--	--	--	--	--	--
RFS Case	170,700	168,000	171,900	-5,000	-4,700	-4,600	-2.8%	-2.7%	-2.6%
EIA Case	166,300	163,600	167,200	-9,400	-9,100	-9,300	-5.4%	-5.3%	-5.3%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	121,800	121,500	127,200	--	--	--	--	--	--
RFS Case	117,700	117,500	123,100	-4,100	-4,000	-4,100	-3.4%	-3.3%	-3.2%
EIA Case	114,200	113,900	119,100	-7,600	-7,600	-8,100	-6.2%	-6.3%	-6.4%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	53,900	51,200	49,300	--	--	--	--	--	--
RFS Case	53,000	50,500	48,800	-900	-700	-500	-1.7%	-1.4%	-1.0%
EIA Case	52,100	49,700	48,100	-1,800	-1,500	-1,200	-3.3%	-2.9%	-2.4%

Table 4A-5. Acetaldehyde Emission Inventories under Various Ethanol Use Cases

Primary	Tons/Year			Change from Reference (tons)			% Change from Reference		
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	19,900	20,000	21,100	--	--	--	--	--	--
RFS Case	23,300	23,400	24,700	3,400	3,400	3,600	17.1%	17.0%	17.1%
EIA Case	27,000	27,300	28,800	7,100	7,300	7,700	35.7%	36.5%	36.5%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	15,500	15,800	17,000	--	--	--	--	--	--
RFS Case	17,900	18,300	19,800	2,400	2,500	2,800	15.5%	15.8%	16.5%
EIA Case	20,900	21,500	23,300	5,400	5,700	6,300	34.8%	36.1%	37.1%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	4,400	4,200	4,100	--	--	--	--	--	--
RFS Case	5,400	5,100	4,900	1,000	900	800	22.7%	21.4%	19.5%
EIA Case	6,100	5,800	5,500	1,700	1,600	1,400	38.6%	38.1%	34.1%

Sensitivity	Tons/Year								
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	19,500	19,500	20,400	--	--	--	--	--	--
RFS Case	22,500	22,400	23,400	3,000	2,900	3,000	15.4%	14.9%	14.7%
EIA Case	26,100	26,100	27,200	6,600	6,600	6,800	33.8%	33.8%	33.3%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	15,100	15,300	16,300	--	--	--	--	--	--
RFS Case	17,100	17,300	18,500	2,000	2,000	2,200	13.2%	13.1%	13.5%
EIA Case	20,000	20,300	21,700	4,900	5,000	5,400	32.5%	32.7%	33.1%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	4,400	4,200	4,100	--	--	--	--	--	--
RFS Case	5,400	5,100	4,900	1,000	900	800	22.7%	21.4%	19.5%
EIA Case	6,100	5,800	5,500	1,700	1,600	1,400	38.6%	38.1%	34.1%

Table 4A-6. Formaldehyde Emission Inventories under Various Ethanol Use Cases

Primary	Tons/Year			Change from Reference (tons)			% Change from Reference		
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	40,400	40,100	41,400	--	--	--	--	--	--
RFS Case	39,800	39,600	41,200	-600	-500	-200	-1.5%	-1.2%	-0.5%
EIA Case	40,200	40,100	41,600	-200	0	200	-0.5%	0.0%	0.5%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	29,900	30,100	32,000	--	--	--	--	--	--
RFS Case	29,300	29,700	31,800	-600	-400	-200	-2.0%	-1.3%	-0.6%
EIA Case	29,600	30,100	32,200	-300	0	200	-1.0%	0.0%	0.6%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	10,500	10,000	9,400	--	--	--	--	--	--
RFS Case	10,500	9,900	9,400	0	-100	0	0.0%	-1.0%	0.0%
EIA Case	10,600	10,000	9,400	100	0	0	1.0%	0.0%	0.0%

Sensitivity	Tons/Year								
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	39,600	39,200	40,300	--	--	--	--	--	--
RFS Case	38,500	38,100	39,200	-1,100	-1,100	-1,100	-2.8%	-2.8%	-2.7%
EIA Case	38,900	38,400	39,500	-700	-800	-800	-1.8%	-2.0%	-2.0%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	29,100	29,200	30,900	--	--	--	--	--	--
RFS Case	28,000	28,200	29,800	-1,100	-1,000	-1,100	-3.8%	-3.4%	-3.6%
EIA Case	28,300	28,400	30,100	-800	-800	-800	-2.7%	-2.7%	-2.6%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	10,500	10,000	9,400	--	--	--	--	--	--
RFS Case	10,500	9,900	9,400	0	-100	0	0.0%	-1.0%	0.0%
EIA Case	10,600	10,000	9,400	100	0	0	1.0%	0.0%	0.0%

Table 4A-7. 1,3-Butadiene Emission Inventories under Various Ethanol Use Cases

Primary	Tons/Year			Change from Reference (tons)			% Change from Reference		
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	18,900	18,500	19,100	--	--	--	--	--	--
RFS Case	18,700	18,600	19,100	-200	100	0	-1.1%	0.5%	0.0%
EIA Case	18,600	18,500	19,100	-300	0	0	-1.6%	0.0%	0.0%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	12,000	12,000	12,800	--	--	--	--	--	--
RFS Case	11,800	12,000	12,800	-200	0	0	-1.7%	0.0%	0.0%
EIA Case	11,800	12,000	12,800	-200	0	0	-1.7%	0.0%	0.0%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	6,900	6,500	6,300	--	--	--	--	--	--
RFS Case	6,900	6,600	6,300	0	100	0	0.0%	1.5%	0.0%
EIA Case	6,800	6,500	6,300	-100	0	0	-1.4%	0.0%	0.0%

Sensitivity	Tons/Year								
Total	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	18,600	18,200	18,700	--	--	--	--	--	--
RFS Case	18,200	18,000	18,300	-400	-200	-400	-2.2%	-1.1%	-2.1%
EIA Case	18,000	17,800	18,200	-600	-400	-500	-3.2%	-2.2%	-2.7%
On-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	11,700	11,700	12,400	--	--	--	--	--	--
RFS Case	11,300	11,400	12,000	-400	-300	-400	-3.4%	-2.6%	-3.2%
EIA Case	11,200	11,300	11,900	-500	-400	-500	-4.3%	-3.4%	-4.0%
Non-Road	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**	**2012**	**2015**	**2020**
Reference	6,900	6,500	6,300	--	--	--	--	--	--
RFS Case	6,900	6,600	6,300	0	100	0	0.0%	1.5%	0.0%
EIA Case	6,800	6,500	6,300	-100	0	0	-1.4%	0.0%	0.0%