Appendix 5a: Additional Cost Information

5a.1 Engineering Cost Information for NonEGU Point and Area Sources

(Full details on controls can be found in Appendix Chapter 3)

5a.1.1 Engineering Costs by Control Measure

Tables 5a.1 and 5a.2 summarize the total incremental annualized engineering costs in 2020 for the modeled control strategy by control measure for nonEGU point and Area sources.

Table 5a.1: NOx NonEGU Point and Area Source Control Measure Annualized Engineering Costs

Control Measure	Source Type	Total Cost (M 2006$)
RACT to 25 tpy (LNB)	Industrial Coal Combustion	$11
	Industrial NG Combustion	$3.3
	Industrial Oil Combustion	$0.98
Switch to Low Sulfur Fuel	Residential Home Heating	$20
Water Heater + LNB Space Heaters	Commercial/Institutional—NG	$7.7
	Residential NG	$12
Biosolid Injection Technology	Cement Kilns	$0.43
LNB	Asphaltic Conc; Rotary Dryer; Conv Plant	$0.39
	Coal Cleaning-Thrml Dryer; Fluidized Bed	$0.79
	Fiberglass Mfg; Textile—Type Fbr; Recup Furn	$1.1
	Fuel Fired Equip; Furnaces; Natural Gas	$0.14
	In-Process Fuel Use; Natural Gas	$4.3
	In-Process Fuel Use; Residual Oil	$0.14
	In-Process; Process Gas; Coke Oven Gas	$0.59
	Lime Kilns	$4.7
	Sec Alum Prod; Smelting Furn	$0.052
	Steel Foundries; Heat Treating	$0.010
	Surf Coat Oper; Coating Oven Htr; Nat Gas	$0.095
LNB + FGR	Fluid Cat Cracking Units	$14
	Fuel Fired Equip; Process Htrs; Process Gas	$3.2
	In-Process; Process Gas; Coke Oven Gas	$3.5
	Iron & Steel Mills—Galvanizing	$0.030
	Iron & Steel Mills—Reheating	$0.58
	Iron Prod; Blast Furn; Blast Htg Stoves	$0.56
	Sand/Gravel; Dryer	$0.049
	Steel Prod; Soaking Pits	$0.11
LNB + SCR	Iron & Steel Mills—Annealing	$1.6
	Process Heaters—Distillate Oil	$38
	Process Heaters—Natural Gas	$420
	Process Heaters—Other Fuel	$110
	Process Heaters—Process Gas	$61
	Process Heaters—Residual Oil	$0.29
NSCR	Rich Burn IC Engines—Gas	$13
	Rich Burn IC Engines—Gas, Diesel, LPG	$2.1
	Rich Burn Internal Combustion Engines—Oil	$6.6
OXY-Firing	Glass Manufacturing—Containers	$5.1

Control Measure	Source Type	Total Cost (M 2006$)
	Glass Manufacturing—Flat	$48
	Glass Manufacturing—Pressed	$22
SCR	Ammonia—NG-Fired Reformers	$10
	Cement Manufacturing—Dry	$120
	Cement Manufacturing—Wet	$93
	IC Engines—Gas	$220
	ICI Boilers—Coal/Cyclone	$2.3
	ICI Boilers—Coal/Wall	$34
	ICI Boilers—Coke	$0.89
	ICI Boilers—Distillate Oil	$12
	ICI Boilers—Liquid Waste	$1.6
	ICI Boilers—LPG	$1.1
	ICI Boilers—Natural Gas	$110
	ICI Boilers—Process Gas	$25
	ICI Boilers—Residual Oil	$31
	Natural Gas Prod; Compressors	$3.3
	Space Heaters—Distillate Oil	$0.088
	Space Heaters—Natural Gas	$2.1
	Sulfate Pulping—Recovery Furnaces	$24
SCR + Steam Injection	Combustion Turbines—Natural Gas	$55
SCR + Water Injection	Combustion Turbines—Oil	$0.69
SNCR	By-Product Coke Mfg; Oven Underfiring	$10
	Comm./Inst. Incinerators	$2.3
	ICI Boilers—Coal/Stoker	$10
	Indust. Incinerators	$0.42
	In-Process Fuel Use; Bituminous Coal	$0.058
	Municipal Waste Combustors	$7.2
	Nitric Acid Manufacturing	$2.5
	Solid Waste Disp; Gov; Other Inc	$0.16
SNCR—Urea	ICI Boilers—MSW/Stoker	$0.29
SNCR—Urea Based	ICI Boilers—Coal/FBC	$0.13
	ICI Boilers—Wood/Bark/Stoker—Large	$8.4
	In-Process; Bituminous Coal; Cement Kilns	$0.33
	In-Process; Bituminous Coal; Lime Kilns	$0.034

Table 5a.2: VOC NonEGU Point and Area Source Control Measure Annualized Engineering Costs

Control Measure	Source	Total Cost (M 2006$)
CARB Long-Term Limits	Consumer Solvents	$320
Catalytic Oxidizer	Conveyorized Charbroilers	$240
Equipment and Maintenance	Oil and Natural Gas Production	$210
Gas Collection (SCAQMD/BAAQMD)	Municipal Solid Waste Landfill	$1.1
Incineration >100,000 lbs bread	Bakery Products	$5.8
Low Pressure/Vacuum Relief Valve	Stage II Service Stations	$16
	Stage II Service Stations—Underground Tanks	$15
OTC Mobile Equipment Repair and Refinishing Rule	Aircraft Surface Coating	$2
	Machn, Electric, Railroad Ctng	$12
OTC Solvent Cleaning Rule	Cold Cleaning	$16
SCAQMD—Low VOC	Rubber and Plastics Mfg	$2.6

Control Measure	Source	Total Cost (M 2006$)
SCAQMD Limits	Metal Furniture, Appliances, Parts	$19
SCAQMD Rule 1168	Adhesives—Industrial	$69
Solvent Utilization	Large Appliances	$4.1
	Metal Furniture	$0.90
	Paper SIC 26	$3.5
Switch to Emulsified Asphalts	Cutback Asphalt	$0
Permanent Total Enclosure (PTE)	Fabric Printing, Coating and Dyeing	$0.069
	Paper and Other Web Coating	$0.85
Petroleum and Solvent Evaporation	Printing and Publishing	$4.4
	Surface Coating	$0.42

5a.1.2 Engineering Costs of Supplemental Controls

5a.1.1.1 Low Emission Combustion (LEC)

The average cost effectiveness for large IC engines using LEC technology was estimated to be $760/ton (ozone season, 2006 dollars).[1] The EC/R report on IC engines (Ec/R, September 1, 2000) estimates the average cost effectiveness for IC engines using LEC technology to range from $600–1,200/ton (ozone season) for engines in the 2,000–8,000 bhp range. The key variables in determining average cost effectiveness for LEC technology are the average uncontrolled emissions at the existing source, the projected level of controlled emissions, annualized costs of the controls, and number of hours of operation in the ozone season. The ACT document uses an average uncontrolled level of 16.8 g/bhp-hr, a controlled level of 2.0 g/bhp-hr (87% decrease), and nearly continuous operation in the ozone season. The EPA believes the ACT document provides a reasonable approach to calculating cost effectiveness for LEC technology.

5a.1.1.2 Leak Detection and Repair (LDAR) for Fugitive Leaks

The control efficiency is 80 percent reduction of VOC at an annualized engineering cost of $6,900 per ton.

5a.1.1.3 Enhanced LDAR for Fugitive Leaks

The control efficiency of this measure is estimated at 50 percent at a engineering cost of $4,360/ton of VOC reduced.[2]

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[1] "NOx Emissions Control Costs for Stationary Reciprocating Internal Combustion Engines in the NOx SIP Call States," E.H. Pechan and Associates, Inc., Springfield, VA, August 11, 2000. Available on the Internet at http://www.epa.gov/ttn/ecas/regdata/cost/pechan8-11.pdf

5a.1.1.4 Flare Gas Recovery

The control efficiency of this measure is 98 percent reduction of VOC emissions at an annualized engineering cost of $3,860/ton. Costs may become negligible as the size of the flare increases due to recovery credit.[3]

5a.1.1.5 Cooling Towers

There is not a general estimate of control efficiency for this measure; one is to apply a continuous flow monitor until VOC emissions have reached a level of 1.7 tons/year for a given cooling tower.[4] The annualized engineering cost for a continuous flow monitor is $90,000– this is constant over a variety of cooling tower sizes.

5a.1.1.6 Wastewater Drains and Separators

The control efficiency is 65 percent reduction of VOC emissions at an annualized engineering cost of $4,360/ton. This is based on actual sampling and cost data for 5 refineries in the Bay Area Air Quality Management District (BAAQMD).[5]

5a.1.1.7 Work Practices and Use of Low VOC Coatings in Solvent Utilization and Other Processes

The control efficiency is 90 percent reduction of VOC emissions at an engineering cost of $1,200/ton (2006 dollars). This is based on analyzes applied to the 2002 National Emissions Inventory (NEI) and summarized in the proposed CTG for paper, film and foil coatings, metal furniture, and large appliances published by US EPA in July 2007.[6]

5a.2 Engineering Cost Information for EGU Sources

(Full details on controls can be found in Appendix Chapter 3)

[3] MARAMA Multipollutant Rule Basis for Flares, part of "Assessment of Control Technology Options for Petroleum Refineries in the mid-Atlantic Region." February 19, 2007. Found on the Internet at http://www.marama.org/reports/021907_Refinery_Control_Options_TSD_Final.pdf.
[4] Bay Area Air Quality Management District (BAAQMD). Proposed Revision of Regulation 8, Rule 8: Wastewater Collection Systems. Staff Report, March 17, 2004.
[5] Bay Area Air Quality Management District (BAAQMD). Proposed Revision of Regulation 8, Rule 8: Wastewater Collection Systems. Staff Report, March 17, 2004.
[6] U.S. Environmental Protection Agency. Consumer and Commercial Products: Control Techniques Guidelines in Lieu of Regulations for Paper, Film, and Foil Coatings; Metal Furniture Coatings; and Large Appliance Coatings. 40 CFR 59. July 10, 2007. Available on the Internet at http://www.epa.gov/ttncaaa1/t1/fr_notices/ctg_ccp092807.pdf. It should be noted that this CTG became final in October 2007.

5a.2.1 Cost of Controls as a Result of Lower Nested Caps within the MWRPO, OTC, and East Texas and other Local Controls Outside of these Regions Nationwide

As previously discussed, the power sector will achieve significant emission reductions under the Clean Air Interstate Rule (CAIR) over the next 10 to 15 years. When fully implemented, CAIR (in conjunction with NOx SIP Call) will reduce ozone season NOx emissions by over 60 percent from 2003 levels within the CAIR states. These reductions will greatly improve air quality and will lessen the challenges that some areas face when solving nonattainment issues significantly.

Power sector impacts analyzed in detail in the Final PM NAAQS RIA 15/35 and in the Proposed Ozone NAAQS RIA (http://www.epa.gov/ttn/ecas/ria.html) provides the baseline for this RIA. The analysis and projections in this section attempt to show the potential impacts of the additional controls applied (see section 3.3.3 of this RIA) to facilitate attainment of the more stringent 8-hr ozone standard. Generally, the incremental impacts of these controls on the power sector are marginal.

Projected Costs. EPA projects that the annualized incremental cost of the new ozone standard approach is $0.15 billion in 2020 ($2004)[7]. The additional annualized costs reflect additional retrofits (SCR and SNCR) and generation shifts. Annualized cost of CAIR is projected to be $6.17 billion in 2020 ($2004). The approach applied in this RIA would add $0.15 billion incremental to this cost. Annualized cost of the EGU controls (in $2004) for the entire country for fossil units > 25MW is about $5,500. Table 5.a3 below summarizes increase in NOx control (SCR and SNCR) capacity.

Table 5a.3: NOx Control (SCR and SNCR) Capacity (GWs)

	Baseline CAIR/CAMR/CAVR	**Modeled Control Strategy**
Retrofits (GWs)		
SCR	57.0	66.4
SNCR	2.1	4.5
Total Controls (GWs) (Existing + Retrofits + New Units)		
SCR	219.6	229.9
SNCR	11.8	15.0

Projected Generation Mix. Coal-fired generation and natural gas/oil-fired generation are projected to remain almost unchanged. Installation of approximately 9.4 GWs of SCR and 2.4 GWs of SNCR incremental to the base case are projected as a result of the lower sub-regional caps. There are very small changes in the generation mix. Coal-fired generation decreases about 6,000 GWh (a decrease of approximately 0.1% of the total generation) and gas-fired generation increases a similar amount. Hydro, nuclear, other, and renewable based generation projected to remain the same. Projected retirements of both coal and oil/gas units remained same compared to the base case approach.

[7] IPM calculates costs in 2004$. All costs presented in Chapter 5 are in 2006$. The costs presented here were converted to 2006$ prior to being compared or added to other control measure costs.

Projected Nationwide Retail Electricity Prices. Retail electricity prices are projected to decrease marginally, about 1%. The extension of the cap-and-trade approach in the form of lower sub-regional caps allows industry to meet the requirements of CAIR in the most cost-effective manner, thereby minimizing the costs passed on to consumers. Retail electricity prices are projected to increase less than 1% within the MWRPO, OTC, and East Texas, and decrease elsewhere.

5a.3 Engineering Cost Information for Onroad and Nonroad Mobile Sources

(Full details on controls can be found in Appendix Chapter 3)

Table 5a.4 and 5a.5 summarize the total incremental engineering costs for the modeled control strategy by mobile source control measure.

Table 5a.4: NOx Mobile Modeled Control Strategy Incremental Annualized Engineering Costs by Control Measure

Sector	Control Measure	Total Cost (M$)
Onroad	Eliminate Long Duration Idling	$—
	Low RVP	$—
	Onroad Retrofit	$280
	Continuous Inspection and Maintenance	$—
	Commuter Programs	$79
Nonroad	Nonroad Retrofit	$150

Table 5a.5: VOC Mobile Modeled Control Strategy Incremental Annualized Engineering Costs by Control Measure

Sector	Control Measure	Total Cost (M$)
Onroad	Low RVP	$95
	Onroad Retrofits	$—
	Continuous Inspection and Maintenance	$—
	Commuter Programs	$—
Nonroad	Low RVP	$36
	Nonroad Retrofits & Engine Rebuilds	$—
	International Aircraft NOx Standard	$—

5a.3.1 Diesel Retrofits and Engine Rebuilds

To calculate engineering costs for the use of selective catalytic reduction as a retrofit technology, the assumption was made that all relevant vehicles would be affected by the control. Therefore, all on-road heavy duty diesel vehicles that received a retrofit were assumed to employ selective catalytic reduction as a retrofit technology. The average cost of a selective catalytic reduction system ranges from $10,000 to $20,000 per vehicle depending on the size of the engine, the sales volume, and other factors. One study calculated the average estimated cost of this system to be $15,000 per heavy duty diesel vehicle. (Source: AirControlNET Documentation, III-160). OTAQ conducted an additional assessment of current SCR costs and calculated that for the year 2020, the cost of SCRs will be approximately $13,000 per unit. This estimate reflects an economy of scale cost reduction of 33%, which is consistent with trends in other mobile source control technologies that enter large scale production[8].

The rebuild/upgrade kit is applied to nonroad equipment. OTAQ estimates the engineering cost of this kit to be $2,000 to $4,000 per vehicle. For this analysis, the average estimated cost is $3,000 per vehicle.

The cost effectiveness numbers are presented in Tables 5a.6, 5a.7, and 5a.8.

Table 5a.6: Summary of Cost Effectiveness for Rebuild/Upgrade Kit for Various Nonroad Vehicles

Nonroad Vehicle	Retrofit Technology	Range of $/ton NOx Emission Reduced		Range of $/ton HC Emission Reduced	
Tractors/Loaders/Backhoes	Rebuild/ Upgrade kit	$1,300	$2,200	$9,600	$18,900
Excavators		$1,100	$4,200	$8,100	$43,400
Crawler Tractor/Dozers		$1,100	$4,200	$8,300	$43,500
Skid Steer Loaders		$1,000	$1,600	$7,400	$14,800
Agricultural Tractors		$1,200	$4,900	$9,300	$34,300

Table 5a.7: Summary of Cost Effectiveness for SCR for Various Nonroad Vehicles

Nonroad Vehicle	Retrofit Technology	Range of $/ton NOx Emission Reduced		Range of $/ton HC Emission Reduced	
Tractors/Loaders/Backhoes	SCR	$2,900	$5,300	$32,200	$63,700
Excavators		$2,700	$10,400	$27,400	$146,200
Crawler Tractor/Dozers		$2,800	$10,400	$27,900	$146,700
Skid Steer Loaders		$2,600	$4,000	$24,900	$52,100
Agricultural Tractors		$3,000	$7,600	$31,200	$115,500

Table 5a.8: Summary of Cost Effectiveness for SCR for Various Highway Vehicles

Highway Vehicle	Retrofit Technology	Range of $/ton NOx Emission Reduced		Range of $/ton HC Emission Reduced	
Class 6&7 Truck	SCR	$5,600	$14,100	$46,900	$126,200
Class 8b Truck		$1,100	$2,500	$14,900	$44,600

5a.3.2 Implement Continuous Inspection and Maintenance Using Remote Onboard Diagnostics (OBD)

Continuous I/M can significantly lower test costs and "convenience" costs of I/M programs. Using the radio-frequency approach as an example, the costs of periodic testing to Remote OBD can be compared. Note that this is just an example to illustrate the difference in cost of traditional

[8] The expected emissions reductions from SCR retrofits are based on data derived from EPA regulations (Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-duty Highway Engines and Vehicles published October 2000), interviews with component manufacturers, and EPA's Summary of Potential Retrofit Technologies available at www.epa.gov/otaq/retrofit/retropotentialtech.htm.

periodic I/M and Remote OBD. In this scenario, the assumption is that all 1996 and newer vehicles currently subject to I/M will participate in a mandatory Remote OBD program. The national fleet of vehicles subject to I/M are considered over a 10 year period a static set of vehicles. The estimated cost of setting up and maintaining a data processing and reporting system is shown in Table 5a.9 and ranges from 50¢ to $3.00 per vehicle in the program per year.[9] For the purposes of this example, we will assume $1 to $3 per vehicle per year. These estimates assume one record per vehicle per month is actually stored (although additional readings will usually be taken since vehicles will routinely pass receivers many times a month). This cost does not include installing Remote OBD on the vehicle or the network of receivers to pick up signals from equipped vehicles, which is covered by the $50 fee discussed above. If we assume an average vehicle life span of 14 years,[10] with the first test at 4 years of age, the typical vehicle will get 5 inspections in a biennial program and 10 in an annual program (not including additional change of ownership inspections, which are required in some areas). Thus, in a Remote OBD program, an additional cost of $10–$30 will be incurred for each vehicle over its life to cover data processing and reporting.

Table 5a.9: Remote OBD VID Service Cost Estimate Per Vehicle Per Year

Number of Vehicles in Remote OBD Program	Level 1 Database Design, Installation, Maintenance, and Communications	Level 2 Add Reporting	Level 3 Add Auditing
250,000	$1.50	$2.00	$3.00
250,001–500,000	$1.00	$1.50	$2.75
500,001–1,500,000	$0.75	$1.00	$2.50
>1,500,000	$0.50	$0.75	$2.00

In addition to test costs, Remote OBD avoids most of the consumer convenience and indirect costs associated with I/M—the time and fuel it takes to drive to the station, get a test, and return home. The one-time installation of the transmitter requires a visit to the test station, but no further visits are required. Hard data are not available on the actual average time motorists spend driving to a test station, getting a test, and returning to their point of origin or to their next stop in a trip chain. In some centralized programs, wait times can be very long. In decentralized programs, motorists often drop off their vehicle (requiring two trips to the test station). For the sake of illustrating the convenience costs associated with I/M, a reasonable range for the typical test cycle is one to two hours. If we assign a cost of $20 per hour[11] and a half-gallon of gas (10 miles round trip with an average fuel economy of 20 mpg) at $3 per gallon, the total cost of the typical cycle is $21.50 to $41.50. Over the life of the vehicle, this would amount to $104 to $208 in a biennial program or $208 to $415 in an annual program. Compare this to the one time installation trip for Remote OBD at a cost of $21.5 to $41.50, it is clear that substantial savings are realized.

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[9] Table provided by Systech International, Inc. and Gordon-Darby, Inc. It should be noted that careful design of the data management system is necessary to achieve these cost levels.
[10] Greenspan, A. & D. Cohen, *Motor Vehicle Stocks, Scrappage, and Sales*; October 1996
[11] This is the same dollar amount assumed in EPA's original Technical Support Document published along with the 1992 Enhanced I/M Rule.

For the purposes of illustrating the nationwide costs and benefits of doing remote OBD, the following analysis assumes 100% participation. It is likely, however, that in the short run states will gradually introduce remote OBD initially on a voluntary basis (except possibly for fleets), and that participation rates will build over time as motorists recognize the cost and convenience advantages. Another caveat is that those states that require motorists to get safety checks, the convenience costs may not be fully realized (see Discussion of Issues, below). Table 5a.10 shows the lifetime inspection and convenience costs of a mandatory, nationwide remote OBD program versus a periodic OBD program (assuming the current nationwide mix of annual and biennial testing and current test costs; see Appendix 3) for a static fleet of about 80 million vehicles. Note that in reality, fleet size generally grows over time and vehicles come and go. Thus, this is a simplifying assumption for the purposes of illustrating the comparative costs. The "low" and "high" refer to the range of convenience costs (1 to 2 hours) and oversight costs in the case of Remote OBD ($1–$3). Current periodic OBD testing costs about $12 billion[12] over a 10-year lifecycle with an additional $9 to $17 billion in convenience costs for a total of $21 to $29 billion. By contrast, Remote OBD has a test and install cost of $4 to $5 billion over the same 10 year period, and a convenience cost of $1 to $2 billion for a total of about $5 to $7 billion. Thus, nationwide installation of Remote OBD would save the nation's motorists about $16 to $22 billion in inspection and convenience costs over a 10 year period.

Table 5a.10: Range of Lifetime Inspection and Convenience Costs of I/M

		Periodic OBD ($B 2006)	**Remote OBD ($B 2006)**	**Savings ($B 2006)**
Test/Install Cost	Low	$12	$4	$8
	High	$12	$5	$7
Convenience Cost	Low	$9	$1	$8
	High	$17	$2	$15
Total	Low	$21	$5	$16
	High	$29	$7	$22

Given that Continuous I/M will actually reduce the cost of I/M, implementation of this measure is highly cost-effective. More information on I/M can be found at http://www.epa.gov/otaq/regs/im/im-tsd.pdf and www.epa.gov/obd/regtech/inspection.htm.

Cost-Effectiveness of Measure: $0/ton NOx

5a.3.3 Eliminating Long Duration Truck Idling

For purposes of this RIA, we identified this measure as a no cost strategy i.e., $0/ton NOx. Both TSEs and MIRTs have upfront capital costs, but these costs can be fully recovered by the fuel savings. The examples below illustrate the potential rate of return on investments in idle reduction strategies.

[12] Test volumes and costs were derived from Sierra Research's annual I/M summary for 2005 and updated in some cases by members of the workgroup.

Truck Stop Electrification

The average price of TSE technology is $11,500 per parking space. The average service life of this technology is 15 years. Truck engines at idle consume approximately 1 gallon per hour of idle. Current TSE projects are operating in environments where trucks are idling, on average, for 8 hours per day per space for 365 days per year (or about 2,920 hours per year). Since TSE technology can completely eliminate long duration idling at truck spaces (i.e., a 100% fuel savings), this translates into 2,920 gallons of fuel saved per year per space. At current diesel prices ($2.90/gallon), this fuel savings translates into $8,468. Therefore, an $11,500 capital investment should be recovered within about 17 months. In this scenario, TSE investments offer over a 70% annual rate of return over the life of the technology.

While it is technically feasible to electrify all parking spaces that support long duration idling trucks, we should note that TSE technology is generally deployed at a minimum of 25-50 parking spaces per location to maximize economies of scale. The financial attractiveness of installing TSE technology will depend on the demonstrated truck idling behavior—the greater the rates of idling, the greater the potential emissions reductions and associated fuel and cost savings.

Mobile Idle Reduction Technologies

The price of MIRT technologies ranges from $1,000-$10,000. The most popular of these technologies is the auxiliary power unit (APU) because it provides air conditioning, heat, and electrical power to operate appliances. The average price of an APU is $7,000. The average service life of an APU is 10 years. An APU consumes two-tenths of a gallon per hour, so the net fuel savings is 0.80 gallons per hour. EPA estimates that trucks idle for 7 hours per rest period, on average, and about 300 days per year (or 2,100 hours per year). Since idling trucks consume 1 gallon of fuel per hour of idle, APUs can reduce fuel consumption for truck drivers/owners by approximately 1,680 gallons per year. At current diesel prices ($2.90/gallon), truck drivers/owners would save $4,872 on fuel if they used an APU. Therefore, a $7,000 capital investment should be recovered within about 18 months. In this scenario, APU investments offer almost a 70% annual rate of return over the life of the technology.

Cost-Effectiveness of Measure: $0/ton NOx

5a.3.4 Commuter Programs

We used the Transportation Research Board's (TRB) cost-effectiveness analysis of Congestion Mitigation and Air Quality Improvement Program (CMAQ) projects to estimate the cost-effectiveness of this measure.[13] TRB conducted an extensive literature review and then synthesized the data to develop comparable estimates of cost-effectiveness of a wide range of CMAQ-funded measures. We took the average of the median cost-effectiveness of a sampling of

[13] Transportation Research Board, National Research Council, 2002. *The Congestion Mitigation and Air Quality Improvement Program: assessing 10 years of experience*, Committee for the Evaluation of the Congestion Mitigation and Air Quality Improvement Program.

CMAQ-funded measures and then applied this number to the overarching commuter reduction measure. The CMAQ-funded measures we selected were:

- regional rideshares
- vanpool programs
- park-and-ride lots
- regional transportation demand management
- employer trip reduction programs

We felt that these measures were a representative sampling of commuter reduction incentive programs. There is a great deal of variability, however, in the type of programs and the level of incentives that employers offer which can impact both the amount of emissions reductions and the cost of commuter reduction incentive programs.

We chose to apply the resulting average cost-effectiveness estimate to one pollutant—NO_x—in order to be able to compare commuter reduction programs to other NO_x reduction strategies. TRB reported the cost-effectiveness of each measure, however, as a $/ton reduction of both VOC and NOx by applying the total cost of the program to a 1:4 weighted sum of VOC and NOx [[total emissions reduction = (VOC * 1) + (NO_x * 4)). There was not enough information in the TRB study to isolate the $/ton cost-effectiveness for just NO_x reductions, so we used the combined NO_x and VOC estimate. The results are presented in Table 5a.11.

Table 5a.11: Cost-Effectiveness of Best Workplaces for Commuters Type Measures from the 2002 TRB Study

	$/ton (2000$) 1:4 VOC:NOx (reported in the RIA as $/ton NOx)		
	Low	**High**	**Median**
Regional Rideshare	$1,200	$16,000	$7,400
Vanpool Programs	$5,200	$89,000	$10,500
Park-and-ride lots	$8,600	$70,700	$43,000
Regional TDM	$2,300	$33,200	$12,500
Employer trip reduction programs	$5,800	$175,500	$22,700
Average of All Measures	$4,620	$76,900	$19,200

Cost-Effectiveness of Measure: $19,200/ton NOx

5a.3.5 Reduce Gasoline RVP from 7.8 to 7.0

Michigan has conducted the most recent study on the cost of reducing RVP to 7.0. The analysis was undertaken as part of their proposed revision to Michigan's SIP for their 7.0 low vapor pressure request for Southeast Michigan. According to their analysis, the costs of the program are:

- 0.6–3.0¢ per gallon
- $1–$11 per vehicle per year
- Total annual cost =$6.9–$48.1 million

Cost-Effectiveness of Measure: Cost per ton will be $5,700 to $36,000 / ton VOC

For more information on RVP:

- Michigan Department of Environmental Quality and Southeast Michigan Council of Governments. *Proposed Revision to State of Michigan State Implementation Plan for 7.0 Low Vapor Pressure Gasoline Vapor Request for Southeast Michigan*. May 24, 2006.
- U.S. EPA. *Guide on Federal and State Summer RVP Standards for Conventional Gasoline Only*. EPA420-B-05-012. November 2005

5a.3.6 Aircraft Engine NOx Standard

The Committee on Aviation Environmental Protection (CAEP) is a committee within the International Civil Aviation Organization (ICAO) that makes recommendations to the ICAO for environmental standards for aircraft. ICAO is a United Nations body that sets voluntary international standards for aircraft. Manufacturers in the U.S. and other countries generally comply with these standards. A few years ago, ICAO set a new standard (CAEP/6) for NOx emissions from commercial aircraft to reduce emissions 12% compared to the existing standard. Compliance with this standard is reflected in the analysis. No costs are attributed to EPA rulemaking.

5a.4 Characterization of Unknown Controls

5a.4.1 Supplemental Control Information

Supplemental emission controls came from a variety of sources. The 0.065 ppm standard geographic areas were broader than those for the modeled control strategy; therefore additional local known controls were available for mobile sources as well as nonEGU point and Area. In addition, supplemental controls were achieved through controls applied to select natural gas and oil fired electric generating units. Other supplemental controls applied to nonEGU point and Area sources are described in the appendix to Chapter 3 (3a.1.6 Supplemental Controls). Lastly, for the Eastern Lake Michigan area, the cut point for applying VOC controls was raised from $5,000/ton (2006$) to $15,000/ton (2006$). Table 5a.12 summarizes the emission reductions achieved through the application of supplemental control measures. The total annualized cost of these measures is broken down by extrapolated cost area in Table 5a.13 and is presented at a seven percent discount rate.

Table 5a.12: Supplemental Local Control Measure Emission Reductions [annual tons/year] Applied for Various Standards[a]

2020 Extrapolated Cost Area	0.065 ppm		0.070 ppm		0.075 ppm		0.079 ppm	
	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC
Ada Co., ID	2,600	340						
Atlanta, GA	16,000	3,500						
Baton Rouge, LA	8,300	23	7,200					
Boston-Lawrence-Worcester, MA	5,200	3,600						
Buffalo-Niagara Falls, NY	630	140	190					
Campbell Co., WY	2,600	69						
Charlotte-Gastonia-Rock Hill, NC-SC	15,000	3,300						
Cincinnati-Hamilton, OH-KY-IN	9,400	3,700						
Cleveland-Akron-Lorain, OH	5,100	390	2,400					
Dallas-Fort Worth, TX	5,100		3,100					
Denver-Boulder-Greeley-Ft Collins-Love, CO	7,000	4,300						
Detroit-Ann Arbor, MI	2,100		2,100					
Dona Ana CO., NM	560	200						
Eastern Lake Michigan, IL-IN-WI	33,000	82,000	29,000	75,000	29,000	74,000	8,200	9,800
El Paso Co., TX	1,700							
Houston, TX	49		53					
Huntington-Ashland, WV-KY	21,000	1,200						
Jackson Co., MS	7,800	410						
Jefferson Co, NY	1,100	710						
Las Vegas, NV	1,000	1,300						
Memphis, TN-AR	14,000	1,100						
Norfolk-Virginia Beach-Newport News	9,100	2,400						
Northeast Corridor, CT-DE-MD-NJ-NY-PA	9,500	750	8,100		7,600			
Phoenix-Mesa, AZ	5,000	3,300						
Pittsburgh-Beaver Valley, PA	4,500	1,400						
Richmond-Petersburg, VA	820	530						
Sacramento Metro, CA	5,600		5,600		5,600		5,600	
Salt Lake City, UT	3,600	2,200						
San Juan Co., NM	16,000	190						
St Louis, MO-IL	18,000	3,400						
Toledo, OH	180	50						
TOTAL by Pollutant	**230,000**	**120,000**	**58,000**	**75,000**	**42,000**	**74,000**	**14,000**	**9,800**

[a] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

Table 5a.13: Supplemental Local Control Measure Total Annualized Costs [M 2006$] Applied for Various Standards (ppm) [a]

2020 Extrapolated Cost Area	0.065 ppm		0.070 ppm		0.075 ppm		0.079 ppm	
	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC
Ada Co., ID	$6.0	$0.8						
Atlanta, GA	$44	$5.8						
Baton Rouge, LA	$52	$0.1	$48					
Boston-Lawrence-Worcester, MA	$13	$1.7						
Buffalo-Niagara Falls, NY	$2.6	$0.3	$0.9					
Campbell Co., WY	$10	$0.2						
Charlotte-Gastonia-Rock Hill, NC-SC	$50	$7.6						
Cincinnati-Hamilton, OH-KY-IN	$30	$7.1						
Cleveland-Akron-Lorain, OH	$27	$1.0	$13					
Dallas-Fort Worth, TX	$16		$15					
Denver-Boulder-Greeley-Ft Collins-Love, CO	$20	$4.9						
Detroit-Ann Arbor, MI	$10		$10					
Dona Ana CO., NM	$1.9	$0.7						
Eastern Lake Michigan, IL-IN-WI	$130	$750	$120	$690	$120	$680	$33	$100
El Paso Co., TX	$8.1							
Houston, TX	$0.7		$0.6					
Huntington-Ashland, WV-KY	$81	$3.40						
Jackson Co., MS	$37	$1.50						
Jefferson Co, NY	$3.9	$1.20						
Las Vegas, NV	$3.6	$4.50						
Memphis, TN-AR	$46	$2.40						
Norfolk-Virginia Beach-Newport News	$23	$3.50						
Northeast Corridor, CT-DE-MD-NJ-NY-PA	$60	$0.99	$55		$52			
Phoenix-Mesa, AZ	$7.9	$6.80						
Pittsburgh-Beaver Valley, PA	$19	$3.10						
Richmond-Petersburg, VA	$2.0	$1.20						
Sacramento Metro, CA	$13		$13		$13		$13	
Salt Lake City, UT	$11	$1.70						
San Juan Co., NM	$54	$0.52						
St Louis, MO-IL	$72	$4.80						
Toledo, OH	$0.6	$0.17						
TOTAL by Pollutant	**$860**	**$820**	**$280**	**$690**	**$190**	**$680**	**$46**	**$100**
TOTAL COSTS	**$1,680**		**$970**		**$870**		**$146**	**[a]**

[a] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

5a.4.2 Modeled Control Strategy Costs Not Needed

As presented in Chapter 4, there were areas in our Modeled control strategy that were "over controlled." Table 4.8 provides the amount of emissions that were not needed to meet the various ozone standards in 2020. Given these targets, the modeled control strategy emission reductions were analyzed to asses what measures could be removed. Table 5a.14 and 5a.15 respectively, show the amount of emission reductions and costs that were removed from the analysis. It was not possible in all extrapolated cost areas to remove all the emissions presented in Table 4.8. This was due to the nature of the EGU trading program, as well as the application of measures statewide for mobile sources. The emission reductions that were not able to be removed from the analysis of attainment for these standards is presented in Table 5a.16. it is important to note that since there was "over control" for 0.070ppm, 0.075 ppm, and 0.079ppm, the full costs of attainment of these levels of the standard will be an overestimate.

Table 5a.14: Modeled Control Strategy Control Measure Emissions Reductions [annual tons/year] removed from Extrapolated Analysis for Various Standards

2020 Extrapolated Cost Area	0.070 ppm		0.075 ppm		0.079 ppm	
	NOX	VOC	NOX	VOC	NOX	VOC
Allegan Co., MI			2,600	240	2,600	240
Atlanta, GA	22,000	3,400	22,000	3,400	22,000	3,400
Baton Rouge, LA			81,000		110,000	1,300
Boston-Lawrence-Worcester-Portsmouth, MA-NH			12,000	3,800	12,000	3,800
Buffalo-Niagara Falls, NY			6,000	1,300	7,000	1,400
Charlotte-Gastonia-Rock Hill, NC-SC	3,200		14,000		14,000	
Cincinnati-Hamilton, OH-KY-IN	29,000	4,000	29,000	4,000	31,000	4,100
Cleveland-Akron-Lorain, OH			24,000	4,100	30,000	4,600
Dallas-Fort Worth, TX			25,000	1,800	25,000	1,800
Denver, CO	12,000	3,600	15,000	4,100	15,000	4,100
Detroit-Ann Arbor, MI			30,000	3,600	30,000	3,600
Eastern Lake Michigan, IL-IN-WI-MI			83	8	83	8
Hancock, Knox, Lincoln & Waldo Cos, ME	7,800		9,300	460	9,300	460
Houston-Galveston-Brazoria, TX						
Huntington-Ashland, WV-KY	1,200	84	1,200	84	1,200	84
Indianapolis, IN	760	190	760	190	760	190
Jefferson Co., NY			1,200	630	1,700	660
Las Vegas, NV			1,500	1,300	1,800	1,300
Muskegon Co., MI	290	90	420	100	420	100
Norfolk-Virginia Beach-Newport News, VA	530		640	85	780	93
Northeast Corridor, CT-DE-DC-NY-NJ-PA-VA					87,000	19,000
Phoenix, AZ	7,600	3,200	7,600	3,200	7,600	3,200
Pittsburgh-Beaver Valley, PA	17,000		23,000	1,500	25,000	1,700
Providence (All RI), RI	1,500	690	1,500	690	1,500	690
Richmond-Petersburg, VA	310		310	58	300	64
Salt Lake City, UT	7,400	2,100	7,400	2,100	7,400	2,100
St Louis, MO-IL	29,000	3,300	29,000	3,300	29,000	3,300
Toledo, OH	1,500	42	1,500	42	1,600	49
Rest of VA					910	50
Rest of OH					46	4
Rest of MI			420	35	420	35
Rest of NY					110	9
Rest of KY	1,100	82	1,100	82	1,100	82
Rest of PA					180	14
TOTALS	**140,000**	**21,000**	**350,000**	**40,000**	**470,000**	**62,000**

Table 5a.15: Modeled Control Strategy Control Measure Annualized Total Costs [M 2006$] Removed from Extrapolated Analysis for Various Standards

2020 Extrapolated Cost Area	0.070 ppm		0.075 ppm		0.079 ppm	
	NOX	VOC	NOX	VOC	NOX	VOC
Allegan Co., MI			$10	$0.9	$10	$0.9
Atlanta, GA	$66	$5.7	$66	$5.7	$66	$5.7
Baton Rouge, LA			$180		$490	$4.1
Boston-Lawrence-Worcester-Portsmouth, MA-NH			$32	$2.8	$32	$2.8
Buffalo-Niagara Falls, NY			$17	$2.3	$20	$2.3
Charlotte-Gastonia-Rock Hill, NC-SC	$3.8		$33		$33	
Cincinnati-Hamilton, OH-KY-IN	$99	$9.0	$99	$9.0	$110	$9.0
Cleveland-Akron-Lorain, OH			$110	$12	$130	$12
Dallas-Fort Worth, TX			$80	$2.1	$80	$2.1
Denver, CO	$41	$4.8	$49	$4.8	$49	$4.8
Detroit-Ann Arbor, MI			$130	$12	$130	$12
Eastern Lake Michigan, IL-IN-WI-MI			$0.2		$0.2	
Hancock, Knox, Lincoln & Waldo Cos, ME	$19		$24	$0.9	$24	$0.9
Houston-Galveston-Brazoria, TX						
Huntington-Ashland, WV-KY	$4.8	$0.2	$4.8	$0.2	$4.8	$0.2
Indianapolis, IN	$3.4	$0.8	$3.4	$0.8	$3.4	$0.8
Jefferson Co., NY			$4.5	$1.2	$5.8	$1.2
Las Vegas, NV			$4.7	$4.4	$5.8	$4.4
Muskegon Co., MI	$0.9	$0.4	$1.2	$0.4	$1.2	$0.4
Norfolk-Virginia Beach-Newport News, VA	$1.4		$2.1	$0.3	$2.6	$0.3
Northeast Corridor, CT-DE-DC-NY-NJ-PA-VA					$300	$21
Phoenix, AZ	$20	$6.7	$20	$6.7	$20	$6.7
Pittsburgh-Beaver Valley, PA	$48		$82	$3.9	$89	$3.9
Providence (All RI), RI	$3.0	$0.3	$3.0	$0.3	$3.0	$0.3
Richmond-Petersburg, VA	$0.6		$0.6	$0.3	$0.8	$0.3
Salt Lake City, UT	$18	$1.7	$18	$1.7	$18	$1.7
St Louis, MO-IL	$130	$4.9	$130	$4.9	$130	$4.9
Toledo, OH	$6.0	$0.2	$6.0	$0.2	$6.3	$0.2
Rest of VA					$2.7	
Rest of OH					$0.2	
Rest of MI			$1.2		$1.2	
Rest of NY					$0.3	
Rest of KY	$3.1		$3.1		$3.1	
Rest of PA					$0.5	
TOTAL by Pollutant	**$460**	**$35**	**$1,100**	**$78**	**$1,800**	**$100**
TOTAL	**$500**		**$1,200**		**$1,900**	

Table 5a.16: Emission Reductions Not Needed [annual tons/year] Remaining After Removing Control Measures Not Needed to Meet Various Ozone Standards [a]

2020 Extrapolated Cost Area	0.070 ppm	0.075 ppm	0.079 ppm
	NOX	NOX	NOX
Allegan Co., MI		460	460
Atlanta, GA	8,700	8,700	8,700
Baton Rouge, LA		(1)	7,606
Boston-Lawrence-Worcester-Portsmouth, MA-NH		1,800	1,800
Buffalo-Niagara Falls, NY		1,000	
Charlotte-Gastonia-Rock Hill, NC-SC	(10)	(40)	(40)
Cincinnati-Hamilton, OH-KY-IN	12,000	12,000	9,000
Cleveland-Akron-Lorain, OH		8,900	14,100
Dallas-Fort Worth, TX		18,000	18,000
Denver, CO	4,300	11,000	11,000
Detroit-Ann Arbor, MI		20,000	20,000
Eastern Lake Michigan, IL-IN-WI-MI			
Hancock, Knox, Lincoln & Waldo Cos, ME	2	6	6
Houston-Galveston-Brazoria, TX			
Huntington-Ashland, WV-KY	10	10	10
Indianapolis, IN	5,800	5,800	5,800
Jefferson Co., NY		700	250
Las Vegas, NV		6,400	6,100
Muskegon Co., MI	130	0	0
Norfolk-Virginia Beach-Newport News, VA	(8)	140	
Northeast Corridor, CT-DE-DC-NY-NJ-PA-VA			11,242
Phoenix, AZ	(90)	(90)	(90)
Pittsburgh-Beaver Valley, PA	(6)	6,700	4,400
Providence (All RI), RI	(4)	(4)	(4)
Richmond-Petersburg, VA	(5)	(5)	8
Salt Lake City, UT			
St Louis, MO-IL	2	1,200	1,200
Toledo, OH	110	110	
TOTALS	**30,000**	**100,000**	**120,000**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

5a.4.3 Fixed Cost Approach Detailed Results and Sensitivities

The range of values from the fixed cost ($10,000/ton) to the fixed cost ($20,000/ton) is presented in Figure 5a.1. You can see that as the amount of unknown emissions increases for the alternate primary standards, the range of total extrapolated cost values becomes larger. The detailed costs by geographic area and alternate primary standard are presented in Tables 5a.17 through 5a.20.

Figure 5a.1: Fixed Cost Approach Sensitivity Analysis Results Ranges

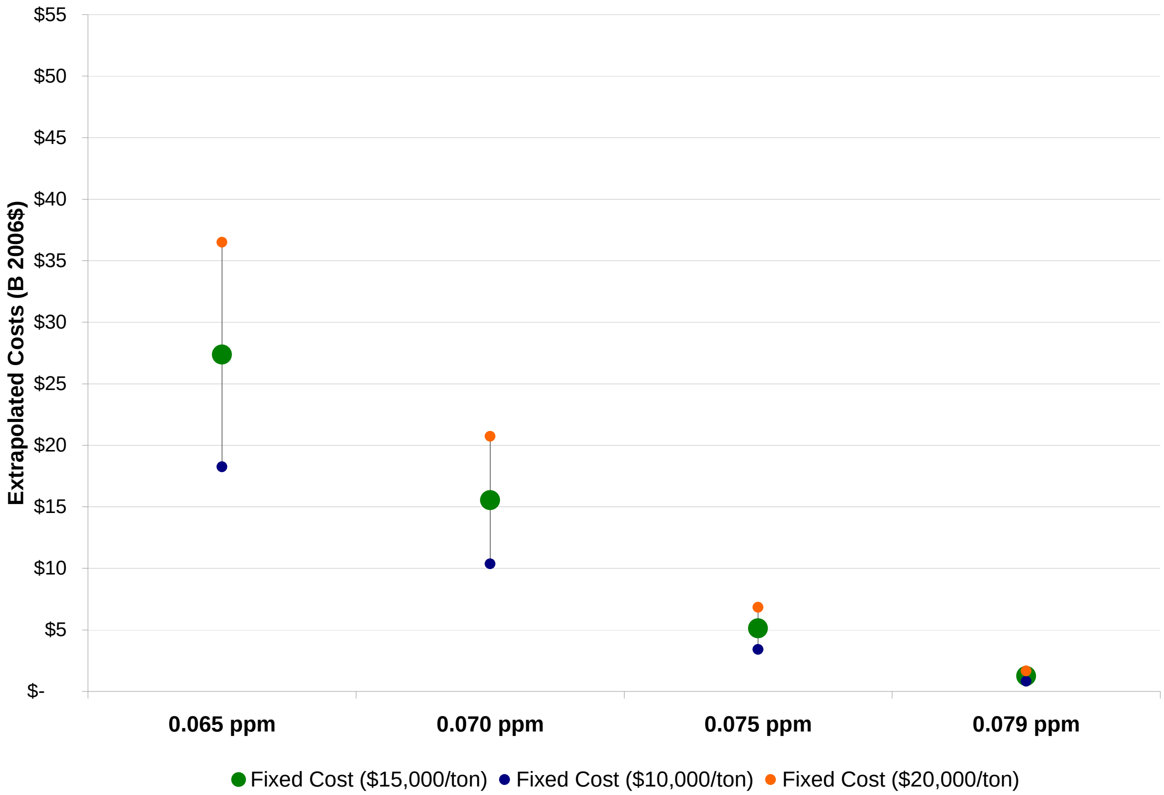


Table 5a.17: Extrapolated Cost by Geographic Area to Meet 0.065 ppm Alternate Standard Fixed Cost Approach [a, b]

2020 Extrapolated Cost Area	Fixed Cost Approach Extrapolated Costs (M 2006$)		
	($10,000/ton)	($15,000/ton)	($20,000/ton)
Ada Co., ID	$28	$42	$55
Atlanta, GA	$55	$83	$110
Baton Rouge, LA	$1,600	$2,500	$3,300
Boston-Lawrence-Worcester, MA	$85	$130	$170
Buffalo-Niagara Falls, NY	$180	$270	$360
Campbell Co., WY	$0.5	$0.8	$1.0
Charlotte-Gastonia-Rock Hill, NC-SC	$470	$710	$940
Cleveland-Akron-Lorain, OH	$780	$1,200	$1,600
Dallas-Fort Worth, TX	$480	$720	$960
Denver-Boulder-Greeley-Ft Collins-Love, CO	$16	$25	$33
Detroit-Ann Arbor, MI	$1,000	$1,500	$2,000
Dona Ana CO., NM	$4.1	$6.2	$8.2
Eastern Lake Michigan, IL-IN-WI	$6,400	$9,600	$13,000
Houston, TX	$1,800	$2,700	$3,600
Huntington-Ashland, WV-KY	$8.0	$12	$16
Jefferson Co, NY	$62	$93	$120
Las Vegas, NV	$39	$59	$78
Memphis, TN-AR	$11	$16	$21
Norfolk-Virginia Beach-Newport News	$210	$310	$410
Northeast Corridor, CT-DE-MD-NJ-NY-PA	$3,400	$5,100	$6,800

2020 Extrapolated Cost Area	Fixed Cost Approach Extrapolated Costs (M 2006$)		
	($10,000/ton)	**($15,000/ton)**	**($20,000/ton)**
Pittsburgh-Beaver Valley, PA	$130	$190	$250
Sacramento Metro, CA	$1,300	$2,000	$2,600
Salt Lake City, UT	$4.3	$6.5	$8.6
San Juan Co., NM	$13	$19	$25
St Louis, MO-IL	$170	$250	$330
Total Extrapolated Cost	**$18,000**	**$27,000**	**$36,000**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

Table 5a.18: Extrapolated Cost by Geographic Area to Meet 0.070 ppm Alternate Standard Fixed Cost Approach[a, b]

2020 Extrapolated Cost Area	Extrapolated Costs (M 2006$)		
	($10,000/ton)	**($15,000/ton)**	**($20,000/ton)**
Baton Rouge, LA	$490	$740	$990
Buffalo-Niagara Falls, NY	$37	$56	$75
Cleveland-Akron-Lorain, OH	$110	$170	$220
Detroit-Ann Arbor, MI	$87	$130	$170
Eastern Lake Michigan, IL-IN-WI	$7,000	$7,500	$10,000
Houston, TX	$1,600	$2,300	$3,100
Northeast Corridor, CT-DE-MD-NJ-NY-PA	$2,200	$3,300	$4,400
Sacramento Metro, CA	$890	$1,300	$1,800
Total Extrapolated Cost	**$10,000**	**$16,000**	**$21,000**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

Table 5a.19: Extrapolated Cost by Geographic Area to Meet 0.075 ppm Alternate Standard Fixed Cost Approach[a, b]

2020 Extrapolated Cost Area	Extrapolated Costs (M 2006$)		
	($10,000/ton)	**($15,000/ton)**	**($20,000/ton)**
Eastern Lake Michigan, IL-IN-WI	$740	$1,800	$1,500
Houston, TX	$1,200	$1,600	$2,500
Northeast Corridor, CT-DE-MD-NJ-NY-PA	$650	$980	$1,300
Sacramento Metro, CA	$440	$660	
Total Extrapolated Cost	**$3,400**	**$5,100**	**$6,800**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

Table 5a.20: Extrapolated Cost by Geographic Area to Meet 0.079 ppm Alternate Standard Fixed Cost Approach[a, b]

2020 Extrapolated Cost Area	Extrapolated Costs (Thousands 2006$)		
	($10,000/ton)	**($15,000/ton)**	**($20,000/ton)**
Houston, TX	$810	$1,200	$1,600
Sacramento Metro, CA	$18	$28	$37
Total Extrapolated Costs (NOX + VOC)	**$830**	**$1,200**	**$1,700**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

5a.4.4 Hybrid Approach

5a.4.4.1 Hybrid Approach Equations

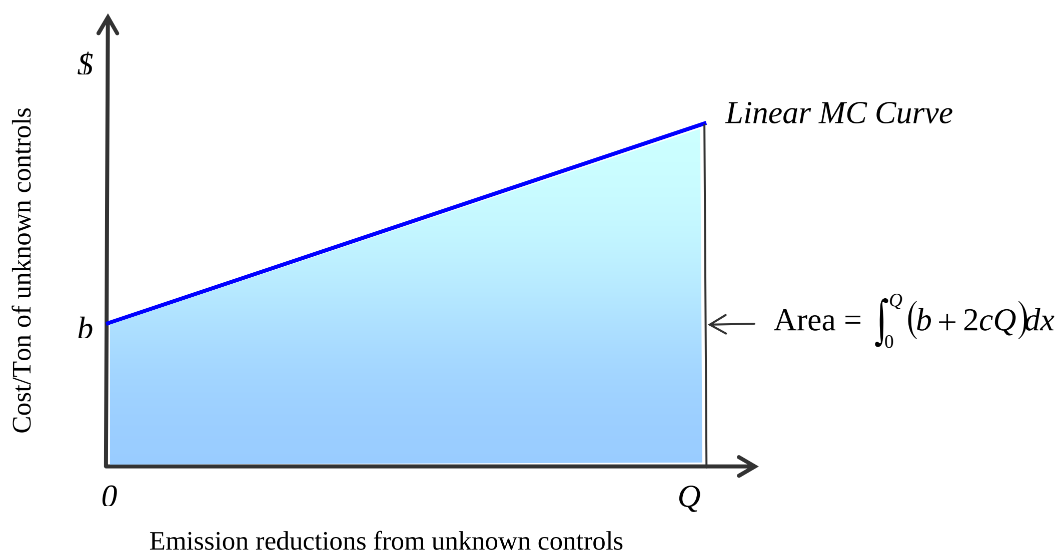
We begin with a linear increasing marginal cost (*MC*) curve represented here as

$$MC = b + 2cQ$$

Where (b+2cQ) is a nonnegative function, and b is the intercept and 2c represents the slope, and Q is the quantity of emissions reduced from unknown controls.

For geographic areas that have reached the baseline in the modeled control strategy the total cost (*TC*) is calculated by taking the integral of the marginal cost function from 0 of emission reductions from unknown controls to all emissions reductions needed from unknown controls (Q).

Figure 5a.2: Example Extrapolated Marginal Cost for Geographic Areas Meeting the Baseline in the Modeled Control Strategy



$$\text{Evaluate } \int_0^Q (b + 2cQ)dx = (bQ + cQ^2 + a) - (b0 + c0^2 + a)$$

Where *MC* is nonnegative for $0 \leq (b + 2cQ) \leq Q$ the definite integral of *MC* equals the area of the shaded region, which is the total cost (*TC*)

$$TC = bQ + cQ^2$$

To calculate average cost (*AC*) divide *TC* by *Q*

$$\frac{TC}{Q} = \frac{bQ + cQ^2}{Q}$$

$$AC = b + cQ$$

Replace the intercept *b* with the national cost/ton jumping off point (*N*), and the slope (*c*) of the average cost curve with $\frac{NM}{E_0}$ where *M* is the multiplier, and E_0 represents the known emission reductions from the modeled control strategy. This slope represents; control technology changes, energy technology changes, relative price changes, technological innovation, and geographic distribution of sources with uncontrolled emissions, and emission reductions from known controls. Lastly, *Q* is represented by E_1 (the total unknown emission reductions)

$$AC = N + \left(\frac{NM}{E_0}\right)E_1$$

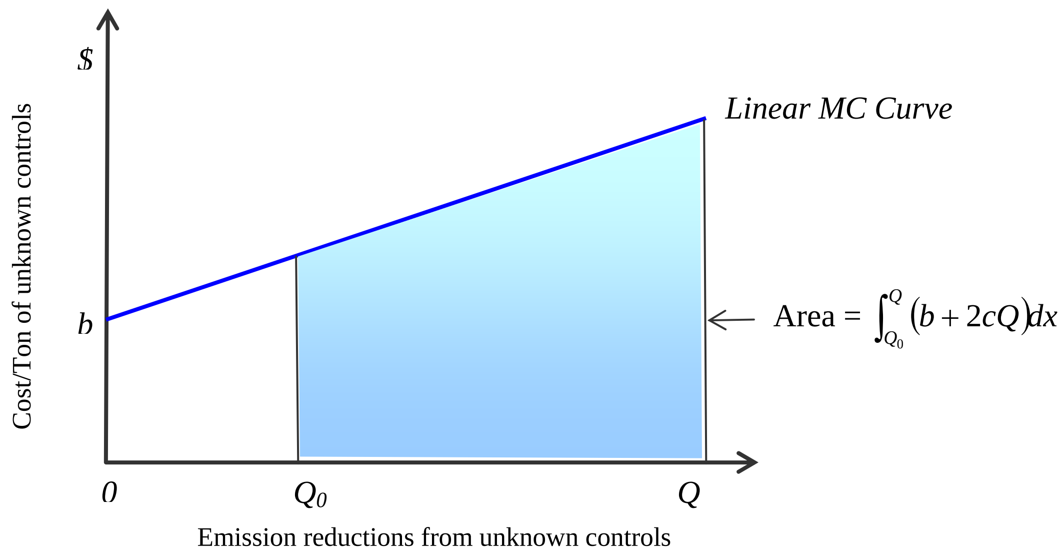
If we replace $\frac{E_1}{E_0}$ with *R*, and pull out *N* the equation becomes

$$AC = N(1+RM)$$

For geographic areas that have not reached the baseline in the modeled control strategy (Houston and parts of California), the total cost is calculated between Q_0 and *Q*, where Q_0 represents the quantity of emission reductions from unknown controls to reach the current ozone standard. Therefore the quantity of emissions that are extrapolated is

$Q - Q_0$.

Figure 5a.3: Example Extrapolated Marginal Cost for Geographic Areas Not Meeting the Baseline in the Modeled Control Strategy



$$\text{Evaluate } \int_{Q_0}^{Q} (b + 2cQ)dx \ = (bQ + cQ^2 + a) - (bQ_0 + cQ_0{}^2 + a)$$

Where *MC* is nonnegative for $Q_0 \leq (b + 2cQ) \leq Q$ the definite integral of *MC* equals the area of the shaded region, which is the total cost (*TC*)

$$= bQ - bQ_0 + cQ^2 - cQ_0{}^2$$

$$TC = \ b(Q - Q_0) + c(Q^2 - Q_0{}^2)$$

To calculate average cost (*AC*) divide *TC* by (Q - Q_0)

$$\frac{TC}{Q} = \frac{b(Q - Q_0) + c(Q^2 - Q_0{}^2)}{(Q - Q_0)}$$

$$AC = b + c(Q + Q_0)$$

Replace the intercept *b* with the national cost/ton jumping off point (*N*), and the slope (*c*) with $\frac{NM}{E_0}$ where *M* is the multiplier, and E_0 represents the known emission reductions from the modeled control strategy. This slope represents; control technology changes, energy technology changes, relative price changes, technological innovation, and geographic distribution of sources with uncontrolled emissions, and emission reductions from known controls. Lastly, *Q* is represented by E_1 (the total unknown emission reductions), and Q_0 is represented by E_{084} (unknown emission reductions to reach the current standard)

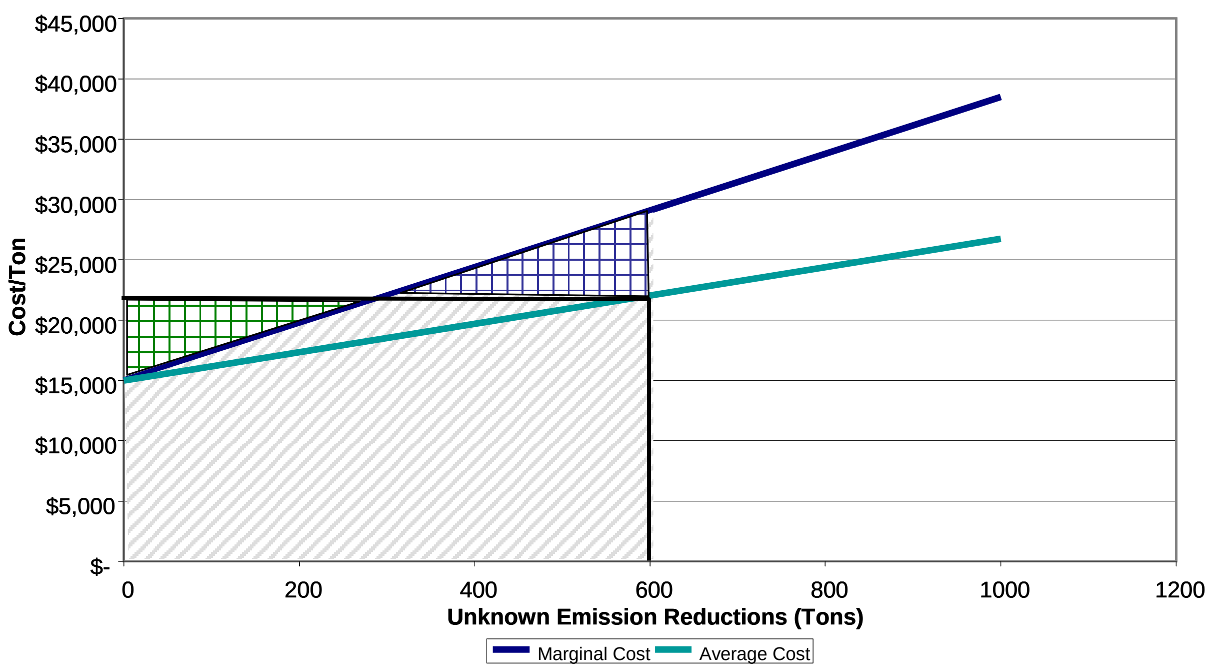
$$AC = N + \left(\frac{NM}{E_0}\right)(E_1 + E_{084})$$

If we replace $\frac{E_1}{E_0}$ with *R*, replace $\frac{E_{084}}{E_0}$ with R_s and pull out *N* the equation becomes

$$AC = N\,(1+RM+R_sM)$$

Figure 5a.4 shows a graphic al example that in the hybrid approach the total cost will be identical if calculated using the marginal cost framework or average cost framework. The total cost using the marginal cost framework is the grey area plus the blue area. The total cost using the average cost framework is the grey area plus the green area. By the nature of geometry, the blue area and the green area are equal. Therefore the total cost under either framework is equal.

Figure 5a.4: Example Marginal Cost versus Average Cost for the Hybrid Approach



<u>5a.4.4.3 Hybrid Approach Detailed Results by Geographic Area</u>

Tables 5a.21 through 5a.24 present the detailed results by geographic area and standard for the hybrid approach (mid).

Table 5a.21: Extrapolated Cost by Geographic Area to Meet 0.065 ppm Alternate Primary Standard Using Hybrid Approach (Mid) [a, b, c]

2020 Extrapolated Cost Area		Ratio of Unknown to Known Emission Reductions	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)
Ada Co., ID		0.81	$18,000	$49
Atlanta, GA		0.10	$15,000	$85
Baton Rouge, LA		0.95	$18,000	$3,000
Boston-Lawrence-Worcester, MA		0.36	$16,000	$140
Buffalo-Niagara Falls, NY		1.60	$21,000	$370
Campbell Co., WY		0.01	$15,000	$0.75
Charlotte-Gastonia-Rock Hill, NC-SC		1.20	$19,000	$910
Cleveland-Akron-Lorain, OH		1.11	$19,000	$1,500
Dallas-Fort Worth, TX		0.85	$18,000	$860
Denver-Boulder-Greeley-Ft Collins-Love, CO		0.04	$15,000	$25
Detroit-Ann Arbor, MI		1.65	$21,000	$2,100
Dona Ana CO., NM		0.27	$16,000	$6.6
Eastern Lake Michigan, IL-IN-WI	NOX	2.00	$22,000	$14,000
	VOC	2.19	$23,000	
El Paso Co., TX		0.00	$15,000	
Houston, TX[d]		1.78	$24,000	$4,200
Huntington-Ashland, WV-KY		0.02	$15,000	$12
Jefferson Co, NY		1.18	$19,000	$120
Las Vegas, NV		0.37	$16,000	$64
Memphis, TN-AR		0.04	$15,000	$16
Norfolk-Virginia Beach-Newport News		0.64	$17,000	$360
Northeast Corridor, CT-DE-MD-NJ-NY-PA		2.15	$23,000	$7,700
Pittsburgh-Beaver Valley, PA		0.35	$16,000	$210
Sacramento Metro, CA		1.90	$22,000	$2,800
Salt Lake City, UT		0.03	$15,000	$6.5
San Juan Co., NM		0.07	$15,000	$19
St Louis, MO-IL		0.23	$16,000	$260
Total Extrapolated Cost				**$39,000**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

[c] Houston did not reach the baseline, and therefore has an additional R to reach the current standard of 0.62.

[d] Houston did not reach the baseline, and therefore has an additional R to reach the current standard of 0.62.

Table 5a.22: Extrapolated Cost by Geographic Area to Meet 0.070 ppm Alternate Primary Standard Using Hybrid Approach (Mid) [a, b]

2020 Extrapolated Cost Area		Ratio of Unknown to Known Emission Reductions	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)
Baton Rouge, LA		0.31	$16,000	$800
Buffalo-Niagara Falls, NY		0.39	$16,000	$61
Cleveland-Akron-Lorain, OH		0.18	$16,000	$170
Detroit-Ann Arbor, MI		0.14	$16,000	$130
Eastern Lake Michigan, IL-IN-WI	NOX	1.65	$21,000	$11,000
	VOC	1.86	$22,000	
Houston, TX[c]		1.63	$23,000	$3,600
Northeast Corridor, CT-DE-MD-NJ-NY-PA		1.47	$20,000	$4,400
Sacramento Metro, CA		1.30	$20,000	$1,700
Total Extrapolated Cost				$22,000

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.
[c] Houston did not reach the baseline, and therefore has an additional R to reach the current standard of 0.62.

Table 5a.23: Extrapolated Cost by Geographic Area to Meet 0.075 ppm Alternate Primary Standard Using Hybrid Approach (Mid) [a, b]

2020 Extrapolated Cost Area		Ratio of Unknown to Known Emission Reductions	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)
Eastern Lake Michigan, IL-IN-WI	NOX	0.50	$17,000	$2,000
	VOC	0.36	$16,000	
Houston, TX[c]		1.36	$22,000	$2,400
Northeast Corridor, CT-DE-MD-NJ-NY-PA		0.46	$17,000	$1,100
Sacramento Metro, CA		0.67	$17,000	$770
Total Extrapolated Cost				**$6,300**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.
[c] Houston did not reach the baseline, and therefore has an additional R to reach the current standard of 0.62.

Table 5a.24: Extrapolated Cost by Geographic Area to Meet 0.075 ppm Alternate Primary Standard Using Hybrid Approach (Mid) [a, b, c]

2020 Extrapolated Cost Area	Ratio of Unknown to Known Emission Reductions	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)
Houston, TX[d]	1.17	$21,000	$1,700
Sacramento Metro, CA	0.07	$15,000	$28
Total Extrapolated Cost			**$1,800**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.
[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.
[c] These estimates assume a particular trajectory of aggressive technological change. An alternative storyline might hypothesize a much less optimistic technological trajectory, with increased costs, or with decreased benefits in 2020 due to a later attainment date.

[d] Houston did not reach the baseline, and therefore has an additional R to reach the current standard of 0.62.

5a.4.4.3 Hybrid Approach Sensitivity Analysis Results

Sensitivity analysis was performed on the variable M to explore the degree that this variable effects total costs of attainment across alternate primary standards. The lowest value of M (0.12), as well as the highest (0.47) was used. The detailed results of these sensitivity analyses are presented in Tables 5a.25 through 5a.29. Figure 5a.5 shows graphically the range of values for national extrapolated costs for the four levels of the alternate primary standard analyzed.

Figure 5a.5: Hybrid Approach Sensitivity Analysis Results Ranges

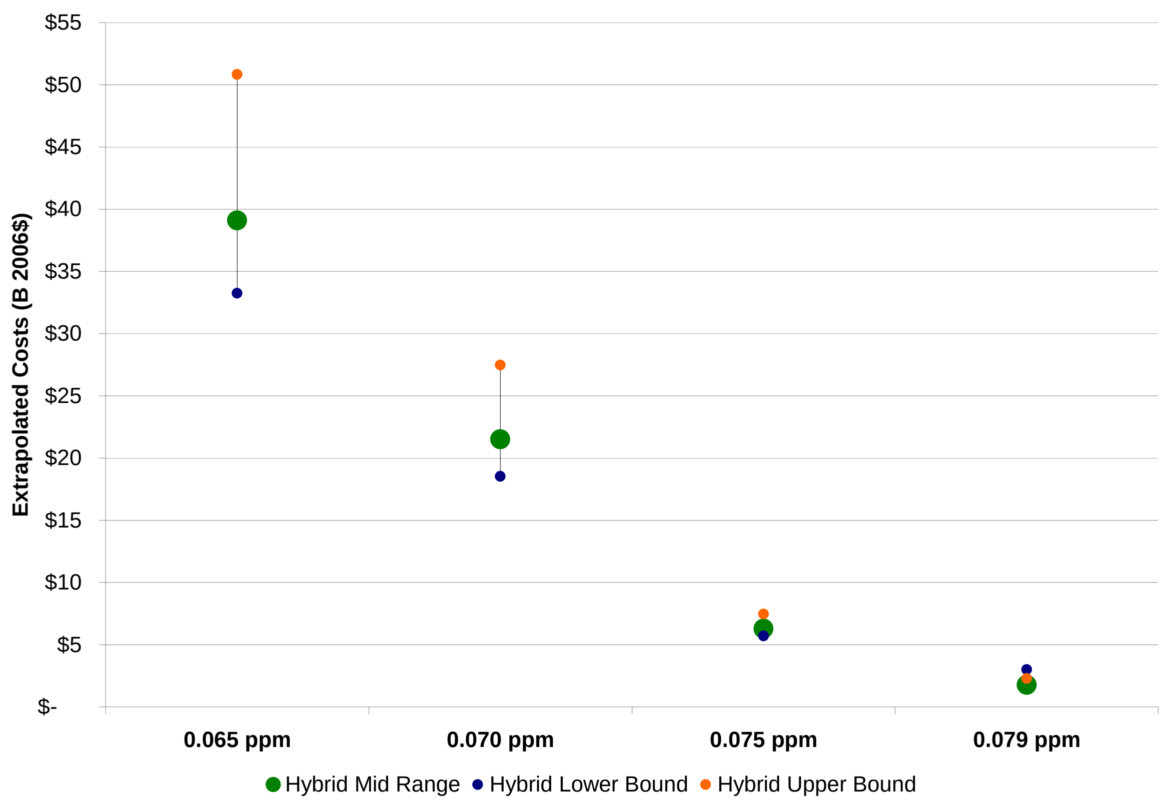


Table 5a.25: Extrapolated Cost by Geographic Area to Meet 0.065 ppm Alternate Standard Hybrid Approach Sensitivities [a, b, c]

2020 Extrapolated Cost Area		Hybrid Approach (Low)		Hybrid Approach (High)	
		Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)
Ada Co., ID		$16,000	$46	$21,000	$57
Atlanta, GA		$15,000	$84	$16,000	$86
Baton Rouge, LA		$17,000	$2,700	$22,000	$3,600
Boston-Lawrence-Worcester, MA		$16,000	$130	$18,000	$150
Buffalo-Niagara Falls, NY		$18,000	$320	$26,000	$480
Campbell Co., WY		$15,000	$0.75	$15,000	$0.75
Charlotte-Gastonia-Rock Hill, NC-SC		$17,000	$810	$23,000	$1,100
Cleveland-Akron-Lorain, OH		$17,000	$1,300	$23,000	$1,800
Dallas-Fort Worth, TX		$17,000	$790	$21,000	$1,000
Denver-Boulder-Greeley-Ft Collins-Love, CO		$15,000	$25	$15,000	$25
Detroit-Ann Arbor, MI		$18,000	$1,800	$27,000	$2,700
Dona Ana CO., NM		$15,000	$6.4	$17,000	$6.9
Eastern Lake Michigan, IL-IN-WI	NOX	$19,000	$12,000	$29,000	$19,000
	VOC	$19,000		$31,000	
Houston, TX		$19,000	$3,400	$32,000	$5,700
Huntington-Ashland, WV-KY		$15,000	$12	$15,000	$12
Jefferson Co, NY		$17,000	$110	$23,000	$140
Las Vegas, NV		$16,000	$61	$18,000	$69
Memphis, TN-AR		$15,000	$16	$15,000	$16
Norfolk-Virginia Beach-Newport News		$16,000	$330	$20,000	$400
Northeast Corridor, CT-DE-MD-NJ-NY-PA		$19,000	$6,400	$30,000	$10,000
Pittsburgh-Beaver Valley, PA		$16,000	$200	$17,000	$220
Sacramento Metro, CA		$18,000	$2,400	$28,000	$3,700
Salt Lake City, UT		$15,000	$6.5	$15,000	$6.6
San Juan Co., NM		$15,000	$19	$16,000	$19
St Louis, MO-IL		$15,000	$250	$17,000	$280
Total Extrapolated Cost			**$33,000**		**$51,000**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

[c] These estimates assume a particular trajectory of aggressive technological change. An alternative storyline might hypothesize a much less optimistic technological trajectory, with increased costs, or with decreased benefits in 2020 due to a later attainment date.

Table 5a.26: Extrapolated Cost by Geographic Area to Meet 0.070 ppm Alternate Standard Hybrid Approach Sensitivities [a, b, c]

2020 Extrapolated Cost Area		Hybrid Approach (Low)		Hybrid Approach (High)	
		Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)
Baton Rouge, LA		$16,000	$770	$17,000	$850
Buffalo-Niagara Falls, NY		$16,000	$59	$18,000	$67
Cleveland-Akron-Lorain, OH		$15,000	$170	$16,000	$180
Detroit-Ann Arbor, MI		$15,000	$130	$16,000	$140
Eastern Lake Michigan, IL-IN-WI	NOX	$18,000	$9,000	$27,000	$14,000
	VOC	$18,000		$28,000	
Houston, TX		$19,000	$3,000	$31,000	$4,800
Northeast Corridor, CT-DE-MD-NJ-NY-PA		$18,000	$3,800	$25,000	$5,500
Sacramento Metro, CA		$17,000	$1,500	$24,000	$2,100
Total Extrapolated Cost			**$19,000**		**$27,000**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

[c] These estimates assume a particular trajectory of aggressive technological change. An alternative storyline might hypothesize a much less optimistic technological trajectory, with increased costs, or with decreased benefits in 2020 due to a later attainment date.

Table 5a.27: Extrapolated Cost by Geographic Area to Meet 0.075 ppm Alternate Standard Hybrid Approach Sensitivities [a, b, c]

2020 Extrapolated Cost Area		Hybrid Approach (Low)		Hybrid Approach (High)	
		Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)
Eastern Lake Michigan, IL-IN-WI	NOX	$16,000	$2,000	$19,000	$2,300
	VOC	$16,000		$18,000	
Houston, TX		$19,000	$2,000	$29,000	$3,100
Northeast Corridor, CT-DE-MD-NJ-NY-PA		$16,000	$1,000	$18,000	$1,200
Sacramento Metro, CA		$16,000	$710	$20,000	$870
Total Extrapolated Cost			**$5,700**		**$7,500**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

[c] These estimates assume a particular trajectory of aggressive technological change. An alternative storyline might hypothesize a much less optimistic technological trajectory, with increased costs, or with decreased benefits in 2020 due to a later attainment date.

Table 5a.28: Extrapolated Cost by Geographic Area to Meet 0.079 ppm Alternate Standard Hybrid Approach Sensitivities [a, b, c]

2020 Extrapolated Cost Area	Hybrid Approach (Low)		Hybrid Approach (High)	
	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)	Average Cost/Ton (2006$)	Hybrid Approach Extrapolated Cost (M 2006$)
Houston, TX	$18,000	$1,500	$28,000	$2,200
Sacramento Metro, CA	$15,000	$28	$15,000	$29
Total Extrapolated Cost		**$1,500**		**$2,300**

[a] All estimates rounded to two significant figures. As such, totals will not sum down columns.

[b] These estimates do not reflect benefits or costs for the San Joaquin Valley or South Coast Air Basins. Please see Appendix 7b for analysis of these areas.

[c] These estimates assume a particular trajectory of aggressive technological change. An alternative storyline might hypothesize a much less optimistic technological trajectory, with increased costs, or with decreased benefits in 2020 due to a later attainment date.