Emission Projections for the EPA Section 812 Second Prospective Clean Air Act Cost/Benefit Analysis

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ABSTRACT

Section 812 of the Clean Air Act Amendments of 1990 requires the U.S. EPA to perform periodic, comprehensive analyses of the total costs and total benefits of program implemented pursuant to the CAA. The first prospective analysis was completed in 1999. The second prospective analysis was initiated during 2005. The first step in the second prospective analysis was the development of base and projection year emission estimates, which will be used to generate benefit estimates of CAAA programs. This paper describes the analysis methods and results of the recently completed emission projections. There are several unique features of this analysis. One is the use of consistent economic assumptions from the Department of Energy's "Annual Energy Outlook 2005" projections as the basis for estimating 2010 and 2020 emissions for all sectors. Another is the analysis of the different emissions paths for both with and without CAAA scenarios. Other features of this analysis include being the first EPA analysis that uses the 2002 National Emission Inventory files as the basis for making 48 state emission projections, incorporating control factor files from the regional planning organizations that had completed emission projections at the time the analysis was performed, and modeling the emission benefits of the expected adoption of measures to meet the 8 hour ozone NAAQS, the Clean Air Visibility Rule, and the $PM_{2.5}$ NAAQS. The results of this study have been reviewed by EPA's Science Advisory Board.

INTRODUCTION

Section 812 of the Clean Air Act Amendments of 1990 (CAAA) requires the U.S. Environmental Protection Agency (EPA) to perform periodic, comprehensive analyses of the total costs and total benefits of programs implemented pursuant to the Clean Air Act (CAA). The first analysis required was a retrospective analysis, addressing the original CAA and covering the period 1970 to 1990. The retrospective was completed in 1997. Section 812 also requires performance of prospective cost-benefit analyses, the first of which was completed in 1999. The prospective analyses address the incremental costs and benefits of the CAAA. The first prospective covered implementation of the CAAA over the period 1990 to 2010.

EPA's Office of Air and Radiation (OAR) began work on the second prospective with the drafting of an analytical plan for the study. This analytical plan was reviewed by a statutorily-mandated outside peer review group, the Advisory Council for Clean Air Compliance Analysis (Council), and the Council provided comments, which have been incorporated into the technical analysis planning. This paper describes the development of base and projection year emission estimates for the second prospective section 812 analysis.

The scope of this analysis is to estimate future emissions of all criteria pollutants except lead: volatile organic compounds (VOCs), oxides of nitrogen (NO_x), carbon monoxide (CO), sulfur dioxide (SO_2), particulate matter of 10 microns or less (PM_{10}), and particulate matter with an aerodynamic diameter of 2.5 microns or less ($PM_{2.5}$). Estimates of current and future year ammonia (NH_3) emissions are also included in this study because of their importance in the atmospheric formation of secondary particles. The study years are 1990, 2000, 2010, and 2020. This paper presents the results of EPA's analysis of the future effects of implementation of the CAAA's programs on air emissions from the following emission sectors: electricity generating units (EGUs), non-electricity generating unit point sources, nonroad engines/vehicles, on-road vehicles, and nonpoint sources. The purpose of this paper is to present the methods used to generate emissions projections under the two different control scenarios, and to provide emission summaries for each. Examples of programs modeled under this analysis include:

- Title I VOC and NO_x reasonably available control technology (RACT) requirements in ozone nonattainment areas (NAAs);
- Title II on-road vehicle and nonroad engine/vehicle provisions; and
- Title III National Emission Standards for Hazardous Air Pollutants (NESHAPs).

The effects of Title IV CAAA programs on emissions from EGUs are analyzed using EPA's Integrated Planning Model (IPM). The results of the EGU modeling are reported here, along with a summary of the approach. The results of this analysis provide the input for the air quality modeling and benefits estimation stages of the second prospective analyses. The emission inputs to the modeling are more detailed than the summaries provided in this paper, but will be available online at www.epa.gov/oar/sect812.

METHODS

Selection of Base Year Inventory

Table 1 summarizes the key databases that were used in this study to estimate emissions for historic years 1990 and 2000. These two years are the respective base years for preparing emission projections for the *with*- and *without-CAAA* scenarios for 2010 and 2020. The *without-CAAA* scenario emission projections are made from a 1990 base year. For EGU and non-EGU point sources, 1990 emissions are estimated using the 1990 EPA National Emission Inventory (NEI) point source file. This file is consistent with the emission estimates used for the First Section 812 Prospective and is thought to be the most comprehensive and complete representation of point source emissions and associated activity in that year. Similarly, the 1990 EPA NEI nonpoint source file (known at the time as the area source file) – with a few notable exceptions – is used to estimate 1990 nonpoint source sector emissions. The exceptions are where 1990 emissions were re-computed using updated methods developed for the 2002 NEI for selected source categories with the largest criteria pollutant emissions and most significant methods changes.

The 1990 onroad and nonroad vehicle/engine sector emissions were estimated independently for this project using consistent modeling approaches and activity estimates across the scenarios and years of interest. For example, MOBILE6.2 emission factors and 1990 and 2000 NEI vehicle miles traveled (VMT) databases were used to estimate onroad vehicle emissions for 1990 and 2000. Similarly, EPA's NONROAD 2004 model was used to estimate 1990 and 2000 emissions for nonroad vehicles/engines.

For calendar year 2000, *with-CAAA* scenario non-EGU point source emissions were estimated using the 2002 EPA NEI point source file (final version 2.0). For nonpoint sources, *with-CAAA* scenario emissions in calendar year 2000 were estimated using the 2002 EPA NEI nonpoint source file (final version 1). We selected the year 2002 NEI to represent the year 2000 emissions for two reasons: (1) because the 2002 NEI incorporates a number of emission methods refinements over the 1999 NEI, improving the accuracy of the base year estimate; and (2) because we believe that emissions for the year 2000 for this sector are not significantly different from emissions for the year 2002. For nonpoint sources, with-CAAA scenario emissions in calendar year 2000 also were estimated using the 2002 EPA NEI nonpoint source file (final) for the same reasons.

The logic for these base year inventory choices relates to the specific definitions of the scenarios themselves. The with-CAAA scenario tracks compliance with CAAA requirements over time; as a result, the best current basis for projecting the with-CAAA scenario incorporates decisions made since 1990 to comply with the Act. The 2002 NEI provides the best current understanding of the technologies applied to meet emission reductions mandated under the CAAA. Over the next several decades, however, we would expect that the mix of economic activity across polluting sectors will change. In addition, we would expect that continued technological progress could improve the effectiveness and/or reduce the cost of applying these technologies. Pollution prevention and changes in production methods could also lead to reductions in air pollution. The change in the mix of economic activity is addressed directly by our choice of activity drivers for the projections, as discussed below. Addressing the pace of technological progress is more difficult; in many cases, we have only limited ability to forecast technological advancements and their effect on air pollution emissions. In other cases, we can use the pace of technological progress to date to project the pace of future improvements. To address this factor, the overall analytical plan includes an assessment of the effects of learning-by-doing on costs, in a sector-specific fashion. This is consistent with our assessment that, for most of the federal measures assessed as part of the with-CAAA scenario, which require specific emission reductions, technologies, or caps, emission outcomes will not be affected by technological progress, but the costs of those reductions will be affected. It is also consistent with the trend in emissions just prior to 1990 as documented in the First Prospective analysis. Just prior to the passage of the CAAA, the steep downward emissions trend that had been seen in the 1970s and early 1980s for many pollutants were starting to be reversed—that is, emissions were starting to move upward as economic activity continued, but the stringency of standards remained largely fixed.

Criteria pollutant emissions were projected to 2010 and 2020 to determine the impact of CAA controls on future year emission levels. Emissions were projected under two scenarios:

Without-CAAA – applies expected increases in activity levels with no additional controls implemented beyond those that were in place when the CAAA were passed.

With-CAAA – applies expected increases in activity levels and incorporates the effects of controls mandated under the 1990 Amendments to the CAA.

The general procedure used to project emissions is as follows:

- Grow base year emissions or activity levels to the future year; and
- Apply future year control efficiencies or emission factors.

Table 2 details the modeling approach used to project emissions for each of the major sectors. Table 3 summarizes the two projection scenarios.

One of the major study objectives was to provide the maximum feasible internal consistency in the use of projection methods. We expect that energy demand, energy prices, and diffusion rates of technologies are closely tied to the rate of growth of future air pollutant emissions and are closely linked to expectations of the future growth path of the U.S. economy. Economic growth projections enter the emissions analysis of the second prospective in three places:

The electricity demand forecast included in IPM (this forecast has in the recent past been based on the reference case economic growth assumptions included in the Department of Energy's AEO 2005);
The fuel consumption forecast for non-utility sectors that serves as the activity driver for major fuel-consuming sectors (this forecast is also based on the reference case economic growth assumptions included in AEO); and
The economic growth projections that serve as activity drivers for several other sources of air pollutants (see Table 2).

In addition, the AirControlNET model that we use to assess compliance options for meeting the new NAAQS, and which also calculates associated emissions implications, has recently been re-designed to accept energy prices and labor rates as global inputs.

For this analysis, the Agency chose to use fully integrated economic growth, energy demand, and fuel price projections for central case economic growth scenarios. The primary advantage of this approach is that it allows the project team to conduct an internally consistent analysis of economic growth across all emitting sectors. The system chosen was the Department of Energy's National Energy Modeling System (NEMS). Our central case emissions estimates rely on the DOE Annual Energy Outlook (AEO) 2005 reference case scenarios. A major strength of this approach is the integrated nature of the key scenario driver data.

Figure 1 illustrates how the control requirements at the Federal, regional, local, and source levels are considered in order to determine the most stringent (or binding) requirement by source category for application in the core scenarios analysis. The core scenarios analysis is what is described in this paper, and it includes the measures that have been adopted by areas to meet attainment requirements for the 1-hour ozone NAAQS, and the PM_{10} NAAQS.

The analysis of local controls to meet attainment requirements for 8-hour ozone and $PM_{2.5}$ ambient standards is described separately. Key components of this analysis include estimating the incremental emission reductions expected to be associated with attaining the 8-hour ozone NAAQS, the $PM_{2.5}$ NAAQS, and the Federal BART rule. These emission reductions are measured from the core scenarios analysis baseline. The bottom part of Figure 1 depicts the key parts of this local controls analysis.

Economic Factors

In keeping with past EPA practice, this study relies on energy data from the U.S. Department of Energy (DOE)'s Energy Information Administration (EIA) to backcast/forecast energy consumption and energy production emission source categories. To reflect the 1990 to 2000 trend in energy consumption for source categories, the project team generally relied on historical time-series energy data for each State from an EIA energy consumption database[1]. For Crude Oil and Natural Gas Production source categories, we obtained relevant 1990 and 2000 State-level activity data from an EIA source that provides the number of operating oil well days (used for Crude Oil Production) and the number of operating gas well days (used for Natural Gas Production)[2]. For source categories that describe railroad and marine distillate fuel consumption emission processes, we obtained State-level 1990 and 2000 consumption estimates from an EIA distillate fuel data resource[3].

Each year, the EIA produces energy projections for the United States. These projections, which forecast U.S. energy supply, demand, and prices through 2025, are published in an EIA document entitled *Annual Energy Outlook 2005 (AEO 2005)*[4]. For most energy sectors/fuel types, *AEO 2005* reports energy forecasts by Census division. These divisions are defined by State boundaries (e.g., Texas is included in the West South Central region). When *AEO 2005* produces Census division forecasts, these regional data were used to project changes in the emissions activity for each State in the division. For example, Stage II (Gasoline Vehicle Refueling) emission activity in Texas is projected using *AEO 2005* projections of West South Central region transportation sector motor gasoline consumption. This study relies on national energy forecasts whenever *AEO 2005* only produces national projections for the energy growth indicator of interest. Figure 2 displays forecast data for 3 of the approximate 50 energy sectors for which *AEO 2005* only produces national projections.

Because population growth and the performance of the U.S. economy are two of the main determinants of energy demand, the EIA also prepares socioeconomic projections. These projections feed into energy demand models incorporated into the EIA's National Energy Modeling System (NEMS). NEMS incorporates population projections and economic output forecasts for most industry sectors by Census division. For non-energy intensive economic sectors (e.g., Wholesale Trade), EIA prepares national-level output forecasts. This study relies on *AEO 2005* historical and forecast socioeconomic data as surrogates for emission activity level changes for most non-energy source categories. When *AEO 2005* reported Census division forecasts, each emission source's State identifier was used to link to the appropriate *AEO 2005* regional projections. National *AEO 2005* data were used whenever NEMS only produces national forecasts for the growth surrogate of interest. Table 6 presents key national *AEO 2005* assumptions over the 2003 to 2025 forecast period. (As noted earlier, year 2000 emission activity data were only needed in preparing the without CAA case emission estimates from 1990 base year emissions. For these years, we relied on historical energy data.)

Non-EGU Point Sources

The non-EGU point source emission projection approach for the with-CAAA scenario uses the 2002 version 2.0 NEI point source emission file (October 26, 2006 release date) as the base year, applied the growth factors described above to estimate activity changes between the base year and the 2010 and 2020 projection years, and applies control factors or emission caps to simulate the effect of air pollution control programs in each forecast year.

One of the important components of the emission projections is identifying and quantifying the effect of federal, state and local air pollution control strategies on post-2002 emission rates. Because of the recent and ongoing activity of the five RPOs in developing emission projections for their own modeling domains, each of the RPOs was queried, and any available control factor files were obtained. The common projection year for the RPOs is 2018. All RPOs have either developed, or are working toward developing, 2018 emission forecasts. Some are also developing emission forecasts for 2009 or 2010 because these are expected 8 hour ozone attainment years. For this section 812 analysis, control factors for the different projection years were reviewed, and adjusted where necessary to account for the timing of regulation implementation. Table 7 lists the RPOs, the geographic areas that they include, their projection years, and the information that was received from each to support this analysis.

In order to estimate the 2010 and 2020 emission benefits of air pollution emission regulations in California, California ARB staff provided a control factor file that was used in the Central California Ozone Study modeling effort. The California file included control factors by district, air basin, and county, with source categories designated by California's Emission Inventory Codes. The California file has both rule-specific and composite (with all rules applied) control factors. The composite control factors were used in this analysis.

The base year for evaluation of the without-CAAA scenario is the 1990 EPA NEI. For point sources, this database was used along with the activity growth indicators described above to estimate without0-CAAA emissions in 2000, 2010, and 2020. Because the 1990 NEI was developed before information was available to state, local and tribal emission inventory preparers about how to estimate PM_filterable and PM-condensable fractions, it was necessary to augment the 1990 NEI point source file to have it include estimates of all of the PM components. In addition to providing a complete reporting of filterable and condensable PM emissions, this augmentation step also fills in PM_{10} or $PM_{2.5}$ primary emission estimates where they appear to be missing, and converts any situation where $PM_{2.5}$ emissions are greater than PM_{10} emissions. The net result of applying the PM augmentation procedures to the 1990 NEI point source file (non-EGU portion) was a 99 thousand ton increase in PM_{10} primary emissions and a 60 thousand ton decrease in $PM_{2.5}$ primary emissions.

Electricity Generating Units

To assess CAAA-related emission impacts for NO_x, SO_2, and mercury, the project team used the Integrated Planning Model (IPM) developed by ICF Resources, Inc. IPM is a dynamic, linear programming model of the electric power sector that represents several key components of energy markets (i.e., markets for fuels, emissions allowances, and electricity) and the linkages among them. The model determines the utility sector's least cost strategy for meeting energy and peak demand requirements over a specified time period, accounting for a number of regulatory and non-regulatory constraints (e.g., emission caps and transmission constraints).

Nonroad Engines/Vehicles

Nonroad engine/vehicle emission estimates were developed using EPA's Office of Transportation and Air Quality's (OTAQ) NONROAD 2004 model for the source categories that this model covers. This version of the model incorporates all Federal engine exhaust standards, and includes updates to the base year diesel engine populations.

The NONROAD sector emissions modeling approach involved (1) revising existing model inputs to better reflect region-specific growth rates, (2) preparing State and county-specific input files to model local fuel programs for the with-CAAA scenario runs, and (3) modifying fleet emission rate inputs to remove the effect of CAAA-related standards for the without-CAAA scenario simulations.

Appropriate temperature and fuel data inputs were compiled for each of the years of interest (1990, 2000, 2010, and 2020). Seasonal, state, or county-specific NONROAD model option files were prepared to generate nationwide emissions for each scenario. The project team performed NONROAD model runs to generate seasonal emissions for each inventory year. Seasonal emissions were summed to develop annual emission estimates at the county and SCC level for each scenario year.

On-Road Vehicles

The general method for computing historical and projection year on-road vehicle emissions is to multiply activity in the form of VMT by pollutant-specific emission factors. Emission factors for these pollutants were generated using MOBILE6.2—EPA's latest mobile source emission factor model. Because California's emission standards differ from those for the rest of the nation, and cannot be accurately estimated with MOBILE6.2, emission factor estimates generated by the ARB were used for the California emission calculations in 2000, 2010, and 2020. (Some non-California states have elected to adopt the California motor vehicle emission standards in accordance with section 177 of the Clean Air Act. The emission effects of these State adoptions have not been incorporated in this analysis.) Control program inputs such as inspection and maintenance programs and fuel programs are specified at the county-level for the MOBILE6.2 simulations. Temporally, emissions are computed by month and summed to develop annual emission estimates.

RESULTS

Table 4 summarizes the national emission estimates by sector for each of the scenario years evaluated in this study. Table 5 provides all sectors combined emission results for the same set of scenario years.

Non-EGU Point Sources

The VOC emission projections for non-EGU point sources show an overall 3 percent increase in VOC emissions from 2002 to 2010 and a 14 percent increase from 2010 to 2020. For VOC emissions, there is no dominant source category. This is a sector where many of the sources added controls in the 1990 to 2000 period in response to EPA NESHAPs. Between 2000 and 2010, there are additional NESHAP requirements for certain source categories like petroleum refineries that produce lower emissions in 2010 than in 2000. However, for most source categories, VOC emissions are estimated to increase from 2000 to 2010. Then, because no additional emission control requirements are imposed after 2010, VOC emissions in the 2010 to 2020 period increase in proportion to expected activity growth in this period.

Non-EGU point source NO_x emissions are a product of fuel combustion. In the eastern United States, many of the large fuel combustion sources are subject to the requirements of the NO_x SIP Call, and these requirements affect industrial boiler, gas turbine, RICE engine, and cement kiln emissions starting after 2002. Outside the NO_x SIP Call area, there are stringent NO_x rules affecting NO_x sources in eastern Texas, the Baton Rouge area in Louisiana, and in many Air Districts in California. Sources and geographic areas affected by these requirements contribute to the expected emission reductions between 2000 and 2010. After 2010, some NO_x emission increases are anticipated as fuel consumption by the industrial sector continues to grow. Uncertainties in the NO_x emission projections include whether NO_x SIP Call States include their affected non-EGU boilers and gas turbines as trading program sources, whose NO_x emissions are effectively capped, and whether sources affected by a 5 month ozone season control program install controls that also reduce NO_x emissions during the 7 month winter season.

Non-EGU SO_2 emissions are expected to stay relatively stable over the forecast period. Industrial fuel combustion SO_2 emissions from boilers decline slightly from 2000 to 2010, and then increase to near 2000 levels by 2020. The slight upward trend in non-EGU SO_2 emissions over the forecast period is a result of string expected activity growth in the chemical industry and other industrial processes. Some industries, such a copper smelting, that have historically been major SO_2 emission contributors, are now modest SO_2 emission contributors to non-EGU SO_2 emissions, and have little influence on future national SO_2 emissions in this sector. Refinery settlements produce SO_2 emission reductions in the forecast period for the petroleum industry.

Electricity Generating Units

For EGUs, under the without-CAAA scenario, NO_x and SO_2 emissions grow significantly between 1990 and 2010, but emissions of both pollutants remain relatively flat during the 2010 to 2020 period. Without-CAAA NO_x emissions from EGUs increase by about 4 percent during this period, while SO_2 emissions fall by about 1 percent. This reflects the confluence of a number of factors during the 2010-2020 period, including increased reliance on coal-fired plants in compliance with the NSPS and a change in relative prices of different types of coal. Based on AEO2005 projections of coal mine productivity, IPM estimates that the price of low-sulfur sub-bituminous coal will decline relative to other types of coal during this period.

Under the with-CAAA scenario, EGU emissions of both NO_x and SO_2 decline significantly between 1990 and 2020. As shown in Table 4, EGU NO_x emissions fell from 6.4 million tons in 1990 to 4.5 million tons in 2001. It is estimated that these emissions will continue falling to 2.4 million tons in 2010 and 2.0 million tons in 2020. Relative to the without-CAAA scenario, this represents a 71 percent reduction in EGU NO_x emissions for 2010 and a 77 percent reduction for 2020. Similarly, SO_2 emissions from EGUs fell from 15.8 million tons in 1990 to 10.8 million tons in 2001. These emissions are expected to continue to decline under the CAAA scenario to 6.4 million tons in 2010 and 4.3 million tons in 2020. For 2001, this represents a 40 percent reduction in SO_2 emissions relative to the without-CAAA scenario and a 77 percent reduction for 2020.

In addition to NO_x and SO_2, we estimate that the CAAA also lead to reduced emissions of PM_{10} and $PM_{2.5}$ from EGUs, although these reductions are not as significant. For 2010, we estimate that primary $PM_{2.5}$ and PM_{10} emissions will be 25 percent and 21 percent less, respectively under the with CAAA scenario than under the without CAAA scenario. By 2020, these differences will change to 34 and 29 percent for $PM_{2.5}$ and PM_{10}, respectively.

Nonroad Engines/Vehicles

For nonroad engines/vehicles, for the with-CAAA scenarios, overall VOC and NO_x emissions Decrease between 1990 and 2000, with further declines in 2010 and 2020. In some cases, the effects of growth outweigh the impact of VOC and CO emission standards (for example, gasoline lawn and garden and light commercial between 2010 and 2020). Overall NO_x emissions for this sector generally decrease with time as well, and are lower in the with-CAAA scenario. This results primarily from the large reductions in NO_x emissions from diesel engine emission standards. For gasoline-powered nonroad equipment, however, NO_x emissions increase relative to the without-CAAA scenario each year. This occurs because of the use of HC and CO-reducing technologies that control the air-fuel mixture in the cylinder, but produce higher NO_x emissions due to higher combustion temperatures and increased supply of oxygen.

$PM_{2.5}$ and PM_{10} emissions from nonroad engines/vehicles are expected to decline with time in the with-CAAA scenario. This occurs because Federal emission standards serve to reduce PM emission rates with time, and reduced fuel sulfur contents reduce PM sulfate and lead to lower PM emissions as well. These reductions in fuel sulfur levels also produce lower SO_2 emissions for this sector during the forecast period.

On-road Vehicles

For on-road vehicle emissions, in all cases—with the exception of ammonia—the total on-road emissions in 2020 with the CAAA control measures in place are below the 1990 emission levels, despite significant increases in VMT during this time period. By contrast, the 2020 without-CAAA emissions are greater than the 1990 total on-road emissions for NO_x, SO_2, and NH_3, and only modest emission decreases occur for VOC, CO, PM_{10}, and $PM_{2.5}$.

For VOC, CO, and NO_x, the on-road vehicle emissions from 1990 to each of the with-CAAA projection scenarios show steady declines over time, while the emissions in the without-CAAA projections initially decrease from 1990 levels, but then begin to increase. Several control programs in place in 1990 account for these initial declines including the Federal Motor Vehicle Control Program, Phase I RVP requirements, and I/M programs already in-place in 1990. By 2000, several CAAAA programs begin to reduce on-road emissions. These include: Phase II RVP requirements, the Tier 1 emission standards, evaporative control requirements, federal reformulated gasoline, oxygenated gasoline, more stringent I/M requirements, and California LEV standards in California. After 2000, the national LEV emission standards, Phase II of the Federal reformulated gasoline program, local low RVP gasoline programs, the Tier 2 emission standards, low sulfur gasoline, heavy-duty vehicle emission standards, and low sulfur diesel fuel all contribute to lowering emissions.

Nonpoint Sources

National nonpoint source VOC emissions are dominated by evaporative emissions from solvent utilization. While there is some additional regulation of these emissions after 2002 in areas with continuing ozone nonattainment, in most areas of the country, solvent utilization emissions grow after 2002 in proportion to activity indicators like population and employment. Another prominent VOC emitting category is Fuel Combustion-Other, which is mostly residential fireplace and woodstove emissions. (Most highly efficient fuel combustors are low VOC emitters.) Fireplace and woodstove emissions are projected to decline after 2002 as NSPS-certified woodstoves replace non-certified stoves. Another prominent VOC-emitting source category with expected emissions declines in 2010 and 2020 is fuel storage and transport. Control programs that contribute to these emission reductions include onboard VRS on gasoline-powered vehicles and more stringent State and local programs to reduce emissions at various points in the gasoline distribution system.

National NO_x emissions for the nonpoint source sector are dominated by off-highway sources (marine, aircraft and railroad). NO_x emission reductions between 2002 and 2010 are a result of Federal emission standards for some commercial marine vessel engines and locomotive engines. Besides off-highway engines, the other nonpoint source NO_x emitters with more than 10 percent of total emissions for this sector are: industrial and other fuel combustion and petroleum and related processes. These are all small fuel combustors that are exempt from regulations like the NO_x SIP Call because of their size. Their NO_x emissions are expected to increase slightly during the study time horizon.

SO_2 emissions for this sector are expected to stay relatively stable from 2002 to 2020. The dominant source type is industrial fuel combustion and these emissions represent coal and fuel oil combustion that occurs in sources that are not included in the 2002 NEI point source file. The off-highway sector SO_2 contribution is small because most of the off-highway source emissions are from diesel engines (Commercial marine vessels and locomotives) or jet aircraft engines.

CONCLUSIONS

This analysis shows that the 1990 CAAA have produced significant reductions in most criteria pollutant emissions since 1990 and that these emission reductions are expected to continue through 2020.

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KEY WORDS

Motor vehicle pollution
Clean Air Act
Electric power
Air pollution control
Off-road vehicles

Table 1. Base year emission data sources for the *With-* and *Without CAAA* scenarios.

Sectors	*Without-CAAA* Scenario – 1990	*With-CAAA* Scenario – 2000
EGU	1990 EPA Point Source NEI	Estimated by the EPA Integrated Planning Model for 2001
Non-EGU Point	1990 EPA Point Source NEI	2002 EPA Point Source NEI (Final Version 2.0)
Nonpoint	1990 EPA Nonpoint Source NEI with Adjustments for Priority Source Categories	2002 EPA Nonpoint Source NEI (Final Version 1)
On-Road	MOBILE6.2 Emission Factors and 1990 NEI VMT Database	MOBILE6.2 Emission Factors and 2000 NEI VMT Database. The California Air Resources Board (ARB) supplied estimates for California
Off-Road/Nonroad	NONROAD 2004 Model Simulation for Calendar Year 1990	NONROAD 2004 Model Simulation for Calendar Year 2000

Table 2. Modeling approach by major sector.

Sector	Growth Forecast	Controls Modeling Approach
Non-EGU Point	U.S. Department of Energy (DOE) *Annual Energy Outlook 2005* forecasts	Based on control factors developed by the five Regional Planning Organizations (RPOs), and California information from the ARB
EGU	DOE *Annual Energy Outlook 2005* forecasts	Integrated Planning Model (IPM)
Nonroad	EPA NONROAD Model growth forecasts are largely based on historical trends in national engine populations by category/sub-category of engine	EPA NONROAD Model
Onroad	National VMT Forecast from *Annual Energy Outlook 2005 (AEO 2005)*	MOBILE6.2 emission factors
Nonpoint	DOE *AEO 2005* forecasts	Based on control factors developed by the five RPOs, and California information from the ARB

Table 3. Projection scenario summary by major sector in the second prospective.

Sector	*Without-CAAA*	***With-CAAA****	
Non-Electricity Generating Unit Point	RACT held at 1990 levels	**NO_x:**	RACT for all NAAs (except NO_x waivers), Ozone Transport Commission (OTC) small NO_x source model rule (where adopted), Cases and settlements, NO_x measures included in ozone State Implementation Plans (SIPs) and SIP Call post-2000, Additional measures to meet PM and ozone National Ambient Air Quality Standards (NAAQS). RACT for all NAAs,
		VOC/HAP:	VOC measures included in ozone SIPs, 2-, 4-, 7-, and 10-year maximum achievable control technology (MACT) standards, New control technique guidelines (CTGs). Cases and settlements,
		SO_x:	Additional measures to meet revised PM NAAQS. Rate-of-Progress (3 percent per year) requirements (further reductions in VOC),
		NO_x/VOC:	Early action compacts.
Electricity Generating Unit	RACT and New Source Review (NSR) held at 1990 levels. 250 ton Prevention of Significant Deterioration (PSD) and New Source Performance Standards (NSPS) held at 1990 levels.	**NO_x:**	RACT and NSR for all non-waived (NO_x waiver) NAAs, SIP Call post -2000, Phase II of the OTC NO_x memorandum of understanding, Title IV Phase I and Phase II limits for all boiler types, 250 ton PSD and NSPS, Clean Air Interstate Rule (CAIR), Clean Air Mercury Rule, Cases and settlements, Additional measures to meet PM and ozone NAAQS.
		SO_x:	Title IV emission allowance program, CAIR, Clean Air Mercury Rule, Cases and settlements, Additional measures to meet revised PM NAAQS.

Table 3 (continued).

Sector	***Without-CAAA***	***With-CAAA****	
Non-road Engines/	Controls (engine standards)	**NO_x**:	Federal Phase I and II compression ignition (CI) and spark-ignition (S-I) engine standards,
Vehicles**	held at 1990 levels.		Federal locomotive standards,
			Federal commercial marine vessel standards,
			Federal recreational marine vessel standards,
			NO_x measures included in ozone SIPs,
			Nonroad Diesel Rule.
			Federal Phase I and II S-I engine standards,
		VOC/HAP:	Federal recreational marine vessel standards,
			Federal large SI/recreational vehicle engine standards,
			Federal large SI/evaporative standards,
			VOC measures included in ozone SIPs.
			Federal large S-I evaporative standards,
		CO:	Federal Phase I and II S-I engine standards.
			Federal Phase I and II CI engine standards,
		PM:	Federal Phase I and II S-I engine standards,
			Federal locomotive standards,
			Federal commercial marine vessel standards,
			Nonroad Diesel Rule.
			Nonroad Diesel Rule,
		SO_x:	Gasoline fuel sulfur limits.

Table 3 (continued).

Sector	*Without-CAAA*	***With-CAAA****	
On-road Motor Vehicles***	Federal Motor Vehicle Control Program - engine standards set prior to 1990. Phase 1 Reid vapor pressure (RVP) limits. Inspection and maintenance (I/M) programs in place by 1990.	**NO_x** :	Tier 1 tailpipe standards (Title II), Tier 2 tailpipe standards, 49-State low-emission vehicle (LEV) program (Title I), I/M programs for ozone and CO NAAs (Title I), Federal reformulated gasoline for ozone NAAs (Title I), California LEV (California only) (Title I), California reformulated gasoline (California only) (Title I), NO_x measures included in ozone SIPs, heavy-duty diesel vehicle (HDDV) standards, HDDV defeat device settlements
		VOC/HAP:	Additional measures to meet PM and ozone NAAQS. Tier 1 tailpipe standards (Title II), Tier 2 tailpipe standards, 49-State LEV program (Title I), I/M programs for ozone and CO NAAs (Title I), Phase 2 RVP limits (Title II), Federal reformulated gasoline for ozone NAAs (Title I), California LEV (California only) (Title I), California reformulated gasoline (California only) (Title I), VOC measures included in ozone SIPs, HDDV standards, Enhanced evaporative test procedures,
		CO:	Additional measures to meet PM and ozone NAAQS. 49-State LEV program (Title I), I/M programs for CO NAAs (Title I), Tier 2 tailpipe standards, California LEV (California only) (Title I), California reformulated gasoline (California only) (Title I),
		PM:	Oxygenated fuel in CO NAAs (Title I), HDDV standards.
		SO_x:	HDDV standards, diesel fuel sulfur content limits (Title II) (1993). Diesel fuel sulfur content limits (Title II) (1993), HDDV standards and associated diesel fuel sulfur content limits, Gasoline fuel sulfur limits, Tier 2 tailpipe standards, Additional measures to meet new PM NAAQS.

Table 3 (continued).

Sector	*Without-CAAA*	*With-CAAA**	
Area/Nonpoint	Controls held at 1990 levels	**NO_x:**	RACT requirements, NO_x measures included in ozone SIPs, Additional measures to meet PM and ozone NAAQS.
		VOC/HAP:	RACT requirements, New CTGs, 2-, 4-, 7-, and 10-year MACT Standards, Onboard vapor recovery (vehicle refueling), Stage II vapor recovery systems (VRS), Federal VOC rules for architectural and industrial maintenance (AIM) coatings, autobody refinishing, and consumer products,
		PM:	Additional measures to meet PM and ozone NAAQS. $PM_{2.5}$ and PM_{10} NAA controls,
		NO_x/VOC:	VOC measures included in ozone SIPs. Rate-of-Progress (3% per year) requirements (further reductions in VOC), Model rules in OTC States, Early action compacts.

NOTES: *Also includes all *Without-CAAA* measures.

**The nonroad mobile source standards included in the *With-CAAA* scenario are based on the standards found within the NONROAD2004 emissions inventory model. Three other nonroad mobile standards, not captured by the NONROAD2004 model, are also included in the *With-CAAA* scenario: the locomotive standards, commercial marine engine standards, and the large SI/evaporative standards.

***The motor vehicle mobile source standards included in the *With-CAAA* scenario are based on the standards found within the MOBILE6.2 emissions inventory model. Note that emissions associated with the Final Rule for Cleaner Highway Motorcycles (promulgated in 2004) are not accounted for in the MOBILE6.2 model, and are not included in the *With-CAAA* scenario.

Table 4. Summary of national (48 state) emission estimates by scenario year.

Pollutant	Sector	1990	2000 *without-CAAA*	2000 *with-CAAA*	2010 *without-CAAA*	2010 *with-CAAA*	2020 *without-CAAA*	2020 *with-CAAA*
VOC	EGU	34,558	40,238	40,882	43,333	42,661	48,001	46,992
	Non-EGU Point	2,609,368	3,077,597	1,402,343	3,462,797	1,435,475	3,999,199	1,647,551
	Nonpoint	11,152,804	12,268,609	8,544,345	13,425,477	8,872,248	15,702,681	9,715,546
	Nonroad	2,665,710	3,217,810	2,564,790	4,076,796	1,874,723	4,753,500	1,489,644
	On-Road Vehicle	9,327,660	5,872,983	5,245,756	5,734,012	2,614,007	6,784,539	1,670,617
NO_x	EGU	6,410,533	7,734,000	4,493,981	8,349,482	2,437,219	8,686,216	1,986,463
	Non-EGU Point	3,133,450	3,331,308	2,292,311	3,555,874	2,246,621	3,997,276	2,509,040
	Nonpoint	4,768,841	4,650,355	3,885,707	4,840,735	3,688,289	5,198,279	3,725,010
	Nonroad	2,067,745	2,190,711	2,091,459	2,664,838	1,643,413	3,162,409	998,918
	On-Road Vehicle	9,535,993	8,782,108	8,073,738	9,105,919	4,349,062	10,695,419	1,915,842
CO	EGU	303,713	496,430	503,306	602,048	617,860	750,538	771,654
	Non-EGU Point	5,667,404	6,466,855	3,112,631	6,808,250	3,290,804	7,381,679	3,677,434
	Nonpoint	16,799,105	15,634,196	14,613,968	14,707,662	14,605,108	15,088,612	15,451,487
	Nonroad	22,176,262	25,458,930	22,330,110	31,541,817	26,229,083	37,199,473	28,999,459
	On-Road Vehicle	109,566,997	79,037,081	67,130,866	80,491,386	42,387,967	95,549,545	36,239,508
SO_2	EGU	15,831,702	18,146,659	10,819,399	18,867,532	6,365,458	18,738,860	4,270,125
	Non-EGU Point	4,293,268	4,099,586	2,193,213	4,487,265	2,177,099	4,871,531	2,387,367
	Nonpoint	2,354,778	2,071,308	1,875,282	2,453,986	1,877,630	3,044,248	1,941,752
	Nonroad	163,254	178,247	177,095	225,300	16,930	270,252	2,750
	On-Road Vehicle	500,064	632,766	253,592	797,345	29,954	986,882	36,457
PM_{10}	EGU	530,663	751,696	728,719	834,655	658,151	896,790	637,311
	Non-EGU Point	1,734,810	2,013,691	597,875	2,201,812	582,635	2,491,106	681,858
	Nonpoint	22,495,048	23,118,860	19,329,848	22,816,379	18,844,942	24,255,816	19,015,260
	Nonroad	308,562	286,623	265,778	323,187	202,507	367,252	131,185
	On-Road Vehicle	384,733	247,056	220,854	229,246	154,216	268,733	135,559
$PM_{2.5}$	EGU	357,674	634,287	610,638	704,443	529,163	762,326	506,512
	Non-EGU Point	1,299,259	1,515,932	365,260	1,651,644	393,943	1,871,552	451,169
	Nonpoint	5,255,977	5,416,570	4,103,247	5,366,784	4,060,026	5,732,422	4,166,546
	Nonroad	283,960	263,798	244,620	297,466	186,440	338,036	120,854
	On-Road Vehicle	321,852	191,723	165,515	169,690	96,356	199,153	70,899
NH_3	EGU	0	3,217	3,162	1,023	822	612	559
	Non-EGU Point	243,615	236,126	153,944	237,459	173,946	255,636	201,670
	Nonpoint	3,257,139	3,621,848	3,551,567	3,828,468	3,713,161	4,130,614	3,986,783
	Nonroad	1,530	1,789	1,715	2,248	2,042	2,665	2,399
	On-Road Vehicle	154,103	272,569	272,464	336,083	334,417	397,618	395,319

Table 5. Emission totals by pollutant - all sectors (thousand tons per year).

Pollutant	**1990**	**2000 *without-CAAA***	**2000 *with-CAAA***	**2010 *without-CAAA***	**2010 *with-CAAA***	**2020 *without-CAAA***	**2020 *with-CAAA***
VOC	25,790	24,477	17,798	26,742	14,839	31,288	14,570
NO_x	25,917	26,688	20,837	28,517	14,365	31,740	11,135
CO	154,513	127,093	107,691	134,151	87,131	155,970	85,140
SO_2	23,143	25,129	15,319	26,831	10,467	27,912	8,638
PM_{10}	24,841	25,688	21,143	25,636	20,442	27,411	20,601
$PM_{2.5}$	6,906	7,292	5,489	7,420	5,266	8,035	5,316
NH_3	3,656	4,136	3,983	4,405	4,224	4,787	4,587

Table 6. Key national assumptions reflected in AEO 2005.

Variable	2003 to 2025 Annual Growth Rate (%)
Population	0.8
Real Gross Domestic Product	3.1
GDP Chain-Type Price Index	2.5
Nonfarm Business Labor Productivity	2.2
Total Industrial Output	2.3
Manufacturing Output	2.6
Energy Intensive Manufacturing Output	1.5
Nonenergy Intensive Manufacturing Output	2.9
Services Sector Output	3.3
Energy Use Per Capita	0.5
Energy Use Per $ of Real Gross Domestic Product	-1.6

Table 7. Regional Planning Organization Criteria Pollutant Control Factors for Regions/States – Base Case 2010 and 2020

Regional Planning Organization	Geographic Area Covered	Analysis Year(s)	Notes
1. Mid-Atlantic/ Northeast Visibility Union (MANE-VU)	Northeast and Mid-Atlantic	2018	MANE-VU provided a matrix that summarized their on-the-books rules by State and sub-state area. Their control factors were not available during this study period.
2. Visibility Improvement - State and Tribal Association of the Southeast (VISTAS)	Southeast	2009 2018	Source: MACTEC, 2005[5]
3. Lake Michigan Air Directors Consortium (LADCO)	Great Lakes area	2007 2009 2012 2018	Source: Pechan, 2004[6]
4. Central Regional Air Planning Association (CENRAP)	Midwest	2018	Source: Pechan, 2005[7]
5. Western Regional Air Partnership (WRAP)	Western	2018	Control factors were not available during this study period.
5a. California		2010 2020	California projection year control factors were provided by the Air Resources Board.

Figure 1. Control applications in the core scenario and local controls for NAAQS compliance analysis.

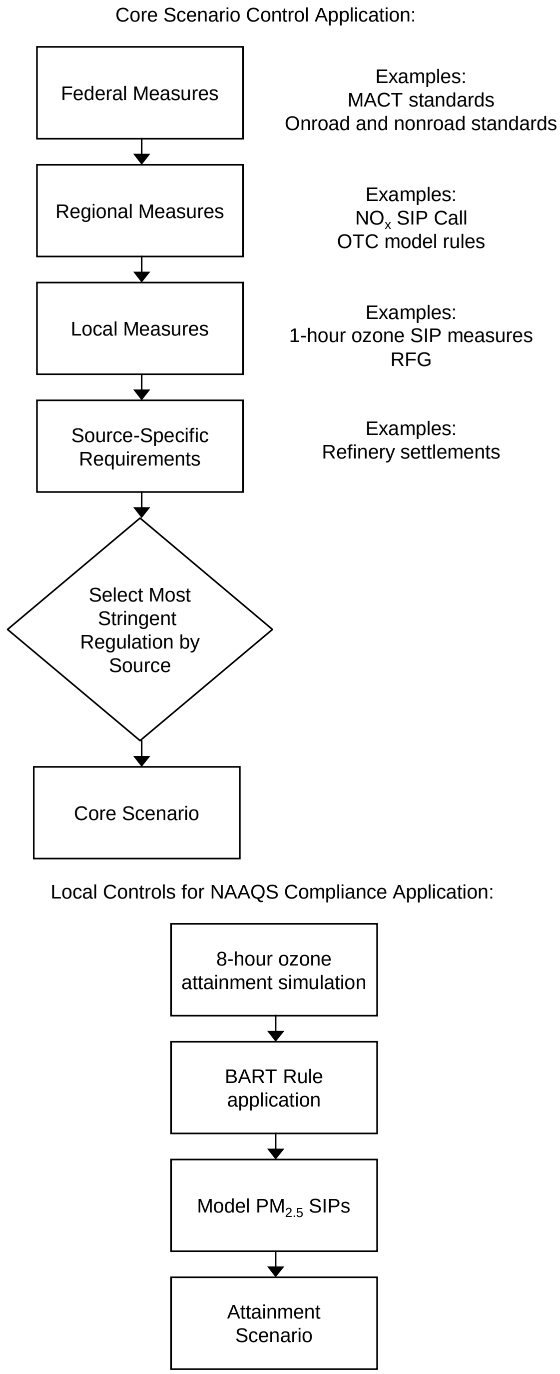

Figure 2. Sample national AEO 2005 energy sector forecasts.