Guidance for Improving Weight of Evidence Through Identification of Additional Emission Reductions, Not Modeled

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November 1999

Introduction

This paper provides guidance for using information from photochemical grid modeling and ambient air quality monitoring to estimate additional levels of emission reductions needed to support the 1-hour NAAQS for ozone beyond the reductions contained in the demonstrations submitted by the States in 1998. Procedures for estimating improvements expected with the implementation of the Tier 2 low sulfur program and benefits towards attainment are also provided. Two techniques are described for estimating additional emission reductions, each with its own strengths and weaknesses. Use is made of the fact that, since 1999 is more than half-way from the model base year (1990) to the attainment year (2005 or 2007 in most areas), air quality data from 1990 to 1999 allows modelers the opportunity to determine the representativeness of the modeled predictions. These techniques identify the additional percentage reduction in NOx and VOC from the 1990 emissions.

General Procedures for Improving Weight of Evidence Through Identification of Additional Emission Reductions, Not Modeled, Including Tier 2.

To strengthen the weight of evidence and account for high modeled peaks, estimate additional measures that at a minimum bring the model estimated future design value to 124 ppb or below. This is done by first estimating a future design value using the model predicted peaks. Multiply the base design value by a ratio (average of model predicted peaks (across all days), after controls divided by before controls). The base design value is an average of three years of monitored design values that represent the modeled base case emissions. If the model estimated future design value is at or below 124 ppb, additional emission reductions should not be needed.

If the model estimated future design value is greater than 124 ppb, estimate additional measures by using two ratios 1) modeled change in design values to modeled change in emissions and 2) air quality design value changes to NET/local emissions changes between two reference years (e.g., 1990 and 1996). Do not include biogenic emissions. First, subtract 124 ppb from estimated future design value to identify additional ozone reduction needed. Then multiply each ratio by the ozone reduction needed to estimate additional VOC and NOx emission reductions needed to strengthen the weight of evidence argument for attainment. This results in the additional percent reduction needed from the 1990 emissions.

To calculate the level of emission reductions needed (in tons per day) multiple the 1990 base emissions by the percent reductions. This results in the total tons per day reduction which are additional reductions needed in the attainment year. To incorporate the impact of Tier 2 subtract the emission reduction estimates being applied towards attainment for Tier 2 from the additional reductions. The remaining reductions may be adjusted to reflect other unmodeled control measures which have been quantified. The following are more details of the procedures with examples.

Estimating Additional Emission Reductions

Each of the methods described in the remainder of this paper begins with a monitored ozone concentration which can be extrapolated to the attainment year and compared with the standard. If the attainment year concentration is over 124 ppb, the methods described in this paper can be used to estimate what would constitute additional emission reductions needed to support a weight of evidence argument for attainment. The differences among the methods lie in the factors used for this extrapolation. These are summarized in Table 1.

Both methods are based on the assumption that we can estimate the relationship between ozone and its precursors (VOC and NOx). We can estimate this relationship by either (1) comparing changes in model predicted ozone to changes in modeled emissions or (2) comparing changes in observed air quality to changes in actual emissions. Both methods for estimating a relationship are equally valid. Both have inherent uncertainty in estimates of emissions inventories and estimates of the change in ozone air quality. Utility of either method is dependent on the availability of data which shows a response in ozone due to a decrease in VOC and NOx emissions. For example, if an area wants to apply method 2 using the NET inventories for the 1990 and 1996 reference years, the VOC and NOx totals for the nonattainment area must show a decrease in VOC and NOx between 1990 and 1996. If this is not the case then use of the NET data for those two reference years in not appropriate.

Table 1. Summary of Methods for Estimating Additional Emission Reductions

Method	Ozone Concentration Being Extrapolated	Extrapolation Ratio (normalized reduction factor)
1	Future Air Quality Design Value	Change in modeled emissions From base to attainment year / Change in modeled concentration
2	Future Air Quality Design Value	Change in actual emissions Between two reference years / Change in monitored concentration

Estimate a Future Air Quality Design Value

Both methods make use of the results of past modeling to derive a modeled response of ozone design values to VOC and NOx controls to estimate a future air quality design value. Relative reduction factors are derived and used similarly to what is described in U.S. EPA, (1999), *Draft Guidance on the Use of Models and Other Analyses In Attainment Demonstrations for the 8-Hour Ozone NAAQS*, EPA-454/R-99-004. If the estimated future design value is < 124 ppb, no additional emission reductions are needed to strengthen the weight of evidence argument for attainment.

(1) Calculate an average (over all modeled days) predicted daily maximum (within the nonattainment area and the down wind plume, or domain wide) 1-hour ozone concentration, first with the base emissions (e.g., 1990) and then with the future emissions (e.g., 2007).

(2) Using results from step 1, calculate the relative reduction factor, RRF, by taking the ratio of the average daily maximum 1-hour ozone concentration obtained with future emissions to that obtained with the base emissions.

$$RRF = AVGf / AVGc \qquad (1)$$

where

AVGf = average (across all days) predicted daily maximum 1-hour ozone concentration for future emissions, ppb.

AVGc = average (across all days) predicted daily maximum 1-hour ozone concentration for base emissions, ppb.

(3) Calculate the base design value, DVB, as the average of 3 nonattainment area ozone design values that represent the period used to predict ozone for base emissions (e.g., if 1990 emissions are used, average design values for 1990, 1991 and 1992)[1]. The nonattainment area ozone design value is the maximum monitored design value from all sites in the nonattainment area.

(4) Estimate the future design value, DVF, for the nonattainment area as the product of the relative reductions factor (step 2) and the base design value (step 3). If the future design value is < 124 ppb additional emission reductions should not be needed, no additional steps are required. If the future design value is > 124 ppb proceed to apply method 1 and method 2 (below) to identify additional emission reductions.

<u>Example 1: Estimate Future Air Quality Design Value</u>

Given: Past results from modeling indicate predicted peaks (for three days) before controls in 1990 are 195, 180, and 165 ppb and after controls in 2007 are 155, 150 and 145 ppb. There are two monitor sites in the nonattainment area. The monitored air quality design values for each site are 185 and 176 in 1990, 145 and 152 in 1991, and 155 and 140 in 1992.

Find: Estimate the future air quality design value in 2007.

Solution:

(1) Compute the base and future average 1-hour daily maximum concentration. The average of the model predicted peaks (in and downwind of the nonattainment area) for the base before controls is: (195 + 180 + 165) / 3 = 180 ppb and for the future after controls is: (155 + 150 + 145) / 3 = 150 ppb.

(2) Using the results in step 1 the relative reduction factor is: 150/180 = 0.83.

(3) Determine the nonattainment area design values representative of the episode used in the base emissions and calculate the base design value. The nonattainment area design value for 1990 is MAX(185, 176) = 185, for 1991 is MAX(145, 152) = 152, and for 1992 is MAX (155, 140) = 155 ppb. The base ozone design value is (185 + 152 + 155) / 3 = 164 ppb.

(4) The estimated future design value is (0.83) (164) = 136 ppb

This is > 124 ppb, so we need to apply the following methods to determine additional emission reductions.

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[1]Note, 1990, 1991 and 1992 design values reflect observations for 1988-90, 1989-91, and 1990-92, respectively. All of these periods include “1990", the year of the base emissions.

Method 1: Estimate Additional Emission Reductions Using Modeled Responses

Method 1 uses the change in nonattainment area monitored base ozone design value and estimated future ozone design value along with changes in modeled emissions before controls (base emissions) and after controls (future emissions) to estimate additional emission reductions.

(1) Calculate the change in air quality design value by subtracting the estimated future design value (e.g., 2007) from the base air quality design value (e.g., 1990). Estimate the percent reduction in NOx emissions and VOC emissions which occurred within the nonattainment area before and after controls. Do not include biogenic emissions. Divide the percent reduction in NOx emissions by the change in the air quality design value and divide the percent reduction in VOC emissions by the change in the air quality design value. This step results in two reduction factors, one for changes in NOx emissions and one for changes in VOC emissions.

(2) Estimate the amount of additional ozone reduction needed by taking the difference between the future design value and 124 ppb, the maximum ozone design value consistent with meeting the NAAQS.

(3) Calculate additional necessary emission reductions by taking the product of each of the reduction factors (step 1) and the amount of ozone reduction needed (step 2).

<u>Example 2: Calculate reduction factor using model predictions and apply to model estimated future design value</u>

Given: Results from modeling used in Example 1 indicate an estimated future design value is 136 ppb and the monitored air quality ozone base design value representative of the nonattainment area is 164 ppb. The control strategy reflects a 30% reduction in VOC and a 35% reduction in NOx emissions. These reductions were obtained by comparing the modeled 1990 base emissions to the modeled 2007 attainment year emissions for the nonattainment area.

Find: The amount of additional VOC and NOx reduction needed to reduce the model estimated future design value to 124 ppb, so that a convincing weight of evidence argument can be made for attainment.

Solution:

(1) Calculate the change in air quality design value as 164 - 136 = 28 ppb. The estimated percent reduction in VOC and NOx are given 30% VOC and 35% NOx. The reduction factor for VOC is 30% / 28 ppb = 1%/ ppb and for NOx is 35% / 28 ppb = 1.2%/ ppb.

(2) The amount of additional ozone reduction needed is (136 - 124) = 12 ppb.

(3) Therefore, the additional reduction needed in VOC is (1%) (12) = 12% of the VOC emissions. And, the additional reduction needed in NOx emissions is (1.2%) (12) = 14% of the

NOx emissions.

Method 2: Estimate Additional Emission Reductions Using Observed Air Quality Changes

This method uses monitored ozone air quality design values and emissions estimates for the nonattainment area to calculate the reduction factors for VOC and NOx. These reduction factors are then applied to the model estimated future design value as calculated in Example 1 to estimate additional emission reductions.

(1) Calculate the percent reduction in NOx emissions and VOC emissions which occurred within the nonattainment area from an earlier year (e.g., 1990) to a more recent year (e.g., 1996). The National Emissions Trends (NET) inventory provides an example of these data. Do not include biogenic emissions.

(2) Calculate the change in the nonattainment area's ozone design value using the same reference years. To account for fluctuations in meteorology average three years of design values to estimate the design value for each of the reference years. The nonattainment area average design values are used to assess the observed change in air quality from the "early" time period to a "recent" time period. Monitors that were only online during one of these periods may not be representative of the actual change in air quality. Rationale for excluding a monitor should be documented.

(3) Divide the percent reduction in NOx emissions by the change in the area's ozone design value. Divide the percent reduction in VOC emissions by the change in the area's ozone design value. This step gives two reduction factors, one for changes in NOx emissions and one for changes in VOC emissions.

(4) Calculate the additional amount of ozone reduction needed by subtracting 124 ppb from the model estimated future design value (see Example 1).

(5) Calculate additional necessary emission reductions by taking the product of each of the reduction factors (step 1) and the amount of ozone reduction needed (step 2).

Example 3: Calculate reduction factor using change in ozone air quality design values and nonattainment area emissions, and apply to model estimated future design value

Given: There are two monitors in the nonattainment area. The monitored air quality design values for each site for reference years 1990 and 1996 are presented in Table 2. Emission reductions between 1990 and 1996 are 30% reduction in VOC and a 35% reduction in NOx emissions. These reductions were obtained by comparing the 1990 NET inventory to the 1996 NET inventory for the nonattainment area. The model estimated future design value in 2007 is 136 ppb.

Table 2. Air Quality Design Values (ppb)

Monitor	1990 Reference Year			1996 Reference Year		
	1990	1991	1992	1996	1997	1998
1	185	145	155	140	146	139
2	176	152	140	135	145	130

Find: The amount of additional VOC and NOx reduction needed to reduce the future design value to 124 ppb, so that a convincing weight of evidence argument can be made for attainment.

Solution:

(1) The estimated percent reduction in VOC and NOx are given 30% VOC and 35% NOx.

(2) Calculate the change in the nonattainment area's ozone design value.

Determine the design value for each reference year by first taking the maximum design from the two sites for each of three years and then averaging the three years design values. The nonattainment area's ozone design value for 1990 is (185 + 152 + 155) / 3 = 164 and for 1996 is (140 + 146 + 139) / 3 = 142 ppb. The change in air quality design value as 164 - 142 = 22 ppb.

(3) The reduction factor for VOC is 30% / 22 ppb = 1.36%/ ppb and for NOx is 35% / 22 ppb = 1.59%/ ppb.

(4) The amount of additional ozone reduction needed is (136 - 124) = 12 ppb.

(5) Therefore, the additional reduction needed in VOC is (1.36%) (12) = 16% of the VOC emissions. And, the additional reduction needed in NOx emissions is (1.59%) (12) = 19% of the NOx emissions.

Incorporate Tier 2 and other unmodeled control measures

Once the percent reductions for VOC and NOx have been determined they can be converted into tons per day reductions. Control measures used to address these additional reductions must be quantified as estimates in tons per day reductions and compared to the level of additional reductions needed. Sufficient additional measures have been identified when the total from all unmodeled controls are equal to or greater than the estimated additional reductions.

(1) Convert the estimated percent reduction in VOC and NOx to tons per day by taking the product of the percent reduction and the total emissions in the base case inventory for each category of emissions, VOC and NOx. This results in tons per day for VOC and tons per day for NOx. These are the additional level of controls needed.

(2) Subtract the Tier 2 emission reduction estimates being applied towards attainment from the additional level of controls for each category of emissions, VOC and NOx. All other unmodeled controls should be subtracted as well. Repeat this step until no additional reductions remain.

<u>Example 4: Adjust additional emission reductions to account for Tier 2</u>

Given: The nonattainment area total emissions in 1990 for VOC and NOx are 1197 tpd and 927 tpd, respectively. Also, as shown in Table 3 the estimated Tier 2 reductions in VOC and NOx are 10 tpd and 25 tpd, respectively. The estimated additional emission reductions are 16% VOC and 19% NOx, as calculated in example 3.

Table 3: Nonattainment Area Emissions Summary (tpd) without Tier 2								
	VOC				NOx			
Year	Point	Area	Mobile	Total	Point	Area	Mobile	Total
1990	400	447	350	1197	300	377	250	927
2007	241	282	200	723	150	312	125	587
Estimated Tier 2 Reduction =				10				25

Find: What are the additional emission reductions in tons per day still needed after incorporating Tier 2?

Solution:

(1) The additional reductions are (.16 * 1197 tpd) = 192 tpd for VOC and (.19 * 927) = 176 tpd for NOx.

(2) After subtracting Tier 2 reductions the remaining reductions are (192 - 10) = 182 tpd for VOC and (176 - 25) = 151 tpd for NOx.

Use of Results

The results from both methods should be considered along with other weight of evidence presented in the technical analyses for the attainment demonstration. For example, where model predicted peaks show greater improvement when low level NOx emissions are reduced verses VOC or elevated NOx, substituting an equal amount of low level NOx reductions for the VOC reductions is acceptable. Also, where modeling demonstrates substantial improvements in model predicted peaks when emission reductions are applied to adjacent counties, the area of controls may be extended to include adjacent counties. However, if emissions from adjacent counties are used they must be included in the total emissions for the base and future. Modeling the additional emission reductions would normally address these two example as well as the following: change in boundary conditions due to transport, location of emissions (such as point, area or mobile), elevated vs low level emission reductions, chemistry and wind flow patterns. Model sensitivity runs may be used to help identify the appropriate controls measures to fill the additional emission reductions needed to provide for attainment in the weight of evidence analyses.

For guidance on VOC and NOx substitution use the, "NOx Substitution Guidance", EPA 1993; "Transmittal of NOx Substitution Guidance", memorandum from John Seitz, 1993; "Clarification of Policy for Nitrogen Oxides (NOx) Substitution", memorandum from John Seitz, 1994; and "Guidance for Implementing the 1-Hour Ozone and Pre-Existing PM10 NAAQS", memorandum from Richard D. Wilson, 1997. The 1993 and 1994 guidance was primarily designed for the post-1996 rate of progress (3%/year VOC reduction) requirement and allowed NOx reductions to be substituted for the otherwise mandatory VOC reductions as long as the NOx reductions were shown to be consistent with the attainment demonstration (in other words, if the attainment demo relied only on VOC reductions, the area could not substitute NOx reductions for the 3%/year requirement, and if the attainment demo relied on both VOC & NOx reductions, NOx could be substituted in part). The 1994 guidance document (Guidance on the Post-1996 Rate-of-Progress Plan and the Attainment Demonstration, EPA-452/R-93-015, Jan. 1994) provided equations & procedures for calculating the amount of NOx reductions that could be substituted for VOC for the rate of progress requirements. Also, the 1997 guidance establishes the 100 & 200 km distances for substitution of emission reductions outside the nonattainment area. These documents are located on the EPA website: "www.epa.gov/ttn/oarpg/t1pgm.html".