NO_x Emissions Control Costs for Stationary Reciprocating Internal Combustion Engines in the NO_x SIP Call States

Revised Final Report

E.H. Pechan & Associates, Inc.

5528-B Hempstead Way
Springfield, VA 22151

703-813-6700 telephone
703-813-6729 facsimile

3622 Lyckan Parkway
Suite 2002
Durham, NC 27707

919-493-3144 telephone
919-493-3182 facsimile

P.O. Box 1575
Shingle Springs, CA 95682

530-672-0441 telephone & facsimile

Prepared for:

Innovative Strategies and Economics Group
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Prepared by:

The Pechan-Avanti Group
a unit of E.H. Pechan & Associates, Inc.
5528-B Hempstead Way
Springfield, VA 22151

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CHAPTER I
INTRODUCTION

On September 24, 1998, the U.S. Environmental Protection Agency (EPA) Administrator signed the final oxides of nitrogen (NO_x) State Implementation Plan (SIP) Call, a rule that called for NO_x emission reductions from point sources in 22 Eastern States and the District of Columbia (DC) (the SIP Call region). Among the type of sources potentially covered by this rule are stationary reciprocating internal combustion engines (RICE), which are a large contributor of NO_x emissions in the SIP Call region. On May 24, 1999, the DC Circuit Court of Appeals issued a stay on further implementation of the NO_x SIP Call, and agreed to hear motions from various parties opposed to implementation of the NO_x SIP Call. On March 3, 2000, a three-judge panel upheld most of the SIP Call provisions. This panel ruled, however, that EPA did not provide adequate notice of the final control level for RICE sources that EPA deemed highly cost effective. In response to this ruling, the EPA will re-propose the part of the NO_x SIP Call particular to RICE sources in the affected States in order to provide adequate notice to the public.

The data and results provided in this report update a previous report of the same name and dated June 7, 2000. The updates include incorporating RICE from Virginia and West Virginia, and modifying the fuel penalty estimate for lean-burn engines.

The analysis included in this report contains control cost estimates associated with the provisions of the re-proposal. This analysis shows that NO_x emission reductions for the large, affected RICEs under the NO_x SIP Call are expected to cost $532 per ton, on average. NO_x emissions within the control region are expected to be reduced by about 53,000 tons per 5 month ozone season in 2007 from what they would otherwise be without this program. Expected total annual costs for RICE NO_x controls under the NO_x SIP Call are $28 million.

This report provides information about the universe of potentially affected stationary RICEs, control cost modeling methods, scenario analyses, and caveats and uncertainties associated with this analysis. Chapter II describes the universe of potentially affected RICEs. Control cost modeling methods are described in Chapter III. Analysis results for the baseline analysis and sensitivity analyses are presented in Chapter IV. Chapter V describes some of the important caveats and uncertainties in this analysis.

All cost results presented in Chapter IV of this report are expressed in 1990 dollars. Where control cost equations listed in this report are expressed in year dollars other than 1990, that is noted in the applicable table. A 7 percent discount rate was used to express capital costs as annual equivalents. The choice of the 7 percent discount rate is based on guidance from the Office of Management and Budget (OMB).

CHAPTER II
UNIVERSE OF UNITS

Stationary RICEs generate electric power, pump gas or other fluids, or compress air for machinery. The primary non-utility application of internal combustion (IC) engines is in the natural gas industry to power compressors used for pipeline transportation, field gathering (collecting gas from wells), underground storage tanks, and in-gas processing plants. RICEs are separated into three design classes: 2 cycle (stroke) lean burn, 4-stroke lean burn, and 4-stroke rich burn. Each of these have design differences that affect both baseline emissions as well as the potential for emissions control.

Table II-1 presents information about the projected 2007 large RICE population in the NO_x SIP Call control region. The list of IC engines and NO_x estimates used in this analysis were supplied to The Pechan-Avanti Group (Pechan-Avanti) by EPA in two spreadsheets named lrge2-00b.123 on May 19, 2000, and ice3-2vawv.xls on August 2, 2000. These lists include the large RICEs in the entire States of Illinois, Indiana, Kentucky, Maryland, Massachusetts, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Alabama, Georgia, Michigan, Missouri, Virginia, and West Virginia. It should be noted that 4 of the 201 engines included in the analysis are in the coarse grid. For this analysis, a large RICE was defined as having emissions greater than or equal to 1 ton per day (tpd) in 1995 (the base year of the analysis).

Table II-1 lists the number of large RICEs (units) in each State, and their respective NO_x emissions expressed in daily and 5-month ozone season terms. The average large RICE emits about 2 tpd, and this value does not vary much from State-to-State. Alabama is the only State in the control region with more than 10,000 tons of NO_x from large RICEs in the 5-month ozone season. Thirteen States have ozone season NO_x emissions from RICE engines in the range between 1,000 and 10,000 tons. States in the control region with no affected engines are Connecticut, New Jersey, Rhode Island, DC, and Wisconsin. Combined, these RICEs are estimated to contribute to more than 60,000 tons of NO_x emissions during the 2007 5-month ozone season.

There are 67 establishments (facilities or plants) with large affected RICEs in the control region, as noted in Table II-1. No State has more than 9 establishments.

Table II-1
Summary of 2007 Major RICE Engine Emissions by State

FIPs State	State	# of Establishments	# of RICE	Ozone Season NO_x (tons/5 months)	Ozone Season Daily NO_x (tpd)
01	Alabama	4	32	11,977	78.3
13	Georgia	2	11	4,561	29.8
17	Illinois	9	28	6,647	43.4
18	Indiana	6	17	5,199	34.0
21	Kentucky	6	10	3,083	20.1
24	Maryland	2	3	609	4.0
25	Massachusetts	1	4	933	6.1
26	Michigan	3	6	1,601	10.5
29	Missouri	4	5	1,401	9.2
36	New York	2	2	417	2.7
37	North Carolina	3	12	3,275	21.4
39	Ohio	5	12	3,329	21.8
42	Pennsylvania	6	15	4,093	26.8
45	South Carolina	1	12	4,891	32.0
47	Tennessee	5	8	3,013	19.7
51	Virginia	4	17	4,077	26.6
54	West Virginia	4	7	1,101	7.2
	Total	**67**	**201**	**60,206**	**393.5**

CHAPTER III
CONTROL COST MODELING METHODS

NO_x controls applied to RICEs in this analysis were low-emission combustion (LEC) applied to lean burn gas-fired engines, non-selective catalytic reduction (NSCR) applied to rich burn gas-fired engines, and selective catalytic reduction (SCR) applied to oil-fired engines. The baseline control assumptions for each technology are 87 percent NO_x reduction for LEC, 90 percent for NSCR, and 90 percent for SCR.

Each control cost reference document reports control costs in specific year dollars. The EPA Alternative Control Techniques (ACT) document for RICEs reports costs in 1993 dollars. The capital cost estimates for LEC that were used in this analysis for controlling NO_x from lean burn gas-fired engines are reported in 1999 dollars. All costs were converted to 1990 dollars using National Income and Product Accounts gross domestic product implicit price deflator index from the Source of Current Business (DOC, 1999), as shown in Table III-1. Each EPA ACT document contains information about interest rates and the expected lifetime of each control technique. In estimating control costs for this analysis, the lifetime from the ACT document was used, and a 7 percent discount rate. The estimated equipment lifetime for IC engine controls is 15 years.

In the September 1998 analysis (Pechan-Avanti, 1998), it was assumed that all gas-fired engines were lean burn (because the Source Classification Codes [SCCs] did not distinguish lean and rich burn). This analysis assumes two thirds of gas-fired engines are lean burn, while one third are rich burn. This provides a more accurate assessment of expected control costs for RICEs than in the September 1998 NO_x SIP Call cost report (Pechan-Avanti, 1998), where all gas-fired engines were assumed to be lean-burn. As more States submit point source data using SCCs that distinguish lean from rich-burn engines, more sophisticated analyses can be performed.

Control costs are estimated in this analysis using an ozone season cost per ton. For controls that operate year round, like LEC, the ozone season cost per ton is the total annualized cost (with 100 percent of both capital and operating cost) divided by the ozone season (5 month) tons reduced. For SCR and NSCR, only five months of the operating cost is counted in computing the total annualized cost.

The estimates of 1995 and 2007 NO_x emissions for the (large) IC engines affected by the NO_x SIP Call were received in an EPA data base. Most of the units in this data base had a zero for NO_x control efficiency. None of the non-zero NO_x control efficiencies were more than 15 percent. Therefore, it was determined that any of the existing controls in place would not affect the performance of the control options needed to meet the NO_x SIP Call requirements. Therefore, when SCR, at an 80 percent control level, was applied to an oil-fired IC engine, and that engine had a 10 percent efficient control in 1995, the NO_x emissions and emission reductions were computed as:

Table III-1
Implicit Price Deflators

Year	Gross Domestic Product	Conversion to 1990 Dollars
1990	92.00	1.000
1991	96.27	0.955
1992	99.13	0.928
1993	101.84	0.903
1994	104.13	0.884
1995	106.75	0.862
1996	108.91	0.845
1997	111.00	0.829
1998	112.32	0.819
1999	113.52	0.810

SOURCE: DOC, 1999.

$$2007\ \textit{Uncontrolled}\ NO_x = [2007\ NO_x\ \textit{emissions}] \times \frac{1}{(1 - 0.1)}$$

Then, 2007 post-control NO_x was estimated as:

$$2007\ \textit{Post-Control}\ NO_x = [2007\ \textit{Uncontrolled}\ NO_x] \times (1 - \textit{control efficiency})$$

This method changes the State-level NO_x emission estimates slightly, in States with existing controls, but allows consistent application of different control efficiencies in the sensitivity analyses.

This cost analysis uses revised estimates of the costs of installing and operating LEC NO_x controls on lean-burn natural gas-fired RICEs. Table III-2 summarizes the revised control cost information for this control technique. Note that all of the costs in this table are presented in 1993 dollars (as were the NO_x ACT document costs). Capital costs were converted from 1999 dollars to 1993 dollars using the gross domestic product implicit price deflators. The maintenance labor rate was converted to 1993 dollars using the Bureau of Labor Statistics (BLS) Employment Cost Index Historical Listing (BLS, 2000). The BLS indices are shown in Table III-3.

The LEC capital cost estimates for 2,000, 4,000, and 8,000 horsepower (hp) engines were provided by Cooper Energy (Hibbard, 1999a; 1999b) and used directly in this analysis. Maintenance and overhead costs were estimated using recommended methods from the EPA Office of Air Quality Planning and Standards (OAQPS) Control Cost Manual (Vatavuk, 1999). The maintenance cost is the maintenance labor rate times the number of expected additional maintenance hours per year (500). The overhead cost is 60 percent of the maintenance labor value. The fuel penalty is based on an estimated one percent decrease in natural gas use. Taxes, insurance, and administrative costs are estimated to be 4 percent of the capital cost. The compliance test cost is $2,440, which is the same value that was estimated in the EPA ACT document (EPA, 1993).

Table III-4 summarizes the ozone season NO_x cost effectiveness values for each of the three engine type control option combinations that were evaluated in this analysis. More detailed information on the control cost equation development for this analysis is presented in Appendix A.

Table III-2
Low-Emission Combustion Cost Components for Lean-Burn RICEs

Size (hp)	Annual Hours	Capital Cost*	Maintenance Cost	Overhead Cost	Fuel Penalty	Taxes, Insurance Admin.	Compliance Test	O&M Cost
2,000	8,000	$337,493	$13,113	$7,868	$-1,643	$13,500	$2,440	$35,277
4,000	8,000	$552,620	$13,113	$7,868	$-2,987	$22,105	$2,440	$42,539
8,000	8,000	$594,784	$13,113	$7,868	$-5,867	$23,791	$2,440	$41,345

NOTE: *Costs are expressed in 1993 dollars.

SOURCE: Hibbard, 1999a; 1999b.

Table III-3
Employment Cost Indices

Year	Index (June 1989 = 100)
1991	107.4
1992	111.5
1993	114.7
1994	118.0
1995	121.9
1996	125.4
1997	129.1
1998	133.7
1999	137.9

SOURCE: BLS, 2000.

Table III-4
Unit Costs for RICE Analysis

Engine Type	Fuel	Control Option	Percentage Reduction	Ozone Season Cost Effectiveness ($/ton)
IC Engine-Lean Burn	Natural Gas	Low Emission Combustion	87%	422
IC Engine-Rich Burn	Natural Gas	Non-selective Catalytic Reduction	90%	342
IC Engine-All	Oil	Selective Catalytic Reduction	90%	1,066

CHAPTER IV
RESULTS

This chapter describes the analysis of the cost impacts for RICEs. This analysis estimates control costs and NO_x emission reductions for large RICEs affected under the NO_x SIP Call re-proposal.

Table IV-1 summarizes the analysis results at the domain level for the main analysis and six sensitivity control scenarios examined. Table IV-2 describes the key assumptions in the baseline analysis as well as how each of the alternative control scenarios (i.e., sensitivity analyses) differs from the baseline. Table IV-3 provides all of the same information as Table IV-1, but with more information reported. Table IV-3 reports results for each of the three engine types, and shows all of the before and after control NO_x emission values (annual tons, 5 month ozone season tons, and ozone season daily tons). The remaining tables in Chapter IV, Tables IV-4 through IV-10, provide State-level results for each scenario.

The average cost per ton (ozone season) for the main analysis is $532 per ton. This ozone season cost per ton is affected mostly by the gas-fired engine control costs. Oil-fired engines are about 3 percent of the population of large RICEs. While oil-fired engine costs are just above $1,000 per ton, they have a negligible influence on regionwide costs. Of the five oil-fired RICEs, four are in Massachusetts and one is in Missouri. Massachusetts has the highest control costs per ton because all of its affected RICEs are oil-fired.

In Scenario B, the control efficiency for LEC applied to lean burn gas-fired engines is reduced to 82 percent. This increases the average cost per ton by about $20 per ton. (The total annual cost changes slightly from the main analysis. *This change is an artifact of the way the total annual cost is estimated, though. Expected annual costs would be the same in Scenarios B and C as they are in the main analysis.*) The RICE NO_x reduction drops by almost 2,000 ozone season tons in Scenario B.

Scenario C increases the NO_x control efficiency for lean burn engines to 90 percent. This additional emission reduction reduces the average cost per ton to about $520 per ton, which is about $12 per ton less than in the main analysis.

Scenario D changes the uncontrolled NO_x emission level for lean burn gas-fired engines to 13.7 grams per brake horsepower-hour (g/bhp-hr) from 16.8 g/bhp-hr. With fewer NO_x tons being reduced, this raises the cost per ton to about $603 per ton.

A control level of 1.2 g/bhp-hr in Scenario E produces the lowest average cost per ton of $513 (and the largest emission reduction).

Scenario F reduces annual operating hours to 6,500. This changes both the emission reductions and the costs. Compared with other scenarios, there are lower emission reductions and costs, and with a cost per ton $49 higher than that in the main analysis.

Scenario G retains the capital cost estimates that were used in the September 1998 Non-Electricity Generating Unit (EGU) cost analysis for the NO_x SIP Call. The capital costs used for this analysis were taken from the ACT document. The scenario has the same emission reductions as the main analysis, but with $334 per ton higher estimated costs.

Table IV-1
Reciprocating IC Engine Cost Analysis Summary

Scenario		Ozone Season NO_x Emissions 5 Month Tons	Ozone Season NO_x 5 Month Ton Reduction	Annual Cost ($1000)	Average Cost Per Ton	Percentage Reduction
A	Main Analysis	60,206	53,006	$28,222	$532	87.8%
B	Control Efficiency = 82%		51,002	$28,007	$549	84.5%
C	Control Efficiency = 91%		54,539	$28,387	$520	90.4%
D	Uncontrolled NO_x = 13.7 g/bhp-hr		52,181	$31,464	$603	84.9%
E	Control Level = 1.2 g/bhp-hr		55,305	$28,390	$513	92.4%
F	Annual Hours = 6,500	49,154	43,281	$25,134	$581	71.7%
G	Previous Capital Cost Values		53,006	$45,899	$866	87.8%

Costs are expressed in 1990 dollars.

Table IV-2
Main Analysis and Scenario Description

Source Category	Description
Main Analysis Scenario A	For lean-burn gas-fired engines, the uncontrolled NO_x emission level is 16.8 g/bhp-hr, the controlled NO_x level (with LEC) is 2.0 g/bhp-hr, the annual hours of operation are 8,000, and LEC costs are estimated as described in Chapter III.
Scenario B	Control level of 3g/bhp-hr for gas-fired lean burn engines
Scenario C	Control level of 1.5g/bhp-hr for gas-fired lean burn engines
Scenario D	Uncontrolled level of 13.7g/bhp-hr for gas-fired lean burn engines
Scenario E	Control level of 1.2g/bhp-hr for gas-fired lean burn engines
Scenario F	Annual operating hours reduced to 6,500 hours/year for gas-fired lean burn engines
Scenario G	Uses the same LEC costs applied to lean burn engines that were used in the September 1998 NO_x SIP call analysis

Table IV-3
Control Measure Summary
Main Analysis and Scenario Results

Source Category	Control Option	# of Sources	Annual Baseline (tons/year)	Annual After Control (tons/year)	Annual Reduction (tons)	Ozone Season Baseline (tons/5 mo)	Ozone Season After Control (tons/5 mo)	Ozone Season Reduction (tons/5 mo.)	Ozone Season Daily Baseline (tons/day)	Ozone Season Daily After Control (tons/day)	Ozone Season Daily Reduction (tons)	Total Annual Cost ($1000)	Cost per Ozone Season Ton ($)
Main Analysis - Scenario A													
IC Engine-Gas leanburn	LEC	131	94,306	11,317	82,990	39,294	4,715	34,579	256.8	30.8	226.0	18,175	422
IC Engine-Gas rich burn	NSCR	65	47,153	5,658	41,495	19,647	2,358	17,289	128.4	15.4	113.0	9,087	342
IC Engine-Oil	SCR	5	3,034	1,896	1,138	1,264	126	1,138	8.3	0.8	7.4	960	1,066
Total		**201**	**144,493**	**18,871**	**125,622**	**60,206**	**7,199**	**53,006**	**394**	**47**	**346**	**28,222**	**532**
Scenario B - Control Efficiency = 82%													
IC Engine-Gas leanburn	LEC	131	94,306	14,523	79,783	39,294	6,051	33,243	256.8	39.6	217.3	18,031	448
IC Engine-Gas rich burn	NSCR	65	47,153	7,262	39,892	19,647	3,026	16,621	128.4	19.8	108.6	9,015	342
IC Engine-Oil	SCR	5	3,034	1,896	1,138	1,264	126	1,138	8.3	0.8	7.4	960	1,066
Total		**201**	**144,493**	**23,681**	**120,812**	**60,206**	**9,203**	**51,002**	**394**	**60**	**333**	**28,007**	**549**
Scenario C - Control Efficiency = 91%													
IC Engine-Gas leanburn	LEC	131	94,306	8,865	85,442	39,294	3,694	35,601	256.8	24.1	232.7	18,284	404
IC Engine-Gas rich burn	NSCR	65	47,153	4,432	42,721	19,647	1,847	17,800	128.4	12.1	116.3	9,142	342
IC Engine-Oil	SCR	5	3,034	1,896	1,138	1,264	126	1,138	8.3	0.8	7.4	960	1,066
Total		**201**	**144,493**	**15,193**	**129,300**	**60,206**	**5,667**	**54,539**	**394**	**37**	**356**	**28,387**	**520**
Scenario D - Uncontrolled NO_x = 13.7 g/bhp-hr													
IC Engine-Gas leanburn	LEC	131	94,306	12,637	81,669	39,294	5,265	34,029	256.8	34.4	222.4	20,336	530
IC Engine-Gas rich burn	NSCR	65	47,153	6,319	40,835	19,647	2,633	17,014	128.4	17.2	111.2	10,168	342
IC Engine-Oil	SCR	5	3,034	1,896	1,138	1,264	126	1,138	8.3	0.8	7.4	960	1,066
Total		**201**	**144,493**	**20,852**	**123,642**	**60,206**	**8,025**	**52,181**	**394**	**52**	**341**	**31,464**	**603**
Scenario E - Control Level = 1.2 g/bhp-hr													
IC Engine-Gas leanburn	LEC	131	94,306	7,639	86,668	39,294	3,183	36,111	256.8	20.8	236.0	18,287	395
IC Engine-Gas rich burn	NSCR	65	47,153	3,819	43,334	19,647	1,591	18,056	128.4	10.4	118.0	9,143	342
IC Engine-Oil	SCR	5	3,034	1,896	1,138	1,264	126	1,138	8.3	0.8	7.4	960	1,066
Total		**201**	**144,493**	**13,354**	**131,139**	**60,206**	**4,901**	**55,305**	**394**	**32**	**361**	**28,390**	**513**
Scenario F - Annual Hours = 6,500													
IC Engine-Gas leanburn	LEC	131	76,624	9,195	67,429	31,927	3,831	28,095	208.7	25.0	183.6	16,116	496
IC Engine-Gas rich burn	NSCR	65	38,312	4,597	33,715	15,963	1,916	14,048	104.3	12.5	91.8	8,058	290
IC Engine-Oil	SCR	5	3,034	1,896	1,138	1,264	126	1,138	8.3	0.8	7.4	960	1,066
Total		**201**	**117,970**	**15,688**	**102,281**	**49,154**	**5,873**	**43,281**	**321**	**38**	**283**	**25,134**	**581**
Scenario G - Previous Capital Cost Values													
IC Engine-Gas leanburn	LEC	131	94,306	11,317	82,990	39,294	4,715	34,579	256.8	30.8	226.0	29,959	936
IC Engine-Gas rich burn	NSCR	65	47,153	5,658	41,495	19,647	2,358	17,289	128.4	15.4	113.0	14,980	342
IC Engine-Oil	SCR	5	3,034	1,896	1,138	1,264	126	1,138	8.3	0.8	7.4	960	1,066
Total		**201**	**144,493**	**18,871**	**125,622**	**60,206**	**7,199**	**53,006**	**394**	**47**	**346**	**45,899**	**866**

Table IV-4
State Summary - Scenario A - Main Analysis

FIPS State	State	Annual Baseline (tons/year)	Annual After Control (tons/year)	Annual Reduction (tons)	Ozone Season Baseline (tons/year)	Ozone Season After Control (tons/year)	Ozone Season Daily Baseline (tons/year)	Ozone Season Daily After Control (tons/year)	Ozone Season Cost ($1,000)	Ozone Season Reduction (tons)	Ozone Season Daily Reduction (tons)	Ozone Season $/Ton
01	Alabama	28,745	3,449	25,296	11,977	1,437	78.3	9.4	4,163	10,540	68.9	395
13	Georgia	10,947	1,314	9,633	4,561	547	29.8	3.6	1,585	4,014	26.2	395
17	Illinois	15,953	1,914	14,039	6,647	798	43.4	5.2	2,311	5,849	38.2	395
18	Indiana	12,477	1,497	10,980	5,199	624	34.0	4.1	1,807	4,575	29.9	395
21	Kentucky	7,398	888	6,510	3,083	370	20.1	2.4	1,071	2,713	17.7	395
24	Maryland	1,463	176	1,287	609	73	4.0	0.5	212	536	3.5	395
25	Massachusetts	2,239	1,399	839	933	93	6.1	0.6	895	839	5.5	1,066
26	Michigan	3,843	461	3,381	1,601	192	10.5	1.3	557	1,409	9.2	395
29	Missouri	3,362	805	2,557	1,401	161	9.2	1.1	690	1,239	8.1	556
36	New York	1,001	120	881	417	50	2.7	0.3	145	367	2.4	395
37	North Carolina	7,859	943	6,916	3,275	393	21.4	2.6	1,138	2,882	18.8	395
39	Ohio	7,989	959	7,031	3,329	399	21.8	2.6	1,157	2,929	19.1	395
42	Pennsylvania	9,824	1,179	8,645	4,093	491	26.8	3.2	1,423	3,602	23.5	395
45	South Carolina	11,737	1,408	10,329	4,891	587	32.0	3.8	1,700	4,304	28.1	395
47	Tennessee	7,230	868	6,363	3,013	362	19.7	2.4	1,047	2,651	17.3	395
51	Virginia	9,785	1,174	8,610	4,077	489	26.6	3.2	1,417	3,588	23.4	395
54	West Virginia	2,641	317	2,324	1,101	132	7.2	0.9	383	969	6.3	395
	Total	**144,493**	**18,871**	**125,622**	**60,206**	**7,199**	**393.5**	**47.1**	**21,701**	**53,006**	**346.4**	**409**

Table IV-5
State Summary - Scenario B
Control Efficiency = 82%

FIPS State	State	Annual Baseline (tons/year)	Annual After Control (tons/year)	Annual Reduction (tons)	Ozone Season Baseline (tons/year)	Ozone Season After Control (tons/year)	Ozone Season Daily Baseline (tons/year)	Ozone Season Daily After Control (tons/year)	Ozone Season Cost ($1,000)	Ozone Season Reduction (tons)	Ozone Season Daily Reduction (tons)	Ozone Season $/Ton
01	Alabama	28,745	4,427	24,318	11,977	1,844	78.3	12.1	4,175	10,133	66.2	412
13	Georgia	10,947	1,686	9,261	4,561	702	29.8	4.6	1,590	3,859	25.2	412
17	Illinois	15,953	2,457	13,496	6,647	1,024	43.4	6.7	2,317	5,623	36.8	412
18	Indiana	12,477	1,922	10,556	5,199	801	34.0	5.2	1,812	4,398	28.7	412
21	Kentucky	7,398	1,139	6,259	3,083	475	20.1	3.1	1,074	2,608	17.0	412
24	Maryland	1,463	225	1,237	609	94	4.0	0.6	212	516	3.4	412
25	Massachusetts	2,239	1,399	839	933	93	6.1	0.6	895	839	5.5	1,066
26	Michigan	3,843	592	3,251	1,601	247	10.5	1.6	558	1,354	8.9	412
29	Missouri	3,362	892	2,470	1,401	198	9.2	1.3	691	1,203	7.9	574
36	New York	1,001	154	847	417	64	2.7	0.4	145	353	2.3	412
37	North Carolina	7,859	1,210	6,649	3,275	504	21.4	3.3	1,141	2,770	18.1	412
39	Ohio	7,989	1,230	6,759	3,329	513	21.8	3.4	1,160	2,816	18.4	412
42	Pennsylvania	9,824	1,513	8,311	4,093	630	26.8	4.1	1,427	3,463	22.6	412
45	South Carolina	11,737	1,808	9,930	4,891	753	32.0	4.9	1,705	4,137	27.0	412
47	Tennessee	7,230	1,113	6,117	3,013	464	19.7	3.0	1,050	2,549	16.7	412
51	Virginia	9,785	1,507	8,278	4,077	628	26.6	4.1	1,421	3,449	22.5	412
54	West Virginia	2,641	407	2,235	1,101	169	7.2	1.1	384	931	6.1	412
	Total	**144,493**	**23,681**	**120,812**	**60,206**	**9,203**	**393.5**	**60.2**	**21,757**	**51,002**	**333.3**	**427**

Table IV-6
State Summary - Scenario C
Control Efficiency = 91%

FIPS State	State	Annual Baseline (tons/year)	Annual After Control (tons/year)	Annual Reduction (tons)	Ozone Season Baseline (tons/year)	Ozone Season After Control (tons/year)	Ozone Season Daily Baseline (tons/year)	Ozone Season Daily After Control (tons/year)	Ozone Season Cost ($1,000)	Ozone Season Reduction (tons)	Ozone Season Daily Reduction (tons)	Ozone Season $/Ton
01	Alabama	28,745	2,702	26,043	11,977	1,126	78.3	7.4	4,156	10,851	70.9	383
13	Georgia	10,947	1,029	9,918	4,561	429	29.8	2.8	1,583	4,132	27.0	383
17	Illinois	15,953	1,500	14,453	6,647	625	43.4	4.1	2,307	6,022	39.4	383
18	Indiana	12,477	1,173	11,305	5,199	489	34.0	3.2	1,804	4,710	30.8	383
21	Kentucky	7,398	695	6,703	3,083	290	20.1	1.9	1,070	2,793	18.3	383
24	Maryland	1,463	137	1,325	609	57	4.0	0.4	211	552	3.6	383
25	Massachusetts	2,239	1,399	839	933	93	6.1	0.6	895	839	5.5	1,066
26	Michigan	3,843	361	3,481	1,601	150	10.5	1.0	556	1,451	9.5	383
29	Missouri	3,362	738	2,624	1,401	134	9.2	0.9	689	1,267	8.3	544
36	New York	1,001	94	907	417	39	2.7	0.3	145	378	2.5	383
37	North Carolina	7,859	739	7,121	3,275	308	21.4	2.0	1,136	2,967	19.4	383
39	Ohio	7,989	751	7,238	3,329	313	21.8	2.0	1,155	3,016	19.7	383
42	Pennsylvania	9,824	923	8,900	4,093	385	26.8	2.5	1,420	3,709	24.2	383
45	South Carolina	11,737	1,103	10,634	4,891	460	32.0	3.0	1,697	4,431	29.0	383
47	Tennessee	7,230	680	6,551	3,013	283	19.7	1.9	1,045	2,729	17.8	383
51	Virginia	9,785	920	8,865	4,077	383	26.6	2.5	1,415	3,694	24.1	383
54	West Virginia	2,641	248	2,393	1,101	103	7.2	0.7	382	997	6.5	383
	Total	**144,493**	**15,193**	**129,300**	**60,206**	**5,667**	**393.5**	**37.0**	**21,665**	**54,539**	**356.5**	**397**

Table IV-7
State Summary - Scenario D
Uncontrolled NO_x = 13.7 g/bhp-hr

FIPS State	State	Annual Baseline (tons/year)	Annual After Control (tons/year)	Annual Reduction (tons)	Ozone Season Baseline (tons/year)	Ozone Season After Control (tons/year)	Ozone Season Daily Baseline (tons/year)	Ozone Season Daily After Control (tons/year)	Ozone Season Cost ($1,000)	Ozone Season Reduction (tons)	Ozone Season Daily Reduction (tons)	Ozone Season $/Ton
01	Alabama	28,745	3,852	24,893	11,977	1,605	78.3	10.5	4,844	10,372	67.8	467
13	Georgia	10,947	1,467	9,480	4,561	611	29.8	4.0	1,845	3,950	25.8	467
17	Illinois	15,953	2,138	13,815	6,647	891	43.4	5.8	2,688	5,756	37.6	467
18	Indiana	12,477	1,672	10,805	5,199	697	34.0	4.6	2,103	4,502	29.4	467
21	Kentucky	7,398	991	6,407	3,083	413	20.1	2.7	1,247	2,669	17.4	467
24	Maryland	1,463	196	1,267	609	82	4.0	0.5	246	528	3.4	467
25	Massachusetts	2,239	1,399	839	933	93	6.1	0.6	895	839	5.5	1,066
26	Michigan	3,843	515	3,328	1,601	215	10.5	1.4	648	1,387	9.1	467
29	Missouri	3,362	841	2,521	1,401	176	9.2	1.2	750	1,224	8.0	613
36	New York	1,001	134	867	417	56	2.7	0.4	169	361	2.4	467
37	North Carolina	7,859	1,053	6,806	3,275	439	21.4	2.9	1,324	2,836	18.5	467
39	Ohio	7,989	1,071	6,919	3,329	446	21.8	2.9	1,346	2,883	18.8	467
42	Pennsylvania	9,824	1,316	8,508	4,093	549	26.8	3.6	1,655	3,545	23.2	467
45	South Carolina	11,737	1,573	10,165	4,891	655	32.0	4.3	1,978	4,235	27.7	467
47	Tennessee	7,230	969	6,261	3,013	404	19.7	2.6	1,218	2,609	17.1	467
51	Virginia	9,785	1,311	8,473	4,077	546	26.6	3.6	1,649	3,531	23.1	467
54	West Virginia	2,641	354	2,287	1,101	147	7.2	1.0	445	953	6.2	467
	Total	**144,493**	**20,852**	**123,642**	**60,206**	**8,025**	**393.5**	**52.4**	**25,050**	**52,181**	**341.1**	**480**

Table IV-8
State Summary - Scenario E
Control Level = 1.2 g/bhp-hr

FIPS State	State	Annual Baseline (tons/year)	Annual After Control (tons/year)	Annual Reduction (tons)	Ozone Season Baseline (tons/year)	Ozone Season After Control (tons/year)	Ozone Season Daily Baseline (tons/year)	Ozone Season Daily After Control (tons/year)	Ozone Season Cost ($1,000)	Ozone Season Reduction (tons)	Ozone Season Daily Reduction (tons)	Ozone Season $/Ton
01	Alabama	28,745	2,328	26,417	11,977	970	78.3	6.3	4,150	11,007	71.9	377
13	Georgia	10,947	887	10,060	4,561	369	29.8	2.4	1,580	4,192	27.4	377
17	Illinois	15,953	1,292	14,661	6,647	538	43.4	3.5	2,303	6,109	39.9	377
18	Indiana	12,477	1,011	11,467	5,199	421	34.0	2.8	1,801	4,778	31.2	377
21	Kentucky	7,398	599	6,799	3,083	250	20.1	1.6	1,068	2,833	18.5	377
24	Maryland	1,463	118	1,344	609	49	4.0	0.3	211	560	3.7	377
25	Massachusetts	2,239	1,399	839	933	93	6.1	0.6	895	839	5.5	1,066
26	Michigan	3,843	311	3,531	1,601	130	10.5	0.8	555	1,471	9.6	377
29	Missouri	3,362	705	2,657	1,401	120	9.2	0.8	688	1,281	8.4	537
36	New York	1,001	81	920	417	34	2.7	0.2	145	383	2.5	377
37	North Carolina	7,859	637	7,223	3,275	265	21.4	1.7	1,135	3,009	19.7	377
39	Ohio	7,989	647	7,342	3,329	270	21.8	1.8	1,153	3,059	20.0	377
42	Pennsylvania	9,824	796	9,028	4,093	332	26.8	2.2	1,418	3,762	24.6	377
45	South Carolina	11,737	951	10,787	4,891	396	32.0	2.6	1,694	4,494	29.4	377
47	Tennessee	7,230	586	6,645	3,013	244	19.7	1.6	1,044	2,769	18.1	377
51	Virginia	9,785	793	8,992	4,077	330	26.6	2.2	1,412	3,747	24.5	377
54	West Virginia	2,641	214	2,427	1,101	89	7.2	0.6	381	1,011	6.6	377
	Total	**144,493**	**13,354**	**131,139**	**60,206**	**4,901**	**393.5**	**32.0**	**21,634**	**55,305**	**361.5**	**391**

Table IV-9
State Summary - Scenario F
Annual Hours = 6,500

FIPS State	State	Annual Baseline (tons/year)	Annual After Control (tons/year)	Annual Reduction (tons)	Ozone Season Baseline (tons/year)	Ozone Season After Control (tons/year)	Ozone Season Daily Baseline (tons/year)	Ozone Season Daily After Control (tons/year)	Ozone Season Cost ($1,000)	Ozone Season Reduction (tons)	Ozone Season Daily Reduction (tons)	Ozone Season $/Ton
01	Alabama	23,355	2,803	20,553	9,731	1,168	63.6	7.6	3,657	8,564	56.0	427
13	Georgia	8,894	1,067	7,827	3,706	445	24.2	2.9	1,393	3,261	21.3	427
17	Illinois	12,962	1,555	11,406	5,401	648	35.3	4.2	2,029	4,753	31.1	427
18	Indiana	10,138	1,217	8,921	4,224	507	27.6	3.3	1,587	3,717	24.3	427
21	Kentucky	6,011	721	5,290	2,505	301	16.4	2.0	941	2,204	14.4	427
24	Maryland	1,188	143	1,046	495	59	3.2	0.4	186	436	2.8	427
25	Massachusetts	2,239	1,399	839	933	93	6.1	0.6	895	839	5.5	1,066
26	Michigan	3,122	375	2,747	1,301	156	8.5	1.0	489	1,145	7.5	427
29	Missouri	2,881	747	2,134	1,200	137	7.8	0.9	644	1,063	6.9	606
36	New York	814	98	716	339	41	2.2	0.3	127	298	2.0	427
37	North Carolina	6,386	766	5,619	2,661	319	17.4	2.1	1,000	2,341	15.3	427
39	Ohio	6,491	779	5,712	2,705	325	17.7	2.1	1,016	2,380	15.6	427
42	Pennsylvania	7,982	958	7,024	3,326	399	21.7	2.6	1,250	2,927	19.1	427
45	South Carolina	9,537	1,144	8,392	3,974	477	26.0	3.1	1,493	3,497	22.9	427
47	Tennessee	5,875	705	5,170	2,448	294	16.0	1.9	920	2,154	14.1	427
51	Virginia	7,950	954	6,996	3,312	397	21.7	2.6	1,245	2,915	19.1	427
54	West Virginia	2,146	258	1,889	894	107	5.8	0.7	336	787	5.1	427
	Total	**117,970**	**15,688**	**102,281**	**49,154**	**5,873**	**321.3**	**38.4**	**19,208**	**43,281**	**282.9**	**444**

Table IV-10
State Summary - Scenario G
Previous Capital Cost Values

FIPS State	State	Annual Baseline (tons/year)	Annual After Control (tons/year)	Annual Reduction (tons)	Ozone Season Baseline (tons/year)	Ozone Season After Control (tons/year)	Ozone Season Daily Baseline (tons/year)	Ozone Season Daily After Control (tons/year)	Ozone Season Cost ($1,000)	Ozone Season Reduction (tons)	Ozone Season Daily Reduction (tons)	Ozone Season $/Ton
01	Alabama	23,355	2,803	20,553	9,731	1,168	63.6	7.6	3,657	8,564	56.0	427
13	Georgia	8,894	1,067	7,827	3,706	445	24.2	2.9	1,393	3,261	21.3	427
17	Illinois	12,962	1,555	11,406	5,401	648	35.3	4.2	2,029	4,753	31.1	427
18	Indiana	10,138	1,217	8,921	4,224	507	27.6	3.3	1,587	3,717	24.3	427
21	Kentucky	6,011	721	5,290	2,505	301	16.4	2.0	941	2,204	14.4	427
24	Maryland	1,188	143	1,046	495	59	3.2	0.4	186	436	2.8	427
25	Massachusetts	2,239	1,399	839	933	93	6.1	0.6	895	839	5.5	1,066
26	Michigan	3,122	375	2,747	1,301	156	8.5	1.0	489	1,145	7.5	427
29	Missouri	2,881	747	2,134	1,200	137	7.8	0.9	644	1,063	6.9	606
36	New York	814	98	716	339	41	2.2	0.3	127	298	2.0	427
37	North Carolina	6,386	766	5,619	2,661	319	17.4	2.1	1,000	2,341	15.3	427
39	Ohio	6,491	779	5,712	2,705	325	17.7	2.1	1,016	2,380	15.6	427
42	Pennsylvania	7,982	958	7,024	3,326	399	21.7	2.6	1,250	2,927	19.1	427
45	South Carolina	9,537	1,144	8,392	3,974	477	26.0	3.1	1,493	3,497	22.9	427
47	Tennessee	5,875	705	5,170	2,448	294	16.0	1.9	920	2,154	14.1	427
51	Virginia	7,950	954	6,996	3,312	397	21.7	2.6	1,245	2,915	19.1	427
54	West Virginia	2,146	258	1,889	894	107	5.8	0.7	336	787	5.1	427
	Total	**117,970**	**15,688**	**102,281**	**49,154**	**5,873**	**321.3**	**38.4**	**19,208**	**43,281**	**282.9**	**444**

CHAPTER V
CAVEATS AND UNCERTAINTIES

Caveats and uncertainties associated with this cost analysis include:

1. Current knowledge about NO_x control techniques and costs is applied in this study. Advances such as alternative catalyst formulations may occur between now and when sources comply with this rulemaking that may lower costs. Scale economies can also lower per unit production costs as the market for these NO_x control techniques expands.

2. The alternative control techniques and corresponding emission reductions and costs may not apply to every unit within the source category. Many factors influence the performance and cost of any control technique. Because control technology references typically evaluate average retrofit situations, costs may be underestimated for the fraction of the source population with difficult to retrofit conditions. Difficult to retrofit conditions may be less of an issue for RICEs than for other point sources, however.

3. Control costs for large RICEs are estimated using cost estimates for 2,000, 4,000 and 8,000 hp engines. Cost estimates will be most uncertain where controls are being applied to large engines that are outside the 2,000 to 8,000 hp range.

4. Because States focused their efforts on reporting ozone season daily emissions, those are expected to be the most reliable emission estimates. The five-month ozone season values are sometimes reported by the States, and sometimes estimated by EPA using temporal allocation factors.

5. NO_x control efficiency estimates associated with source category-control strategy combinations are represented as point estimates. In practice, control effectiveness will vary by unit. The sensitivity analyses shown earlier in this report provide an indication of how cost effectiveness is affected by uncertainties in control efficiency.

6. Operating costs for LEC are probably overstated in this analysis because a slight fuel penalty for operating with LEC was applied. It is likely that fuel efficiency will increase with LEC.

7. Estimates of the fraction of the IC engine population that are lean burn versus rich burn are uncertain because the emission data bases used in this analysis do not usually make this distinction.

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APPENDIX A
DETAILED CONTROL COST WORKSHEETS

APPENDIX A
DETAILED CONTROL COST WORKSHEETS

The details of the control cost and efficiency input parameters used in this analysis are provided in Tables A-1 through A-7 as shown below.

Table A-1	Scenario A - Main Analysis Unit Cost Calculations
Table A-2	Scenario B - Control Efficiency = 82%
Table A-3	Scenario C - Control Efficiency = 91%
Table A-4	Scenario D - Uncontrolled NO_x = 13.7 g/bhp-hr
Table A-5	Scenario E - Control Level = 1.2 g/bhp-hr
Table A-6	Scenario F - Annual Hours = 6,500
Table A-7	Scenario G - Previous Capital Cost Values

Table A-1
Scenario A Main Analysis Unit Cost Calculations

Measure/Size	hp	Year ($)	Capital	Equip Life	Interest	CRF	Fraction Capital to O&M (from ACT)	O&M Cost	Emission Factor (g/bhp-hr)	Hours of Operation	Total Annual Cost	Fraction Capital to Annual	Control Efficiency	Controlled Emission Factor (g/bhp-hr)	Reduction (tons)	Annual Cost Per Ton (1993$)	Ozone Season Cost Per Ton (1993$)		Annual cost per ton (in 1990$)	Ozone Season cost per ton (in 1990$)
IC Engines																				
L-E (Low)/ lean burn	2,000	1993	337,493	15	0.07	0.1098	2.04	35,277	16.8	8,000	72,332	4.67	0.87	2.00	258	281	673		253	608
L-E (Low)/ lean burn	4,000	1993	552,620	15	0.07	0.1098	1.97	42,539	16.8	8,000	103,213	5.35	0.87	2.00	516	200	480		181	434
L-E (Low)/ lean burn	8,000	1993	594,784	15	0.07	0.1098	1.87	41,345	16.8	8,000	106,649	5.58	0.87	2.00	1,031	103	248		93	224
																		Average	**176**	**422**
NSCR / rich burn	2000	1993	72,400	15	0.07	0.1098	0.68	106,050	15.8	8,000	114,000	0.64	0.90	1.58	251	455	499		411	451
NSCR / rich burn	4000	1993	133,000	15	0.07	0.1098	0.93	143,400	15.8	8,000	158,000	0.84	0.90	1.58	502	315	356		285	321
NSCR / rich burn	8000	1993	253,000	15	0.07	0.1098	1.17	216,200	15.8	8,000	244,000	1.04	0.90	1.58	1,003	243	282		220	255
																		Average	**305**	**342**
											Input control efficiency		**0.879**							
																		Gas Fired Ave	219	395
Oil																				
SCR	2,000	1993	382,000	15	0.07	0.1098	2.04	195,100	12.0	8,000	237,042	1.61	0.90	1.20	190	1,244	1,553		1124	1403
SCR	4,000	1993	577,000	15	0.07	0.1098	1.97	268,600	12.0	8,000	331,951	1.74	0.90	1.20	381	871	1,104		787	997
SCR	8,000	1993	967,000	15	0.07	0.1098	1.87	417,000	12.0	8,000	523,171	1.85	0.90	1.20	762	687	882		620	797
																		Oil Fired Ave	**844**	**1066**

Table A-2
Scenario B Unit Cost Calculations - Control Efficiency = 82%

Measure/Size	hp	Year ($)	Capital	Equip Life	Interest	CRF	Fraction Capital to O&M (from ACT)	O&M Cost	Emission Factor (g/bhp-hr)	Hours of Operation	Total Annual Cost	Fraction Capital to Annual	Control Efficiency	Controlled Emission Factor (g/bhp-hr)	Reduction (tons)	Annual Cost Per Ton	Ozone Season Cost Per Ton		Annual cost per ton (in 1990$)	Ozone Season cost per ton (in 1990$)
IC Engines																				
L-E (Low)/ lean burn	2,000	1993	337,493	15	0.07	0.1098	2.04	35,277	16.8	8,000	72,332	4.67	0.82	3.00	243	298	714		269	645
L-E (Low)/ lean burn	4,000	1993	552,620	15	0.07	0.1098	1.97	42,539	16.8	8,000	103,213	5.35	0.82	3.00	486	212	510		192	461
L-E (Low)/ lean burn	8,000	1993	594,784	15	0.07	0.1098	1.87	41,345	16.8	8,000	106,649	5.58	0.82	3.00	972	110	263		99	238
																		Average	**187**	**448**
NSCR / rich burn	2000	1993	72,400	15	0.07	0.1098	0.68	106,050	15.8	8,000	114,000	0.64	0.90	1.58	251	455	499		411	451
NSCR / rich burn	4000	1993	133,000	15	0.07	0.1098	0.93	143,400	15.8	8,000	158,000	0.84	0.90	1.58	502	315	356		285	321
NSCR / rich burn	8000	1993	253,000	15	0.07	0.1098	1.17	216,200	15.8	8,000	244,000	1.04	0.90	1.58	1,003	243	282		220	255
																		Average	**305**	**342**
											Input control efficiency		**0.846**							
																		Gas Fired Ave	**226**	**412**
Oil																				
SCR	2,000	1993	382,000	15	0.07	0.1098	2.04	195,100	12.0	8,000	237,042	1.61	0.90	1.20	190	1,244	1,553		1124	1403
SCR	4,000	1993	577,000	15	0.07	0.1098	1.97	268,600	12.0	8,000	331,951	1.74	0.90	1.20	381	871	1,104		787	997
SCR	8,000	1993	967,000	15	0.07	0.1098	1.87	417,000	12.0	8,000	523,171	1.85	0.90	1.20	762	687	882		620	797
																		Oil Fired Ave	**844**	**1066**

Table A-3
Scenario C Unit Cost Calculations - Control Efficiency = 91%

Measure/Size	hp	Year ($)	Capital	Equip Life	Interest	CRF	Fraction Capital to O&M (from ACT)	O&M Cost	Emission Factor (g/bhp-hr)	Hours of Operation	Total Annual Cost	Fraction Capital to Annual	Control Efficiency	Controlled Emission Factor (g/bhp-hr)	Reduction (tons)	Annual Cost Per Ton	Ozone Season Cost Per Ton		Annual cost per ton (in 1990$)	Ozone Season cost per ton (in 1990$)
IC Engines																				
L-E (Low)/ lean burn	2,000	1993	337,493	15	0.07	0.1098	2.04	35,277	16.8	8,000	72,332	4.67	0.91	1.50	270	268	644		242	582
L-E (Low)/ lean burn	4,000	1993	552,620	15	0.07	0.1098	1.97	42,539	16.8	8,000	103,213	5.35	0.91	1.50	539	191	459		173	415
L-E (Low)/ lean burn	8,000	1993	594,784	15	0.07	0.1098	1.87	41,345	16.8	8,000	106,649	5.58	0.91	1.50	1,079	99	237		89	214
																		Average	**168**	**404**
NSCR / rich burn	2000	1993	72,400	15	0.07	0.1098	0.68	106,050	15.8	8,000	114,000	0.64	0.90	1.58	251	455	499		411	451
NSCR / rich burn	4000	1993	133,000	15	0.07	0.1098	0.93	143,400	15.8	8,000	158,000	0.84	0.90	1.58	502	315	356		285	321
NSCR / rich burn	8000	1993	253,000	15	0.07	0.1098	1.17	216,200	15.8	8,000	244,000	1.04	0.90	1.58	1,003	243	282		220	255
																		Average	**305**	**342**
											Input control efficiency		**0.9058**							
																		Gas Fired Ave	**214**	**383**
Oil																				
SCR	2,000	1993	382,000	15	0.07	0.1098	2.04	195,100	12.0	8,000	237,042	1.61	0.90	1.20	190	1,244	1,553		1124	1403
SCR	4,000	1993	577,000	15	0.07	0.1098	1.97	268,600	12.0	8,000	331,951	1.74	0.90	1.20	381	871	1,104		787	997
SCR	8,000	1993	967,000	15	0.07	0.1098	1.87	417,000	12.0	8,000	523,171	1.85	0.90	1.20	762	687	882		620	797
																		Oil Fired Ave	**844**	**1066**

Table A-4
Scenario D Unit Cost Calculations - Uncontrolled NO_x = 13.7 g/bhp-hr

Measure/Size	hp	Year ($)	Capital	Equip Life	Interest	CRF	Fraction Capital to O&M (from ACT)	O&M Cost	Emission Factor (g/bhp-hr)	Hours of Operation	Total Annual Cost	Fraction Capital to Annual	Control Efficiency	Controlled Emission Factor (g/bhp-hr)	Reduction (tons)	Annual Cost Per Ton	Ozone Season Cost Per Ton		Annual cost per ton (in 1990$)	Ozone Season cost per ton (in 1990$)
IC Engines																				
L-E (Low)/ lean burn	2,000	1993	337,493	15	0.07	0.1098	2.04	35,277	13.7	8,000	72,332	4.67	0.85	2.00	205	352	845		318	764
L-E (Low)/ lean burn	4,000	1993	552,620	15	0.07	0.1098	1.97	42,539	13.7	8,000	103,213	5.35	0.85	2.00	411	251	603		227	545
L-E (Low)/ lean burn	8,000	1993	594,784	15	0.07	0.1098	1.87	41,345	13.7	8,000	106,649	5.58	0.85	2.00	822	130	312		117	281
																		Average	**221**	**530**
NSCR / rich burn	2000	1993	72,400	15	0.07	0.1098	0.68	106,050	15.8	8,000	114,000	0.64	0.90	1.58	251	455	499		411	451
NSCR / rich burn	4000	1993	133,000	15	0.07	0.1098	0.93	143,400	15.8	8,000	158,000	0.84	0.90	1.58	502	315	356		285	321
NSCR / rich burn	8000	1993	253,000	15	0.07	0.1098	1.17	216,200	15.8	8,000	244,000	1.04	0.90	1.58	1,003	243	282		220	255
																		Average	**305**	**342**
											Input control efficiency		**0.866**							
																		Gas Fired Ave	**249**	**467**
Oil																				
SCR	2,000	1993	382,000	15	0.07	0.1098	2.04	195,100	12.0	8,000	237,042	1.61	0.90	1.20	190	1,244	1,553		1124	1403
SCR	4,000	1993	577,000	15	0.07	0.1098	1.97	268,600	12.0	8,000	331,951	1.74	0.90	1.20	381	871	1,104		787	997
SCR	8,000	1993	967,000	15	0.07	0.1098	1.87	417,000	12.0	8,000	523,171	1.85	0.90	1.20	762	687	882		620	797
																		Oil Fired Ave	**844**	**1066**

Table A-5
Scenario E Unit Cost Calculations - Control Level = 1.2 g/bhp-hr

Measure/Size	hp	Year ($)	Capital	Equip Life	Interest	CRF	Fraction Capital to O&M (from ACT)	O&M Cost	Emission Factor (g/bhp-hr)	Hours of Operation	Total Annual Cost	Fraction Capital to Annual	Control Efficiency	Controlled Emission Factor (g/bhp-hr)	Reduction (tons)	Annual Cost Per Ton	Ozone Season Cost Per Ton		Annual cost per ton (in 1990$)	Ozone Season cost per ton (in 1990$)
IC Engines																				
L-E (Low)/ lean burn	2,000	1993	337,493	15	0.07	0.1098	2.04	35,277	16.8	8,000	72,332	4.67	0.93	1.20	276	262	630		237	569
L-E (Low)/ lean burn	4,000	1993	552,620	15	0.07	0.1098	1.97	42,539	16.8	8,000	103,213	5.35	0.93	1.20	551	187	449		169	406
L-E (Low)/ lean burn	8,000	1993	594,784	15	0.07	0.1098	1.87	41,345	16.8	8,000	106,649	5.58	0.93	1.20	1,102	97	232		87	210
																		Average	**165**	**395**
NSCR / rich burn	2000	1993	72,400	15	0.07	0.1098	0.68	106,050	15.8	8,000	114,000	0.64	0.90	1.58	251	455	499		411	451
NSCR / rich burn	4000	1993	133,000	15	0.07	0.1098	0.93	143,400	15.8	8,000	158,000	0.84	0.90	1.58	502	315	356		285	321
NSCR / rich burn	8000	1993	253,000	15	0.07	0.1098	1.17	216,200	15.8	8,000	244,000	1.04	0.90	1.58	1,003	243	282		220	255
																		Average	**305**	**342**
											Input control efficiency		**0.919**							
																		Gas Fired Ave	**211**	**377**
Oil																				
SCR	2,000	1993	382,000	15	0.07	0.1098	2.04	195,100	12.0	8,000	237,042	1.61	0.90	1.20	190	1,244	1,553		1124	1403
SCR	4,000	1993	577,000	15	0.07	0.1098	1.97	268,600	12.0	8,000	331,951	1.74	0.90	1.20	381	871	1,104		787	997
SCR	8,000	1993	967,000	15	0.07	0.1098	1.87	417,000	12.0	8,000	523,171	1.85	0.90	1.20	762	687	882		620	797
																		Oil Fired Ave	**844**	**1066**

Table A-6
Scenario F Unit Cost Calculations - Annual Hours = 6,500

Measure/Size	hp	Year ($)	Capital	Equip Life	Interest	CRF	Fraction Capital to O&M (from ACT)	O&M Cost	Emission Factor (g/bhp-hr)	Hours of Operation	Total Annual Cost	Fraction Capital to Annual	Control Efficiency	Controlled Emission Factor (g/bhp-hr)	Reduction (tons)	Annual Cost Per Ton	Ozone Season Cost Per Ton		Annual cost per ton (in 1990$)	Ozone Season cost per ton (in 1990$)
IC Engines																				
L-E (Low)/ lean burn	2,000	1993	337,493	15	0.07	0.1098	2.04	31,343	16.8	6,500	68,398	4.93	0.87	2.00	209	327	784		295	708
L-E (Low)/ lean burn	4,000	1993	552,620	15	0.07	0.1098	1.97	38,605	16.8	6,500	99,279	5.57	0.87	2.00	419	237	569		214	514
L-E (Low)/ lean burn	8,000	1993	594,784	15	0.07	0.1098	1.87	37,411	16.8	6,500	102,715	5.79	0.87	2.00	838	123	294		111	266
																		Average	**207**	**496**
NSCR / rich burn	2000	1993	72,400	15	0.07	0.1098	0.84	86,166	15.8	8,000	114,000	0.64	0.90	1.58	251	455	420		411	379
NSCR / rich burn	4000	1993	133,000	15	0.07	0.1098	1.14	116,512	15.8	8,000	158,000	0.84	0.90	1.58	502	315	302		285	273
NSCR / rich burn	8000	1993	253,000	15	0.07	0.1098	1.44	175,662	15.8	8,000	244,000	1.04	0.90	1.58	1,003	243	242		220	218
																		Average	**305**	**290**
											Input control efficiency		**0.879**							
																		Gas Fired Ave	**239**	**427**
Oil																				
SCR	2,000	1993	382,000	15	0.07	0.1098	2.04	195,100	12.0	8,000	237,042	1.61	0.90	1.20	190	1,244	1,553		1124	1403
SCR	4,000	1993	577,000	15	0.07	0.1098	1.97	268,600	12.0	8,000	331,951	1.74	0.90	1.20	381	871	1,104		787	997
SCR	8,000	1993	967,000	15	0.07	0.1098	1.87	417,000	12.0	8,000	523,171	1.85	0.90	1.20	762	687	882		620	797
																		Oil Fired Ave	**844**	**1066**

Table A-7
Scenario G Unit Cost Calculations - Previous Capital Cost Values

Measure/Size	hp	Year ($)	Capital	Equip Life	Interest	CRF	Fraction Capital to O&M (from ACT)	O&M Cost	Emission Factor (g/bhp-hr)	Hours of Operation	Total Annual Cost	Fraction Capital to Annual	Control Efficiency	Controlled Emission Factor (g/bhp-hr)	Reduction (tons)	Annual Cost Per Ton	Ozone Season Cost Per Ton		Annual cost per ton (in 1990$)	Ozone Season cost per ton (in 1990$)
IC Engines																				
L-E (Low)/Small	2,500	1993	1,190,000	15	0.07	0.1098		35,277			165,932	7.17	0.87	2.00	325	511	1,225		461	1107
L-E (Low)/Medium-Large	4,000	1993	1,710,000	15	0.07	0.1098		42,539			230,287	7.43	0.87	2.00	522	441	1,059		399	956
L-E (Low)/Medium-Large	11,000	1993	4,150,000	15	0.07	0.1098		41,345			496,993	8.35	0.87	2.00	1,445	344	825		311	746
																		Average	**390**	**936**
NSCR / rich burn	2000	1993	72,400	15	0.07	0.1098	0.68	106,050	15.8	8,000	114,000	0.64	0.90	1.58	251	455	499		411	451
NSCR / rich burn	4000	1993	133,000	15	0.07	0.1098	0.93	143,400	15.8	8,000	158,000	0.84	0.90	1.58	502	315	356		285	321
NSCR / rich burn	8000	1993	253,000	15	0.07	0.1098	1.17	216,200	15.8	8,000	244,000	1.04	0.90	1.58	1,003	243	282		220	255
																		Average	**305**	**342**
											Input control efficiency		**0.880**							
																		Gas Burn Ave	**361**	**738**
Oil																				
SCR	2,000	1993	382,000	15	0.07	0.1098	2.04	195,100	12.0	8,000	237,042	1.61	0.90	1.20	190	1,244	1,553		1124	1403
SCR	4,000	1993	577,000	15	0.07	0.1098	1.97	268,600	12.0	8,000	331,951	1.74	0.90	1.20	381	871	1,104		787	997
SCR	8,000	1993	967,000	15	0.07	0.1098	1.87	417,000	12.0	8,000	523,171	1.85	0.90	1.20	762	687	882		620	797
																		Oil Burn Ave	**844**	**1066**

APPENDIX B
SOURCE CLASSIFICATION CODES AFFECTED BY THE NO_x SIP CALL

Table B-1
Source Classification Codes Affected by the NO_x SIP Call

20200202	Internal Combustion Engines; Industrial; Natural Gas; Reciprocating
20200204	Internal Combustion Engines; Industrial; Natural Gas; Reciprocating; Cogeneration
20200252	Internal Combustion Engines; Industrial; Natural Gas; 2-cycle Lean Burn
20200254	Internal Combustion Engines; Industrial; Natural Gas; 4-cycle Lean Burn
20200401	Internal Combustion Engines; Industrial; Large Bore Engine; Diesel
20200501	Internal Combustion Engines; Industrial; Residual/Crude Oil; Reciprocating
20300201	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Reciprocating