Chapter 5: Cost Estimates

Synopsis

This chapter summarizes the data sources and methodology used to estimate the costs of attaining the alternative more stringent levels for the ozone primary standard analyzed in this RIA (bounds of the proposed range, 0.075 and 0.070 ppm, and the more stringent alternative of 0.065 ppm.[1]). The chapter presents cost estimates for the illustrative control strategy outlined in Chapter 3 (which uses currently available known controls). The control strategy discussion is followed by a presentation of estimates for the costs of the additional tons of emissions that are needed to move to full attainment of the alternate standards analyzed (methodology and numbers discussed in Chapter 4). For detailed analysis of the economic impacts of the 0.070 ppm control strategy as well as a description of EPA's computable general equilibrium model (EMPAX-CGE), please see Appendix 5.

As noted in Chapter 3, EPA first modeled a illustrative control strategy aimed at attaining a tighter standard of 0.070 ppm in 2020. These controls were insufficient to bring all areas into attainment with 0.070 ppm, and EPA then developed methodology to estimate additional tons of emissions needed to attain the bounds of the proposed range, 0.075 and 0.070 ppm, and the tighter alternative of 0.065 ppm. This chapter presents the costs associated with each portion of the control analysis, clearly identifying the relative costs of modeled versus extrapolated emissions reductions as well as providing an estimate of the total cost of reaching attainment nationwide. Section 5.1 summarizes the methodology and the engineering costs associated with applying known and supplemental controls to partially attain a 0.070 ppm alternative standard, incremental to reaching the current baseline (effectively 0.084ppm) in 2020.

Section 5.2 describes the methodology used to estimate the cost of extrapolated tons needed to reach attainment of the bounds of the proposed alternative standard (0.070 and 0.075 ppm, as well as the more stringent alternative of 0.065 ppm) and provides estimates of how much additional cost will be associated with moving from the modeled partial attainment scenario to the nationwide attainment scenario (see Chapter 4 for discussion of extrapolated tons needed to attain 0.075, 0.070, and 0.065 ppm). In general, EPA increased the tons required for each area using the same impact/ton estimate (5 ppb = 50,000 tons) and extrapolated cost approaches in order to estimate additional costs for reaching a standard level of 0.065 ppm as well as estimate cost savings for the 0.075 ppm standard level (compared to the 0.070 ppm case).

Section 5.3 then combines the results from Sections 5.1 and 5.2 to describe the total estimated cost of reaching attainment nationwide, including both the costs of modeled controls for reaching partial attainment (engineering costs) and the additional costs of tons of extrapolated emissions reductions needed to reach attainment.

The costs described in this chapter generally include the costs of purchasing, installing, and operating the referenced technologies. For a variety of reasons, actual control costs may vary

[1] The less stringent option analyzed, which is the current standard, or baseline, would not require additional costs and therefore costs for that level are not presented in this RIA.

from the estimates EPA presents here. As discussed throughout this report, the technologies and control strategies selected for analysis are illustrative of one way in which nonattainment areas could meet a revised standard. There are numerous ways to construct and evaluate potential control programs that would bring areas into attainment with alternative standards, and EPA anticipates that state and local governments will consider programs that are best suited for local conditions. Furthermore, based on past experience, EPA believes that it is reasonable to anticipate that the marginal cost of control will decline over time due to technological improvements and more widespread adoption of previously niche control technologies. Also, EPA recognizes the extrapolated portion of the cost estimates reflects substantial uncertainty about which sectors, and which technologies, might become available for cost-effective application in the future. This is explained in further detail in Section 5.4.

It is also important to recognize that the cost estimates are limited in their scope. Because we are not certain of the specific actions that states will take to design State Implementation Plans to meet the revised standards, we do not present estimated costs that government agencies may incur for managing the requirement and implementation of these control strategies or for offering incentives that may be necessary to encourage or motivate the implementation of the technologies, especially for technologies that are not necessarily market driven. This analysis does not assume specific control measures that would be required in order to implement these technologies on a regional or local level.

5.1 Modeled Controls

5.1.1 Sector methodology

5.1.1.1 Non-EGU Point and Area Sources: AirControlNET

After designing a national hypothetical control strategy to meet an alternative standard of 0.070 ppm using the methodology discussed in Chapter 3 (see sub-section 3.2.1), EPA used AirControlNET to estimate engineering control costs. AirControlNET calculates costs using three different methods: (1) by multiplying an average annualized cost-per-ton estimate against the total tons of a pollutant reduced to derive a total cost estimate; (2) by calculating cost using an equation that incorporates information regarding key plant information; or (3) by using both cost per ton and cost equations. Most control cost information within AirControlNET has been developed based on the cost-per-ton approach. This is because estimating cost using an equation requires more data, and parameters used in other non-cost per ton methods may not be readily available or broadly representative across sources within the emissions inventory. The costing equations used in AirControlNET require either plant capacity or stack flow to determine annual, capital and/or operating and maintenance (O&M) costs. Capital costs are converted to annual costs, in dollars per ton, using the capital recovery factor.[2] Applied controls and their respective costs are provided in Ozone NAAQS RIA docket.

The control strategy for Non-EGU Point and Area Sources incorporated cost-per-ton caps. These caps were pollutant specific and applicable only in the eastern U.S. portion of the analysis.

[2] For more information on this cost methodology and the role of AirControlNext, see Section 6 of the 2006 PM RIA, AirControlNET 4.1 Control Measures Documentation (Pechan, 2006b), or http://www.epa.gov/ttn/catc/products.html#cccinfo

For reductions of NOx emissions the cap was $16,000/ton. This was based upon the approximate benefit per ton of reductions in NOx, as well as an examination of the marginal cost curve for NOx reductions from these sectors. There were two controls whose cost per ton was greater than this cap, due to the large capital component of installing these controls. A similar process was followed for reductions from VOCs. The marginal cost curve was analyzed and there was a clear break in the curve at approximately $6,000/ton. At this cap, over sixty percent of the possible reductions are being controlled at less than thirty percent of the total cost of the VOC reductions.

Supplemental controls were applied in order to achieve the highest possible emission reduction from Non-EGU point and area sources. Supplemental control measures are those controls that are 1) applied in these analyses but are not found in AirControlNET, and 2) are in AirControlNET but whose data have been modified to better approximate their applicability to source categories in 2020. The controls and associated data such as control cost estimates not found in AirControlNET are taken from technical reports prepared to support preliminary 8-hour ozone State Implementation Plans (SIPs) prepared by States and from various reports prepared by the staffs of various local air quality regulatory agencies (e.g. Bay Area Air Quality Management District). The reports that are the sources of additional controls data are included within footnotes in the Chapter 3 Appendix. Modification of control data, including percent reduction levels and control cost data, in AirControlNET occurred as a result of a review of the nonEGU point and area NOx control measures by technical staff. The changes EPA supplied are provided later on in the chapter 3 appendix.

5.1.1.2 EGU Sources: The Integrated Planning Model

Costs for the electric power sector are estimated using the Integrated Planning Model (IPM). The model determines the least-cost means of meeting energy and peak demand requirements over a specified period, while complying with specified constraints, including air pollution regulations, transmission bottlenecks, fuel market restrictions, and plant-specific operational constraints. IPM is unique in its ability to provide an assessment that integrates power, environmental, and fuel markets. The model accounts for key operating or regulatory constraints (e.g. emission limits, transmission capabilities, renewable generation requirements, fuel market constraints) that are placed on the power, emissions, and fuel markets. IPM is particularly well-suited to consider complex treatment of emission regulations involving trading and banking of emission allowances, as well as traditional command-and-control emission policies.[3] Applied controls and their respective costs are provided in the docket. IPM is described in further detail in Appendix 3.

5.1.1.3 Onroad and Nonroad Mobile Sources

Cost information for mobile source controls was taken from studies conducted by EPA for previous rulemakings and studies conducted for development of voluntary and local measures

[3] The application of the 0.070 EGU control strategy results in NOx allowance price decreasing from $1340/ton in the base case to $715/ton. See Technical Support Document on EGU Control Strategies for more details. Further detailed information on IPM is available in Section 6 of the 2006 PM RIA or at http://www.epa.gov/airmarkets/epa-ipm

that could be used by state or local programs to assist in improving air quality. Applied controls and their respective costs are provided in the docket.

5.1.2 Known Controls— Cost by Sector

In this section, we provide engineering cost estimates of the control strategies identified in Chapter 3 that include control technologies on non-EGU stationary sources, area sources, EGUs, and onroad and nonroad mobile sources. Engineering costs generally refer to the capital equipment expense, the site preparation costs for the application, and annual operating and maintenance costs. The Appendix to this chapter provides economic impacts for these engineering costs and a more in-depth evaluation of how these engineering costs will impact society through a distributional analysis of changes in price and production levels in affected industries.

The economic impacts of the cost of these model controls was not included in this analysis. Incorporating the economic impact of the extrapolated portion of the costs was too uncertain to be included as part of these estimates, and it was determined best to keep the modeled and extrapolated costs on the same basis.

The total annualized cost of control in each sector in the control scenario is provided in Table 5.1. These numbers reflect the engineering costs across sectors annualized at an interest rate of 7 percent for control measures applied to non-EGU point, area, and mobile sources.[4] This interest rate is consistent with the guidance provided in the Office of Management and Budget's (OMB's) (2003) Circular A-4. Also consistent with that guidance, we provide annualized control costs for non-EGU point sources at a 3 percent discount rate to show the sensitivity of our annualized control costs to the choice of interest rate. Sufficient information on annualized capital calculations was not available for area source and mobile controls to provide a reliable 3 percent discount rate estimate. Therefore, with the exception of the 3 % Total Annualized Cost estimate on Table 5.1, cost estimates presented throughout the chapter are based on 7% discount rate data.

The total annualized engineering costs associated with the application of known and supplemental controls to reach a revised 0.070 ppm standard, incremental to the current standard, are approximately $3.9 billion.

[4] A different plant-specific interest rate is applied in estimating control costs within IPM. See PM RIA for details.

Table 5.1 Comparison of Modeled Control Costs Nationwide, by sector, for a 0.070 ppm control scenario[5]

Source Category	0.070 ppm Control Strategy		
	Total Cost ($B 1999)		Average Cost per Ton ($1999)
	East	**West**	
A. Electric Generating Units (EGU) Sector			
Controls for NOx Cap-and-Trade Program and Local Measures in Projected Nonattainment Areas	*$0.20*	*$0*	$2,000
Total	**$0.20**	**$0**	
B. Onroad	*$0.51*	*$0.11*	$2,300
C. Nonroad	*$0.09*	*$0.02*	$4,400
Total	**$0.60**	**$0.13**	
D. Non-EGU Sector			
Point Sources (Ex: Pulp & Paper, Iron & Steel, Cement, Chemical Manu.)	*$2.30*	*$0.34*	$3,600
E. Area Sector			
Area Sources (Ex: Res. Woodstoves, Agriculture)	*$0.31*	*$0.01*	$2,000
Total	**$2.6**	**$0.35**	
Total Annualized Costs (using a 7% interest rate)	**$3.90**		
Total Annualized Costs (using a 3% interest rate)[6]	**$3.60**		

5.1.3 Limitations and Uncertainties Associated with Engineering Cost Estimates

EPA bases its estimates of emissions control costs on the best available information from engineering studies of air pollution controls and has developed a reliable modeling framework for analyzing the cost, emissions changes, and other impacts of regulatory controls. The annualized cost estimates of the private compliance costs are meant to show the increase in production (engineering) costs to the various affected sectors in our control strategy analyses. To estimate these annualized costs, EPA uses conventional and widely-accepted approaches that are commonplace for estimating engineering costs in annual terms. However, our cost analysis is subject to uncertainties and limitations.

There are some unquantified costs that are not adequately captured in this illustrative analysis. These costs include the costs of federal and State administration of control programs, which we believe are less than the alternative of States developing approvable SIPs, securing EPA approval of those SIPs, and Federal/State enforcement. Additionally, control measure costs referred to as

[5] All estimates provided reflect the cost of a control strategy for 0.070 ppm, incremental to a 2020 baseline of compliance with the current standard of 0.084 ppm.
[6] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For this 0.070 ppm control strategy, data for calculating annualized costs at a 3% discount was only available for Non-EGU point sources. Therefore, the total annualized cost value presented in this referenced cell is an aggregation of costs at 3% and 7% discount rate.

"no cost" may require limited government agency resources for administration and oversight of the program not included in this analysis; those costs are generally outweighed by the saving to the industrial, commercial, or private sector. The Agency also did not consider transactional costs and/or effects on labor supply in the illustrative analysis.

The illustrative analysis does not take into account the potential for advancements in the capabilities of pollution control technologies as well as reductions in their costs over time. This is discussed in Section 5.4..

5.2 Extrapolated Costs

This section presents the results and methodology behind the extrapolated cost calculations of attainment of the alternate standards (the ends of the proposed range – 0.075 and 0.070ppm, and the more stringent alternative of 0.065ppm). Consistent with the rest of this RIA, this section presents two sets of results. The first reflects full attainment in 2020 in all locations except two areas of California, which are not required to attain the current standard until after 2020. This estimate includes costs for those two areas in California to attain their 2020 "glidepath" target. The second estimate is for California only, and includes California attaining its appropriate 2020 targets, plus the estimated additional costs that might result from full attainment in a year beyond 2020. As discussed in Chapter 3, the application of the 0.070 ppm control strategy was not successful in reaching nationwide attainment of the alternate ozone standards. Many areas remained in non-attainment for all three alternate standard scenarios; therefore, the engineering costs detailed in Section 5.1 represent only the costs of partial attainment.

The estimation of the costs of unidentified controls needed to reach attainment is inherently a difficult issue. The degree to which unspecified controls are needed to achieve attainment depends upon other variables in the analysis, such as attainment date assumptions. We will better understand the true scope of the issue in the future as states conduct detailed area-by-area analyses to determine available controls and attainment dates that are appropriate under the Clean Air Act. We do not attempt to determine attainment dates in this analysis.

In this draft RIA we use two different approaches to estimating the costs of unspecified control measures.[7] This reflects the difficulty in defining a "best" approach to this issue as well as the uncertainty related to the extrapolated costs. Our approaches have yet to be peer reviewed and reflect a range of views about the likely cost of future techniques and strategies that reduce air pollutant emissions. [The higher-cost estimation approaches are implicitly more pessimistic about prospects for technological advances that avoid large increases in the cost per ton of emission reduction relative to controls employed in the past.] A separate section discusses historical experience which has shown numerous technological advances in emission reduction technologies, and provides a few examples of today's emerging technologies. (See Section 5.4) We will continue to consider these issues between now and the publication of the final RIA for the final ozone NAAQS rule.

[7] One approach assumes the Marginal Cost of abatement increases at a constant rate. The other approach assumes a fixed cost for abatement tons and provides estimates for two fixed cost/ton values.

This section provides the additional costs of reaching nationwide full attainment of the alternate ozone standards utilizing three values: a lower fixed cost per ton estimate based on the majority of the known cost/ton control values, an upper fixed cost per ton estimate based on the cost of the last few known control measures used and an increasing marginal cost estimate similar to that used in the PM NAAQS Final RIA. In addition to presenting the full attainment cost, this section will provide the methodology behind each approach.

Prior to presenting the aforementioned full attainment costs, it is important to provide information from EPA's Science Advisory Board Council Advisory, dated June 8, 2007, on the issue of estimating costs of unidentified control measures. In that letter, the Council advises against any approach that deviates from using a fixed cost/ton estimate such as the increasing marginal cost approach provided below. This increasing marginal cost approach 'grows' extrapolated costs that have an unquantifiable level of uncertainty at a rate with an equivalent level of uncertainty. This approach is presented in this Proposal RIA in order to maintain a consistency with the PM NAAQS Final RIA cost extrapolation . EPA is going to reconsider its approach to estimating the full attainment costs in the final RIA, in light of this advice

> *812 Council Advisory, Direct Cost Report, Unidentified Measures (charge question 2.a)*
>
> *"The Project Team has been unable to identify measures that yield sufficient emission reductions to comply with the National Ambient Air Quality Standards (NAAQS) and relies on unidentified pollution control measures to make up the difference. Emission reductions attributed to unidentified measures appear to account for a large share of emission reductions required for a few large metropolitan areas but a relatively small share of emission reductions in other locations and nationwide.*
>
> *"The Council agrees with the Project Team that there is little credibility and hence limited value to assigning costs to these unidentified measures. It suggests taking great care in reporting cost estimates in cases where unidentified measures account for a significant share of emission reductions. At a minimum, the components of the total cost associated with identified and unidentified measures should be clearly distinguished. In some cases, it may be preferable to not quantify the costs of unidentified measures and to simply report the quantity and share of emissions reductions attributed to these measures.*
>
> *"When assigning costs to unidentified measures, the Council suggests that a simple, transparent method that is sensitive to the degree of uncertainty about these costs is best. Of the three approaches outlined, assuming a fixed cost/ton appears to be the simplest and most straightforward. Uncertainty might be represented using alternative fixed costs per ton of emissions avoided."*

5.2.1 Increasing Marginal Cost Methodology

This approach stems from the assumption that each unit of incremental reduction in non-attainment areas will result in an increase in cost per ton or marginal cost of abatement.

Therefore, EPA estimated constantly increasing marginal cost curves for emission reductions using cost per ton values from control strategy data in representative non-attainment areas. These curves were then used to estimate a cost of full attainment using the emission reduction targets detailed in Chapter 4 of this report.

5.2.1.1 Marginal Cost Regions

EPA grouped the non-attainment areas described in Chapter 4 along with their emission reduction targets into six regions of the country (Table 5.2) in order to acquire sufficient and representative data for deriving the slopes of the marginal cost curves. As a way of maintaining some consistency with the modeled controls and the economic impact analysis, the six regions were loosely based on EMPAX-CGE regions[8] with a few exceptions.

- Nonattainment areas in Virginia were grouped with the Northeast due to the fact that Northern Virginia is part of the Ozone Transport Region (OTR) which makes up the Northeast. Resources were not available to disaggregate states by counties.
- Nonattainment areas in Louisiana were grouped with Texas and Oklahoma (Plains region) due to the similarity in industry mix among those states.
- California was separated from the rest of the west due to the severity of the ozone problem in the state, the glide path targets unique to the state, and because EPA determined the rest of the west was not an ideal representation of California.

Table 5.2 Regions and Slopes for Extrapolated Costs

Region	Marginal Cost Slope
Northeast (OTR)	0.035
Midwest	0.045
Southeast	0.036
Plains (TX/LA)	0.033
West (Not CA)	0.152

[8] For more information on EMPAX-CGE regions, see Appendix 5.4. Data sets used to calculate the slopes of the marginal cost curve were not based on EMPAX-CGE modeling. The only similarity with EMPAX-CGE is the regional breakdown. Therefore, the extrapolated costs do not represent social costs in any way nor are they linked to the CGE baseline data, structure, or sector detail. Linking extrapolated costs to individual sectors is beyond the scope of this analysis.

CA	0.211

5.2.1.2 Derivation of the Marginal Cost Slopes

Due to the efficaciousness and efficiency of NOx controls compared to VOC controls, control strategy cost per ton data was acquired for each region using a selection criteria defined in Table 5.3 and applied in Ordinary Least Squares regression equations. Results of these equations provided the slope for the marginal cost curves. For each equation, the dependant variable (**Y** = cost/ton)[9] and was regressed conditional to (**X** = cumulative emissions reductions).[10]

$$\boldsymbol{Y} = c + \beta \boldsymbol{X} + e$$

c = constant
β = slope
e = residual

The intent of the regression equations was not necessarily to accurately capture the relation between cost/ton and cumulative reductions but instead it was to identify a slope that would provide a rough approximation of an increasing cost/ton rate as related to cumulative emission reductions. This slope would then provide an increasing cost/ton rate in the extrapolated portion of the costs that was equivalent to the rate observed under the modeled costs.

Table 5.3 Data Selection Criteria for Extrapolated Costs
1) Determine if area has sufficient NOx emissions remaining to reach attainment
2) If area has sufficient NOx remaining to reach attainment, then use NOx cost/ton data due to their cost effectiveness compared VOC controls
3) If area does not have sufficient NOx emissions to reach attainment, then include VOC controls in the data set if: • VOC controls were part of the control strategy for the area in question • VOC control cost/ton inclusions to the regression data set would significantly alter the value of the slope for the marginal cost curve derived using only NOx cost/ton data

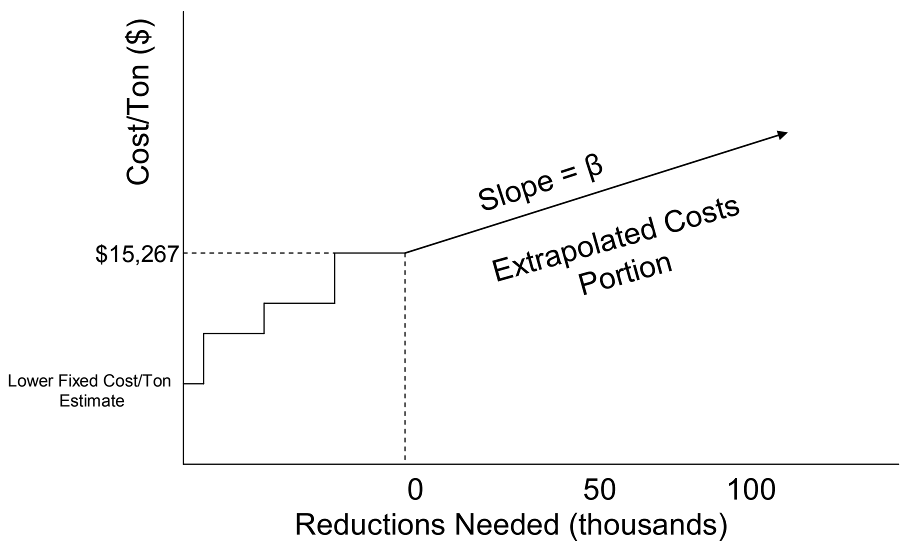
Note: Data analysis demonstrated that VOC control data would only be needed for California. Due to lack of available ozone data, NOx controls from California also include control cost from the PM NAAQS RIA control strategies.

[9] For the east regions, the full cost/ton data set was applied and had a maximum value of $15,267/ton. For the west, the cost/ton data was truncated at $15,267/ton in order to maintain a consistent comparison with the east regions and because the few remaining controls had costs greater $35,000/ton and were therefore judged to be less feasible.
[10] EPA recognizes that these regression equations may be misspecified. As stated above, the objective was not to accurately capture the relation between control cost/ton and emission reduction for statistical or economic inference purposes. These equations represent the most statistically adequate models that could be specified given the data, time, and resource constraints.

5.2.1.3 Calculating Extrapolated Costs Using Marginal Cost Approach

Once the slope of the marginal cost curve was derived, the extrapolation was calculated by multiplying that slope with the emission reduction target and adding that value to the highest of the observed cost/ton value (Figure 5.1). For this illustrative analysis, the highest of the observed cost/ton values was roughly $15,267/ton which represented the intercept of the marginal cost equation. Total costs could then be estimated by adding the area under the marginal cost curve in Figure 5.1 or by taking the integral of the marginal cost function and inputting the emission reduction target into the equation for total cost.[11]

Figure 5.1 Extrapolated Cost Example (MC Approach)



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5.2.2 Fixed Cost per Ton Values

Similar to the 1997 Ozone NAAQS RIA, a fixed cost/ton value was also applied to estimate the extrapolated costs of nationwide full attainment. Total costs for each non-attainment area was calculated by multiplying the fixed cost/ton value with the emission reduction targets for each region. For this particular illustrative analysis, a pair of fixed cost/ton values was used to calculate costs.

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[11] *Total Cost = $15,267x +* $(\beta/2)x^2$, where x = emission reduction target

5.2.2.1 Fixed Cost/Ton Methodology

NOx control strategy data for the East and West were examined for 'clustering' within their individual distributions. Cost/ton data for the east and west were stratified into thousands (Ex. $0-$1000, $1000-$2000,…) with individual source counts aggregated within each interval. California was separated from the west so source cost/ton counts were conducted separately for the state. This was the result of limited ozone NOx data availability for the state, the low number of NOx emissions remaining for CA, and the inclusion of ozone VOC controls as well as NOx controls from PM NAAQS RIA control strategies which were required to resolve these data and emissions issues.

For the East, 90% of the controls were below $6,000/ton. As a result, the control cost closest to $6,000/ton ($6,012) was selected to represent the cost of the majority of the modeled controls as well as the lower estimate of the Eastern fixed cost/ton approach. For the West, 94% of the controls had a cost/ton value below $4,000/ton. Therefore, $4,213 was selected as the lower estimate for the western fixed cost/ton approach. For California, the lower estimate was $9,035 using the same method but including VOC and PM NAAQS NOx control data from the PM NAAQS RIA hypothetical control scenario. This lower estimate for CA captured 81% of the cost/ton data below $15,267 and 65% of all cost/ton data for controls applied in the ozone and PM control strategies after multiplying VOC controls by a 4 to 1 substitution factor.

In addition to a lower fixed cost/ton estimate, an upper fixed cost/ton value was used for calculating extrapolated costs. This upper value as estimated at $15,267 for all regions for the following reasons.

- This value represented the highest, in terms of cost/ton, of the controls applied in the East. The East control strategy made up the majority of the modeled controls for the ozone standard.
- In the case of the West, the next highest controls were roughly $35,000 and $39,000 per ton. Controls with these costs were determined to be significantly less feasible to implement compared other controls.
- This value provides a consistent platform from which to incorporate and compare marginal cost values derived using the increasing marginal cost approach.

5.2.3 Results

Tables 5.4 to 5.6 provide the extrapolated cost values for 2020 attainment of the 0.075, 0.070, 0.065 ppm standards in each area (including the California 2020 glidepath targets) applying the increasing marginal cost value as well as the two fixed cost/ton values. The reader should be aware of the following stipulations prior to making inferences from the extrapolated costs presented in the following tables.

- The two extrapolated cost approaches provide nothing more than three rough estimates of potential costs with the marginal cost approach providing the highest value. Neither result includes a probability or a link to sectors where reductions will be attained.

Therefore, there are no expected values within this range of outcomes and no assumptions made about the types of controls that would be applied in 2020.

- 0.070 ppm extrapolated costs were estimated using data from the 0.070 ppm control strategy. Therefore, although the degree of uncertainty is still significant, these results can be expected to have a higher level of confidence than results for the 0.075 and 0.065 ppm alternate standards.
- The use of the 0.070 ppm control strategy as a starting point for extrapolating the 0.075 ppm standard resulted in over attainment of 0.075 ppm in some areas. For over attaining areas, cost savings and emission increases were extrapolated using the impact/ton estimates derived in Chapter 4 and their appropriate emission targets until reaching the 0.075 ppm standard.
- Several new non-attainment counties were added to the analysis as a result of moving to the 0.065 ppm alternate standard. Most of these counties were in states within the 0.070 ppm control strategy region described in Chapter 3. For the east, this region was made up of counties with 0.070 ppm violating monitors and their 200 km buffers which made up most of the eastern part of the US. In the west, this region was made up of six states (AZ, CA, CO, NM, NV, UT). Due to the geographic scope of the 0.070 control strategy, no additional controls were available and costs had to be extrapolated using the same impact/ton estimates applied in the 0.070 ppm estimates. Two new states were added to the non-attainment region (KS and AL). Since controls were available for these states, AirControlNET was used to identify controls that would achieve the required emission reduction targets.

Table 5.4 Extrapolated Costs of Meeting the 0.075 ppm Standard				
Extrapolated Costs for 075 Standard	**MC Curve Estimate ($M 1999)**	**Lower Fixed Cost/Ton Estimate ($M 1999)**	**Upper Fixed Cost/Ton Estimate* ($M 1999)**	**Cost/Ton Estimate of Last Control Applied on MC Curve Estimate ($ 1999)**
Extrapolated Costs				
CA – Los Angeles**	$0	$0	$0	
CA – Kern County**	$0	$0	$0	
Houston / Dallas	$1,254	$400	$1,008	$20,085
Ozone Transport Region	$1,307	$443	$1,114	$19,187
Lake Michigan region	$1,310	$449	$1,130	$19,362
Richmond / Norfolk	$790	$297	$748	$16,982
Detroit	$396	$152	$382	$16,392
Phoenix	$282	$72	$260	$17,851
Denver	$160	$42	$153	$16,787
Cleveland/Columbus/Cincinnati	$92	$36	$92	$15,537
Atlanta	$15	$6	$15	$15,303
Total Cost	$5,606	$1,896		
Extrapolated Cost Savings				
Baton Rouge, LA	($225)	($91)		
Indianapolis, IN	($209)	($85)		
Louisville, KY-IN	($284)	($115)		
St. Louis, MO-IL	($30)	($12)		
Total Cost Savings	($748)	($303)		
Total Extrapolated Cost	**$4,858**	**$1,593**		

*Due to the limited amount of controls in the modeled control strategy which had this value, deducting this amount would likely result in an over estimate of the savings.
** Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions expected by 2020 or earlier.

Table 5.5 Extrapolated Costs of Meeting the 0.070 ppm Standard				
Extrapolated Costs for 0.070 Standard	**MC Curve Estimate ($M 1999)**	**Lower Fixed Cost/Ton Estimate ($M 1999)**	**Upper Fixed Cost/Ton Estimate ($M 1999)**	**Cost/Ton Estimate of Last Control Applied on MC Curve Estimate ($ 1999)**
CA – Los Angeles **	$0	$0	$0	
CA – Kern County**	$829	$181	$305	$43,541
Houston / Dallas	$2,299	$703	$1,771	$21,735
Ozone Transport Region	$2,310	$746	$1,878	$20,937
Lake Michigan region	$2,334	$752	$1,893	$21,612
Richmond / Norfolk	$1,683	$600	$1,511	$18,732
Detroit	$1,272	$455	$1,145	$18,642
Phoenix	$1,364	$282	$1,023	$25,451
Denver	$1,190	$253	$916	$24,387
Cleveland/Columbus/Cincinnati	$926	$339	$855	$17,787
Atlanta	$825	$309	$779	$17,103
St. Louis	$785	$291	$733	$17,427
Indianapolis	$579	$218	$550	$16,887
Baton Rouge	$555	$212	$534	$16,422
Louisville	$491	$188	$473	$16,383
Memphis	$313	$121	$305	$15,987
Charlotte	$217	$85	$214	$15,771
Salt Lake City	$211	$55	$198	$17,243
Las Vegas	$177	$46	$168	$16,939
Tampa	$77	$30	$76	$15,447
Total Extrapolated Cost	**$18,441**	**$5,867**	**$15,328**	

* EPA was not able to estimate benefit changes when moving the standard from 0.070 to 0.075 for Memphis, Charlotte, Salt Lake City, Las Vegas, and Tampa. Therefore, in order to maintain a consistent comparison, cost savings were not estimated for these locations.
** Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions expected by 2020 or earlier.

Table 5.6 Extrapolated Costs of Meeting the 0.065 ppm Standard				
Extrapolated Costs for 065 Standard	**MC Curve Estimate ($M 1999)**	**Lower Fixed Cost/Ton Estimate ($M 1999)**	**Upper Fixed Cost/Ton Estimate ($M 1999)**	**Cost/Ton Estimate of Last Control Applied on MC Curve Estimate ($ 1999)**
CA – Los Angeles**	$0	$0	$0	$15,267
CA – Kern County**	$2,230	$452	$763	$49,871
Houston / Dallas	$3,427	$1,006	$2,534	$23,385
Ozone Transport Region	$3,401	$1,049	$2,641	$22,687
Lake Michigan region	$3,471	$1,055	$2,656	$23,862
Richmond / Norfolk	$2,663	$903	$2,275	$20,482
Detroit	$2,260	$758	$1,908	$20,892
Phoenix	$2,827	$493	$1,786	$33,051
Denver	$2,599	$463	$1,679	$31,987
Cleveland/Columbus/Cincinnati	$1,871	$643	$1,618	$20,037
Atlanta	$1,726	$612	$1,542	$18,903
St. Louis	$1,712	$594	$1,496	$19,677
Indianapolis	$1,479	$521	$1,313	$19,137
Baton Rouge	$1,417	$515	$1,298	$18,072
Louisville	$1,355	$491	$1,237	$18,183
Memphis	$1,157	$424	$1,069	$17,787
Charlotte	$1,051	$388	$977	$17,571
Salt Lake City	$1,263	$265	$962	$24,843
Las Vegas	$1,214	$257	$931	$24,539
Tampa	$894	$333	$840	$17,247
Jackson, MS	$757	$285	$718	$16,959
New Mexico areas (Farmington / Las Cruces)	$819	$185	$672	$21,955
OK areas (Tulsa, Marshall)	$704	$267	$672	$16,719
Huntington, WV-KY	$639	$242	$611	$16,707
El Paso, TX	$538	$206	$519	$16,389
Kansas City, MO/KS	$325	$142	$317	$16,122
Little Rock, AR	$442	$170	$427	$16,275
Mobile AL	$70	$70	$70	$16,239
Columbia, SC	$154	$61	$153	$15,627
Extrapolated Total	**$42,465**	**$12,851**	**$33,684**	

** Los Angeles and Kern Counties have expected attainment dates after 2020. This analysis counts the portion of reductions expected by 2020 or earlier.

5.3 Summary of costs

Table 5.7 presents a summary of the total national cost of attaining 0.075, 0.070, and 0.065 ppm standards in 2020 (including the California glidepath). This summary includes the costs presented above from the modeled controls and the extrapolated costs. The range presented in the extrapolated costs and the total costs represent the upper and lower bound cost estimates.

Table 5.7 Total Costs of Attainment in 2020 for Different Levels of the Ozone Standard (National Attainment in 2020)

	Level of Standard in 2020		
	0.065 ppm	0.070 ppm	0.075 ppm
Modeled Costs ($B)	$3.9	$3.9	$3.9
Extrapolated Costs ($B)	$13 to $42	$5.9 to $18	$1.6 to $4.9
Total Costs ($B)	$17 to $46	$10 to $22	$5.5 to $8.8

Table 5.8 presents an estimate of total costs for California only to attain the analyzed standards in a year beyond 2020. This includes the cost estimate to California to reach its glidepath targets by 2020; the increment beyond those targets to achieve full attainment in a year beyond 2020; and the sum of those two as the total estimated costs for California.

Table 5.8 California Extrapolated Costs ($M)

		0.075	**0.070**	**0.065**
CA (Glidepath)				
	Marginal Cost Approach	$0	$829	$2,230
	Lower Estimate (fixed cost)	$0	$181	$452
	Upper Estimate (fixed cost)	*	$305	$763
CA Increment Needed for Full Attainment	**Marginal Cost Approach**	$6,227	$12,022	$18,301
	Lower Estimate (fixed cost)	$1,050	$1,773	$2,405
	Upper Estimate (fixed cost)	*	$2,995	$4,064
CA (Full Attainment-Later Year)				
	Marginal Cost Approach	$6,227	$12,851	$20,530
	Lower Estimate (fixed cost)	$1,050	$1,953	$2,857
	Upper Estimate (fixed cost)	*	$3,301	$4,827

* Due to the limited amount of controls in the modeled control strategy which had this value, deducting this amount would likely result in an over estimate of the savings.

It is important to note that the national cost estimate for attainment in 2020, and the full California estimate cannot be combined. Tables 5.7 and 5.8 represent two different scenarios in two different years. EPA did the analysis this way because to force full attainment in an earlier year than would be required under the Clean Air Act would likely lead to an overstatement of costs because those areas might benefit from these existing federal or state programs that would be implemented between 2020 and the attainment year; because additional new technologies may become available between 2020 and the attainment year; or because the cost of existing technologies might fall over time. As such, we use the best available data to estimate costs and benefits of fully attaining in some future year, which is likely to be closer to the actual attainment date for these areas, while recognizing that the estimates of costs and benefits for California in a year between 2020 and some future year are likely to be relatively more uncertain compared with the national estimates for 2020. While adding the future year full attainment costs for California to the 2020 costs may give an idea of the overall magnitude of costs, it is not appropriate to use that combined estimate as a representation of the costs of full attainment in 2020 or of full attainment in some future year, because each estimate is based on different baseline conditions for emissions and air quality and represent different years.

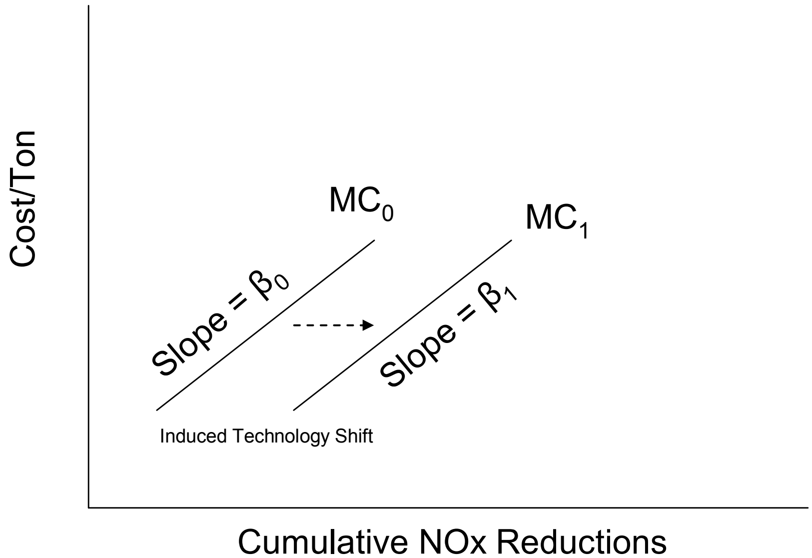
5.4 Technology Innovation and Regulatory Cost Estimates

The history of the Clean Air Act provides many examples in which technological innovation and "learning by doing" have made it possible to achieve greater emissions reductions than had been feasible earlier, or have reduced the costs of emission control in relation to original estimates. Innovative companies have successfully responded to the regulatory challenges and market opportunities provided by the Act, producing breakthrough technologies for multiple sectors. Studies[12] have suggested that costs of some EPA programs have been less than originally estimated due in part to inadequate inability to predict and account for future technological innovation in regulatory impact analyses.

A constantly increasing marginal cost curve similar to the one utilized for estimating extrapolated costs in this RIA is likely to induce the type of innovation that would result in lower costs than estimated early in this chapter. Breakthrough technologies in control equipment could by 2020 result in a rightward shift in the marginal cost curve (Figure 5.2)[13] as well as perhaps a decrease in its slope, reducing marginal costs per unit of abatement, and thus deviate from the assumption of one constantly increasing marginal cost curve. In addition, elevated abatement costs may result in significant increases in the cost of production and would likely induce production efficiencies, in particular those related to energy inputs, which would lower emissions from the production side.

[12] Harrinton et al ,2000, and previous studies cited by Harrington
[13] Figure 5.2 shows a linear marginal abatement cost curve. It is possible that the shape of the marginal abatement cost curve is non-linear.

Figure 5.2 Technological Innovation Reflected by Marginal Cost Shift



Examples of Technological Advances in Pollution Control

There are numerous examples of low-emission technologies developed and/or commercialized over the past 15 or 20 years, such as:

- Selective catalytic reduction (SCR) and ultra-low NOx burners for NOx emissions
- Scrubbers which achieve 95% and even greater SO2 control on boilers
- Sophisticated new valve seals and leak detection equipment for refineries and chemical plans
- Low or zero VOC paints, consumer products and cleaning processes
- CFC-free air conditioners, refrigerators, and solvents
- Water and power-based coatings to replace petroleum-based formulations
- Vehicles far cleaner than believed possible in the late 1980s due to improvements in evaporative controls, catalyst design and fuel control systems for light-duty vehicles; and treatment devices and retrofit technologies for heavy-duty engines
- Continued development of activated carbon injection (ACI) technology for control of mercury from electric generating units
- Development of integrated gasification combined cycle (IGCC) and ultra-super critical pulverized coal technologies for electricity generation
- Idle-reduction technologies for engines, including truck stop electrification efforts
- Market penetration of gas-electric hybrid vehicles, biodiesel and other clean fuels

These technologies were not commercially available two decades ago, and some were not even in existence. Yet today, all of these technologies are on the market, and many are widely employed. Several are key components of major pollution control programs,

Influence on Regulatory Cost Estimates

Studies indicate that it is not uncommon for pre-regulatory cost estimates to be higher than later estimates, in part because of inability to predict technological advances. Over longer time horizons, such as the time allowed for areas with high levels of ozone pollution to meet the ozone NAAQS, the opportunity for technical advances is greater.

- *Multi-rule study:* Harrington et al. of Resources for the Future (2000) conducted an analysis of the predicted and actual costs of 28 federal and state rules, including 21 issued by EPA and OSHA, and found a tendency for predicted costs to overstate actual implementation costs. Costs were considered accurate if they fell within the analysis error bounds or if they fall within 25 percent (greater or less than) the predicted amount. They found that predicted total costs were overestimated for 14 of the 28 rules, while total costs were underestimated for only three rules. Differences can result because of quantity differences (e.g., overestimate of pollution reductions) or differences in per-unit costs (e.g., cost per unit of pollution reduction). Per-unit costs of regulations were overestimated in 14 cases, while they were underestimated in six cases. In the case of EPA rules, the agency overestimated per-unit costs for five regulations, underestimated them for four regulations (three of these were relatively small pesticide rules), and accurately estimated them for four. Based on examination of eight economic incentive rules, "for those rules that employed economic incentive mechanisms, overestimation of per-unit costs seems to be the norm," the study said.

  Based on the case study results and existing literature, the authors identified technological innovation as one of five explanations of why predicted and actual regulatory cost estimates differ: "Most regulatory cost estimates ignore the possibility of technological innovation … Technical change is, after all, notoriously difficult to forecast … In numerous case studies actual compliance costs are lower than predicted because of unanticipated use of new technology."[14]

  It should be noted that many (though not all) of the EPA rules examined by Harrington had compliance dates of several years, which allowed a limited period for technical innovation. Much longer time periods (ranging up to 20 years) are allowed by the statute for meeting the ozone NAAQS in areas with high ozone levels, where a substantial fraction of the estimated cost in this analysis is incurred."

- *Acid Rain SO2 Trading Program*: Recent cost estimates of the Acid Rain SO2 trading program by Resources for the Future (RFF) and MIT have been as much as 83 percent lower than originally projected by EPA.[15] Note that the original EPA cost analysis also relied on an optimization model like IPM to approximate the results of emissions trading.

[14] Harrington et al., 2000.
[15] Carlson et al., 2000; Ellerman, 2003.

As noted in the RIA for the Clean Air Interstate Rule, the ex ante numbers in 1989 were an overestimate in part because of the limitation of economic modeling to predict technological improvement of pollution controls and other compliance options such as fuel switching. Harrington et al report that scrubbing turned out to be more efficient (95% removal vs. 80-85% removal) and more reliable (95% vs. 85% reliability) than expected, and that unanticipated opportunities arose to blend low and high sulfur coal in older boilers up to a 40/60 mixture, compared with the 5/95 mixture originally estimated.

Phase 2 Cost Estimates	
Ex ante estimates	\$2.7 to \$6.2 billion[16]
Ex post estimates	\$1.0 to \$1.4 billion

- *EPA Fuel Control Rules:* A 2002 study by two economists with EPA's Office of Transportation and Air Quality[17] examined EPA vehicle and fuels rules and found a general pattern that "all ex ante estimates tended to exceed actual price impacts, with the EPA estimates exceeding actual prices by the smallest amount." The paper notes that cost is not the same as price, but suggests that a comparison nonetheless can be instructive.[18] An example focusing on fuel rules is provided:

[16] 2010 Phase II cost estimate in \$1995.
[17] Anderson et al, 2002.
[18] The paper notes: "Cost is not the same as price. This simple statement reflects the fact that a lot happens between a producer's determination of manufacturing cost and its decisions about what the market will bear in terms of price change."

Table 5.9 Comparison of Inflation-Adjusted Estimated Costs and Actual Price Changes for EPA Fuel Control Rules[19]

	Inflation-adjusted Cost Estimates (c/gal)				Actual Price Changes (c/gal)
	EPA	DOE	API	Other	
Gasoline					
Phase 2 RVP Control (7.8 RVP - Summer) (1995$)	1.1		1.8		0.5
Reformulated Gasoline Phase 1 (1997$)	3.1-5.1	3.4-4.1	8.2-14.0	7.4 (CRA)	2.2
Reformulated Gasoline Phase 2 (Summer) (2000$)	4.6-6.8	7.6-10.2	10.8-19.4	12	7.2 (5.1, when corrected to 5yr MTBE price)
30 ppm sulfur gasoline (Tier 2)	1.7-1.9	2.9-3.4	2.6	5.7 (NPRA), 3.1 (AIAM)	N/A
Diesel					
500 ppm sulfur highway diesel fuel (1997$)	1.9-2.4			3.3 (NPRA)	2.2
15 ppm sulfur highway diesel fuel	4.5	4.2-6.0	6.2	4.2-6.1 (NPRA)	N/A

- *CFC Phase-Out:* EPA used a combination of regulatory, market based (i.e., a cap-and-trade system among manufacturers), and voluntary approaches to phase out the most harmful ozone depleting substances. This was done more efficiently than either EPA or industry originally anticipated. The phaseout for Class I substances was implemented 4-6 years faster, included 13 more chemicals, and cost 30 percent less than was predicted at the time the 1990 Clean Air Act Amendments were enacted.[20]

  The Harrington study states, "When the original cost analysis was performed for the CFC phase-out it was not anticipated that the hydrofluorocarbon HFC-134a could be substituted for CFC-12 in refrigeration. However, as Hammit (1997) notes, 'since 1991 most new U.S. automobile air conditioners have contained HFC-134a (a compound for which no commercial production technology was available in 1986) instead of CFC-12" (p.13). He cites a similar story for HCFRC-141b and 142b, which are currently substituting for CFC-11 in important foam-blowing applications."

[19] Anderson et al., 2002.
[20] Holmstead, 2002.

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