Chapter 6: Cost Analysis Approach and Results

Synopsis

This chapter describes our illustrative analysis of the engineering costs and monitoring costs associated with attaining the proposed alternative standards for the National Ambient Air Quality Standard (NAAQS) for NO_2. We present our analysis of these costs in four separate sections. Section 6.1 presents the cost estimates. Sections 6.2 and 6.3 summarize the illustrative economic and energy impacts of the proposed alternative standard, respectively, while Section 6.4 outlines the main limitations of the analysis. As mentioned previously, the analysis presented here represents an alternative standard of 50 pbb. We also intended to analyze 100 ppb, and 200 ppb, yet none of the counties in the current monitoring network were projected to exceed these alternative levels in our analysis year of 2020.

Section 6.1 breaks out discussion of cost estimates into five subsections. The first subsection summarizes the data and methods that we employed to estimate the costs associated with the control strategies outlined in Chapter 4. The second subsection presents county level estimates of the costs of identified controls associated with the regulatory alternatives examined in this RIA. Following this discussion, the third subsection describes the approach used to estimate the extrapolated costs of unspecified emission reductions that may be needed to comply with the alternative standards. The fourth subsection provides a brief discussion of the monitoring costs associated with the NAAQS. The fifth subsection provides the estimated total costs of the regulatory alternatives examined. This section concludes with a discussion of technological innovation and how that affects regulatory cost estimates.

It should be noted again that overall data limitations are very significant for this analysis. One critical area of uncertainty is the limited NO_2 monitoring network (discussed in chapter 2). Because monitors are present in only 409 counties nationwide, the universe of monitors exceeding the alternative NAAQS level of 50 ppb is very small—only six counties.

It is important to note also that this analysis does not attempt to estimate attainment or nonattainment for any areas of the country other than those counties currently served by one of the 409 monitors in the current network. Chapter 2 explains that the current network is focused on community-wide ambient levels of NO_2, and not near-roadway levels, which may be significantly higher, and the proposal also contains requirements for an NO_2 monitoring network that will include monitors near major roadways. We recognize that once a network of near-roadway monitors is put in place, more areas could find themselves exceeding the new hourly NO_2 NAAQS. However for this RIA analysis, we lack sufficient data to predict which counties might exceed the new NAAQS after implementation of a near-roadway monitoring network. Therefore we lack a credible analytic path to estimating costs and benefits for such a future scenario.

In addition, this chapter presents cost estimates associated with both identified control measures and unspecified emission reductions needed to reach attainment. Identified control measures include known measures for known sources that may be implemented to attain the alternative standard, whereas the achievement of unspecified emission reductions requires implementation of hypothetical additional measures in areas that would not attain the selected standard following the implementation of identified controls to known sources.

Note that the universe of sources achieving unspecified emission reductions beyond identified controls is not completely understood; therefore we are not able to identify known control devices or work practices to achieve these reductions. We calculated extrapolated costs for unspecified emission reductions using a fixed cost per ton approach. Section 6.1 below describes in more detail our approaches for estimating both the costs of identified controls and the extrapolated costs of unspecified emission reductions needed beyond identified controls.

As is discussed throughout this RIA, the technologies and control strategies selected for this analysis are illustrative of one approach that nonattainment areas may employ to comply with the revised NO_2 standard. Potential control programs may be designed and implemented in a number of ways, and EPA anticipates that State and Local governments will consider those programs that are best suited for local conditions. As such, the costs described in this chapter generally cover the annualized costs of purchasing, installing, and operating the referenced technologies. We also present monitoring costs. Because we are uncertain of the specific actions that State Agencies will take to design State Implementation Plans to meet the revised standard, we do not estimate the costs that government agencies may incur to implement these control strategies.

6.1 Engineering Cost Estimates

6.1.1 Data and Methods: Identified Control Costs

Consistent with the emissions control strategy analysis presented in Chapter 4, our analysis of the costs associated with the final NO_2 NAAQS focuses NOx emission controls for nonEGU, area, EGU, and mobile sources.

6.1.1.1 NonEGU Point and Area Sources

After designing the hypothetical control strategy using the methodology discussed in Chapter 4, EPA used AirControlNET to estimate engineering control costs for nonEGU and Area sources. AirControlNET calculates engineering 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 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 engineering costs 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 using the capital recovery factor (CRF)[1]. Where possible, cost calculations are used to calculate total annual control cost (TACC) which is a function of the capital (CC) and O&M costs. The capital recovery factor incorporates the interest rate and equipment life (in years) of the control equipment. Operating costs are calculated as a function of annual O&M and other variable costs. The resulting TACC equation is TACC = (CRF * CC) + O&M.

Engineering costs will differ based upon quantity of emissions reduced, plant capacity, or stack flow which can vary by emissions inventory year. Engineering costs will also differ by the year the costs are calculated for (i.e., 1999$ versus 2006$). For capital investment, we do not assume early capital investment in order to attain standards by 2020. For 2020, our estimate of annualized costs represents a “snapshot” of the annualized costs, which include annualized capital and O&M costs, for those controls included in our identified control strategy analysis. Our engineering cost analysis uses the equivalent uniform annual costs (EUAC) method, in which annualized costs are calculated based on the equipment life for the control measure along with the interest rate by use of the CRF as mentioned previously in this chapter. Annualized costs are estimated as equal for each year the control is expected to operate. Hence, our annualized costs for nonEGU point and area sources estimated for 2020 are the same whether the control measure is installed in 2019 or in 2010. We make no presumption of additional capital investment in years beyond 2020. The EUAC method is discussed in detail in

[1] For more information on this cost methodology and the role of AirControlNET, see Section 6 of the 2006 PM RIA, AirControlNET 4.1 Control Measures Documentation (Pechan, 2006b), or the EPA Air Pollution Control Cost Manual, Section 1, Chapter 2, found at http://www.epa.gov/ttn/catc/products.html#cccinfo.

the EPA Air Pollution Control Cost Manual[2]. Applied controls and their respective engineering costs are provided in the NO_2 NAAQS RIA docket.

6.1.1.2 EGU Sources: the Integrated Planning Model

The EGU analysis included in this RIA utilizes the latest version of IPM (v3.0) as part of the updated modeling platform. Results for EGU sources presented in this RIA do not reflect a new run from that model. Instead, we apply NO x controls to specific EGUs, and the data for these NOx controls are taken from the latest IPM version. IPM v3.0 includes input and model assumption updates in modeling the power sector and incorporates Federal and State rules and regulations adopted before September 2006 and various new source review (NSR) settlements. A detailed discussion of uncertainties associated with the EGU sector modeling can be found in the 2006 PM NAAQS RIA (pg. 3-50).

The economic modeling using IPM presented in this and other chapters has been developed for specific analyses of the power sector. EPA's modeling is based on its best judgment for various input assumptions that are uncertain, particularly assumptions for future fuel prices and electricity demand growth. To some degree, EPA addresses the uncertainty surrounding these two assumptions through sensitivity analyses. More detail on IPM can be found in the model documentation, which provides additional information on the assumptions discussed here as well as all other assumptions and inputs to the model[3].

IPM v3.0 includes SO_2, NOx, and mercury (Hg) emission control technology options for meeting existing and future federal, regional, and state, SO_2, NO_x and Hg emission limits. The NOx control technology options include Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR) systems. It is important to note that beyond these emission control options, IPM offers other compliance options for meeting emission limits. These include fuel switching, re-powering, and adjustments in the dispatching of electric generating units. Table 6.1 summarizes retrofit NOx emission control performance assumptions that are included in IPM v3.0.

[2] http://epa.gov/ttn/catc/products.html#cccinfo
[3] http://www.epa.gov/airmarkets/progsregs/epa-ipm.html

Table 6.1: Summary of Retrofit NOx Emission Control Performance Assumptions

	Selective Catalytic Reduction (SCR)		Selective Non-Catalytic Reduction (SNCR)	
Unit Type	**Coal**	**Oil/Gas[a]**	**Coal**	**Oil/Gas[a]**
Percent Removal	90% down to 0.06 lb/mmBtu	80%	35%	50%
Size Applicability	Units > 100 MW	Units > 25 MW	Units > 25 MW and Units < 200 MW	Units > 25 MW

[a] Controls to oil- or gas-fired EGUs are not applied as part of EGU control measures applied for this RIA. The control assumptions in this Table are taken from Khan, S. and Srivastava, R. "Updating Performance and Cost of NOx Control Technologies in the Integrated Planning Model," Mega Symposium, August 30-September 2, 2004, Washington, D.C.

Existing coal-fired units that are retrofit with SCR have a NOx removal efficiency of 90%, with a minimum controlled NOx emission rate of 0.06 lb/mmBtu in IPM v3.0. Detailed cost and performance derivations for NOx controls are discussed in detail in the EPA's documentation of IPM v. 3.0[4].

6.1.1.3 Onroad and Nonroad Mobile Sources

Engineering cost information for mobile source controls is identical to that provided in the recent Ozone NAAQS RIA[Error! Bookmark not defined.], and was taken from studies conducted by EPA for previous rulemakings and programs involving voluntary and local measures that could be used by state or local programs to assist in improving air quality.

Engineering costs, in terms of dollars per ton emissions reduced, were applied to emission reductions calculated for the onroad and nonroad mobile sectors that were generated using the National Mobile Inventory Model (NMIM). NMIM is an EPA model for estimating air emissions from highway vehicles and nonroad mobile equipment. NMIM uses current versions of EPA's model for onroad mobile sources, MOBILE6, and nonroad mobile sources, NONROAD, to calculate emission inventories[5].

6.1.2 Identified Control Strategy Analysis Engineering Costs

In this section, we provide engineering cost estimates of the control strategies identified in Chapter 4 that include control measures applied to nonEGU sources, area sources, EGUs, and onroad and nonroad mobile sources. Engineering costs generally refer to the capital equipment

[4] http://www.epa.gov/airmarkets/progsregs/epa-ipm/past-modeling.html.
[5] More information regarding the National Mobile Inventory Model (NMIM) can be found at http://www.epa.gov/otaq/nmim.htm

installation expense, the site preparation costs for the application, and annual operating and maintenance costs.

The total annualized cost of control in each geographic area of our analysis for the hypothetical control scenario is provided in Table 6.2. These numbers reflect the engineering costs across all sectors annualized at a discount rate of 7% and 3%, consistent with the guidance provided in the Office of Management and Budget's (OMB) (2003) Circular A-4. However, it is important to note that it is not possible to estimate both 7% and 3% discount rates for controls applied to every emissions sector. Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. In this RIA, the point source sectors were the only sectors with available data to perform a sensitivity analysis 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% discount rate estimate. Figure 6.1 does reveal that over two thirds of the costs of the identified control strategy are related to point sources. It is expected that the 3% discount rate value is slightly overestimated due to the addition of cost sectors at a higher discount rate. With the exception of the 3 % Total Annualized Cost estimate in Table 6.2, engineering cost estimates presented throughout this and subsequent chapters are based on a 7% discount rate.

Table 6.2 summarizes these costs by geographic area. As indicated in the table, the estimated costs of these controls under the 50 ppb alternative standard are $44 million per year, assuming a discount rate of seven percent. Applying a three percent discount rate this value becomes $36 million per year. Consistent with Chapter 4's summary of the air quality impacts associated with identified controls, the cost estimates in Table 6.2 reflect partial attainment with the alternative standard being examined in this RIA. Table 6.3 represents the average cost per ton of the applied controls by geographic area. These costs range from $800 to approximately $4,000 per ton using a discount rate of seven percent. Table 6.4 presents the average cost per ton by emissions sector for this analysis. Figure 6.1 indicates the percentage of the costs by emissions sector. Consistent with the identified control strategy analysis emission reductions presented in Chapter 4, a majority of the costs are from point source controls applied to both nonEGU and EGU sources.

Table 6.2: Annual Control Costs of Identified Controls applied for the Alternative Standard Analysis of 50 ppb (Millions of 2006$) [a, b]

State	County	3% Discount Rate[c]	7% Discount Rate
CA	Los Angeles	-[d]	-[d]
CO	Adams	$14	$18
LA	East Baton Rouge	$6.6	$8.3
TX	El Paso	$9.0[d]	$10[d]
UT	Salt Lake	$6.9	$7.7
VA	Charles City	$0.03	$0.04
	Total	**$36**	**$44**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.
[c] 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 identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.
[d] These values represent partial attainment costs for the identified control strategy analysis. These locations were not able to attain the alternative standard being analyzed with identified controls only.

Table 6.3: Annual Cost per Ton of Identified Controls applied for the Alternative Standard Analysis of 50 ppb by Geographic Area (2006$) [a, b]

State	County	3% Discount Rate[c]	7% Discount Rate
CA	Los Angeles	-	-
CO	Adams	$1,600	$2,100
LA	East Baton Rouge	$1,200	$1,600
TX	El Paso	$3,400	$3,900
UT	Salt Lake	$1,500	$1,700
VA	Charles City	$700	$800

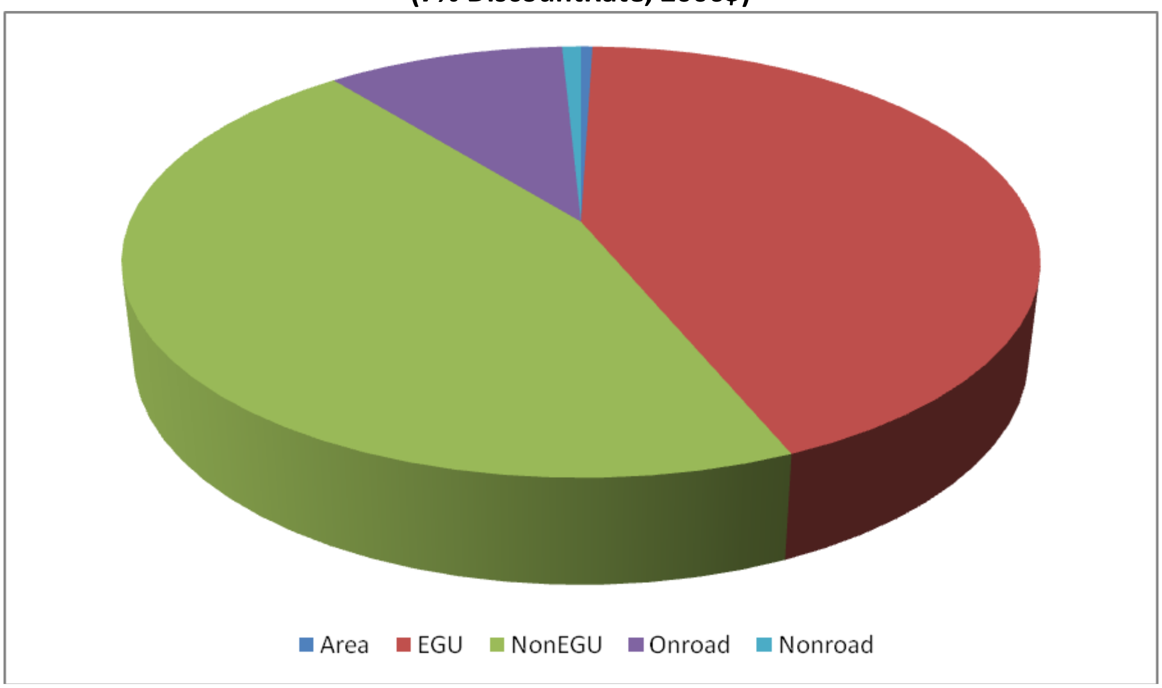
[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.
[c] Total annualized costs were calculated using a 3% discount rate for controls which had a capital component and where equipment life values were available. For this identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

Table 6.4: Annual Cost per Ton of Identified Controls applied for the Alternative Standard Analysis of 50 ppb by Emissions Sector (2006$) [a, b]

Emissions Sector	3% Discount Rate[c]	7% Discount Rate
NonEGU	$1,800	$2,200
Area	$1,800	$1,800
Onroad	$1,900	$1,900
Nonroad	$4,300	$4,300
EGU	$1,600	$2,000

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.
[c] 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 identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.

Figure 6.1: Percentage of Identified Control Costs by Emissions Sector (7% DiscountRate, 2006$)



6.1.3 Extrapolated Costs

Prior to presenting the methodology for estimating costs for unspecified emission reductions, it is important to provide information from EPA's Science Advisory Board Council Advisory on the issue of estimating costs of unidentified control measures.[6]

> *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*

[6] U.S. Environmental Protection Agency, Advisory Council on Clean Air Compliance Analysis (COUNCIL), *Council Advisory on OAR's Direct Cost Report and Uncertainty Analysis Plan*, Washington, DC. June 8, 2007.

simplest and most straightforward. Uncertainty might be represented using alternative fixed costs per ton of emissions avoided."

EPA has considered this advice and the requirements of E.O. 12866 and OMB circular A-4, which provides guidance on the estimation of benefits and costs of regulations.

As indicated above the identified control costs do not result in attainment of the selected or alternative standards in two areas. In these areas, unspecified emission reductions needed beyond identified controls will likely be necessary to reach attainment. Emission reductions needed beyond identified controls is an issue for Los Angeles County and El Paso County. Unfortunately all identified emission control measures were exhausted for Los Angeles County during the hypothetical controls analysis of the Ozone NAAQS. Due to the complete lack of data on potential additional control measures to be applied in Los Angeles County and very limited data for El Paso County, establishing a credible method to cost emission reductions needed beyond identified potential controls is an extremely challenging task.

Regarding Los Angeles County, it should be noted that the California Air Resources (CARB) included a number of control measures to reduce emissions at the Port of Los Angeles and the Port of Long Beach in its 2007 state implementation plan (SIP) that addresses the 8-hour ozone and PM2.5 nonattainment problems in the South Coast nonattainment area. These control measures are expected to result in significant NOx emission reductions, but are not reflected in this analysis due to data and resource limitations. See the discussion in Chapter 3 for more details on local control programs underway in southern California.

Taking into consideration the above SAB advice we estimated the costs of unspecified future emission reductions using a fixed cost per ton approach. In previous analyses we have estimated the extrapolated costs using other marginal cost based approaches in addition to the fixed cost per ton approach (the dataset of applied NOx control measures was much more robust for the recent Ozone NAAQS RIA[Error! Bookmark not defined.]). We examine the data available for each analysis and determine on a case by case basis the appropriate extrapolation technique. Less than fifty control measures were applied in the analysis across the six geographic areas analyzed for the area-wide analysis. During the ozone NAAQS analysis the dataset used to calculate extrapolated costs contained many thousand observations. Due to the limited number of control measures applied in this analysis, we concluded that it would not be credible to establish a marginal cost-based approach or a representative value for the costs of further NOx emission reductions.

Another consideration for this analysis is the unique circumstances (Chapter 3, Sections 3.3.2.2 and 3.3.2.3) for Los Angeles and El Paso. These two geographic areas have specific local conditions that may affect their ability to attain any alternative NO_2 standard. The Los Angeles County monitor appears to be affected significantly by port emissions. The Port of Long Beach is currently undertaking its own significant action to reduce both NOx and PM emissions from ships, trucks, trains, and cargo-handling equipment. The nature of these controls appear to be most similar to the types of mobile controls used elsewhere in this analysis; therefore we considered applying the average cost of these controls instead of a higher fixed cost per ton. We decided, however, that we did not have enough information about these controls to assign them emission reductions or definite costs. The nature of these controls appear to be primarily mobile sources also affected our consideration of applying a version of the "hybrid" approach to the extrapolated costs used in the ozone NAAQS RIA. We ultimately decided against applying the "hybrid" cost approach for this analysis since that estimate was based primarily on nonEGU point source control costs. Additionally, the El Paso monitors are very close to the international border with the city of Juarez just to the southwest, and emissions from across the international border could affect the modeled monitor concentrations. In the past, state implementation plan (SIP) policy has allowed for a waiver of full attainment in similar instances.

Therefore the extrapolated costs presented here are perhaps misnamed, in that they represent a lack of information regarding known control or other strategies that may be implemented in Los Angeles and El Paso, and do not necessarily represent unknown control measures that will need to be developed in the future for these areas to attain the alternative standard analyzed. For these reasons, we have relied upon a simple fixed cost approach utilized for the ozone NAAQS analysis to represent the fixed cost of unspecified emission reductions for this analysis. The primary estimate presented is $15,000 (2006$), with sensitivities of $10,000/ton and $20,000/ton. The $15,000 per ton amount is commensurate with that used in the Ozone NAAQS RIA[Error! Bookmark not defined.] using 2006 dollars. The ozone NAAQS estimated the central estimate through averaging the control measure dataset cost per ton utilized in that analyses as well as looking into previous EPA analyses where NOx control measures were applied. In addition, the use of a fixed cost per ton is consistent with what an advisory committee to the Section 812 second prospective analysis on the Clean Air Act

Amendments suggested. In addition, we scanned the most recent NOx emission trades on California's Regional Clean Air Incentives Market (RECLAIM) Program website[7]. These trading values were less than the primary estimate presented in this RIA.

The estimation of engineering costs for unspecified emission reductions needed to reach attainment many years in the future is inherently a difficult issue. The universe of sources where unspecified emission reductions beyond identified controls are achieved is not completely understood; therefore, we are not able to identify known control devices or work practices to achieve these reductions. We expect that additional control measures that we were not able to identify may be available today, or may be developed by 2020. As described later in this chapter, our experience with Clean Air Act implementation shows that technological advances and development of innovative strategies can make possible emissions reductions that are unforeseen today, and to reduce costs of emerging technologies over time. But we cannot quantitatively predict the amount of technology advance in the future. For areas needing significant additional emission reductions, much of the control must be for sources that historically have not been controlled. The relationship of the cost of such control to the cost of control options available today is not at all clear. Available, current known control measures increase in cost beyond the range of what has ever been implemented and would still not provide the needed additional control for full attainment in the analysis year 2020. We recognize that a single fixed cost of control does not account for the different sets of conditions that might describe situations where controls are needed beyond identified controls. Yet, the limited emission controls dataset applied for the identified control strategy analysis does not enable us the ability to estimate extrapolated costs using more sophisticated methods.

We have utilized the fixed cost per ton for this proposed rule RIA, however, Chapter 7 contains a basic analysis of attainment for different standards for a hypothetical near roadway network using simple assumptions regarding the relationship between area and roadway monitors. We will continue to develop this analysis, including identifying specific control measures to illustrate attainment in counties that are projected to violate a new NO_2 standard in 2020. We will investigate alternative options for extrapolating costs of attainment in the final NO_2 NAAQS RIA if the dataset and information is more robust and enables us to credibly extrapolate unknown control costs.

[7] http://www.aqmd.gov/RECLAIM/rtc_main.html; page last updated March 31, 2009, data for previous 3 months.

Table 6.5 presents the extrapolated costs for Los Angeles and El Paso. For the primary estimate using the fixed cost of $15,000/ton, over 77% of the extrapolated costs are attributed to Los Angeles County. Both Los Angeles and El Paso have unique air quality situations which contribute to the projected nonattainment for these counties. See Chapter 4 for a complete discussion of the air quality projections for these counties.

Table 6.5: Extrapolated Costs applied for the Alternative Standard Analysis of 50 ppb (Millions of 2006$) [a, b]

State	County	$10,000/ton	**$15,000/ton**	$20,000/ton
CA	Los Angeles	$180	**$270**	$360
TX	El Paso	$56	**$84**	$112
	Total	$240	**$350**	$470

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] Estimates of extrapolated costs are assumed using a 7% discount rate. Given the fixed cost per ton approach used here, 3% discount rate estimates could not be calculated.

6.1.4 Monitoring Costs

The proposed amendments would revise the technical requirements for NO2 monitoring sites, require the siting and operation of additional NO2 ambient air monitors, and the reporting of the collected ambient NO2 monitoring data to EPA's Air Quality System (AQS). We have estimated the burden based on the proposed monitoring requirements of this rule. Details of the burden estimate are contained in the information collection request (ICR) accompanying the proposed rule.[8] The ICR estimates annualized costs of a new monitoring network at approximately $7.1 million per year.

6.1.5 Summary of Cost Estimates

Table 6.6 provides a summary of total costs to achieve the alternative standard of 50 ppb in the year 2020. Figures 6.2 and 6.3 present the portion of total costs that is represented by identified controls and the portion of costs that is represented by extrapolated costs for unspecified emission reductions.

The significant difference between the costs of identified controls alone and the cost of achieving attainment (i.e. including both identified controls and emission reductions beyond identified controls) in this and other areas reflects the limited information available to EPA on the control measures that sources may implement. Although AirControlNET contains information on a large number of different point source controls, we would expect that State and local air quality managers would have access to additional information on the controls available to the most significant sources.

[8] ICR 2358.01, May 2009.

Table 6.6: Total Costs for Alternative Standard 50 ppb (Millions of 2006$)[a, b]

		3% Discount Rate[c]	7% Discount Rate
Identified Control Costs		$36	$44
Monitoring Costs		$3.6[d]	$3.6[d]
Extrapolated Costs	Fixed Cost ($10,000/ton)	$240	$240
	Fixed Cost ($15,000/ton)	$350	$350
	Fixed Cost ($20,000/ton)	$470	$470
Total Costs	Fixed Cost ($10,000/ton)	$280	$280
	Fixed Cost ($15,000/ton)	**$390**	**$400**
	Fixed Cost ($20,000/ton)	$510	$520

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.
[c] 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 the identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized identified control cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.
[d] These numbers do not represent a different discount rate for 3% and 7%.

Figure 6.2: Identified Control Costs versus Extrapolated Costs (Fixed Cost $15,000/ton) by County (Millions of $2006)

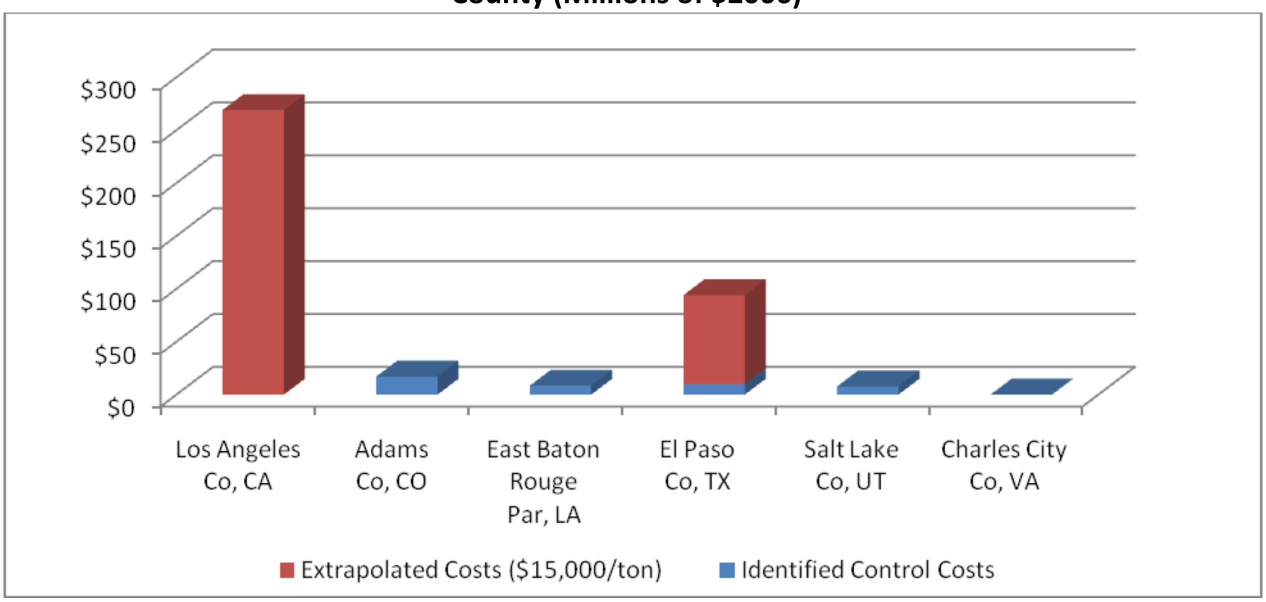
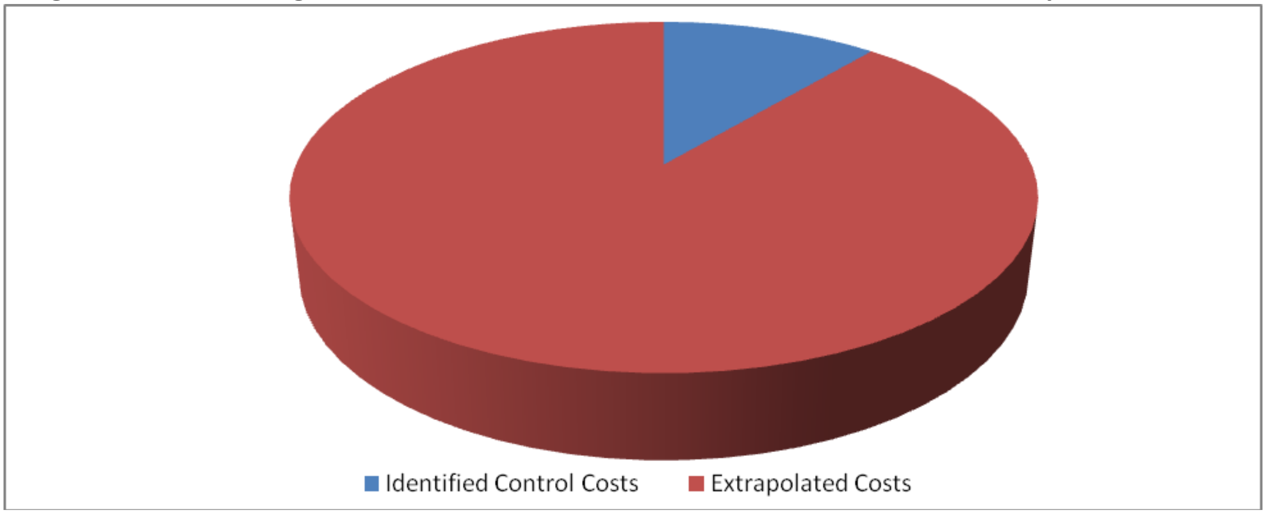


Figure 6.3: Percentage of Total Costs for Identified Control Costs versus Extrapolated Costs

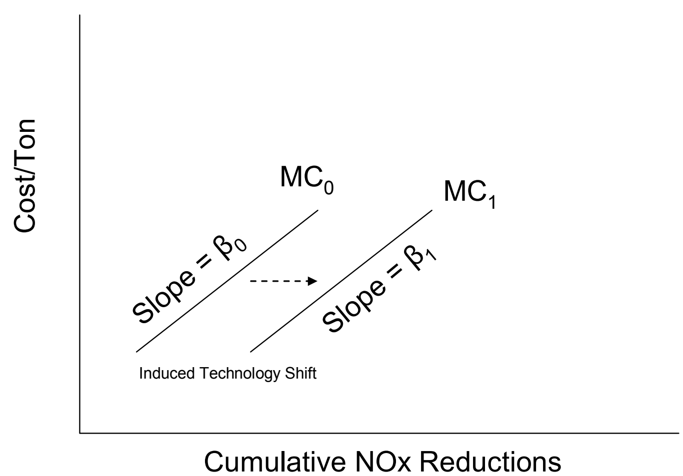


6.1.6 Technology Innovation and Regulatory Cost Estimates

There are 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. Studies[9] 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.

Constantly increasing marginal costs are 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 for such equipment (Figure 6.4)[10] as well as perhaps a decrease in its slope, reducing marginal costs per unit of abatement, and thus deviate from the assumption of a static 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.

Figure 6.4: Technological Innovation Reflected by Marginal Cost Shift



[9] Harrington et al. (2000) and previous studies cited by Harrington.
Harrington, W., R.D. Morgenstern, and P. Nelson. 2000. "On the Accuracy of Regulatory Cost Estimates." *Journal of Policy Analysis and Management* 19(2):297-322.

[10] 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.

6.1.6.1 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
- Chlorofluorocarbon (*CFC)* free air conditioners, refrigerators, and solvents
- Water and powder-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
- Idle-reduction technologies for engines, including truck stop electrification efforts
- Market penetration of gas-electric hybrid vehicles, and clean fuels
- The development of retrofit technology to reduce emissions from in-use vehicles and non-road equipment

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 and most of the examples are discussed further below.

What is known as “learning by doing” or “learning curve impacts”, which is a concept distinct from technological innovation, has also 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. Learning curve impacts can be defined generally as the extent to which variable costs (of production and/or pollution control) decline as firms gain experience with a specific technology. Such impacts have been identified to occur in a number of studies conducted for various production processes. Impacts such as these would manifest themselves as a lowering of expected costs for operation of technologies in the future below what they may have been.

The magnitude of learning curve impacts on pollution control costs has been estimated for a variety of sectors as part of the cost analyses done for the Draft Direct Cost Report for the second EPA Section 812 Prospective Analysis of the Clean Air Act Amendments of 1990.[11] In that report, learning curve adjustments were included for those sectors and technologies for which learning curve data was available. A typical learning curve adjustment example is to reduce either capital or O&M costs by a certain percentage given a doubling of output from that sector or for that technology. In other words, capital or O&M costs will be reduced by some percentage for every doubling of output for the given sector or technology.

T.P. Wright, in 1936, was the first to characterize the relationship between increased productivity and cumulative production. He analyzed man-hours required to assemble successive airplane bodies. He suggested the relationship is a log linear function, since he observed a constant linear reduction in man-hours every time the total number of airplanes assembled was doubled. The relationship he devised between number assembled and assembly time is called Wright's Equation (Gumerman and Marnay, 2004)[12]. This equation, shown below, has been shown to be widely applicable in manufacturing:

$$\text{Wright's Equation: } C_N = C_o * N^b,$$

Where:

N	=	cumulative production
C_N	=	cost to produce N^{th} unit of capacity
C_o	=	cost to produce the first unit
B	=	learning parameter = ln (1-LR)/ln(2), where
LR	=	learning by doing rate, or cost reduction per doubling of capacity or output.

The percentage adjustments to costs can range from 5 to 20 percent, depending on the sector and technology. Learning curve adjustments were prepared in a memo by IEc supplied to US EPA and applied for the mobile source sector (both onroad and nonroad) and for application of various EGU control technologies within the Draft Direct Cost Report.[13] Advice received from the SAB Advisory Council on Clean Air Compliance Analysis in June 2007 indicated an interest in

[11] E.H. Pechan and Associates and Industrial Economics, Direct Cost Estimates for the Clean Air Act Second Section 812 Prospective Analysis: Draft Report, prepared for U.S. EPA, Office of Air and Radiation, February 2007. Available at http://www.epa.gov/oar/sect812/mar07/direct_cost_draft.pdf.

[12] Gumerman, Etan and Marnay, Chris. Learning and Cost Reductions for Generating Technologies in the National Energy Modeling System (NEMS), Ernest Orlando Lawrence Berkeley National Laboratory, University of California at Berkeley, Berkeley, CA. January 2004, LBNL-52559.

[13] Industrial Economics, Inc. Proposed Approach for Expanding the Treatment of Learning Curve Impacts for the Second Section 812 Prospective Analysis: Memorandum, prepared for U.S. EPA, Office of Air and Radiation, August 13, 2007.

expanding the treatment of learning curves to those portions of the cost analysis for which no learning curve impact data are currently available. Examples of these sectors are non-EGU point sources and area sources. The memo by IEc outlined various approaches by which learning curve impacts can be addressed for those sectors. The recommended learning curve impact adjustment for virtually every sector considered in the Draft Direct Cost Report is a 10% reduction in O&M costs for two doubling of cumulative output, with proxies such as cumulative fuel sales or cumulative emission reductions being used when output data was unavailable.

For this RIA, we do not have the necessary data for cumulative output, fuel sales, or emission reductions for sectors included in our analysis in order to properly generate control costs that reflect learning curve impacts. Clearly, the effect of including these impacts would be to lower our estimates of costs for our control strategies in 2020, but we are not able to include such an analysis in this RIA.

6.1.6.2 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 the opportunity for technical advances is greater.

- *Multi-rule study:* Harrington et al. of Resources for the Future[14] conducted an analysis of the predicted and actual costs of 28 federal and state rules, including 21 issued by EPA and the Occupational Safety and Health Administration (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. It is worth noting here, that the controls applied for this NAAQS do not

[14] Harrington, W., R.D. Morgenstern, and P. Nelson. 2000. "On the Accuracy of Regulatory Cost Estimates." *Journal of Policy Analysis and Management* 19(2):297-322.

use an economic incentive mechanism. In addition, Harrington also states that overestimation of total costs can be due to error in the quantity of emission reductions achieved, which would also cause the benefits to be overestimated.

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.”

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.

- *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] 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. The fuel switching from high-sulfur to low-sulfur coal was spurred by a reduction in rail transportation costs due to deregulation of rail rates during the 1990’s 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[a]
Ex post estimates	$1.0 to $1.4 billion
[a] 2010 Phase II cost estimate in 1995$.	

- *EPA Fuel Control Rules:* A 2002 study by EPA’s Office of Transportation and Air Quality[16] examined EPA vehicle and fuels rules and found a general pattern that “all ex ante

[15] Carlson, Curtis, Dallas R. Burtraw, Maureen, Cropper, and Karen L. Palmer. 2000. “Sulfur Dioxide Control by Electric Utilities: What Are the Gains from Trade?” *Journal of Political Economy* 108(#6):1292-1326.
Ellerman, Denny. January 2003. Ex Post Evaluation of Tradable Permits: The U.S. SO2 Cap-and-Trade Program. Massachusetts Institute of Technology Center for Energy and Environmental Policy Research.

[16] Anderson, J.F., and Sherwood, T., 2002. “Comparison of EPA and Other Estimates of Mobile Source Rule Costs to Actual Price Changes,” Office of Transportation and Air Quality, U.S. Environmental Protection Agency. Technical Paper published by the Society of Automotive Engineers. SAE 2002-01-1980.

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.[17] An example focusing on fuel rules is provided:

Table 6.7: Comparison of Inflation-Adjusted Estimated Costs and Actual Price Changes for EPA Fuel Control Rules[a]

	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

[a] Anderson, J.F., and Sherwood, T., 2002. "Comparison of EPA and Other Estimates of Mobile Source Rule Costs to Actual Price Changes," Office of Transportation and Air Quality, U.S. Environmental Protection Agency. Technical Paper published by the Society of Automotive Engineers. SAE 2002-01-1980.

- Chlorofluorocarbon (*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.[18]

[17] 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."

[18] Holmstead, Jeffrey, 2002. "Testimony of Jeffrey Holmstead, Assistant Administrator, Office of Air and Radiation, U.S. Environmental Protection Agency, Before the Subcommittee on Energy and air Quality of the committee on Energy and Commerce, U.S. House of Representatives, May 1, 2002, p. 10.

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[19] 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."

- Additional examples of decreasing costs of emissions controls include: SCR catalyst costs decreasing from \$11k-\$14k/m^3 in 1998 to \$3.5k-\$5k/m^3 in 2004, and improved low NOx burners reduced emissions by 50% from 1993-2003 while the associated capital cost dropped from \$25-\$38/kW to \$15/kW[20].

We cannot estimate the precise interplay between EPA regulation and technology improvement, but it is clear that a *priori* cost estimation often results in overestimation of costs because changes in technology (whatever the cause) make less costly control possible.

[19] Hammit, J.K. (2000). "Are the costs of proposed environmental regulations overestimated? Evidence from the CFC phaseout." *Environmental and Resource Economics*, 16(#3): 281-302.
[20] ICF Consulting. October 2005. The Clean Air Act Amendment: Spurring Innovation and Growth While Cleaning the Air. Washington, DC. Available at http://www.icfi.com/Markets/Environment/doc_files/caaa-success.pdf.

6.2 Economic Impacts

The assessment of economic impacts (Table 6.8) was conducted simply based on those source categories which are assumed in this analysis to become controlled. The impacts presented here are an extension of the engineering costs, where engineering costs are allocated to specific source categories by North American Industry Classification System (NAICS) code.

Table 6.8: Annual Costs of Identified Controls by Industry for Alternative Standard 50 ppb (Millions of 2006$)[a, b, c]

NAICS Code	Industry Description	3% Discount Rate[d]	7% Discount Rate	Industry Revenue in 2007[e]	Cost/Revenue Ratio
11	Agriculture, Forestry, Fishing, and Hunting	$0.03	$0.03	-	-
212	Mining	$2.7	$3.3	$78,000	< 0.01%
2221	Electric Power Generation, Transmission and Distribution	$15	$19	$560,000	< 0.01%
23	Construction	$0.02	$0.02	$1,700,000	< 0.01%
322	Paper Manufacturing	$0.03	$0.04	$170,000	< 0.01%
324	Petroleum and Coal Products Manufacturing	$7.4	$9.2	$590,000	< 0.01%
325	Chemical Manufacturing	$5.2	$6.5	$720,000	< 0.01%
331	Primary Metal Manufacturing	$0.23	$0.25	$250,000	< 0.01%
484	Truck Transportation	$3.9	$3.9	$220,000	< 0.01%
486	Pipeline Transportation	$0.27	$0.30	$24,000	< 0.01%
488	Support Activities for Transportation	$0.01	$0.01	$93,000	< 0.01%
928	National Security and International Affairs	$0.04	$0.06	-	-

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] All estimates provided reflect the engineering cost of the identified control strategy analysis, incremental to a 2020 baseline of compliance with the current PM2.5 and Ozone standards.
[c] NAICS codes were unavailable for area source controls and the best workplaces for commuters control. These controls account for less than 1% of the total identified control strategy costs.
[d] 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 the identified control strategy, data for calculating annualized costs at a 3% discount was available for point sources. Therefore, the total annualized identified control cost value presented in this referenced cell is an aggregation of engineering costs at 3% and 7% discount rate.
[e] Source: U.S. Census Bureau 2007 Economic Census

6.2 Energy Impacts

This section summarizes the energy consumption impacts alternative NO_2 NAAQS of 50 ppb. The NO_2 NAAQS revisions do not constitute a "significant energy action" as defined in Executive Order 13211; this information merely represents impacts of the illustrative control strategy applied in the RIA. The rule does not prescribe specific control strategies by which these ambient standards will be met. Such strategies will be developed by States on a case-by-case basis, and EPA cannot predict whether the control options selected by States will include regulations on energy suppliers, distributors, or users. Thus, EPA concludes that this rule is not likely to have any adverse energy effects.

For this RIA, implementation of the control measures needed for attainment with the alternative standards will likely lead to increased energy consumption among NOx emitting facilities. To control emissions effectively, these measures require a significant amount of electricity that affected facilities are not expected to consume under baseline conditions. The available information on these controls suggests that they are not typically powered by natural gas or other fossil fuels; therefore, our analysis of energy impacts focuses exclusively on electricity consumption. In addition, because the energy consumption associated with emission reductions beyond identified controls is uncertain, we only consider the energy impacts associated with identified controls.

To assess the electricity consumption impacts associated with identified controls, we relied on the AirControlNET outputs generated for this analysis. For most identified controls, AirControlNET estimates electricity costs separately from other operating and maintenance (O&M) costs. Therefore, for sources expected to implement these controls, AirControlNET provides direct estimates of the additional electricity costs expected under the standard alternatives. We calculate the electricity consumption associated with these costs based on the unit cost of electricity assumed by AirControlNET (7.8 cents/kilowatt hour in 2006 dollars).

For a number of identified controls, AirControlNET does not separate the cost of electricity from other O&M costs. Similarly, the cost data for several controls identified from sources other than AirControlNET do not distinguish between electricity and other O&M costs. We estimate the electricity costs associated with these measures based on electricity's assumed share of total O&M, which we estimate based on AirControlNET's results for those controls where it separates electricity costs from other O&M costs. For some controls, O&M costs are not estimated separately from capital costs. In these cases, we assume that O&M represents a fixed share of annual costs based on the cost data for those controls where O&M and capital are calculated separately.

Table 6.9 summarizes the estimated energy impacts associated with the selected and alternative standards. As indicated in the table, we estimate that sources installing identified controls under the alternative standards will increase their electricity consumption in 2020 by approximately 1,400 megawatt-hours (MWh) under the selected standard.

Table 6.9: Summary of Energy Impacts

	Alternative Standard: 50 ppb
Electricity Cost (millions of year 2006$)	$0.11
Electricity Consumption (Megawatt-hours consumed in 2020)	1,400

6.4 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 engineering cost analysis is subject to uncertainties and limitations.

- One of these limitations is that we do not have sufficient information for all of our known control measures to calculate cost estimates that vary with an interest rate. We are able to calculate annualized costs at an interest rate other than 7% (e.g., 3% interest rate) where there is sufficient information—available capital cost data, and equipment life—to annualize the costs for individual control measures. For the vast majority of nonEGU point source control measures, we do have sufficient capital cost and equipment life data for individual control measures to prepare annualized capital costs using the standard capital recovery factor. Hence, we are able to provide annualized cost estimates at different interest rates for the point source control measures.

- For area source control measures, the engineering cost information is available only in annualized cost/ton terms. We have extremely limited capital cost and equipment life data for area source control measures. We know that these annualized cost/ton estimates reflect an interest rate of 7% because these estimates are typically products of technical memos and reports prepared as part of rules issued by EPA over the last 10 years or so, and the costs estimated in these reports have followed the policy provided in OMB circular A-4 that recommends the use of 7% as the interest rate for annualizing regulatory costs. Capital cost information for these area source controls, however, is often limited since these measures are often not the traditional add-on controls where the capital cost is well known and convenient to estimate. The limited availability of useful capital cost data for such control measures has led to our use of annualized cost/ton estimates to represent the engineering costs of these controls in our cost tools and hence in this RIA.

- For mobile source measures, the situation is very much like that for our area source measures. We do not have sufficient capital cost information to compute annualized costs for interest rates other than 7%.

- 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 "no cost" [21] 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 analysis also did not consider transactional costs and/or effects on labor supply in the illustrative analysis.

[21] "No cost" options considered in this RIA were continuous I&M and Elimination of Long Duration Idling.