Final Report

EVALUATION OF CANDIDATE MOBILE SOURCE CONTROL MEASURES

Prepared for

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EXECUTIVE SUMMARY

The Lake Michigan Air Directors Consortium (LADCO) is working with the States in the upper Midwest, Illinois, Indiana, Michigan, Ohio, and Wisconsin, to develop the necessary technical support for new State Implementation Plans (SIPs) for regional haze, PM2.5, and 8-hour ozone. To support this process, LADCO contracted with ENVIRON to identify and evaluate candidate control measures for on-road and nonroad mobile sources for the LADCO states.

The project objectives were to review, recommend and assess emission control measures for mobile sources; develop white papers for selected control measures to reduce emissions from mobile sources in the LADCO states; and estimate potential emission reductions from these selected control measures in the LADCO states.

To achieve these objectives, ENVIRON reviewed mobile source emission inventories to identify major sources in the LADCO states; reviewed control measure literature for mobile sources and developed a master list of potential control measures; performed a qualitative screening analysis to develop a short list of control measures; performed technical and economical analyses on selected control measures; and developed emission reduction scenarios to estimate overall potential emission reductions, costs, and vehicle or equipment penetration rates for selected control measures.

In carrying out the qualitative screening analysis, ENVIRON identified and compiled a master list of more than 70 emission control measures for mobile sources by several control measure categories, including alternative and conventional fuel, equipment or fleet modernization, idling restriction/reduction, inspection/maintenance programs, low-emission vehicle (LEV) programs, retrofitting, ozone action days/public awareness programs, intelligent transportation system (ITS) and VMT reduction programs. Section 2 of the report presents the master list and results of the qualitative screening analysis.

The objective of the qualitative screening analysis was to refine and reduce the master list to a shorter list for further technical and economic analyses, as well as for developing white papers on selected control measures for mobile sources. The screening evaluation for these control measures was based on approximate contribution levels to the NOx, PM, and VOC emission inventories and past experience in program effectiveness and feasibility for these measures.

While the criteria included emission benefits, emission impacts, cost effectiveness, technical feasibility, likely public acceptance, and EPA creditability, the qualitative screening analysis was heavily weighted on the emission impacts on reducing NOx and PM emissions, with primary focus on NOx emissions. This was decided based on the results from LADCO's source apportionment study, showing that on-road NOx emissions are the dominant source of ozone and PM-nitrate concentrations in the region, as well as the results of LADCO's Urban Organics Study, suggesting that mobile sources are the dominant source of primary organic carbon concentrations in these areas.

As presented in Section 2 of the report, emission inventory data show that more than 40% of NOx and 50% of PM emissions from the 2009 on-road emission inventory are from heavy-duty diesel vehicles in the LADCO states. As for the NONROAD equipment, more than 80% and 55% of the 2009 NONROAD NOx and PM emissions, respectively, are from the NONROAD diesel equipment for all LADCO states. Construction and agricultural diesel equipment each contribute more than 30% and 20% of the NOx and PM emissions, respectively. Therefore, it was determined that control measures targeting these sources (i.e. on-road heavy-duty diesel vehicles, nonroad diesel construction and agricultural equipment) would provide substantial and effective NOx and/or PM emission reductions.

Using the emission inventories and information/data from past experience of control measures, ENVIRON ranked and prioritized the control measures in the master list based on preliminary emission reduction potential for each control measure. With the ranking results and discussion with LADCO states, 15 control measures were selected for technical and economic analyses, with control measures for on-road HDDVs and diesel construction and agricultural equipment as primary control measures. These selected control measures are summarized in Table ES-1.

Table ES-1. Selected control measures for different mobile emission sources.

On-road Diesel Vehicles
- Measure 16b: California Diesel Fuel

On-road Heavy Heavy-Duty Diesel Vehicles
- Measure 16a: Emulsified Diesel Fuel
- Measure 31: Fleet Modernization
- Measure 42: Accelerate Low NOx Calibration/Reflashing Program
- Measure 46: Aftertreatment Device Retrofits
- Measure 47: NG/Dual Fuel Retrofits
- Measure 29a: Fleet Modernization via HDD AFVs
- Measure 67: Speed Limit Restriction Program

Nonroad Diesel Equipment
- Measure 16b: California Diesel Fuel

NONROAD Diesel Construction Equipment
- Measure 16a: Emulsified Diesel Fuel
- Measure 20: Equipment Fleet Modernization
- Measure 51: Aftertreatment Device Retrofits for Nonroad Equipment
    - Measure 51a: Lean NOx Catalyst
    - Measure 51b: EGR+DPF Retrofit
    - Measure 51c: SCR Retrofit

NONROAD Diesel Agricultural Equipment
- Measure 16a: Emulsified Diesel Fuel
- Measure 20: Equipment Fleet Modernization
- Measure 51: Aftertreatment Device Retrofits for Nonroad Equipment
    - Measure 51a: Lean NOx Catalyst
    - Measure 51b: EGR+DPF Retrofit
    - Measure 51c: SCR Retrofit

On-road Light-Duty Vehicles
- Measure 40: Implementing/Expanding I/M Programs for LDVs
- Measure 28/29/43/45: Accelerated Vehicle Replacement of Older Fleet Vehicles (10 Years old or older)
- Measure 44: Vehicle Scrappage Program for 25 Years Old Vehicles

For each selected control measure, ENVIRON developed a White Paper that includes a technical descriptions of the control measure; estimates of emission reductions, costs, and cost-effectiveness; and issues related to implementation. These White Papers are presented in Section 3 of the report.

Per LADCO's request, several emission reduction scenarios were developed to estimate potential emission reductions and associated costs using the results from the detailed cost benefit analyses of the selected control measures. Section 4 of this report presents a few of many potential emission reduction scenarios based on those primary selected control measures for reducing NOx emissions from on-road diesel vehicles and nonroad diesel equipment, focusing on the on-road HDDVs and diesel construction and agricultural equipment as they are the primary sources of NOx emissions in the mobile source emission inventories in the LADCO states. These emission reduction scenarios provide a general idea of potential emission reductions from target sources, as well as available measures to cost effectively reduce these available or excess emissions and associated costs to achieve the potential emission reductions.

To develop these emission reduction scenarios, ENVIRON identified major emission contributors based on emission inventories; generated or estimated vehicle or equipment population data; identified and selected control measures for target sources; applied potential emission reductions and associated cost estimates on a per vehicle or equipment basis, and cost-effectiveness values for selected measures; developed criteria for penetration or compliance rates based on cost effectiveness values and vehicle or equipment availability (turnover rates); and estimated potential total emission reductions and measure costs for selected measures and combinations of selected measures.

Table ES-2 presents the summary results of an example emission reduction scenario for the on-road diesel vehicles in the LADCO states. As shown in this table, this scenario for heavy HDDVs could achieve more than 100 tons per day (tpd) of NOx emissions reduction for selected incentive/voluntary measures (i.e. all measures, except the California Diesel Fuel and Low NOx Calibration/Reflashing) for a cost of about $1.2 billion with an average cost-effectiveness value of about $5,200 per ton of NOx reduced. The total number of vehicles involved under this scenario for voluntary/incentive programs is about 40,000, which is about 20% of the total available fleet in 2009. Assuming that a LADCO emission reduction program would begin in 2007, the 20% vehicle penetration rate would translate to about 7% turnover rate per year in a three-year time frame which is a viable penetration rate to achieve.

Table ES-2. Summary results of an example emission reduction scenario to reduce NOx emissions from on-road diesel vehicles in the LADCO states in 2009.

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Measure 16a: Reformulated Diesel Fuels (Incentive/Voluntary Program)							
Emulsified Diesel Fuel (3 yrs of fuel cost)							
MY 1989 and Earlier	$9,039	0.33	$8,434	88,148	2,644	$22,303,773	2.39
Sub Total					**2,644**	**22,303,773**	**2.39**
Measure 47: NG/Dual Fuel Retrofits (Incentive/Voluntary Program)							
LNG/Dual Fuel Retrofit: HDDVs (2.0 g NOx)							
MY 1989 and Earlier	$9,870	1.49	$42,575	88,148	2,644	$112,586,878	10.79
Sub Total					**2,644**	**112,586,878**	**10.79**
Measure 29a: Fleet Modernization via HDD AFVs							
LNG/Dual Fuel Retrofit: Refuse Trucks (2.0 g NOx)							

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
MY 1989 and Earlier	$4,844	1.79	$44,257	1,763	88	$3,901,182	0.43
MY 1990	$10,733	0.81	$44,257	166	2	$73,536	0.00
Sub Total					**90**	**3,974,717**	**0.44**
LNG/Dual Fuel Retrofit: Transit Buses (2.0 g NOx)							
MY 1989 and Earlier	$6,554	2.24	$42,575	233	12	$495,624	0.07
Sub Total					**12**	**495,624**	**0.07**
Measure 31: Fleet Modernization (Incentive/Voluntary Program)							
Diesel Engine/Vehicle Upgrades (MY 1990 Engine 6 g NOx)							
MY 1989 and Earlier	$6,053	0.82	$35,000	88,148	4,407	$154,258,593	9.95
Sub Total					**4,407**	**154,258,593**	**9.95**
Diesel Engine/Vehicle Upgrades (MY 2001/2 Engine 4 g NOx)							
MY 1989 and Earlier	$4,772	1.19	$40,000	88,148	4,407	$176,295,535	14.42
Sub Total					**4,407**	**176,295,535**	**14.42**
Diesel Engine/Vehicle Upgrades (MY 2002/4 Engine 2.4 g NOx)							
MY 1989 and Earlier	$4,423	1.45	$45,000	88,148	4,407	$198,332,477	17.50
MY 1990	$10,246	0.63	$45,000	8,308	83	$3,738,478	0.14
Sub Total					**4,490**	**202,070,955**	**17.64**
Measure 46: Aftertreatment Device Retrofits (Incentive/Voluntary Program)							
Lean NOx Catalyst							
MY 1989 and Earlier	$5,905	0.55	$20,000	88,148	4,407	$88,147,768	6.64
MY 1990	$10,682	0.30	$20,000	8,308	83	$1,661,546	0.07
Sub Total					**4,490**	**89,809,313**	**6.71**
EGR+DPF Retrofit							
MY 1989 and Earlier	$5,970	0.55	$23,000	88,148	4,407	$101,369,933	6.64
MY 1990	$10,846	0.30	$23,000	8,308	83	$1,910,778	0.07
Sub Total					**4,490**	**103,280,710**	**6.71**
SCR Retrofit							
MY 1989 and Earlier	$3,139	1.37	$27,500	88,148	8,815	$242,406,361	33.19
MY 1990	$5,685	0.76	$27,500	8,308	415	$11,423,127	0.86
MY 1991 – 1997	$7,055	0.61	$27,500	49,786	1,494	$41,073,438	2.49
MY 1998 – 2001	$8,984	0.48	$27,500	22,943	688	$18,927,968	0.90
Sub Total					**11,412**	**313,830,895**	**37.45**
Overall Projects							
MY 1989 and Earlier				88,148	36,240	1,100,098,124	102.02
MY 1990				8,308	666	18,807,464	1.14
MY 1991 - 1997				49,786	1,494	41,073,438	2.49
MY 1998 - 2001				22,943	688	18,927,968	0.90
Total				**193,330**	**39,089**	**1,178,906,995**	**106.57**
Measure 42: Accelerate Low NOx Calibration/Reflash Program (Mandatory Phase-in)							
Diesel Engine Reflash (MY 1993-1998 Engines)							
MY 1993-1998	$2,485	0.16	$398	146,134	87,680	$34,858,835	38.44
MY 1993-1998	$1,842	0.22	$398	40,201	32,161	$12,786,148	19.02
Sub Total					**119,841**	**47,644,983**	**57.45**
Measure 16b: California Diesel Fuel (Mandatory Program)							
California Diesel Fuel (All Diesel Vehicles)							
LDDVs	$29,622	0.00072	$21	40,800	20,400	$437,256	0.04
LDDTs	$72,642	0.00046	$33	91,974	45,987	$1,522,696	0.06
Class 2b HDDVs	$165,553	0.00041	$67	1,680,666	840,333	$56,475,121	0.93
Class 3-5 HDDVs	$41,629	0.00186	$77	353,078	176,539	$13,655,581	0.90
Class 6-7 HDDVs	$23,417	0.00524	$123	565,913	282,956	$34,746,503	4.07
Class 8 HDDVs	$3,787	0.09519	$360	203,639	101,819	$36,700,580	26.55
Buses	$14,199	0.02311	$328	125,592	62,796	$20,607,405	3.98
Sub Total					**1,530,831**	**164,145,142**	**36.53**
Grand Total						**1,395,167,461**	**200.5**

Assuming that the LADCO states adopt the California Diesel Fuel measure as a mandatory program, the measure would provide more than 35 tpd of NOx emission reduction with a conservative 50% compliance rate for a cost of about $165 million. The average cost-effectiveness value for the California Diesel Fuel measure was estimated to be about $13,000 per ton of NOx reduced. Thus, it would not be as cost-effective to implement it as a voluntary-type program. If the Low NOx Calibration/Reflashing measure were adopted as a mandatory program, the measure would reduce about 60 tpd of NOx emissions for a cost of about $48 million in 2009 from the applicable HDDVs, with assumed compliance rates of 60% and 80% for medium HDDVs, and heavy HDDVs, respectively. The cost-effectiveness value for the Low NOx Calibration/Reflashing measure was estimated to be about $2,000 per ton of NOx reduced.

The potential total NOx emission reduction from the emission reduction scenario for on-road diesel vehicles for all measures shown in Table ES-2, focusing on HDDVs, would be about 200 tpd in 2009 for a total cost of about $1.4 billion. This scenario is conservative in that a 7% vehicle penetration rate is assumed based on an average cost-effectiveness value of $5,000, which is much less than the $13,000 cost-effectiveness limit in the Texas Emission Reduction Program (TERP).

Table ES-3 presents the summary results of an example emission reduction scenario for major NOx emission contributors from construction equipment. As shown in this table, this scenario shows that, with all selected measures, except the California Diesel Fuel measure, NOx emissions could be reduced by more than 55 tpd in the LADCO states in 2009 for a cost of about $830 million. The average cost-effectiveness value was estimated to be less than $4,000 per ton of NOx reduced. The total equipment count in this scenario is about 16,500 units, which is about 20% of the targeted construction equipment population in 2009. Assuming that a LADCO emission reduction program would begin in 2007, the 20% equipment penetration rate would translate to about 7% turnover rate per year in a three-year time frame, which is a viable penetration rate to achieve. Also shown in Table ES-3, the California Diesel Fuel measure would provide an addition of about 20 tpd of NOx emissions reduction for a cost of about $70 million.

Table ES-3. Summary results of an example emission reduction scenario for some major construction equipment in LADCO states in 2009.

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)			
Sub Total	**0**	**0**	**0.00**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)			
Excavators	1,074	40,503,000	2.26
Rubber Tire Loaders	967	67,620,723	3.92
Crawler Tractor/Dozer	813	58,993,621	3.76
Tractors/Loaders/Backhoes	1,481	28,195,250	0.99
Off-Highway Trucks	133	18,082,569	1.49
Sub Total	**4,468**	**213,395,163**	**12.42**
Measure 51a: Lean NOx Catalyst			
Excavators	1,632	44,378,947	2.30
Rubber Tire Loaders	1,190	61,905,928	3.25
Crawler Tractor/Dozer	947	51,423,880	3.19
Tractors/Loaders/Backhoes	140	2,800,000	0.11
Off-Highway Trucks	266	30,454,853	2.91

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Sub Total	**4,175**	**190,963,608**	**11.76**
Measure 51b: EGR+DPF Retrofit			
Excavators	125	3,965,684	0.20
Rubber Tire Loaders	47	3,330,950	0.16
Crawler Tractor/Dozer	185	12,554,261	0.61
Tractors/Loaders/Backhoes	0	0	0.00
Off-Highway Trucks	45	5,924,957	0.45
Sub Total	**402**	**25,775,853**	**1.42**
Measure 51c: SCR Retrofit			
Excavators	3,018	112,742,763	7.67
Rubber Tire Loaders	1,760	124,811,283	7.97
Crawler Tractor/Dozer	1,598	115,875,696	8.72
Tractors/Loaders/Backhoes	808	22,220,000	0.90
Off-Highway Trucks	266	23,392,250	5.46
Sub Total	**7,450**	**399,041,993**	**30.72**
Grand Total (Voluntary Programs)	**16,495**	**829,176,616**	**56.32**
Measure 16b: CA Diesel (All Diesel Equipment)			
Railway Maintenance	1,120	144,510	0.04
Pleasure Craft	34,461	2,383,585	0.69
Recreational	3,266	77,563	0.02
Construction and Mining	126,920	29,236,523	8.46
Industrial	56,331	6,378,901	1.85
Lawn and Garden	36,697	1,448,864	0.42
Agricultural	233,537	27,251,763	7.88
Commercial	103,414	3,607,695	1.04
Logging	589	212,576	0.06
Airport Ground Support	1,617	370,126	0.11
Underground Mining	368	68,374	0.02
Sub Total	**598,319**	**71,180,481**	**20.59**
Grand Total		**900,357,096**	**76.91**

Table ES-4 presents the summary results of an example emission reduction scenario for major agricultural equipment. This table shows that this scenario could reduce NOx emissions by more than 50 tpd for a cost of about $1.3 billion. The average cost-effectiveness value was estimated to be about $6,700 per ton of NOx reduced. The total equipment count involved in this scenario is about 37,500 units, which is about 10% of the targeted agricultural equipment population in 2009. Assuming that a LADCO emission reduction program would begin in 2007, the 10% equipment penetration rate would translate to a turnover rate of about 3% per year in a three-year time frame - a very viable penetration rate to achieve. Given the favorable average cost-effectiveness value and turnover rates, a more aggressive cost-effectiveness criteria could be used to increase the penetration rates, and hence, the potential emission reductions if funding were a secondary issue.

Table ES-4. Summary results of an example emission reduction scenario for some major agricultural equipment in LADCO states in 2009.

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)			
Sub Total	**0**	**0**	**0.0**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)			
Agricultural Tractors	10,797	354,163,200	12.6
Sub Total	**10,797**	**354,163,200**	**12.6**
Measure 51a: Lean NOx Catalyst			
Agricultural Tractors	8,030	252,610,105	8.6
Sub Total	**8,030**	**252,610,105**	**8.6**
Measure 51b: EGR+DPF Retrofit			
Sub Total	**0**	**0**	**0.0**
Measure 51c: SCR Retrofit			
Agricultural Tractors	18,673	725,979,342	33.2
Sub Total	**18,673**	**725,979,342**	**33.2**
Grand Total (Voluntary Programs)	**37,500**	**1,332,752,647**	**54.4**

Based on these emission reduction scenarios shown in Tables ES-3 and ES-4, a total NOx reduction of more than 130 tpd could be achieved in 2009 by implementing selected control measures in 2007 for nonroad diesel equipment focusing on construction and agricultural equipment.

Table ES-5 shows the state-by-state potential NOx emission reductions for the three emission reduction scenarios.

Table ES-5. State-by-state potential NOx emission reductions for the three emission reduction scenarios.

	NOx Emission Reductions (tpd)		
	On-Road HDDV	Construction Equipment	Agricultural Equipment
Illinois	50.0	23.10	20.2
Indiana	34.3	12.48	10.9
Michigan	39.2	12.48	6.1
Ohio	50.5	20.70	9.0
Wisconsin	26.6	9.41	8.2
Total	**200.6**	**78.2**	**54.4**

In addition to the three primary emission reduction scenarios, ENVIRON also estimated potential emission benefits of several secondary control measures for on-road vehicles: speed limit reduction measure for HD diesel vehicles, and LEVII, accelerated vehicle replacement and scrappage, and I/M programs for light-duty vehicles. A detailed assessment of potential emission reductions for these selected secondary measures would require substantial MOBILE 6 modeling that was not possible within the available project resources. Thus, some limited results based on available data in existing studies are presented in this report.

Diesel fuel costs were key assumptions of most of the selected control measures in determining the cost effectiveness of the measures, a sensitivity analysis was conducted to assess the impact of increasing fuel costs by 30% on the emission reduction scenarios. In summary, the fuel sensitivity results show that there were no major impacts on potential emission reductions if the assumed fuel costs were to increase by 30%. A summary of the sensitivity analysis is presented in Table ES-6.

Table ES-6. Summary of fuel sensitivity analysis for the three example scenarios.

Scenarios	Potential NOx Emission Reductions (tpd)		
	Baseline Diesel Fuel Cost ($2.15/gallon)	30% Increase in Diesel Fuel Cost ($2.76/gallon)	Differences
On-road HDDVs	200.5	191.7	8.8
Construction Diesel Equipment	76.9	74.4	2.5
Agricultural Diesel Equipment	54.4	51.8	2.6
Total	331.8	317.9	13.9

Some of the selected emission control measures would reduce PM emissions, in addition to reducing NOx emissions. For each emission reduction scenario, ENVIRON also estimated the potential PM emission reductions by estimating the per-vehicle or equipment PM emission reduction and the number of vehicle or equipment recommended for each measure. The state-by-state potential PM emission reductions for the three different scenarios are presented in Table ES-7. It is very important to note that these PM emissions reductions are those that are associated with the control measures evaluated and this study has focused exclusively on control measures for reducing NOx emissions. There are other control measures for which the cost-effectiveness for PM emissions reduction will be lower; but this study did not focus on those measures.

Table ES-7. State-by-state potential PM emission reductions for the three emission reduction scenarios.

	PM Emission Reductions (tpd)		
	On-Road HDDV	Construction Equipment	Agricultural Equipment
Illinois	1.163	0.121	0.226
Indiana	0.800	0.062	0.122
Michigan	0.751	0.069	0.068
Ohio	1.190	0.114	0.101
Wisconsin	0.608	0.048	0.091
Total	**4.511**	**0.414**	**0.608**

1. INTRODUCTION

As part of the Midwest Regional Planning Organization (MRPO), The Lake Michigan Air Directors Consortium (LADCO) is working with the States in the upper Midwest, Illinois, Indiana, Michigan, Ohio, and Wisconsin, to develop the necessary technical support for new State Implementation Plans (SIPs) for regional haze, PM2.5, and 8-hour ozone. In July 2005, LADCO issued a contract to ENVIRON to identify and evaluate candidate control measures for mobile sources for the LADCO states.

The project objectives were to review, recommend and assess emission control measures for mobile sources; develop white papers for selected control measures to reduce emissions from mobile sources in the LADCO states; and estimate potential emission reductions from these selected control measures in the LADCO states.

To achieve these objectives, ENVIRON:

- Identified and compiled a draft master list of potential emission control measures for mobile sources, and discussed and finalized the master list based on LADCO's comments[1].

- Compiled or generated 2009 mobile source emission inventories by vehicle or equipment types, and by model year and/or technology type, for LADCO states to identify major emission sources, and to estimate available emissions and vehicles or equipment for control measure qualitative screening and emission reduction scenario analyses.

- Performed a qualitative screening analysis on the control measures in the master list, and recommended a short list of control measures for further technical and economical analyses based mainly on potential creditable emission reductions tailored to LADCO states' needs, cost effectiveness, technical or implementation feasibility, and likely public acceptance.

- Prepared a technical memorandum presenting the results of the qualitative analysis and recommended measures, and discussed and finalized the short list of selected control measures based on LADCO's comments.

- Performed technical and economic analyses on selected control measures on major emission contributors by estimating potential emission reductions for the selected control measures and costs associated with implementing these measures, and calculated the cost-effectiveness of these control measures based on the potential emission reductions and cost data.

- Prepared emission reduction scenarios to estimate overall potential emission reductions, costs, and vehicle or equipment penetration rates for selected control measures based on a set of penetration rate criteria as a function of cost-effectiveness values of the selected control measures.

[1] Appendix A provides a list of major control measure references reviewed in this project.

This report presents the results of the project for each step in the analysis. Section 2 presents the results of the qualitative screening analysis. Section 3 presents the results of the technical and economic analyses of the selected control measures. Section 4 presents potential emission reduction scenarios for on-road vehicles and non-road equipment in 2009 for the LADCO states.

2. QUALITATIVE SCREENING ANALYSIS OF CONTROL MEASURES

QUALITATIVE SCREENING ANALYSIS

In carrying out the qualitative screening analysis, ENVIRON identified and compiled a draft master list of control measures for mobile sources, and presented and discussed the draft master list with the LADCO states[1]. ENVIRON finalized the master list of mobile source control measures for the qualitative screening analysis based on LADCO's comments. The objective of the qualitative screening analysis was to refine and reduce the master list to a shorter list for further technical and economic analyses, as well as for developing white papers on selected control measures for mobile sources. The following general criteria were used to qualitatively evaluate the candidate control measures:

- Emission impacts in terms of potential emission reduction
- Emission benefit relative to mobile source category
- Technical feasibility
- SIP creditable (permanent, quantifiable, surplus, enforceable)
- Cost effectiveness
- Implementation feasibility
- Public acceptability

Of these criteria, the potential emissions reduction was deemed to be of the highest importance.

The qualitative screening assessment was performed on more than 70 emission control measures listed in the preliminary master list in Table 2-1, in the following control measure categories:

- Alternative fuels,
- Conventional fuels;
- Equipment modernization programs,
- Fleet modernization programs,
- Idling restriction/reduction programs,
- Inspection/maintenance programs,
- Low-emission vehicles (LEV) programs,
- Retrofitting programs,
- Ozone action days/public awareness programs,
- Intelligent transportation system (ITS) programs, and
- VMT reduction programs.

To the extent that data and/or information were available, ENVIRON estimated preliminary potential emission benefits for the control strategies based on their control effectiveness or efficiency, and potential emission impacts based on the emission benefits and estimated ranges of penetration rates. Section 3 of this report presents the results of the technical and economic analyses that provide refined emission reduction benefit and impact estimates for those selected control measures.

[1] Appendix A provides a lost of major control measure references reviewed in this project.

Table 2-1. Master list for mobile source control measures.

Control ID	Category	Source	Control Measures
1	Alternative Fuels	On-road	Alternative fuel pilot projects
2	Alternative Fuels	On-road	Private sector clean fuel fleets
3	Alternative Fuels	On-road	Public sector clean fuel fleets
4	Alternative Fuels	On-road	Alternative fuel vehicle conversion
5	Alternative Fuels	On-road	Clean fuel Incentives
6	Alternative Fuels	On-road	Alternative fuel, hybrid, fuel cell school/transit bus programs
7	Alternative Fuels	On-road	Alternative fuel refuse trucks programs
8	Alternative Fuels	Nonroad	Hybrid diesel electric and LNG switching engine locomotive pilot programs
9	Alternative Fuels	Nonroad	Accelerate the turnover of residential gasoline lawn & garden equipment to electric
10	Alternative Fuels	Nonroad	Accelerate the turnover of industry equipment to alternative fuels or electric
11	Alternative Fuels	Nonroad	Airport ground support equipment electrification
12	Alternative Fuels	Nonroad	Shoreside power for marine vessels at berth
13	Conventional Fuels	On- & Nonroad	RFG/California RFG
14	Conventional Fuels	On & Nonroad	Lower RVP Gasoline
15	Conventional Fuels	Nonroad	Early phase in of ULSD fuels for Nonroad equipment, commercial marine; locomotives
16	Conventional Fuels	On- & Nonroad	Reformulated diesel fuels (e.g. Fischer-Trope diesel; emulsified diesel; CA diesel)
17	Conventional Fuels	On- & Nonroad	Diesel fuel additives
18	Conventional Fuels	On-road	Gas cap replacement program (give free vouchers to failed vehicles w/ faulty or missing gas caps) Toledo Metro COG has such program (Ohio & Michigan)
19	Conventional Fuels	On & Nonroad	Stage II Vapor Recovery
20	Equipment Modernization	Nonroad	Accelerated purchase of Tier2/Tier 3/Tier 4 Nonroad engines or on-road engines
21	Equipment Modernization	Nonroad	Accelerate the turnover of large SI engines to engines meeting Large SI Nonroad Engine Standards
22	Equipment Modernization	Nonroad	Replace 2-stroke engines with 4-stroke engines in recreation vehicles/marine/equipment
23	Equipment Modernization	Nonroad	Accelerate the turnover of older locomotives to Tier 2 locomotives
24	Equipment Modernization	Nonroad	Accelerate the turnover of older commercial marine engines to Tier 2 engines
25	Equipment Modernization	Nonroad	Accelerate the turnover of older agricultural engines to Tier 2/Tier3/Tier 4 Nonroad engines or on-road engines
26	Equipment Modernization	Nonroad	Residential L&G equipment (e.g. lawnmowers) exchange/rebate/buy back programs
27	Equipment Modernization	Nonroad	Contract-based incentives/requirements (Green Contracting) to contractors on construction projects
28	Fleet Modernization	On-road	Accelerated replacement of current LD vehicles with LEVs or Tier 2 vehicles
29	Fleet Modernization	On-road	Accelerated replacement of current LD and HD vehicles with AFVs
30	Fleet Modernization	On-road	Buy back and scrap pre-1980 LDVs and high emitters
31	Fleet Modernization	On-road	Repower HDDVs with older, high emitting engines with low emission diesel engines
32	Fleet Modernization	On-road	Accelerate the turnover of older HDDVs to cleaner late model HDDVs
33	Idling Restriction/Reduction	On-road	Idling restrictions for public and private diesel fleets
34	Idling Restriction/Reduction	On- & Nonroad	Idling reduction programs
35	Idling Restriction/Reduction	On-road	Truck stop electrification
36	Idling Restriction/Reduction	Nonroad	Idling restrictions on linehaul and switching locomotives (automatic start-stop devices)
37	Idling Restriction/Reduction	Nonroad	Idling restrictions on construction equipment
38	I/M Programs	On-road	Enforce smoking vehicle program
39	I/M Programs	On-road	Remote-sensing programs to capture high emitters
40	I/M Programs	On-road	LDV I/M programs (IM-240, RSD, ASM, RG240 etc.) - OBD only
41	I/M Programs	On-road	HDDV I/M programs (smoke; diesel OBD etc.)
42	I/M Programs	On-road	HDDV accelerated reflashing programs
43	LEV Programs	On-road	LEV programs/requirements for public and private fleets
44	LEV Programs	On-road	Scrappage of high emitter LDVs and replace with LEVs
45	LEV Programs	On-road	ULEV/SULEV/ZEV pilot programs
46	Retrofitting	On-road	Aftertreatment retrofit programs for HD diesel vehicles (DPFs, catalysts, EGRs etc.)

Control ID	Category	Source	Control Measures
47	Retrofitting	On-road	Retrofit programs for HD diesel vehicles to AFVs (NG, dual-fuel etc.)
48	Retrofitting	On-road	Aftertreatment retrofit programs for HD gasoline vehicles (3-way catalysts)
49	Retrofitting	On-road	Retrofit programs for HD gasoline vehicles to AFVs (NG, LPG, bi-fuel etc.)
50	Retrofitting	On-road	Retrofit programs for LDVs to AFVs or bi-fuel vehicles
51	Retrofitting	Nonroad	Aftertreatment retrofit programs for Nonroad diesel equipment (DPFs, catalysts, EGRs etc.)
52	Retrofitting	Nonroad	Alternative fuel retrofit programs for Nonroad diesel equipment
53	Retrofitting	Nonroad	Retrofit programs for Nonroad gasoline/SI engine equipment (A/F control; catalysts)
54	Retrofitting	Nonroad	Alternative fuel retrofit programs for Nonroad gasoline equipment
55	Retrofitting	Nonroad	Retrofit programs for switching locomotive engines
56	Retrofitting	Nonroad	Retrofit programs for commercial marine engines
57	Retrofitting	Nonroad	Repower/replace auxiliary engines of commercial marine with low emitting engines
58	Retrofitting	Nonroad	Aircraft Electrification: Idling
59	Ozone Action Days/Public Awareness	Various	Employer-based ozone action days
60	Ozone Action Days/Public Awareness	Various	L&G equipment usage control/restriction programs
61	Ozone Action Days/Public Awareness	Various	Public awareness & outreach programs
62	Ozone Action Days/Public Awareness	Various	School-based public awareness programs
63	Ozone Action Days/Public Awareness	Various	Education and promotion campaigns
64	Intelligent Transport Systems	Various	Dynamic message signs
65	Intelligent Transport Systems	Various	Video monitor system deployment
65a	Intelligent Transport Systems	Various	Improved traffic light signalization (e.g. periodic retiming)
65b	Intelligent Transport Systems	Various	Traffic incident management (removal of crashed vehicles or other traffic obstructions within a certain period)
66	Intelligent Transport Systems	Various	Internet site/system to provide road and route information
67	Intelligent Transport Systems	On-road	Speed limit restriction (65mph)
68	VMT Reduction Programs	Various	Ridesharing (e.g. carpool, vanpool) programs
69	VMT Reduction Programs	Various	Enhance/expand regional transit service
70	VMT Reduction Programs	Various	Build, extend and expand HOV lanes
71	VMT Reduction Programs	Various	Bicycle and pedestrian accommodation programs
72	VMT Reduction Programs	Various	Telecommuting
73	VMT Reduction Programs	Various	Green space preservation
74	VMT Reduction Programs	Various	Mixed land-use development

The screening evaluation for these control measures was based on approximate contribution levels to the NOx, PM, and VOC emission inventories, and past experience in program effectiveness and feasibility for these measures. As discussed earlier, while the criteria included emission benefits, emission impacts, cost effectiveness, technical feasibility, likely public acceptance, and EPA creditability, the qualitative screening analysis was heavily weighted on the emission impacts. For each measure, the preliminary emission reduction potential was provided. In addition, numerical values of 1, 2, and 3 were assigned to each of the ranking criteria representing low, medium, or high ranks. The values of these criteria were then totaled up to represent the overall ranking for the control measures.

Source apportionment analyses were examined by LADCO to determine the importance of on-road and non-road sources on ozone and PM2.5 concentrations in nonattainment areas in the region. Model-based source apportionment information was developed by using the OSAT/APCA algorithm for ozone and PSAT algorithm for PM2.5 in CAMx modeling. This source apportionment modeling shows that on-road NOx emissions are the dominant source of ozone and PM-nitrate concentrations in the region - on the order of 30-40% of anthropogenic emissions. Monitoring-based source apportionment was developed with Positive Matrix Factorization (PMF) and Chemical Mass Balance (CMB) analyses using data from LADCO's Urban Organics Study. This information suggests that mobile sources are the dominant source of primary organic carbon concentrations in these areas - on the order of 40-50%. Although further analyses are underway to better define the smoker/non-smoker and gasoline/diesel splits, initial results indicate that smoking vehicles may comprise a significant portion of the PM emissions. Thus, the emission impact assessment in the qualitative screening analysis was focused on reducing NOx and PM emissions, with primary focus on the NOx emissions. While the primary focus for this project was on reducing NOx emissions, some measures (e.g. idling reduction measures) that were ranked lower than those selected measures may provide higher PM reductions.

In addition to estimating the control efficiencies, low and high penetration or compliance rates were assumed for each control measure based on vehicle/equipment availability and turnover rates (assuming that control measures would be implemented in 2007), as well as past experiences and engineering judgment. For example, a 10% penetration rate per year for a control measure starting in 2007 would provide a total 30% penetration rate in 2009.

Information on past experience of control measures was based on a variety of reports and studies. These include the EPA Transportation Control Measure and Congestion Mitigation Air Quality Program reports; SIP-related reports for Sacramento, Los Angeles, San Joaquin Valley, San Francisco, and Washington, DC; and Ozone Early Action Compacts (EACs)'s for San Antonio and Dallas-Fort Worth, TX, Triad, NC, Tulsa, OK, Kansas City, KS, Northern Shenandoah Valley, VA, Eastern Panhandle Region, WV, and Tennessee, as well as other relevant references or studies. Appendix A provides a list of major references reviewed in this project.

EMISSION INVENTORIES

For the purposes of this study, emission impacts were calculated using a combination of data supplied by LADCO (i.e., the Base K data developed in December 2005) and the 2002 National Emissions Inventory (NEI). Specifically, LADCO has prepared a modeling inventory for 2002 and 2009 for on-road and non-road sources based on data supplied by its states and the Emissions Modeling System (EMS). On-road emissions were separated into gasoline- and diesel-based emissions. Non-road emissions reflect both sources included in EPA's NONROAD model and other sources (i.e., commercial marine, airports, and locomotives).

On-road emissions by vehicle type and model year were needed for this study. This resolution was not available in the current LADCO data, but was available in the 2002 NEI data. Consequently, the 2009 on-road emissions for this study were derived by multiplying the 2002 NEI emissions by the ratio of LADCO's 2009 and 2002 emissions[2]. Table 2-2 shows the estimated 2009 on-road emission inventory by vehicle type for the LADCO states. State-by-state estimated 2009 on-road emissions by vehicle type are provided in Appendix B.

ENVIRON generated the 2009 non-road emissions inventory using EPA's draft NONROAD2004 model with inputs and option files provided by LADCO[3]. For commercial marine, airports, and locomotives, ENVIRON used an earlier version of LADCO's modeling inventory (i.e., 2002 Base J), because the 2009 Base K data were not yet available. Table 2-3 shows the 2009 non-road emissions by equipment and fuel types for the LADCO states. Table

[2] Note that average day emissions were derived by dividing the annual NEI emissions by 365.
[3] NONROAD2005 was released by EPA after the work for this study was completed.

2-4 shows the 2002 commercial marine and locomotive emissions for the LADCO states. State-by-state nonroad emissions by equipment types are provided in Appendix B.

Table 2-2. Estimated 2009 on-road emission inventory by vehicle types for the LADCO states.

Vehicle Types	Emissions (tpd)			
	TOG (Base K)	CO (Base J)	NOx (Base K)	PM10 (Base J)
LDGV	589	7,859	585	11.7
LDGT1	297	4,580	337	6.3
LDGT2	142	1,860	142	2.4
HDGV	51	564	128	2.7
Motorcycle	8	50	6	0.2
LDDV	1	1	1	0.4
LDDT	1	1	2	0.4
Class 2b diesel	3	7	30	1.0
Class 3, 4, 5 diesel	2	7	29	0.7
Class 6, 7 diesel	11	26	131	3.4
Class 8 diesel	45	171	857	16.8
Buses	3	9	39	1.8
Total	1,153	15,135	2,287	47.8

Table 2-3. 2009 NONROAD equipment NOx, PM and VOC emissions by fuel and equipment types for the LADCO states.

Equipment Type	NOx Emissions (tpd)				
	Diesel	Gasoline	CNG	LPG	Total
Agricultural Equipment	254.33	1.73	0.01	0.01	256.09
Airport Ground Support Equipment	3.45	0.03	0.00	0.04	3.53
Commercial Equipment	33.67	10.80	1.37	5.29	51.12
Construction and Mining Equipment	272.85	2.94	0.00	0.71	276.50
Industrial Equipment	59.53	2.22	4.91	66.26	132.92
Lawn and Garden Equipment	13.52	23.73	0.00	0.33	37.58
Logging Equipment	1.98	0.06	0.00	0.00	2.05
Pleasure Craft	22.24	30.26	0.00	0.00	52.51
Railway Maintenance Equipment	1.35	0.02	0.00	0.00	1.37
Recreational Vehicles	0.72	8.46	0.00	0.05	9.23
Underground Mining Equipment	0.64	0.00	0.00	0.00	0.64
Total	664.29	80.24	6.30	72.70	823.53
Equipment Type	**PM Emissions (tpd)**				
	Diesel	**Gasoline**	**CNG**	**LPG**	**Total**
Agricultural Equipment	21.59	0.05	0.00	0.00	21.64
Airport Ground Support Equipment	0.22	0.00	0.00	0.00	0.22
Commercial Equipment	3.18	0.68	0.02	0.04	3.91
Construction and Mining Equipment	18.98	1.04	0.00	0.01	20.03
Industrial Equipment	4.47	0.04	0.06	0.75	5.32
Lawn and Garden Equipment	1.01	7.34	0.00	0.00	8.36
Logging Equipment	0.13	0.09	0.00	0.00	0.22
Pleasure Craft	0.46	14.63	0.00	0.00	15.09
Railway Maintenance Equipment	0.14	0.00	0.00	0.00	0.14
Recreational Vehicles	0.12	11.88	0.00	0.00	12.00

Equipment Type	VOC Emissions (tpd)				
Underground Mining Equipment	0.07	0.00	0.00	0.00	0.07
Total	50.38	35.74	0.08	0.81	87.00
Equipment Type	**Diesel**	**Gasoline**	**CNG**	**LPG**	**Total**
Agricultural Equipment	22.60	2.09	0.03	0.00	24.73
Airport Ground Support Equipment	0.23	0.02	0.00	0.01	0.26
Commercial Equipment	4.67	18.88	2.72	0.77	27.04
Construction and Mining Equipment	21.55	9.30	0.01	0.13	30.98
Industrial Equipment	4.94	1.75	13.59	12.50	32.78
Lawn and Garden Equipment	1.43	89.94	0.00	0.06	91.43
Logging Equipment	0.14	0.65	0.00	0.00	0.79
Pleasure Craft	0.75	198.85	0.00	0.00	199.60
Railway Maintenance Equipment	0.22	0.02	0.00	0.00	0.25
Recreational Vehicles	0.21	384.34	0.00	0.01	384.56
Underground Mining Equipment	0.12	0.00	0.00	0.00	0.12
Total	56.87	705.84	16.35	13.49	792.56

Table 2-4. 2002 locomotive and commercial marine emissions for the LADCO states.

Equipment Type	Emissions (tpd)[1]			
	VOC	**CO**	**NOx**	**PM10**
Locomotives	24.1	57.4	520.4	14.4
Commercial Marine	4.6	24.1	178.1	8.8

[1] Emission data were extracted from ENVIRON's 2004 report to LADCO entitled "LADCO Nonroad Emission Inventory Project for Locomotive, Commercial Marine, and Recreation Marine Emission Sources," December 2004. Annual emissions were divided by 365 to obtain tons per day emissions, and THC emissions were converted to VOC emissions by multiplying a factor of 1.053 from a NONROAD technical support report (EPA420-R-05-015, December 2005).

Figure 2-1 shows the emission contributions to the 2009 on-road emission inventory by vehicle type. As shown in this figure, more than 40% of NOx and 50% of PM emissions from the 2009 on-road emission inventory are from heavy-duty diesel vehicles. The emissions contributions are similar for each LADCO state individually (see Appendix B).

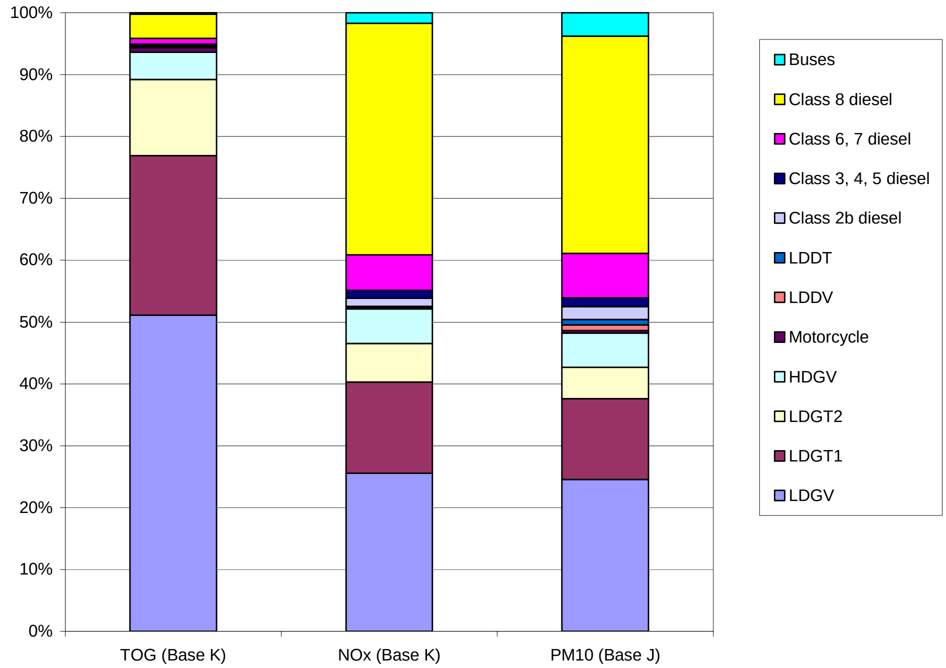

Figure 2-1. Emission contributions to the 2009 on-road emission inventory by vehicle types.

Table 2-5 shows that, among the NONROAD equipment, more than 80% and 55% of the 2009 NONROAD NOx and PM emissions, respectively, are from the NONROAD diesel equipment for all LADCO states. Construction and agricultural diesel equipment each contribute more than 30% and 20% of the NOx and PM emissions, respectively. Therefore, control measures targeting these sources (i.e. on-road heavy-duty diesel vehicles, nonroad diesel construction and agricultural equipment) would provide substantial and effective NOx and/or PM emission reductions.

Table 2-5. Emission contributions to the 2009 NONROAD NOx and PM emissions by fuel and equipment types for the LADCO states.

Equipment Type	NOx Emission Contributions				
	Diesel	Gasoline	CNG	LPG	Total
Agricultural Equipment	30.88%	0.21%	0.00%	0.00%	31.10%
Airport Ground Support Equipment	0.42%	0.00%	0.00%	0.00%	0.43%
Commercial Equipment	4.09%	1.31%	0.17%	0.64%	6.21%
Construction and Mining Equipment	33.13%	0.36%	0.00%	0.09%	33.58%
Industrial Equipment	7.23%	0.27%	0.60%	8.05%	16.14%
Lawn and Garden Equipment	1.64%	2.88%	0.00%	0.04%	4.56%
Logging Equipment	0.24%	0.01%	0.00%	0.00%	0.25%
Pleasure Craft	2.70%	3.67%	0.00%	0.00%	6.38%
Railway Maintenance Equipment	0.16%	0.00%	0.00%	0.00%	0.17%
Recreational Vehicles	0.09%	1.03%	0.00%	0.01%	1.12%
Underground Mining Equipment	0.08%	0.00%	0.00%	0.00%	0.08%
Total	80.66%	9.74%	0.76%	8.83%	100.00%

Equipment Type	PM Emission Contributions				
	Diesel	Gasoline	CNG	LPG	Total
Agricultural Equipment	24.82%	0.06%	0.00%	0.00%	24.87%
Airport Ground Support Equipment	0.25%	0.00%	0.00%	0.00%	0.25%
Commercial Equipment	3.66%	0.78%	0.02%	0.04%	4.50%
Construction and Mining Equipment	21.81%	1.19%	0.00%	0.01%	23.02%
Industrial Equipment	5.14%	0.04%	0.06%	0.86%	6.11%
Lawn and Garden Equipment	1.17%	8.44%	0.00%	0.01%	9.61%
Logging Equipment	0.15%	0.11%	0.00%	0.00%	0.26%
Pleasure Craft	0.53%	16.82%	0.00%	0.00%	17.35%
Railway Maintenance Equipment	0.17%	0.00%	0.00%	0.00%	0.17%
Recreational Vehicles	0.14%	13.65%	0.00%	0.00%	13.79%
Underground Mining Equipment	0.08%	0.00%	0.00%	0.00%	0.08%
Total	57.91%	41.08%	0.09%	0.93%	100.00%

SCREENING RESULTS

Using the emission inventories and information/data from past experience of control measures, ENVIRON ranked and prioritized the control measures in the master list based on preliminary emission reduction potential for each control measure. A summary of the screening results prioritized by the highest potential NOx emission reductions is shown in Table 2-6. The low and high values represent the low-end and high-end estimates of assumed ranges of penetration or compliance rates. The estimated potential source emissions, control efficiencies and penetration or compliance rates used to estimate the potential emission reductions are shown in Table 2-7. With these ranking results, ENVIRON originally recommended that the top ten control measures (highlighted in yellow in Tables 2-6 and 2-7), many of which are consistent with the goal and effort of the Midwest Clean Diesel Initiative, for further technical and economic analyses.

After discussing the recommended measures with LADCO states, LADCO subsequently requested that ENVIRON evaluate a few secondary control measures on low emission vehicles (LEV), accelerated fleet turnover or scrappage programs, inspection and maintenance (I/M) programs for light-duty vehicles, and a speed limit restriction control measure for on-road vehicles (highlighted in green in Tables 2-6 and 2-7).

In summary, ten primary control measures and nine secondary control measures were selected for technical and economic analyses based on the results from the screening analysis of more than 70 control measures for mobile sources, as well as recommendations from the LADCO states.

Table 2-6. Preliminary screening results with control measures order by potential NOx emission reductions.

Control ID	Vehicle/ Equipment Types	Control Measures	Preliminary NOx Emission Reduction Potential in 2009 (tpd)		Preliminary PM Emission Reduction Potential in 2009 (tpd)	
			High	Low	High	Low
46	HDDV	Aftertreatment retrofit programs for HD diesel vehicles (DPFs, catalysts, EGRs etc.)	135	68	4	2
28	LDV	Accelerated replacement of current LD vehicles with LEVs or Tier 2 vehicles	126	25	2	0

Control ID	Vehicle/ Equipment Types	Control Measures	Preliminary NOx Emission Reduction Potential in 2009 (tpd)		Preliminary PM Emission Reduction Potential in 2009 (tpd)	
			High	Low	High	Low
51	Diesel Equipment	Aftertreatment retrofit programs for nonroad diesel equipment (DPFs, catalysts, EGRs etc.)	102	51	10	5
32	HDDV	Accelerate the turnover of older HDDVs to cleaner late model HDDVs	90	18	3	1
29	LDV & HDV	Accelerated replacement of current LD and HD vehicles with AFVs	88	18	3	1
20	Diesel Equipment	Accelerated purchase of Tier2/Tier 3/Tier 4 nonroad engines or on-road engines	80	40	8	4
42	HDDV	HDDV accelerated reflashing programs	77	26	0	0
31	HDDV	Repower HDDVs with older, high emitting engines with low emission diesel engines	64	13	3	1
16	Diesel Vehicles/Equipment	Reformulated diesel fuels (e.g. Fischer-Trope diesel; emulsified diesel; CA diesel)	59	30	10	5
47	HDDV	Retrofit programs for HD diesel vehicles to AFVs (NG, dual-fuel etc.)	58	12	3	1
68	LDV	Ridesharing (e.g. carpool, vanpool) programs	47	28	1	1
45	LDV	ULEV/SULEV/ZEV pilot programs	45	9	1	0
43	LDV	LEV programs/requirements for public and private fleets	44	9	1	0
52	Diesel Equipment	Alternative fuel retrofit programs for nonroad diesel equipment	44	9	7	1
50	LDV	Retrofit programs for LDVs to AFVs or bi-fuel vehicles	42	8	1	0
30	LDV	Buy back and scrap pre-1980 LDVs and high emitters	42	21	0	0
44	LDV	Scrappage of high emitter LDVs and replace with LEVs	38	8	0	0
40	LDV	LDV I/M programs (IM-240, RSD, ASM, RG240 etc.) - OBD only	34	21	4	3
25	Agricultural Equipment	Accelerate the turnover of older agricultural engines to Tier 2/Tier3/Tier 4 nonroad engines or on-road engines	31	15	4	2
67	LDV	Speed limit restriction (65mph)	29	16	0	0
1	LDV & HDV	Alternative fuel pilot projects	29	6	1	0
5	LDV & HDV	Clean fuel Incentives	29	6	1	0
24	Marine	Accelerate the turnover of older commercial marine engines to Tier 2 engines	29	6	2	0
64	LDV	Dynamic message signs	28	9	1	0
65	LDV	Video monitor system deployment	28	9	1	0
70	LDV	Build, extend and expand HOV lanes	28	9	1	0
27	Construction Equipment	Contract-based incentives/requirements (Green Contracting) to contractors on construction projects	28	14	2	1
53	SI Equipment	Retrofit programs for nonroad gasoline/SI engine equipment (A/F control; catalysts)	28	14	11	6
4	LDV & HDV	Alternative fuel vehicle conversion	27	5	1	0
23	Locomotive	Accelerate the turnover of older locomotives to Tier 2 locomotives	26	5	1	0
13	Gasoline Vehicles/Equipment	RFG/California RFG	24	12	6	3
33	HDDV	Idling restrictions for public and private diesel fleets	22	14	0	0
59	LDV	Employer-based ozone action days	19	9	0	0
61	LDV	Public awareness & outreach programs	19	9	0	0
62	LDV	School-based public awareness programs	19	9	0	0
63	LDV	Education and promotion campaigns	19	9	0	0
65a	LDV	Improved traffic light signalization	19	9	0	0
65b	LDV	Traffic incident management	19	9	0	0

Control ID	Vehicle/ Equipment Types	Control Measures	Preliminary NOx Emission Reduction Potential in 2009 (tpd)		Preliminary PM Emission Reduction Potential in 2009 (tpd)	
			High	Low	High	Low
66	LDV	Internet site/system to provide road and route information	19	9	0	0
69	LDV	Enhance/expand regional transit service	19	9	0	0
71	LDV	Bicycle and pedestrian accommodation programs	19	9	0	0
72	LDV	Telecommuting	19	9	0	0
73	Various	Green space preservation	19	9	0	0
74	Various	Mixed land-use development	19	9	0	0
21	Large SI Equipment	Accelerate the turnover of large SI engines to engines meeting Large SI Non-Road Engine Standards	18	9	0	0
36	Locomotive	Idling restrictions on linehaul and switching locomotives (automatic start-stop devices)	18	7	0	0
2	LDV & HDV	Private sector clean fuel fleets	18	5	1	0
8	Locomotive	Hybrid diesel electric and LNG switching engine locomotive pilot programs	16	8	0	0
12	Marine	Shoreside power for marine vessels at berth	15	3	1	0
56	Marine	Retrofit programs for commercial marine engines	15	3	1	0
48	HDGV	Aftertreatment retrofit programs for HD gasoline vehicles (3-way catalysts)	14	3	0	0
34	HDDV/Nonroad Diesel Equipment	Idling reduction programs	14	7	1	0
15	Diesel Equipment	Early phase in of ULSD fuels for nonroad equipment	14	7	5	3
10	Industrial Equipment	Accelerate the turnover of industry equipment to alternative fuels or electric	14	7	1	1
55	Locomotive	Retrofit programs for switching locomotive engines	10	5	0	0
7	HDDV	Alternative fuel refuse trucks programs	8	4	0	0
38	LDV & HDV	Enforce smoking vehicle program	7	1	0	0
17	Diesel Vehicles/Equipment	Diesel fuel additives	7	4	0	0
6	Buses	Alternative fuel, hybrid, fuel cell school/transit bus programs	7	3	0	0
37	Construction Equipment	Idling restrictions on construction equipment	7	2	0	0
35	HDDV	Truck stop electrification	6	3	0	0
57	Marine	Repower/replace auxiliary engines of commercial marine with low emitting engines	6	3	0	0
9	Lawn & Garden Equipment	Accelerate the turnover of residential gasoline lawn & garden equipment to electric	6	3	2	1
49	HDGV	Retrofit programs for HD gasoline vehicles to AFVs (NG, LPG, bi-fuel etc.)	5	1	0	0
54	SI Equipment	Alternative fuel retrofit programs for nonroad gasoline equipment	5	1	3	1
39	LDV	Remote-sensing programs to capture high emitters	4	1	0	0
3	LDV & HDV	Public sector clean fuel fleets	3	1	0	0
60	Lawn & Garden Equipment	L&G equipment usage control/restriction programs	2	0	1	0
11	Ground Support Equipment	Airport ground support equipment electrification	1	0	0	0
58	Aircraft	Aircraft Electrification: Idling	1	0	0	0
22	Recreation SI Equipment	Replace 2-stroke engines with 4-stroke engines in recreation vehicles/marine/equipment	0	0	10	5
26	Lawn &	Residential L&G equipment (e.g. lawnmowers)	0	0	1	0

Control ID	Vehicle/ Equipment Types	Control Measures	Preliminary NOx Emission Reduction Potential in 2009 (tpd)		Preliminary PM Emission Reduction Potential in 2009 (tpd)	
			High	Low	High	Low
	Garden Equipment	exchange/rebate/buy back programs				
14	Gasoline Vehicles/Equipment	Lower RVP Gasoline	0	0	0	0
18	LDV	Gas cap replacement program (give free vouchers to failed vehicles w/ faulty or missing gas caps) Toledo Metro COG has such program (Ohio & Michigan)	0	0	0	0
19	Area Sources	Stage II Vapor Recovery	0	0	0	0
41	HDDV	HDDV I/M programs (smoke; diesel OBD etc.)	-2	-1	3	1

Table 2-7. Preliminary emission source potential, control efficiencies and penetration rates in 2009 used in the qualitative screening analysis.

Control ID	Preliminary Emission Source Potential in 2009			Estimated Control Efficiencies			Penetration Rate	
	NOx	PM	VOC	NOx	PM	VOC	High Penetration Rate	Low Penetration Rate
46	859	22	36	15-90%	30-90%	10-90%	30%	15%
28	936	21	917	90%	60%	90%	15%	3%
51	648	57	62	15-90%	30-90%	10-90%	30%	15%
32	859	22	36	70%	90%	0-5%	15%	3%
29	1962	48	1008	10-50%	20-70%	10-60%	15%	3%
20	671	58	62	30-50%	0-90%	0-5%	30%	15%
42	859	22	36	20-40%	0	0	30%	10%
31	859	22	36	50%	90%	0-5%	15%	3%
16	1582	82	103	5-20%	20-60%	0-5%	30%	15%
47	859	22	36	40-60%	80-90%	0-5%	15%	3%
68	936	21	917	3-5%	3-5%	3-5%	NA	NA
45	936	21	917	95-98%	60-95%	90-95%	5%	1%
43	328	7	321	90%	60%	90%	15%	3%
52	648	57	62	40-60%	80-90%	0-5%	15%	3%
50	936	21	917	10-50%	20-70%	10-60%	15%	3%
30	280	1	261	10-50%	20-70%	10-60%	50%	25%
44	280	1	261	90%	60%	90%	15%	3%
40	936	21	917	0-9%	0-50%	5-28%	80%	50%
25	258	26	25	30-50%	0-90%	0-5%	30%	15%
67	936	21	917	2-4%	1-2%	0	90%	50%
1	1962	48	1008	10-50%	20-70%	10-60%	5%	1%
5	1962	48	1008	10-50%	20-70%	10-60%	5%	1%
24	387	17	12	50%	69%	0-5%	15%	3%
64	936	21	917	1-3%	1-3%	1-3%	NA	NA
65	936	21	917	1-3%	1-3%	1-3%	NA	NA
70	936	21	917	1-3%	1-3%	1-3%	NA	NA
27	281	22	39	5-10%	5-10%	5-10%	NA	NA
53	110	40	963	80-90%	90-95%	90-95%	30%	15%
4	1962	48	1008	5-50%	10-70%	5-60%	5%	1%
23	341	9	14	50%	69%	0-5%	15%	3%
13	1161	63	1931	7%	0-5%	27%	30%	15%
33	908	24	39	2-4%	1.5-3%	0-5%	80%	50%
59	936	21	917	1-2%	1-2%	1-2%	NA	NA
61	936	21	917	1-2%	1-2%	1-2%	NA	NA
62	936	21	917	1-2%	1-2%	1-2%	NA	NA
63	936	21	917	1-2%	1-2%	1-2%	NA	NA
65a	936	21	917	1-2%	1-2%	1-2%	NA	NA

Control ID	Preliminary Emission Source Potential in 2009			Estimated Control Efficiencies			Penetration Rate	
	NOx	PM	VOC	NOx	PM	VOC	High Penetration Rate	Low Penetration Rate
65b	936	21	917	1-2%	1-2%	1-2%	NA	NA
66	936	21	917	1-2%	1-2%	1-2%	NA	NA
69	936	21	917	1-2%	1-2%	1-2%	NA	NA
71	936	21	917	1-2%	1-2%	1-2%	NA	NA
72	936	21	917	1-2%	1-2%	1-2%	NA	NA
73	936	21	917	1-2%	1-2%	1-2%	NA	NA
74	936	21	917	1-2%	1-2%	1-2%	NA	NA
21	93	2	226	50-80%	0-5%	50-80%	30%	15%
36	341	9	14	3-10%	3-10%	3-10%	80%	30%
2	589	14	303	10-50%	20-70%	10-60%	10%	3%
8	68	2	3	70-90%	70-90%	70-90%	30%	15%
12	387	17	12	70-80%	70-80%	60-80%	5%	1%
56	194	8	6	50%	69%	0-5%	15%	3%
48	112	3	45	80-90%	90-95%	90-95%	15%	3%
34	1579	81	102	2-4%	1.5-3%	0-5%	30%	15%
15	671	58	62	0	3-10%	0	30%	15%
10	63	5	9	50-95%	70-95%	50-95%	30%	15%
55	68	2	3	50%	69%	0-5%	30%	15%
7	36	1	1	50-90%	70-90%	50-90%	30%	15%
38	1962	48	1008	0-5%	0-50%	0-5%	15%	3%
17	1582	82	103	1-2%	0	0%	30%	15%
6	33	2	2	50-90%	70-90%	50-90%	30%	15%
37	276	21	24	2-4%	1.5-3%	0-5%	80%	30%
35	716	17	28	2-4%	1.5-3%	0-5%	30%	15%
57	39	2	1	50%	69%	0-5%	30%	15%
9	20	6	114	90-95%	90-95%	90-95%	30%	15%
49	112	3	45	10-50%	20-70%	10-60%	15%	3%
54	110	40	963	10-50%	20-70%	10-60%	15%	3%
39	936	21	917	0-5%	0-50%	0-5%	15%	3%
3	98	2	50	10-50%	20-70%	10-60%	10%	3%
60	47	10	191	1-5%	1-5%	1-5%	NA	NA
11	4	0	0	90-95%	90-95%	90-95%	30%	15%
58	26	1	7	2-4%	1.5-3%	0-5%	80%	30%
22	17	37	737	0	90%	90%	30%	15%
26	20	6	114	0	90%	90%	15%	3%
14	1161	63	1931	0	0%	5-10%	80%	50%
18	933	20	915	0%	0%	2%	15%	3%
19	1161	63	1931	0%	0%	3-5%	80%	50%
41	908	24	39	0 to -1%	20-30%	0-5%	50%	25%

3. TECHNICAL AND ECONOMIC ANALYSIS OF SELECTED CONTROL MEASURES

As discussed in Section 2, more than 15 selected mobile source control measures were selected for further technical and economic analyses based on the screening analysis of more than 70 measures. These selected control measures were grouped together as follows due to their similarities in measure descriptions and targeted emission sources.

<u>On-road Diesel Vehicles</u>
- Measure 16b: California Diesel Fuel

<u>On-road Heavy Heavy-Duty Diesel Vehicles</u>
- Measure 16a: Emulsified Diesel Fuel
- Measure 31: Fleet Modernization
- Measure 42: Accelerate Low NOx Calibration/Reflashing Program
- Measure 46: Aftertreatment Device Retrofits
- Measure 47: NG/Dual Fuel Retrofits
- Measure 29a: Fleet Modernization via HDD AFVs
- Measure 67: Speed Limit Restriction Program

<u>Nonroad Diesel Equipment</u>
- Measure 16b: California Diesel Fuel

<u>NONROAD Diesel Construction Equipment</u>
- Measure 16a: Emulsified Diesel Fuel
- Measure 20: Equipment Fleet Modernization
- Measure 51: Aftertreatment Device Retrofits for Nonroad Equipment
    - Measure 51a: Lean NOx Catalyst
    - Measure 51b: EGR+DPF Retrofit
    - Measure 51c: SCR Retrofit

<u>NONROAD Diesel Agricultural Equipment</u>
- Measure 16a: Emulsified Diesel Fuel
- Measure 20: Equipment Fleet Modernization
- Measure 51: Aftertreatment Device Retrofits for Nonroad Equipment
    - Measure 51a: Lean NOx Catalyst
    - Measure 51b: EGR+DPF Retrofit
    - Measure 51c: SCR Retrofit

<u>On-road Light-Duty Vehicles</u>
- Measure 40: Implementing/Expanding I/M Programs for LDVs
- Measure 28/29/43/45: Accelerated Vehicle Replacement of Older Fleet Vehicles (10 Years old or older)
- Measure 44: Vehicle Scrappage Program for 25 Years Old Vehicles

Detailed descriptions of these selected measures or measure groups are presented in this section. Each measure description includes a technical description of the control measure; estimates of emission reductions, costs, and cost-effectiveness; and issues related to implementation. Tables for each control measure providing details on the affected fleet emissions reductions and costs, and cost-effectiveness, are provided in Appendices corresponding to their measure identifications.

Measure 16a: Water Emulsified Diesel Fuels for On-road Heavy-Duty Diesel Vehicle and Nonroad Diesel Equipment

Description - Emulsified diesel fuel consists of regular diesel fuel to which water and stabilizing surfactants have been added. The NOx and PM emission reductions are achieved by the lower peak combustion temperature that is due to the cooling effect of the water content. Typically 15% of the volume of emulsified diesel fuels is water, which lowers the energy content of the fuel. There are two emulsified fuel suppliers, Lubrizol and Aquazole, currently supplying emulsified diesel fuels in the California market. Lubrizol's PuriNOx emulsified diesel fuel has been verified by CARB for about 14% NOx emission reduction, 63% PM emission reduction, and 25% HC emission reduction.

The EPA, however, has performed an analysis and found that the NOx reduction depends upon the base emission level of the engine. Therefore, as new diesel engines meet lower emission standards, the emission reduction percentage with the use of fuel/water will be less than with current engines. EPA estimated that the use of fuel/water emulsions will result in a NOx emission reduction of about 14% from highway engines and 21% from nonroad diesel engines.

The emission reduction estimates are consistent with the emission reduction range provided in the EPA website on verified technologies[1], and discussion in the EPA Draft Guidance for Qualifying and Using Emission Reductions From Mobile Source Retrofit Projects in State Implementation Plans and Transportation and General Conformity (EPA Draft Retrofit Guidance).

Emissions - NOx emission factors for on-road HDDVs were calculated based on the emission standards and conversion factors for HDDVs from the EPA's MOBILE6 model.

For nonroad equipment, the NOx emission factors were calculated based on the Tier 0, Tier 1, Tier 2, and Tier 3 nonroad emission standards; load factors and activity data were extracted from the NONROAD2004 model using the LADCO input and option files.

ENVIRON assumed that the use of emulsion fuel would reduce NOx emissions by about 18% (average value of 14% to 21% reduction as reported by the EPA), while increasing volumetric fuel consumption by 15%.

Cost - ENVIRON assumed that the use of emulsion fuel would entail no incremental capital cost, while the fuel would sell at the same price as diesel on a volumetric basis. Thus, the only cost would be the incremental fuel cost due to the 15% increase in volumetric fuel consumption. Using historical data from Annual Energy Outlook 2005, diesel fuel cost was assumed to be $2.13 in 2007 to 2009.

For HDDVs, this incremental fuel cost was estimated to be about $3,000 per year. In order to claim the SIP credit in CY 2009, the incremental fuel cost for 3 years for a total cost of about $9,000 for an incentive/voluntary program that would begin in CY 2007.

[1] http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm

For nonroad equipment, the estimated incremental fuel cost ranges from $400 to $6,200 per year and $2,000 to $37,200 per year for agricultural and construction equipment, respectively, or $1,500 to $25,000 per year and $8,500 to $148,900 per year for agricultural and construction equipment, respectively, for a three-year program.

Emission Reductions - The emission reduction would be proportional to the amount of fuel used. For the HDDVs, ENVIRON estimated the effect on emissions from a HDDV traveling 50,000 miles per year. The emission reduction analysis shows that the emission reduction values range from 0.01 to 0.33 tons per year per vehicle, depending on the model year group.

Emission reductions on a per equipment basis by horsepower and technology groups for major nonroad construction and agricultural equipment types with Tier 0, Tier 1, Tier 2, and Tier 3 engines are provided in Appendix M16a. Nonroad equipment emission reductions vary depending on the equipment type and horsepower range. The range of emission reductions is shown by equipment and engine type in Table M16a-1.

Detailed emission reduction values on a per-vehicle basis by model year group for on-road HDDVs, as well as on per-equipment basis by equipment type and technology group for nonroad construction and agricultural equipment, are provided in Appendix M16a.

Table M16a-1. Emission reduction values for water emulsified diesel per equipment (tons/year/equipment).

Nonroad Equipment Category	Tier 0 Engines	Tier 1 Engines	Tier 2 Engines	Tier 3 Engines
Agricultural	0.02 – 0.36	0.01 – 0.26	0.01 – 0.17	0.01 – 0.11
Construction	0.07 – 2.85	0.05 – 2.16	0.04 – 1.43	0.02 – 0.25

Cost-Effectiveness - The cost-effectiveness of the use of emulsified diesel fuel would depend on the baseline level of NOx emissions of the engine. The cost-effectiveness values of using emulsified diesel fuel on on-road diesel vehicles range from about $9,000/tons of NOx reduced for MY 1989 and earlier trucks, to more than $500,000/tons of NOx reduced for MY2007+ trucks. Appendix M16a provides the potential NOx emission reduction per vehicle and cost-effectiveness values by model year groups for on-road HDDVs with the use of emulsified diesel fuel.

Thus, only the lifetime cost-effectiveness values for the MY 1989 and earlier engines are lower than the $13,000 per ton of NOx reduced cost-effectiveness value, which is the general cost effectiveness limit for incentive/voluntary programs (e.g. Carl Moyer Program in California[2], and TERP program in Texas[3]) to reduce NOx emissions[4].

The range of cost-effectiveness values by equipment category and engine type is shown in Table M16a-2. All these values were over the generally accepted cost-effectiveness minimum of $13,000 per ton of NOx reduced.

[2] http://www.arb.ca.gov/msprog/moyer/moyer.htm
[3] http://www.tceq.state.tx.us/implementation/air/terp/index.html
[4] Cost-effectiveness guidelines for the CARB Carl Moyer program recently have been revised to include PM and VOC emission reduction benefits, in addition to the NOx emission reduction benefit.

Detailed cost-effectiveness values for on-road HDDVs, and some major types of nonroad construction and agricultural equipment with Tier 0, Tier 1, Tier 2, and Tier 3 engines are provided in Appendix M16a.

Table M16a-2. Cost effectiveness values for water emulsified diesel per equipment ($/ton).

Nonroad Equipment Type	Tier 0 Engines	Tier 1 Engines	Tier 2 Engines	Tier 3 Engines
Agricultural	15,000 – 22,000	21,000 – 23,000	29,000 – 31,000	48,000 – 50,000
Construction	15,000 – 50,000	21,000 – 68,000	31,000 – 100,000	50,000-160,000

Technical Implementation Feasibility and Public Acceptance - The measure is feasible, as it has already been implemented in emission reduction programs in a few U.S. states, including California and Texas. Furthermore, emulsified diesel fuels have been verified by CARB and EPA. However, the degree of acceptability of the use the emulsion fuel would depend on the fuel availability, as well as the acceptance of vehicle owners/operators of the fuels on the effects of the emulsion fuel on fuel consumption, performance, and engine durability.

Appendix M16a: Water Emulsified Diesel Fuels for On-road Heavy-Duty Diesel Vehicle and Nonroad Diesel Equipment – Refer to Appendix M16a for detailed emission reduction and cost-effectiveness results.

Measure 16b: California Low Sulfur Diesel Fuel for On-Road Heavy-Duty Diesel Vehicle and Nonroad Diesel Equipment

Description – Diesel fuel reformulation could lower NOx and PM emissions through fuel replacement alone. Several fuel reformulations options exist that could be used, including California reformulated diesel fuel, cetane improvements, and extreme reformulation using advanced technologies such as the Fischer-Tropsch (FT) process. Reformulated fuels also include biodiesel or biodiesel blends or other types of additives or blends with typical diesel fuel. Biodiesel or biodiesel blends reduce PM emissions but increase NOx emissions, cetane additives provide limited NOx emission reduction, and FT diesel fuels provide substantial NOx and PM emissions but commercially scarce and costly. Thus, this measure focuses only on the California diesel fuels.

The emissions benefit from these reformulated diesel fuels depends upon a number of fuel properties[5]. The NOx emissions are affected by the cetane level, aromatics level, specific gravity, and 50% distillation temperature. In general, lower in any of the aromatics level, specific gravity, and 50% distillation temperature properties, and higher in cetane level, would reduce NOx emissions. The PM emissions are affected by the same variables and are also affected by sulfur level, and oxygen content. In general, lower sulfur level or higher oxygen content would reduce PM emissions.

The California reformulated diesel fuel regulation adopted in 1988 and took effect in 1993 set limits on aromatic hydrocarbon content at 10%, on sulfur content at 500 ppm[6]. Subsequently, in July 2003, California adopted the California low sulfur diesel fuel regulation that lower the sulfur content limit from 500 ppm to 15 ppm, and still requires the 10% aromatic hydrocarbon content for both on-road and off-road applications, starting June 2006[6]. The 15 ppm sulfur content limit is aligned with the sulfur limit of the EPA ultra low sulfur diesel (ULSD) fuel regulations, starting in mid 2006 for on-road vehicles[7], 2010 for off-road engines, and 2012 for locomotive marine engines. While reducing aromatics reduces the NOx and PM emissions, most of the PM emission reductions from California reformulated diesel fuels result from lower fuel sulfur levels. Federal diesel fuel with lower sulfur levels will provide equivalent PM reductions.

As one of the ozone SIP measures, the State of Texas adopted its Texas Low Emission Diesel (TxLED) Program[8]. The TxLED Program contains similar fuel property requirements as the California reformulated diesel fuel regulations.

Emissions – The 2009 NOx emission inventory for on-road vehicles in the LADCO States was estimated based on the 2002 NEI emission inventory, and the ratio of 2009/2002 Base K emissions provided by LADCO. The 2009 off-road emission inventory for LADCO States was generated by running the EPA NONROAD2004 model using LADCO input and option files.

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[5] "Diesel Fuel Impact Model Data Analysis Plan Review," Prepared by Robert L. Mason, Ph.D. and Janet P. Buckingham of Southwest Research Institute for Environmental Protection Agency, July 2001.
[6] http://www.arb.ca.gov/fuels/diesel/diesel.htm#currentreg
[7] Implementation dates have been postponed to September 1, 2006 (instead of July 15, 2006) for terminals, and October 15, 2006 (instead of September 1, 2006) for retailers.
[8] http://www.tceq.state.tx.us/implementation/air/sip/cleandiesel.html

ENVIRON assumed that the use of California low sulfur diesel fuels would reduce NOx emissions by about 6%. This emission reduction estimate is consistent to the emission reduction estimated for the California reformulated diesel fuels[9], and presented in an EPA memo on TxLED.[10]

The 2009 NOx emission inventories for on-road diesel vehicles by vehicle class, and NONROAD diesel equipment by equipment type, are provided in Appendix M16b.

Cost - ENVIRON assumed that the use of California low sulfur diesel fuels would increase the fuel price in the range of $0.05 to $0.10 based on the experience in California and TxLED diesel fuels. Using historical data from Annual Energy Outlook 2005, diesel fuel cost was assumed to be $2.13 in 2007 to 2009[11].

Based on nationwide average VMT and fuel economy data used in the MOBILE 6 model, the incremental annual fuel costs for the use of California low sulfur diesel fuels on on-road vehicles range from $20 to $360, depending on the vehicle types. Average VMT and fuel economy data, as well as incremental fuel cost estimates, for different on-road diesel vehicle types are provided in Appendix M16b.

In order to estimate the incremental fuel costs for the NONROAD diesel equipment, ENVIRON assumed that the cost effectiveness of this measure is the same for both on-road diesel vehicles and nonroad diesel equipment. Based on this assumption, the incremental fuel costs for NONROAD diesel equipment types were estimated to range from $25 to $360. Detailed incremental fuel costs for different NONROAD diesel equipment types are provided in Appendix M16b.

Emission Reductions – Potential NOx emission reductions for on-road diesel vehicles and NONROAD diesel equipment were estimated based on the 2009 emission inventories and the assumed 6% emission reduction factor. The potential NOx emission reductions for on-road diesel vehicles range from about 0.0004 tpy per vehicle for Class 2B diesel trucks (i.e. 8,501 to 10,000 lbs GVWR) to 0.0950 for Class 8 HDDVs (i.e. 30,001 lbs and over). As for the NONROAD diesel equipment, the potential NOx emission reductions range from about 0.0025 tpy per equipment for recreational diesel equipment to 0.0380 for logging diesel equipment.

Detailed emission reduction values on a per-vehicle or per equipment are provided in Appendix M16b.

Cost-Effectiveness - The cost-effectiveness of the use of the California low sulfur diesel fuels for on-road diesel vehicles range from about $3,800 per ton of NOx reduced for Class 8 HDDVs, to $170,000 per ton of NOx reduced for Class 2B diesel trucks. The average cost-effectiveness value, weighted based on potential emission reductions, is about $8,000 per ton of NOx reduced.

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[9] "California Diesel Fuel," Fact Sheet, October 6, 2000 & "California Low Sulfur Diesel," Fact Sheet Updated June 27, 2003. (http://www.arb.ca.gov/fuels/diesel/diesel.htm)

[10] "Texas Low Emission Diesel (LED) Fuel Benefits," EPA Memorandum from Robert Larson OTAQ to Karl Edlund Region VI, September 27, 2001. (http://www.epa.gov/otaq/models/analysis.htm)

[11] Capital costs resulting from regional refinery changes or infrastructure and/or transportation cost to supply the California diesel fuel in the LADCO states were assumed to be part of the incremental fuel costs. Also, a fuel cost sensitivity analysis was performed to assess the impact of increasing fuel costs by 30%, and the sensitivity analysis results were discussed in Section 4 of the report.

Since similar fuel cost and emission reduction factor were used for on-road diesel vehicles and NONROAD equipment, the cost-effectiveness value for NONROAD equipment was assumed to be the same, and it was used to estimate the incremental fuel costs for the NONROAD equipment.

Technical Implementation Feasibility and Public Acceptance - The measure is feasible, as it has already been implemented in California and Texas. Furthermore, the potential emission reductions have been reviewed/discussed by CARB and EPA. It should be noted that older diesel engines might experience fuel system leaks resulting from combination of a change from higher to lower aromatics fuel and aged O-rings and elastomeric parts that have lost their elasticity, when first switched to the use of higher aromatic diesel fuels.

Appendix M16b: California Low Sulfur Diesel Fuel for On-Road Heavy-Duty Diesel Vehicle and Nonroad Diesel Equipment – Refer to Appendix M16b for detailed emission reduction and cost-effectiveness results.

Measure 20/25: Nonroad Equipment Modernization via Diesel Engines or Equipment Replacement

Description - By far the most widely employed method for reducing emissions from diesel engines is the replacement of the engines with new lower-emitting engines or replacement of the entire vehicle or piece of equipment with cleaner diesel engines, including remanufactured or new engines. The expected percentage emission reduction from this approach will depend upon the engine model year to be replaced and the emission standard that the new engine meets.

This measure focuses nonroad construction and agricultural equipment as they are identified as the major NOx emission contributors to the NONROAD NOx emission inventories in the LADCO States.

The EPA adopted the first Tier 1 emission standards for the nonroad compression-ignition (CI) engines at or above 50 hp (37 kW) on June 1994. Subsequently in October 1998, the EPA adopted Tier 1 emission standards for nonroad CI engines below 50 hp, as well as Tier 2 and Tier 3 emission standards for all engine sizes of these nonroad CI engines. The Tier 1 standards were phasing in from 1996 to 2000. The more stringent Tier 2 standards for all engine sizes are phasing in from 2001 to 2006, and yet more stringent Tier 3 standards are phasing in from 2006 to 2008. These NOx+NMHC emission standards, along with Tier 0 uncontrolled emission levels, are summarized in Table M20/25-1. While the EPA Tiers 1 to 3 emission standards are geared toward reducing NOx emissions from nonroad diesel engines, the recently adopted Tier 4 emission standards will further reduce NOx emissions, as well as PM emissions, by more than 90%. However, engines meeting the Tier 4 emission standards are not expected to be available and/or cost effective in the 2007-2009 timeframe.

Table M20/25-1. NOx+NMHC emission standards and uncontrolled levels for nonroad diesel engines.

Engine Power (hp)	Model Year	Regulation	NOx+NMHC Emission Standard (g/hp-hr)
25 to < 50	Pre-1998	Tier 0 (uncontrolled)	7.2
	1999 – 2003	Tier 1	7.1
	2004 +	Tier 2	5.6
50 to < 100	Pre-1998	Tier 0 (uncontrolled)	8.8
	1998 – 2003	Tier 1	6.9
	2004 – 2007	Tier 2	5.6
	2008+	Tier 3	3.5
100 to < 175	Pre-1997	Tier 0 (uncontrolled)	9.5
	1997 – 2002	Tier 1	6.9
	2003 – 2006	Tier 2	4.9
	2007+	Tier 3	3.0
175 to < 300	Pre-1996	Tier 0 (uncontrolled)	9.3
	1996 – 2002	Tier 1	6.9
	2003 – 2005	Tier 2	4.9
	2006+	Tier 3	3.0
300 to < 600	Pre-1996	Tier 0 (uncontrolled)	9.5
	1996 – 2000	Tier 1	6.9
	2001 – 2005	Tier 2	4.8

Engine Power (hp)	Model Year	Regulation	NOx+NMHC Emission Standard (g/hp-hr)
	2006+	Tier 3	3.0
600 to < 750	Pre-1996	Tier 0 (uncontrolled)	9.7
	1996 – 2001	Tier 1	6.9
	2002 – 2005	Tier 2	4.8
	2006+	Tier 3	3.0

This control measure consists of replacing the engine or the entire vehicle with a new engine meeting the current emission standard or better, or a remanufactured engine that has lower emissions than the older engine. The actual emission reduction realized will depend upon the actual engine replaced and the emission standard that the new engine meets. Like any scrappage program, the scrapped engine or vehicle should be in good working order and would otherwise be used for many years to come if not replaced under this program. The life of the emission credit generated will be equivalent to the remaining life of the engine or vehicle to be replaced.

For nonroad agricultural and construction equipment modernization program, replacing Tier 0 and Tier 1 baseline engines with Tier 2 engines, and replacing Tier 0, Tier 1, and Tier 2 baseline engines with Tier 3 engines were investigated for several major nonroad construction and agricultural equipment types based on their contribution to the NOx emissions.

Emissions - For nonroad equipment, the NOx emission factors were calculated based on the Tier 0, Tier 1, Tier 2, and Tier 3 nonroad emission standards; load factors and activity data were extracted from the NONROAD2004 model using the LADCO input and option files. Detailed emission rates, load factors, and activity data for major construction and agricultural equipment types are provided in Appendix M20/25.

Cost – ENVIRON estimated that Tier 2 engines cost about $100 per horsepower yielding a range of Tier 2 engine costs of about $13,800 to $136,000, and $3,800 to $67,500 for construction equipment and agricultural equipment, respectively, depending on the horsepower range. Tier 3 engines were estimated to cost about $120 per horsepower yielding a range of Tier 3 engine costs of about $16,500 to $118,500, and $4,500 to $81,000 for construction equipment and agricultural equipment, respectively, depending on the horsepower range. The typical range of incremental capital costs on engine or equipment replacement for TERP and Carl Moyer funded projects is about $20,000 to $50,000. Since limited cost data are available, ENVIRON assumed that the incremental engine or equipment replacement for Tier 3 engines was about 20% more than the Tier 2 engines. Capital recover factor for the project life was calculated using an assumed 3% discount rate.

Emission Reductions - The emission reduction would depend on the technology group (i.e. Tier 0, Tier 1, Tier 2 or Tier 3), equipment type or horsepower range of the engine replaced and the emission standard that the remanufactured or new engine meets. The emission reduction values for equipment modernization via replacing lower emission engines or equipment for construction and agricultural equipment are summarized in Table M20/25-2. Detailed emission reductions values on a per-equipment basis for major construction and agricultural equipment types are provided in Appendix M20/25.

Table M20/25-2. Emission reduction values for engine or equipment replacement.

	Emission Reduction per Equipment (tpy)		
	Tier 0 with Tier 2	Tier 1 with Tier 3	Tier 2 with Tier 3
Agricultural	0.02 – 1.07	0.04 – 0.84	0.02 – 0.36
Construction	0.21 – 7.90	0.18 – 2.00	0.08 – 0.64

Cost-Effectiveness - The cost-effectiveness of the engine or equipment replacement would depend on the technology group, equipment type or horsepower range of the engine replaced. The range of cost effectiveness values for nonroad equipment engine or equipment replacement is summarized in Table M20/25-3. Detailed cost effectiveness values for major construction and agricultural equipment types are provided in Appendix M20/25.

Table M20/25-3. Cost effectiveness values for engine or equipment replacement.

	Cost Effectiveness ($/ton NOx reduced)		
	Tier 0 with Tier 2	Tier 1 with Tier 3	Tier 2 with Tier 3
Agricultural	$7,000 – 26,000	$11,000 – $36,000	$22,000 – $84,000
Construction	$2,000 – 8,000	$4,000 – 11,000	$9,000 – $25,000

Technical Implementation Feasibility and Public Acceptance - The measure is feasible, as the emission reductions are based on available certified lower emission engines or equipment with lower emission engines. In addition, such equipment fleet modernization program has already been implemented in many states in the U.S. (e.g. California, Texas etc.). However, guidelines or mechanism, especially on eligible equipment or engines, and project/emission credit life, should be clearly defined to avoid potential issues related to surplus emissions versus normal turnover rates.

Appendix M20/25: Nonroad Equipment Modernization via Diesel Engines or Equipment Replacement – Refer to Appendix M20/25 for detailed emission reduction and cost-effectiveness results.

Measure 31/32: On-Road Fleet Modernization via Diesel Engine or Vehicle Replacement

Description - By far the most widely employed method for reducing emissions from diesel engines is the replacement of the engines with new lower-emitting engines or replacement of the entire vehicle or piece of equipment with cleaner diesel engines, including remanufactured or new engines. The expected percentage emission reduction from this approach will depend upon the engine model year to be replaced and the emission standard that the new engine meets.

This measure focuses on the fleet modernization of Class 8 HDDVs as they are identified as the major NOx emission contributors to the on-road NOx emission inventory in the LADCO States.

The EPA has recently adopted a tighter combined NOx and NMHC emission standard for model years 2004 to 2006 HD engines, and much more stringent NOx and PM emission standards for model year 2007 and later HD engines. These emission standards, along with those for early model year HD engines, are presented in Table M31/32-1. As shown in Table M31/32-1, the combined NOx and NMHC emissions for MY 2004-2006 HD engines are reduced by more than 50%, as compared to MY 1998 HD engines. The PM emission standards for MY1992 and later HD engines were reduced by more than 80% as compared to those for MY 1990 and earlier HD engines. The emissions from MY 2007 and later HD engines are further reduced by more than 85% for the combined NOx and NMHC emissions and 90% for the particulate matter (PM) emissions, as compared to MY 2004/2006 HD engines.

Table M31/32-1. EPA emission standards for heavy-duty engines for on-road vehicles.

	Pollutant (g/bhp-hr)			
Model Year	**Hydrocarbons (HC)**	**Carbon Monoxide (CO)**	**Nitrogen Oxides (NOx)**	**Particulate Matter (PM)**
1988-1989*	1.3	15.5	10.7	0.60
1990	1.3	15.5	6.0	0.60
1991	1.3	15.5	5.0	0.25
1992-1994	1.3	15.5	5.0	0.10
1998-2003	1.3	15.5	4.0	0.10 (truck) 0.05 (urban bus)
2004–2006	**2.5 combined NMHC+NOx	15.5	**2.5 combined NMHC+NOx	0.10 (truck) 0.05 (urban bus)
2007+	0.14 NMHC	15.5	0.20	0.01

***** The adopted Federal NOx emission limit of 6.0 g/bhp-hr was adopted in 1988, but was postponed until 1990.
****** The 2004 standards apply to all GVW classes, and are defined as a combined non-methane hydrocarbon plus nitrogen oxides (NMHC + NOx) emission standard of 2.5 g/bhp-hr.

This control measure consists of replacing the engine or the entire vehicle with a new engine meeting the current emission standard or better, or a remanufactured engine that has lower emissions than the older engine. The actual emission reduction realized will depend upon the actual engine replaced and the emission standard that the new engine meets. Like any scrappage program, the scrapped engine or vehicle should be in good working order and would otherwise be used for many years to come if not replaced under this program. The life of the emission credit generated will be equivalent to the remaining life of the engine or vehicle to be replaced.

Four cases of diesel engine or vehicle replacement were investigated for on-road HDDVs in this measure:

- Replacing pre-1987 engines (10.7 g/bhp-hr) with remanufactured MY 1990 (6 g/bhp-hr) engines or with remanufactured MY2001/2 (4 g/bhp-hr) engines or with new MY2002/4 (2.5 g/bhp-hr) engines;
- Replacing MY 1988 to 1990 (6 g/bhp-hr) engines with remanufactured MY2001/2 (4 g/bhp-hr) engines or with new MY2002/4 (2.5 g/bhp-hr) engines;
- Replacing 1991 to 1997 (5 g/bhp-hr) engines with remanufactured MY2001/2 (4 g/bhp-hr) engines or with new MY2002/4 (2.5 g/bhp-hr) engines;
- Replacing MY 1998 to 2001 engines with new MY2002/4 (2.5 g/bhp-hr) engines or with new MY 2007 (0.2 g/bhp-hr) engines.

Emissions - NOx emission factors for on-road HDDVs were calculated based on the emission standards and conversion factors for HDDVs from the EPA's MOBILE6 model. It was also assumed that the replacement vehicle or vehicle with replacement engine would travel 50,000 mile annually within the nonattainment or maintenance area that the SIP or conformity analysis or emission credit applies to, and 8 years of vehicle life. Emission rates and conversion factors by different model year groups are provided in Appendix M31/32.

Cost – For the on-road HDDVs, ENVIRON assumed that the incremental engine or vehicle replacement costs for the remanufactured MY 1990, and MY 2001 and 2002 engines were $35,000 and $40,000, respectively, and $45,000 for the new MY 2002 and 2004 engines. These cost estimates were consistent with the engine replacement costs funded by the California Carl Moyer[12] and Sacramento Emergency Clean Air Transportation (SECAT)[13] Programs, and Texas Emission Reduction Plan[14] or VMEP programs (e.g. in Houston-Galveston and Dallas Fort-Worth areas). Since limited cost data are available, ENVIRON assumed that the incremental engine or vehicle replacement cost for MY 2007 engines was about 30% more than the MY 2004 engines or about $60,000. Capital recover factor for the project life was calculated using an assumed 3% discount rate.

Emission Reductions - The emission reduction would depend on the model year or equipment type or horsepower range of the engine replaced and the emission standard that the remanufactured or new engine meets.

The annual NOx emission reduction values for on-road HDDVs range from 0.17 to 1.5 tpy per vehicle. Potential emission reductions for on-road HDDVs for replacing vehicles with older, high emitting engines with vehicles with remanufactured or new lower emission engines are provided in Appendix M31/32.

Cost-Effectiveness - The cost-effectiveness of the fleet modernization measure would depend on the model year and equipment type or horsepower range of the engine replaced.

Replacing MY 1989 and earlier engines with either MY 1990, MY 2001 and 2002 or MY 2002 and 2004 engines, and replacing MY1990 engines with MY2002/2004 engines would have cost-effectiveness values less than $13,000 per ton of NOx reduced. On the other hand, replacing

[12] http://www.arb.ca.gov/msprog/moyer/moyer.htm
[13] http://www.4secat.com
[14] http://www.tceq.state.tx.us/implementation/air/terp/index.html

MY 1991 and later engines with newer MY 2001/2002, MY2002/2004 or MY 2007 engines or vehicles would not be as cost-effectiveness. Detailed cost-effectiveness values for the fleet modernization measure for on-road HDDVs are provided in Appendix M31/32.

Technical Implementation Feasibility and Public Acceptance - The measure is feasible, as it has already been implemented in emission reduction programs in many states in the U.S (e.g. California, Texas etc.) However, guidelines or mechanism, especially on eligible vehicles and project/emission credit life, should be clearly defined to avoid potential issues related to surplus emissions versus normal turnover rates.

Appendix M31/32: On-Road Fleet Modernization via Diesel Engine or Vehicle Replacement – Refer to Appendix M31/32 for detailed emission reduction and cost-effectiveness results.

Measure 29a/47: Replacement of On-road HDDVs with Natural Gas/Dual-Fuel Engines or Vehicles

Description – This measure is very similar to the diesel engine replacement measure, except that it would replace older diesel engines or on-road HDDVs with new lower emission natural gas (NG) or Dual-Fuel (natural gas/diesel) engines, retrofit diesel engines with Dual-Fuel conversion kits, or replace entire diesel vehicles with NG/Dual Fuel vehicles. The NG/Dual-Fuel engines are certified to 2.0 g/bhp-hr of NOx emission level. Some of the certified NG/Dual-Fuel engines are shown in Table M29a/47-1. NG/Dual-Fuel engines also produce substantially lower PM emissions as compared to diesel engines. PM emissions can be reduced by more 90% and 99% for a NG/Dual-Fuel engine with and without an oxidation catalyst, respectively, in comparison to a comparable diesel engine. This measure would target HDDV fleets that have centralized refueling stations or practices, such as short-haul trucks, refuse trucks or transit buses.

Table M29a/47-1. Some of the certified NG/Dual-Fuel engines for HD vehicles.

Engine Type	Engine	Typical Application	Size (Liters)	Power (hp)	NO_x Cert. Level
Spark-Ignited	Cummins B5.9G	MHD	5.9	150/195/230	2.5
	Cummins C8.3G	HHD, Transit	8.3	250/275	2.5
	DDC Series 50G	Transit	8.5	275	2.0
	DDC Series 60G	HHD	12.7	330	2.5
	Mack E7G	HHD, Transit	11.9	325	2.0
	DDC	Transit	12.7	275	2.0
	John Deere	MHD	6.8	225	2.5
	John Deere	MHD	8.1	250	2.5
	John Deere	School Bus	8.1	280	2.0
	Ford	Shuttle	5.4	225	0.5
	Baytech (retrofit)	MHD	5.7	211	1.5
Pilot-Ignition Dual Fuel	Caterpillar/PSA 3126	MHD	7.2	200/240/250	2.5
	Caterpillar/PSA C-10	HHD, Refuse	10.3	305/350	2.5
	Caterpillar/PSA C-12	HHD, Refuse	12	370/410	2.5

Five cases of NG/Dual-Fuel engine replacement or repowering are investigated in this study:

- Replacing pre-1989 (10.7 g/bhp-hr) engines with new dedicated NG or Dual Fuel engines or Dual-Fuel retrofit system, or replacing the entire vehicle with a NG/Dual Fuel vehicle;
- Replacing MY 1990 (6 g/bhp-hr) engines with new dedicated NG or Dual Fuel engines or Dual-Fuel retrofit system, or replacing the entire vehicle with a NG/Dual Fuel vehicle;
- Replacing 1991 to 1997 (5 g/bhp-hr) engines with new dedicated NG or Dual Fuel engines or Dual-Fuel retrofit system, or replacing the entire vehicle with a NG/Dual Fuel vehicle;
- Replacing MY 1998 to 2001 (4 g/bhp-hr) engines with new dedicated NG or Dual Fuel engines or Dual-Fuel retrofit system, or replacing the entire vehicle a NG/Dual Fuel vehicle; and

- Replacing MY 2002 to 2006 (2.4 g/bhp-hr) engines with new dedicated NG or Dual Fuel engines or Dual-Fuel retrofit system, or replacing the entire NG/Dual Fuel vehicle.

Emissions – NOx emission factors for on-road HDDVs were calculated based on the emission standards and conversion factors for HDDVs from the EPA's MOBILE6 model. The NG/Dual-Fuel engines were assumed to certify as 2.0 g/bhp-hr NOx emission levels. The useful life for the replacement engine/vehicle was assumed to be 8 years. Annual VMT of 50,000 miles is assumed for Class 8 trucks, 50,000 miles for buses, and equivalent 20,000 miles[15] for refuse trucks.

Cost - ENVIRON assumed that the engine replacement costs for the new NG/Dual Fuel engines and Dual-Fuel retrofit systems were $35,000 and $30,000, respectively, while whole truck replacement cost was assumed to be $150,000. These cost estimates were consistent with the incremental capital costs funded by other similar programs (Sacramento Emergency Clean Air Transportation Program, Texas Emission Reduction Plan, or Houston-Galveston and Dallas Fort-Worth VMEP programs.) Capital recover factor for the project life was calculated using an assumed 3% discount rate.

In addition to incremental capital costs, fuel cost and energy consumption differences were also included in the cost-effectiveness analysis. Using historical data from Annual Energy Outlook 2005, diesel and natural gas fuel costs were assumed to be $2.13 and $1.68, respectively, in 2007 to 2009. In addition, energy consumption for NG/Dual Fuel engine is assumed to be 10% higher than the diesel.

Emission Reductions – Potential NOx emission reductions would depend on the model year of the engine replaced, ranging from 0.06 to 1.51 tons per HD diesel truck per year, 0.08 to 1.82 tons per refuse truck per year, and 0.1 to 2.24 tons per transit bus per year. Detail emission reductions are provided in Appendix M29a/47.

Cost-Effectiveness - The cost-effectiveness of this measure would depend on the model year of the engine replaced. Replacing MY 1990 and earlier engines with NG/Dual Fuel engines are generally below $13,000 per ton of NOx reduced. Detailed cost-effectiveness values for this measure are provided in Appendix M29a/47.

Technical Implementation Feasibility and Public Acceptance - The measure is feasible, especially for targeted fleets with centralized fueling facilities, as it has already been implemented in throughout the U.S. The NG/Dual Fuel engines and retrofit systems are certified with the EPA and CARB.

Appendix M29a/47: Replacement of On-road HDDVs with Natural Gas/Dual-Fuel Engines or Vehicles – Refer to Appendix M29a/47 for detailed emission reduction and cost-effectiveness results.

[15] Refuse trucks are generally traveled less than 50,000 miles annually. However, emissions for refuse trucks were estimated based on an equivalent 50,000-miles to account for more severe duty cycles (i.e. stop and go, and garbage bin pickup-dump) as compared to that for a typical Class 8 truck.

Measure 42: Accelerated Low NOx Rebuild/Chip Reflashing Program for On-Road Heavy-Duty Diesel Vehicles

Description – The Environmental Protection Agency (EPA), the Department of Justice, and California Air Resources Board (CARB) discovered that seven large diesel engine manufacturers had designed engines with advanced computer controls (software) that maximized fuel economy and created "off-cycle" NOx emissions during certain periods of vehicle operation, such as long-haul or steady-state driving, during the 1990s. As part of the federal Consent Decrees signed in 1998 between them, the EPA and the Department of Justice, seven engine manufacturers are required to partially mitigate their off-cycle NOx emissions via a number of mitigation measures, including development of low NOx software and installation of low NOx software upgrades free of charge upon rebuild or upon request on applicable vehicles that produce off-cycle emissions[16]. Most 1993-1999 model year Class 7 and Class 8 HDDVs with model year 1993-1998 engines manufactured by Caterpillar, Cummins, Detroit Diesel Corporation, Mack/Renault, Volvo and International have an obligation to have low NOx software installed. However, years later, evidence has shown that the installation of the low NOx software has not been done on as many applicable trucks as anticipated; California, in 2003, estimated that only less than 10% of the applicable trucks had been installed with low NOx software over a 4 year period after signing of the Consent Decrees[17].

Resulting from the finding, CARB, in 2004, adopted the heavy-duty diesel engine software upgrade regulation (chip reflashing) to accelerate the low NOx software upgrade[2]. The program requires that:

- 1993 and 1994 model year Low NOx Rebuild Engines (i.e. engines with off-cycle NOx emissions) must have a Low NOx Rebuild Kit installed by April 30, 2005;
- 1995 and 1996 model year must have a Low NOx Rebuild Kit installed by August 31, 2005;
- 1997 and 1998 model year Low NOx Rebuild Engines other than MHDDE, must have a Low NOx Rebuild Kit installed by December 31, 2005; and
- 1997 and 1998 model year MHDDE Low NOx Rebuild Engines must have a Low NOx Rebuild Kit installed by December 31, 2006.

This control measure would be to adopt regulations similar to the CARB Low NOx Software Upgrade program with a set phase in schedule that would require all low NOx rebuild engines to have low NOx rebuild kit installed by 2009.

Emissions – NOx emission factor for MY 1993-1998 medium and heavy HDDVs with low NOx rebuild kit installed was estimated at 6.0 g/bhp-hr (after rebuild NOx level) based on the EPA's MOBILE6 model.

ENVIRON assumed that the Low NOx Rebuild/Chip Reflashing Program would reduce NOx emissions by about 5% to 40%, with an average of 23% based on a study to assess the low NOx

[16] http://www.epa.gov/compliance/resources/cases/civil/caa/diesel/condec.html
[17] http://www.arb.ca.gov/regact/chip04/chip04.htm

rebuild on in-use service trucks conducted by the University of California, Riverside[18], while increasing fuel consumption by 2%.

Cost - ENVIRON assumed that the phase-in of the Low NOx Rebuild/Chip Reflashing Program would entail no incremental capital cost as per the Consent Decrees. Thus, the only cost would be the incremental fuel cost due to the 2% increase in the fuel consumption. Using historical data from Annual Energy Outlook 2005, diesel fuel cost was assumed to be $2.13 in 2007 to 2009[19]. This incremental fuel cost was estimated to be about $400 for vehicles traveling 50,000 miles.

Emission Reductions – Potential NOx emission reductions for the Low NOx Rebuild Program were estimated to be 0.16 tpy per vehicle for MY 1993-1998 medium-HDDVs, and 0.22 tpy per vehicle for MY 1993-1998 heavy-HDDVs. Detailed emission reductions for different vehicle groups for this measure are provided in Appendix M42.

Cost-Effectiveness - Lifetime cost-effectiveness values for medium-HDDVs and heavy-HDDVs are $2,500 and $1,800, respectively. Detailed cost effectiveness for different vehicle groups for this measure are provided in Appendix M42.

Technical Implementation Feasibility and Public Acceptance - The measure is feasible, as it has been implemented in California, and low NOx rebuild kits are available and the manufacturers are required to install them on trucks upon rebuild or upon request. However, due to the potential fuel economy penalty, this measure would be more effective as a mandatory, instead of voluntary, program as experienced in California.

Appendix M42: Accelerated Low NOx Rebuild/Chip Reflashing Program for On-Road Heavy-Duty Diesel Vehicles – Refer to Appendix M42 for detailed emission reduction and cost-effectiveness results.

[18] "Evaluation of the Effectiveness of Low NOx ECM Reprogramming to In Service Heavy-Duty Vehicles," UC Riverside CE-CERT, CRC Poster Session, 1998.

[19] Note that a fuel cost sensitivity analysis was performed to assess the impact of increasing fuel costs by 30%, and the sensitivity analysis results were discussed in Section 4 of the report.

Measure 46/51: NOx Retrofit Technologies for Diesel Engines

Description - This control measure includes encouraging fleet owners and operators to retrofit on-road HDDVs and nonroad equipment with emission-reduction devices to reduce NOx diesel exhaust emissions. The primary purpose of these devices is to significantly reduce NOx emissions but often PM retrofit devices are also included in many NOx retrofit devices.

This measure focuses on the fleet modernization of Class 8 HDDVs, and major construction and agricultural equipment types as they are identified as the major NOx emission contributors to the NOx emission inventory in the LADCO States.

The technologies available to reduce NOx emissions from mobile sources include retarded engine timing modification, Exhaust Gas Recirculation (EGR), lean NOx catalyst, and Selective Catalytic Reduction (SCR). Examples of verified and demonstrated emission reductions effectiveness are shown in Table M46/51-1.

The NOx control retrofits will not reduce PM emissions by themselves and may increase PM emissions. Often a NOx control device is accompanied by a particulate control device, such as a diesel particulate filter (DPF), in a package offered by the vendor. This is especially true for retarded timing and EGR NOx control strategies. For the EGR+DPF retrofit, the PM emissions would be reduced by more than 90%. Unless these technologies are coupled by a DPF or diesel oxidation catalyst (DOC), the lean NOx and SCR retrofits would have a limited effect on PM emission reductions. While it would not provide NOx emission reduction, a DOC would provide about 30% PM emission reductions.

Table M46/51-1. NOx retrofit control technologies.

Emission Control Device	Verification Status	NOx Control Efficiency
Lean NOx reduction catalyst (Example Vendor: Cleaire's Lonestar)	EPA Certification Process	40%
EGR+DPF (Example Vendor: STT Emtec System)	EPA Certification Process	Up to 50%
SCR (Example Vendor: Extengine etc.)	CARB/EPA Verification Process	70 to 99%

Emissions – NOx emission factors for on-road HDDVs were calculated based on the emission standards and conversion factors for HDDVs from the EPA's MOBILE6 model. It was also assumed that the vehicle with installed retrofit device would travel 50,000 mile annually within the nonattainment or maintenance area that the SIP or conformity analysis or emission credit applies to, and 8 years of project life. Detailed emissions by different model year groups are provided in Appendix M46/51.

For nonroad equipment, the NOx emission factors were calculated based on the Tier 0, Tier 1, Tier 2, and Tier 3 nonroad emission standards; load factors and activity data were extracted from the NONROAD2004 model results using LADCO input and option files. The useful life for these retrofit technologies was assumed to be 10 years. Detailed emission rates, load factors, and activity data for major construction and agricultural equipment types are provided in Appendix M46/51.

The control efficiency for the lean NOx catalyst was assumed to be 40%. The NOx control efficiencies for the EGR+DPF, and SCR systems were assumed to be 30% and 75%, respectively. The control efficiencies are consistent with the emission reduction range provided in the EPA website on verified technologies[20], and discussion in the EPA Draft Guidance for Qualifying and Using Emission Reductions From Mobile Source Retrofit Projects in State Implementation Plans and Transportation and General Conformity (EPA Draft Retrofit Guidance).

Cost – The major costs for these NOx retrofit systems include both capital and operational costs. The average capital costs for installation of these systems are estimated to be $85 per hp for lean NOx catalyst systems, $95 per hp for EGR+DPF systems, and $115 per hp for SCR systems. These costs were consistent with the incremental capital costs funded by other similar programs (e.g. Sacramento Emergency Clean Air Transportation Program, Texas Emission Reduction Plan, or Houston-Galveston and Dallas Fort-Worth VMEP programs.)

Table M46/51-2 provides a summary of the estimated capital costs. For the lean NOx catalyst system, a 2% increase in the fuel consumption was assumed. For the EGR+DPF system, it was assumed that it would increase fuel consumption by 3%. For the SCR system, it was assumed that the urea consumption was equivalent to about 2% of the fuel consumption. Capital recover factor for the project life was calculated using an assumed 3% discount rate.

Table M46/51-2. Estimated average capital cost for some NOx retrofit control technologies.

Control Technology		Capital Cost
On-road HDDVs		
Lean NOx Reduction Catalyst		$20,000
EGR+DPF		$23,000
SCR		$27,500
Nonroad Construction Equipment		
Lean NOx reduction catalyst - Lonestar	175 – 750+ hp	$20,000 - $ 114,500
EGR+DPF	175 – 750+ hp	$23,000 - $ 131,700
SCR	175 – 750+ hp	$27,500 - $ 157,400
Nonroad Agricultural Equipment		
Lean NOx reduction catalyst - Lonestar	25 - 750 hp	$5,200 - $ 56,800
EGR+DPF	100 - 750 hp	$5,600 - $ 65,400
SCR	100 - 750 hp	$6,300 - $ 78,200

Emission Reductions - The emission reduction values for the lean NOx catalyst, EGR+DPF, and SCR retrofits for on-road HDDVs are presented in Appendix M46/51. The annual NOx emission reduction values for the lean NOx catalyst strategy for on-road HDDVs range from 0.11 to 0.55 tons per year (tpy) per vehicle. For the EGR+DPF and SCR retrofit system, the annual NOx emission reduction values range from 0.11 to 0.55, and 0.29 to 1.37 tpy per vehicle, respectively.

[20] http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm

The emission reduction values for the lean NOx catalyst, EGR+DPF, and SCR system retrofits for major nonroad construction and agricultural equipment are presented in Appendix M46/51. Annual emission reduction values associated with each control measure vary depending on the equipment types and horsepower ranges. Table M46/51-3 summarizes the range of annual emission reduction values for all three after treatment measures investigated.

Table M46/51-3. Potential emission reductions by equipment type and NOx retrofit control technology.

Nonroad Equipment Category	Control Technology	Emission Reductions Per Equipment (tpy)			
		Tier 0 Engines	Tier 1 Engines	Tier 2 Engines	Tier 3 Engines
Construction	Lean NOx Catalyst	0.16 - 6.34	0.12 - 4.81	0.08 - 3.18	0.05 - 0.54
	EGR+DPF System	0.12 - 4.75	0.09 - 3.60	0.06 - 2.38	0.04 - 0.42
	SCR System	0.31 - 11.9	0.22 - 9.01	0.15 - 5.95	0.09 - 1.05
Agricultural	Lean NOx Catalyst	0.03 - 0.81	0.03 - 0.58	0.03 - 0.38	0.02 - 0.24
	EGR+DPF System	0.03 - 0.61	0.02 - 0.43	0.02 - 0.29	0.01 - 0.18
	SCR System	0.06 - 1.52	0.06 - 0.72	0.05 - 0.71	0.03 - 0.45

Cost-Effectiveness – The cost-effectiveness values for on-road HDDVs by MY group and retrofit technology are summarized in Table M46/521-4. The cost-effectiveness values for major construction and agricultural equipment by technology type and retrofit technology are summarized in Table M46/521-5.

Table M46/51-4. Cost-effectiveness values for HDDVs by model year group and NOx retrofit control technology.

Control Technology	Cost-Effectiveness Values ($/ton of NOx Reduced)				
	MY 1989 & Earlier	MY 1990	MY 1991-1997	MY 1998 - 2001	MY 2002 - 2006
Lean NOx Catalyst	$6,000	$11,000	$13,000	$17,000	$28,000
EGR+DPF System	$6,000	$11,000	$14,000	$17,000	$29,000
SCR System	$3,000	$6,000	$7,000	$9,000	$15,000

Table M46/51-5. Cost-effectiveness ranges for major construction and agricultural equipment and NOx retrofit control technology.

Nonroad Equipment Category	Control Technology	Cost-Effectiveness Values ($/ton of NOx Reduced)			
		Tier 0 Engines	Tier 1 Engines	Tier 2 Engines	Tier 3 Engines
Construction	Lean NOx	3,000 - 16,000	4,000 - 22,000	6,000 - 33,000	12,000 - 54,000
	EGR+DPF	7,000 - 32,000	9,000 - 45,000	13,000 - 66,000	26,000 - 108,000
	SCR	2,000 - 12,000	3,000 - 17,000	4,000 - 25,000	9,000 - 40,000
Agricultural	Lean NOx	9,000 - 28,000	12,000 - 38,000	18,000 - 57,000	30,000 - 91,000
	EGR+DPF	16,000 - 45,000	22,000 - 61,000	33,000 - 92,000	54,000 - 147,000
	SCR	7,000 - 20,000	9,000 - 28,000	14,000 - 42,000	22,000 - 67,000

Technical Implementation Feasibility and Public Acceptance – These NOx retrofit strategies are feasible, as they have already been implemented in California, Texas and elsewhere in the U.S. All of these NOx retrofit technologies, except the lean NOx catalyst and SCR system for limited nonroad equipment, are unverified technologies. Therefore, until they are verified, guidelines and enforcement mechanism should be developed to assure the emission reductions are real. This would include emission measurement to assess the emission performance and durability of those unverified technologies.

Appendix M46/51 - NOx Retrofit Technologies for Diesel Engines – Refer to Appendix M46/51 for detailed emission reduction and cost-effectiveness results.

Measure 28/29/43/44/45: LEVII, and Accelerated Vehicle Replacement and Scrappage Programs

Description - This control measure discusses the accelerated replacement or scrapping of older light-duty vehicles, LDVs (i.e. passenger cars or light-duty trucks), with lower emission vehicles, as well as provides general assessment of the implementation of a LEV II Program instead of a Tier II Program in the LADCO States based on findings of past studies[21].

LEVII Program - The Environmental Protection Agency (EPA) sets emission standards for new vehicles sold in the United States, but California has the authority to set its own vehicle standards. Other states may adopt either California or the federal standards. In the late 1990's, California established the Low Emission Vehicle (LEV) Program[22] that contained more stringent emission standards compared to the federal standards for LDVs, and several Northeast states adopted the California LEV program. California, subsequently in November 1998, adopted the second-generation of the LEV Program, so called LEVII program. The EPA, in December 1999, adopted the Tier 2 emission standards for LDVs, phasing in between 2004 and 2007 for light LDVs or LDTs, and 2008 to 2009 for heavy LDTs and medium-duty passenger vehicles.

A number of emission benefit assessments of the LEVII program relative to the Tier 2 program have been conducted in several states (e.g. Northeast states[23,24], Texas.). While results from these studies showed that there would be substantial long-term emission benefits for the LEVII program, the NOx emission benefits for the LEVII program would be limited during the first few years after program implementation. Figure M28-1 shows the NESCAUM modeling of NOx emission benefits for the LEV II program implemented in 2009 in the Northeast states[25]. As shown in this figure, potential NOx emission benefits for the LEV II program range are about 2% in 2012, 5% in 2015, and 12% in 2020. Given the lead time required for adopting such a program, the LEVII program would not provide substantial NOx emission benefits for the LADCO States in 2009; if implemented in 2009, analysis showed that the LEVII program would provide about 3 tons per year or 0.008 tons per day of NOx emission reduction in the LADCO States in 2009 (i.e. during the first year of the program implementation), based on the projected 2009 LADCO emission inventory for LDVs, and modeling results of the NESCAUM study.

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[21] A detailed assessment to compare emission reductions of the LEV II Program to the Tier 2 Program would require an extensive MOBILE6 modeling effort, and was out of the scope for this work.
[22] http://www.arb.ca.gov/msprog/levprog/levprog.htm.
[23] "Comparing the Emissions Reductions of the LEV II Program to the Tier 2 Program," White Paper prepared by NESCAUM, and Cambridge Systematics, Inc., October 2003.
[24] "Preliminary Assessment of LEV-II Program Benefits for Texas," H37 Final Report by ERG, and Cambridge Systematics, Inc. for Houston Advanced Research Center, December 31, 2004.
[25] Spreadsheet file provided by Coralie Cooper of NESCAUM.

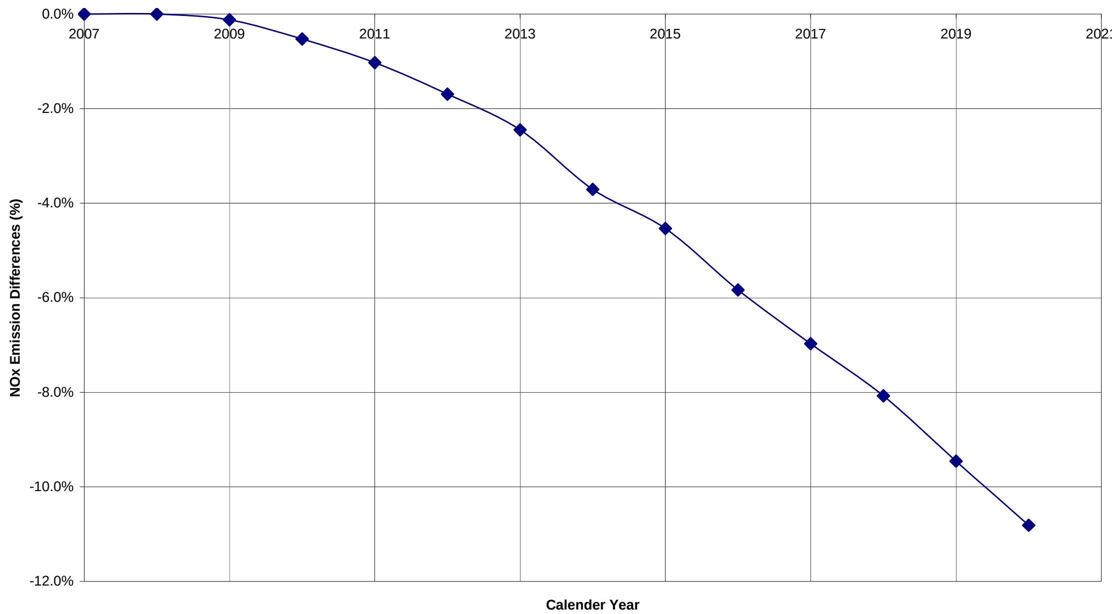

Figure M28-1. LEV II versus Tier 2 programs using EPA input assumptions for both programs implemented in 2009 in the Northeast States[26].

Accelerated Vehicle Replacement/Scrappage Program - The accelerated vehicle replacement program would include replacing older (10 years old or older) light-duty vehicles with lower emission vehicles (i.e. fleet modernization), and buy-back and scrapping 25 years and older vehicles. The accelerated vehicle replacement program would target fleet light-duty vehicles 10 years old or older, and the scrappage program would target all light-duty vehicles 25 years old or older. The actual emission reduction realized would depend upon the model year of the replaced/scrapped vehicle, and the replacement vehicle. Like any replacement or scrappage program, the replaced or scrapped vehicle should be in good working order and would otherwise be used for many years to come if not replaced under these programs. The life of the emission credit generated will be equivalent to the remaining life of the engine or vehicle to be replaced. These programs should follow the EPA guidance document on accelerated vehicle retirement or scrappage for LDVs[27].

As discussed earlier, potential emission reductions would depend upon model year of the replaced vehicle and the replacement vehicle. While a detailed MOBILE6 modeling assignment is beyond the scope of this project, three cases were investigated as examples to estimate the potential emission benefits, associated costs, and cost-effectiveness values of the accelerated vehicle replacement program: replacing a 10 year old vehicle with Tier 2 LDV, SULEV, or ZEV. Emission reductions might be higher if the replaced vehicle is older than 10 years old. For the scrappage program of 25 years old and older vehicles, replacement of 1983 and earlier model vehicles with a 2007 LDV was investigated.

[26] Spreadsheet file provided by Coralie Cooper of NESCAUM.
[27] "Guidance for the Implementation of Accelerated Retirement of Vehicles Programs," EPA 420-R-93-018, Environmental Protection Agency, Ann Arbor, MI, February 1993.

Emissions - NOx emissions for LDVs were based on the MOBILE6 model using national default conditions[28], and MOBILE6 default annual mileage accumulation rate data by vehicle type was used to estimate annual vehicle mileage. For the accelerated vehicle replacement program and the scrappage program, the useful life was estimated based on the estimated average remaining life of the LDV to be replaced or scrapped. The useful life was assumed to be 10 years for the accelerated vehicle replacement program, and 3 years for the scrappage program as per the EPA LDV Vehicle Replacement Guidance[29].

Cost – For the accelerated vehicle replacement program, incremental costs to trade in a 1996/7 vehicle for a Tier 2 vehicle, SULEV (e.g. a hybrid vehicle), or ZEV would be about $10,000, $16,000, and $20,000, respectively, based on typical retails price for a compact car. For the vehicle scrappage program, an incurred cost of $1,000 per vehicle was assumed. Capital recover factor for the project life was calculated using an assumed 3% discount rate.

Emission Reductions – For the accelerated vehicle replacement and scrappage programs, the emission reductions would depend on the model year of the LDV replaced. Table M28-1 shows the potential emission reductions for LDVs. For the LEV II program, NOx emission reductions are an estimated 0.009 tons per day in 2009. For the example accelerated vehicle replacement of a 10 year old vehicle, NOx emission reductions were estimated to be about 0.0119, 0.0125, and 0.0127 tons per year for replacement with a Tier 2 vehicle, SULEV, or ZEV, respectively. For the scrappage program of 25 years old and older vehicles, the NOx emission reduction was estimated to be 0.00634 tpy.

Cost-Effectiveness - The cost-effectiveness of the accelerated replacement and scrappage programs would depend on the model year of the engine replaced. As shown in Table M28-1, the cost effectiveness values of the example accelerated vehicle replacement program to replace 10 year old vehicles with a Tier 2 vehicle, SULEV, or ZEV were estimated to be about $100,000, $160,000, and $190,000 per ton of NOx reduced per year, respectively. The cost effectiveness of the scrappage program of 25 years and older vehicles was estimated to be about $56,000 per ton of NOx reduced per year. These cost-effectiveness values are substantially higher than most selected measures for the on-road heavy-duty diesel vehicles and NONROAD diesel equipment.

Technical Implementation Feasibility and Public Acceptance – While they might not be as cost effective in reducing NOx emissions when comparing to those selected measures for heavy-duty vehicles and nonroad diesel equipment, these measure are feasible as they have been implemented in emission reduction programs in several states in the U.S.

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[28] "Emission Inventories and Potential Emission Control Strategies for Ozone Early Action Compact Areas in Tennessee," Draft Report to Division of Transportation Planning, Tennessee Department of Transportation, and Division of Air Pollution Control, Tennessee Department of Environmental and Conservation, Department of Civic and Environmental Engineering, University of Tennessee, April 2003.

[29] "Guidance for the Implementation of Accelerated Retirement of Vehicles Programs," EPA 420-R-93-018, Environmental Protection Agency, Ann Arbor, MI, February 1993.

Table M28-1. Potential NOx emission reductions and cost-effectiveness values for LEV II, Accelerated Vehicle Replacement and Scrappage programs.

Measure 28: Implementing LEV II Program in 2009 instead of Tier 2 Program (First Year Program Implementation)			
2009 LADCO States	**Baseline NOx Emissions (tpd)**	**NOx Emission Reduction**	
		(%)	**(tpd)**
LDGV	585	0.00%	0.000
LDGT1	337	0.17%	0.006
LDGT2	142	0.24%	0.003
Total	1,064		0.009

Measure 29/43/45: Accelerated Vehicle Replacement with Lower Emissions Vehicles (Example Case: Replacing 10 Years Old Vehicles)				
	NOx Emissions			
	1996 LDVs	**2006 LDVs**	**SULEV**	**ZEV**
Annual mileage	10,482	10,482	10,482	10,482
Incremental Capital Cost		10,000	16,000	20,000
Useful Life (years)	10	10	10	10
Annualized Capital Cost ($/yr)		$1,221	$1,953	$2,442
NOx g/mile	1.10	0.07	0.02	0
NO tons/year	0.013	0.001	0.000242692	0
Emission Reduction (tons/year)		0.0119	0.0125	0.0127
Cost-Effectiveness ($/ton)		102,568	156,657	192,083

Measure 44: Scrappage Program for LDVs Over 25 Years Old and Older				
	NOx		**VOC**	
	1983 & Earlier	**2007 Avg Veh**	**1983 & Earlier**	**2007 Avg Veh**
Annual mileage	3,587	3,587	3,587	3,587
Incremental Capital Cost		1,000		1,000
Useful Life (years)	3	3	3	3
Annualized Capital Cost ($/yr)		$354		$354
NOx g/mile	2.51	0.90	2.58	1.15
NO tons/year	0.010	0.004	0.010	0.005
Emission Reduction (tons/year)		0.00634		0.0056
Cost-Effectiveness ($/ton)		$55,773		$62,652

Measure 40: Inspection and Maintenance Programs for LDVs

Description – Implementing and/or expanding a vehicle inspection and maintenance (I/M) program can reduce emissions from in-use vehicles, especially from high emitters and/or vehicles with defective emission control systems. An I/M program can consist of a combination of exhaust and evaporative emission control system inspections[30]. The exhaust inspection can consist of idle test, ASM test, IM240 test, OBD test, or a combination of these tests. The evaporative inspection can consist of a fill-pipe pressure test, gas cap inspection and an evaporative OBD check[1].

Currently, all LADCO States except Michigan have adopted some sort of I/M program in their non-attainment counties. Illinois has a biennial I/M program (Vehicle Emission Testing program) for 1986 and newer light-duty vehicles in the counties of Cook, Dupage, Lake Kane, Kendall, McHenry, Will, Madison, Monroe, and St. Clair[31]. Indiana's Vehicle Emissions Testing Program is also a biennial I/M program for 1976 and newer LDVs in the Clark, Floyd, Lake and Porter counties[32]. The Ohio's E-Check I/M program is also a biennial program; the program applies to all LDVs, including diesel vehicles, 25 years old and newer, in the counties of Butler, Clark, Clermont, Cuyahoga, Geauga, Greene, Hamilton, Lake, Lorain, Medina, Montgomery, Portage, Summit and Warren[33]. The Vehicle Inspection Program in Wisconsin is also a biennial program for 1968 and newer light-duty vehicles in the counties of Kenosha, Milwaukee, Ozaukee, Racine, Sheboygan, Washington, and Waukesha[34].

All of these I/M programs consist of a combination of idle, I/M 240, and OBD tests for exhaust emissions based on the model year of the vehicle, as well as evaporative test/inspections. The Ohio's E-Check I/M program recently switched to ASM 2525, replacing the I/M240 test.

This control measure focuses on implementing more stringent I/M programs and/or expanding the existing I/M programs in the LADCO States.

Emissions – NOx emissions were calculated based on the 2009 emission inventory estimated using the 2002 NEI Emissions & LADCO Base J 2002/2009 gasoline and diesel emission ratios. Vehicle population estimates by vehicle type were developed using the calculated FHWA VMT data, and MOBILE6 default annual VMT data for different vehicle types. MOBILE6 modeling results from a recent study showed that implementing a stringent I/M program, similar to the existing I/M programs in Illinois, Indiana, Ohio and Wisconsin, in areas with no I/M program would provide about 8% NOx emissions benefit immediately, and 40% NOx emissions reduction in about 20 years[35]. This reduction was used in this measure to estimate the potential emission reduction on per vehicle basis for the LADCO States.[36]

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[30] http://www.epa.gov/otaq/im.htm
[31] http://www.epa.state.il.us/air/vim/
[32] http://www.in.gov/idem/air/programs/imsite/index.html
[33] http://www.epa.state.oh.us/dapc/mobile.html
[34] http://www.dot.wisconsin.gov/drivers/vehicles/im.htm
[35] "Emission Inventories and Potential Emission Control Strategies for Ozone Early Action Compact Areas in Tennessee," Draft Report to Tennessee Department of Environmental and Conservation, prepared by Department of Civic and Environmental Engineering, University of Tennessee, April 2003.
[36] Detailed assessment to quantify emission reductions of an I/M program would be program, state and county specific. It would require extensive MOBILE6 modeling effort, and was out of the scope for this work.

Cost – While the existing I/M programs in Illinois, Indiana and Wisconsin do not charge testing fees, there would be costs incurred resulting from program implementation or expansion, as well as vehicle repair costs due to test failures. The Ohio's E-Check I/M program charges a test fee of $19.50. The Tennessee study estimated that the average cost of the I/M Program per vehicle tested was about $58[6]. This cost estimate was used in the cost-effectiveness analysis of this measure.

Emission Reductions – Potential NOx emission reductions would depend on the effectiveness of the I/M Program. Based on MOBILE6 modeling results, the Tennessee study reported that a potential NOx emissions reduction of 0.00187 tons per year per vehicle could be achieved with a stringent I/M Program in those areas not currently covered by an I/M program.

Cost-Effectiveness - The cost-effectiveness of this measure would depend on inspection failure rates as well as repair costs. The cost effectiveness value reported in the Tennessee study was about $30,000 per ton of NOx reduced.

Technical Implementation Feasibility and Public Acceptance - The measure is feasible, as it has already been implemented in throughout the States, including four LADCO States.

Table M40-1. Potential NOx emission reduction and cost-effectiveness value for an I/M program Measure[37].

	Short Term (2007)		Long Term (2030)	
	NOx	VOC	NOx	VOC
Stringent I/M 240 with 5% waiver vs. No I/M (%)	8.2	25.55	41.5	36.75
Stringent I/M 240 with 5% waiver vs. No I/M (tpy/veh.)	0.00187	0.00417	0.00187	0.00213
Cost Estimate ($/per veh.)				$57.70
NOx Cost-Effectiveness ($/ton)				31,000
VOC Cost-Effectiveness ($/ton)				14,000

[37] "Emission Inventories and Potential Emission Control Strategies for Ozone Early Action Compact Areas in Tennessee," Draft Report to Tennessee Department of Environmental and Conservation, prepared by Department of Civic and Environmental Engineering, University of Tennessee, April 2003.

Measure 67: Vehicle Speed Reduction Program (65 mph to 55 mph)

Description – For on-road vehicles, especially heavy-duty diesel trucks, emissions vary significantly as a function of vehicle speed. As shown in Table M67-1, MOBILE6 estimates that heavy-duty diesel trucks emit more NOx at higher speeds than they do at lower speeds. Light-duty vehicles follow the same trend as well but to a lesser extent. Thus, this measure consists of reducing NOx emissions from HD diesel trucks via reducing the LADCO area-wide speed limit from 65 mph to 55 mph for HD trucks.

Table M67-1. NOx and VOC emission factors as predicted by MOBILE6.

SPEED (mph)	LDGV (g/mile)	LDGT34 (g/mile)	HDGV (g/mile)	HDDV (g/mile)
5	1.368	2.134	2.498	14.644
15	0.727	1.257	2.751	10.9
25	0.725	1.27	3.004	9.243
35	0.713	1.268	3.257	8.84
45	0.729	1.295	3.51	9.507
55	0.75	1.329	3.764	11.555
65	0.773	1.369	4.017	16.046
Reduction from 65 to 55	-3%	-2.9%	-6.3%	-28%

Emissions – The area-wide emission reductions were estimated based on similar studies in Dallas, Fort Worth, Houston and Galveston, Texas, and the State of Tennessee. NOx emissions were calculated based on the 2009 emission inventory estimated using the 2002 NEI Emissions & LADCO Base K 2002/2009 gasoline and diesel emission ratios. Vehicle population estimates by vehicle types were developed using the calculated FHWA VMT data, and MOBILE6 default annual VMT data for different vehicle types.

Cost - The primary cost of this measure is in enforcement and signage. According to salary.com, the average salary for a highway patrol officer in the U.S. is about $41,000. Including fringe benefits, $100,000 annual cost was assumed for a highway patrol officer. If ten additional highway patrol officers for each LADCO state were added to enforce the 55 mph speed limit, annual costs for the five LADCO states would be $5,000,000.

Emission Reductions - The reduction in NOx emissions was estimated to be 3.0% area-wide on HD diesel trucks based on past studies in Dallas, Fort Worth, Houston and Galveston, Texas, and State of Tennessee. Based on the estimated 3.0% NOx emissions reduction, potential emissions reductions from all on-road HD diesel vehicles with a 100% compliance rate were estimated to be about 32 tons per day (tpd) as shown in Table M67-2. Assuming a 50% compliance rate, the potential emission reduction would be about 16 tpd, and this value was used to calculate the cost effectiveness of the program. On a per vehicle basis, the potential emission reduction was estimated to be about 0.004 tons per year (tpy) per HD truck. While emission reduction estimates are provided here, more accurate emission reduction estimates would need to be determined on a link-by-link and hour-by-hour basis using the CONCEPT model.

Cost-Effectiveness - The speed limit decrease would be enforced 7 days a week so the emission reduction would occur each day of the year. Assuming a 50% compliance rate, total annual NOx emission reductions would be about 5,000 tpy. Thus, the cost effectiveness of the measure was estimated to be about $840/ton of NOx reduced.

Technical Implementation Feasibility and Public Acceptance - The measure is feasible, as it has already been implemented in other areas in the U.S. However, the effectiveness of the measure would depend on program enforcement.

Table M67-2. Potential NOx emission reduction and cost-effectiveness value for a vehicle speed reduction program for HD diesel trucks.

LADCO States	Baseline NOx Emissions (tpd)	Emission Reduction (tpd)			Vehicle Population	Emission Reduction per Veh (tpy)
		(%)	100% Compliance	50% Compliance		
Class 2b diesel	30.15				1680666	
Class 3, 4, 5 diesel	28.99				353078	
Class 6, 7 diesel	131.14				565913	
Class 8 diesel	856.58				203639	
Buses	38.69				148281	
Total On-Road HD Trucks	1085.56	3%	32.6	16.3	2951576	0.00403

Notes:
Enforcement Cost: 5,000,000 ($/year)
- Assumed 10 additional officers per state at a cost of $100,000 of salary & fringe benefits per officer to enforce the speed limit program.
Cost-Effectiveness (assumed a 50% compliance rate): 841$/ton of NOx reduced
Emissions Reduction - Area Wide On-road Heavy-Duty Diesel Trucks: 3%

4. EMISSION REDUCTION SCENARIOS

Introduction

As presented in Section 3, there are a variety of possible emission reduction measures that can be implemented in the LADCO states to reduce NOx emissions from mobile sources. In parallel to or part of the Midwest Clean Diesel Initiative[1], many of the selected control measures could be implemented in a major voluntary/incentive mobile source emission reduction program, similar to the Texas Emission Reduction Plan (TERP) or California's Carl Moyer and Sacramento Emergency Clean Air Transportation (SECAT) programs[2], to be developed and implemented by LADCO states. As per LADCO request, several emission reduction scenarios were developed to estimate potential emission reductions and associated costs using the results from the detailed cost benefit analyses of the selected control measures.

This section presents a few of many potential emission reduction scenarios based on those primary selected control measures for reducing NOx emissions from on-road diesel vehicles and nonroad diesel equipment, focusing on the on-road HDDVs and diesel construction and agricultural equipment as they are the primary sources of NOx emissions in the mobile source emission inventories in the LADCO states. The control measures included in these scenarios have a range of costs, potential NO_x emission reductions, and cost effectiveness. Some of the measures (technologies) discussed are as yet unverified technologies by the Environmental Protection Agency (EPA) or the California Air Resources Board (CARB) but have been implemented and funded in some emission reduction programs, such as the TERP.

The general approach for developing these emission reduction scenarios was as follows:

- Identify major emission contributors based on emission inventories;
- Generate/estimate vehicle or equipment population data;
- Identify and select control measures for target sources;
- Estimate potential emission reductions and associated cost estimates on a per vehicle or equipment basis, and cost-effectiveness values for selected measures;
- Develop criteria for penetration or compliance rates based on cost effectiveness values and vehicle or equipment availability (turnover rates); and
- Estimate potential total emission reductions and measure costs for selected measures and combinations of selected measures.

The emission reduction scenario analysis provides a general idea of whether there are excess emissions, and potential emission reductions from target sources, as well as available measures to cost effectively reduce these available or excess emissions and associated costs to achieve the potential emission reductions.

In addition to the emission reduction scenarios for those primary selected control measures, ENVIRON also estimated emission reduction potentials for a few secondary selected control

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[1] http://www.epa.gov/cleandiesel/ & "Midwest Clean Diesel Initiative," a presentation by Julie Magee of Region V, EPA, 2005.

[2] General program descriptions for a few selected voluntary/incentive programs are provided in Appendix C.

measures, namely the speed limit measure, and LEV, scrappage and I/M programs for light-duty vehicles.

As discussed in Section 3, fuel costs are key assumptions in determining the cost effectiveness of all of the primary selected control measures, except the fleet modernization measures. A sensitivity analysis was conducted to assess the impact of increasing fuel costs by 30% on the emission reduction scenarios. The results of the sensitivity analysis are presented in this section. Finally, state-by-state summary results for the emission reduction scenarios are also presented.

Emission Reduction Scenario for On-road Heavy-Duty Diesel Vehicles

Table 4-1 shows an example emission reduction scenario for on-road diesel vehicles in the LADCO states. This emission reduction scenario focuses on Class 8 HDDVs (the largest truck class), as they contribute to more than 40% of NOx and 50% of PM emissions in the 2009 on-road emission inventories in every LADCO state (see Figure 2-1). Based on projected 2009 VMT and average annual VMT, it was estimated that there will be more than 200,000 Class 8 HDDVs operating in the LADCO states in 2009[3]. In addition to measures for heavy HDDVs, this emission reduction scenario also includes the California Diesel Fuel measure applicable to all diesel vehicles, and the Low NOx Calibration/Reflashing measure applicable to MY 1993 to 1998 medium and heavy HDDVs.

For the scenario shown in Table 4-1, ENVIRON assumed penetration rates based on cost effectiveness values of all selected measures, except for California Diesel Fuel and Low NOx Calibration/Reflashing Measures, using the following criteria:

Cost-Effectiveness (CE) Value ($/ton of NOx reduced)	Penetration Rate (%)
CE < 4,000	10
4,000 < CE < 7,000	5
7,000 < CE < 10,000	3
10,000 < CE < 13,000	1
13,000 and over	0

For the California Diesel Fuel measure, ENVIRON assumed that it would be a mandatory measure with a 50% compliance rate to provide a conservative emission reduction estimate, accounting for non-compliance and/or out-of-state vehicles, as well as vehicles that would participate in other diesel reformulation or alternative fuel programs.

For the Low NOx Calibration/Reflashing program, ENVIRON assumed that it would be a mandatory measure implemented in 2007, with cumulative compliance rates of 60% and 80% in 2009 for applicable model year (1993 to 1998) medium HDDVs and heavy HDDVs, respectively. These compliance rates account for HDDVs that have been reflashed or do not have calibration that produces excess off-cycle emissions.

As shown in Table 4-1, this scenario for heavy HDDVs could achieve more than 100 tons per day (tpd) of NOx emissions reduction for selected incentive/voluntary measures (i.e. all

[3] Estimated 2009 vehicle population data for the LADCO states, and individual states are provided in Appendix D.

measures, except the California Diesel Fuel and Low NOx Calibration/Reflashing) for a cost of about $1.2 billion with an average cost-effectiveness value of $5,200 per ton of NOx reduced. The total number of vehicles involved under this scenario for voluntary/incentive programs is about 40,000, which is about 20% of the total available fleet in 2009. Assuming that a LADCO emission reduction program would begin in 2007, the 20% vehicle penetration rate would translate to about 7% turnover rate per year in a three-year time frame, which is a viable penetration rate to achieve.

Assuming that the LADCO states adopted the California Diesel Fuel measure as a mandatory program, the measure would provide more than 35 tpd of NOx emission reduction with a conservative 50% compliance rate for a cost of about $165 million. The average cost-effectiveness value for the California Diesel Fuel measure was estimated to be about $13,000 per ton of NOx reduced. Thus, it would not be as cost-effective to implement it as a voluntary-type program. If the Low NOx Calibration/Reflashing measure were adopted as a mandatory program, the measure would reduce about 60 tpd of NOx emissions for a cost of about $48 million in 2009 from the applicable HDDVs, with assumed compliance rates of 60% and 80% for medium HDDVs, and heavy HDDVs, respectively. The cost-effectiveness value for the Low NOx Calibration/Reflashing measure was estimated to be about $2,000 per ton of NOx reduced.

The potential total NOx emission reduction from the emission reduction scenario for on-road diesel vehicles for all measures shown in Table 4-1, focusing on HDDVs, would be about 200 tpd in 2009 for a total cost of about $1.4 billion. This scenario is conservative in that a 7% vehicle penetration rate is assumed based on an average cost-effectiveness value of $5,000, which is much less than the $13,000 cost-effectiveness limit for the TERP.

Table 4-1. An example emission reduction scenario to reduce NOx emissions from on-road diesel vehicles in the LADCO states in 2009.

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Measure 16a: Reformulated Diesel Fuels (Incentive/Voluntary Program)							
Emulsified Diesel Fuel (3 yrs of fuel cost)							
MY 1989 and Earlier	$9,039	0.33	$8,434	88,148	2,644	$22,303,773	2.39
MY 1990	$15,843	0.18	$8,137	8,308	-	$0	0.00
MY 1991 - 1997	$19,661	0.15	$8,137	49,786	-	$0	0.00
MY 1998 - 2001	$25,037	0.11	$8,137	22,943	-	$0	0.00
MY 2002 - 2006	$41,728	0.07	$8,137	24,145	-	$0	0.00
Sub Total					**2,644**	**22,303,773**	**2.39**
Measure 47: NG/Dual Fuel Retrofits (Incentive/Voluntary Program)							
LNG/Dual Fuel Retrofit: HDDVs (2.0 g NOx)							
MY 1989 and Earlier	$9,870	1.49	$42,575	88,148	2,644	$112,586,878	10.79
MY 1990	$21,869	0.67	$42,575	8,308	-	$0	0.00
MY 1991 - 1997	$30,155	0.49	$42,575	49,786	-	$0	0.00
MY 1998 - 2001	$46,080	0.32	$42,575	22,943	-	$0	0.00
MY 2002 - 2006	$230,402	0.06	$42,575	24,145	-	$0	0.00
Sub Total					**2,644**	**112,586,878**	**10.79**
Measure 29a: Fleet Modernization via HDD AFVs							
LNG/Dual Fuel Retrofit: Refuse Trucks (2.0 g NOx)							
MY 1989 and Earlier	$4,844	1.79	$44,257	1,763	88	$3,901,182	0.43

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
MY 1990	$10,733	0.81	$44,257	166	2	$73,536	0.00
MY 1991 - 1997	$14,799	0.59	$44,257	996	-	$0	0.00
MY 1998 - 2001	$22,614	0.38	$44,257	459	-	$0	0.00
MY 2002 - 2006	$113,072	0.08	$44,257	483	-	$0	0.00
Sub Total					**90**	**3,974,717**	**0.44**
LNG/Dual Fuel Retrofit: Transit Buses (2.0 g NOx)							
MY 1989 and Earlier	$6,554	2.24	$42,575	233	12	$495,624	0.07
MY 1990	$14,255	1.03	$42,575	54	-	$0	0.00
MY 1991 - 1997	$19,007	0.77	$42,575	1,444	-	$0	0.00
MY 1998 - 2001	$28,511	0.52	$42,575	1,195	-	$0	0.00
MY 2002 - 2006	$142,555	0.10	$42,575	1,870	-	$0	0.00
Sub Total					**12**	**495,624**	**0.07**
Measure 31: Fleet Modernization (Incentive/Voluntary Program)							
Diesel Engine/Vehicle Upgrades (MY 1990 Engine 6 g NOx)							
MY 1989 and Earlier	$6,053	0.82	$35,000	88,148	4,407	$154,258,593	9.95
Sub Total					**4,407**	**154,258,593**	**9.95**
Diesel Engine/Vehicle Upgrades (MY 2001/2 Engine 4 g NOx)							
MY 1989 and Earlier	$4,772	1.19	$40,000	88,148	4,407	$176,295,535	14.42
MY 1990	$15,385	0.37	$40,000	8,308	-	$0	0.00
MY 1991 - 1997	$32,652	0.17	$40,000	49,786	-	$0	0.00
Sub Total					**4,407**	**176,295,535**	**14.42**
Diesel Engine/Vehicle Upgrades (MY 2002/4 Engine 2.4 g NOx)							
MY 1989 and Earlier	$4,423	1.45	$45,000	88,148	4,407	$198,332,477	17.50
MY 1990	$10,246	0.63	$45,000	8,308	83	$3,738,478	0.14
MY 1991 - 1997	$14,915	0.38	$45,000	49,786	-	$0	0.00
MY 1998 - 2001	$24,724	0.26	$45,000	22,943	-	$0	0.00
Sub Total					**4,490**	**202,070,955**	**17.64**
Measure 46: Aftertreatment Device Retrofits (Incentive/Voluntary Program)							
Lean NOx Catalyst							
MY 1989 and Earlier	$5,905	0.55	$20,000	88,148	4,407	$88,147,768	6.64
MY 1990	$10,682	0.30	$20,000	8,308	83	$1,661,546	0.07
MY 1991 – 1997	$13,256	0.24	$20,000	49,786	-	$0	0.00
MY 1998 – 2001	$16,881	0.19	$20,000	22,943	-	$0	0.00
MY 2002 – 2006	$28,134	0.11	$20,000	24,145	-	$0	0.00
Sub Total					**4,490**	**89,809,313**	**6.71**
EGR+DPF Retrofit							
MY 1989 and Earlier	$5,970	0.55	$23,000	88,148	4,407	$101,369,933	6.64
MY 1990	$10,846	0.30	$23,000	8,308	83	$1,910,778	0.07
MY 1991 – 1997	$13,459	0.24	$23,000	49,786	-	$0	0.00
MY 1998 – 2001	$17,139	0.19	$23,000	22,943	-	$0	0.00
MY 2002 – 2006	$28,566	0.11	$23,000	24,145	-	$0	0.00
Sub Total					**4,490**	**103,280,710**	**6.71**
SCR Retrofit							

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
MY 1989 and Earlier	$3,139	1.37	$27,500	88,148	8,815	$242,406,361	33.19
MY 1990	$5,685	0.76	$27,500	8,308	415	$11,423,127	0.86
MY 1991 – 1997	$7,055	0.61	$27,500	49,786	1,494	$41,073,438	2.49
MY 1998 – 2001	$8,984	0.48	$27,500	22,943	688	$18,927,968	0.90
MY 2002 – 2006	$14,973	0.29	$27,500	24,145	-	$0	0.00
Sub Total					**11,412**	**313,830,895**	**37.45**
Overall Projects							
MY 1989 and Earlier				88,148	36,240	1,100,098,124	102.02
MY 1990				8,308	666	18,807,464	1.14
MY 1991 - 1997				49,786	1,494	41,073,438	2.49
MY 1998 - 2001				22,943	688	18,927,968	0.90
MY 2002 - 2006				24,145	-	-	-
Total				**193,330**	**39,089**	**1,178,906,995**	**106.57**
Measure 42: Accelerate Low NOx Calibration/Reflash Program (Mandatory Phase-in)							
Diesel Engine Reflash (MY 1993-1998 Engines)							
MY 1993-1998 Medium-HDDVs	$2,485	0.16	$398	146,134	87,680	$34,858,835	38.44
MY 1993-1998 Heavy-HDDVs	$1,842	0.22	$398	40,201	32,161	$12,786,148	19.02
Sub Total					**119,841**	**47,644,983**	**57.45**
Measure 16b: California Diesel Fuel (Mandatory Program)							
California Diesel Fuel (All Diesel Vehicles)							
LDDVs	$29,622	0.00072	$21	40,800	20,400	$437,256	0.04
LDDTs	$72,642	0.00046	$33	91,974	45,987	$1,522,696	0.06
Class 2b HDDVs	$165,553	0.00041	$67	1,680,666	840,333	$56,475,121	0.93
Class 3-5 HDDVs	$41,629	0.00186	$77	353,078	176,539	$13,655,581	0.90
Class 6-7 HDDVs	$23,417	0.00524	$123	565,913	282,956	$34,746,503	4.07
Class 8 HDDVs	$3,787	0.09519	$360	203,639	101,819	$36,700,580	26.55
Buses	$14,199	0.02311	$328	125,592	62,796	$20,607,405	3.98
Sub Total					**1,530,831**	**164,145,142**	**36.53**
Grand Total						**1,395,167,461**	**200.5**

Emission Reduction Scenarios for Construction and Agricultural Diesel Equipment

As discussed in Section 2, more than 85% of the NOx emissions are from the NONROAD diesel equipment for all LADCO states. Table 4-2 shows the 2009 NOx emissions by equipment type from NONROAD equipment in the LADCO states. As shown in this table, construction and agricultural diesel equipment each contribute about 40% of NONROAD equipment NOx emissions.

Table 4-3 shows, as highlighted, the 2009 NOx emissions and populations for major diesel construction equipment emission sources by equipment type and horsepower range[4]. Major

[4] Complete 2009 NONROAD population and emission data for LADCO states as a whole and by individual LADCO state are provided in Appendix D.

emission contributors from diesel construction equipment include off-highway trucks, rubber tire loaders, crawler tractors/dozers, excavators, and tractors/loaders/backhoes with different horsepower ranges. The equipment population for these major construction equipment types in the LADCO states was estimated to be more than 80,000 units.

Table 4-4 shows, as highlighted, the 2009 NOx emissions and populations for major emission agricultural equipment sources by equipment type and horsepower range[3]. Major emission contributors from diesel agricultural equipment include mostly agricultural tractors and combines of varied horsepower ranges. The equipment population for these major agricultural equipment types in the LADCO states was estimated to be more than 400,000 units.

Table 4-2. 2009 NOx emissions from NONROAD equipment in the LADCO states.

Equipment Type	2009 LADCO NONROAD NOx Emissions (tpd)				
	CNG	Diesel	Gasoline	LPG	Total
Construction and Mining	0.00	272.85	2.94	0.71	276.50
Agricultural Equipment	0.01	254.33	1.73	0.01	256.09
Industrial Equipment	4.91	59.53	2.22	66.26	132.92
Pleasure Craft	0.00	22.24	30.26	0.00	52.51
Commercial Equipment	1.37	33.67	10.80	5.29	51.12
Lawn and Garden Equipment	0.00	13.52	23.73	0.33	37.58
Recreational Equipment	0.00	0.72	8.46	0.05	9.23
Airport Ground Support Equipment	0.00	3.45	0.03	0.04	3.53
Logging Equipment	0.00	1.98	0.06	0.00	2.05
Railway Maintenance Equipment	0.00	1.35	0.02	0.00	1.37
Underground Mining Equipment	0.00	0.64	0.00	0.00	0.64
Total	6.30	664.29	80.24	72.70	823.53

Table 4-3. Major NOx emission contributors from construction equipment in the LADCO states, 2009.

Code	SCC	Population	NOx Emissions (tpd)	NOx Contribution (%)
R9:750+_Off-highway Trucks	2270002051	1,500	27.7	10.17%
R8:600-749_Rubber Tire Loaders	2270002060	6,046	17.7	6.49%
R9:750+_Crawler Tractor/Dozers	2270002069	1,932	14.4	5.29%
R7:300-599_Excavators	2270002036	8,204	14.3	5.25%
R6:175-299_Excavators	2270002036	11,222	12.3	4.51%
R7:300-599_Rubber Tire Loaders	2270002060	8,241	11.2	4.12%
R8:600-749_Crawler Tractor/Dozers	2270002069	3,122	10.4	3.80%
R7:300-599_Crawler Tractor/Dozers	2270002069	6,166	9.8	3.58%
R5:100-174_Tractors/Loaders/Backhoes	2270002066	20,644	9.5	3.47%
R9:750+_Rubber Tire Loaders	2270002060	1,008	9.5	3.47%
R6:175-299_Tractors/Loaders/Backhoes	2270002066	13,736	8.5	3.10%
Other Construction Equipment (<3%each)		172,019	127.6	46.75%
Total		253,840	272.8	100.00%

Table 4-4. Major NOx emission contributors from agricultural equipment in the LADCO states, 2009.

Code	SCC	Population	NOx Emissions (tpy)	NOx Contribution (%)
R8:600-749_Agricultural Tractors	2270005015	31,270	68.1	26.8%
R7:300-599_Agricultural Tractors	2270005015	60,432	59.5	23.4%
R6:175-299_Agricultural Tractors	2270005015	70,097	40.9	16.1%
R7:300-599_Combines	2270005020	36,051	18.4	7.2%
R5:100-174_Agricultural Tractors	2270005015	42,069	16.2	6.4%
R4:75-99_Agricultural Tractors	2270005015	47,732	13.3	5.2%
R6:175-299_Combines	2270005020	30,233	9.6	3.8%
R2:25-49_Agricultural Tractors	2270005015	72,373	8.4	3.3%
R3:50-74_Agricultural Tractors	2270005015	30,145	5.6	2.2%
Other Agricultural Equipment (<2% each)		46,671	14.4	5.7%
Total		467,073	254.3	100.0%

Given the substantial potential available emissions reduction from available units, emission reduction scenarios for nonroad equipment were focused on these major construction and agricultural equipment types.

Example potential emission reduction scenarios for the construction and agricultural equipment with different selected measures are summarized in Tables 4-5 and 4-6, respectively[5,6]. For these scenarios, ENVIRON assumed different penetration rates by cost-effectiveness values. The penetration rates were based on the following cost-effectiveness criteria:

Cost-Effectiveness (CE) Value ($/ton of NOx reduced)	Penetration Rate (%)
CE < 4,000	30
4,000 < CE < 7,000	20
7,000 < CE < 10,000	10
10,000 < CE < 13,000	5
13,000 and over	0

In addition to selected measures for construction equipment, Table 4-5 also includes potential emission reductions and associated costs for the California Diesel Fuel measure for all diesel equipment with a conservative 50% compliance rate to account for non-compliance equipment and equipment that would participate in other diesel reformulation or alternative fuel programs.

As shown in Table 4-5, the example emission reduction scenario for major NOx emission contributors from construction equipment with all selected measures, except the California Diesel Fuel measure, could reduce NOx emissions by more than 55 tpd in the LADCO states in 2009 for a cost of about $830 million. The average cost-effectiveness value was estimated to be

[5] Note that no units are assigned to the emulsified diesel fuel measure for construction and agricultural equipment, or to the EGR+DPF measure for the agricultural equipment. In these cases the cost-effectiveness values do not meet the assumed criteria; the measures are included in these tables for completeness.
[6] Detailed emission reduction scenario results by technology groups and cost-effectiveness data are provided in Appendix E.

less than $4,000 per ton of NOx reduced. The total equipment count in this scenario is about 16,500 units, which is about 20% of the targeted construction equipment population in 2009. Assuming that a LADCO emission reduction program would begin in 2007, the 20% equipment penetration rate would translate to about 7% turnover rate per year in a three-year time frame, which is a viable penetration rate to achieve. Also shown in Table 4-5, the California Diesel Fuel measure would provide an addition of about 20 tpd of NOx emissions reduction for a cost of about $70 million.

For the agricultural equipment, the example emission reduction scenario shown in Table 4-6 for major agricultural equipment including all selected measures could reduce NOx emissions by more than 50 tpd for a cost of about $1.3 billion. The average cost-effectiveness value was estimated to be about $6,700 per ton of NOx reduced. The total equipment count involved in this scenario is about 37,500 units, which is about 10% of the targeted agricultural equipment population in 2009. Assuming that a LADCO emission reduction program would begin in 2007, the 10% equipment penetration rate would translate to a turnover rate of about 3% per year in a three-year time frame - a very viable penetration rate to achieve. Given the favorable average cost-effectiveness value and turnover rates, a more aggressive cost-effectiveness criteria could be used to increase the penetration rates, and hence, the potential emission reductions, if funding were a secondary issue.

Based on these emission reduction scenarios, a total NOx reduction of more than 130 tpd could be achieved in 2009 by implementing selected control measures in 2007 for nonroad diesel equipment, focusing on construction and agricultural equipment.

Table 4-5. An example emission reduction scenario for some major construction equipment in LADCO states in 2009.

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)			
Excavators	0	0	0.00
Rubber Tire Loaders	0	0	0.00
Crawler Tractor/Dozer	0	0	0.00
Tractors/Loaders/Backhoes	0	0	0.00
Off-Highway Trucks	0	0	0.00
Sub Total	**0**	**0**	**0.00**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)			
Excavators	1,074	40,503,000	2.26
Rubber Tire Loaders	967	67,620,723	3.92
Crawler Tractor/Dozer	813	58,993,621	3.76
Tractors/Loaders/Backhoes	1,481	28,195,250	0.99
Off-Highway Trucks	133	18,082,569	1.49
Sub Total	**4,468**	**213,395,163**	**12.42**
Measure 51a: Lean NOx Catalyst			
Excavators	1,632	44,378,947	2.30
Rubber Tire Loaders	1,190	61,905,928	3.25
Crawler Tractor/Dozer	947	51,423,880	3.19
Tractors/Loaders/Backhoes	140	2,800,000	0.11
Off-Highway Trucks	266	30,454,853	2.91
Sub Total	**4,175**	**190,963,608**	**11.76**
Measure 51b: EGR+DPF Retrofit			

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Excavators	125	3,965,684	0.20
Rubber Tire Loaders	47	3,330,950	0.16
Crawler Tractor/Dozer	185	12,554,261	0.61
Tractors/Loaders/Backhoes	0	0	0.00
Off-Highway Trucks	45	5,924,957	0.45
Sub Total	**402**	**25,775,853**	**1.42**
Measure 51c: SCR Retrofit			
Excavators	3,018	112,742,763	7.67
Rubber Tire Loaders	1,760	124,811,283	7.97
Crawler Tractor/Dozer	1,598	115,875,696	8.72
Tractors/Loaders/Backhoes	808	22,220,000	0.90
Off-Highway Trucks	266	23,392,250	5.46
Sub Total	**7,450**	**399,041,993**	**30.72**
Grand Total (Voluntary Programs)	**16,495**	**829,176,616**	**56.32**
Measure 16b: CA Diesel (All Diesel Equipment)			
Railway Maintenance	1,120	144,510	0.04
Pleasure Craft	34,461	2,383,585	0.69
Recreational	3,266	77,563	0.02
Construction and Mining	126,920	29,236,523	8.46
Industrial	56,331	6,378,901	1.85
Lawn and Garden	36,697	1,448,864	0.42
Agricultural	233,537	27,251,763	7.88
Commercial	103,414	3,607,695	1.04
Logging	589	212,576	0.06
Airport Ground Support	1,617	370,126	0.11
Underground Mining	368	68,374	0.02
Sub Total	**598,319**	**71,180,481**	**20.59**
Grand Total		**900,357,096**	**76.91**

Table 4-6. An example emission reduction scenario for some major agricultural equipment in LADCO states in 2009.

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)			
Agricultural Tractors	0	0	0.0
Combines	0	0	0.0
Sub Total	**0**	**0**	**0.0**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)			
Agricultural Tractors	10,797	354,163,200	12.6
Combines	0	0	0.0
Sub Total	**10,797**	**354,163,200**	**12.6**
Measure 51a: Lean NOx Catalyst			
Agricultural Tractors	8,030	252,610,105	8.6
Combines	0	0	0.0
Sub Total	**8,030**	**252,610,105**	**8.6**
Measure 51b: EGR+DPF Retrofit			
Agricultural Tractors	0	0	0.0
Combines	0	0	0.0

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Sub Total	**0**	**0**	**0.0**
Measure 51c: SCR Retrofit			
Agricultural Tractors	18,673	725,979,342	33.2
Combines	0	0	0.0
Sub Total	**18,673**	**725,979,342**	**33.2**
Grand Total (Voluntary Programs)	**37,500**	**1,332,752,647**	**54.4**

Emission Reduction Potentials for Secondary Selected Control Measures for On-Road Vehicles

As discussed earlier, ENVIRON estimated the potential emission benefits of several secondary control measures for on-road vehicles: speed limit reduction measure for HD diesel vehicles, and LEVII, accelerated vehicle replacement and scrappage, and I/M programs for light-duty vehicles. A detailed assessment of potential emission reductions for these selected secondary measures would require substantial MOBILE 6 modeling that was not possible within the available project resources. We have therefore presented some limited results based on available data in existing studies.

Table 4-7 shows NOx emission reduction estimates for the speed limit control measure for HD diesel vehicles, based on the studies described under this control measure in Section 3. Table 4-8 shows NOx emission reduction estimates for light-duty vehicles in the LADCO states in 2009 for a LEV II program implemented in 2007, based on the NESCAUM study described in Section 3. Table 4-9 shows potential NOx emission reduction estimates on a per 1,000 vehicles basis for the accelerated replacement and scrappage, and I/M programs measures for light-duty vehicles to illustrate the emission reduction potentials of these measures.

Table 4-7. NOx emission reduction estimates for speed limit restriction for HD diesel vehicles in LADCO states in 2009.

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Assumed Units	Total Cost	Total NOx (tons/day)
Measure 67: Speed Limit Restriction - 65mph to 55 mph (HD Diesel Vehicles)							
On-road HD Vehicles	$841	0.00403	$1.69	2,951,576	1,475,788	$5,000,000	16.28
Note: Assumed a 50% compliance rate for 3 years starting in 2007.							

Table 4-8. NOx emission reduction estimates for light-duty vehicles in LADCO states in 2009 for a LEVII Program implemented in 2007.

2009 LADCO States	Baseline NOx Emissions (tpd)	NOx Emission Reduction	
		(%)	(tpd)
LDGV	585	0.00%	0.000
LDGT1	337	0.17%	0.006
LDGT2	142	0.24%	0.003
Total	1,064		0.009

Table 4-9. NOx emission reduction estimates on a per 1,000 vehicles basis for Accelerated Vehicle Replacement and Scrappage, and I/M programs measures for light-duty vehicles in LADCO states in 2009.

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Total Cost for 1,000 vehicles	Total NOx (tons/day) for 1,000 vehicles
Measure 40: Implementing/Expanding I/M Programs for LDVs						
LDVs	$31,000	0.00187	$58	NA	$57,700	0.01
Sub Total					**57,700**	**0.01**
Measure 29/43/45: Accelerated Vehicle Replacement of Fleet LDVs. Example -- Replace 10 Year Old Vehicles.						
Replaced MY 1996/99 LDVs w/ Tier 2 Vehicles	$102,568	0.01190	$10,000	16,951,653	$10,000,000	0.03
Replaced MY 1996/99 LDVs w/ SULEVs	$156,657	0.01247	$16,000	16,951,653	$16,000,000	0.03
Replaced MY 1996/99 LDVs w/ ZEVs	$192,083	0.01271	$20,000	16,951,653	$20,000,000	0.03
Sub Total					**46,000,000**	**0.10**
Measure 44: Vehicle Scrappage Program for 25 Year and Older Vehicles						
LDVs	$55,773	0.00634	$1,000	6,535,052	$1,000,000	0.02
Sub Total					**1,000,000**	**0.02**

Fuel Sensitivity Analysis Results

ENVIRON conducted a sensitivity analysis of increasing the fuel costs of the selected control measures, and applied the same criteria on the penetration rates as a function of the cost effectiveness values for these selected measures to assess the impacts of the fuel costs increases on the potential emission reductions. As suggested in discussion with LADCO, the fuel costs were increased by 30% from $2.15 to $2.76 per gallon for diesel fuel, and $1.68 to $2.18 per diesel-equivalent gallon for natural gas. Table 4-10 shows the results of the emission reduction scenario for the on-road HD diesel vehicles with the 30% increases in fuel costs. Table 4-11 and Table 4-12 present the fuel sensitivity results of the emission reduction scenario for construction and agricultural equipment, respectively.

As shown in Table 4-10, increasing the fuel costs by 30% would reduce the overall NOx emission reduction for the emission reduction scenario for on-road HD diesel vehicles by only about 9 tpd, mostly from reduction in Measure 16a: Emulsified Fuel, and Measure 47 and 49a: NG/Dual Fuel Retrofit or HDD AFV Fleet Modernization. The penetration rate was reduced to about 18% for three years or 6% per year. While the cost-effectiveness values for most of the individual measures increased, the average cost effectiveness value for voluntary/incentive type measures for the on-road HDDV emission reduction scenario decreased slightly from about $5,200 to $5,000 per ton of NOx reduced due to lower penetration rates for measures with higher cost-effectiveness values. While the potential emission reduction remain the same because of similar assumed compliance rates, the average cost-effectiveness value and program cost for the Low NOx Calibration/Reflashing measure increased from $2,000 to $3,000 per ton of NOx reduced, and $48 million to $62 million, respectively. The cost-effectiveness value and potential NOx emission reduction for the California Diesel Fuel measure remain the same, as these values were estimated based on fuel price differences. While there were some cost increases in some individual measures, the overall all cost for the on-road scenario was reduced from $1.40 billion to $1.32 billion due to lower penetration rates for measures with higher cost-effectiveness values.

As shown in Tables 4-11 and 4-12, increasing the fuel costs by 30% would reduce the overall NOx emission reduction for the emission reduction scenario for major diesel construction and agricultural equipment by only about 3 tpd each, mostly from reduction in Measure 51b: Lean NOx Retrofit. The overall penetration rates were reduced slightly by less than 1% each. Compared to the baseline fuel cost scenario, the average cost-effectiveness value for the diesel construction equipment was about the same at $4,000 per ton of NOx reduced, and the program cost was reduced by about $45 million because of lower penetration rates. As for the agricultural equipment, the average cost effectiveness value was reduced from about $6,700 to $6,500 ton per NOx reduced, and the program cost was reduced by about $95 million because of lower penetration rates. Table 4-13 summarizes the emission reductions in the fuel cost sensitivity analysis for the three scenarios.

In summary, the fuel sensitivity results show that there were no major impacts on potential emission reductions if the assumed fuel costs were to increase by 30%.

Table 4-10. Emission reduction scenario for on-road diesel vehicles in the LADCO states in 2009, with 30% increases in fuel costs.

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Measure 16a: Reformulated Diesel Fuels (Incentive/Voluntary Program)							
Emulsified Diesel Fuel (3 yrs of fuel cost)							
MY 1989 and Earlier	$11,751	0.33	$10,965	88,148	881	$9,664,968	0.80
MY 1990	$20,596	0.18	$10,579	8,308	-	$0	0.00
MY 1991 – 1997	$25,559	0.15	$10,579	49,786	-	$0	0.00
MY 1998 – 2001	$32,548	0.11	$10,579	22,943	-	$0	0.00
MY 2002 – 2006	$54,247	0.07	$10,579	24,145	-	$0	0.00
Sub Total					**881**	**9,664,968**	**0.80**
Measure 47: NG/Dual Fuel Retrofits (Incentive/Voluntary Program)							
LNG/Dual Fuel Retrofit: HDDVs (2.0 g NOx)							
MY 1989 and Earlier	$11,899	1.49	$45,598	88,148	881	$40,193,240	3.60
MY 1990	$26,364	0.67	$45,598	8,308	-	$0	0.00
MY 1991 – 1997	$36,353	0.49	$45,598	49,786	-	$0	0.00
MY 1998 – 2001	$55,552	0.32	$45,598	22,943	-	$0	0.00
MY 2002 – 2006	$277,760	0.06	$45,598	24,145	-	$0	0.00
Sub Total					**881**	**40,193,240**	**3.60**
Measure 29a: Fleet Modernization via HDD AFVs							
LNG/Dual Fuel Retrofit: Refuse Trucks (2.0 g NOx)							
MY 1989 and Earlier	$5,520	1.79	$47,784	1,763	88	$4,212,095	0.43
MY 1990	$12,231	0.81	$47,784	166	2	$79,396	0.00
MY 1991 – 1997	$16,865	0.59	$47,784	996	-	$0	0.00
MY 1998 – 2001	$25,772	0.38	$47,784	459	-	$0	0.00
MY 2002 – 2006	$128,858	0.08	$47,784	483	-	$0	0.00
Sub Total					**90**	**4,291,492**	**0.44**
LNG/Dual Fuel Retrofit: Transit Buses (2.0 g NOx)							
MY 1989 and Earlier	$7,901	2.24	$45,598	233	7	$318,486	0.04
MY 1990	$17,186	1.03	$45,598	54	-	$0	0.00
MY 1991 – 1997	$22,914	0.77	$45,598	1,444	-	$0	0.00
MY 1998 – 2001	$34,371	0.52	$45,598	1,195	-	$0	0.00
MY 2002 – 2006	$171,856	0.10	$45,598	1,870	-	$0	0.00

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Sub Total					**7**	**318,486**	**0.04**
Measure 31: Fleet Modernization (Incentive/Voluntary Program)							
Diesel Engine/Vehicle Upgrades (MY 1990 Engine 6 g NOx)							
MY 1989 and Earlier	$6,053	0.82	$35,000	88,148	4,407	$154,258,593	9.95
Sub Total					**4,407**	**154,258,593**	**9.95**
Diesel Engine/Vehicle Upgrades (MY 2001/2 Engine 4 g NOx)							
MY 1989 and Earlier	$4,772	1.19	$40,000	88,148	4,407	$176,295,535	14.42
MY 1990	$15,385	0.37	$40,000	8,308	-	$0	0.00
MY 1991 – 1997	$32,652	0.17	$40,000	49,786	-	$0	0.00
Sub Total					**4,407**	**176,295,535**	**14.42**
Diesel Engine/Vehicle Upgrades (MY 2002/4 Engine 2.4 g NOx)							
MY 1989 and Earlier	$4,423	1.45	$45,000	88,148	4,407	$198,332,477	17.50
MY 1990	$10,246	0.63	$45,000	8,308	83	$3,738,478	0.14
MY 1991 – 1997	$14,915	0.38	$45,000	49,786	-	$0	0.00
MY 1998 – 2001	$24,724	0.26	$45,000	22,943	-	$0	0.00
Sub Total					**4,490**	**202,070,955**	**17.64**
Measure 46: Aftertreatment Device Retrofits (Incentive/Voluntary Program)							
Lean NOx Catalyst							
MY 1989 and Earlier	$6,122	0.55	$20,000	88,148	4,407	$88,147,768	6.64
MY 1990	$11,062	0.30	$20,000	8,308	83	$1,661,546	0.07
MY 1991 – 1997	$13,728	0.24	$20,000	49,786	-	$0	0.00
MY 1998 – 2001	$17,481	0.19	$20,000	22,943	-	$0	0.00
MY 2002 – 2006	$29,136	0.11	$20,000	24,145	-	$0	0.00
Sub Total					**4,490**	**89,809,313**	**6.71**
EGR+DPF Retrofit							
MY 1989 and Earlier	$5,974	0.55	$23,000	88,148	4,407	$101,369,933	6.64
MY 1990	$10,851	0.30	$23,000	8,308	83	$1,910,778	0.07
MY 1991 – 1997	$13,466	0.24	$23,000	49,786	-	$0	0.00
MY 1998 – 2001	$17,148	0.19	$23,000	22,943	-	$0	0.00
MY 2002 – 2006	$28,581	0.11	$23,000	24,145	-	$0	0.00
Sub Total					**4,490**	**103,280,710**	**6.71**
SCR Retrofit							
MY 1989 and Earlier	$3,226	1.37	$27,500	88,148	8,815	$242,406,361	33.19
MY 1990	$5,837	0.76	$27,500	8,308	415	$11,423,127	0.86
MY 1991 – 1997	$7,244	0.61	$27,500	49,786	1,494	$41,073,438	2.49
MY 1998 – 2001	$9,224	0.48	$27,500	22,943	688	$18,927,968	0.90
MY 2002 – 2006	$15,374	0.29	$27,500	24,145	-	$0	0.00
Sub Total					**11,412**	**313,830,895**	**37.45**
Overall Projects							
MY 1989 and Earlier				88,148	32,710	1,015,199,456	93.21
MY 1990				8,308	666	18,813,325	1.14
MY 1991 - 1997				49,786	1,494	41,073,438	2.49
MY 1998 - 2001				22,943	688	18,927,968	0.90
MY 2002 - 2006				24,145	-	-	-
Total				**193,330**	**35,558**	**1,094,014,188**	**97.75**
Measure 42: Accelerate Low NOx Calibration/Reflash Program (Mandatory Phase-in)							
Diesel Engine Reflash (MY 1993-1998 Engines)							

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
MY 1993-1998 Medium-HDDVs	$3,230	0.16	$517	146,134	87,680	$45,316,485	38.44
MY 1993-1998 Heavy-HDDVs	$2,395	0.22	$517	40,201	32,161	$16,621,993	19.02
Sub Total					**119,841**	**61,938,478**	**57.45**
Measure 16b: California Diesel Fuel (Mandatory Program)							
California Diesel Fuel (All Diesel Vehicles)							
LDDVs	$29,622	0.00072	$21	40,800	20,400	$437,256	0.04
LDDTs	$72,642	0.00046	$33	91,974	45,987	$1,522,696	0.06
Class 2b HDDVs	$165,553	0.00041	$67	1,680,666	840,333	$56,475,121	0.93
Class 3-5 HDDVs	$41,629	0.00186	$77	353,078	176,539	$13,655,581	0.90
Class 6-7 HDDVs	$23,417	0.00524	$123	565,913	282,956	$34,746,503	4.07
Class 8 HDDVs	$3,787	0.09519	$360	203,639	101,819	$36,700,580	26.55
Buses	$14,199	0.02311	$328	125,592	62,796	$20,607,405	3.98
Sub Total					**1,530,831**	**164,145,142**	**36.53**
Grand Total						**1,324,707,785**	**191.7**

Table 4-11. Emission reduction scenario for major construction equipment in the LADCO states in 2009, with 30% increase in fuel costs.

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)			
Excavators	0	0	0.00
Rubber Tire Loaders	0	0	0.00
Crawler Tractor/Dozer	0	0	0.00
Tractors/Loaders/Backhoes	0	0	0.00
Off-Highway Trucks	0	0	0.00
Sub Total	**0**	**0**	**0.00**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)			
Excavators	1,074	40,503,000	2.26
Rubber Tire Loaders	967	67,620,723	3.92
Crawler Tractor/Dozer	813	58,993,621	3.76
Tractors/Loaders/Backhoes	1,481	28,195,250	0.99
Off-Highway Trucks	133	18,082,569	1.49
Sub Total	**4,468**	**213,395,163**	**12.42**
Measure 51a: Lean NOx Catalyst			
Excavators	1,074	28,423,158	1.80
Rubber Tire Loaders	760	39,990,618	2.08
Crawler Tractor/Dozer	947	51,423,880	3.19
Tractors/Loaders/Backhoes	140	2,800,000	0.11
Off-Highway Trucks	222	25,417,208	2.33
Sub Total	**3,143**	**148,054,864**	**9.51**
Measure 51b: EGR+DPF Retrofit			
Excavators	125	3,965,684	0.20
Rubber Tire Loaders	27	2,067,161	0.10
Crawler Tractor/Dozer	185	12,554,261	0.61
Tractors/Loaders/Backhoes	0	0	0.00

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Off-Highway Trucks	44	5,793,292	0.43
Sub Total	**381**	**24,380,397**	**1.34**
Measure 51c: SCR Retrofit			
Excavators	3,018	112,742,763	7.67
Rubber Tire Loaders	1,745	122,752,956	7.77
Crawler Tractor/Dozer	1,598	115,875,696	8.72
Tractors/Loaders/Backhoes	808	22,220,000	0.90
Off-Highway Trucks	266	23,392,250	5.46
Sub Total	**7,435**	**396,983,665**	**30.53**
Grand Total (Voluntary Programs)	**15,427**	**782,814,089**	**53.79**
Measure 16b: CA Diesel (All Diesel Equipment)			
Railway Maintenance	1,120	144,510	0.04
Pleasure Craft	34,461	2,383,585	0.69
Recreational	3,266	77,563	0.02
Construction and Mining	126,920	29,236,523	8.46
Industrial	56,331	6,378,901	1.85
Lawn and Garden	36,697	1,448,864	0.42
Agricultural	233,537	27,251,763	7.88
Commercial	103,414	3,607,695	1.04
Logging	589	212,576	0.06
Airport Ground Support	1,617	370,126	0.11
Underground Mining	368	68,374	0.02
Sub Total	**598,319**	**71,180,481**	**20.59**
Grand Total		**853,994,570**	**74.39**

Table 4-12. Emission reduction scenario for major agricultural equipment in the LADCO states in 2009, with 30% increase in fuel costs.

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)			
Agricultural Tractors	0	0	0.0
Combines	0	0	0.0
Sub Total	**0**	**0**	**0.0**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)			
Agricultural Tractors	10,797	354,163,200	12.6
Combines	0	0	0.0
Sub Total	**10,797**	**354,163,200**	**12.6**
Measure 51a: Lean NOx Catalyst			
Agricultural Tractors	5,063	157,049,053	5.9
Combines	0	0	0.0
Sub Total	**5,063**	**157,049,053**	**5.9**
Measure 51b: EGR+DPF Retrofit			
Agricultural Tractors	0	0	0.0
Combines	0	0	0.0
Sub Total	**0**	**0**	**0.0**
Measure 51c: SCR Retrofit			
Agricultural Tractors	18,673	725,979,342	33.2

Equipment Type	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
Combines	0	0	0.0
Sub Total	**18,673**	**725,979,342**	**33.2**
Grand Total (Voluntary Programs)	**34,533**	**1,237,191,595**	**51.8**

Table 4-13. Fuel sensitivity analysis for the three scenarios – changes in NOx emission reductions.

Scenarios	Potential NOx Emission Reductions (tpd)		
	Baseline Diesel Fuel Cost ($2.15/gallon)	30% Increase in Diesel Fuel Cost ($2.76/gallon)	Differences
On-road HDDVs	200.5	191.7	8.8
Construction Diesel Equipment	76.9	74.4	2.5
Agricultural Diesel Equipment	54.4	51.8	2.6
Total	331.8	317.9	13.9

State-by-State Emission Reduction Summary Results

In addition to estimating the potential emission reductions for the selected measures for the LADCO region, ENVIRON was also asked to provide potential emission reductions for each of the five LADCO states individually. For the state-by-state analysis, the evaluation began with an analysis of the major NOx contributors to the on-road HDDV, and NONROAD construction and agricultural equipment.

The fraction of on-road NOx emissions from HDDV is similar across all LADCO states. Major NOx contributors by equipment type and horsepower range are the same for agricultural equipment for all five states. However, as shown in Table 4-14, there are some differences in the major NOx contributors for construction equipment. The shaded lines in the table are the equipment types that were used in the LADCO region-wide emission reduction scenario.

Table 4-14. NONROAD diesel construction equipment major NOx emission contributors for the LADCO region, and for each state individually.

Equipment Category/Type	Major NOx Contributors for Construction Equipment					
	LADCO	IL	IN	MI	OH	WI
R4:75-99_Skid Steer Loaders				3.2%		
R5:100-174_Tractors/Loaders/Backhoes	3.5%	3.4%		5.2%		
R6:175-299_Excavators	4.5%	4.9%	4.5%	3.6%	4.6%	4.7%
R6:175-299_Tractors/Loaders/Backhoes				4.7%		
R7:300-599_Crawler Tractor/Dozers	3.6%	3.5%	3.9%		3.8%	3.9%
R7:300-599_Excavators	5.3%	5.7%	5.3%	4.2%	5.4%	5.5%
R7:300-599_Rubber Tire Loaders	4.1%	4.6%	4.0%	3.6%	4.0%	3.9%
R8:600-749_Crawler Tractor/Dozers	3.8%	3.7%	4.1%	3.2%	4.0%	4.1%
R8:600-749_Rubber Tire Loaders	6.5%	7.3%	6.4%	5.7%	6.3%	6.2%
R8:600-749_Scrapers			3.5%		3.2%	3.5%
R9:750+_Crawler Tractor/Dozers	5.3%	5.2%	5.8%	4.4%	5.6%	5.8%
R9:750+_Off-highway Trucks	10.2%	8.5%	11.2%	9.9%	11.4%	10.6%
R9:750+_Rubber Tire Loaders	3.5%	3.9%	3.4%		3.4%	3.3%
Grand Total	50.2%	50.8%	52.0%	47.8%	51.5%	51.6%

Table 4-15 summarizes the potential emission reductions for on-road HDDVs, diesel construction and agricultural equipment, based on similar cost-effectiveness and penetration rate criteria as those for the whole LADCO region. Because of the differences among states in the construction equipment major NOx contributors, shown in Table 4-14, the emission reduction scenarios, and hence the sum of emission reductions, for these states are different from the region-wide analysis shown in Table 4-5.

Table 4-15. State-by-state potential NOx emission reductions for the three emission reduction scenarios[7].

	NOx Emission Reductions (tpd)		
	On-Road HDDV	Construction Equipment	Agricultural Equipment
Illinois	50.0	23.10	20.2
Indiana	34.3	12.48	10.9
Michigan	39.2	12.48	6.1
Ohio	50.5	20.70	9.0
Wisconsin	26.6	9.41	8.2
Total	**200.6**	**78.2**	**54.4**

Particulate Emission Reduction Summary Results

As discussed in the measure descriptions, some of the selected emission control measures would reduce PM emissions, in addition to reducing NOx emissions. For each emission reduction scenario, ENVIRON estimated the potential PM emission reductions by estimating the per-vehicle or equipment PM emission reduction, and the number of vehicles or equipment recommended for each measure. In order to estimate the per-vehicle or equipment PM emission reduction, ENVIRON updated each of the selected control measures with either a PM control factor for fuel and retrofit control measures or PM emission rates for natural gas and fleet modernization measures. The control factors for the selected control measures are shown in Table 4-16. The PM emission rates for on-road HDDVs and nonroad engines are shown in Table 4-17 and Table 4-18, respectively.

Based on these control factors and emission rates, and the number of vehicles recommended, the potential PM emission reduction for the on-road HDDV emission reduction scenario is estimated to be about 4.5 tpd (see Table 4-19). Table 4-20 and Table 4-21 show that the potential PM emission reductions for the construction and agricultural equipment emission reduction scenarios to be about 0.40 and 0.61 tpd, respectively. The state-by-state PM emission reductions for different scenarios are provided in Table 4-22. Again, because of the differences among states in the construction equipment major NOx contributors, the sum of the state by state PM emission reduction is different from the region-wide analysis.

It is very important to note that these PM emissions reductions are those that are associated with the control measures evaluated, and this study has focused exclusively on control measures for

[7] Detailed emission reduction scenario results by technology groups and cost-effectiveness data are available in electronic format.

reducing NOx emissions. There are other control measures for which the cost-effectiveness for PM emissions reduction will be lower; but this study did not focus on those measures.

Table 4-16. PM control factors for selected control measures.

Measure Descriptions	PM Control Factors
On-road HDDV Emission Reduction Measures	
Measure 16a: Emulsified Diesel Fuels	63%
Measure 16a: California Diesel Fuels	0%
Measure 47: NG/Dual Fuel Retrofits	Varying based on PM emission rates
Measure 29a: Fleet Modernization via HDD AFVs	Varying based on PM emission rates
Measure 31: Fleet Modernization	Varying based on PM emission rates
Measure 46a: Lean NOx Catalyst Retrofit	0%
Measure 46b: ERG+DPF Retrofit	90%
Measure 46c: SCR Retrofit	0%
Measure 42: Accelerate Low NOx Calibration Program	0%
Diesel Construction and Agricultural Equipment	
Measure 16a: Emulsified Diesel Fuels	63%
Measure 16b: California Diesel Fuels	0%
Measure 20: Fleet Modernization	Varying based on PM emission rates
Measure 51a: Lean NOx Catalyst Retrofit	0%
Measure 51b: ERG+DPF Retrofit	90%
Measure 51c: SCR Retrofit	0%

Table 4-17. Estimated PM basic emission rates for on-road heavy-duty vehicles based on emission standards.

Model Year	Estimated PM Basic Emission Rates (g/bhp-hr)[1]	
	Diesel	NG/Dual Fuel
MY 1989 and Earlier	0.60	0.01
MY 1990	0.60	0.01
MY 1991 - 1997	0.18	0.01
MY 1998 - 2001	0.10	0.01
MY 2002 - 2006	0.10	0.01
MY 2007	0.01	0.01

[1] Basic emission rates for diesel were estimated based on emission standards for heavy-duty diesel engines. Basic emission rates for NG/Dual Fuel were estimated based on general emission data of a natural gas engine with an oxidation catalyst.

Table 4-18. Estimated PM basic emission rates for nonroad diesel engines based on emission standards.

HP Range	Estimated PM Emission Rates (g/bhp-hr)[1]			
	Tier 0	Tier 1	Tier 2	Tier 3
25-50 HP	0.55	0.48	0.28	0.02
50-100 HP	0.55	0.55	0.19	0.19
50-75 HP	0.55	0.55	0.19	0.19
75-100 HP	0.55	0.55	0.19	0.19
100-175 HP	0.42	0.30	0.13	0.11
175-300 HP	0.42	0.12	0.09	0.09
300-600 HP	0.41	0.12	0.09	0.09
600-750 HP	0.41	0.12	0.09	0.09

HP Range	Estimated PM Emission Rates (g/bhp-hr)[1]			
	Tier 0	Tier 1	Tier 2	Tier 3
750+ HP	0.41	0.12	0.09	NA

[1] Basic emission rates were based on PM emission standards for nonroad diesel engines, and were extracted from the Carl Moyer Program Guidelines, January 2006 (http://www.arb.ca.gov/msprog/moyer/guidelines/revisions05.htm).

Table 4-19. Estimated PM emission reduction for the on-road HDDV emission reduction scenario.

Technology	Estimated PM Reductions per Vehicle (tons/year)	Units Recommended	Total PM (tons/day)
Measure 16a: Reformulated Diesel Fuels (Incentive/Voluntary Program)			
Emulsified Diesel Fuel (3 yrs of fuel cost)			
MY 1989 and Earlier	0.06	2,644	0.469
MY 1990	0.06	-	0.000
MY 1991 - 1997	0.02	-	0.000
MY 1998 - 2001	0.01	-	0.000
MY 2002 - 2006	0.01	-	0.000
Sub Total		**2,644**	**0.469**
Measure 47: NG/Dual Fuel Retrofits (Incentive/Voluntary Program)			
LNG/Dual Fuel Retrofit: HDDVs (2.0 g NOx)			
MY 1989 and Earlier	0.10	2,644	0.732
MY 1990	0.10	-	0.000
MY 1991 - 1997	0.03	-	0.000
MY 1998 - 2001	0.01	-	0.000
MY 2002 - 2006	0.01	-	0.000
Sub Total		**2,644**	**0.732**
Measure 29a: Fleet Modernization via HDD AFVs			
LNG/Dual Fuel Retrofit: Refuse Trucks (2.0 g NOx)			
MY 1989 and Earlier	0.12	88	0.029
MY 1990	0.12	2	0.001
MY 1991 - 1997	0.03	-	0.000
MY 1998 - 2001	0.02	-	0.000
MY 2002 - 2006	0.02	-	0.000
Sub Total		**90**	**0.030**
LNG/Dual Fuel Retrofit: Transit Buses (2.0 g NOx)			
MY 1989 and Earlier	0.15	12	0.005
MY 1990	0.15	-	0.000
MY 1991 - 1997	0.04	-	0.000
MY 1998 - 2001	0.02	-	0.000
MY 2002 - 2006	0.02	-	0.000
Sub Total		**12**	**0.005**
Measure 31: Fleet Modernization (Incentive/Voluntary Program)			
Diesel Engine/Vehicle Upgrades (MY 1990 Engine 6 g NOx)			
MY 1989 and Earlier	0.00	4,407	0.023
Sub Total		**4,407**	**0.023**
Diesel Engine/Vehicle Upgrades (MY 2001/2 Engine 4 g NOx)			

Technology	Estimated PM Reductions per Vehicle (tons/year)	Units Recommended	Total PM (tons/day)
MY 1989 and Earlier	0.09	4,407	1.048
MY 1990	0.08	-	0.000
MY 1991 - 1997	0.01	-	0.000
Sub Total		**4,407**	**1.048**
Diesel Engine/Vehicle Upgrades (MY 2002/4 Engine 2.4 g NOx)			
MY 1989 and Earlier	0.09	4,407	1.048
MY 1990	0.08	83	0.019
MY 1991 - 1997	0.02	-	0.000
MY 1998 - 2001	0.26	-	0.000
Sub Total		**4,490**	**1.067**
Measure 46: Aftertreatment Device Retrofits (Incentive/Voluntary Program)			
Lean NOx Catalyst	**0.00**	**4,490**	**0.000**
EGR+DPF Retrofit			
MY 1989 and Earlier	0.09	4,407	1.117
MY 1990	0.09	83	0.021
MY 1991 - 1997	0.03	-	0.000
MY 1998 - 2001	0.01	-	0.000
MY 2002 - 2006	0.01	-	0.000
Sub Total		**4,490**	**1.137**
SCR Retrofit	0.00	**11,412**	**0.000**
Overall Projects			
MY 1989 and Earlier		36,240	4.471
MY 1990		666	0.041
MY 1991 - 1997		1,494	0.000
MY 1998 - 2001		688	0.000
MY 2002 - 2006		-	0.000
Total		**39,089**	**4.511**
Measure 42: Accelerate Low NOx Calibration/Reflash Program (Mandatory Phase-in)			
Diesel Engine Reflash (MY 1993-1998 Engines)	0.00	**119,841**	**0.000**
Measure 16b: California Diesel Fuel (Mandatory Program)			
California Diesel Fuel (All Diesel Vehicles)	0.00	**1,530,831**	**0.000**
Grand Total			**4.511**

Table 4-20. Estimated PM emission reduction for the diesel construction equipment emission reduction scenario.

Equipment Type	Total Unit Recom.	Total PM (tpd)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)		**0.000**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)		
Excavators	1,074	0.012
Rubber Tire Loaders	967	0.085
Crawler Tractor/Dozer	813	0.124
Tractors/Loaders/Backhoes	1,481	0.049
Off-Highway Trucks	133	0.022
Sub Total	**4,468**	**0.292**
Measure 51a: Lean NOx Catalyst		**0.000**
Measure 51b: EGR+DPF Retrofit		
Excavators	125	0.010
Rubber Tire Loaders	47	0.021
Crawler Tractor/Dozer	185	0.056
Tractors/Loaders/Backhoes	0	0.000
Off-Highway Trucks	45	0.024
Sub Total	**402**	**0.112**
Measure 51c: SCR Retrofit		**0.000**
Grand Total (Voluntary Programs)	**16,495**	**0.403**
Measure 16b: CA Diesel (All Diesel Equipment)		**0.000**
Grand Total		**0.403**

Table 4-21. Estimated PM emission reduction for the diesel agricultural equipment emission reduction scenario.

Equipment Type	Total Unit Recom.	Total PM (tpd)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)	**0**	**0.000**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)		
Agricultural Tractors	10,797	0.608
Combines	0	0.000
Sub Total	**10,797**	**0.608**
Measure 51a: Lean NOx Catalyst	**8,030**	**0.000**
Measure 51b: EGR+DPF Retrofit	**0**	**0.000**
Measure 51c: SCR Retrofit	**18,673**	**0.000**
Grand Total (Voluntary Programs)	**37,500**	**0.608**

Table 4-22. State-by-state potential PM emission reductions for the three emission reduction scenarios.[8]

	PM Emission Reductions (tpd)		
	On-Road HDDV	Construction Equipment	Agricultural Equipment
Illinois	1.163	0.121	0.226
Indiana	0.800	0.062	0.122
Michigan	0.751	0.069	0.068
Ohio	1.190	0.114	0.101
Wisconsin	0.608	0.048	0.091
Total	**4.511**	**0.414**	**0.608**

[8] Detailed emission reduction scenario results by technology groups and cost-effectiveness data are available in electronic format.

Appendix A

Control Measure Reference Studies Reviewed

Reference	Reference ID
AACOG. 2003. “1st Biannual Report: The Early Action Compact for the San Antonio Metropolitan Statistical Area,” Report to Texas Commission of Environmental Quality, Alamo Area Council of Governments, San Antonio, TX, June 2003.	AACOG. 2003.
CARB. 2003. “Proposal to Reduce Idling from New 2007+ Heavy-Duty Diesel Trucks,” Presentation by Daniel Hawelti to a June 4, 2003 Public Workshop, California Air Resources Board, June 4, 2003.	CARB. 2003.
CMAQ. 1999. “Summary Review of Costs and Emissions Information for 24 Congestion Mitigation and Air Quality Improvement Program Projects,” Final Report to the Office of Policy, Environmental Protection Agency, Hagler Bailey Services, Inc., Arlington, VA, September 28, 1999.	CMAQ. 1999.
ENVIRON. 2003a. "Workplan for the Winchester-Frederick and Berkeley-Jefferson Counties Ozone Early Action Plan (EAP) Projects," Memorandum to Wilbur-Smith Associates, ENVIRON International Corporation, September 24, 2003.	ENVIRON. 2003a.
ENVIRON. 2000a. "Evaluation of Attainment Control Strategies for the Dallas-Fort Worth State Implementation Plan," Report to the North Central Texas Council of Governments, ENVIRON International Corporation, March 2000.	ENVIRON. 2000a.
ENVIRON. 2000b. “Initial Evaluation of Emissions Reduction Potential of Candidate Measures to Obtain NOx Reductions in the Houston-Galveston Area – Draft Report.” Prepared for the Houston-Galveston Area Council. July 25.	ENVIRON. 2000b.
MWAQC. 2003. “Plan to Improve Air Quality in the Washington, DC-MD-VA Region, State Implementation Plan (SIP) “Severe Area SIP”, Demonstration Rate of Progress for 2002 and 2005; Revision to 1990 Base Year Emissions; and Severe Area Attainment Demonstration for the Washington DC-MD-VA Nonattainment Area,” District of Columbia Department of Health, Maryland Department of the Environment, and the Virginia Department of Environmental Quality, Metropolitan Washington Committee, August 4, 2003.	MWAQC. 2003.
NETAC. 2003. "Identification of Potential Emission Reduction Strategies for the Northeast Texas Early Action Compact," Final Report to the East Texas Council of Governments, Northeast Texas Air Care (with Contribution from ENVIRON International Corporation), June 11, 2003.	NETAC. 2003.
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Appendix B1

State-by-State 2009 On-road Emission Inventory

Estimated 2009 Emission Inventory based on 2002 NEI Emissions & Base J/K 2009/2002 Gasoline and Diesel Emission Ratios.

LADCO States	Emissions (tpd)				Emissions (%)			
	TOG	CO (Base J)	NOx	PM10 (Base J)	TOG	CO (Base J)	NOx	PM10 (Base J)
LDGV	589.26	7858.58	584.83	11.74	51.1%	51.9%	25.6%	24.5%
LDGT1	297.16	4579.94	337.25	6.26	25.8%	30.3%	14.7%	13.1%
LDGT2	142.01	1859.54	142.03	2.43	12.3%	12.3%	6.2%	5.1%
HDGV	50.54	564.49	128.33	2.65	4.4%	3.7%	5.6%	5.5%
Motorcycle	8.47	50.14	6.05	0.19	0.7%	0.3%	0.3%	0.4%
LDDV	0.60	1.36	1.30	0.44	0.1%	0.0%	0.1%	0.9%
LDDT	1.21	1.43	1.85	0.42	0.1%	0.0%	0.1%	0.9%
Class 2b diesel	2.59	7.11	30.15	0.98	0.2%	0.0%	1.3%	2.0%
Class 3, 4, 5 diesel	2.43	6.71	28.99	0.70	0.2%	0.0%	1.3%	1.5%
Class 6, 7 diesel	10.90	26.40	131.14	3.43	0.9%	0.2%	5.7%	7.2%
Class 8 diesel	44.92	170.66	856.58	16.79	3.9%	1.1%	37.5%	35.1%
Buses	2.69	8.74	38.69	1.81	0.2%	0.1%	1.7%	3.8%
Total	1152.78	15135.10	2287.20	47.83	100.0%	100.0%	100.0%	100.0%
IL								
	TOG	CO (Base J)	NOx	PM10 (Base J)	TOG	CO (Base J)	NOx	PM10 (Base J)
LDGV	101.16	1249.90	101.82	2.10	44.9%	45.1%	22.4%	19.4%
LDGT1	65.85	959.07	75.40	1.47	29.2%	34.6%	16.6%	13.6%
LDGT2	33.15	401.43	32.61	0.58	14.7%	14.5%	7.2%	5.3%
HDGV	9.94	103.41	28.51	0.68	4.4%	3.7%	6.3%	6.3%
Motorcycle	2.17	11.52	1.63	0.08	1.0%	0.4%	0.4%	0.8%
LDDV	0.13	0.22	0.20	0.28	0.1%	0.0%	0.0%	2.6%
LDDT	0.30	0.38	0.43	0.26	0.1%	0.0%	0.1%	2.4%
Class 2b diesel	0.49	1.42	6.30	0.23	0.2%	0.1%	1.4%	2.1%
Class 3, 4, 5 diesel	0.41	1.19	5.35	0.14	0.2%	0.0%	1.2%	1.3%
Class 6, 7 diesel	1.91	4.89	25.31	0.71	0.9%	0.2%	5.6%	6.6%
Class 8 diesel	8.64	35.41	162.07	3.54	3.8%	1.3%	35.6%	32.7%
Buses	0.98	3.49	15.31	0.76	0.4%	0.1%	3.4%	7.0%
Total	225.14	2772.34	454.94	10.82	100.0%	100.0%	100.0%	100.0%
IN								
	TOG	CO (Base J)	NOx	PM10 (Base J)	TOG	CO (Base J)	NOx	PM10 (Base J)
LDGV	106.33	1214.22	107.02	2.18	52.8%	54.8%	29.8%	28.8%
LDGT1	49.14	606.12	51.72	0.95	24.4%	27.4%	14.4%	12.5%
LDGT2	26.41	275.14	22.49	0.38	13.1%	12.4%	6.3%	5.0%
HDGV	8.70	81.56	18.75	0.39	4.3%	3.7%	5.2%	5.2%
Motorcycle	0.90	4.64	0.70	0.02	0.4%	0.2%	0.2%	0.2%
LDDV	0.12	0.18	0.20	0.02	0.1%	0.0%	0.1%	0.3%
LDDT	0.21	0.24	0.27	0.03	0.1%	0.0%	0.1%	0.4%
Class 2b diesel	0.38	1.03	3.87	0.13	0.2%	0.0%	1.1%	1.8%
Class 3, 4, 5 diesel	0.41	1.09	4.35	0.11	0.2%	0.0%	1.2%	1.5%
Class 6, 7 diesel	1.81	4.24	19.37	0.54	0.9%	0.2%	5.4%	7.1%
Class 8 diesel	6.76	24.57	126.38	2.61	3.4%	1.1%	35.2%	34.4%
Buses	0.34	1.01	4.21	0.21	0.2%	0.0%	1.2%	2.8%
Total	201.49	2214.05	359.33	7.57	100.0%	100.0%	100.0%	100.0%
MI								
	TOG	CO (Base J)	NOx	PM10 (Base J)	TOG	CO (Base J)	NOx	PM10 (Base J)
LDGV	118.43	1832.60	121.31	2.37	43.2%	45.7%	18.8%	20.8%
LDGT1	79.91	1371.30	90.14	1.65	29.2%	34.2%	13.9%	14.5%
LDGT2	39.55	560.88	38.48	0.68	14.4%	14.0%	6.0%	5.9%
HDGV	12.10	163.56	38.15	0.67	4.4%	4.1%	5.9%	5.9%
Motorcycle	3.26	21.08	2.08	0.05	1.2%	0.5%	0.3%	0.4%
LDDV	0.10	0.50	0.46	0.08	0.0%	0.0%	0.1%	0.7%
LDDT	0.29	0.29	0.58	0.07	0.1%	0.0%	0.1%	0.6%
Class 2b diesel	0.89	2.11	11.23	0.29	0.3%	0.1%	1.7%	2.5%
Class 3, 4, 5 diesel	0.75	1.79	9.64	0.18	0.3%	0.0%	1.5%	1.6%
Class 6, 7 diesel	3.32	6.95	43.43	0.86	1.2%	0.2%	6.7%	7.6%
Class 8 diesel	14.62	49.07	280.90	4.15	5.3%	1.2%	43.4%	36.4%
Buses	0.69	1.87	10.21	0.36	0.3%	0.0%	1.6%	3.2%
Total	273.91	4011.99	646.61	11.40	100.0%	100.0%	100.0%	100.0%

OH

	TOG	CO (Base J)	NOx	PM10 (Base J)	TOG	CO (Base J)	NOx	PM10 (Base J)
LDGV	187.47	2338.87	168.03	3.11	58.3%	57.6%	31.7%	27.5%
LDGT1	73.85	1097.31	79.46	1.33	23.0%	27.0%	15.0%	11.7%
LDGT2	31.55	430.72	32.19	0.49	9.8%	10.6%	6.1%	4.3%
HDGV	13.28	135.88	26.86	0.54	4.1%	3.3%	5.1%	4.8%
Motorcycle	1.44	8.14	1.03	0.02	0.4%	0.2%	0.2%	0.2%
LDDV	0.18	0.31	0.29	0.04	0.1%	0.0%	0.1%	0.3%
LDDT	0.28	0.36	0.37	0.04	0.1%	0.0%	0.1%	0.4%
Class 2b diesel	0.54	1.69	5.47	0.22	0.2%	0.0%	1.0%	1.9%
Class 3, 4, 5 diesel	0.56	1.73	5.92	0.17	0.2%	0.0%	1.1%	1.5%
Class 6, 7 diesel	2.50	6.75	26.50	0.85	0.8%	0.2%	5.0%	7.5%
Class 8 diesel	9.61	40.11	178.23	4.19	3.0%	1.0%	33.6%	37.0%
Buses	0.45	1.56	5.54	0.32	0.1%	0.0%	1.0%	2.8%
Total	321.70	4063.42	529.87	11.32	100.0%	100.0%	100.0%	100.0%

WI

	TOG	CO (Base J)	NOx	PM10 (Base J)	TOG	CO (Base J)	NOx	PM10 (Base J)
LDGV	75.87	1222.99	86.65	1.98	58.1%	59.0%	29.2%	29.5%
LDGT1	28.41	546.13	40.52	0.86	21.8%	26.3%	13.7%	12.8%
LDGT2	11.34	191.37	16.27	0.30	8.7%	9.2%	5.5%	4.5%
HDGV	6.52	80.08	16.06	0.36	5.0%	3.9%	5.4%	5.4%
Motorcycle	0.71	4.76	0.62	0.02	0.5%	0.2%	0.2%	0.2%
LDDV	0.08	0.14	0.15	0.02	0.1%	0.0%	0.1%	0.3%
LDDT	0.13	0.17	0.21	0.02	0.1%	0.0%	0.1%	0.3%
Class 2b diesel	0.28	0.86	3.28	0.11	0.2%	0.0%	1.1%	1.7%
Class 3, 4, 5 diesel	0.31	0.91	3.72	0.10	0.2%	0.0%	1.3%	1.4%
Class 6, 7 diesel	1.36	3.57	16.53	0.47	1.0%	0.2%	5.6%	7.0%
Class 8 diesel	5.29	21.49	109.01	2.31	4.1%	1.0%	36.8%	34.3%
Buses	0.24	0.81	3.41	0.17	0.2%	0.0%	1.2%	2.5%
Total	130.55	2073.29	296.44	6.72	100.0%	100.0%	100.0%	100.0%

Appendix B2

State-by-State 2009 NONROAD Emission Inventory

2009 NONROAD NOx Emission Inventories for LADCO States

LADCO States	2009 Sum of NOx-Exhaust (tpy)				
Equipment Type	**CNG**	**Diesel**	**Gasoline**	**LPG**	**Grand Total**
Railway Maintenance	0	492	6	1	499
Pleasure Craft	0	8119	11045	0	19165
Recreational	0	264	3087	19	3370
Construction and Mining	1	99590	1072	260	100922
Industrial	1794	21729	809	24183	48515
Lawn and Garden	0	4935	8660	122	13718
Agricultural	5	92829	633	5	93471
Commercial	499	12289	3941	1931	18660
Logging	0	724	24	0	748
Airport Ground Support	0	1261	11	15	1287
Underground Mining	0	233	0	0	233
	2298	242465	29289	26536	300588

	2009 LADCO NONROAD NOx Emissions (tpd)				
Equipment Type	**CNG**	**Diesel**	**Gasoline**	**LPG**	**Grand Total**
Railway Maintenance	0.00	1.35	0.02	0.00	1.37
Pleasure Craft	0.00	22.24	30.26	0.00	52.51
Recreational	0.00	0.72	8.46	0.05	9.23
Construction and Mining	0.00	272.85	2.94	0.71	276.50
Industrial	4.91	59.53	2.22	66.26	132.92
Lawn and Garden	0.00	13.52	23.73	0.33	37.58
Agricultural	0.01	254.33	1.73	0.01	256.09
Commercial	1.37	33.67	10.80	5.29	51.12
Logging	0.00	1.98	0.06	0.00	2.05
Airport Ground Support	0.00	3.45	0.03	0.04	3.53
Underground Mining	0.00	0.64	0.00	0.00	0.64
Total	6.30	664.29	80.24	72.70	823.53

Illinois	2009 Sum of NOx-Exhaust (tpy)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0	133	1	0	135
Pleasure Craft	0	1821	1343	0	3164
Recreational	0	37	416	3	456
Construction and Mining	0	28633	410	76	29118
Industrial	416	5276	187	5612	11491
Lawn and Garden	0	1316	2260	33	3609
Agricultural	2	34453	235	2	34691
Commercial	153	3768	1208	592	5721
Logging	0	1	0	0	1
Airport Ground Support	0	617	6	7	629
Underground Mining	0	72	0	0	72
	571	76126	6068	6324	89088

	Sum of NOx-Exhaust (tpd)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0.00	0.37	0.00	0.00	0.37
Pleasure Craft	0.00	4.99	3.68	0.00	8.67
Recreational	0.00	0.10	1.14	0.01	1.25
Construction and Mining	0.00	78.45	1.12	0.21	79.78
Industrial	1.14	14.45	0.51	15.37	31.48
Lawn and Garden	0.00	3.61	6.19	0.09	9.89
Agricultural	0.00	94.39	0.64	0.00	95.04
Commercial	0.42	10.32	3.31	1.62	15.67
Logging	0.00	0.00	0.00	0.00	0.00
Airport Ground Support	0.00	1.69	0.02	0.02	1.72
Underground Mining	0.00	0.20	0.00	0.00	0.20
	1.56	208.56	16.62	17.33	244.08

Indiana	2009 Sum of NOx-Exhaust (tpy)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0	66	1	0	67
Pleasure Craft	0	1625	1112	0	2738
Recreational	0	30	304	2	337
Construction and Mining	0	14868	141	40	15049
Industrial	278	3218	123	3775	7394
Lawn and Garden	0	675	1202	17	1894
Agricultural	1	18645	127	1	18774
Commercial	65	1597	512	251	2425
Logging	0	24	1	0	25
Airport Ground Support	0	153	1	2	156
Underground Mining	0	70	0	0	70
	344	40972	3525	4087	48929
	Sum of NOx-Exhaust (tpd)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0.00	0.18	0.00	0.00	0.18
Pleasure Craft	0.00	4.45	3.05	0.00	7.50
Recreational	0.00	0.08	0.83	0.01	0.92
Construction and Mining	0.00	40.73	0.39	0.11	41.23
Industrial	0.76	8.82	0.34	10.34	20.26
Lawn and Garden	0.00	1.85	3.29	0.05	5.19
Agricultural	0.00	51.08	0.35	0.00	51.44
Commercial	0.18	4.38	1.40	0.69	6.64
Logging	0.00	0.07	0.00	0.00	0.07
Airport Ground Support	0.00	0.42	0.00	0.00	0.43
Underground Mining	0.00	0.19	0.00	0.00	0.19
	0.94	112.25	9.66	11.20	134.05

Michigan	2009 Sum of NOx-Exhaust (tpy)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0	110	1	0	111
Pleasure Craft	0	520	5040	0	5560
Recreational	0	71	1124	5	1200
Construction and Mining	0	18383	104	38	18525
Industrial	397	4791	177	5372	10736
Lawn and Garden	0	1016	1834	25	2876
Agricultural	1	10373	71	1	10444
Commercial	99	2433	780	382	3695
Logging	0	326	11	0	337
Airport Ground Support	0	273	2	3	279
Underground Mining	0	0	0	0	0
Grand Total	496	38296	9145	5827	53763
	Sum of NOx-Exhaust (tpd)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0.00	0.30	0.00	0.00	0.30
Pleasure Craft	0.00	1.42	13.81	0.00	15.23
Recreational	0.00	0.19	3.08	0.01	3.29
Construction and Mining	0.00	50.36	0.28	0.11	50.75
Industrial	1.09	13.13	0.48	14.72	29.41
Lawn and Garden	0.00	2.78	5.03	0.07	7.88
Agricultural	0.00	28.42	0.19	0.00	28.62
Commercial	0.27	6.67	2.14	1.05	10.12
Logging	0.00	0.89	0.03	0.00	0.92
Airport Ground Support	0.00	0.75	0.01	0.01	0.76
Underground Mining	0.00	0.00	0.00	0.00	0.00
Grand Total	1.36	104.92	25.05	15.96	147.30

Ohio	2009 Sum of NOx-Exhaust (tpy)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0	126	1	0	127
Pleasure Craft	0	2206	1647	0	3853
Recreational	0	64	527	5	596
Construction and Mining	0	26626	303	76	27005
Industrial	457	5605	213	6089	12364
Lawn and Garden	0	1479	2425	37	3940
Agricultural	1	15425	105	1	15531
Commercial	123	3031	972	476	4602
Logging	0	70	2	0	72
Airport Ground Support	0	167	2	2	171
Underground Mining	0	91	0	0	91
Grand Total	581	54889	6198	6686	68352

	2009 Sum of NOx-Exhaust (tpd)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0.00	0.34	0.00	0.00	0.35
Pleasure Craft	0.00	6.04	4.51	0.00	10.56
Recreational	0.00	0.18	1.44	0.01	1.63
Construction and Mining	0.00	72.95	0.83	0.21	73.99
Industrial	1.25	15.36	0.58	16.68	33.87
Lawn and Garden	0.00	4.05	6.64	0.10	10.79
Agricultural	0.00	42.26	0.29	0.00	42.55
Commercial	0.34	8.30	2.66	1.30	12.61
Logging	0.00	0.19	0.01	0.00	0.20
Airport Ground Support	0.00	0.46	0.00	0.01	0.47
Underground Mining	0.00	0.25	0.00	0.00	0.25
Grand Total	1.59	150.38	16.98	18.32	187.27

Wisconsin	2009 Sum of NOx-Exhaust (tpy)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0	58	1	0	59
Pleasure Craft	0	1947	1902	0	3850
Recreational	0	62	715	5	782
Construction and Mining	0	11080	115	29	11225
Industrial	246	2839	109	3336	6530
Lawn and Garden	0	449	938	11	1398
Agricultural	1	13933	95	1	14030
Commercial	59	1460	468	229	2218
Logging	0	302	10	0	312
Airport Ground Support	0	51	0	1	52
Underground Mining	0	0	0	0	0
Grand Total	306	32183	4354	3612	40455

	2009 Sum of NOx-Exhaust (tpd)				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0.00	0.16	0.00	0.00	0.16
Pleasure Craft	0.00	5.34	5.21	0.00	10.55
Recreational	0.00	0.17	1.96	0.01	2.14
Construction and Mining	0.00	30.36	0.32	0.08	30.75
Industrial	0.67	7.78	0.30	9.14	17.89
Lawn and Garden	0.00	1.23	2.57	0.03	3.83
Agricultural	0.00	38.17	0.26	0.00	38.44
Commercial	0.16	4.00	1.28	0.63	6.08
Logging	0.00	0.83	0.03	0.00	0.86
Airport Ground Support	0.00	0.14	0.00	0.00	0.14
Underground Mining	0.00	0.00	0.00	0.00	0.00
Grand Total	0.84	88.17	11.93	9.90	110.84

Appendix B3

State-by-State 2002 Locomotive and Commercial Marine Vessel Emission Inventory

2002 Locomotive and Commercial Marine Emissions for the LADCO states (ENVIRON, 2004)

Equipment Type	Emissions (tpd)			
	VOC	**CO**	**NOx**	**PM10**
Locomotives	24.1	57.4	520.4	14.4
Commercial Marine	4.6	24.1	178.1	8.8

	2002 Locomotive Emissions (tpy)			
	VOC	CO	NOx	PM10
Illinois	3,396	8,196	74,448	2,056
Indiana	1,601	3,730	33,813	933
Michigan	462	1,071	9,863	267
Ohio	2,369	5,641	51,063	1,413
Wisconsin	953	2,299	20,755	577
Total	8,781	20,937	189,942	5,246
	2002 Locomotive Emissions (tpd)			
	VOC	CO	NOx	PM10
Illinois	9.3	22.5	204.0	5.6
Indiana	4.4	10.2	92.6	2.6
Michigan	1.3	2.9	27.0	0.7
Ohio	6.5	15.5	139.9	3.9
Wisconsin	2.6	6.3	56.9	1.6
Total	24.1	57.4	520.4	14.4

	2002 Commercial Marine Emissions (tpy)			
	VOC	CO	NOx	PM10
Illinois	446	3,520	19,430	513
Indiana	151	1,172	6,363	173
Michigan	641	1,886	22,839	1,675
Ohio	277	1,542	10,568	489
Wisconsin	167	691	5,805	347
Total	1,683	8,811	65,005	3,197
	2002 Commercial Marine Emissions (tpd)			
	VOC	CO	NOx	PM10
Illinois	1.2	9.6	53.2	1.4
Indiana	0.4	3.2	17.4	0.5
Michigan	1.8	5.2	62.6	4.6
Ohio	0.8	4.2	29.0	1.3
Wisconsin	0.5	1.9	15.9	1.0
Total	4.6	24.1	178.1	8.8

Appendix C

General Program Descriptions of
Some Voluntary/Incentive Type Emission Reduction Programs

General Program Descriptions of Some Voluntary/Incentive Type Emission Reduction Programs

In addressing emissions from in-use diesel engines, federal, state, and county-level air pollution regulatory agencies, have embarked on a number of initiatives in recent years to reduce emissions from in-use on-road HDDVs and non-road diesel equipment in addition to the emission reductions gained through EPA regulations.

Many emission control programs for on-road HDDVs and non-road equipment have been or are being implemented at the federal, state, and local levels in the U.S. for the past few years to reduce in-use emissions from these sources. While some are regulatory or voluntary programs, most of the emission control programs are monetary incentive programs. The major emission control programs that are applicable to on-road HDDV fleets and/or non-road equipment are as follows:

- Federal Programs
  - U.S. Department of Transportation's (U.S. DOT) Transportation Equity Act for the 21st Century (TEA-21)
    - Congestion Mitigation and Air Quality Improvement Program (CMAQ)
  - U.S. Department of Energy's (U.S. DOE) Energy Policy Act of 1992 (EPAct)
    - State & Alternative Fuel Provider Program
    - Federal Fleet Program
    - Private & Local Government Fleet Program
    - Alternative Fuel Petition Program
    - Clean Cities Program
  - U.S. EPA's Office of Air & Radiation Programs
    - National Clean Diesel Campaign (NCDC)
      - Voluntary Diesel Retrofit Program
      - Clean School Bus USA
      - West Coast Diesel Emissions Reduction Collaboration
      - Midwest Clean Diesel Initiative
      - Northeast Diesel Collaboration

- California Programs
  - California Air Resources Board (CARB)
    - Diesel Risk Reduction Plan
    - Carl Moyer Program
  - California Department of Transportation's (Caltrans) Greening the Fleet Program
  - South Coast Air Quality Management District's (SCAQMD) MSRC Funding Program (AB 2766)
  - Sacramento Emergency Clean Air & Transportation (SECAT) Program (AB 2511)
  - San Joaquin Valley Emergency Clean Air Attainment Program (AB 2511)
  - Gateway Cities Clean Air Program
  - Port of Los Angeles and Port of Oakland Clean Air Programs
  - Bay Area Air Quality Management District's (BAAQMD) Transportation Fund for Clean Air (TFCA) Program

- Programs in Other States
  - Texas Commission on Environmental Quality's (TCEQ) Texas Emissions Reduction Plan or TERP (SB 5)
  - Houston-Galveston Area Council (H-GAC)'s Clean Cities/Clean Vehicles Program
  - New York State Department of Environment Conservation's Clean Water/Clean Air Bond Act Program
  - Puget Sound Clean Air Agency's Diesel Solutions Program

This section provides general overview of a few incentive-based voluntary programs, namely the Carl Moyer and SECAT programs in California, and the TERP program in Texas.

CARL MOYER PROGRAM

The California Assembly Bill 1571 grants the CARB and California Energy Commission (CEC) with the authority to implement a voluntary, incentive-based program called Carl Moyer Program to reduce emissions from heavy-duty vehicles and off-road equipment[1]. The purpose of the Carl Moyer Program is to reduce emissions and help California meets its air quality obligations under the SIP. The Carl Moyer Program provides grants for the extra capital cost of vehicles and equipment that are cleaner than required. In essence, the program buys critical near-term emission benefits that California needs to meet impending federal air quality deadlines. The Carl Moyer Program provides funds on an incentive basis for the incremental cost of cleaner HD vehicle and equipment, with emphasis on reducing NOx emissions. The incentives are available for both on-road and off-road sources, including HD trucks, marine engines, locomotive engines, stationary agricultural pump engines, forklifts, airport ground support equipment, and auxiliary power units. The Carl Moyer Program is administrated by CARB, and the grants are available through participating local air pollution control and air quality management districts. Both private companies and public agencies operating HD engines in California are eligible to apply for the grants. The Carl Moyer Program is considered one of the most cost-effective emission reduction programs in the U.S. with an average cost-effectiveness of $5,000 per ton of NOx emission reduction.

The Carl Moyer Program is funded by California's fiscal budget, with matching funds from local air districts. California's Governor and Legislature have appropriated more than $114 million over the last four fiscal years (1998/1999, 1999/2000, 2000/2001, 2001/2002) to fund the Carl Moyer program. Local air districts have provided $41 million in matching funds, mostly collected through vehicle registration fees. In the spring of 2002, California Voters passed Proposition 40, the California Clean Water, Clean Air, Safe Neighborhood Parks, and Coastal Protection Act, which allocated $50 million to CARB over two years for distribution to air districts for projects similar to those funded by the Carl Moyer Program. For the $25 million made available to CARB for the 2002/2003 fiscal year, $5 million is to be allocated upon acquiring low-emitting school buses under the Lower-Emission School Bus Program[2].

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[1] CARB's Carl Moyer Program Website: http://www.arb.ca.gov/msprog/moyer/moyer.htm.

[2] Lower-Emission School Bus Program Website: http://www.arb.ca.gov/msprog/schoolbus/schoolbus.htm.

As part of AB 923, the Carl Moyer incentive program expanded to include agricultural sources of air pollution as well as cars and light-duty trucks. AB923 also expands the program to include hydrocarbon and particulate matter pollution. Finally, AB923 provides additional funding for the Moyer Program from an adjustment to the tire fee, and authorizes local air districts to increase motor vehicle registration fees by up to $2 for programs to reduce air pollution. Combined with continuing funding that was provided in the fiscal year 2004-2005 budget (SB1107), up to $140 million a year of incentive funding is available to help clean up California's air.

The Carl Moyer Program is mainly administrated by CARB. CARB is responsible for the development and supervision of the general projects for the program, developing guidelines and evaluation criteria, including emission benefit and cost-effectiveness calculation. The California Energy Commission (CEC) is responsible for developing two portions of the program, namely the infrastructure demonstration and advanced technology projects, which funds engine research and development, certification testing, training, or operational controls. Air Quality Districts in California are responsible to outreach, solicit, approve, and issue Carl Moyer grants locally according to its guidelines, as well as monitor the implementation of these eligible projects. More than twenty Air Quality Districts have participated in the Carl Moyer Program, applying grants and implementing eligible projects. Most Air Quality Districts have more than one staff member who deals with the Carl Moyer Program.

The engine portion of the Carl Moyer Program funds the incremental cost of cleaner HD on-road diesel vehicles (trucks and buses) over 14,000 pounds gross vehicle weight, and cleaner off-road equipment such as combines, cranes, graders, tractors, marine vessels, locomotives, stationary agricultural equipment, forklifts, and airport ground support equipment.

As part of the requirements, air quality districts and port authorities are required to provide $1 in district or port funding for every $2 in state funding for those projects they approve. This matching was modified to $1 for every $3.68 in the third year of Carl Moyer program. Also, air quality districts can use up to 15% in-kind contributions (i.e., administrative costs) as matching funds - many districts used funds from motor vehicle fees as a source for matching funds.

Projects must have a cost-effectiveness of $12,000 per ton of NOx reduction or better during the first two years. This cost-effectiveness requirement was increased to $13,000 in the third year and to $13,600 in the fourth year of the program. Five years is the minimum project life under the program.

Changes have been proposed and made throughout the implementation of the Carl Moyer Program. Some of the notable changes included the increase in the cost-effectiveness value from $12,000 to $13,600 per ton of NOx reduced to reflect the increase in the cost-of-living and the inclusion of the PM emission reduction.

The funding for the Carl Moyer Program has been over subscribed since its implementation due to strong district responses to calls for project applications. Some of the key strategies for the success of the Carl Moyer Program include the following:

- Smooth initial implementation of the program;
- Quick response from CARB to accelerate the second year funding schedule to meet demand;
- Participation and assistance from the local level (air districts) to solicit, evaluate, and implement projects;
- Inter-agency collaborations (CARB, CEC, California Department of Transportation, port authorities, California Department of Commerce, etc.);
- Participation of the NGOs and local businesses (construction, agricultural, goods transportation industries, etc.);
- Effective outreach programs via workshops and public meetings; and
- Complement by the statewide Diesel Risk Reduction Program via mandatory regulations

SACRAMENTO EMERGENCY CLEAN AIR AND TRANSPORTATION PROGRAM (SECAT)

The Sacramento Emergency Clean Air and Transportation (SECAT) [3] Program was created by California Assembly Bill 2511 to assist the Greater Sacramento Area to meet the 2005 State Implementation Plan by reducing 3 tons per day of NOx from HD vehicles by 2005. Similar to the Carl Moyer Program, the SECAT Program is an incentive based voluntary program. However, the SECAT Program is dedicated to reducing NOx emissions from on-road HD vehicles only. The control measures for the SECAT program include:

- New low emissions or zero emission vehicle purchases;
- Repowering of existing high-emitting diesel vehicles with newer, low-emitting diesel engines;
- Retrofitting of existing diesel engines with aftertreatment devices;
- Use of cleaner diesel fuel formulations;
- Other verified, cost-effective NOx reduction technologies; and
- Fleet modernization;

The AB 2511 set aside $50 million of California's 2000/2001 budget for the SECAT Program. In addition, local political leaders approved an additional $20 million from CMAQ funds for SECAT. To date, the SECAT Program has funded $25 million on projects. Due to the California budget crisis, the SECAT program was temporarily stalled until November 2005, in which a total of $34.5 million has been appropriated for the program.

Since its implementation began in December 2000, the grant solicitations for SECAT have been successful and the program oversubscribed. The major key strategy for the SECAT program was the diesel power retrofit. Most of the NO_x reduction achieved by SECAT was from repowering trucks with remanufactured lower emission diesel engines, as well as replacing high emitting older model year trucks with newer model year trucks (i.e. fleet modernization). The success of the SECAT diesel repower strategy was due in large to the active role of engine distributors/dealerships in performing outreach to equipment owners, as well as in facilitating the

[3] SECAT Website: http://www.4secat.com/index1.html

application process. The outreach effort from engine distributors/dealerships was effective in term of identifying older vehicles that would provide the most emission reduction when repowered. In addition, the simple application and approval process in the program made it easy for fleet owners to submit grant applications. The dealership outreach efforts were effective in identifying the oldest vehicles that would provide the most emission reductions when repowered.

The other key strategies adding to the success of the SECAT program were the formation of the technical and policy review groups who developed the objective funding criteria, which are directly related to technical supporting documentation and application assessment software (such as the emission calculator and project tracking software program), early involvement of stakeholders including public agencies, private industries, NGOs, and technology providers, as well as the extensive and effective outreach programs.

TEXAS EMISSIONS REDUCTION PLAN

The Texas Emissions Reduction Plan was established to reduce emissions in the nonattainment and near nonattainment areas of Texas through voluntary incentive programs[4]. The TERP is funded through revenues deposited in the Emission Reduction Plan Fund, which consists of fees and surcharges established by the Texas Legislature. The TERP is expected to receive approximately $130 million per fiscal year through 2008. Texas Commission on Environmental Quality (TCEQ) administers TERP grants and other financial TERP incentives.

TERP provides funding for cleaner on- and off-road engines, energy efficiency programs, cleaner fuel and other infrastructure programs, and for research and development of new technologies. The main program funded by TERP that applies to heavy-duty diesel engines for on-and non-road applications is the Emissions Reduction Incentive Grants Program. The Emission Reduction Incentive Grants Program provides monetary grants to eligible projects in nonattainment areas and affected counties. The grants offset the incremental costs associated with reducing NOx emissions from high emitting internal combustion engines.

The guidelines for TERP were laid out in Senate Bill 5 (Rule Log 2001-025b-114-AI). TCEQ is responsible to develop and revise guidelines for the Emission Reduction Incentive Grants Program. According to the legislation, the TERP fund is to be distributed as follows:

- 72% for diesel reduction programs with
  - Not more than 3% of the 72% for infrastructure projects; and
  - Not more than 15% of the 72% for on-road diesel purchases;
- 10% for light-duty purchases and lease incentives;
- 7.5% for energy efficiency programs;
- 7.5% for new technology and research; and
- 3% for administration.

[4] http://www.tceq.state.tx.us/implementation/air/terp/index.html

In general, the guidelines specify that the TERP must meet the following conditions:

- On-road heavy-duty vehicles with gross vehicle weight ratings (GVWR) of 8,500 lbs or more;
- Non-road equipment with engine size of 25 hp or greater;
- Stationary equipment with engine size of 25 hp or greater that are not covered by permit requirement;
- 75% of the activity occurs within the eligible 41 counties, including those counties in the HGB and DFW areas;
- Cost effectiveness values must not exceed $13,000 per ton of NOx reduced; and
- For retrofits or add-ons, the system must be certified or verified to emit at least 25% less NOx than the engine prior to the retrofit or add-on (certification or verification means approved by the EPA, CARB, or otherwise accepted by the TCEQ).

In addition to funding new purchases, repowers, or replacement cleaner equipment/engines, or retrofit with emission control systems, the TERP also funds on-site refueling stations for qualified fuels, on-site electrification charging stations, on-site idling reduction infrastructure, and on-vehicle idling reduction systems. On a case-by-case basis, the TERP also funds demonstration programs for low-emission repower, retrofit or advanced technologies for on-road heavy-duty vehicles, and non-road equipment.

Since the establishment of TERP, TCEQ has completed several grant application and selection processes. Other the first couple round of solicitations due to funding issues, the grant solicitations for the TERP have been successful and the program has been oversubscribed. While the cost effectiveness limit is set at $13,000 per ton of NOx reduced, average cost-effective value funded projects was less than $7,000 per ton of NOx reduced.

Appendix D

LADCO States Vehicle VMT and Population Estimates

&

LADCO States NONROAD Population Data

2002 Vehicle VMT by Vehicle Types: **LADCO STATES**

	LADCO States
HDDV	30034390332
HDGV	5132360278
LDDT	775018548
LDDV	347160019
LDGT1	146366054544
LDGT2	48425559959
LDGV	212411813290
MC	1182643029
Total	444675000000

Assumptions:
On-road vehicle VMT & population estimates by vehicle types for LADCO states in 2009 were generated by projecting the 2002 FHWA VMT data by facility types (http://www.fhwa.dot.gov/policy/ohim/hs02/xls/vm2.xls) with an assumed constant growth rate of 2% per year as suggested by LADCO, and vehicle mix fractions developed in ENVIRON's Vehicle Mix study for LADCO, as well as data in MOBILE6 technical support document M6.FLT.007.

Growth Rates: 2% per year

2009 Vehicle VMT by Vehicle Types

	LADCO States
HDDV	34500073711
HDGV	5895468692
LDDT	890252698
LDDV	398777738
LDGT1	168128589085
LDGT2	55625746673
LDGV	243994405566
MC	1358485098
Total	510791799262

2009 Vehicle VMT Estimates By Vehicle Types and Model Years

Age	*MC*	*LDGV*	*LDGT1*	*LDGT2*	*HDGV2b-3*	*HDGV4-8*	*LDDV*	*LDDT12*	*LDDT34*	*HDDV2b*	*HDDV3*	*HDDV4-5*	*HDDV6-7*	*HDDV8a*	*HDDV8b*	*HDGBS*	*HDDBS*	*HDGBT*	*HDDBT*
2009+	195621854	12931703495	9768271026	3304169352	162030590	88863815	21135220	38130698	13897129	871147561	77049705	78110927	236090904	62287813	143538247	7549973	44182174	850657	4978016
2008	228225496	17226005033	13013152795	4105180104	295069623	177727629	28153708	50797178	17266131	1586423789	140313180	156221854	472181809	124575626	287076493	15099946	88364349	1701314	9956031
2007	183395488	17226005033	12929088501	3827051371	268332965	166253455	28153708	50469031	16096339	1442675782	127599213	146136102	441697544	116532969	268542709	14115167	82601456	1701314	9956031
2006	148074876	17201605592	12777772770	3560047787	244173334	155511675	28113831	49878366	14973338	1312783005	116110688	136694122	413159083	109003673	251191932	13171420	77078685	1701314	9956031
2005	119546689	17152806711	12525579887	3320857076	222268602	145502290	28034075	48893925	13967317	1195013553	105694426	127895913	386566426	101987738	235024162	12309739	72036154	1701314	9956031
2004	95093957	17030809508	12155696991	3092791515	201974513	135981167	27834686	47450077	13008088	1085903620	96044065	119526885	361270972	95314044	219645064	11509606	67353804	1701314	9956031
2003	76075165	16811214543	11651311224	2881413678	183935322	127192438	27475786	45481194	12119046	988917013	87465967	111801629	337921322	89153710	205448974	10750505	62911574	1701314	9956031
2002	61131829	16494021816	11029235444	2681160990	167184644	118891972	26957375	43052905	11276795	898858020	79500590	104505553	315868875	83335618	192041555	10032437	58709465	1701314	9956031
2001	48905464	15981633565	10255843934	2497596026	152044609	111323899	26119942	40033952	10504733	817458547	72301114	97853249	295762232	78030887	179817144	9375918	54867537	1701314	9956031
2000	39396068	15298449229	9364762412	2330718786	138515216	103999959	25003364	36555592	9802857	744718591	65867541	91415535	276304190	72897276	167987069	8760431	51265730	1698543	9939816
1999	31245157	14346871047	8372803736	2169404120	125952208	97408412	23448131	32683456	9124378	677174347	59893508	85621593	258791953	68277026	157340001	8185976	47904042	1693002	9907386
1998	131773054	13151298460	7330406484	2019214604	114677714	91060997	21494120	28614431	8492690	616557717	54532197	80042241	241928317	63827896	147087269	7652554	44782476	1681918	9842526
1997	0	11174943775	6254383514	1880150238	104369605	85201844	18264020	24414148	7907794	561136799	49630426	74892070	226361884	59721008	137623209	7139648	41780969	1648668	9647946
1996	0	8856996922	5195173403	1752211020	94705752	79586823	14475632	20279494	7369690	509179688	45035016	69956489	211444052	55785239	128553485	6667775	39019583	1573854	9210140
1995	0	7027038880	4186401868	1635396952	86330414	74460064	11484799	16341728	6878377	464150192	41052328	65450090	197823423	52191712	120272432	6236934	36498318	1415915	8285883
1994	0	5563072447	3278507487	1524145459	78599332	69577437	9092132	12797739	6410460	422584503	37376000	61158281	184851395	48769304	112385715	5826610	34097113	1124973	6583304
1993	0	4416298741	2471490260	1418456540	71512507	65183073	7217877	9647526	5965939	384482621	34006033	57295652	173176570	45689138	105287670	5436801	31815968	703801	4118619
1992	0	3513519440	1798975903	1318330196	65069939	61032840	5742399	7022349	5544814	349844547	30942426	53647615	162150346	42780091	98583961	5088025	29774944	335275	1962019
1991	0	2781536223	1429093007	1229329001	59271627	57126738	4546066	5578501	5170481	318670281	28185180	50214167	151772724	40042166	92274587	4739249	27733919	274316	1605288
1990	0	2195949650	1361841572	1145890381	53795444	53464768	3589000	5315984	4819543	289227918	25581115	46995310	142043703	37475360	86359550	4431506	25933015	224440	1313418
1989	0	1756759720	1311402995	1068014336	48963518	49802797	2871200	5119095	4492001	263249362	23283410	43776454	132314683	34908555	80444512	4144279	24252172	182877	1070192
1988	0	1390768112	1260964418	995700865	44453720	46629089	2273033	4922207	4187856	239002711	21138885	40986778	123882865	32683990	75318146	3877568	22691388	149627	875612
1987	0	1097974825	1210525841	928949969	40588180	43699513	1794500	4725319	3907105	218219866	19300721	38411692	116099648	30630545	70586116	3610857	21130605	121918	713462
1986	0	878379860	1160087265	862199073	36722639	40769937	1435600	4528431	3626355	197437022	17462557	35836607	108316431	28577101	65854086	3385178	19809942	102522	599956
1985 & Earlier	0	2488742937	6035816348	4077367231	160742076	195060955	4067533	23560965	17149151	864219946	76436983	171457776	518232507	136725172	315074338	16064209	94007181	315879	1848514
Total	1358485098	243994405566	168128589085	55625746673	3221284094	2441313586	398777738	656294289	233958409	17319037003	1531803273	2145904585	6486013858	1711203656	3943358425	205162310	1200602565	27708703	162150346

2009 Vehicle Population Estimates By Vehicle Types and Model Years

Age	MC	LDGV	LDGT1	LDGT2	HDGV2b-3	HDGV4-8	LDDV	LDDT12	LDDT34	HDDV2b	HDDV3	HDDV4-5	HDDV6-7	HDDV8a	HDDV8b	HDGBS	HDDBS	HDGBT	HDDBT
2009+	40,874	867,317	501,040	154,900	8,111	4,154	1,418	1,409	534	32,102	2,353	2,556	5,803	709	1,156	760	4,445	24	110
2008	51,000	1,215,324	707,852	206,654	15,713	9,025	1,986	2,083	719	63,889	4,841	5,458	12,806	1,592	2,550	1,519	8,891	53	228
2007	44,043	1,278,368	747,001	206,868	15,200	9,173	2,089	2,297	727	63,495	4,975	5,452	13,217	1,671	2,631	1,420	8,311	59	235
2006	38,431	1,342,826	785,503	206,643	14,713	9,322	2,195	2,519	733	63,142	5,115	5,445	13,640	1,754	2,715	1,325	7,755	65	243
2005	33,742	1,408,508	820,811	206,984	14,247	9,475	2,302	2,740	741	62,816	5,262	5,440	14,080	1,842	2,803	1,239	7,248	71	251
2004	29,423	1,471,090	850,703	206,986	13,772	9,621	2,404	2,951	748	62,383	5,402	5,429	14,518	1,932	2,889	1,158	6,777	78	259
2003	26,044	1,527,459	872,627	207,072	13,341	9,777	2,496	3,139	756	62,087	5,559	5,423	14,982	2,028	2,982	1,082	6,330	91	268
2002	23,413	1,576,414	885,811	206,896	12,899	9,928	2,576	3,297	762	61,671	5,710	5,412	15,451	2,127	3,075	1,009	5,907	95	277
2001	21,263	1,606,679	885,346	206,960	12,479	10,100	2,626	3,403	770	61,297	5,868	5,411	15,962	2,235	3,176	943	5,520	104	286
2000	19,807	1,617,856	870,979	207,378	12,093	10,251	2,644	3,448	779	61,028	6,041	5,398	16,452	2,343	3,273	881	5,158	115	295
1999	18,620	1,596,048	841,065	207,281	11,697	10,431	2,609	3,421	786	60,646	6,207	5,399	17,001	2,463	3,382	824	4,820	126	303
1998	96,325	1,538,884	797,303	207,163	11,330	10,595	2,515	3,323	793	60,346	6,386	5,389	17,535	2,584	3,488	770	4,506	137	311
1997	0	1,375,547	738,678	207,133	10,968	10,770	2,248	3,147	801	60,021	6,567	5,384	18,102	2,713	3,600	718	4,204	148	315
1996	0	1,146,834	668,190	207,289	10,586	10,929	1,874	2,900	809	59,518	6,734	5,371	18,654	2,844	3,710	671	3,926	156	311
1995	0	957,101	588,143	207,749	10,266	11,108	1,564	2,594	819	59,294	6,936	5,365	19,257	2,986	3,829	628	3,672	154	289
1994	0	797,002	504,696	207,904	9,943	11,279	1,303	2,254	827	58,995	7,136	5,353	19,851	3,131	3,947	586	3,431	135	237
1993	0	665,506	418,259	207,772	9,622	11,478	1,088	1,886	835	58,664	7,337	5,355	20,519	3,291	4,079	547	3,201	93	153
1992	0	556,994	335,880	207,350	9,314	11,676	910	1,523	841	58,337	7,543	5,354	21,196	3,459	4,214	512	2,996	49	75
1991	0	463,821	295,328	207,622	9,024	11,874	758	1,343	850	58,067	7,765	5,351	21,891	3,633	4,351	477	2,790	44	64
1990	0	385,187	312,564	207,815	8,713	12,074	630	1,420	859	57,604	7,962	5,348	22,604	3,815	4,492	446	2,609	39	54
1989	0	324,125	335,483	207,987	8,436	12,219	530	1,517	868	57,290	8,190	5,319	23,229	3,989	4,616	417	2,440	35	45
1988	0	269,947	360,585	208,218	8,148	12,428	441	1,619	878	56,851	8,402	5,318	23,994	4,191	4,768	390	2,283	32	38
1987	0	224,168	387,989	208,565	7,913	12,656	366	1,725	888	56,725	8,667	5,322	24,813	4,407	4,930	363	2,126	29	32
1986	0	188,655	417,748	207,859	7,616	12,829	308	1,834	893	56,090	8,860	5,301	25,540	4,614	5,074	341	1,993	26	28
1985 & Earlier	0	562,174	2,443,650	1,055,492	35,460	66,665	919	10,589	4,579	268,308	43,829	27,082	134,816	24,778	26,781	1,616	9,458	90	89
Total	442,986	24,963,835	17,373,234	5,980,541	301,605	319,836	40,800	68,380	23,594	1,680,666	199,643	153,435	565,913	91,129	112,509	20,642	120,797	2,047	4,795

2002 Vehicle VMT by Vehicle Types: **ILLINOIS**

	Illinois
HDDV	7740169249
HDGV	1238900704
LDDT	182061920
LDDV	81716992
LDGT1	34455441874
LDGT2	11372334595
LDGV	49999002042
MC	331372624
Total	105401000000

Assumptions:
On-road vehicle VMT & population estimates by vehicle types for LADCO states in 2009 were generated by projecting the 2002 FHWA VMT data by facility types (http://www.fhwa.dot.gov/policy/ohim/hs02/xls/vm2.xls) with an assumed constant growth rate of 2% per year as suggested by LADCO, and vehicle mix fractions developed in ENVIRON's Vehicle Mix study for LADCO, as well as data in MOBILE6 technical support document M6.FLT.007.

Growth Rates: 2%

2009 Vehicle VMT by Vehicle Types

	Illinois
HDDV	8891021481
HDGV	1423107482
LDDT	209131918
LDDV	93867138
LDGT1	39578472253
LDGT2	13063237757
LDGV	57433137042
MC	380642984
Total	121072618056

2009 Vehicle VMT Estimates By Vehicle Types and Model Years

Age	*MC*	*LDGV*	*LDGT1*	*LDGT2*	*HDGV2b-3*	*HDGV4-8*	*LDDV*	*LDDT12*	*LDDT34*	*HDDV2b*	*HDDV3*	*HDDV4-5*	*HDDV6-7*	*HDDV8a*	*HDDV8b*	*HDGBS*	*HDDBS*	*HDGBT*	*HDDBT*
2009+	54812590	3043956263	2299509238	775956323	39112572	21450841	4974958	8957396	3264616	224503627	19856496	20129984	60843038	16052206	36991273	1822488	11386198	205340	1282885
2008	63948021	4054779475	3063373752	964066946	71226871	42901681	6627020	11932917	4056038	408837619	36160140	40259968	121686076	32104412	73982545	3644977	22772395	410680	2565771
2007	51386803	4054779475	3043584516	898750758	64772908	40131930	6627020	11855831	3781239	371792289	32883621	37660767	113829970	30031737	69206200	3407261	21287239	410680	2565771
2006	41490085	4049036161	3007963891	836047216	58941013	37538971	6617633	11717076	3517432	338317593	29922911	35227472	106475317	28091360	64734727	3179450	19863965	410680	2565771
2005	33496583	4037549534	2948596183	779875294	53653429	35122805	6598860	11485818	3281104	307967202	27238533	32960084	99622117	26283282	60568128	2971448	18564453	410680	2565771
2004	26645009	4008832966	2861523544	726316019	48754638	32824501	6551926	11146639	3055769	279848458	24751537	30803300	93103221	24563403	56604777	2778304	17357763	410680	2565771
2003	21316007	3957143142	2742788127	676675716	44400157	30702989	6467446	10684123	2846921	254854018	22540873	28812422	87085777	22975822	52946300	2595065	16212955	410680	2565771
2002	17128934	3882480064	2596347780	629648060	40356710	28699339	6345419	10113686	2649066	231644895	20488114	26932149	81402636	21476440	49491071	2421730	15130029	410680	2565771
2001	13703147	3761870476	2414286807	586539375	36702056	26872482	6148298	9404495	2467698	210667419	18632736	25217782	76220949	20109357	46340715	2263253	14139925	410680	2565771
2000	11038647	3601057693	2204520905	547349662	33436195	25104555	5885470	8587383	2302818	191921590	16974738	23558717	71206413	18786373	43291984	2114681	13211702	410011	2561592
1999	8754789	3377068458	1971007918	509466273	30403610	23513421	5519388	7677768	2143435	174514748	15435169	22065559	66693330	17595687	40548126	1976013	12345361	408674	2553235
1998	36922369	3095646087	1725621390	474195531	27682059	21981219	5059439	6721901	1995043	158893223	14053504	20627703	62347399	16449101	37905892	1847250	11540902	405998	2536520
1997	0	2630437677	1472319168	441537436	25193784	20566877	4299115	5735200	1857644	144610686	12790268	19300452	58335770	15390714	35466907	1723440	10767383	397972	2486374
1996	0	2084822875	1222974793	411491989	22861026	19211467	3407377	4763916	1731236	131220808	11605984	18028502	54491292	14376426	33129546	1609535	10055745	379913	2373547
1995	0	1654074347	985503959	384059190	20839303	17973919	2703374	3838884	1615820	119616247	10579604	16867157	50981117	13450337	30995435	1505534	9405989	341788	2135357
1994	0	1309475525	771780209	357932715	18973097	16795301	2140171	3006355	1505900	108904344	9632177	15761114	47638093	12568348	28962947	1406486	8787174	271557	1696585
1993	0	1039539780	581803542	333112563	17262408	15734545	1698995	2266329	1401477	99085100	8763702	14765675	44629371	11774558	27133708	1312390	8199300	169891	1061410
1992	0	827037173	423489653	309598735	15707236	14732720	1351687	1649641	1302549	90158514	7974179	13825538	41787801	11024867	25406094	1228199	7673307	80932	505632
1991	0	654737762	336417014	288697554	14307581	13789826	1070085	1310462	1214613	82124587	7263609	12940704	39113382	10319275	23780104	1144008	7147314	66217	413699
1990	0	516898233	320585625	269102698	12985685	12905863	844804	1248794	1132173	74536989	6592515	12111172	36606114	9657783	22255738	1069721	6683203	54178	338481
1989	0	413518587	308712084	250814165	11819306	12021900	675843	1202542	1055229	67842050	6000373	11281639	34098846	8996291	20731373	1000388	6250032	44145	275799
1988	0	327368881	296838542	233831956	10730686	11255798	535043	1156290	983782	61593440	5447707	10562711	31925880	8422998	19410256	936006	5847803	36118	225654
1987	0	258449117	284965000	218156071	9797583	10548628	422402	1110039	917830	56237489	4973993	9899085	29920065	7893805	18190763	871625	5445573	29430	183866
1986	0	206759293	273091459	202480185	8864480	9841457	337922	1063787	851878	50881538	4500279	9235460	27914251	7364611	16971271	817148	5105225	24748	154615
1985 & Earlier	0	585817998	1420867154	957535328	38801538	47085774	957445	5534777	4028558	222718310	19698592	44186421	133553812	35235474	81197876	3877740	24226611	76250	476381
Total	380642984	57433137042	39578472253	13063237757	777585928	589308808	93867138	154172050	54959868	4463292784	394761354	553021536	1671512039	440994665	1016243755	49524140	309407548	6688605	41787801

2009 Vehicle Population Estimates By Vehicle Types and Model Years

Age	MC	LDGV	LDGT1	LDGT2	HDGV2b-3	HDGV4-8	LDDV	LDDT12	LDDT34	HDDV2b	HDDV3	HDDV4-5	HDDV6-7	HDDV8a	HDDV8b	HDGBS	HDDBS	HDGBT	HDDBT
2009+	11,453	204,155	117,948	36,377	1,958	1,003	334	331	125	8,273	606	659	1,496	183	298	183	1,146	6	28
2008	14,290	286,072	166,633	48,531	3,793	2,179	468	489	169	16,465	1,248	1,407	3,300	410	657	367	2,291	13	59
2007	12,341	300,911	175,848	48,581	3,669	2,214	492	540	171	16,363	1,282	1,405	3,406	431	678	343	2,142	14	61
2006	10,768	316,084	184,912	48,528	3,552	2,250	517	592	172	16,272	1,318	1,403	3,515	452	700	320	1,999	16	63
2005	9,454	331,545	193,224	48,609	3,439	2,287	542	644	174	16,188	1,356	1,402	3,629	475	722	299	1,868	17	65
2004	8,244	346,276	200,261	48,609	3,324	2,322	566	693	176	16,077	1,392	1,399	3,741	498	745	280	1,746	19	67
2003	7,298	359,544	205,422	48,629	3,220	2,360	588	737	178	16,000	1,433	1,397	3,861	523	768	261	1,631	22	69
2002	6,560	371,068	208,525	48,588	3,114	2,397	606	775	179	15,893	1,472	1,395	3,982	548	792	244	1,522	23	71
2001	5,958	378,191	208,416	48,603	3,012	2,438	618	799	181	15,797	1,512	1,395	4,114	576	818	228	1,423	25	74
2000	5,550	380,823	205,034	48,701	2,919	2,475	622	810	183	15,727	1,557	1,391	4,240	604	844	213	1,329	28	76
1999	5,217	375,689	197,992	48,678	2,824	2,518	614	804	185	15,629	1,599	1,391	4,381	635	872	199	1,242	30	78
1998	26,990	362,233	187,690	48,650	2,735	2,557	592	781	186	15,552	1,646	1,389	4,519	666	899	186	1,161	33	80
1997	0	323,786	173,889	48,644	2,648	2,600	529	739	188	15,468	1,693	1,388	4,665	699	928	173	1,083	36	81
1996	0	269,950	157,296	48,680	2,555	2,638	441	681	190	15,338	1,735	1,384	4,807	733	956	162	1,012	38	80
1995	0	225,289	138,452	48,788	2,478	2,681	368	609	192	15,281	1,787	1,383	4,963	769	987	151	946	37	74
1994	0	187,604	118,809	48,825	2,400	2,723	307	529	194	15,204	1,839	1,380	5,116	807	1,017	142	884	33	61
1993	0	156,652	98,461	48,793	2,323	2,771	256	443	196	15,118	1,891	1,380	5,288	848	1,051	132	825	22	39
1992	0	131,109	79,068	48,694	2,248	2,819	214	358	198	15,034	1,944	1,380	5,462	891	1,086	124	772	12	19
1991	0	109,178	69,522	48,758	2,178	2,866	178	315	200	14,964	2,001	1,379	5,642	936	1,121	115	719	11	16
1990	0	90,668	73,579	48,804	2,103	2,915	148	334	202	14,845	2,052	1,378	5,825	983	1,158	108	672	10	14
1989	0	76,295	78,975	48,844	2,036	2,949	125	356	204	14,764	2,111	1,371	5,986	1,028	1,190	101	629	9	12
1988	0	63,542	84,884	48,898	1,967	3,000	104	380	206	14,651	2,165	1,371	6,184	1,080	1,229	94	588	8	10
1987	0	52,766	91,335	48,980	1,910	3,055	86	405	209	14,619	2,233	1,371	6,395	1,136	1,270	88	548	7	8
1986	0	44,407	98,340	48,814	1,838	3,097	73	431	210	14,455	2,283	1,366	6,582	1,189	1,308	82	514	6	7
1985 & Earlier	0	132,328	575,250	247,873	8,560	16,092	216	2,488	1,076	69,146	11,295	6,979	34,743	6,386	6,902	390	2,438	22	23
Total	124123	5876165	4089763	1404480	72804	77205	9604	16063	5543	433125	51450	39542	145841	23485	28995	4983	31131	494	1236

2002 Vehicle VMT by Vehicle Types: **INDIANA**

	Indiana
HDDV	5325758716
HDGV	852447280
LDDT	125270886
LDDV	56226805
LDGT1	23707668912
LDGT2	7824933557
LDGV	34402687120
MC	228006725
Total	72523000000

Assumptions:
On-road vehicle VMT & population estimates by vehicle types for LADCO states in 2009 were generated by projecting the 2002 FHWA VMT data by facility types (http://www.fhwa.dot.gov/policy/ohim/hs02/xls/vm2.xls) with an assumed constant growth rate of 2% per year as suggested by LADCO, and vehicle mix fractions developed in ENVIRON's Vehicle Mix study for LADCO, as well as data in MOBILE6 technical support document M6.FLT.007.

Growth Rates: 2% per year

2009 Vehicle VMT by Vehicle Types

	Indiana
HDDV	6117622707
HDGV	979193973
LDDT	143896871
LDDV	64586925
LDGT1	27232659493
LDGT2	8988389027
LDGV	39517873623
MC	261908057
Total	83306130675

2009 Vehicle VMT Estimates By Vehicle Types and Model Years

Age	*MC*	*LDGV*	*LDGT1*	*LDGT2*	*HDGV2b-3*	*HDGV4-8*	*LDDV*	*LDDT12*	*LDDT34*	*HDDV2b*	*HDDV3*	*HDDV4-5*	*HDDV6-7*	*HDDV8a*	*HDDV8b*	*HDGBS*	*HDDBS*	*HDGBT*	*HDDBT*
2009+	37714760	2094447302	1582217517	533910308	26912089	14759626	3423107	6163293	2246276	154473644	13662609	13850787	41864116	11045001	25452492	1253995	7834472	141288	882712
2008	44000554	2789961878	2107807845	663343110	49008893	29519252	4559837	8210652	2790828	281307868	24880616	27701574	83728231	22090001	50904983	2507990	15668945	282576	1765424
2007	35357588	2789961878	2094191515	618401165	44568131	27613476	4559837	8157611	2601748	255818182	22626150	25913149	78322700	20663861	47618535	2344425	14647057	282576	1765424
2006	28547978	2786010090	2069682121	575256898	40555394	25829345	4553378	8062139	2420230	232785332	20588982	24238878	73262202	19328751	44541860	2187676	13667748	282576	1765424
2005	23047909	2778106516	2028833132	536606825	36917179	24166860	4540461	7903018	2257621	211902215	18741949	22678761	68546739	18084672	41674959	2044557	12773596	282576	1765424
2004	18333564	2758347579	1968921281	499754430	33546480	22585471	4508167	7669640	2102575	192554622	17030728	21194749	64061298	16901279	38947906	1911661	11943312	282576	1765424
2003	14666851	2722781493	1887223303	465598552	30550304	21125728	4450039	7351398	1958874	175356761	15509642	19824890	59920891	15808916	36430627	1785580	11155607	282576	1765424
2002	11785863	2671408257	1786462463	433240351	27768139	19747082	4366076	6958899	1822736	159387318	14097205	18531136	56010506	14777240	34053196	1666314	10410481	282576	1765424
2001	9428690	2588420722	1661192229	403578667	25253491	18490081	4230444	6470927	1697943	144953399	12820580	17351536	52445156	13836594	31885539	1557271	9729222	282576	1765424
2000	7595334	2477770676	1516859134	376613500	23006358	17273628	4049600	5908699	1584494	132055004	11679765	16209987	48994817	12926292	29787806	1455043	9090543	282116	1762548
1999	6023885	2323650969	1356186443	350547172	20919735	16178821	3797711	5282823	1474828	120077922	10620438	15182594	45889511	12107020	27899847	1359630	8494441	281195	1756798
1998	25405082	2130013388	1187343954	326278522	19047124	15124562	3481235	4625122	1372724	109329259	9669759	14193252	42899217	11318091	26081811	1271033	7940919	279354	1745297
1997	0	1809918612	1013054933	303807549	17335023	14151399	2958081	3946205	1278184	99501910	8800567	13280013	40138946	10589850	24403625	1185843	7408686	273832	1710793
1996	0	1434498813	841489178	283134254	15729929	13218786	2344505	3277896	1191207	90288770	7985700	12404826	37493686	9891951	22795363	1107468	6919031	261406	1633161
1995	0	1138114760	678093221	264258637	14338847	12367269	1860103	2641411	1111793	82304049	7279482	11605742	35078449	9254740	21326950	1035909	6471955	235173	1469269
1994	0	901007519	531036860	246281859	13054771	11556300	1472582	2068575	1036161	74933537	6627588	10844710	32778222	8647871	19928462	967757	6046169	186850	1167365
1993	0	715273513	400320095	229203920	11877701	10826429	1169023	1559387	964310	68177234	6030018	10159781	30708019	8101690	18669822	903013	5641672	116896	730322
1992	0	569057380	291389457	213024820	10807638	10137106	930052	1135064	896242	62035141	5486773	9512903	28752827	7585852	17481107	845084	5279753	55687	347909
1991	0	450503759	231477606	198643398	9844581	9488331	736291	901687	835736	56507257	4997853	8904077	26912646	7100358	16362316	787154	4917835	45562	284653
1990	0	355660863	220584542	185160814	8935027	8880105	581282	859254	779012	51286478	4536095	8333303	25187476	6645206	15313450	736041	4598495	37278	232898
1989	0	284528690	212414744	172577069	8132480	8271878	465026	827430	726069	46679908	4128661	7762529	23462307	6190055	14264583	688334	4300444	30375	189769
1988	0	225251880	204244946	160892164	7383436	7744749	368145	795606	676908	42380443	3748390	7267858	21967160	5795591	13355566	644035	4023683	24852	155265
1987	0	177830431	196075148	150106097	6741398	7258168	290641	763782	631529	38695187	3422443	6811239	20587024	5431470	12516473	599737	3746922	20250	126512
1986	0	142264345	187905351	139320030	6099360	6771587	232513	731957	586150	35009931	3096496	6354619	19206888	5067349	11677379	562253	3512739	17028	106385
1985 & Earlier	0	403082311	977652476	658848916	26698076	32398190	658787	3808300	2771920	153245225	13553960	30403239	91894034	24244383	55869618	2668147	16669543	52465	327782
Total	261908057	39517873623	27232659493	8988389027	535031587	405484224	64586925	106080773	37816098	3071046599	271622448	380516132	1150113069	303434086	699244275	34075950	212893270	4602212	28752827

2009 Vehicle Population Estimates By Vehicle Types and Model Years

Age	MC	LDGV	LDGT1	LDGT2	HDGV2b-3	HDGV4-8	LDDV	LDDT12	LDDT34	HDDV2b	HDDV3	HDDV4-5	HDDV6-7	HDDV8a	HDDV8b	HDGBS	HDDBS	HDGBT	HDDBT
2009+	7,880	140,473	81,156	25,030	1,347	690	230	228	86	5,692	417	453	1,029	126	205	126	788	4	20
2008	9,833	196,837	114,654	33,393	2,610	1,499	322	337	116	11,329	858	968	2,271	282	452	252	1,577	9	40
2007	8,491	207,047	120,996	33,427	2,525	1,524	338	371	117	11,259	882	967	2,344	296	467	236	1,474	10	42
2006	7,409	217,487	127,232	33,391	2,444	1,548	355	407	118	11,196	907	966	2,419	311	481	220	1,375	11	43
2005	6,505	228,125	132,951	33,446	2,366	1,574	373	443	120	11,139	933	965	2,497	327	497	206	1,285	12	44
2004	5,673	238,261	137,793	33,446	2,287	1,598	389	477	121	11,062	958	963	2,574	343	512	192	1,202	13	46
2003	5,021	247,391	141,344	33,460	2,216	1,624	404	507	122	11,009	986	962	2,657	360	529	180	1,122	15	47
2002	4,514	255,320	143,479	33,432	2,142	1,649	417	533	123	10,936	1,013	960	2,740	377	545	168	1,047	16	49
2001	4,099	260,221	143,404	33,442	2,073	1,678	425	550	124	10,869	1,041	960	2,830	396	563	157	979	17	51
2000	3,819	262,032	141,077	33,510	2,009	1,703	428	557	126	10,822	1,071	957	2,917	415	580	146	915	19	52
1999	3,590	258,499	136,232	33,494	1,943	1,733	422	553	127	10,754	1,101	957	3,015	437	600	137	855	21	54
1998	18,571	249,241	129,143	33,475	1,882	1,760	407	537	128	10,701	1,132	956	3,109	458	618	128	799	23	55
1997	0	222,787	119,647	33,470	1,822	1,789	364	509	129	10,643	1,165	955	3,210	481	638	119	745	25	56
1996	0	185,744	108,230	33,495	1,758	1,815	304	469	131	10,554	1,194	952	3,308	504	658	111	696	26	55
1995	0	155,014	95,265	33,569	1,705	1,845	253	419	132	10,514	1,230	951	3,415	529	679	104	651	26	51
1994	0	129,084	81,748	33,595	1,651	1,873	211	364	134	10,461	1,265	949	3,520	555	700	97	608	22	42
1993	0	107,787	67,748	33,573	1,598	1,906	176	305	135	10,402	1,301	950	3,638	584	723	91	568	15	27
1992	0	90,212	54,404	33,505	1,547	1,939	147	246	136	10,344	1,338	949	3,759	613	747	85	531	8	13
1991	0	75,122	47,836	33,549	1,499	1,972	123	217	137	10,297	1,377	949	3,882	644	772	79	495	7	11
1990	0	62,386	50,628	33,580	1,447	2,005	102	230	139	10,214	1,412	948	4,008	677	797	74	463	7	10
1989	0	52,496	54,340	33,608	1,401	2,029	86	245	140	10,159	1,452	943	4,119	707	819	69	433	6	8
1988	0	43,721	58,406	33,645	1,353	2,064	71	262	142	10,081	1,490	943	4,255	743	846	65	405	5	7
1987	0	36,307	62,845	33,701	1,314	2,102	59	279	143	10,059	1,537	944	4,400	782	874	60	377	5	6
1986	0	30,555	67,665	33,587	1,265	2,131	50	296	144	9,946	1,571	940	4,529	818	900	57	353	4	5
1985 & Earlier	0	91,051	395,811	170,554	5,890	11,073	149	1,712	740	47,577	7,772	4,802	23,906	4,394	4,749	268	1,677	15	16
Total	85,405	4,043,198	2,814,033	966,377	50,094	53,122	6,608	11,053	3,814	298,019	35,401	27,207	100,349	16,159	19,950	3,429	21,420	340	850

2002 Vehicle VMT by Vehicle Types: **MICHIGAN**

	Michigan
HDDV	4997876762
HDGV	1072926883
LDDT	178830305
LDDV	79859882
LDGT1	33635866001
LDGT2	11180443007
LDGV	48862718749
MC	135478411
Total	100144000000

Assumptions:
On-road vehicle VMT & population estimates by vehicle types for LADCO states in 2009 were generated by projecting the 2002 FHWA VMT data by facility types (http://www.fhwa.dot.gov/policy/ohim/hs02/xls/vm2.xls) with an assumed constant growth rate of 2% per year as suggested by LADCO, and vehicle mix fractions developed in ENVIRON's Vehicle Mix study for LADCO, as well as data in MOBILE6 technical support document M6.FLT.007.

Growth Rates: 2% per year

2009 Vehicle VMT by Vehicle Types

	Michigan
HDDV	5740989405
HDGV	1232455733
LDDT	205419808
LDDV	91733902
LDGT1	38637037194
LDGT2	12842814640
LDGV	56127904710
MC	155622109
Total	115033977501

2009 Vehicle VMT Estimates By Vehicle Types and Model Years

Age	*MC*	*LDGV*	*LDGT1*	*LDGT2*	*HDGV2b-3*	*HDGV4-8*	*LDDV*	*LDDT12*	*LDDT34*	*HDDV2b*	*HDDV3*	*HDDV4-5*	*HDDV6-7*	*HDDV8a*	*HDDV8b*	*HDGBS*	*HDDBS*	*HDGBT*	*HDDBT*
2009+	22409584	2974778950	2244811861	762863190	33872715	18577101	4861897	8798402	3206669	144963427	12821466	12998059	39286739	10365012	23885501	1578332	7352141	177831	828367
2008	26144514	3962630072	2990506679	947799720	61684705	37154202	6476413	11721106	3984043	263989064	23348834	25996119	78573477	20730024	47771002	3156664	14704281	355662	1656735
2007	21008985	3962630072	2971188160	883585647	56095371	34755510	6476413	11645389	3714122	240068658	21233164	24317798	73500739	19391684	44686886	2950795	13745306	355662	1656735
2006	16962810	3957017282	2936414827	821940137	51044767	32509927	6467240	11509097	3454997	218453832	19321415	22746604	68751793	18138771	41799627	2753503	12826289	355662	1656735
2005	13694746	3945791701	2878459271	766716034	46465553	30417451	6448893	11281943	3222864	198856391	17588095	21282537	64326638	16971283	39109227	2573368	11987186	355662	1656735
2004	10893548	3917727749	2793457789	714060494	42223046	28427047	6403026	10948785	3001529	180699938	15982226	19889887	60117345	15860746	36550066	2406099	11208019	355662	1656735
2003	8714838	3867212634	2677546678	665257798	38451929	26589752	6320466	10494479	2796388	164560869	14554786	18604365	56231843	14835635	34187764	2247408	10468809	355662	1656735
2002	7002995	3794246358	2534589640	619023666	34950177	24854528	6201212	9934168	2602044	149574590	13229306	17390261	52562203	13867475	31956701	2097295	9769556	355662	1656735
2001	5602396	3676377758	2356859269	576642377	31785132	23272412	6008571	9237564	2423896	136029299	12031277	16283283	49216354	12984740	29922496	1960048	9130240	355662	1656735
2000	4513041	3519219625	2152082972	538113933	28956794	21741333	5751716	8434956	2261943	123924997	10960697	15212014	45978436	12130481	27953911	1831380	8530881	355083	1654036
1999	3579309	3300320797	1924124452	500869771	26330480	20363361	5393953	7541487	2105389	112685288	9966587	14247873	43064310	11361648	26182184	1711289	7971479	353924	1648640
1998	15095345	3025294064	1684574822	466194171	23973532	19036425	4944457	6602587	1959631	102598370	9074437	13319440	40258114	10621290	24476077	1599777	7452034	351607	1637847
1997	0	2570658036	1437297784	434087135	21818608	17811561	4201413	5633400	1824670	93376044	8258758	12462425	37667780	9937882	22901209	1492553	6952568	344656	1605468
1996	0	2037442941	1193884449	404548661	19798366	16637733	3329941	4679356	1700506	84730114	7494058	11641119	35185376	9282950	21391960	1393907	6493059	329016	1532615
1995	0	1616483656	962062226	377578750	18047490	15565978	2641936	3770744	1587139	77236975	6831318	10891231	32918833	8684969	20013950	1303840	6073508	295999	1378813
1994	0	1279716227	753422225	351893121	16431297	14545258	2091533	2952992	1479171	70320231	6219558	10177052	30760221	8115463	18701560	1218061	5673935	235177	1095496
1993	0	1015915075	567964447	327491773	14949787	13626610	1660384	2226102	1376600	63979882	5658778	9534291	28817470	7602907	17520409	1136571	5294340	147131	685359
1992	0	808241828	413416298	304374707	13602959	12758998	1320968	1620360	1279429	58215929	5148979	8927239	26982650	7118827	16404877	1063659	4954703	70090	326490
1991	0	639858114	328414816	283826204	12390814	11942422	1045766	1287202	1193054	53028371	4690159	8355895	25255761	6663222	15354965	990747	4615067	57346	267128
1990	0	505151142	312960001	264561982	11246011	11176882	825605	1226627	1112077	48129011	4256829	7820261	23636802	6236092	14370672	926412	4315387	46920	218559
1989	0	404120914	301368890	246582041	10235890	10411342	660484	1181197	1036499	43806046	3874479	7284627	22017843	5808963	13386380	866367	4035686	38231	178085
1988	0	319929057	289777779	229886382	9293111	9747874	522883	1135766	966319	39771278	3517619	6820410	20614745	5438784	12533326	810611	3775964	31280	145706
1987	0	252575571	278186668	214475004	8485014	9135443	412803	1090335	901538	36312906	3211739	6391903	19319578	5097080	11745892	754854	3516241	25487	118724
1986	0	202060457	266595557	199063627	7676917	8523011	330242	1044905	836757	32854534	2905859	5963395	18024410	4755376	10958458	707676	3296476	21432	99836
1985 & Earlier	0	572504628	1387069635	941378313	33603349	40777758	935686	5436534	3957051	143810636	12719506	28531454	86236550	22751771	52429988	3358245	15643278	66035	307602
Total	155622109	56127904710	38637037194	12842814640	673413812	510359919	91733902	151435483	53984326	2881976681	254899930	357089541	1079306008	284753074	656195089	42889459	199786431	5792542	26982650

2009 Vehicle Population Estimates By Vehicle Types and Model Years

Age	MC	LDGV	LDGT1	LDGT2	HDGV2b-3	HDGV4-8	LDDV	LDDT12	LDDT34	HDDV2b	HDDV3	HDDV4-5	HDDV6-7	HDDV8a	HDDV8b	HDGBS	HDDBS	HDGBT	HDDBT
2009+	4,682	199,516	115,142	35,763	1,696	868	326	325	123	5,342	391	425	966	118	192	159	740	5	18
2008	5,842	279,570	162,669	47,712	3,285	1,887	457	481	166	10,631	806	908	2,131	265	424	318	1,479	11	38
2007	5,045	294,073	171,666	47,761	3,177	1,918	481	530	168	10,566	828	907	2,199	278	438	297	1,383	12	39
2006	4,402	308,901	180,514	47,710	3,076	1,949	505	581	169	10,507	851	906	2,270	292	452	277	1,291	13	40
2005	3,865	324,010	188,628	47,788	2,978	1,981	530	632	171	10,453	876	905	2,343	306	466	259	1,206	15	42
2004	3,371	338,406	195,497	47,789	2,879	2,011	553	681	173	10,381	899	903	2,416	321	481	242	1,128	16	43
2003	2,984	351,373	200,535	47,809	2,789	2,044	574	724	174	10,332	925	902	2,493	337	496	226	1,053	19	45
2002	2,682	362,635	203,565	47,768	2,697	2,076	593	761	176	10,262	950	901	2,571	354	512	211	983	20	46
2001	2,436	369,597	203,458	47,783	2,609	2,111	604	785	178	10,200	976	900	2,656	372	528	197	919	22	48
2000	2,269	372,168	200,157	47,879	2,528	2,143	608	796	180	10,155	1,005	898	2,738	390	545	184	858	24	49
1999	2,133	367,151	193,282	47,857	2,445	2,181	600	789	181	10,092	1,033	898	2,829	410	563	172	802	26	50
1998	11,035	354,001	183,225	47,830	2,368	2,215	579	767	183	10,042	1,063	897	2,918	430	580	161	750	29	52
1997	0	316,428	169,753	47,823	2,293	2,251	517	726	185	9,988	1,093	896	3,012	451	599	150	700	31	52
1996	0	263,815	153,554	47,859	2,213	2,285	431	669	187	9,904	1,121	894	3,104	473	617	140	653	33	52
1995	0	220,169	135,159	47,965	2,146	2,322	360	598	189	9,867	1,154	893	3,204	497	637	131	611	32	48
1994	0	183,340	115,982	48,001	2,079	2,358	300	520	191	9,817	1,187	891	3,303	521	657	123	571	28	39
1993	0	153,091	96,119	47,970	2,012	2,399	250	435	193	9,762	1,221	891	3,414	548	679	114	533	19	25
1992	0	128,130	77,188	47,873	1,947	2,441	209	351	194	9,708	1,255	891	3,527	576	701	107	499	10	13
1991	0	106,696	67,868	47,936	1,887	2,482	174	310	196	9,663	1,292	890	3,643	605	724	100	464	9	11
1990	0	88,607	71,829	47,980	1,822	2,524	145	328	198	9,586	1,325	890	3,761	635	748	93	434	8	9
1989	0	74,561	77,096	48,020	1,764	2,554	122	350	200	9,533	1,363	885	3,865	664	768	87	406	7	8
1988	0	62,098	82,865	48,073	1,703	2,598	101	374	202	9,460	1,398	885	3,993	697	793	82	380	7	6
1987	0	51,567	89,162	48,153	1,654	2,646	84	398	205	9,439	1,442	886	4,129	733	820	76	354	6	5
1986	0	43,398	96,001	47,990	1,592	2,682	71	423	206	9,334	1,474	882	4,250	768	844	71	332	6	5
1985 & Earlier	0	129,321	561,567	243,691	7,413	13,936	211	2,443	1,057	44,648	7,293	4,507	22,434	4,123	4,456	338	1,574	19	15
Total	50,747	5,742,622	3,992,481	1,380,781	63,051	66,862	9,386	15,778	5,444	279,671	33,222	25,532	94,171	15,164	18,722	4,315	20,101	428	798

2002 Vehicle VMT by Vehicle Types: **OHIO**

	Ohio
HDDV	7920820442
HDGV	1267815949
LDDT	186311142
LDDV	83624221
LDGT1	35259612489
LDGT2	11637758482
LDGV	51165950600
MC	339106675
Total	107861000000

Assumptions:
On-road vehicle VMT & population estimates by vehicle types for LADCO states in 2009 were generated by projecting the 2002 FHWA VMT data by facility types (http://www.fhwa.dot.gov/policy/ohim/hs02/xls/vm2.xls) with an assumed constant growth rate of 2% per year as suggested by LADCO, and vehicle mix fractions developed in ENVIRON's Vehicle Mix study for LADCO, as well as data in MOBILE6 technical support document M6.FLT.007.

Growth Rates: 2% per year

2009 Vehicle VMT by Vehicle Types

	Ohio
HDDV	9098532917
HDGV	1456322010
LDDT	214012939
LDDV	96057944
LDGT1	40502211513
LDGT2	13368126372
LDGV	58773594126
MC	389526977
Total	123898384798

2009 Vehicle VMT Estimates By Vehicle Types and Model Years

Age	*MC*	*LDGV*	*LDGT1*	*LDGT2*	*HDGV2b-3*	*HDGV4-8*	*LDDV*	*LDDT12*	*LDDT34*	*HDDV2b*	*HDDV3*	*HDDV4-5*	*HDDV6-7*	*HDDV8a*	*HDDV8b*	*HDGBS*	*HDDBS*	*HDGBT*	*HDDBT*
2009+	56091885	3115000489	2353178489	794066706	40025438	21951491	5091071	9166457	3340810	229743415	20319936	20599806	62263080	16426855	37854628	1865024	11651945	210133	1312827
2008	65440532	4149415745	3134871171	986567726	72889266	43902982	6781691	12211424	4150704	418379659	37004097	41199613	124526161	32853711	75709256	3730048	23303890	420265	2625655
2007	52586142	4149415745	3114620065	919727094	66284671	41068586	6781691	12132539	3869491	380469712	33651106	38539748	116486697	30732661	70821433	3486784	21784071	420265	2625655
2006	42458440	4143538386	3078168075	855560088	60316663	38415110	6772085	11990546	3599526	346213735	30621295	36049661	108960391	28746997	66245599	3253656	20327578	420265	2625655
2005	34278374	4131783667	3017414758	798077144	54905670	35942551	6752873	11753890	3357683	315154983	27874265	33729353	101947242	26896719	61981754	3040800	18997737	420265	2625655
2004	27266888	4102396870	2928309892	743267826	49892543	33590606	6704844	11406795	3127089	286379963	25329224	31522231	95276197	25136699	57925901	2843148	17762884	420265	2625655
2003	21813511	4049500635	2806803258	692468946	45436431	31419579	6618392	10933484	2913367	260802167	23066965	29484888	89118310	23512065	54182036	2655632	16591357	420265	2625655
2002	17528714	3973094963	2656945075	644343691	41298613	29369165	6493517	10349734	2710893	237051357	20966295	27560730	83302528	21977688	50646165	2478252	15483155	420265	2625655
2001	14022971	3849670415	2470634902	600228874	37558661	27499670	6291795	9623991	2525293	215584278	19067613	25806351	77999903	20578698	47422281	2316076	14469943	420265	2625655
2000	11296282	3685104352	2255973181	560124495	34216577	25690481	6022833	8787808	2356565	196400932	17370919	24108565	72868330	19224836	44302395	2164036	13520056	419581	2621378
1999	8959120	3455887335	2017010133	521356928	31113213	24062211	5648207	7856963	2193461	178587824	15795417	22580557	68249915	18006361	41494496	2022132	12633495	418212	2612826
1998	37784117	3167896723	1765896422	485262987	28328143	22494248	5177523	6878787	2041606	162601701	14381505	21109142	63802552	16833014	38790594	1890364	11810260	415474	2595720
1997	0	2691830611	1506682268	451842671	25781793	21046897	4399454	5869057	1901000	147985818	13088786	19750913	59697294	15749924	36294685	1763664	11018687	407260	2544405
1996	0	2133481467	1251518336	421095981	23394590	19659852	3486903	4875103	1771642	134283428	11876861	18449277	55763089	14711964	33902771	1647100	10290441	388780	2428944
1995	0	1692679511	1008505067	393022915	21325680	18393420	2766469	3928481	1653532	122408022	10826526	17260827	52170988	13764261	31718851	1540672	9625520	349765	2185195
1994	0	1340037946	789793125	366286663	19415918	17187294	2190121	3076522	1541047	111446110	9856987	16128969	48749939	12861686	29638926	1439312	8992262	277895	1736182
1993	0	1063802054	595382509	340887222	17665302	16101781	1738649	2319224	1434186	101397690	8968242	15110298	45670996	12049369	27766994	1343020	8390667	173856	1086183
1992	0	846339755	433373663	316824595	16073834	15076574	1383234	1688143	1332950	92262763	8160292	14148219	42763105	11282181	25999058	1256864	7852398	82821	517434
1991	0	670018973	344268798	295435593	14641512	14111673	1095061	1341048	1242961	84041329	7433137	13242733	40026266	10560121	24335118	1170708	7314129	67763	423355
1990	0	528962347	328067913	275383403	13288764	13207078	864521	1277940	1158598	76276641	6746380	12393840	37460480	9883190	22775175	1094688	6839185	55442	346381
1989	0	423169878	315917250	256668026	12095162	12302484	691617	1230609	1079858	69425446	6140418	11544946	34894693	9206260	21215231	1023736	6395905	45175	282236
1988	0	335009487	303766586	239289462	10981134	11518502	547530	1183278	1006743	63030997	5574853	10809239	32671012	8619586	19863280	957852	5984287	36961	230921
1987	0	264481174	291615923	223247710	10026253	10794827	432261	1135946	939251	57550040	5090083	10130125	30618383	8078041	18615325	891968	5572669	30117	188158
1986	0	211584939	279465259	207205959	9071372	10071151	345809	1088615	871760	52069084	4605313	9451010	28565754	7536497	17367371	836220	5224378	25325	158223
1985 & Earlier	0	599490660	1454029393	979883663	39707144	48184729	979791	5663955	4122583	227916430	20158346	45217707	136670883	36057850	83092989	3968244	24792046	78030	487499
Total	389526977	58773594126	40502211513	13368126372	795734346	603062944	96057944	157770339	56242600	4567463524	403974862	565928747	1710524188	451287233	1039962312	50680006	316628946	6844713	42763105

2009 Vehicle Population Estimates By Vehicle Types and Model Years

Age	MC	LDGV	LDGT1	LDGT2	HDGV2b-3	HDGV4-8	LDDV	LDDT12	LDDT34	HDDV2b	HDDV3	HDDV4-5	HDDV6-7	HDDV8a	HDDV8b	HDGBS	HDDBS	HDGBT	HDDBT
2009+	11,720	208,920	120,701	37,226	2,004	1,026	341	339	128	8,466	620	674	1,531	187	305	188	1,172	6	29
2008	14,624	292,748	170,522	49,664	3,881	2,229	478	501	173	16,849	1,277	1,439	3,377	420	672	375	2,345	13	60
2007	12,629	307,934	179,953	49,715	3,755	2,266	503	552	175	16,745	1,312	1,438	3,486	441	694	351	2,192	14	62
2006	11,020	323,461	189,228	49,661	3,634	2,303	529	606	176	16,652	1,349	1,436	3,597	463	716	327	2,045	16	64
2005	9,675	339,283	197,734	49,743	3,519	2,341	555	659	178	16,566	1,388	1,435	3,713	486	739	306	1,911	18	66
2004	8,437	354,358	204,935	49,744	3,402	2,377	579	709	180	16,452	1,425	1,432	3,829	509	762	286	1,787	19	68
2003	7,468	367,936	210,216	49,764	3,296	2,415	601	755	182	16,374	1,466	1,430	3,951	535	786	267	1,669	22	71
2002	6,713	379,728	213,392	49,722	3,186	2,453	621	793	183	16,264	1,506	1,427	4,075	561	811	249	1,558	23	73
2001	6,097	387,018	213,280	49,737	3,083	2,495	633	818	185	16,166	1,548	1,427	4,210	589	838	233	1,456	26	75
2000	5,679	389,711	209,819	49,838	2,987	2,532	637	829	187	16,094	1,593	1,424	4,339	618	863	218	1,360	28	78
1999	5,339	384,457	202,613	49,814	2,889	2,577	628	822	189	15,994	1,637	1,424	4,484	649	892	203	1,271	31	80
1998	27,620	370,688	192,071	49,786	2,799	2,617	606	799	191	15,915	1,684	1,421	4,624	681	920	190	1,188	34	82
1997	0	331,343	177,948	49,779	2,709	2,660	542	756	193	15,829	1,732	1,420	4,774	715	949	177	1,109	37	83
1996	0	276,250	160,967	49,816	2,615	2,700	451	697	194	15,696	1,776	1,416	4,920	750	978	166	1,035	38	82
1995	0	230,547	141,684	49,927	2,536	2,744	377	623	197	15,637	1,829	1,415	5,078	787	1,010	155	968	38	76
1994	0	191,983	121,581	49,964	2,456	2,786	314	542	199	15,559	1,882	1,412	5,235	826	1,041	145	905	33	62
1993	0	160,308	100,759	49,932	2,377	2,835	262	453	201	15,471	1,935	1,412	5,411	868	1,076	135	844	23	40
1992	0	134,169	80,914	49,831	2,301	2,884	219	366	202	15,385	1,989	1,412	5,590	912	1,111	126	790	12	20
1991	0	111,726	71,145	49,896	2,229	2,933	183	323	204	15,314	2,048	1,411	5,773	958	1,147	118	736	11	17
1990	0	92,784	75,297	49,943	2,152	2,983	152	341	207	15,192	2,100	1,410	5,961	1,006	1,185	110	688	10	14
1989	0	78,076	80,818	49,984	2,084	3,018	128	365	209	15,109	2,160	1,403	6,126	1,052	1,217	103	644	9	12
1988	0	65,025	86,865	50,040	2,013	3,070	106	389	211	14,993	2,216	1,403	6,328	1,105	1,257	96	602	8	10
1987	0	53,998	93,467	50,123	1,955	3,126	88	415	213	14,960	2,286	1,403	6,544	1,162	1,300	90	561	7	8
1986	0	45,444	100,636	49,953	1,881	3,169	74	441	215	14,792	2,337	1,398	6,736	1,217	1,338	84	526	7	7
1985 & Earlier	0	135,417	588,676	253,659	8,760	16,468	221	2,546	1,101	70,760	11,559	7,142	35,554	6,535	7,063	399	2,494	22	23
Total	127,020	6,013,311	4,185,216	1,437,259	74,504	79,007	9,828	16,438	5,672	443,234	52,651	40,465	149,245	24,033	29,672	5,099	31,857	506	1,265

2002 Vehicle VMT by Vehicle Types: **WISCONSIN**

	Wisconsin
HDDV	4049765163
HDGV	700269463
LDDT	102544295
LDDV	45732119
LDGT1	19307465268
LDGT2	6410090319
LDGV	27981454779
MC	148678594
Total	58746000000

Assumptions:
On-road vehicle VMT & population estimates by vehicle types for LADCO states in 2009 were generated by projecting the 2002 FHWA VMT data by facility types (http://www.fhwa.dot.gov/policy/ohim/hs02/xls/vm2.xls) with an assumed constant growth rate of 2% per year as suggested by LADCO, and vehicle mix fractions developed in ENVIRON's Vehicle Mix study for LADCO, as well as data in MOBILE6 technical support document M6.FLT.007.

Growth Rates: 2% per year

2009 Vehicle VMT by Vehicle Types

	Wisconsin
HDDV	4651907201
HDGV	804389496
LDDT	117791162
LDDV	52531830
LDGT1	22178208632
LDGT2	7363178877
LDGV	32141896064
MC	170784971
Total	67480688232

2009 Vehicle VMT Estimates By Vehicle Types and Model Years

Age	*MC*	*LDGV*	*LDGT1*	*LDGT2*	*HDGV2b-3*	*HDGV4-8*	*LDDV*	*LDDT12*	*LDDT34*	*HDDV2b*	*HDDV3*	*HDDV4-5*	*HDDV6-7*	*HDDV8a*	*HDDV8b*	*HDGBS*	*HDDBS*	*HDGBT*	*HDDBT*
2009+	24593036	1703520491	1288553921	437372825	22107777	12124756	2784187	5045151	1838758	117463448	10389197	10532290	31833931	8398739	19354353	1030133	5957418	116065	671224
2008	28691875	2269217862	1716593348	543402601	40259887	24249512	3708747	6721079	2284517	213909579	18919493	21064580	63667863	16797479	38708706	2060267	11914837	232131	1342447
2007	23055971	2269217862	1705504244	506586707	36611884	22683953	3708747	6677661	2129740	194526943	17205172	19704642	59557438	15713026	36209655	1925902	11137782	232131	1342447
2006	18615562	2266003673	1685543856	471243448	33315496	21218323	3703494	6599509	1981153	177012512	15656087	18431508	55709380	14697794	33870118	1797135	10393105	232131	1342447
2005	15029077	2259575293	1652276543	439581779	30326771	19852622	3692988	6469256	1848044	161132762	14251583	17245178	52123690	13751782	31690094	1679565	9713182	232131	1342447
2004	11954948	2243504345	1603484484	409392746	27557805	18553541	3666722	6278217	1721127	146420640	12950351	16116719	48712911	12851917	29616414	1570394	9081825	232131	1342447
2003	9563958	2214576639	1536949858	381412666	25096502	17354390	3619443	6017710	1603496	133343198	11793701	15075064	45564501	12021273	27702247	1466820	8482846	232131	1342447
2002	7685324	2172792174	1454890486	354905222	22811006	16221858	3551152	5696418	1492056	121199860	10719669	14091278	42591002	11236775	25894423	1368846	7916244	232131	1342447
2001	6148259	2105294192	1352870727	330606732	20745269	15189255	3440835	5296974	1389903	110224150	9748909	13194297	39879870	10521498	24246112	1279269	7398207	232131	1342447
2000	4952764	2015296883	1235326221	308517195	18899292	14189962	3293746	4836745	1297036	100416069	8881421	12326252	37256194	9829294	22650974	1195291	6912548	231753	1340261
1999	3928054	1889943489	1104474790	287163976	17185170	13290598	3088872	4324415	1207265	91308565	8075897	11545010	34894886	9206310	21215348	1116911	6459266	230997	1335888
1998	16566142	1732448198	966969896	267283393	15646856	12424544	2831466	3786034	1123685	83135164	7352991	10792704	32621034	8606400	19832895	1044130	6038362	229484	1327143
1997	0	1472098840	825029361	248875446	14240397	11625109	2405958	3230286	1046296	75662340	6692048	10098267	30522094	8052637	18556783	974148	5633646	224948	1300906
1996	0	1166750827	685306647	231940135	12921842	10858985	1906905	2683221	975099	68656568	6072414	9432765	28510609	7521948	17333844	909765	5261307	214740	1241873
1995	0	925686607	552237395	216477459	11779094	10159480	1512917	2162208	910092	62584899	5535397	8825133	26674036	7037405	16217246	850980	4921346	193190	1117249
1994	0	732835230	432475068	201751101	10724249	9493284	1197726	1693295	848181	56980281	5039690	8246436	24924919	6575936	15153820	794994	4597573	153494	887677
1993	0	581768319	326019667	187761061	9757309	8893708	950826	1276484	789366	51842715	4585292	7725608	23350713	6160614	14196737	741808	4289989	96028	555345
1992	0	462843303	237306832	174507339	8878272	8327442	756458	929141	733646	47172200	4172203	7233716	21863964	5768365	13292825	694220	4014782	45746	264554
1991	0	366417615	188514773	162726253	8087139	7794486	598863	738103	684117	42968736	3800422	6770758	20464670	5399190	12442084	646633	3739575	37428	216453
1990	0	289277065	179643490	151681485	7339958	7294839	472786	703369	637684	38998799	3449296	6336735	19152832	5053088	11644515	604643	3496746	30623	177098
1989	0	231421652	172990027	141373034	6680680	6795193	378229	677318	594346	35495913	3139479	5902712	17840994	4706986	10846945	565454	3270105	24952	144302
1988	0	183208808	166336565	131800902	6065354	6362166	299431	651267	554104	32226552	2850317	5526559	16704068	4407031	10155718	529063	3059652	20415	118065
1987	0	144638532	159683102	122965087	5537932	5962449	236393	625217	516957	29424243	2602463	5179340	15654598	4130149	9517663	492672	2849200	16635	96201
1986	0	115710826	153029640	114129273	5010510	5562731	189115	599166	479811	26621935	2354609	4832122	14605128	3853268	8879607	461880	2671125	13988	80897
1985 & Earlier	0	327847340	796197690	539721012	21931969	26614505	535825	3117400	2269039	116529345	10306580	23118955	69877228	18435694	42483868	2191833	12675703	43099	249249
Total	170784971	32141896064	22178208632	7363178877	439518420	333097690	52531830	86835645	30955517	2335257415	206544680	289348628	874558554	230734597	531712993	27992754	161886371	3780631	21863964

2009 Vehicle Population Estimates By Vehicle Types and Model Years

Age	MC	LDGV	LDGT1	LDGT2	HDGV2b-3	HDGV4-8	LDDV	LDDT12	LDDT34	HDDV2b	HDDV3	HDDV4-5	HDDV6-7	HDDV8a	HDDV8b	HDGBS	HDDBS	HDGBT	HDDBT
2009+	5,139	114,254	66,093	20,504	1,107	567	187	186	71	4,329	317	345	783	96	156	104	599	3	15
2008	6,412	160,097	93,374	27,355	2,144	1,231	262	276	95	8,615	653	736	1,727	215	344	207	1,199	7	31
2007	5,537	168,402	98,538	27,383	2,074	1,252	275	304	96	8,562	671	735	1,782	225	355	194	1,121	8	32
2006	4,831	176,893	103,617	27,353	2,007	1,272	289	333	97	8,514	690	734	1,839	237	366	181	1,046	9	33
2005	4,242	185,546	108,275	27,399	1,944	1,293	303	363	98	8,470	709	734	1,899	248	378	169	977	10	34
2004	3,699	193,790	112,218	27,399	1,879	1,313	317	390	99	8,412	728	732	1,958	260	390	158	914	11	35
2003	3,274	201,215	115,110	27,410	1,820	1,334	329	415	100	8,372	750	731	2,020	273	402	148	853	12	36
2002	2,943	207,664	116,849	27,387	1,760	1,355	339	436	101	8,316	770	730	2,083	287	415	138	796	13	37
2001	2,673	211,651	116,788	27,395	1,703	1,378	346	450	102	8,265	791	730	2,152	301	428	129	744	14	39
2000	2,490	213,124	114,893	27,451	1,650	1,399	348	456	103	8,229	815	728	2,218	316	441	120	695	16	40
1999	2,341	210,251	110,947	27,438	1,596	1,423	344	453	104	8,177	837	728	2,292	332	456	112	650	17	41
1998	12,110	202,720	105,174	27,422	1,546	1,446	331	440	105	8,137	861	727	2,364	348	470	105	608	19	42
1997	0	181,204	97,441	27,418	1,496	1,469	296	416	106	8,093	886	726	2,441	366	485	98	567	20	42
1996	0	151,075	88,142	27,439	1,444	1,491	247	384	107	8,025	908	724	2,515	383	500	92	529	21	42
1995	0	126,081	77,583	27,500	1,401	1,516	206	343	108	7,995	935	723	2,597	403	516	86	495	21	39
1994	0	104,991	66,576	27,520	1,357	1,539	172	298	109	7,955	962	722	2,677	422	532	80	463	18	32
1993	0	87,669	55,173	27,503	1,313	1,566	143	250	110	7,910	989	722	2,767	444	550	75	432	13	21
1992	0	73,374	44,307	27,447	1,271	1,593	120	202	111	7,866	1,017	722	2,858	466	568	70	404	7	10
1991	0	61,100	38,957	27,483	1,231	1,620	100	178	113	7,830	1,047	722	2,952	490	587	65	376	6	9
1990	0	50,741	41,231	27,508	1,189	1,647	83	188	114	7,767	1,074	721	3,048	514	606	61	352	5	7
1989	0	42,698	44,254	27,531	1,151	1,667	70	201	115	7,725	1,104	717	3,132	538	622	57	329	5	6
1988	0	35,561	47,566	27,562	1,112	1,696	58	214	116	7,666	1,133	717	3,235	565	643	53	308	4	5
1987	0	29,530	51,180	27,608	1,080	1,727	48	228	117	7,649	1,169	718	3,346	594	665	50	287	4	4
1986	0	24,852	55,106	27,514	1,039	1,750	41	243	118	7,563	1,195	715	3,444	622	684	46	269	4	4
1985 & Earlier	0	74,056	322,347	139,716	4,838	9,096	121	1,401	606	36,178	5,910	3,652	18,178	3,341	3,611	221	1,275	12	12
Total	55,691	3,288,538	2,291,741	791,644	41,152	43,639	5,375	9,047	3,122	226,617	26,919	20,689	76,306	12,288	15,170	2,816	16,288	279	647

2009 NONROAD Equipment Population for LADCO States

LADCO States	**2009 Equipment Population**				
Equipment Type	**CNG**	**Diesel**	**Gasoline**	**LPG**	**Grand Total**
Railway Maintenance	-	2,241	2,295	27	4,563
Pleasure Craft	-	68,922	2,565,241	-	2,634,163
Recreational	-	6,532	3,049,445	725	3,056,702
Construction and Mining	5	253,840	123,092	3,610	380,546
Industrial	13,985	112,663	21,488	136,312	284,447
Lawn and Garden	-	73,395	19,735,605	1,150	19,810,150
Agricultural	17	467,073	239,613	51	706,754
Commercial	6,082	206,828	1,373,799	38,582	1,625,291
Logging	-	1,178	19,523	-	20,700
Airport Ground Support	-	3,233	273	96	3,602
Underground Mining	-	735	-	-	735
	20,089	1,196,639	27,130,373	180,552	28,527,653

Illinois	2009 Equipment Population				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	-	607	622	7	1,236
Pleasure Craft	-	15,292	327,175	-	342,467
Recreational	-	908	438,748	101	439,757
Construction and Mining	1	72,820	40,645	1,149	114,615
Industrial	3,241	27,922	4,979	31,631	67,773
Lawn and Garden	-	19,568	4,912,012	307	4,931,887
Agricultural	6	173,353	88,932	19	262,310
Commercial	1,865	63,409	421,173	11,828	498,274
Logging	-	2	40	-	42
Airport Ground Support	-	1,581	133	47	1,762
Underground Mining	-	227	-	-	227
	5,113	375,688	6,234,459	45,089	6,660,350

Indiana	2009 Equipment Population				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	-	299	307	4	610
Pleasure Craft	-	13,584	238,125	-	251,709
Recreational	-	750	325,723	83	326,556
Construction and Mining	1	33,437	14,276	533	48,246
Industrial	2,150	16,522	3,284	21,276	43,233
Lawn and Garden	-	10,034	2,725,408	157	2,735,599
Agricultural	4	93,815	48,128	10	141,957
Commercial	791	26,881	178,550	5,014	211,235
Logging	-	39	650	-	689
Airport Ground Support	-	392	33	12	436
Underground Mining	-	221	-	-	221
	2,945	195,973	3,534,483	27,089	3,760,491

Michigan	2009 Equipment Population				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0	499	511	6	1016
Pleasure Craft	0	4941	1040396	0	1045337
Recreational	0	1746	1073421	194	1075360

Construction and Mining	1	60790	26605	460	87856
Industrial	3071	25014	4700	30277	63062
Lawn and Garden	0	15117	4459434	237	4474788
Agricultural	2	52191	26775	6	78973
Commercial	1204	40953	272018	7639	321815
Logging	0	531	8800	0	9331
Airport Ground Support	0	701	59	21	781
Underground Mining	0	0	0	0	0
Grand Total	4,278	202,481	6,912,719	38,841	7,158,319

Ohio	2009 Equipment Population				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	0	571	585	7	1163
Pleasure Craft	0	18406	327078	0	345483
Recreational	0	1588	565431	176	567194
Construction and Mining	1	61254	29586	1066	91908
Industrial	3625	28618	5627	34322	72191
Lawn and Garden	0	21994	5111759	345	5134098
Agricultural	3	77609	39814	8	117435
Commercial	1500	51007	338801	9514	400822
Logging	0	114	1883	0	1997
Airport Ground Support	0	429	36	13	478
Underground Mining	0	287	0	0	287
Grand Total	5129	261876	6420600	45452	6733057

Wisconsin	2009 Equipment Population				
Equipment Type	CNG	Diesel	Gasoline	LPG	Grand Total
Railway Maintenance	-	264	270	3	537
Pleasure Craft	-	16,700	632,466	-	649,166
Recreational	-	1,541	646,123	171	647,835
Construction and Mining	-	25,540	11,980	401	37,921
Industrial	1,898	14,586	2,898	18,805	38,188
Lawn and Garden	-	6,682	2,526,992	105	2,533,779
Agricultural	3	70,105	35,964	8	106,079
Commercial	723	24,579	163,257	4,585	193,144
Logging	-	492	8,150	-	8,642
Airport Ground Support	-	131	11	4	146
Underground Mining	-	-	-	-	-
Grand Total	2,623	160,620	4,028,111	24,081	4,215,436

LADCO 2009 Diesel Construction Equipment - Major NOx Emissions Contributors

Sum of Population			
Equipment Type	HP Range	Tech Type	Total
Crawler Tractor/Dozers	R4:75-99	T0	0
		T1	28
		T2	50
		T4A	32
	R4:75-99 Total		109
	R5:100-174	T0	9
		T1	795
		T2	1,433
		T3B	913
	R5:100-174 Total		3,151
	R6:175-299	T0	5
		T1	1,157
		T2	2,813
		T3	3,145
	R6:175-299 Total		7,120
	R7:300-599	T1	1,006
		T2	1,658
		T3	3,502
	R7:300-599 Total		6,166
	R8:600-749	T0	81
		T1	601
		T2	1,164
		T3	1,276
	R8:600-749 Total		3,122
	R9:750+	T0	93
		T1	736
		T2	612
		T3	491
	R9:750+ Total		1,932
Crawler Tractor/Dozers Total			21,600
Excavators	R1:1-24	T0	1
		T1	1
		T2	82
		T4A	190
	R1:1-24 Total		274
	R2:25-49	T0	3
		T1	4
		T2	726
		T4A	1,653
	R2:25-49 Total		2,386
	R3:50-74	T0	0
		T2	263
		T4A	595
	R3:50-74 Total		858
	R4:75-99	T1	121
		T2	317
		T4A	228
	R4:75-99 Total		665
	R5:100-174	T1	546
		T2	1,430
		T3B	1,027
	R5:100-174 Total		3,003
	R6:175-299	T1	1,437
		T2	3,994
		T3	5,790
	R6:175-299 Total		11,222
	R7:300-599	T1	1,051
		T2	1,785
		T3	5,369
	R7:300-599 Total		8,204
	R8:600-749	T0	20
		T1	287
		T2	835
		T3	1,032
	R8:600-749 Total		2,173
	R9:750+	T0	6
		T1	78
		T2	67
		T3	32
	R9:750+ Total		183
Excavators Total			28,969
Off-highway Trucks	R6:175-299	T1	0
		T2	1
		T3	4
	R6:175-299 Total		5
	R7:300-599	T1	35
		T2	23
		T3	421
	R7:300-599 Total		479
	R8:600-749	T1	59
		T2	253
		T3	705
	R8:600-749 Total		1,017
	R9:750+	T0	5
		T1	439
		T2	667
		T3	389
	R9:750+ Total		1,500

Off-highway Trucks Total			3,002
Rubber Tire Loaders	R2:25-49	T0	3
		T1	12
		T2	233
		T4A	251
	R2:25-49 Total		498
	R3:50-74	T0	3
		T1	14
		T2	263
		T4A	282
	R3:50-74 Total		561
	R4:75-99	T0	15
		T1	275
		T2	314
		T4A	190
	R4:75-99 Total		794
	R5:100-174	T0	63
		T1	1,184
		T2	1,350
		T3B	816
	R5:100-174 Total		3,413
	R6:175-299	T0	97
		T1	2,191
		T2	3,182
		T3	3,162
	R6:175-299 Total		8,632
	R7:300-599	T0	45
		T1	2,140
		T2	2,163
		T3	3,894
	R7:300-599 Total		8,241
	R8:600-749	BASE	26
		T0	332
		T1	1,718
		T2	1,938
		T3	2,031
	R8:600-749 Total		6,046
	R9:750+	BASE	4
		T0	144
		T1	440
		T2	270
		T3	150
	R9:750+ Total		1,008
Rubber Tire Loaders Total			29,194
Tractors/Loaders/Backhoes	R1:1-24	T0	0
		T1	0
		T2	0
		T4A	0
	R1:1-24 Total		1
	R2:25-49	T0	69
		T1	213
		T2	365
		T4A	232
	R2:25-49 Total		878
	R3:50-74	T0	22
		T1	68
		T2	141
		T4A	83
	R3:50-74 Total		313
	R4:75-99	BASE	140
		T0	1,348
		T1	2,323
		T2	1,302
		T4A	730
	R4:75-99 Total		5,843
	R5:100-174	BASE	496
		T0	4,761
		T1	8,208
		T2	4,601
		T3B	2,578
	R5:100-174 Total		20,644
	R6:175-299	BASE	330
		T0	2,477
		T1	5,279
		T2	3,010
		T3	2,640
	R6:175-299 Total		13,736
	R7:300-599	BASE	2
		T0	10
		T1	32
		T2	12
		T3	19
	R7:300-599 Total		75
Tractors/Loaders/Backhoes Total			41,490
Grand Total			124,254

LADCO 2009 Population and Emissions for Major NOx Emission Contributors (Ag Tractors & Combines) by Technology Types (Tier 0, Tier 1, Tier 2 and Tier 3 Engines)

			Data	
Equipment Type	HP Range	Tech Type	Sum of Population	Sum of NOx-Exhaust
Agricultural Tractors	R1:1-24	T0	0	0
		T1	1	0
		T2	1	0
		T4A	1	0
	R1:1-24 Total		2	0
	R2:25-49	T0	5,938	363
		T1	17,824	697
		T2	30,034	1,232
		T4A	18,576	787
	R2:25-49 Total		72,373	3,079
	R3:50-74	T0	2,249	211
		T1	6,804	437
		T2	13,355	857
		T4A	7,737	524
	R3:50-74 Total		30,145	2,030
	R4:75-99	BASE	1,342	274
		T0	11,448	1,438
		T1	18,630	1,897
		T2	10,488	897
		T4A	5,824	336
	R4:75-99 Total		47,732	4,841
	R5:100-174	BASE	1,183	334
		T0	10,090	1,756
		T1	16,420	2,316
		T2	9,244	1,095
		T3B	5,133	428
	R5:100-174 Total		42,069	5,928
	R6:175-299	BASE	1,971	864
		T0	13,340	4,371
		T1	26,468	5,855
		T2	15,151	2,426
		T3	13,168	1,418
	R6:175-299 Total		70,097	14,935
	R7:300-599	BASE	1,699	1,318
		T0	8,619	5,000
		T1	25,699	9,914
		T2	9,493	2,628
		T3	14,921	2,845
	R7:300-599 Total		60,432	21,706
	R8:600-749	BASE	4,594	6,258
		T0	8,367	8,521
		T1	7,184	5,253
		T2	5,675	2,992
		T3	5,449	1,824
	R8:600-749 Total		31,270	24,847
	R9:750+	BASE	0	1
		T0	1	1
		T1	1	1
		T2	0	0
		T3	1	0
	R9:750+ Total		3	4
Agricultural Tractors Total			354,123	77,370
Combines	R5:100-174	BASE	1,658	160
		T0	719	42
		T1	514	24
		T2	263	10
		T3B	142	4
	R5:100-174 Total		3,296	241
	R6:175-299	BASE	15,211	2,294
		T0	5,910	649
		T1	4,692	348
		T2	2,400	129
		T3	2,020	73
	R6:175-299 Total		30,233	3,492
	R7:300-599	BASE	18,138	4,465
		T0	6,232	1,117
		T1	6,410	764
		T2	2,105	180
		T3	3,167	187
	R7:300-599 Total		36,051	6,714
	R8:600-749	BASE	991	364
		T0	309	83
		T1	231	44
		T2	172	24
		T3	160	14
	R8:600-749 Total		1,862	529
Combines Total			71,443	10,976
Grand Total			425,566	88,346

Appendix E

Detailed Emission Reduction Scenario Results by Technology Groups for Diesel Construction and Agricultural Equipment in the LADCO States

A Preliminary Scenario for Off Road Strategies for Diesel Construction Equipment in the LADCO States: Tier 0 Engines

Tier 0 Engines

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)							
Excavators							
175-300 HP	$15,329	0.34	$14,687	0	0	$0	0.000
300-600 HP	$15,006	0.66	$27,827	0	0	$0	0.000
Rubber Tire Loaders							
300-600 HP	$15,006	0.46	$19,394	45	0	$0	0.000
600-750 HP	$14,697	0.70	$29,091	359	0	$0	0.000
750+ HP	$15,666	1.15	$51,076	148	0	$0	0.000
Crawler Tractor/Dozer							
300-600 HP	$15,006	0.56	$23,855	110	0	$0	0.000
600-750 HP	$14,697	0.86	$35,783	74	0	$0	0.000
750+ HP	$15,666	1.06	$47,047	497	0	$0	0.000
Tractors/Loaders/Backhoes							
100-175 HP	$49,101	0.07	$10,296	5257	0	$0	0.000
175-300 HP	$50,157	0.13	$17,784	2807	0	$0	0.000
Off-Highway Trucks							
750+ HP	$15,666	2.85	$126,370	5	0	$0	0.000
Sub Total				**9301**	**0**	**-**	**0.000**
Measure 20: Fleet Modernization (Tier 2 Engines)							
Excavators							
175-300 HP	$2,962	0.94	$23,750	0	0	$0	0.000
300-600 HP	$2,785	1.89	$45,000	0	0	$0	0.000
Rubber Tire Loaders							
300-600 HP	$3,997	1.32	$45,000	45	13	$585,000	0.047
600-750 HP	$3,841	2.06	$67,500	359	108	$7,290,000	0.610
750+ HP	$4,349	3.19	$118,510	148	30	$3,555,293	0.263
Crawler Tractor/Dozer							
300-600 HP	$3,249	1.62	$45,000	110	33	$1,485,000	0.147
600-750 HP	$3,123	2.53	$67,500	74	22	$1,485,000	0.153
750+ HP	$3,536	2.94	$88,749	497	149	$13,223,559	1.201
Tractors/Loaders/Backhoes							
100-175 HP	$7,675	0.21	$13,750	5257	526	$7,232,500	0.303
175-300 HP	$8,005	0.35	$23,750	2807	281	$6,673,750	0.268
Off-Highway Trucks							
750+ HP	$2,016	7.90	$135,959	5	1	$135,959	0.022
Sub Total				**9301**	**1163**	**41,666,061**	**3.012**
Measure 51a: Lean NOx Catalyst							
Excavators							
175-300 HP	$3,764	0.75	$20,000	0	0	$0	0.000
300-600 HP	$3,685	1.46	$37,895	0	0	$0	0.000
Rubber Tire Loaders							
300-600 HP	$5,011	1.02	$37,895	45	9	$341,053	0.025
600-750 HP	$4,908	1.50	$54,737	359	72	$3,941,053	0.295
750+ HP	$5,231	2.56	$99,798	148	30	$2,993,931	0.211
Crawler Tractor/Dozer							
300-600 HP	$4,193	1.25	$37,895	110	22	$833,684	0.075
600-750 HP	$4,106	1.84	$54,737	74	15	$821,053	0.076

750+ HP	$4,377	2.36	$74,736	497	99	$7,398,841	0.640
Tractors/Loaders/Backhoes							
100-175 HP	$16,312	0.16	$20,000	5257	0	$0	0.000
175-300 HP	$10,542	0.28	$20,000	2807	140	$2,800,000	0.107
Off-Highway Trucks							
750+ HP	$2,781	6.34	$114,492	5	1	$114,492	0.017
Sub Total				**9301**	**388**	**19,244,106**	**1.446**
Measure 51b: EGR+DPF Retrofit							
Excavators							
175-300 HP	$8,102	0.56	$23,000	0	0	$0	0.000
300-600 HP	$7,931	1.09	$43,579	0	0	$0	0.000
Rubber Tire Loaders							
300-600 HP	$9,964	0.76	$43,579	45	4	$174,316	0.008
600-750 HP	$9,759	1.17	$65,368	359	36	$2,353,263	0.115
750+ HP	$10,402	1.92	$114,767	148	7	$803,371	0.037
Crawler Tractor/Dozer							
300-600 HP	$8,710	0.94	$43,579	110	11	$479,368	0.028
600-750 HP	$8,530	1.43	$65,368	74	7	$457,579	0.028
750+ HP	$9,093	1.77	$85,946	497	50	$4,297,306	0.242
Tractors/Loaders/Backhoes							
100-175 HP	$32,476	0.12	$23,000	5257	0	$0	0.000
175-300 HP	$23,788	0.21	$23,000	2807	0	$0	0.000
Off-Highway Trucks							
750+ HP	$6,646	4.75	$131,666	5	1	$131,666	0.013
Sub Total				**9301**	**116**	**8,696,870**	**0.471**
Measure 51c: SCR Retrofit							
Excavators							
175-300 HP	$2,775	1.41	$27,500	0	0	$0	0.000
300-600 HP	$2,716	2.73	$52,105	0	0	$0	0.000
Rubber Tire Loaders							
300-600 HP	$3,689	1.90	$52,105	45	13	$677,368	0.068
600-750 HP	$3,613	2.92	$78,158	359	108	$8,441,053	0.863
750+ HP	$3,851	4.80	$137,222	148	45	$6,174,983	0.592
Crawler Tractor/Dozer							
300-600 HP	$3,089	2.34	$52,105	110	33	$1,719,474	0.212
600-750 HP	$3,025	3.59	$78,158	74	22	$1,719,474	0.216
750+ HP	$3,224	4.42	$102,762	497	149	$15,311,490	1.806
Tractors/Loaders/Backhoes							
100-175 HP	$12,009	0.31	$27,500	5257	263	$7,232,500	0.223
175-300 HP	$7,778	0.52	$27,500	2807	281	$7,727,500	0.402
Off-Highway Trucks							
750+ HP	$2,054	11.88	$157,426	5	1	$157,426	0.033
Sub Total				**9301**	**915**	**49,161,267**	**4.414**
Grand Total					**2582**	**$ 118,768,304**	**9.343**

A Preliminary Scenario for Off Road Strategies for Diesel Construction Equipment in LADCO States: Tier 1 Engines

Tier 1 Engines

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Emulsified Diesel Fuel (3 yrs of fuel cost)							
Excavators							
175-300 HP	$20,661	0.25	$14,687	1437	0	$0	0.000
300-600 HP	$20,661	0.48	$27,827	1051	0	$0	0.000
Rubber Tire Loaders							
300-600 HP	$20,661	0.33	$19,394	2140	0	$0	0.000
600-750 HP	$20,661	0.50	$29,091	1718	0	$0	0.000
750+ HP	$20,661	0.87	$51,076	440	0	$0	0.000
Crawler Tractor/Dozer							
300-600 HP	$20,661	0.41	$23,855	1006	0	$0	0.000
600-750 HP	$20,661	0.61	$35,783	601	0	$0	0.000
750+ HP	$20,661	0.81	$47,047	736	0	$0	0.000
Tractors/Loaders/Backhoes							
100-175 HP	$67,603	0.05	$10,296	8208	0	$0	0.000
175-300 HP	$67,603	0.09	$17,784	5279	0	$0	0.000
Off-Highway Trucks							
750+ HP	$20,661	2.16	$126,370	439	0	$0	0.000
Sub Total				**23055**	**0**	**-**	**0.000**
Diesel Engine Upgrades (Tier 3 Engines, except Tier 2 Engines for 750+ HP Engines)							
Excavators							
175-300 HP	$4,077	0.82	$28,500	1437	287	$8,179,500	0.644
300-600 HP	$4,077	1.55	$54,000	1051	210	$11,340,000	0.893
Rubber Tire Loaders							
300-600 HP	$5,850	1.08	$54,000	2140	428	$23,112,000	1.269
600-750 HP	$5,850	1.62	$81,000	1718	344	$27,864,000	1.530
750+ HP	$8,437	1.65	$118,510	440	44	$5,214,430	0.198
Crawler Tractor/Dozer							
300-600 HP	$4,756	1.33	$54,000	1006	201	$10,854,000	0.733
600-750 HP	$4,756	2.00	$81,000	601	120	$9,720,000	0.656
750+ HP	$6,860	1.52	$88,749	736	147	$13,046,062	0.611
Tractors/Loaders/Backhoes							
100-175 HP	$11,017	0.18	$16,500	8208	410	$6,765,000	0.197
175-300 HP	$11,017	0.30	$28,500	5279	264	$7,524,000	0.219
Off-Highway Trucks							
750+ HP	$3,912	4.07	$135,959	439	132	$17,946,610	1.473
Sub Total				**23055**	**2587**	**141,565,601**	**8.425**
Lean NOx Catalyst							
Excavators							
175-300 HP	$5,073	0.56	$20,000	1437	287	$5,740,000	0.439
300-600 HP	$5,073	1.06	$37,895	1051	210	$7,957,895	0.609
Rubber Tire Loaders							
300-600 HP	$6,899	0.74	$37,895	2140	428	$16,218,947	0.865
600-750 HP	$6,899	1.07	$54,737	1718	344	$18,829,474	1.004

750+ HP	$6,899	1.94	$99,798	440	88	$8,782,197	0.468
Crawler Tractor/Dozer							
300-600 HP	$5,772	0.91	$37,895	1006	201	$7,616,842	0.500
600-750 HP	$5,772	1.31	$54,737	601	120	$6,568,421	0.431
750+ HP	$5,772	1.79	$74,736	736	147	$10,986,157	0.720
Tractors/Loaders/Backhoes							
100-175 HP	$22,459	0.12	$20,000	8208	0	$0	0.000
175-300 HP	$14,208	0.21	$20,000	5279	0	$0	0.000
Off-Highway Trucks							
750+ HP	$3,668	4.81	$114,492	439	132	$15,112,935	1.738
Sub Total				**23055**	**1957**	**97,812,868**	**6.773**
EGR+DPF Retrofit							
Excavators							
175-300 HP	$10,920	0.42	$23,000	1437	72	$1,656,000	0.083
300-600 HP	$10,920	0.79	$43,579	1051	53	$2,309,684	0.115
Rubber Tire Loaders							
300-600 HP	$13,719	0.55	$43,579	2140	0	$0	0.000
600-750 HP	$13,719	0.83	$65,368	1718	0	$0	0.000
750+ HP	$13,719	1.46	$114,767	440	0	$0	0.000
Crawler Tractor/Dozer							
300-600 HP	$11,992	0.68	$43,579	1006	50	$2,178,947	0.093
600-750 HP	$11,992	1.02	$65,368	601	30	$1,961,053	0.084
750+ HP	$11,992	1.34	$85,946	736	37	$3,180,007	0.136
Tractors/Loaders/Backhoes							
100-175 HP	$44,713	0.09	$23,000	8208	0	$0	0.000
175-300 HP	$32,062	0.15	$23,000	5279	0	$0	0.000
Off-Highway Trucks							
750+ HP	$8,765	3.60	$131,666	439	44	$5,793,292	0.434
Sub Total				**23055**	**286**	**17,078,983**	**0.945**
SCR Retrofit							
Excavators							
175-300 HP	$3,740	1.05	$27,500	1437	431	$11,852,500	1.236
300-600 HP	$3,740	1.98	$52,105	1051	315	$16,413,158	1.712
Rubber Tire Loaders							
300-600 HP	$5,079	1.38	$52,105	2140	428	$22,301,053	1.621
600-750 HP	$5,079	2.07	$78,158	1718	344	$26,886,316	1.955
750+ HP	$5,079	3.64	$137,222	440	88	$12,075,521	0.878
Crawler Tractor/Dozer							
300-600 HP	$4,253	1.70	$52,105	1006	201	$10,473,158	0.937
600-750 HP	$4,253	2.55	$78,158	601	120	$9,378,947	0.839
750+ HP	$4,253	3.35	$102,762	736	147	$15,105,966	1.351
Tractors/Loaders/Backhoes							
100-175 HP	$16,534	0.22	$27,500	8208	0	$0	0.000
175-300 HP	$10,483	0.39	$27,500	5279	264	$7,260,000	0.280
Off-Highway Trucks							
750+ HP	$2,709	9.01	$157,426	439	132	$20,780,285	3.258
Sub Total				**23055**	**2470**	**152,526,904**	**14.068**
Grand Total					**7300**	**$ 408,984,357**	**30.212**

A Preliminary Scenario for Off Road Strategies for Diesel Construction Equipment in the LADCO States

Technology	Tier 0 Engines			Tier 1 Engines			Tier 2 Engines			Tier 3 Engines			Total Unit Available	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
	NOx Red. (tons/yr/veh)	# of Units Available	Units Recom.	NOx Red. (tons/yr/veh)	# of Units Available	Units Recom.	NOx Red. (tons/yr/veh)	# of Units Available	Units Recom.	NOx Red. (tons/yr/veh)	# of Units Available	Units Recom.				
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)																
Excavators																
175-300 HP	0.34	0	0	0.25	1,437	0	0.17	3,994	0	0.10	5,790	0	11,222	0	-	0.000
300-600 HP	0.66	0	0	0.48	1,051	0	0.31	1,785	0	0.20	5,369	0	8,204	0	-	0.000
Rubber Tire Loaders																
300-600 HP	0.46	45	0	0.33	2,140	0	0.22	2,163	0	0.14	3,894	0	8,241	0	-	0.000
600-750 HP	0.70	359	0	0.50	1,718	0	0.33	1,938	0	0.21	2,031	0	6,046	0	-	0.000
750+ HP	1.15	148	0	0.87	440	0	0.58	270	0	0.00	150	0	1,008	0	-	0.000
Crawler Tractor/Dozer																
300-600 HP	0.56	110	0	0.41	1,006	0	0.27	1,658	0	0.17	3,502	0	6,276	0	-	0.000
600-750 HP	0.86	74	0	0.61	601	0	0.40	1,164	0	0.25	1,276	0	3,115	0	-	0.000
750+ HP	1.06	497	0	0.81	736	0	0.53	612	0	0.00	491	0	2,335	0	-	0.000
Tractors/Loaders/Backhoes																
100-175 HP	0.07	5,257	0	0.05	8,208	0	0.04	4,601	0	0.02	2,578	0	20,644	0	-	0.000
175-300 HP	0.13	2,807	0	0.09	5,279	0	0.06	3,010	0	0.04	2,640	0	13,736	0	-	0.000
Off-Highway Trucks																
750+ HP	2.85	5	0	2.16	439	0	1.43	667	0	0.00	389	0	1,500	0	-	0.000
Sub Total		**9,301**	**-**		**23,055**	**0**		**21,863**	**0**		**28,109**	**0**	**82,328**	**0**	**-**	**0.000**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)																
Excavators																
175-300 HP	0.94	0	0	0.82	1,437	287	0.37	3,994	399	0.00	5,790	0	11,222	686	19,551,000	1.044
300-600 HP	1.89	0	0	1.55	1,051	210	0.66	1,785	178	0.00	5,369	0	8,204	388	20,952,000	1.213
Rubber Tire Loaders																
300-600 HP	1.32	45	13	1.08	2,140	428	0.46	2,163	0	0.00	3,894	0	8,241	441	23,697,000	1.316
600-750 HP	2.06	359	108	1.62	1,718	344	0.69	1,938	0	0.00	2,031	0	6,046	452	35,154,000	2.139
750+ HP	3.19	148	30	1.65	440	44	0.00	270	0	0.00	150	0	1,008	74	8,769,723	0.461
Crawler Tractor/Dozer																
300-600 HP	1.62	110	33	1.33	1,006	201	0.56	1,658	83	0.00	3,502	0	6,276	317	16,821,000	1.008
600-750 HP	2.53	74	22	2.00	601	120	0.84	1,164	58	0.00	1,276	0	3,115	200	15,903,000	0.943
750+ HP	2.94	497	149	1.52	736	147	0.00	612	0	0.00	491	0	2,335	296	26,269,621	1.812
Tractors/Loaders/Backhoes																
100-175 HP	0.21	5,257	526	0.18	8,208	410	0.08	4,601	0	0.00	2,578	0	20,644	936	13,997,500	0.500
175-300 HP	0.35	2,807	281	0.30	5,279	264	0.14	3,010	0	0.00	2,640	0	13,736	545	14,197,750	0.487
Off-Highway Trucks																
750+ HP	7.90	5	1	4.07	439	132	0.00	667	0	0.00	389	0	1,500	133	18,082,569	1.495
Sub Total		**9,301**	**1,163**		**23,055**	**2587**		**21,863**	**718**		**28,109**	**0**	**82,328**	**4468**	**213,395,163**	**12.418**
Measure 51a: Lean NOx Catalyst																
Excavators																
175-300 HP	0.75	0	0	0.56	1,437	287	0.38	3,994	399	0.23	5,790	290	11,222	976	19,520,000	1.034
300-600 HP	1.46	0	0	1.06	1,051	210	0.70	1,785	178	0.44	5,369	268	8,204	656	24,858,947	1.271
Rubber Tire Loaders																
300-600 HP	1.02	45	9	0.74	2,140	428	0.49	2,163	108	0.30	3,894	0	8,241	545	20,652,632	1.034
600-750 HP	1.50	359	72	1.07	1,718	344	0.70	1,938	97	0.44	2,031	0	6,046	513	28,080,000	1.486
750+ HP	2.56	148	30	1.94	440	88	1.28	270	14	0.00	150	0	1,008	132	13,173,296	0.728
Crawler Tractor/Dozer																

300-600 HP	1.25	110	22	0.91	1,006	201	0.60	1,658	166	0.37	3,502	0	6,276	389	14,741,053	0.847
600-750 HP	1.84	74	15	1.31	601	120	0.87	1,164	116	0.54	1,276	0	3,115	251	13,738,947	0.782
750+ HP	2.36	497	99	1.79	736	147	1.18	612	61	0.00	491	0	2,335	307	22,943,880	1.558
Tractors/Loaders/Backhoes																
100-175 HP	0.16	5,257	0	0.12	8,208	0	0.08	4,601	0	0.05	2,578	0	20,644	0	-	0.000
175-300 HP	0.28	2,807	140	0.21	5,279	0	0.14	3,010	0	0.09	2,640	0	13,736	140	2,800,000	0.107
Off-Highway Trucks																
750+ HP	6.34	5	1	4.81	439	132	3.18	667	133	0.00	389	0	1,500	266	30,454,853	2.912
Sub Total		**9,301**	**388**		**23,055**	**1957**		**21,863**	**1272**		**28,109**	**558**	**82,328**	**4175**	**190,963,608**	**11.760**
Measure 51b: EGR+DPF Retrofit																
Excavators																
175-300 HP	0.56	0	0	0.42	1,437	72	0.28	3,994	0	0.17	5,790	0	11,222	72	1,656,000	0.083
300-600 HP	1.09	0	0	0.79	1,051	53	0.52	1,785	0	0.33	5,369	0	8,204	53	2,309,684	0.115
Rubber Tire Loaders																
300-600 HP	0.76	45	4	0.55	2,140	0	0.37	2,163	0	0.23	3,894	0	8,241	4	174,316	0.008
600-750 HP	1.17	359	36	0.83	1,718	0	0.55	1,938	0	0.34	2,031	0	6,046	36	2,353,263	0.115
750+ HP	1.92	148	7	1.46	440	0	0.96	270	0	0.00	150	0	1,008	7	803,371	0.037
Crawler Tractor/Dozer																
300-600 HP	0.94	110	11	0.68	1,006	50	0.45	1,658	0	0.28	3,502	0	6,276	61	2,658,316	0.121
600-750 HP	1.43	74	7	1.02	601	30	0.67	1,164	0	0.42	1,276	0	3,115	37	2,418,632	0.111
750+ HP	1.77	497	50	1.34	736	37	0.89	612	0	0.00	491	0	2,335	87	7,477,313	0.378
Tractors/Loaders/Backhoes																
100-175 HP	0.12	5,257	0	0.09	8,208	0	0.06	4,601	0	0.04	2,578	0	20,644	0	-	0.000
175-300 HP	0.21	2,807	0	0.15	5,279	0	0.10	3,010	0	0.06	2,640	0	13,736	0	-	0.000
Off-Highway Trucks																
750+ HP	4.75	5	1	3.60	439	44	2.38	667	0	0.00	389	0	1,500	45	5,924,957	0.447
Sub Total		**9,301**	**116**		**23,055**	**286**		**21,863**	**0**		**28,109**	**0**	**82,328**	**402**	**25,775,853**	**1.417**
Measure 51c: SCR Retrofit																
Excavators																
175-300 HP	1.41	0	0	1.05	1,437	431	0.71	3,994	799	0.43	5,790	579	11,222	1809	49,747,500	3.469
300-600 HP	2.73	0	0	1.98	1,051	315	1.31	1,785	357	0.82	5,369	537	8,204	1209	62,995,263	4.200
Rubber Tire Loaders																
300-600 HP	1.90	45	13	1.38	2,140	428	0.91	2,163	216	0.57	3,894	195	8,241	852	44,393,684	2.535
600-750 HP	2.92	359	108	2.07	1,718	344	1.37	1,938	194	0.86	2,031	102	6,046	748	58,462,105	3.785
750+ HP	4.80	148	45	3.64	440	88	2.41	270	27	0.00	150	0	1,008	160	21,955,494	1.648
Crawler Tractor/Dozer																
300-600 HP	2.34	110	33	1.70	1,006	201	1.12	1,658	332	0.70	3,502	175	6,276	741	38,610,000	2.508
600-750 HP	3.59	74	22	2.55	601	120	1.69	1,164	233	1.05	1,276	64	3,115	439	34,311,316	2.316
750+ HP	4.42	497	149	3.35	736	147	2.22	612	122	0.00	491	0	2,335	418	42,954,381	3.898
Tractors/Loaders/Backhoes																
100-175 HP	0.31	5,257	263	0.22	8,208	0	0.15	4,601	0	0.09	2,578	0	20,644	263	7,232,500	0.223
175-300 HP	0.52	2,807	281	0.39	5,279	264	0.26	3,010	0	0.16	2,640	0	13,736	545	14,987,500	0.682
Off-Highway Trucks																
750+ HP	11.88	5	1	9.01	439	132	5.95	667	133	0.00	389	0	1,500	266	23,392,250	5.461
Sub Total		**9,301**	**915**		**23,055**	**2470**		**21,863**	**2413**		**28,109**	**1652**	**82,328**	**7450**	**399,041,993**	**30.725**
Grand Total (Voluntary Program)		**9,301**	**2,582**		**23,055**	**7,300**		**21,863**	**4,403**		**28,109**	**2,210**	**82,328**	**16,495**	**$ 829,176,616**	**56.319**

A Preliminary Scenario for Off Road Strategies for Diesel Agricultural Equipment in the LADCO States: Tier 0 Engines

Tier 0 Engines

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)							
Agricultural Tractors							
25-50 HP	$21,987	0.02	$934	5,938	0	$0	0.000
50-75 HP	$17,989	0.03	$1,556	2,249	0	$0	0.000
75-100 HP	$17,989	0.04	$2,179	12,790	0	$0	0.000
100-175 HP	$15,006	0.07	$3,083	11,273	0	$0	0.000
175-300 HP	$15,329	0.12	$5,325	15,311	0	$0	0.000
300-600 HP	$15,006	0.24	$10,090	10,318	0	$0	0.000
600-750 HP	$14,697	0.36	$15,135	12,961	0	$0	0.000
Combines							
175-300 HP	$15,329	0.04	$1,682	21,121	0	$0	0.000
300-600 HP	$15,006	0.08	$3,186	24,370	0	$0	0.000
Sub Total				**116,331**	**0**	**-**	**0.000**
Measure 20: Fleet Modernization (Tier 2 Engines)							
Agricultural Tractors							
25-50 HP	$21,320	0.02	$3,750	5,938	0	$0	0.000
50-75 HP	$12,594	0.06	$6,600	2,249	112	$739,200	0.019
75-100 HP	$10,905	0.09	$8,750	12,790	640	$5,600,000	0.165
100-175 HP	$7,833	0.21	$13,750	11,273	1127	$15,496,250	0.635
175-300 HP	$8,170	0.34	$23,750	15,311	1531	$36,361,250	1.429
300-600 HP	$7,682	0.69	$45,000	10,318	1032	$46,440,000	1.942
600-750 HP	$7,383	1.07	$67,500	12,961	1296	$87,480,000	3.806
Combines							
175-300 HP	$25,871	0.11	$23,750	21,121	0	$0	0.000
300-600 HP	$24,326	0.22	$45,000	24,370	0	$0	0.000
Sub Total				**116,331**	**5738**	**192,116,700**	**7.996**
Measure 51a: Lean NOx Catalyst							
Agricultural Tractors							
25-50 HP	$19,055	0.03	$5,158	5,938	0	$0	0.000
50-75 HP	$13,290	0.07	$7,263	2,249	0	$0	0.000
75-100 HP	$12,305	0.10	$9,368	12,790	640	$5,995,789	0.167
100-175 HP	$10,498	0.16	$13,579	11,273	564	$7,658,526	0.249
175-300 HP	$9,240	0.27	$20,000	15,311	1531	$30,620,000	1.145
300-600 HP	$9,045	0.53	$37,895	10,318	1032	$39,107,368	1.494
600-750 HP	$8,859	0.81	$56,842	12,961	1296	$73,667,368	2.873
Combines							
175-300 HP	$27,853	0.09	$20,000	21,121	0	$0	0.000
300-600 HP	$27,266	0.17	$37,895	24,370	0	$0	0.000
Sub Total				**116,331**	**5063**	**157,049,053**	**5.927**
Measure 51b: EGR+DPF Retrofit							
Agricultural Tractors							
25-50 HP	$31,154	0.03	$5,632	5,938	0	$0	0.000
50-75 HP	$22,423	0.05	$8,053	2,249	0	$0	0.000
75-100 HP	$21,109	0.07	$10,474	12,790	0	$0	0.000
100-175 HP	$18,087	0.12	$15,316	11,273	0	$0	0.000

175-300 HP	$16,498	0.20	$23,000	15,311	0	$0	0.000
300-600 HP	$16,150	0.40	$43,579	10,318	0	$0	0.000
600-750 HP	$15,817	0.61	$65,368	12,961	0	$0	0.000
Combines							
175-300 HP	$45,037	0.06	$23,000	21,121	0	$0	0.000
300-600 HP	$44,089	0.13	$43,579	24,370	0	$0	0.000
Sub Total				**116,331**	**0**	**-**	**0.000**
Measure 51c: SCR Retrofit							
Agricultural Tractors							
25-50 HP	$12,589	0.06	$6,342	5,938	297	$1,883,605	0.051
50-75 HP	$9,073	0.13	$9,237	2,249	225	$2,078,289	0.079
75-100 HP	$8,548	0.18	$12,132	12,790	1279	$15,516,289	0.625
100-175 HP	$7,422	0.30	$17,921	11,273	1127	$20,197,026	0.934
175-300 HP	$6,790	0.51	$27,500	15,311	3062	$84,205,000	4.293
300-600 HP	$6,647	0.99	$52,105	10,318	2064	$107,545,263	5.601
600-750 HP	$6,510	1.52	$78,158	12,961	2592	$202,585,263	10.773
Combines							
175-300 HP	$20,440	0.16	$27,500	21,121	0	$0	0.000
300-600 HP	$20,009	0.31	$52,105	24,370	0	$0	0.000
Sub Total				**116,331**	**10646**	**434,010,737**	**22.356**
Grand Total					**21447**	**$ 783,176,489**	**36.279**

A Preliminary Scenario for Off Road Strategies for Diesel Agricultural Equipment in LADCO States: Tier 1 Engines

Tier 1 Engines

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Emulsified Diesel Fuel (3 yrs of fuel cost)							
Agricultural Tractors							
25-50 HP	$23,470	0.01	$934	17824	0	$0	0.000
50-75 HP	$22,943	0.02	$1,556	6804	0	$0	0.000
75-100 HP	$22,943	0.03	$2,179	18630	0	$0	0.000
100-175 HP	$20,661	0.05	$3,083	16420	0	$0	0.000
175-300 HP	$20,661	0.09	$5,325	26468	0	$0	0.000
300-600 HP	$20,661	0.17	$10,090	25699	0	$0	0.000
600-750 HP	$20,661	0.26	$15,135	7184	0	$0	0.000
Combines							
175-300 HP	$20,661	0.03	$1,682	4692	0	$0	0.000
300-600 HP	$20,661	0.05	$3,186	6410	0	$0	0.000
Sub Total				**130,130**	**0**	**-**	**0.000**
Diesel Engine Upgrades (Tier 3 Engines, except Tier 2 Engines for 750+ HP Engines)							
Agricultural Tractors							
25-50 HP	$13,315	0.04	$4,500	17,824	0	$0	0.000
50-75 HP	$12,738	0.07	$7,500	6,804	340	$2,550,000	0.064
75-100 HP	$12,738	0.10	$10,500	18,630	931	$9,775,500	0.246
100-175 HP	$11,244	0.17	$16,500	16,420	821	$13,546,500	0.387
175-300 HP	$11,244	0.30	$28,500	26,468	1323	$37,705,500	1.077
300-600 HP	$11,244	0.56	$54,000	25,699	1285	$69,390,000	1.982
600-750 HP	$11,244	0.84	$81,000	7,184	359	$29,079,000	0.831
Combines							
175-300 HP	$35,606	0.09	$28,500	4,692	0	$0	0.000
300-600 HP	$35,606	0.18	$54,000	6,410	0	$0	0.000
Sub Total				**130,130**	**5059**	**162,046,500**	**4.587**
Lean NOx Catalyst							
Agricultural Tractors							
25-50 HP	$20,340	0.03	$5,158	17,824	0	$0	0.000
50-75 HP	$16,950	0.05	$7,263	6,804	0	$0	0.000
75-100 HP	$15,693	0.07	$9,368	18,630	0	$0	0.000
100-175 HP	$14,454	0.12	$13,579	16,420	0	$0	0.000
175-300 HP	$12,454	0.20	$20,000	26,468	1323	$26,460,000	0.734
300-600 HP	$12,454	0.38	$37,895	25,699	1285	$48,694,737	1.351
600-750 HP	$12,454	0.58	$56,842	7,184	359	$20,406,316	0.566
Combines							
175-300 HP	$37,541	0.06	$20,000	4,692	0	$0	0.000
300-600 HP	$37,541	0.12	$37,895	6,410	0	$0	0.000
Sub Total				**130,130**	**2967**	**95,561,053**	**2.651**
EGR+DPF Retrofit							
Agricultural Tractors							

50-75 HP	$33,256	0.02	$5,632	17,824	0	$0	0.000
75-100 HP	$28,598	0.04	$8,053	6,804	0	$0	0.000
100-175 HP	$26,921	0.06	$10,474	18,630	0	$0	0.000
175-300 HP	$24,903	0.09	$15,316	16,420	0	$0	0.000
300-600 HP	$22,236	0.15	$23,000	26,468	0	$0	0.000
600-750 HP	$22,236	0.29	$43,579	25,699	0	$0	0.000
600-750 HP	$22,236	0.43	$65,368	7,184	0	$0	0.000
Combines							
175-300 HP	$60,703	0.05	$23,000	4,692	0	$0	0.000
300-600 HP	$60,703	0.09	$43,579	6,410	0	$0	0.000
Sub Total				**130,130**	**0**	**-**	**0.000**
SCR Retrofit							
Agricultural Tractors							
50-75 HP	$13,438	0.06	$6,342	17,824	0	$0	0.000
75-100 HP	$11,572	0.10	$9,237	6,804	340	$3,140,526	0.093
100-175 HP	$10,901	0.14	$12,132	18,630	931	$11,294,500	0.357
175-300 HP	$10,219	0.22	$17,921	16,420	821	$14,713,184	0.494
300-600 HP	$9,152	0.38	$27,500	26,468	2647	$72,792,500	2.753
600-750 HP	$9,152	0.72	$52,105	25,699	2570	$133,910,526	5.065
600-750 HP	$9,152	1.08	$78,158	7,184	718	$56,117,368	2.123
Combines							
175-300 HP	$27,549	0.12	$27,500	4,692	0	$0	0.000
300-600 HP	$27,549	0.23	$52,105	6,410	0	$0	0.000
Sub Total				**130,130**	**8027**	**291,968,605**	**10.886**
Grand Total					**16053**	**$ 549,576,158**	**18.124**

A Preliminary Scenario for Off Road Strategies for Diesel Agricultural Equipment in LADCO States: Tier 2 Engines

Tier 2 Engines

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Emulsified Diesel Fuel (3 yrs of fuel cost)							
Agricultural Tractors							
25-50 HP	$29,208	0.01	$934	30034	0	$0	0.000
50-75 HP	$29,757	0.02	$1,556	13355	0	$0	0.000
75-100 HP	$29,757	0.03	$2,179	10488	0	$0	0.000
100-175 HP	$30,625	0.04	$3,083	9244	0	$0	0.000
175-300 HP	$30,625	0.06	$5,325	15151	0	$0	0.000
300-600 HP	$31,263	0.11	$10,090	9493	0	$0	0.000
600-750 HP	$31,263	0.17	$15,135	5675	0	$0	0.000
Combines							
175-300 HP	$30,625	0.02	$1,682	2400	0	$0	0.000
300-600 HP	$31,263	0.04	$3,186	2105	0	$0	0.000
Sub Total				**97,945**	**0**	**-**	**0.000**
Diesel Engine Upgrades (Tier 3 Engines)							
Agricultural Tractors							
25-50 HP	$21,737	0.02	$4,500	30,034	0	$0	0.000
50-75 HP	$22,826	0.04	$7,500	13,355	0	$0	0.000
75-100 HP	$22,826	0.05	$10,500	10,488	0	$0	0.000
100-175 HP	$25,229	0.08	$16,500	9,244	0	$0	0.000
175-300 HP	$25,229	0.13	$28,500	15,151	0	$0	0.000
300-600 HP	$26,631	0.24	$54,000	9,493	0	$0	0.000
600-750 HP	$26,631	0.36	$81,000	5,675	0	$0	0.000
Combines							
175-300 HP	$79,892	0.04	$3,341	2,400	0	$0	0.000
300-600 HP	$84,331	0.08	$6,330	2,105	0	$0	0.000
Sub Total				**97,945**	**0**	**-**	**0.000**
Lean NOx Catalyst							
Agricultural Tractors							
25-50 HP	$25,313	0.03	$5,158	30,034	0	$0	0.000
50-75 HP	$21,984	0.04	$7,263	13,355	0	$0	0.000
75-100 HP	$20,354	0.06	$9,368	10,488	0	$0	0.000
100-175 HP	$21,424	0.08	$13,579	9,244	0	$0	0.000
175-300 HP	$18,460	0.14	$20,000	15,151	0	$0	0.000
300-600 HP	$18,844	0.25	$37,895	9,493	0	$0	0.000
600-750 HP	$18,844	0.38	$56,842	5,675	0	$0	0.000
Combines							
175-300 HP	$55,646	0.04	$20,000	2,400	0	$0	0.000
300-600 HP	$56,805	0.08	$37,895	2,105	0	$0	0.000
Sub Total				**97,945**	**0**	**-**	**0.000**
EGR+DPF Retrofit							
Agricultural Tractors							

25-50 HP	$41,385	0.02	$5,632	30,034	0	$0	0.000
50-75 HP	$37,091	0.03	$8,053	13,355	0	$0	0.000
75-100 HP	$34,917	0.04	$10,474	10,488	0	$0	0.000
100-175 HP	$36,913	0.06	$15,316	9,244	0	$0	0.000
175-300 HP	$32,960	0.10	$23,000	15,151	0	$0	0.000
300-600 HP	$33,647	0.19	$43,579	9,493	0	$0	0.000
600-750 HP	$33,647	0.29	$65,368	5,675	0	$0	0.000
Combines							
175-300 HP	$89,978	0.03	$23,000	2,400	0	$0	0.000
300-600 HP	$91,853	0.06	$43,579	2,105	0	$0	0.000
Sub Total				**97,945**	**0**	**-**	**0.000**
SCR Retrofit							
Agricultural Tractors							
25-50 HP	$16,723	0.05	$6,342	30,034	0	$0	0.000
50-75 HP	$15,008	0.08	$9,237	13,355	0	$0	0.000
75-100 HP	$14,139	0.11	$12,132	10,488	0	$0	0.000
100-175 HP	$15,147	0.15	$17,921	9,244	0	$0	0.000
175-300 HP	$13,566	0.26	$27,500	15,151	0	$0	0.000
300-600 HP	$13,849	0.48	$52,105	9,493	0	$0	0.000
600-750 HP	$13,849	0.71	$78,158	5,675	0	$0	0.000
Combines							
175-300 HP	$40,836	0.08	$27,500	2,400	0	$0	0.000
300-600 HP	$41,686	0.15	$52,105	2,105	0	$0	0.000
Sub Total				**97,945**	**0**	**-**	**0.000**
Grand Total					**0**	**$ -**	**0.000**

A Preliminary Scenario for Off Road Strategies for Diesel Agricultural Equipment in LADCO States: Tier 3 Engines

Tier 3 Engines

Technology	Project Cost-Effectiveness ($/ton)	Estimated NOx Reductions per Vehicle (tons/year)	Cost per Unit ($)	Number of Units Available	Units Recommended	Total Cost	Total NOx (tons/day)
Emulsified Diesel Fuel (3 yrs of fuel cost)							
Agricultural Tractors							
25-50 HP	$47,611	0.01	$934	0	0	$0	0.000
50-75 HP	$47,611	0.01	$1,556	0	0	$0	0.000
75-100 HP	$47,611	0.02	$2,179	0	0	$0	0.000
100-175 HP	$50,021	0.02	$3,083	5133	0	$0	0.000
175-300 HP	$50,021	0.04	$5,325	13168	0	$0	0.000
300-600 HP	$50,021	0.07	$10,090	14921	0	$0	0.000
600-750 HP	$50,021	0.11	$15,135	5449	0	$0	0.000
Combines							
175-300 HP	$50,021	0.01	$1,682	2020	0	$0	0.000
300-600 HP	$50,021	0.02	$3,186	3167	0	$0	0.000
Sub Total				**43,858**	**0**	**-**	**0.000**
Diesel Engine Upgrades (NA)							
Agricultural Tractors							
25-50 HP	NA	0	$0	0	0	$0	0.000
50-75 HP	NA	0	$0	0	0	$0	0.000
75-100 HP	NA	0	$0	0	0	$0	0.000
100-175 HP	NA	0	$0	5,133	0	$0	0.000
175-300 HP	NA	0	$0	13,168	0	$0	0.000
300-600 HP	NA	0	$0	14,921	0	$0	0.000
600-750 HP	NA	0	$0	5,449	0	$0	0.000
Combines							
175-300 HP	NA	0	$0	2,020	0	$0	0.000
300-600 HP	NA	0	$0	3,167	0	$0	0.000
Sub Total				**43,858**	**0**	**-**	**0.000**
Lean NOx Catalyst							
Agricultural Tractors							
25-50 HP	$41,262	0.02	$5,158	0	0	$0	0.000
50-75 HP	$35,175	0.03	$7,263	0	0	$0	0.000
75-100 HP	$32,566	0.04	$9,368	0	0	$0	0.000
100-175 HP	$34,993	0.05	$13,579	5,133	0	$0	0.000
175-300 HP	$30,151	0.08	$20,000	13,168	0	$0	0.000
300-600 HP	$30,151	0.16	$37,895	14,921	0	$0	0.000
600-750 HP	$30,151	0.24	$56,842	5,449	0	$0	0.000
Combines							
175-300 HP	$90,888	0.03	$20,000	2,020	0	$0	0.000
300-600 HP	$90,888	0.05	$37,895	3,167	0	$0	0.000
Sub Total				**43,858**	**0**	**-**	**0.000**
EGR+DPF Retrofit							

Agricultural Tractors							
25-50 HP	$67,461	0.01	$5,632	0	0	$0	0.000
50-75 HP	$59,345	0.02	$8,053	0	0	$0	0.000
75-100 HP	$55,867	0.03	$10,474	0	0	$0	0.000
100-175 HP	$60,290	0.04	$15,316	5,133	0	$0	0.000
175-300 HP	$53,835	0.06	$23,000	13,168	0	$0	0.000
300-600 HP	$53,835	0.12	$43,579	14,921	0	$0	0.000
600-750 HP	$53,835	0.18	$65,368	5,449	0	$0	0.000
Combines							
175-300 HP	$146,964	0.02	$23,000	2,020	0	$0	0.000
300-600 HP	$146,964	0.04	$43,579	3,167	0	$0	0.000
Sub Total				**43,858**	**0**	**-**	**0.000**
SCR Retrofit							
Agricultural Tractors							
25-50 HP	$27,260	0.03	$6,342	0	0	$0	0.000
50-75 HP	$24,014	0.05	$9,237	0	0	$0	0.000
75-100 HP	$22,622	0.07	$12,132	0	0	$0	0.000
100-175 HP	$24,740	0.09	$17,921	5,133	0	$0	0.000
175-300 HP	$22,158	0.16	$27,500	13,168	0	$0	0.000
300-600 HP	$22,158	0.30	$52,105	14,921	0	$0	0.000
600-750 HP	$22,158	0.45	$78,158	5,449	0	$0	0.000
Combines							
175-300 HP	$66,698	0.05	$27,500	2,020	0	$0	0.000
300-600 HP	$66,698	0.09	$52,105	3,167	0	$0	0.000
Sub Total				**43,858**	**0**	**-**	**0.000**
Grand Total					**0**	**$ -**	**0.000**

A Preliminary Scenario for Off Road Strategies for Diesel Agricultural Equipment in the LADCO States

Technology	Tier 0 Engines			Tier 1 Engines			Tier 2 Engines			Tier 3 Engines			Total Unit Available	Total Unit Recom.	Total Cost ($)	Total NOx (tpd)
	NOx Red. (tons/yr/veh)	# of Units Available	Units Recom.	NOx Red. (tons/yr/veh)	# of Units Available	Units Recom.	NOx Red. (tons/yr/veh)	# of Units Available	Units Recom.	NOx Red. (tons/yr/veh)	# of Units Available	Units Recom.				
Measure 16a: Emulsified Diesel Fuel (3 yrs of fuel cost)																
Agricultural Tractors																
25-50 HP	0.02	5,938	0	0.01	17,824	0	0.01	30,034	0	0.01	0	0	53,797	0	0	0.000
50-75 HP	0.03	2,249	0	0.02	6,804	0	0.02	13,355	0	0.01	0	0	22,408	0	0	0.000
75-100 HP	0.04	12,790	0	0.03	18,630	0	0.03	10,488	0	0.02	0	0	41,908	0	0	0.000
100-175 HP	0.07	11,273	0	0.05	16,420	0	0.04	9,244	0	0.02	5,133	0	42,069	0	0	0.000
175-300 HP	0.12	15,311	0	0.09	26,468	0	0.06	15,151	0	0.04	13,168	0	70,097	0	0	0.000
300-600 HP	0.24	10,318	0	0.17	25,699	0	0.11	9,493	0	0.07	14,921	0	60,432	0	0	0.000
600-750 HP	0.36	12,961	0	0.26	7,184	0	0.17	5,675	0	0.11	5,449	0	31,270	0	0	0.000
Combines																
175-300 HP	0.04	21,121	0	0.03	4,692	0	0.02	2,400	0	0.01	2,020	0	30,233	0	0	0.000
300-600 HP	0.08	24,370	0	0.05	6,410	0	0.04	2,105	0	0.02	3,167	0	36,051	0	0	0.000
Sub Total		**116,331**	**0**		**130,130**	**0**		**97,945**	**0**		**43,858**	**0**	**388,265**	**0**	**0**	**0.000**
Measure 20: Fleet Modernization (Tier 2 or Tier 3 Engines)																
Agricultural Tractors																
25-50 HP	0.02	5,938	0	0.04	17,824	0	0.02	30,034	0	0.00	0	0	53,797	0	0	0.000
50-75 HP	0.06	2,249	112	0.07	6,804	340	0.04	13,355	0	0.00	0	0	22,408	452	3,289,200	0.083
75-100 HP	0.09	12,790	640	0.10	18,630	931	0.05	10,488	0	0.00	0	0	41,908	1,571	15,375,500	0.411
100-175 HP	0.21	11,273	1,127	0.17	16,420	821	0.08	9,244	0	0.00	5,133	0	42,069	1,948	29,042,750	1.022
175-300 HP	0.34	15,311	1,531	0.30	26,468	1,323	0.13	15,151	0	0.00	13,168	0	70,097	2,854	74,066,750	2.506
300-600 HP	0.69	10,318	1,032	0.56	25,699	1,285	0.24	9,493	0	0.00	14,921	0	60,432	2,317	115,830,000	3.924
600-750 HP	1.07	12,961	1,296	0.84	7,184	359	0.36	5,675	0	0.00	5,449	0	31,270	1,655	116,559,000	4.636
Combines																
175-300 HP	0.11	21,121	0	0.09	4,692	0	0.04	2,400	0	0.00	2,020	0	30,233	0	0	0.000
300-600 HP	0.22	24,370	0	0.18	6,410	0	0.08	2,105	0	0.00	3,167	0	36,051	0	0	0.000
Sub Total		**116,331**	**5,738**		**130,130**	**5,059**		**97,945**	**0**		**43,858**	**0**	**388,265**	**10,797**	**354,163,200**	**12.583**
Measure 51a: Lean NOx Catalyst																
Agricultural Tractors																
25-50 HP	0.03	5,938	0	0.03	17,824	0	0.03	30,034	0	0.02	0	0	53,797	0	0	0.000
50-75 HP	0.07	2,249	0	0.05	6,804	0	0.04	13,355	0	0.03	0	0	22,408	0	0	0.000
75-100 HP	0.10	12,790	640	0.07	18,630	0	0.06	10,488	0	0.04	0	0	41,908	640	5,995,789	0.167
100-175 HP	0.16	11,273	564	0.12	16,420	0	0.08	9,244	0	0.05	5,133	0	42,069	564	7,658,526	0.249
175-300 HP	0.27	15,311	1,531	0.20	26,468	1,323	0.14	15,151	0	0.08	13,168	0	70,097	2,854	57,080,000	1.879
300-600 HP	0.53	10,318	1,032	0.38	25,699	1,285	0.25	9,493	0	0.16	14,921	0	60,432	2,317	87,802,105	2.844
600-750 HP	0.81	12,961	1,296	0.58	7,184	359	0.38	5,675	0	0.24	5,449	0	31,270	1,655	94,073,684	3.439
Combines																
175-300 HP	0.09	21,121	0	0.06	4,692	0	0.04	2,400	0	0.03	2,020	0	30,233	0	0	0.000
300-600 HP	0.17	24,370	0	0.12	6,410	0	0.08	2,105	0	0.05	3,167	0	36,051	0	0	0.000
Sub Total		**116,331**	**5,063**		**130,130**	**2,967**		**97,945**	**0**		**43,858**	**0**	**388,265**	**8,030**	**252,610,105**	**8.578**

Measure 51b: EGR+DPF Retrofit																
Agricultural Tractors																
25-50 HP	0.03	5,938	0	0.02	17,824	0	0.02	30,034	0	0.01	0	0	53,797	0	0	0.000
50-75 HP	0.05	2,249	0	0.04	6,804	0	0.03	13,355	0	0.02	0	0	22,408	0	0	0.000
75-100 HP	0.07	12,790	0	0.06	18,630	0	0.04	10,488	0	0.03	0	0	41,908	0	0	0.000
100-175 HP	0.12	11,273	0	0.09	16,420	0	0.06	9,244	0	0.04	5,133	0	42,069	0	0	0.000
175-300 HP	0.20	15,311	0	0.15	26,468	0	0.10	15,151	0	0.06	13,168	0	70,097	0	0	0.000
300-600 HP	0.40	10,318	0	0.29	25,699	0	0.19	9,493	0	0.12	14,921	0	60,432	0	0	0.000
600-750 HP	0.61	12,961	0	0.43	7,184	0	0.29	5,675	0	0.18	5,449	0	31,270	0	0	0.000
Combines																
175-300 HP	0.06	21,121	0	0.05	4,692	0	0.03	2,400	0	0.02	2,020	0	30,233	0	0	0.000
300-600 HP	0.13	24,370	0	0.09	6,410	0	0.06	2,105	0	0.04	3,167	0	36,051	0	0	0.000
Sub Total		**116,331**	**0**		**130,130**	**0**		**97,945**	**0**		**43,858**	**0**	**388,265**	**0**	**0**	**0.000**
Measure 51c: SCR Retrofit																
Agricultural Tractors																
25-50 HP	0.06	5,938	297	0.06	17,824	0	0.05	30,034	0	0.03	0	0	53,797	297	1,883,605	0.051
50-75 HP	0.13	2,249	225	0.10	6,804	340	0.08	13,355	0	0.05	0	0	22,408	565	5,218,816	0.172
75-100 HP	0.18	12,790	1,279	0.14	18,630	931	0.11	10,488	0	0.07	0	0	41,908	2,210	26,810,789	0.982
100-175 HP	0.30	11,273	1,127	0.22	16,420	821	0.15	9,244	0	0.09	5,133	0	42,069	1,948	34,910,211	1.429
175-300 HP	0.51	15,311	3,062	0.38	26,468	2,647	0.26	15,151	0	0.16	13,168	0	70,097	5,709	156,997,500	7.046
300-600 HP	0.99	10,318	2,064	0.72	25,699	2,570	0.48	9,493	0	0.30	14,921	0	60,432	4,634	241,455,789	10.666
600-750 HP	1.52	12,961	2,592	1.08	7,184	718	0.71	5,675	0	0.45	5,449	0	31,270	3,310	258,702,632	12.895
Combines																
175-300 HP	0.16	21,121	0	0.12	4,692	0	0.08	2,400	0	0.05	2,020	0	30,233	0	0	0.000
300-600 HP	0.31	24,370	0	0.23	6,410	0	0.15	2,105	0	0.09	3,167	0	36,051	0	0	0.000
Sub Total		**116,331**	**10,646**		**130,130**	**8,027**		**97,945**	**0**		**43,858**	**0**	**388,265**	**18,673**	**725,979,342**	**33.241**
Grand Total (Voluntary Program)		**116,331**	**21,447**		**130,130**	**16,053**		**97,945**	**0**		**43,858**	**0**	**388,265**	**37,500**	**1,332,752,647**	**54.403**

Appendix M16a

Water Emulsified Diesel Fuels for On-road Heavy-Duty Diesel Vehicle and Non-road Diesel Equipment

Table M16a-NR-AG: Measure 16a Emulsified Diesel Fuel for Agricultural Equipment

Measure 16a: Emulsified Diesel Fuel

Cost of diesel:	2.13	
Increamental Fuel Cost	15%	
Cost of PuriNOx	2.44	Assuming 15% increase in fuel cost due to lower volumetric effciency & fuel price
EPA Reduction (15 to 21%)	18 %	
CARB Reduction	14 %	

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx
NOx (g/bhp-hr)	7.2	5.90	8.8	7.22	8.8	7.22	9.5	7.79	9.3	7.63	9.5	7.79	9.7	7.95
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,036	1,726	1,726	2,416	2,416	3,420	3,420	5,906	5,906	11,191	11,191	16,787	16,787
Fuel Cost ($/yr)	2,201	2,531	3,668	4,218	5,135	5,905	7,266	8,356	12,551	14,434	23,781	27,348	35,672	41,022
Incremental Fuel Cost/yr		$ 330		$ 550		$ 770		$ 1,090		$ 1,883		$ 3,567		$ 5,351
Three Year Grant Amount		$934		$1,556		$2,179		$3,083		$5,325		$10,090		$15,135
NOx Emission Factor (g/hr)	159	131	325	266	454	373	771	632	1303	1069	2522	2068	3863	3168
NOx (tons/year)	0.08	0.07	0.17	0.14	0.24	0.20	0.40	0.33	0.68	0.56	1.32	1.08	2.02	1.66
NOx Reduction (tons/year)		0.02		0.03		0.04		0.07		0.12		0.24		0.36
Cost-Effectiveness ($/ton)		$21,987		$17,989		$17,989		$15,006		$15,329		$15,006		$14,697
One-Year Cost-Effectiveness		$62,193		$50,885		$50,885		$42,447		$43,360		$42,447		$41,572

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx
NOx (g/bhp-hr)	6.745	5.53	6.9	5.66	6.9	5.66	6.9	5.66	6.9	5.66	6.9	5.66	6.9	5.66
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,036	1,726	1,726	2,416	2,416	3,420	3,420	5,906	5,906	11,191	11,191	16,787	16,787
Fuel Cost ($/yr)	2,201	2,531	3,668	4,218	5,135	5,905	7,266	8,356	12,551	14,434	23,781	27,348	35,672	41,022
Incremental Fuel Cost/yr		$ 330		$ 550		$ 770		$ 1,090		$ 1,883		$ 3,567		$ 5,351
Three Year Grant Amount		$934		$1,556		$2,179		$3,083		$5,325		$10,090		$15,135
NOx Emission Factor (g/hr)	149	122	254	209	356	292	560	459	967	793	1832	1502	2748	2253
NOx (tons/year)	0.08	0.06	0.13	0.11	0.19	0.15	0.29	0.24	0.51	0.42	0.96	0.79	1.44	1.18
NOx Reduction (tons/year)		0.01		0.02		0.03		0.05		0.09		0.17		0.26
Cost-Effectiveness ($/ton)		$23,470		$22,943		$22,943		$20,661		$20,661		$20,661		$20,661
One-Year Cost-Effectiveness		$66,388		$64,897		$64,897		$58,441		$58,441		$58,441		$58,441

Table M16a-NR-AG: Measure 16a Emulsified Diesel Fuel for Agricultural Equipment

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx
NOx (g/bhp-hr)	5.42	4.44	5.32	4.36	5.32	4.36	4.655	3.82	4.655	3.82	4.56	3.74	4.56	3.74
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,036	1,726	1,726	2,416	2,416	3,420	3,420	5,906	5,906	11,191	11,191	16,787	16,787
Fuel Cost ($/yr)	2,201	2,531	3,668	4,218	5,135	5,905	7,266	8,356	12,551	14,434	23,781	27,348	35,672	41,022
Incremental Fuel Cost/yr		$ 330		$ 550		$ 770		$ 1,090		$ 1,883		$ 3,567		$ 5,351
Three Year Grant Amount		$934		$1,556		$2,179		$3,083		$5,325		$10,090		$15,135
NOx Emission Factor (g/hr)	120	98	196	161	275	225	378	310	652	535	1211	993	1816	1489
NOx (tons/year)	0.06	0.05	0.10	0.08	0.14	0.12	0.20	0.16	0.34	0.28	0.63	0.52	0.95	0.78
NOx Reduction (tons/year)		0.01		0.02		0.03		0.04		0.06		0.11		0.17
Cost-Effectiveness ($/ton)		$29,208		$29,757		$29,757		$30,625		$30,625		$31,263		$31,263
One-Year Cost-Effectiveness		$82,618		$84,171		$84,171		$86,626		$86,626		$88,431		$88,431

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx
NOx (g/bhp-hr)	3.325	2.73	3.325	2.73	3.325	2.73	2.85	2.34	2.85	2.34	2.85	2.34	2.85	2.34
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,036	1,726	1,726	2,416	2,416	3,420	3,420	5,906	5,906	11,191	11,191	16,787	16,787
Fuel Cost ($/yr)	2,201	2,531	3,668	4,218	5,135	5,905	7,266	8,356	12,551	14,434	23,781	27,348	35,672	41,022
Incremental Fuel Cost/yr		$ 330		$ 550		$ 770		$ 1,090		$ 1,883		$ 3,567		$ 5,351
Three Year Grant Amount		$934		$1,556		$2,179		$3,083		$5,325		$10,090		$15,135
NOx Emission Factor (g/hr)	74	60	123	101	172	141	231	190	399	327	757	620	1135	931
NOx (tons/year)	0.04	0.03	0.06	0.05	0.09	0.07	0.12	0.10	0.21	0.17	0.40	0.32	0.59	0.49
NOx Reduction (tons/year)		0.01		0.01		0.02		0.02		0.04		0.07		0.11
Cost-Effectiveness ($/ton)		$47,611		$47,611		$47,611		$50,021		$50,021		$50,021		$50,021
One-Year Cost-Effectiveness		$134,673		$134,673		$134,673		$141,489		$141,489		$141,489		$141,489

Table M16a-NR-AG: Measure 16a Emulsified Diesel Fuel for Agricultural Equipment

Combines	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx
NOx (g/bhp-hr)	9.3	7.63	9.5	7.79	6.9	5.66	6.9	5.66	4.655	3.82	4.56	3.74	2.85	2.34	2.85	2.34
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,865	1,865	3,534	3,534	1,865	1,865	3,534	3,534	1,865	1,865	3,534	3,534	1,865	1,865	3,534	3,534
Fuel Cost ($/yr)	3,964	4,558	7,510	8,636	3,964	4,558	7,510	8,636	3,964	4,558	7,510	8,636	3,964	4,558	7,510	8,636
Incremental Fuel Cost/yr		$ 595		$ 1,126		$ 595		$ 1,126		$ 595		$ 1,126		$ 595		$ 1,126
Three Year Grant Amount		$1,682		$3,186		$1,682		$3,186		$1,682		$3,186		$1,682		$3,186
NOx Emission Factor (g/hr)	1303	1069	2522	2068	967	793	1832	1502	652	535	1211	993	399	327	757	620
NOx (tons/year)	0.22	0.18	0.42	0.34	0.16	0.13	0.30	0.25	0.11	0.09	0.20	0.16	0.07	0.05	0.13	0.10
NOx Reduction (tons/year)		0.04		0.08		0.03		0.05		0.02		0.04		0.01		0.02
Cost-Effectiveness ($/ton)		$15,329		$15,006		$20,661		$20,661		$30,625		$31,263		$50,021		$50,021
One-Year Cost-Effectiveness		$43,360		$42,447		$58,441		$58,441		$86,626		$88,431		$141,489		$141,489

Measure 16a: Emulsified Diesel Fuel

Cost of diesel:	2.13	
Increamental Fuel Cost	15%	Assumed 15% fuel penalty due to lower volumetric effciency.
Cost of PuriNOx	2.44	
EPA Reduction (15 to 21%)	18 %	
CARB Reduction	14 %	

Excavators	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx
NOx (g/bhp-hr)	9.3	7.63	9.5	7.79	6.9	5.66	6.9	5.66	4.655	3.82	4.56	3.74	2.85	2.34	2.85	2.34
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	16,289	16,289	30,864	30,864	16,289	16,289	30,864	30,864	16,289	16,289	30,864	30,864	16,289	16,289	30,864	30,864
Fuel Cost ($/yr)	34,615	39,807	65,586	75,424	34,615	39,807	65,586	75,424	34,615	39,807	65,586	75,424	34,615	39,807	65,586	75,424
Incremental Fuel Cost/yr		$ 5,192		$ 9,838		$ 5,192		$ 9,838		$ 5,192		$ 9,838		$ 5,192		$ 9,838
Three Year Grant Amount		$14,687		$27,827		$14,687		$27,827		$14,687		$27,827		$14,687		$27,827
NOx Emission Factor (g/hr)	1303	1069	2522	2068	967	793	1832	1502	652	535	1211	993	399	327	757	620
NOx (tons/year)	1.88	1.54	3.64	2.99	1.40	1.14	2.65	2.17	0.94	0.77	1.75	1.43	0.58	0.47	1.09	0.90
NOx Reduction (tons/year)		0.34		0.66		0.25		0.48		0.17		0.31		0.10		0.20
Cost-Effectiveness ($/ton)		$15,329		$15,006		$20,661		$20,661		$30,625		$31,263		$50,021		$50,021
One-Year Cost-Effectiveness		$43,360		$42,447		$58,441		$58,441		$86,626		$88,431		$141,489		$141,489

Rubber Tire Loaders	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx
NOx (g/bhp-hr)	9.5	7.79	9.7	7.95	9.1	7.46	6.9	5.66	6.9	5.66	6.9	5.66	4.56	3.74	4.56	3.74	4.56	3.74	2.85	2.34	2.85	2.34
Average Horsepower (hp)	450	450	675	675	1,185	1,185	450	450	675	675	1,185	1,185	450	450	675	675	1,185	1,185	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	21,510	21,510	32,266	32,266	56,649	56,649	21,510	21,510	32,266	32,266	56,649	56,649	21,510	21,510	32,266	32,266	56,649	56,649	21,510	21,510	32,266	32,266
Fuel Cost ($/yr)	45,710	52,566	68,565	78,849	120,379	138,436	45,710	52,566	68,565	78,849	120,379	138,436	45,710	52,566	68,565	78,849	120,379	138,436	45,710	52,566	68,565	78,849
Incremental Fuel Cost/yr		$ 6,856		$ 10,285		$ 18,057		$ 6,856		$ 10,285		$ 18,057		$ 6,856		$ 10,285		$ 18,057		$ 6,856		$ 10,285
Three Year Grant Amount		$19,394		$29,091		$51,076		$19,394		$29,091		$51,076		$19,394		$29,091		$51,076		$19,394		$29,091
NOx Emission Factor (g/hr)	2522	2068	3863	3168	6363	5217	1832	1502	2748	2253	4825	3956	1211	993	1816	1489	3188	2614	757	620	1135	931
NOx (tons/year)	2.54	2.08	3.89	3.19	6.40	5.25	1.84	1.51	2.77	2.27	4.86	3.98	1.22	1.00	1.83	1.50	3.21	2.63	0.76	0.62	1.14	0.94
NOx Reduction (tons/year)		0.46		0.70		1.15		0.33		0.50		0.87		0.22		0.33		0.58		0.14		0.21
Cost-Effectiveness ($/ton)		$15,006		$14,697		$15,666		$20,661		$20,661		$20,661		$31,263		$31,263		$31,263		$50,021		$50,021
One-Year Cost-Effectiveness		$42,447		$41,572		$44,313		$58,441		$58,441		$58,441		$88,431		$88,431		$88,431		$141,489		$141,489

Crawler Tractors/Dozers	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx
NOx (g/bhp-hr)	9.5	7.79	9.7	7.95	9.1	7.46	6.9	5.66	6.9	5.66	6.9	5.66	4.56	3.74	4.56	3.74	4.56	3.74	2.85	2.34	2.85	2.34
Average Horsepower (hp)	450	450	675	675	887	887	450	450	675	675	887	887	450	450	675	675	887	887	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	26,458	26,458	39,687	39,687	52,181	52,181	26,458	26,458	39,687	39,687	52,181	52,181	26,458	26,458	39,687	39,687	52,181	52,181	26,458	26,458	39,687	39,687
Fuel Cost ($/yr)	56,223	64,657	84,335	96,986	110,884	127,516	56,223	64,657	84,335	96,986	110,884	127,516	56,223	64,657	84,335	96,986	110,884	127,516	56,223	64,657	84,335	96,986
Incremental Fuel Cost/yr		$ 8,434		$ 12,650		$ 16,633		$ 8,434		$ 12,650		$ 16,633		$ 8,434		$ 12,650		$ 16,633		$ 8,434		$ 12,650
Three Year Grant Amount		$23,855		$35,783		$47,047		$23,855		$35,783		$47,047		$23,855		$35,783		$47,047		$23,855		$35,783
NOx Emission Factor (g/hr)	2522	2068	3863	3168	4765	3907	1832	1502	2748	2253	3613	2963	1211	993	1816	1489	2388	1958	757	620	1135	931
NOx (tons/year)	3.12	2.56	4.78	3.92	5.90	4.84	2.27	1.86	3.40	2.79	4.47	3.67	1.50	1.23	2.25	1.84	2.96	2.42	0.94	0.77	1.41	1.15
NOx Reduction (tons/year)		0.56		0.86		1.06		0.41		0.61		0.81		0.27		0.40		0.53		0.17		0.25
Cost-Effectiveness ($/ton)		$15,006		$14,697		$15,666		$20,661		$20,661		$20,661		$31,263		$31,263		$31,263		$50,021		$50,021
One-Year Cost-Effectiveness		$42,447		$41,572		$44,313		$58,441		$58,441		$58,441		$88,431		$88,431		$88,431		$141,489		$141,489

Table M16a-NR-Con: Measure 16a Emulsified Diesel Fuel for Construction Equipment.

Tractors/Loaders/Backhoes	100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP	
	Tier 0 Baseline	With PuriNOx	Tier 0 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx	Tier 3 Baseline	With PuriNOx
NOx (g/bhp-hr)	9.5	7.79	9.3	7.63	6.9	5.66	6.9	5.66	4.655	3.82	4.655	3.82	2.85	2.34	2.85	2.34
Average Horsepower (hp)	138	138	238	238	138	138	238	238	138	138	238	238	138	138	238	238
Load Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Activity (hr/yr)	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362
Energy Consumption Factor (bhp-hr/gal)	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4
Fuel Usage (gal/yr)	11,419	11,419	19,724	19,724	11,419	11,419	19,724	19,724	11,419	11,419	19,724	19,724	11,419	11,419	19,724	19,724
Fuel Cost ($/yr)	24,266	27,906	41,914	48,201	24,266	27,906	41,914	48,201	24,266	27,906	41,914	48,201	24,266	27,906	41,914	48,201
Incremental Fuel Cost/yr		$ 3,640		$ 6,287		$ 3,640		$ 6,287		$ 3,640		$ 6,287		$ 3,640		$ 6,287
Three Year Grant Amount		$10,296		$17,784		$10,296		$17,784		$10,296		$17,784		$10,296		$17,784
NOx Emission Factor (g/hr)	274	225	464	380	199	163	344	282	134	110	232	190	82	67	142	117
NOx (tons/year)	0.41	0.34	0.70	0.57	0.30	0.25	0.52	0.42	0.20	0.17	0.35	0.29	0.12	0.10	0.21	0.17
NOx Reduction (tons/year)		0.07		0.13		0.05		0.09		0.04		0.06		0.02		0.04
Cost-Effectiveness ($/ton)		$49,101		$50,157		$67,603		$67,603		$100,207		$100,207		$163,671		$163,671
One-Year Cost-Effectiveness		$138,889		$141,876		$191,224		$191,224		$283,447		$283,447		$462,963		$462,963

Off-Highway Trucks	750+ HP		750+ HP		750+ HP	
	Tier 0 Baseline	With PuriNOx	Tier 1 Baseline	With PuriNOx	Tier 2 Baseline	With PuriNOx
NOx (g/bhp-hr)	9.1	7.46	6.9	5.66	4.56	3.74
Average Horsepower (hp)	1360	1360	1360	1360	1360	1360
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,969	1,969	1,969	1,969	1,969	1,969
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	140,159	140,159	140,159	140,159	140,159	140,159
Fuel Cost ($/yr)	297,838	342,513	297,838	342,513	297,838	342,513
Incremental Fuel Cost/yr		$ 44,676		$ 44,676		$ 44,676
Three Year Grant Amount		$126,370		$126,370		$126,370
NOx Emission Factor (g/hr)	7300	5986	5535	4539	3658	2999
NOx (tons/year)	15.84	12.99	12.01	9.85	7.94	6.51
NOx Reduction (tons/year)		2.85		2.16		1.43
Cost-Effectiveness ($/ton)		$15,666		$20,661		$31,263
One-Year Cost-Effectiveness		$44,313		$58,441		$88,431

Table M16a-OR: Measure 16a - Emulsified Diesel Fuel for On-Road Diesel Vehicles

Measure 16a: Emulsified Diesel Fuel

Cost of diesel:	2.13	
Increamental Fuel Cost	15%	
Cost of PuriNOx	2.44	Assuming 15% increase in fuel cost due to lower volumetric effciency & fuel price
EPA Reduction (15 to 21%)	18	%
CARB Reduction	14	%

	MY1989 & Earlier		MY 1990		MY 1991 - 1997		MY 1998 - 2001		MY 2002 - 2006		MY 2007+	
	Baseline	w/PuriNOx	Baseline	w/PuriNOx	Baseline	w/PuriNOx	Baseline	w/PuriNOx	Baseline	w/PuriNOx	Baseline	w/PuriNOx
Annual mileage	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Diesel mpg	5.35	5.35	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54
Fuel Cost/mile	$0.40	$0.46	$0.38	$0.44	$0.38	$0.44	$0.38	$0.44	$0.38	$0.44	$0.38	$0.44
Fuel Cost/year	$19,878	$22,860	$19,179	$22,056	$19,179	$22,056	$19,179	$22,056	$19,179	$22,056	$19,179	$22,056
Incremental Fuel Cost/year		$2,982		$2,877		$2,877		$2,877		$2,877		$2,877
Three Year Grant Amount		$8,434		$8,137		$8,137		$8,137		$8,137		$8,137
Emission Std (g/bhp-hr)	10.7		6		5		4		2.4		0.19	
Coversion Factor (bhp-hr/mi)	3.11		3.05		2.95		2.90		2.90		2.90	
NOx g/mile	33.24	27.26	18.30	15.01	14.75	12.09	11.58	9.50	6.95	5.70	0.55	0.45
NO tons/year	1.83	1.50	1.01	0.83	0.81	0.67	0.64	0.52	0.38	0.31	0.03	0.02
NOx Reduction tons/year		0.33		0.18		0.15		0.11		0.07		0.01
Cost-Effectiveness ($/ton)		$9,039		$15,843		$19,661		$25,037		$41,728		$527,093
One-Year Cost-Effectiveness		$25,568		$44,814		$55,613		$70,820		$118,033		$1,490,941

Appendix M16b

California Low Sulfur Diesel Fuel for On-Road Heavy-Duty Diesel Vehicle and Non-Road Diesel Equipment

Measure 16b: California Diesel Fuel for Nonroad Equipment

Cost of diesel ($/gal):	2.13	
Increamental Fuel Cost ($/gal)	0.08	
Emission Reduction	6.2	%
Cost-Effectiveness	9,470	$/tons of NOx reduced

Equipment Type	Diesel NOx (tpd)	W/ CA Diesel NOx (tpd)	NOx Reduction (tpd)	Equip Population	Emission Reduction (tpy per equipment)	Cost ($/yr)
Railway Maintenance	1.35	1.27	0.08	2,241	0.013620	129
Pleasure Craft	22.24	20.87	1.38	68,922	0.007304	69
Recreational	0.72	0.68	0.04	6,532	0.002508	24
Construction and Mining	272.85	255.93	16.92	253,840	0.024325	230
Industrial	59.53	55.84	3.69	112,663	0.011958	113
Lawn and Garden	13.52	12.68	0.84	73,395	0.004169	39
Agricultural	254.33	238.56	15.77	467,073	0.012322	117
Commercial	33.67	31.58	2.09	206,828	0.003684	35
Logging	1.98	1.86	0.12	1,178	0.038118	361
Airport Ground Support	3.45	3.24	0.21	3,233	0.024177	229
Underground Mining	0.64	0.60	0.04	735	0.019638	186

Note:
Cost effectiveness of the California Diesel Fuel Measure was assumed to be the same for on-road diesel vehicles and NONROAD diesel equipment.

TABLE 16b-1: California Low Sulfur Diesel Fuels for On-road Diesel Vehicles

Measure 16b: California Diesel Fuel for On-Road Diesel Vehicles

Cost of diesel:	2.13	
Increamental Fuel Cost	0.08	
Emission Reduction	6.2	%

Estimated Incremental Diesel Fuel Costs

	LDVs		LDTs		Class 2B		Class 3-5		Class 6-7		Class 8		Buses	
	Baseline	w/ CA Diesel	Baseline	w/ CA Diesel	Baseline	w/ CA Diesel	Baseline	w/ CA Diesel	Baseline	w/ CA Diesel	Baseline	w/ CA Diesel	Baseline	w/ CA Diesel
Annual mileage	9,774	9,774	9,757	9,757	10,305	10,305	10,829	10,829	11,461	11,461	26,913	26,913	21,878	21,878
Diesel mpg	34.20	34.20	22.10	22.10	11.50	11.50	10.50	10.50	7.00	7.00	5.60	5.60	5.00	5.00
Fuel Cost/mile	$0.06	$0.06	$0.10	$0.10	$0.18	$0.19	$0.20	$0.21	$0.30	$0.31	$0.38	$0.39	$0.43	$0.44
Fuel Cost/year	$607	$629	$938	$971	$1,904	$1,971	$2,192	$2,269	$3,479	$3,602	$10,213	$10,573	$9,298	$9,626
Incremental Fuel Cost/year		$21		$33		$67		$77		$123		$360		$328

Estimated Emission Reductions

2009 LADCO States	NOx Emissions (tpd)			Vehicle Population	Emission Reduction per Veh (tpy)	Cost-Effectiveness ($/ton)
	Baseline	w/ CA Diesel	Reduction			
LDDV	1.30	1.2	0.1	40800	0.0007236	29,622
LDDT	1.85	1.7	0.1	91974	0.0004558	72,642
Class 2b diesel	30.15	28.3	1.9	1680666	0.0004059	165,553
Class 3, 4, 5 diesel	28.99	27.2	1.8	353078	0.0018581	41,629
Class 6, 7 diesel	131.14	123.0	8.1	565913	0.0052440	23,417
Class 8 diesel	856.58	803.5	53.1	203639	0.0951907	3,787
Buses	38.69	30.7	8.0	125592	0.0231123	14,199
Emission Reduction Weighted Average Cost-Effectiveness ($/ton)						7,957

Appendix M20/25

Nonroad Equipment Modernization via Diesel Engines or Equipment Replacement

Measure 20/25: Diesel Equipment Fleet Modernization via Replacing Tier 0 and Tier 1 Engines with Tier 2 and/or Tier 3 Engines.

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	Tier 2 Engines	Tier 0 Baseline	Tier 2 Engine	Tier 0 Baseline	Tier 2 Engines	Tier 0 Baseline	Tier 2 Engine	Tier 0 Baseline	Tier 2 Engines	Tier 0 Baseline	Tier 2 Engine	Tier 0 Baseline	Tier 2 Engine
NOx (g/bhp-hr)	7.2	5.42	8.8	5.32	8.8	5.32	9.5	4.655	9.3	4.655	9.5	4.56	9.7	4.56
Average Horsepower (hp)	38	38	63	66	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Incremental Capital Cost		$ 3,750		$ 6,600		$ 8,750		$ 13,750		$ 23,750		$ 45,000		$ 67,500
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$440		$774		$1,026		$1,612		$2,784		$5,275		$7,913
NOx Emission Factor (g/hr)	159	120	325	207	454	275	771	378	1303	652	2522	1211	3863	1816
NOx (tons/year)	0.08	0.06	0.17	0.11	0.24	0.14	0.40	0.20	0.68	0.34	1.32	0.63	2.02	0.95
NOx Reduction (tons/year)		0.02		0.06		0.09		0.21		0.34		0.69		1.07
Cost-Effectiveness ($/ton)		$21,320		$12,594		$10,905		$7,833		$8,170		$7,682		$7,383
One-Year Cost-Effectiveness		$181,860		$107,426		$93,020		$66,813		$69,690		$65,529		$62,979

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 1 Baseline	Tier 2 Engines	Tier 1 Baseline	Tier 2 Engine	Tier 1 Baseline	Tier 2 Engines	Tier 1 Baseline	Tier 2 Engines	Tier 1 Baseline	Tier 2 Engines	Tier 1 Baseline	Tier 2 Engines	Tier 1 Baseline	Tier 2 Engines
NOx (g/bhp-hr)	6.745	5.42	6.9	5.32	6.9	5.32	6.9	4.655	6.9	4.655	6.9	4.56	6.9	4.56
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Incremental Capital Cost		$ 3,750		$ 6,250		$ 8,750		$ 13,750		$ 23,750		$ 45,000		$ 67,500
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$440		$733		$1,026		$1,612		$2,784		$5,275		$7,913
NOx Emission Factor (g/hr)	149	120	254	196	356	275	560	378	967	652	1832	1211	2748	1816
NOx (tons/year)	0.08	0.06	0.13	0.10	0.19	0.14	0.29	0.20	0.51	0.34	0.96	0.63	1.44	0.95
NOx Reduction (tons/year)		0.02		0.03		0.04		0.10		0.16		0.33		0.49
Cost-Effectiveness ($/ton)		$28,641		$24,018		$24,018		$16,904		$16,904		$16,217		$16,217
One-Year Cost-Effectiveness		$244,310		$204,880		$204,880		$144,192		$144,192		$138,338		$138,338

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 1 Baseline	Tier 3 Engines	Tier 1 Baseline	Tier 3 Engine	Tier 1 Baseline	Tier 3 Engines	Tier 1 Baseline	Tier 3 Engine	Tier 1 Baseline	Tier 3 Engines	Tier 1 Baseline	Tier 3 Engine	Tier 1 Baseline	Tier 3 Engine
NOx (g/bhp-hr)	6.745	3.325	6.9	3.325	6.9	3.325	6.9	2.85	6.9	2.85	6.9	2.85	6.9	2.85
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Incremental Capital Cost		$ 4,500		$ 7,500		$ 10,500		$ 16,500		$ 28,500		$ 54,000		$ 81,000
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$528		$879		$1,231		$1,934		$3,341		$6,330		$9,496
NOx Emission Factor (g/hr)	149	74	254	123	356	172	560	231	967	399	1832	757	2748	1135
NOx (tons/year)	0.08	0.04	0.13	0.06	0.19	0.09	0.29	0.12	0.51	0.21	0.96	0.40	1.44	0.59
NOx Reduction (tons/year)		0.04		0.07		0.10		0.17		0.30		0.56		0.84
Cost-Effectiveness ($/ton)		$13,315		$12,738		$12,738		$11,244		$11,244		$11,244		$11,244
One-Year Cost-Effectiveness		$113,583		$108,658		$108,658		$95,914		$95,914		$95,914		$95,914

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 2 Baseline	Tier 3 Engines	Tier 2 Baseline	Tier 3 Engine	Tier 2 Baseline	Tier 3 Engines	Tier 2 Baseline	Tier 3 Engine	Tier 2 Baseline	Tier 3 Engines	Tier 2 Baseline	Tier 3 Engine	Tier 2 Baseline	Tier 3 Engine
NOx (g/bhp-hr)	5.42	3.325	5.32	3.325	5.32	3.325	4.655	2.85	4.655	2.85	4.56	2.85	4.56	2.85
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Incremental Capital Cost		$ 4,500		$ 7,500		$ 10,500		$ 16,500		$ 28,500		$ 54,000		$ 81,000
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$528		$879		$1,231		$1,934		$3,341		$6,330		$9,496
NOx Emission Factor (g/hr)	120	74	196	123	275	172	378	231	652	399	1211	757	1816	1135
NOx (tons/year)	0.06	0.04	0.10	0.06	0.14	0.09	0.20	0.12	0.34	0.21	0.63	0.40	0.95	0.59
NOx Reduction (tons/year)		0.02		0.04		0.05		0.08		0.13		0.24		0.36
Cost-Effectiveness ($/ton)		$21,737		$22,826		$22,826		$25,229		$25,229		$26,631		$26,631
One-Year Cost-Effectiveness		$185,419		$194,713		$194,713		$215,210		$215,210		$227,166		$227,166

Combines	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0 Baseline	Tier 2 Engines	Tier 0 Baseline	Tier 2 Engine	Tier 1 Baseline	Tier 2 Engines	Tier 1 Baseline	Tier 2 Engine	Tier 1 Baseline	Tier 3 Engines	Tier 1 Baseline	Tier 3 Engine	Tier 2 Baseline	Tier 3 Engines	Tier 2 Baseline	Tier 3 Engine
NOx (g/bhp-hr)	9.3	4.655	9.5	4.56	6.9	4.655	6.9	4.56	6.9	2.85	6.9	2.85	4.655	2.85	4.56	2.85
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Incremental Capital Cost		$ 23,750		$ 45,000		$ 23,750		$ 45,000		$ 28,500		$ 54,000		$ 28,500		$ 54,000
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,784		$5,275		$2,784		$5,275		$3,341		$6,330		$3,341		$6,330
NOx Emission Factor (g/hr)	1303	652	2522	1211	967	652	1832	1211	967	399	1832	757	652	399	1211	757
NOx (tons/year)	0.22	0.11	0.42	0.20	0.16	0.11	0.30	0.20	0.16	0.07	0.30	0.13	0.11	0.07	0.20	0.13
NOx Reduction (tons/year)		0.11		0.22		0.05		0.10		0.09		0.18		0.04		0.08
Cost-Effectiveness ($/ton)		$25,871		$24,326		$53,528		$51,355		$35,606		$35,606		$79,892		$84,331
One-Year Cost-Effectiveness		$220,686		$207,507		$456,608		$438,070		$303,729		$303,729		$681,497		$719,358

Measure 20/25: Diesel Equipment Fleet Modernization via Replacing Tier 0 and Tier 1 Engines with Tier 2 and/or Tier 3 Engines.

Excavators	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0	Tier 2	Tier 0	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 3	Tier 1	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3
	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine
NOx (g/bhp-hr)	9.3	4.655	9.5	4.56	6.9	4.655	6.9	4.56	6.9	2.85	6.9	2.85	4.655	2.85	4.56	2.85
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310
Incremental Capital Cost		$ 23,750		$ 45,000		$ 23,750		$ 45,000		$ 28,500		$ 54,000		$ 28,500		$ 54,000
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,784		$5,275		$2,784		$5,275		$3,341		$6,330		$3,341		$6,330
NOx Emission Factor (g/hr)	1303	652	2522	1211	967	652	1832	1211	967	399	1832	757	652	399	1211	757
NOx (tons/year)	1.88	0.94	3.64	1.75	1.40	0.94	2.65	1.75	1.40	0.58	2.65	1.09	0.94	0.58	1.75	1.09
NOx Reduction (tons/year)		0.94		1.89		0.45		0.90		0.82		1.55		0.37		0.66
Cost-Effectiveness ($/ton)		$2,962		$2,785		$6,129		$5,880		$4,077		$4,077		$9,148		$9,656
One-Year Cost-Effectiveness		$25,269		$23,760		$52,283		$50,161		$34,778		$34,778		$78,034		$82,369

Rubber Tire Loaders	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		300-600 HP		600-750 HP	
	Tier 0	Tier 2	Tier 0	Tier 2	Tier 0	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 3	Tier 1	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3
	Baseline	Engines	Baseline	Engine	Baseline	Engine	Baseline	Engines	Baseline	Engine	Baseline	Engine	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine
NOx (g/bhp-hr)	9.5	4.56	9.7	4.56	9.1	4.56	6.9	4.56	6.9	4.56	6.9	4.56	6.9	2.85	6.9	2.85	4.56	2.85	4.56	2.85
Average Horsepower (hp)	450	450	675	675	1,185	1,185	450	450	675	675	1,185	1,185	450	450	675	675	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913
Incremental Capital Cost		$ 45,000		$ 67,500		$ 118,510		$ 45,000		$ 67,500		$ 118,510		$ 54,000		$ 81,000		$ 54,000		$ 81,000
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$5,275		$7,913		$13,893		$5,275		$7,913		$13,893		$6,330		$9,496		$6,330		$9,496
NOx Emission Factor (g/hr)	2522	1211	3863	1816	6363	3188	1832	1211	2748	1816	4825	3188	1832	757	2748	1135	1211	757	1816	1135
NOx (tons/year)	2.54	1.22	3.89	1.83	6.40	3.21	1.84	1.22	2.77	1.83	4.86	3.21	1.84	0.76	2.77	1.14	1.22	0.76	1.83	1.14
NOx Reduction (tons/year)		1.32		2.06		3.19		0.63		0.94		1.65		1.08		1.62		0.46		0.69
Cost-Effectiveness ($/ton)		$3,997		$3,841		$4,349		$8,437		$8,437		$8,437		$5,850		$5,850		$13,855		$13,855
One-Year Cost-Effectiveness		$34,092		$32,766		$37,096		$71,972		$71,972		$71,972		$49,901		$49,901		$118,186		$118,186

Crawler Tractors/Dozers	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		300-600 HP		600-750 HP	
	Tier 0	Tier 2	Tier 0	Tier 2	Tier 0	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 3	Tier 1	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3
	Baseline	Engines	Baseline	Engine	Baseline	Engine	Baseline	Engines	Baseline	Engine	Baseline	Engine	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine
NOx (g/bhp-hr)	9.5	4.56	9.7	4.56	9.1	4.56	6.9	4.56	6.9	4.56	6.9	4.56	6.9	2.85	6.9	2.85	4.56	2.85	4.56	2.85
Average Horsepower (hp)	450	450	675	675	887	887	450	450	675	675	887	887	450	450	675	675	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123	1,123
Incremental Capital Cost		$ 45,000		$ 67,500		$ 88,749		$ 45,000		$ 67,500		$ 88,749		$ 54,000		$ 81,000		$ 54,000		$ 81,000
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$5,275		$7,913		$10,404		$5,275		$7,913		$10,404		$6,330		$9,496		$6,330		$9,496
NOx Emission Factor (g/hr)	2522	1211	3863	1816	4765	2388	1832	1211	2748	1816	3613	2388	1832	757	2748	1135	1211	757	1816	1135
NOx (tons/year)	3.12	1.50	4.78	2.25	5.90	2.96	2.27	1.50	3.40	2.25	4.47	2.96	2.27	0.94	3.40	1.41	1.50	0.94	2.25	1.41
NOx Reduction (tons/year)		1.62		2.53		2.94		0.77		1.15		1.52		1.33		2.00		0.56		0.84
Cost-Effectiveness ($/ton)		$3,249		$3,123		$3,536		$6,860		$6,860		$6,860		$4,756		$4,756		$11,264		$11,264
One-Year Cost-Effectiveness		$27,717		$26,638		$30,159		$58,513		$58,513		$58,513		$40,569		$40,569		$96,085		$96,085

Tractors/Loaders/Backhoes	100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP	
	Tier 0	Tier 2	Tier 0	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 3	Tier 1	Tier 3	Tier 2	Tier 3	Tier 2	Tier 3
	Baseline	Engines	Baseline	Engines	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine
NOx (g/bhp-hr)	9.5	4.655	9.3	4.655	6.9	4.655	6.9	4.655	6.9	2.85	6.9	2.85	4.655	2.85	4.655	2.85
Average Horsepower (hp)	138	138	238	238	138	138	238	238	138	138	238	238	138	138	238	238
Load Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Activity (hr/yr)	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362
Incremental Capital Cost		$ 13,750		$ 23,750		$ 13,750		$ 23,750		$ 16,500		$ 28,500		$ 16,500		$ 28,500
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$1,612		$2,784		$1,612		$2,784		$1,934		$3,341		$1,934		$3,341
NOx Emission Factor (g/hr)	274	134	464	232	199	134	344	232	199	82	344	142	134	82	232	142
NOx (tons/year)	0.41	0.20	0.70	0.35	0.30	0.20	0.52	0.35	0.30	0.12	0.52	0.21	0.20	0.12	0.35	0.21
NOx Reduction (tons/year)		0.21		0.35		0.10		0.17		0.18		0.30		0.08		0.14
Cost-Effectiveness ($/ton)		$7,675		$8,005		$16,563		$16,563		$11,017		$11,017		$24,720		$24,720
One-Year Cost-Effectiveness		$65,466		$68,284		$141,283		$141,283		$93,979		$93,979		$210,868		$210,868

Off-Highway Trucks	750+ HP		750+ HP	
	Tier 0	Tier 2	Tier 1	Tier 2
	Baseline	Engines	Baseline	Engines
NOx (g/bhp-hr)	9.1	4.56	6.9	4.56
Average Horsepower (hp)	1360	1360	1360	1360
Load Factor	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,969	1,969	1,969	1,969
Incremental Capital Cost		$ 135,959		$ 135,959
Useful Life (years)	10	10	10	10
Annualized Capital Cost ($/yr)		$15,939		$15,939
NOx Emission Factor (g/hr)	7300	3658	5535	3658
NOx (tons/year)	15.84	7.94	12.01	7.94
NOx Reduction (tons/year)		7.90		4.07
Cost-Effectiveness ($/ton)		$2,016		$3,912
One-Year Cost-Effectiveness		$17,201		$33,373

Appendix M29a/47

Replacement of On-road HDDVs with Natural Gas/Dual-Fuel Engines or Vehicles

Measure 29/47a: LNG/Dual Fuel Retrofit

Cost of diesel:	2.13				
Cost of LNG	1.68				
Diesel (gal/mile)	0.18		LHV (Btu/gal)		
LNG (gal/mile)	0.36	Diesel	130,800	0.18	23,782
		LNG	72,900	0.36	26,160
					10.00%

HD Diesel Tractors	MY1989 & Earlier				MY 1990				MY 1991 - 1997				MY 1998 - 2001				MY 2002 - 2006			
	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine
NOx (g/bhp-hr)	10.7	2.0	2.0	2.0	6.0	2.0	2.0	2.0	5.0	2.0	2.0	2.0	4.0	2.0	2.0	2.0	2.4	2.0	2.0	2.0
Annual Mileage	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000
Useful Life (years)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Annualized Capital Cost ($/yr)		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274
Conversion Factor (bhp-hr/mi)	3.11	2.90	3.11	3.11	3.05	2.90	3.05	3.05	2.95	2.90	2.95	2.95	2.90	2.90	2.90	2.90	2.90	2.90	2.90	2.90
Diesel (gal/mile)	0.18			0.03	0.18			0.03	0.18			0.03	0.18			0.03	0.18			0.03
LNG (gal/mile)		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31
Fuel Cost per Mile	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57
Fuel Cost per year	$19,318	$30,053	$30,053	$28,733	$19,318	$30,053	$30,053	$28,733	$19,318	$30,053	$30,053	$28,733	$19,318	$30,053	$30,053	$28,733	$19,318	$30,053	$30,053	$28,733
Added Fuel Cost per year		$10,735	$10,735	$9,415		$10,735	$10,735	$9,415		$10,735	$10,735	$9,415		$10,735	$10,735	$9,415		$10,735	$10,735	$9,415
NOx (g/mi)	33.24	5.79	6.21	6.21	18.30	5.79	6.10	6.10	14.75	5.79	5.90	5.90	11.58	5.79	5.79	5.79	6.95	5.79	5.79	5.79
NOx (tons/year)	1.83	0.32	0.34	0.34	1.01	0.32	0.34	0.34	0.81	0.32	0.33	0.33	0.64	0.32	0.32	0.32	0.38	0.32	0.32	0.32
NOx Reduction (tons/year)		1.51	1.49	1.49		0.69	0.67	0.67		0.49	0.49	0.49		0.32	0.32	0.32		0.06	0.06	0.06
Cost-Effectiveness ($/ton)		$14,122	$3,347	$2,869		$30,992	$7,415	$6,356		$43,288	$10,225	$8,764		$66,962	$15,624	$13,392		$334,809	$78,122	$66,962
C-E including Fuel ($/ton)		$21,216	$10,553	$9,188		$46,562	$23,381	$20,358		$65,036	$32,239	$28,071		$100,603	$49,265	$42,895		$503,015	$246,327	$214,477
One-Year Cost-Effectiveness		$99,130	$23,493	$20,137		$217,554	$52,052	$44,616		$303,871	$71,773	$61,520		$470,052	$109,679	$94,010		$2,350,259	$548,394	$470,052

Refuse Trucks	MY1989 & Earlier				MY 1990				MY 1991 - 1997				MY 1998 - 2001				MY 2002 - 2006			
	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine
NOx (g/bhp-hr)	10.7	2.0	2.0	2.0	6.0	2.0	2.0	2.0	5.0	2.0	2.0	2.0	4.0	2.0	2.0	2.0	2.4	2.0	2.0	2.0
Annual Mileage	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Incremental Capital Cost		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000
Useful Life (years)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Annualized Capital Cost ($/yr)		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274
Conversion Factor (bhp-hr/mi)	9.32	8.69	9.32	9.32	9.15	8.69	9.15	9.15	8.85	8.69	8.85	8.85	8.69	8.69	8.69	8.69	8.69	8.69	8.69	8.69
Diesel (gal/mile)	0.18			0.03	0.18			0.03	0.18			0.03	0.18			0.03	0.18			0.03
LNG (gal/mile)		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31
Fuel Cost per Mile	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57
Fuel Cost per year	$7,727	$12,021	$12,021	$11,493	$7,727	$12,021	$12,021	$11,493	$7,727	$12,021	$12,021	$11,493	$7,727	$12,021	$12,021	$11,493	$7,727	$12,021	$12,021	$11,493
Added Fuel Cost per year		$4,294	$4,294	$3,766		$4,294	$4,294	$3,766		$4,294	$4,294	$3,766		$4,294	$4,294	$3,766		$4,294	$4,294	$3,766
NOx (g/mi)	99.73	17.37	18.64	18.64	54.90	17.37	18.30	18.30	44.24	17.37	17.70	17.70	34.74	17.37	17.37	17.37	20.84	17.37	17.37	17.37
NOx (tons/year)	2.20	0.38	0.41	0.41	1.21	0.38	0.40	0.40	0.98	0.38	0.39	0.39	0.77	0.38	0.38	0.38	0.46	0.38	0.38	0.38
NOx Reduction (tons/year)		1.82	1.79	1.79		0.83	0.81	0.81		0.59	0.59	0.59		0.38	0.38	0.38		0.08	0.08	0.08
Cost-Effectiveness ($/ton)		$11,768	$2,789	$2,391		$25,827	$6,179	$5,297		$36,074	$8,520	$7,303		$55,802	$13,020	$11,160		$279,008	$65,102	$55,802
C-E including Fuel ($/ton)		$14,133	$5,191	$4,497		$31,017	$11,501	$9,964		$43,323	$15,859	$13,739		$67,015	$24,234	$20,995		$335,076	$121,170	$104,973
One-Year Cost-Effectiveness		$82,608	$19,578	$16,781		$181,295	$43,377	$37,180		$253,226	$59,811	$51,267		$391,710	$91,399	$78,342		$1,958,549	$456,995	$391,710

Transit Buses	MY1989 & Earlier				MY 1990				MY 1991 - 1997				MY 1998 - 2001				MY 2002 - 2006			
	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine	Diesel Baseline	Whole Truck	Dedicated LNG	Dual-Fuel Engine
NOx (g/bhp-hr)	10.7	2.0	2.0	2.0	6.0	2.0	2.0	2.0	5.0	2.0	2.0	2.0	4.0	2.0	2.0	2.0	2.4	2.0	2.0	2.0
Annual Mileage	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000		$ 150,000	$35,000	$30,000
Useful Life (years)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Annualized Capital Cost ($/yr)		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274		$21,368	$4,986	$4,274
Conversion Factor (bhp-hr/mi)	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68	4.68
Diesel (gal/mile)	0.18			0.03	0.18			0.03	0.18			0.03	0.18			0.03	0.18			0.03
LNG (gal/mile)		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31		0.36	0.36	0.31
Fuel Cost per Mile	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57	$0.39	$0.60	$0.60	$0.57
Fuel Cost per year	$19,318	$30,053	$30,053	$28,733	$19,318	$30,053	$30,053	$28,733	$19,318	$30,053	$30,053	$28,733	$19,318	$30,053	$30,053	$28,733	$19,318	$30,053	$30,053	$28,733
Added Fuel Cost per year		$10,735	$10,735	$9,415		$10,735	$10,735	$9,415		$10,735	$10,735	$9,415		$10,735	$10,735	$9,415		$10,735	$10,735	$9,415
NOx (g/mi)	50.07	9.36	9.36	9.36	28.07	9.36	9.36	9.36	23.40	9.36	9.36	9.36	18.72	9.36	9.36	9.36	11.23	9.36	9.36	9.36
NOx (tons/year)	2.76	0.52	0.52	0.52	1.55	0.52	0.52	0.52	1.29	0.52	0.52	0.52	1.03	0.52	0.52	0.52	0.62	0.52	0.52	0.52
NOx Reduction (tons/year)		2.24	2.24	2.24		1.03	1.03	1.03		0.77	0.77	0.77		0.52	0.52	0.52		0.10	0.10	0.10
Cost-Effectiveness ($/ton)		$9,524	$2,222	$1,905		$20,715	$4,834	$4,143		$27,621	$6,445	$5,524		$41,431	$9,667	$8,286		$207,154	$48,336	$41,431
C-E including Fuel ($/ton)		$14,309	$7,007	$6,101		$31,123	$15,241	$13,270		$41,497	$20,321	$17,694		$62,245	$30,482	$26,540		$311,226	$152,408	$132,701
One-Year Cost-Effectiveness		$66,858	$15,600	$13,372		$145,416	$33,930	$29,083		$193,888	$45,240	$38,778		$290,831	$67,861	$58,166		$1,454,157	$339,303	$290,831

Appendix M31/32

On-Road Fleet Modernization via Diesel Engine or Vehicle Replacement

Measure 31/32: Fleet Modernization via Vehicle/Engine Replacement

	MY1989 & Earlier				MY 1990			MY 1991 - 1997			MY 1998 - 2001/2		
	Diesel Baseline	MY 1990 Engines	MY 2001/2 Engine	MY 2002/4 Engine	Diesel Baseline	MY 2001/2 Engine	MY 2002/4 Engine	Diesel Baseline	MY 2001/2 Engine	MY 2002/4 Engine	Diesel Baseline	MY 2002/4 Engine	MY 2007 Engine
NOx (g/bhp-hr)	10.7	6.0	4.0	2.4	6.0	4.0	2.4	5.0	4.0	2.4	4.0	2.4	0.19
Annual Mileage	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 35,000	$40,000	$45,000		$40,000	$45,000		$40,000	$45,000		$45,000	$60,000
Useful Life (years)	8	8	8	8	8	8	8	8	8	8	8	8	8
Annualized Capital Cost ($/yr)		$4,986	$5,698	$6,411		$5,698	$6,411		$5,698	$6,411		$6,411	$8,547
Conversion Factor (bhp-hr/mi)	3.11	3.05	2.90	2.90	3.05	2.90	2.90	2.95	2.90	2.90	2.90	2.90	2.90
NOx (g/mi)	33.24	18.30	11.58	6.95	18.30	11.58	6.95	14.75	11.58	6.95	11.58	6.88	0.55
NOx (tons/year)	1.83	1.01	0.64	0.38	1.01	0.64	0.38	0.81	0.64	0.38	0.64	0.38	0.03
NOx Reduction (tons/year)		0.82	1.19	1.45		0.37	0.63		0.17	0.43		0.26	0.35
Cost-Effectiveness ($/ton)		$6,053	$4,772	$4,423		$15,385	$10,246		$32,652	$14,915		$24,724	$24,517
One-Year Cost-Effectiveness		$42,492	$33,499	$31,049		$108,000	$71,924		$229,205	$104,698		$173,558	$172,101

Appendix M42

Accelerated Low NOx Rebuild/Chip Reflashing Program for On-Road Heavy-Duty Diesel Vehicles

Measure 42: HDDE Low NOx Calibration/Reflash Program

Cost of Diesel:	2.13
Increamental Fuel Consumption	2%
NOx Reduction	23%

	Medium-HDDVs		Heavy-HDDVs	
	MY1993-MY1998		MY1993-MY1998	
	Off-Cycle Baseline	**Reflashed**	**Off-Cycle Baseline**	**Reflashed**
Annual mileage	50,000	50,000	50,000	50,000
Incremental Capital Cost		0		0
Useful Life (years)	8	8	8	8
Annualized Capital Cost ($/yr)		$0		$0
Diesel mpg	5.35	5.35	5.35	5.35
Fuel Cost/mile	$0.40	$0.40	$0.40	$0.40
Fuel Cost/year	$19,878	$20,276	$19,878	$20,276
Incremental Fuel Cost/year		$398		$398
Emission Std (g/bhp-hr)	7.4	6	7.4	6
Coversion Factor (bhp-hr/mi)	2.15	2.15	2.90	2.90
NOx g/mile	15.80	12.90	21.32	17.40
NO tons/year	0.87	0.71	1.17	0.96
NOx Reduction tons/year		0.16		0.22
Cost-Effectiveness ($/ton)		$0		$0
CE Including Fuel ($/ton)		$2,485		$1,842
One-Year Cost-Effectiveness		$2,485		$1,842

Appendix M46/51

NOx Retrofit Technologies for Diesel Engines

Measure 51a: Lean NOx Catalyst Lonestar
Cost of diesel: 2.13
Increamental Fuel Cost 2% Assuming 2% increase in fuel consumption
Emission Reduction 40%

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar
NOx (g/bhp-hr)	7.2	4.32	8.8	5.28	8.8	5.28	9.5	5.70	9.3	5.58	9.5	5.70	9.7	5.82
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,056	1,726	1,761	2,416	2,465	3,420	3,488	5,906	6,025	11,191	11,415	16,787	17,122
Fuel Cost ($/yr)	1,553	1,584	2,589	2,641	3,625	3,697	5,129	5,232	8,860	9,037	16,787	17,122	25,180	25,684
Incremental Fuel Cost/yr		$ 31		$ 52		$ 72		$ 103		$ 177		$ 336		$ 504
Incremental Capital Cost		$5,158		$7,263		$9,368		$13,579		$20,000		$37,895		$56,842
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$605		$851		$1,098		$1,592		$2,345		$4,442		$6,664
NOx Emission Factor (g/hr)	159	96	325	195	454	273	771	462	1303	782	2522	1513	3863	2318
NOx (tons/year)	0.08	0.05	0.17	0.10	0.24	0.14	0.40	0.24	0.68	0.41	1.32	0.79	2.02	1.21
NOx Reduction (tons/year)		0.03		0.07		0.10		0.16		0.27		0.53		0.81
Cost-Effectiveness ($/ton)		$18,124		$12,529		$11,543		$9,862		$8,591		$8,410		$8,236
CE Including Fuel ($/ton)		$19,055		$13,290		$12,305		$10,498		$9,240		$9,045		$8,859
One-Year Cost-Effectiveness		$154,599		$106,871		$98,463		$84,127		$73,279		$71,737		$70,257

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar
NOx (g/bhp-hr)	6.745	4.05	6.9	4.14	6.9	4.14	6.9	4.14	6.9	4.14	6.9	4.14	6.9	4.14
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,056	1,726	1,761	2,416	2,465	3,420	3,488	5,906	6,025	11,191	11,415	16,787	17,122
Fuel Cost ($/yr)	1,553	1,584	2,589	2,641	3,625	3,697	5,129	5,232	8,860	9,037	16,787	17,122	25,180	25,684
Incremental Fuel Cost/yr		$ 31		$ 52		$ 72		$ 103		$ 177		$ 336		$ 504
Incremental Capital Cost		$5,158		$7,263		$9,368		$13,579		$20,000		$37,895		$56,842
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$605		$851		$1,098		$1,592		$2,345		$4,442		$6,664
NOx Emission Factor (g/hr)	149	90	254	153	356	214	560	336	967	580	1832	1099	2748	1649
NOx (tons/year)	0.08	0.05	0.13	0.08	0.19	0.11	0.29	0.18	0.51	0.30	0.96	0.58	1.44	0.86
NOx Reduction (tons/year)		0.03		0.05		0.07		0.12		0.20		0.38		0.58
Cost-Effectiveness ($/ton)		$19,346		$15,978		$14,721		$13,579		$11,579		$11,579		$11,579
CE Including Fuel ($/ton)		$20,340		$16,950		$15,693		$14,454		$12,454		$12,454		$12,454
One-Year Cost-Effectiveness		$165,028		$136,299		$125,576		$115,828		$98,768		$98,768		$98,768

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar
NOx (g/bhp-hr)	5.42	3.25	5.32	3.19	5.32	3.19	4.655	2.79	4.655	2.79	4.56	2.74	4.56	2.74
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,056	1,726	1,761	2,416	2,465	3,420	3,488	5,906	6,025	11,191	11,415	16,787	17,122
Fuel Cost ($/yr)	1,553	1,584	2,589	2,641	3,625	3,697	5,129	5,232	8,860	9,037	16,787	17,122	25,180	25,684
Incremental Fuel Cost/yr		$ 31		$ 52		$ 72		$ 103		$ 177		$ 336		$ 504
Incremental Capital Cost		$5,158		$7,263		$9,368		$13,579		$20,000		$37,895		$56,842
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$605		$851		$1,098		$1,592		$2,345		$4,442		$6,664
NOx Emission Factor (g/hr)	120	72	196	118	275	165	378	227	652	391	1211	726	1816	1090
NOx (tons/year)	0.06	0.04	0.10	0.06	0.14	0.09	0.20	0.12	0.34	0.20	0.63	0.38	0.95	0.57
NOx Reduction (tons/year)		0.03		0.04		0.06		0.08		0.14		0.25		0.38
Cost-Effectiveness ($/ton)		$24,076		$20,724		$19,093		$20,127		$17,163		$17,520		$17,520
CE Including Fuel ($/ton)		$25,313		$21,984		$20,354		$21,424		$18,460		$18,844		$18,844
One-Year Cost-Effectiveness		$205,371		$176,779		$162,871		$171,688		$146,401		$149,451		$149,451

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar
NOx (g/bhp-hr)	3.325	2.00	3.325	2.00	3.325	2.00	2.85	1.71	2.85	1.71	2.85	1.71	2.85	1.71
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,056	1,726	1,761	2,416	2,465	3,420	3,488	5,906	6,025	11,191	11,415	16,787	17,122
Fuel Cost ($/yr)	1,553	1,584	2,589	2,641	3,625	3,697	5,129	5,232	8,860	9,037	16,787	17,122	25,180	25,684
Incremental Fuel Cost/yr		$ 31		$ 52		$ 72		$ 103		$ 177		$ 336		$ 504
Incremental Capital Cost		$5,158		$7,263		$9,368		$13,579		$20,000		$37,895		$56,842
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$605		$851		$1,098		$1,592		$2,345		$4,442		$6,664
NOx Emission Factor (g/hr)	74	44	123	74	172	103	231	139	399	240	757	454	1135	681
NOx (tons/year)	0.04	0.02	0.06	0.04	0.09	0.05	0.12	0.07	0.21	0.13	0.40	0.24	0.59	0.36
NOx Reduction (tons/year)		0.02		0.03		0.04		0.05		0.08		0.16		0.24
Cost-Effectiveness ($/ton)		$39,245		$33,158		$30,550		$32,874		$28,032		$28,032		$28,032
CE Including Fuel ($/ton)		$41,262		$35,175		$32,566		$34,993		$30,151		$30,151		$30,151
One-Year Cost-Effectiveness		$334,770		$282,847		$260,594		$280,425		$239,122		$239,122		$239,122

	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
Combines	**Tier 0**	**Lonestar**	**Tier 0**	**Lonestar**	**Tier 1**	**Lonestar**	**Tier 1**	**Lonestar**	**Tier 2**	**Lonestar**	**Tier 2**	**Lonestar**	**Tier 3**	**Lonestar**	**Tier 3**	**Lonestar**
	Baseline		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**	
NOx (g/bhp-hr)	9.3	5.58	9.5	5.70	6.9	4.14	6.9	4.14	4.655	2.79	4.56	2.74	2.85	1.71	2.85	1.71
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,865	1,902	3,534	3,605	1,865	1,902	3,534	3,605	1,865	1,902	3,534	3,605	1,865	1,902	3,534	3,605
Fuel Cost ($/yr)	2,798	2,854	5,301	5,407	2,798	2,854	5,301	5,407	2,798	2,854	5,301	5,407	2,798	2,854	5,301	5,407
Incremental Fuel Cost/yr		$ 56		$ 106		$ 56		$ 106		$ 56		$ 106		$ 56		$ 106
Incremental Capital Cost		$20,000		$37,895		$20,000		$37,895		$20,000		$37,895		$20,000		$37,895
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,345		$4,442		$2,345		$4,442		$2,345		$4,442		$2,345		$4,442
NOx Emission Factor (g/hr)	1303	782	2522	1513	967	580	1832	1099	652	391	1211	726	399	240	757	454
NOx (tons/year)	0.22	0.13	0.42	0.25	0.16	0.10	0.30	0.18	0.11	0.06	0.20	0.12	0.07	0.04	0.13	0.08
NOx Reduction (tons/year)		0.09		0.17		0.06		0.12		0.04		0.08		0.03		0.05
Cost-Effectiveness ($/ton)		$27,203		$26,631		$36,666		$36,666		$54,348		$55,481		$88,769		$88,769
CE Including Fuel ($/ton)		$27,853		$27,266		$37,541		$37,541		$55,646		$56,805		$90,888		$90,888
One-Year Cost-Effectiveness		$232,051		$227,166		$312,764		$312,764		$463,603		$473,262		$757,219		$757,219

Measure 51a: Lean NOx Catalyst Lonestar
Cost of diesel: 2.13
Increamental Fuel Cost 2% Assuming 2% increase in fuel consumption
Emission Reduction 40%

Excavators	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar
NOx (g/bhp-hr)	9.3	5.58	9.5	5.70	6.9	4.14	6.9	4.14	4.655	2.79	4.56	2.74	2.85	1.71	2.85	1.71
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310	1,310
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	16,289	16,615	30,864	31,481	16,289	16,615	30,864	31,481	16,289	16,615	30,864	31,481	16,289	16,615	30,864	31,481
Fuel Cost ($/yr)	24,434	24,923	46,296	47,222	24,434	24,923	46,296	47,222	24,434	24,923	46,296	47,222	24,434	24,923	46,296	47,222
Incremental Fuel Cost/yr		$ 489		$ 926		$ 489		$ 926		$ 489		$ 926		$ 489		$ 926
Incremental Capital Cost		$20,000		$37,895		$20,000		$37,895		$20,000		$37,895		$20,000		$37,895
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,345		$4,442		$2,345		$4,442		$2,345		$4,442		$2,345		$4,442
NOx Emission Factor (g/hr)	1303	782	2522	1513	967	580	1832	1099	652	391	1211	726	399	240	757	454
NOx (tons/year)	1.88	1.13	3.64	2.19	1.40	0.84	2.65	1.59	0.94	0.57	1.75	1.05	0.58	0.35	1.09	0.66
NOx Reduction (tons/year)		0.75		1.46		0.56		1.06		0.38		0.70		0.23		0.44
Cost-Effectiveness ($/ton)		$3,115		$3,049		$4,198		$4,198		$6,223		$6,353		$10,164		$10,164
CE Including Fuel ($/ton)		$3,764		$3,685		$5,073		$5,073		$7,520		$7,677		$12,283		$12,283
One-Year Cost-Effectiveness		$26,571		$26,011		$35,813		$35,813		$53,084		$54,190		$86,704		$86,704

Rubber Tire Loaders	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar
NOx (g/bhp-hr)	9.5	5.70	9.7	5.82	9.1	5.46	6.9	4.14	6.9	4.14	6.9	4.14	4.56	2.74	4.56	2.74	4.56	2.74	2.85	1.71	2.85	1.71
Average Horsepower (hp)	450	450	650	650	1,185	1,185	450	450	650	650	1,185	1,185	450	450	650	650	1,185	1,185	450	450	650	650
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913	913
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Fuel Usage (gal/yr)	21,510	21,941	31,071	31,692	56,649	57,782	21,510	21,941	31,071	31,692	56,649	57,782	21,510	21,941	31,071	31,692	56,649	57,782	21,510	21,941	31,071	31,692
Fuel Cost ($/yr)	32,266	32,911	46,606	47,538	84,973	86,673	32,266	32,911	46,606	47,538	84,973	86,673	32,266	32,911	46,606	47,538	84,973	86,673	32,266	32,911	46,606	47,538
Incremental Fuel Cost/yr		$ 645		$ 932		$ 1,699		$ 645		$ 932		$ 1,699		$ 645		$ 932		$ 1,699		$ 645		$ 932
Incremental Capital Cost		$37,895		$54,737		$99,798		$37,895		$54,737		$99,798		$37,895		$54,737		$99,798		$37,895		$54,737
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$4,442		$6,417		$11,699		$4,442		$6,417		$11,699		$4,442		$6,417		$11,699		$4,442		$6,417
NOx Emission Factor (g/hr)	2522	1513	3720	2232	6363	3818	1832	1099	2646	1588	4825	2895	1211	726	1749	1049	3188	1913	757	454	1093	656
NOx (tons/year)	2.54	1.52	3.74	2.25	6.40	3.84	1.84	1.11	2.66	1.60	4.86	2.91	1.22	0.73	1.76	1.06	3.21	1.93	0.76	0.46	1.10	0.66
NOx Reduction (tons/year)		1.02		1.50		2.56		0.74		1.07		1.94		0.49		0.70		1.28		0.30		0.44
Cost-Effectiveness ($/ton)		$4,375		$4,285		$4,568		$6,024		$6,024		$6,024		$9,115		$9,115		$9,115		$14,584		$14,584
CE Including Fuel ($/ton)		$5,011		$4,908		$5,231		$6,899		$6,899		$6,899		$10,439		$10,439		$10,439		$16,703		$16,703
One-Year Cost-Effectiveness		$37,322		$36,552		$38,962		$51,385		$51,385		$51,385		$77,754		$77,754		$77,754		$124,406		$124,406

Crawler Tractors/Dozers	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 0 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 1 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 2 Baseline	Lonestar	Tier 3 Baseline	Lonestar	Tier 3 Baseline	Lonestar
NOx (g/bhp-hr)	9.5	5.70	9.7	5.82	9.1	5.46	6.9	4.14	6.9	4.14	6.9	4.14	4.56	2.74	4.56	2.74	4.56	2.74	2.85	1.71	2.85	1.71
Average Horsepower (hp)	450	450	650	650	887	887	450	450	650	650	887	887	450	450	650	650	887	887	450	450	650	650
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,123	1,123	1,123	1,123	1,123	1,123	1123	1123	1123	1123	1123	1123	1123	1123	1123	1123	1123	1123	1123	1123	1123	1123
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Fuel Usage (gal/yr)	26,458	26,987	38,217	38,982	52,181	53,224	26,458	26,987	38,217	38,982	52,181	53,224	26,458	26,987	38,217	38,982	52,181	53,224	26,458	26,987	38,217	38,982
Fuel Cost ($/yr)	39,687	40,481	57,326	58,472	78,271	79,836	39,687	40,481	57,326	58,472	78,271	79,836	39,687	40,481	57,326	58,472	78,271	79,836	39,687	40,481	57,326	58,472
Incremental Fuel Cost/yr		$ 794		$ 1,147		$ 1,565		$ 794		$ 1,147		$ 1,565		$ 794		$ 1,147		$ 1,565		$ 794		$ 1,147
Incremental Capital Cost		$37,895		$54,737		$74,736		$37,895		$54,737		$74,736		$37,895		$54,737		$74,736		$37,895		$54,737
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$4,442		$6,417		$8,761		$4,442		$6,417		$8,761		$4,442		$6,417		$8,761		$4,442		$6,417
NOx Emission Factor (g/hr)	2522	1513	3720	2232	4765	2859	1832	1099	2646	1588	3613	2168	1211	726	1749	1049	2388	1433	757	454	1093	656
NOx (tons/year)	3.12	1.87	4.60	2.76	5.90	3.54	2.27	1.36	3.28	1.97	4.47	2.68	1.50	0.90	2.16	1.30	2.96	1.77	0.94	0.56	1.35	0.81
NOx Reduction (tons/year)		1.25		1.84		2.36		0.91		1.31		1.79		0.60		0.87		1.18		0.37		0.54
Cost-Effectiveness ($/ton)		$3,557		$3,484		$3,713		$4,897		$4,897		$4,897		$7,411		$7,411		$7,411		$11,857		$11,857
CE Including Fuel ($/ton)		$4,193		$4,106		$4,377		$5,772		$5,772		$5,772		$8,735		$8,735		$8,735		$13,975		$13,975
One-Year Cost-Effectiveness		$30,343		$29,717		$31,676		$41,776		$41,776		$41,776		$63,214		$63,214		$63,214		$101,142		$101,142

Tractors/Loaders/Backhoes	**100-175 HP**		**175-300 HP**		**100-175 HP**		**175-300 HP**		**100-175 HP**		**175-300 HP**		**100-175 HP**		**175-300 HP**	
	Tier 0	**Lonestar**	**Tier 0**	**Lonestar**	**Tier 1**	**Lonestar**	**Tier 1**	**Lonestar**	**Tier 2**	**Lonestar**	**Tier 2**	**Lonestar**	**Tier 3**	**Lonestar**	**Tier 3**	**Lonestar**
	Baseline		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**	
NOx (g/bhp-hr)	9.5	5.70	9.3	5.58	6.9	4.14	6.9	4.14	4.655	2.79	4.655	2.79	2.85	1.71	2.85	1.71
Average Horsepower (hp)	138	138	238	238	138	138	238	238	138	138	238	238	138	138	238	238
Load Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Activity (hr/yr)	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362
Energy Consumption Factor (bhp-hr/gal)	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4
Fuel Usage (gal/yr)	11,419	11,648	19,724	20,119	11,419	11,648	19,724	20,119	11,419	11,648	19,724	20,119	11,419	11,648	19,724	20,119
Fuel Cost ($/yr)	17,129	17,471	29,586	30,178	17,129	17,471	29,586	30,178	17,129	17,471	29,586	30,178	17,129	17,471	29,586	30,178
Incremental Fuel Cost/yr		$ 343		$ 592		$ 343		$ 592		$ 343		$ 592		$ 343		$ 592
Incremental Capital Cost		$20,000		$20,000		$20,000		$20,000		$20,000		$20,000		$20,000		$20,000
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,345		$2,345		$2,345		$2,345		$2,345		$2,345		$2,345		$2,345
NOx Emission Factor (g/hr)	274	165	464	278	199	120	344	206	134	81	232	139	82	49	142	85
NOx (tons/year)	0.41	0.25	0.70	0.42	0.30	0.18	0.52	0.31	0.20	0.12	0.35	0.21	0.12	0.07	0.21	0.13
NOx Reduction (tons/year)		0.16		0.28		0.12		0.21		0.08		0.14		0.05		0.09
Cost-Effectiveness ($/ton)		$14,233		$8,417		$19,596		$11,345		$29,047		$16,816		$47,443		$27,467
CE Including Fuel ($/ton)		$16,312		$10,542		$22,459		$14,208		$33,291		$21,060		$54,375		$34,399
One-Year Cost-Effectiveness		$121,409		$71,801		$167,157		$96,775		$247,773		$143,448		$404,696		$234,298

Off-Highway Trucks	**750+ HP**		**750+ HP**		**750+ HP**	
	Tier 0	**Lonestar**	**Tier 1**	**Lonestar**	**Tier 2**	**Lonestar**
	Baseline		**Baseline**		**Baseline**	
NOx (g/bhp-hr)	9.1	5.46	6.9	4.14	4.56	2.74
Average Horsepower (hp)	1360	1360	1360	1360	1360	1360
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,969	1,969	1,969	1,969	1,969	1,969
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	140,159	142,962	140,159	142,962	140,159	142,962
Fuel Cost ($/yr)	210,238	214,443	210,238	214,443	210,238	214,443
Incremental Fuel Cost/yr		$ 4,205		$ 4,205		$ 4,205
Incremental Capital Cost		$114,492		$114,492		$114,492
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$13,422		$13,422		$13,422
NOx Emission Factor (g/hr)	7300	4380	5535	3321	3658	2195
NOx (tons/year)	15.84	9.51	12.01	7.21	7.94	4.76
NOx Reduction (tons/year)		6.34		4.81		3.18
Cost-Effectiveness ($/ton)		$2,118		$2,793		$4,227
CE Including Fuel ($/ton)		$2,781		$3,668		$5,551
One-Year Cost-Effectiveness		$18,066		$23,827		$36,053

Measure 46a- Lean NOx Catalysts

	Lonestar
Cost of Diesel:	2.13
Increamental Fuel Consumption	2%
NOx Reduction	40%

	MY1989 & Earlier		MY 1990		MY 1991 - 1997		MY 1998 - 2001		MY 2002 - 2006	
	Baseline	Lonestar	Baseline	Lonestar	Baseline	Lonestar	Baseline	Lonestar	Baseline	Lonestar
Annual mileage	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 20,000		$ 20,000		$ 20,000		$ 20,000		$ 20,000
Useful Life (years)	8	8	8	8	8	8	8	8	8	8
Annualized Capital Cost ($/yr)		$2,849		$2,849		$2,849		$2,849		$2,849
Diesel mpg	5.35	5.35	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54
Fuel Cost/mile	$0.40	$0.40	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38
Fuel Cost/year	$19,878	$20,276	$19,179	$19,562	$19,179	$19,562	$19,179	$19,562	$19,179	$19,562
Incremental Fuel Cost/year		$398		$384		$384		$384		$384
Emission Std (g/bhp-hr)	10.7		6		5		4		2.4	
Coversion Factor (bhp-hr/mi)	3.11		3.05		2.95		2.90		2.90	
NOx g/mile	33.24	14.96	18.30	8.24	14.75	6.64	11.58	5.21	6.95	3.13
NO tons/year	1.83	0.82	1.01	0.45	0.81	0.37	0.64	0.29	0.38	0.17
NOx Reduction tons/year		0.55		0.30		0.24		0.19		0.11
Cost-Effectiveness ($/ton)		$5,182		$9,414		$11,683		$14,878		$24,796
CE Including Fuel ($/ton)		$5,905		$10,682		$13,256		$16,881		$28,134
One-Year Cost-Effectiveness		$36,378		$66,086		$82,011		$104,436		$174,061

Measure 51b: EGR+DPF Retrofit

Cost of diesel:	2.13
Addition Cost for ULSD	0.05
Increamental Fuel Consumption	3%
NOx Reduction	30%

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF
NOx (g/bhp-hr)	7.2	5.04	8.8	6.16	8.8	6.16	9.5	6.65	9.3	6.51	9.5	6.65	9.7	6.79
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-h	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,067	1,726	1,778	2,416	2,489	3,420	3,522	5,906	6,084	11,191	11,527	16,787	17,290
Fuel Cost ($/yr)	2,201	2,320	3,668	3,867	5,135	5,413	7,266	7,661	12,551	13,232	23,781	25,071	35,672	37,606
Incremental Fuel Cost/yr		$ 119		$ 199		$ 278		$ 394		$ 681		$ 1,290		$ 1,935
Incremental Capital Cost		$5,632		$8,053		$10,474		$15,316		$23,000		$43,579		$65,368
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$660		$944		$1,228		$1,795		$2,696		$5,109		$7,663
NOx Emission Factor (g/hr)	159	112	325	227	454	318	771	539	1303	912	2522	1766	3863	2704
NOx (tons/year)	0.08	0.06	0.17	0.12	0.24	0.17	0.40	0.28	0.68	0.48	1.32	0.92	2.02	1.42
NOx Reduction (tons/year)		0.03		0.05		0.07		0.12		0.20		0.40		0.61
Cost-Effectiveness ($/ton)		$26,384		$18,520		$17,206		$14,832		$13,172		$12,895		$12,629
CE Including Fuel ($/ton)		$31,154		$22,423		$21,109		$18,087		$16,498		$16,150		$15,817
One-Year Cost-Effectiveness		$225,062		$157,983		$146,773		$126,517		$112,361		$109,996		$107,728

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF
NOx (g/bhp-hr)	6.745	4.72	6.9	4.83	6.9	4.83	6.9	4.83	6.9	4.83	6.9	4.83	6.9	4.83
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-h	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,067	1,726	1,778	2,416	2,489	3,420	3,522	5,906	6,084	11,191	11,527	16,787	17,290
Fuel Cost ($/yr)	2,201	2,320	3,668	3,867	5,135	5,413	7,266	7,661	12,551	13,232	23,781	25,071	35,672	37,606
Incremental Fuel Cost/yr		$ 119		$ 199		$ 278		$ 394		$ 681		$ 1,290		$ 1,935
Incremental Capital Cost		$5,632		$8,053		$10,474		$15,316		$23,000		$43,579		$65,368
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$660		$944		$1,228		$1,795		$2,696		$5,109		$7,663
NOx Emission Factor (g/hr)	149	104	254	178	356	249	560	392	967	677	1832	1282	2748	1924
NOx (tons/year)	0.08	0.05	0.13	0.09	0.19	0.13	0.29	0.21	0.51	0.35	0.96	0.67	1.44	1.01
NOx Reduction (tons/year)		0.02		0.04		0.06		0.09		0.15		0.29		0.43
Cost-Effectiveness ($/ton)		$28,164		$23,620		$21,944		$20,420		$17,754		$17,754		$17,754
CE Including Fuel ($/ton)		$33,256		$28,598		$26,921		$24,903		$22,236		$22,236		$22,236
One-Year Cost-Effectiveness		$240,244		$201,486		$187,188		$174,190		$151,444		$151,444		$151,444

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF
NOx (g/bhp-hr)	5.42	3.79	5.32	3.72	5.32	3.72	4.655	3.26	4.655	3.26	4.56	3.19	4.56	3.19
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-h	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,067	1,726	1,778	2,416	2,489	3,420	3,522	5,906	6,084	11,191	11,527	16,787	17,290
Fuel Cost ($/yr)	2,201	2,320	3,668	3,867	5,135	5,413	7,266	7,661	12,551	13,232	23,781	25,071	35,672	37,606
Incremental Fuel Cost/yr		$ 119		$ 199		$ 278		$ 394		$ 681		$ 1,290		$ 1,935
Incremental Capital Cost		$5,632		$8,053		$10,474		$15,316		$23,000		$43,579		$65,368
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$660		$944		$1,228		$1,795		$2,696		$5,109		$7,663
NOx Emission Factor (g/hr)	120	84	196	137	275	192	378	264	652	457	1211	847	1816	1271
NOx (tons/year)	0.06	0.04	0.10	0.07	0.14	0.10	0.20	0.14	0.34	0.24	0.63	0.44	0.95	0.67
NOx Reduction (tons/year)		0.02		0.03		0.04		0.06		0.10		0.19		0.29
Cost-Effectiveness ($/ton)		$35,049		$30,635		$28,461		$30,269		$26,316		$26,864		$26,864
CE Including Fuel ($/ton)		$41,385		$37,091		$34,917		$36,913		$32,960		$33,647		$33,647
One-Year Cost-Effectiveness		$298,976		$261,326		$242,782		$258,198		$224,482		$229,158		$229,158

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF
NOx (g/bhp-hr)	3.325	2.33	3.325	2.33	3.325	2.33	2.85	2.00	2.85	2.00	2.85	2.00	2.85	2.00
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-h	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,067	1,726	1,778	2,416	2,489	3,420	3,522	5,906	6,084	11,191	11,527	16,787	17,290
Fuel Cost ($/yr)	2,201	2,320	3,668	3,867	5,135	5,413	7,266	7,661	12,551	13,232	23,781	25,071	35,672	37,606
Incremental Fuel Cost/yr		$ 119		$ 199		$ 278		$ 394		$ 681		$ 1,290		$ 1,935
Incremental Capital Cost		$5,632		$8,053		$10,474		$15,316		$23,000		$43,579		$65,368
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$660		$944		$1,228		$1,795		$2,696		$5,109		$7,663
NOx Emission Factor (g/hr)	74	51	123	86	172	120	231	162	399	280	757	530	1135	795
NOx (tons/year)	0.04	0.03	0.06	0.04	0.09	0.06	0.12	0.08	0.21	0.15	0.40	0.28	0.59	0.42
NOx Reduction (tons/year)		0.01		0.02		0.03		0.04		0.06		0.12		0.18
Cost-Effectiveness ($/ton)		$57,133		$49,017		$45,538		$49,439		$42,983		$42,983		$42,983
CE Including Fuel ($/ton)		$67,461		$59,345		$55,867		$60,290		$53,835		$53,835		$53,835
One-Year Cost-Effectiveness		$487,353		$418,121		$388,451		$421,724		$366,653		$366,653		$366,653

	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
Combines	**Tier 0**	**EGR +**	**Tier 0**	**EGR +**	**Tier 1**	**EGR +**	**Tier 1**	**EGR +**	**Tier 2**	**EGR +**	**Tier 2**	**EGR +**	**Tier 3**	**EGR +**	**Tier 3**	**EGR +**
	Baseline	**DPF**	**Baseline**	**DPF**	**Baseline**	**DPF**	**Baseline**	**DPF**	**Baseline**	**DPF**	**Baseline**	**DPF**	**Baseline**	**DPF**	**Baseline**	**DPF**
NOx (g/bhp-hr)	9.3	6.51	9.5	6.65	6.9	4.83	6.9	4.83	4.655	3.26	4.56	3.19	2.85	2.00	2.85	2.00
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Energy Consumption Factor (bhp-h	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,865	1,921	3,534	3,640	1,865	1,921	3,534	3,640	1,865	1,921	3,534	3,640	1,865	1,921	3,534	3,640
Fuel Cost ($/yr)	3,964	4,178	7,510	7,917	3,964	4,178	7,510	7,917	3,964	4,178	7,510	7,917	3,964	4,178	7,510	7,917
Incremental Fuel Cost/yr		$ 215		$ 407		$ 215		$ 407		$ 215		$ 407		$ 215		$ 407
Incremental Capital Cost		$23,000		$43,579		$23,000		$43,579		$23,000		$43,579		$23,000		$43,579
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,696		$5,109		$2,696		$5,109		$2,696		$5,109		$2,696		$5,109
NOx Emission Factor (g/hr)	1303	912	2522	1766	967	677	1832	1282	652	457	1211	847	399	280	757	530
NOx (tons/year)	0.22	0.15	0.42	0.29	0.16	0.11	0.30	0.21	0.11	0.08	0.20	0.14	0.07	0.05	0.13	0.09
NOx Reduction (tons/year)		0.06		0.13		0.05		0.09		0.03		0.06		0.02		0.04
Cost-Effectiveness ($/ton)		$41,712		$40,834		$56,220		$56,220		$83,334		$85,070		$136,113		$136,113
CE Including Fuel ($/ton)		$45,037		$44,089		$60,703		$60,703		$89,978		$91,853		$146,964		$146,964
One-Year Cost-Effectiveness		$355,811		$348,321		$479,572		$479,572		$710,858		$725,668		$1,161,069		$1,161,069

Measure 51b: EGR+DPF Retrofit

Cost of diesel:	2.13
Addition Cost for ULSD	0.05
Increamental Fuel Consumption	3%
NOx Reduction	30%

Excavators	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF
NOx (g/bhp-hr)	9.3	6.51	9.5	6.65	6.9	4.83	6.9	4.83	4.655	3.26	4.56	3.19	2.85	2.00	2.85	2.00
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,310	1,310	1,310	1,310	1,310.00	1,310	1,310	1,310	1,310.00	1,310	1,310	1,310	1,310.00	1,310	1,310	1,310
Energy Consumption Factor (bhp-h	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.10	19.1	19.1	19.1
Fuel Usage (gal/yr)	16,289	16,778	30,864	31,790	16,289	16,778	30,864	31,790	16,289	16,778	30,864	31,790	16,289	16,778	30,864	31,790
Fuel Cost ($/yr)	34,615	36,492	65,586	69,143	34,615	36,492	65,586	69,143	34,615	36,492	65,586	69,143	34,615	36,492	65,586	69,143
Incremental Fuel Cost/yr		$ 1,877		$ 3,557		$ 1,877		$ 3,557		$ 1,877		$ 3,557		$ 1,877		$ 3,557
Incremental Capital Cost		$23,000		$43,579		$23,000		$43,579		$23,000		$43,579		$23,000		$43,579
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,696		$5,109		$2,696		$5,109		$2,696		$5,109		$2,696		$5,109
NOx Emission Factor (g/hr)	1303	912	2522	1766	967	677	1832	1282	652	457	1211	847	399	280	757	530
NOx (tons/year)	1.88	1.32	3.64	2.55	1.40	0.98	2.65	1.85	0.94	0.66	1.75	1.22	0.58	0.40	1.09	0.76
NOx Reduction (tons/year)		0.56		1.09		0.42		0.79		0.28		0.52		0.17		0.33
Cost-Effectiveness ($/ton)		$4,776		$4,676		$6,437		$6,437		$9,542		$9,741		$15,585		$15,585
CE Including Fuel ($/ton)		$8,102		$7,931		$10,920		$10,920		$16,186		$16,523		$26,437		$26,437
One-Year Cost-Effectiveness		$40,742		$39,884		$54,913		$54,913		$81,396		$83,092		$132,947		$132,947

Rubber Tire Loaders	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF
NOx (g/bhp-hr)	9.5	6.65	9.7	6.79	9.1	6.37	6.9	4.83	6.9	4.83	6.9	4.83	4.56	3.19	4.56	3.19	4.56	3.19	2.85	2.00	2.85	2.00
Average Horsepower (hp)	450	450	675	675	1,185	1,185	450	450	675	675	1,185	1,185	450	450	675	675	1,185	1,185	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	913	913	913	913	913	913	913.00	913	913	913	913	913	913.00	913	913	913	913	913	913.00	913	913	913
Energy Consumption Factor (bhp-h	19.1	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1
Fuel Usage (gal/yr)	21,510	22,156	32,266	33,234	56,649	58,348	21,510	22,156	32,266	33,234	56,649	58,348	21,510	22,156	32,266	33,234	56,649	58,348	21,510	22,156	32,266	33,234
Fuel Cost ($/yr)	45,710	48,189	68,565	72,283	120,379	126,908	45,710	48,189	68,565	72,283	120,379	126,908	45,710	48,189	68,565	72,283	120,379	126,908	45,710	48,189	68,565	72,283
Incremental Fuel Cost/yr		$ 2,479		$ 3,719		$ 6,529		$ 2,479		$ 3,719		$ 6,529		$ 2,479		$ 3,719		$ 6,529		$ 2,479		$ 3,719
Incremental Capital Cost		$43,579		$65,368		$114,767		$43,579		$65,368		$114,767		$43,579		$65,368		$114,767		$43,579		$65,368
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$5,109		$7,663		$13,454		$5,109		$7,663		$13,454		$5,109		$7,663		$13,454		$5,109		$7,663
NOx Emission Factor (g/hr)	2522	1766	3863	2704	6363	4454	1832	1282	2748	1924	4825	3377	1211	847	1816	1271	3188	2232	757	530	1135	795
NOx (tons/year)	2.54	1.78	3.89	2.72	6.40	4.48	1.84	1.29	2.77	1.94	4.86	3.40	1.22	0.85	1.83	1.28	3.21	2.25	0.76	0.53	1.14	0.80
NOx Reduction (tons/year)		0.76		1.17		1.92		0.55		0.83		1.46		0.37		0.55		0.96		0.23		0.34
Cost-Effectiveness ($/ton)		$6,709		$6,570		$7,004		$9,237		$9,237		$9,237		$13,977		$13,977		$13,977		$22,362		$22,362
CE Including Fuel ($/ton)		$9,964		$9,759		$10,402		$13,719		$13,719		$13,719		$20,759		$20,759		$20,759		$33,214		$33,214
One-Year Cost-Effectiveness		$57,227		$56,047		$59,742		$78,791		$78,791		$78,791		$119,223		$119,223		$119,223		$190,756		$190,756

Crawler Tractors/Dozers	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF
NOx (g/bhp-hr)	9.5	6.65	9.7	6.79	9.1	6.37	6.9	4.83	6.9	4.83	6.9	4.83	4.56	3.19	4.56	3.19	4.56	3.19	2.85	2.00	2.85	2.00
Average Horsepower (hp)	450	450	675	675	887	887	450	450	675	675	887	887	450	450	675	675	887	887	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,123	1,123	1,123	1,123	1,123	1,123	1,123.00	1,123	1,123	1,123	1,123	1,123	1,123.00	1,123	1,123	1,123	1,123	1,123	1,123.00	1,123	1,123	1,123
Energy Consumption Factor (bhp-h	19.1	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1
Fuel Usage (gal/yr)	26,458	27,252	39,687	40,878	52,181	53,746	26,458	27,252	39,687	40,878	52,181	53,746	26,458	27,252	39,687	40,878	52,181	53,746	26,458	27,252	39,687	40,878
Fuel Cost ($/yr)	56,223	59,273	84,335	88,909	110,884	116,897	56,223	59,273	84,335	88,909	110,884	116,897	56,223	59,273	84,335	88,909	110,884	116,897	56,223	59,273	84,335	88,909
Incremental Fuel Cost/yr		$ 3,049		$ 4,574		$ 6,014		$ 3,049		$ 4,574		$ 6,014		$ 3,049		$ 4,574		$ 6,014		$ 3,049		$ 4,574
Incremental Capital Cost		$43,579		$65,368		$85,946		$43,579		$65,368		$85,946		$43,579		$65,368		$85,946		$43,579		$65,368
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$5,109		$7,663		$10,076		$5,109		$7,663		$10,076		$5,109		$7,663		$10,076		$5,109		$7,663
NOx Emission Factor (g/hr)	2522	1766	3863	2704	4765	3335	1832	1282	2748	1924	3613	2529	1211	847	1816	1271	2388	1671	757	530	1135	795
NOx (tons/year)	3.12	2.19	4.78	3.35	5.90	4.13	2.27	1.59	3.40	2.38	4.47	3.13	1.50	1.05	2.25	1.57	2.96	2.07	0.94	0.66	1.41	0.98
NOx Reduction (tons/year)		0.94		1.43		1.77		0.68		1.02		1.34		0.45		0.67		0.89		0.28		0.42
Cost-Effectiveness ($/ton)		$5,454		$5,342		$5,694		$7,509		$7,509		$7,509		$11,363		$11,363		$11,363		$18,181		$18,181
CE Including Fuel ($/ton)		$8,710		$8,530		$9,093		$11,992		$11,992		$11,992		$18,145		$18,145		$18,145		$29,032		$29,032
One-Year Cost-Effectiveness		$46,525		$45,566		$48,571		$64,057		$64,057		$64,057		$96,928		$96,928		$96,928		$155,085		$155,085

Tractors/Loaders/Backhoes	100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP	
	Tier 0 Baseline	EGR + DPF	Tier 0 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF	Tier 3 Baseline	EGR + DPF
NOx (g/bhp-hr)	9.5	6.65	9.3	6.51	6.9	4.83	6.9	4.83	4.655	3.26	4.655	3.26	2.85	2.00	2.85	2.00
Average Horsepower (hp)	138	138	238	238	138	138	238	238	138	138	238	238	138	138	238	238
Load Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Activity (hr/yr)	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362
Energy Consumption Factor (bhp-h	16.4	16.4	16.4	16.4	16.40	16.4	16.40	16.4	16.40	16.4	16.40	16.4	16.40	16.4	16.40	16.4
Fuel Usage (gal/yr)	11,419	11,762	19,724	20,316	11,419	11,762	19,724	20,316	11,419	11,762	19,724	20,316	11,419	11,762	19,724	20,316
Fuel Cost ($/yr)	24,266	25,582	41,914	44,187	24,266	25,582	41,914	44,187	24,266	25,582	41,914	44,187	24,266	25,582	41,914	44,187
Incremental Fuel Cost/yr		$ 1,316		$ 2,273		$ 1,316		$ 2,273		$ 1,316		$ 2,273		$ 1,316		$ 2,273
Incremental Capital Cost		$23,000		$23,000		$23,000		$23,000		$23,000		$23,000		$23,000		$23,000
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,696		$2,696		$2,696		$2,696		$2,696		$2,696		$2,696		$2,696
NOx Emission Factor (g/hr)	274	192	464	325	199	139	344	241	134	94	232	163	82	58	142	100
NOx (tons/year)	0.41	0.29	0.70	0.49	0.30	0.21	0.52	0.36	0.20	0.14	0.35	0.24	0.12	0.09	0.21	0.15
NOx Reduction (tons/year)		0.12		0.21		0.09		0.15		0.06		0.10		0.04		0.06
Cost-Effectiveness ($/ton)		$21,824		$12,906		$30,047		$17,396		$44,538		$25,785		$72,746		$42,116
CE Including Fuel ($/ton)		$32,476		$23,788		$44,713		$32,062		$66,277		$47,524		$108,253		$77,623
One-Year Cost-Effectiveness		$186,160		$110,095		$256,308		$148,389		$379,919		$219,953		$620,534		$359,257

Off-Highway Trucks	750+ HP		750+ HP		750+ HP	
	Tier 0 Baseline	EGR + DPF	Tier 1 Baseline	EGR + DPF	Tier 2 Baseline	EGR + DPF
NOx (g/bhp-hr)	9.1	6.37	6.9	4.83	4.56	3.19
Average Horsepower (hp)	1360	1360	1360	1360	1360	1360
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,969	1,969	1,969	1,969	1,969	1,969
Energy Consumption Factor (bhp-h	19.1	19.1	19.10	19.1	19.10	19.1
Fuel Usage (gal/yr)	140,159	144,364	140,159	144,364	140,159	144,364
Fuel Cost ($/yr)	297,838	313,991	297,838	313,991	297,838	313,991
Incremental Fuel Cost/yr		$ 16,153		$ 16,153		$ 16,153
Incremental Capital Cost		$131,666		$131,666		$131,666
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$15,435		$15,435		$15,435
NOx Emission Factor (g/hr)	7300	5110	5535	3874	3658	2560
NOx (tons/year)	15.84	11.09	12.01	8.41	7.94	5.56
NOx Reduction (tons/year)		4.75		3.60		2.38
Cost-Effectiveness ($/ton)		$3,247		$4,283		$6,481
CE Including Fuel ($/ton)		$6,646		$8,765		$13,263
One-Year Cost-Effectiveness		$27,702		$36,534		$55,282

Measure 46b: EGR+DPF Retrofit

Cost of diesel:	2.13
Increamental Fuel Consumption	3%
NOx Reduction	30%

	MY1989 & Earlier		MY 1990		MY 1991 - 1997		MY 1998 - 2001		MY 2002 - 2006	
	Baseline	EGR+DPF	Baseline	EGR+DPF	Baseline	EGR+DPF	Baseline	EGR+DPF	Baseline	EGR+DPF
Annual mileage	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 23,000		$ 23,000		$ 23,000		$ 23,000		$ 23,000
Useful Life (years)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Annualized Capital Cost ($/yr)		$3,276		$3,276		$3,276		$3,276		$3,276
Diesel mpg	5.35	5.35	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54
Fuel Cost/mile	$0.40	$0.40	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38
Fuel Cost/year	$19,878	$19,884	$19,179	$19,184	$19,179	$19,184	$19,179	$19,184	$19,179	$19,184
Incremental Fuel Cost/year		$6		$6		$6		$6		$6
Emission Std (g/bhp-hr)	10.7		6		5		4		2.4	
Coversion Factor (bhp-hr/mi)	3.11		3.05		2.95		2.90		2.90	
NOx g/mile	33.24	23.27	18.30	12.81	14.75	10.32	11.58	8.11	6.95	4.86
NO tons/year	1.83	1.28	1.01	0.71	0.81	0.57	0.64	0.45	0.38	0.27
NOx Reduction tons/year		0.55		0.30		0.24		0.19		0.11
Cost-Effectiveness ($/ton)		$5,960		$10,827		$13,435		$17,109		$28,515
CE Including Fuel ($/ton)		$5,970		$10,846		$13,459		$17,139		$28,566
One-Year Cost-Effectiveness		$41,834		$75,999		$94,313		$120,102		$200,170

Measure 51c: SCR Retrofits

Cost of diesel:	2.13
Urea Cost (equivalent to % fuel)	2%
NOx Reduction	75%

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR
NOx (g/bhp-hr)	7.2	1.80	8.8	2.20	8.8	2.20	9.5	2.38	9.3	2.33	9.5	2.38	9.7	2.43
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,056	1,726	1,761	2,416	2,465	3,420	3,488	5,906	6,025	11,191	11,415	16,787	17,122
Urea Fuel Cost ($/yr)	2,201	2,245	3,668	3,741	5,135	5,238	7,266	7,412	12,551	12,802	23,781	24,257	35,672	36,385
Incremental Urea Fuel Cost/yr		$ 44		$ 73		$ 103		$ 145		$ 251		$ 476		$ 713
Incremental Capital Cost		$6,342		$9,237		$12,132		$17,921		$27,500		$52,105		$78,158
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$743		$1,083		$1,422		$2,101		$3,224		$6,108		$9,162
NOx Emission Factor (g/hr)	159	40	325	81	454	114	771	193	1303	326	2522	631	3863	966
NOx (tons/year)	0.08	0.02	0.17	0.04	0.24	0.06	0.40	0.10	0.68	0.17	1.32	0.33	2.02	0.51
NOx Reduction (tons/year)		0.06		0.13		0.18		0.30		0.51		0.99		1.52
NOx reduction (tons/day)		0.0003		0.0005		0.0007		0.0012		0.0020		0.0040		0.0061
Cost-Effectiveness ($/ton)		$11,885		$8,498		$7,972		$6,942		$6,300		$6,167		$6,040
CE Including Fuel ($/ton)		$12,589		$9,073		$8,548		$7,422		$6,790		$6,647		$6,510
One-Year Cost-Effectiveness		$101,383		$72,486		$68,002		$59,215		$53,738		$52,607		$51,522

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR
NOx (g/bhp-hr)	6.745	1.69	6.9	1.73	6.9	1.73	6.9	1.73	6.9	1.73	6.9	1.73	6.9	1.73
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,056	1,726	1,761	2,416	2,465	3,420	3,488	5,906	6,025	11,191	11,415	16,787	17,122
Urea Fuel Cost ($/yr)	2,201	2,245	3,668	3,741	5,135	5,238	7,266	7,412	12,551	12,802	23,781	24,257	35,672	36,385
Incremental Urea Fuel Cost/yr		$ 44		$ 73		$ 103		$ 145		$ 251		$ 476		$ 713
Incremental Capital Cost		$6,342		$9,237		$12,132		$17,921		$27,500		$52,105		$78,158
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$743		$1,083		$1,422		$2,101		$3,224		$6,108		$9,162
NOx Emission Factor (g/hr)	149	37	254	64	356	89	560	140	967	242	1832	458	2748	687
NOx (tons/year)	0.08	0.02	0.13	0.03	0.19	0.05	0.29	0.07	0.51	0.13	0.96	0.24	1.44	0.36
NOx Reduction (tons/year)		0.06		0.10		0.14		0.22		0.38		0.72		1.08
NOx reduction (tons/day)		0.0002		0.0004		0.0006		0.0009		0.0015		0.0029		0.0043
Cost-Effectiveness ($/ton)		$12,687		$10,838		$10,167		$9,558		$8,491		$8,491		$8,491
CE Including Fuel ($/ton)		$13,438		$11,572		$10,901		$10,219		$9,152		$9,152		$9,152
One-Year Cost-Effectiveness		$108,222		$92,447		$86,727		$81,528		$72,430		$72,430		$72,430

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR
NOx (g/bhp-hr)	5.42	1.36	5.32	1.33	5.32	1.33	4.655	1.16	4.655	1.16	4.56	1.14	4.56	1.14
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,056	1,726	1,761	2,416	2,465	3,420	3,488	5,906	6,025	11,191	11,415	16,787	17,122
Urea Fuel Cost ($/yr)	2,201	2,245	3,668	3,741	5,135	5,238	7,266	7,412	12,551	12,802	23,781	24,257	35,672	36,385
Incremental Urea Fuel Cost/yr		$ 44		$ 73		$ 103		$ 145		$ 251		$ 476		$ 713
Incremental Capital Cost		$6,342		$9,237		$12,132		$17,921		$27,500		$52,105		$78,158
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$743		$1,083		$1,422		$2,101		$3,224		$6,108		$9,162
NOx Emission Factor (g/hr)	120	30	196	49	275	69	378	94	652	163	1211	303	1816	454
NOx (tons/year)	0.06	0.02	0.10	0.03	0.14	0.04	0.20	0.05	0.34	0.09	0.63	0.16	0.95	0.24
NOx Reduction (tons/year)		0.05		0.08		0.11		0.15		0.26		0.48		0.71
NOx reduction (tons/day)		0.0002		0.0003		0.0004		0.0006		0.0010		0.0019		0.0029
Cost-Effectiveness ($/ton)		$15,788		$14,056		$13,187		$14,167		$12,586		$12,848		$12,848
CE Including Fuel ($/ton)		$16,723		$15,008		$14,139		$15,147		$13,566		$13,849		$13,849
One-Year Cost-Effectiveness		$134,679		$119,902		$112,485		$120,847		$107,361		$109,597		$109,597

Agricultural Tractors	25-50 HP		50-75 HP		75-100 HP		100-175 HP		175-300 HP		300-600 HP		600-750 HP	
	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR
NOx (g/bhp-hr)	3.325	0.83	3.325	0.83	3.325	0.83	2.85	0.71	2.85	0.71	2.85	0.71	2.85	0.71
Average Horsepower (hp)	38	38	63	63	88	88	138	138	238	238	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	475	475	475	475	475	475	475	475	475	475	475	475	475	475
Energy Consumption Factor (bhp-hr/gal)	17.2	17.2	17.2	17.2	17.2	17.2	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,036	1,056	1,726	1,761	2,416	2,465	3,420	3,488	5,906	6,025	11,191	11,415	16,787	17,122
Urea Fuel Cost ($/yr)	2,201	2,245	3,668	3,741	5,135	5,238	7,266	7,412	12,551	12,802	23,781	24,257	35,672	36,385
Incremental Urea Fuel Cost/yr		$ 44		$ 73		$ 103		$ 145		$ 251		$ 476		$ 713
Incremental Capital Cost		$6,342		$9,237		$12,132		$17,921		$27,500		$52,105		$78,158
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$743		$1,083		$1,422		$2,101		$3,224		$6,108		$9,162
NOx Emission Factor (g/hr)	74	18	123	31	172	43	231	58	399	100	757	189	1135	284
NOx (tons/year)	0.04	0.01	0.06	0.02	0.09	0.02	0.12	0.03	0.21	0.05	0.40	0.10	0.59	0.15
NOx Reduction (tons/year)		0.03		0.05		0.07		0.09		0.16		0.30		0.45
NOx reduction (tons/day)		0.0001		0.0002		0.0003		0.0004		0.0006		0.0012		0.0018
Cost-Effectiveness ($/ton)		$25,736		$22,490		$21,099		$23,139		$20,557		$20,557		$20,557
CE Including Fuel ($/ton)		$27,260		$24,014		$22,622		$24,740		$22,158		$22,158		$22,158
One-Year Cost-Effectiveness		$219,536		$191,844		$179,976		$197,384		$175,356		$175,356		$175,356

	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
Combines	**Tier 0**	**With**	**Tier 0**	**With**	**Tier 1**	**With**	**Tier 1**	**With**	**Tier 2**	**With**	**Tier 2**	**With**	**Tier 3**	**With**	**Tier 3**	**With**
	Baseline	**SCR**	**Baseline**	**SCR**	**Baseline**	**SCR**	**Baseline**	**SCR**	**Baseline**	**SCR**	**Baseline**	**SCR**	**Baseline**	**SCR**	**Baseline**	**SCR**
NOx (g/bhp-hr)	9.3	2.33	9.5	2.38	6.9	1.73	6.9	1.73	4.655	1.16	4.56	1.14	2.85	0.71	2.85	0.71
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,865	1,902	3,534	3,605	1,865	1,902	3,534	3,605	1,865	1,902	3,534	3,605	1,865	1,902	3,534	3,605
Urea Fuel Cost ($/yr)	3,964	4,043	7,510	7,660	3,964	4,043	7,510	7,660	3,964	4,043	7,510	7,660	3,964	4,043	7,510	7,660
Incremental Urea Fuel Cost/yr		$ 79		$ 150		$ 79		$ 150		$ 79		$ 150		$ 79		$ 150
Incremental Capital Cost		$27,500		$52,105		$27,500		$52,105		$27,500		$52,105		$27,500		$52,105
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$3,224		$6,108		$3,224		$6,108		$3,224		$6,108		$3,224		$6,108
NOx Emission Factor (g/hr)	1303	326	2522	631	967	242	1832	458	652	163	1211	303	399	100	757	189
NOx (tons/year)	0.22	0.05	0.42	0.10	0.16	0.04	0.30	0.08	0.11	0.03	0.20	0.05	0.07	0.02	0.13	0.03
NOx Reduction (tons/year)		0.16		0.31		0.12		0.23		0.08		0.15		0.05		0.09
NOx reduction (tons/day)		0.0006		0.0013		0.0005		0.0009		0.0003		0.0006		0.0002		0.0004
Cost-Effectiveness ($/ton)		$19,949		$19,529		$26,888		$26,888		$39,856		$40,686		$65,097		$65,097
CE Including Fuel ($/ton)		$20,440		$20,009		$27,549		$27,549		$40,836		$41,686		$66,698		$66,698
One-Year Cost-Effectiveness		$170,171		$166,588		$229,360		$229,360		$339,976		$347,059		$555,294		$555,294

Measure 51c: SCR Retrofits

Cost of diesel:	2.13
Urea Cost (equivalent to % fuel)	2%
NOx Reduction	75%

Excavators	175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP		175-300 HP		300-600 HP	
	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR
NOx (g/bhp-hr)	9.3	2.33	9.5	2.38	6.9	1.73	6.9	1.73	4.655	1.16	4.56	1.14	2.85	0.71	2.85	0.71
Average Horsepower (hp)	238	238	450	450	238	238	450	450	238	238	450	450	238	238	450	450
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,310	1,310	1,310	1,310	1,310.00	1,310	1,310	1,310	1,310.00	1,310	1,310	1,310	1,310.00	1,310	1,310	1,310
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.10	19.1	19.1	19.1
Fuel Usage (gal/yr)	16,289	16,615	30,864	31,481	16,289	16,615	30,864	31,481	16,289	16,615	30,864	31,481	16,289	16,615	30,864	31,481
Urea Fuel Cost ($/yr)	34,615	35,307	65,586	66,897	34,615	35,307	65,586	66,897	34,615	35,307	65,586	66,897	34,615	35,307	65,586	66,897
Incremental Urea Fuel Cost/yr		$ 692		$ 1,312		$ 692		$ 1,312		$ 692		$ 1,312		$ 692		$ 1,312
Incremental Capital Cost		$27,500		$52,105		$27,500		$52,105		$27,500		$52,105		$27,500		$52,105
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$3,224		$6,108		$3,224		$6,108		$3,224		$6,108		$3,224		$6,108
NOx Emission Factor (g/hr)	1303	326	2522	631	967	242	1832	458	652	163	1211	303	399	100	757	189
NOx (tons/year)	1.88	0.47	3.64	0.91	1.40	0.35	2.65	0.66	0.94	0.24	1.75	0.44	0.58	0.14	1.09	0.27
NOx Reduction (tons/year)		1.41		2.73		1.05		1.98		0.71		1.31		0.43		0.82
Cost-Effectiveness ($/ton)		$2,284		$2,236		$3,079		$3,079		$4,564		$4,659		$7,454		$7,454
CE Including Fuel ($/ton)		$2,775		$2,716		$3,740		$3,740		$5,544		$5,659		$9,055		$9,055
One-Year Cost-Effectiveness		$19,485		$19,075		$26,263		$26,263		$38,929		$39,740		$63,583		$63,583

Rubber Tire Loaders	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR
NOx (g/bhp-hr)	9.5	2.38	9.7	2.43	9.1	2.28	6.9	1.73	6.9	1.73	6.9	1.73	4.56	1.14	4.56	1.14	4.56	1.14	2.85	0.71	2.85	0.71
Average Horsepower (hp)	450	450	675	675	1,185	1,185	450	450	675	675	1,185	1,185	450	450	675	675	1,185	1,185	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	913	913	913	913	913	913	913.00	913	913	913	913	913	913.00	913	913	913	913	913	913.00	913	913	913
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1
Fuel Usage (gal/yr)	21,510	21,941	32,266	32,911	56,649	57,782	21,510	21,941	32,266	32,911	56,649	57,782	21,510	21,941	32,266	32,911	56,649	57,782	21,510	21,941	32,266	32,911
Urea Fuel Cost ($/yr)	45,710	46,624	68,565	69,936	120,379	122,787	45,710	46,624	68,565	69,936	120,379	122,787	45,710	46,624	68,565	69,936	120,379	122,787	45,710	46,624	68,565	69,936
Incremental Urea Fuel Cost/yr		$ 914		$ 1,371		$ 2,408		$ 914		$ 1,371		$ 2,408		$ 914		$ 1,371		$ 2,408		$ 914		$ 1,371
Incremental Capital Cost		$52,105		$78,158		$137,222		$52,105		$78,158		$137,222		$52,105		$78,158		$137,222		$52,105		$78,158
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$6,108		$9,162		$16,087		$6,108		$9,162		$16,087		$6,108		$9,162		$16,087		$6,108		$9,162
NOx Emission Factor (g/hr)	2522	631	3863	966	6363	1591	1832	458	2748	687	4825	1206	1211	303	1816	454	3188	797	757	189	1135	284
NOx (tons/year)	2.54	0.63	3.89	0.97	6.40	1.60	1.84	0.46	2.77	0.69	4.86	1.21	1.22	0.30	1.83	0.46	3.21	0.80	0.76	0.19	1.14	0.29
NOx Reduction (tons/year)		1.90		2.92		4.80		1.38		2.07		3.64		0.91		1.37		2.41		0.57		0.86
Cost-Effectiveness ($/ton)		$3,209		$3,142		$3,350		$4,418		$4,418		$4,418		$6,684		$6,684		$6,684		$10,695		$10,695
CE Including Fuel ($/ton)		$3,689		$3,613		$3,851		$5,079		$5,079		$5,079		$7,685		$7,685		$7,685		$12,296		$12,296
One-Year Cost-Effectiveness		$27,369		$26,805		$28,572		$37,682		$37,682		$37,682		$57,019		$57,019		$57,019		$91,231		$91,231

Crawler Tractors/Dozers	300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP		750+ HP		300-600 HP		600-750 HP	
	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR
NOx (g/bhp-hr)	9.5	2.38	9.7	2.43	9.1	2.28	6.9	1.73	6.9	1.73	6.9	1.73	4.56	1.14	4.56	1.14	4.56	1.14	2.85	0.71	2.85	0.71
Average Horsepower (hp)	450	450	675	675	887	887	450	450	675	675	887	887	450	450	675	675	887	887	450	450	675	675
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,123	1,123	1,123	1,123	1,123	1,123	1,123.00	1,123	1,123	1,123	1,123	1,123	1,123.00	1,123	1,123	1,123	1,123	1,123	1,123.00	1,123	1,123	1,123
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1
Fuel Usage (gal/yr)	26,458	26,987	39,687	40,481	52,181	53,224	26,458	26,987	39,687	40,481	52,181	53,224	26,458	26,987	39,687	40,481	52,181	53,224	26,458	26,987	39,687	40,481
Urea Fuel Cost ($/yr)	56,223	57,348	84,335	86,022	110,884	113,101	56,223	57,348	84,335	86,022	110,884	113,101	56,223	57,348	84,335	86,022	110,884	113,101	56,223	57,348	84,335	86,022
Incremental Urea Fuel Cost/yr		$ 1,124		$ 1,687		$ 2,218		$ 1,124		$ 1,687		$ 2,218		$ 1,124		$ 1,687		$ 2,218		$ 1,124		$ 1,687
Incremental Capital Cost		$52,105		$78,158		$102,762		$52,105		$78,158		$102,762		$52,105		$78,158		$102,762		$52,105		$78,158
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$6,108		$9,162		$12,047		$6,108		$9,162		$12,047		$6,108		$9,162		$12,047		$6,108		$9,162
NOx Emission Factor (g/hr)	2522	631	3863	966	4765	1191	1832	458	2748	687	3613	903	1211	303	1816	454	2388	597	757	189	1135	284
NOx (tons/year)	3.12	0.78	4.78	1.20	5.90	1.47	2.27	0.57	3.40	0.85	4.47	1.12	1.50	0.37	2.25	0.56	2.96	0.74	0.94	0.23	1.41	0.35
NOx Reduction (tons/year)		2.34		3.59		4.42		1.70		2.55		3.35		1.12		1.69		2.22		0.70		1.05
Cost-Effectiveness ($/ton)		$2,609		$2,555		$2,723		$3,591		$3,591		$3,591		$5,434		$5,434		$5,434		$8,695		$8,695
CE Including Fuel ($/ton)		$3,089		$3,025		$3,224		$4,253		$4,253		$4,253		$6,435		$6,435		$6,435		$10,296		$10,296
One-Year Cost-Effectiveness		$22,251		$21,793		$23,229		$30,636		$30,636		$30,636		$46,357		$46,357		$46,357		$74,171		$74,171

Tractors/Loaders/Backhoes	100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP	
	Tier 0 Baseline	With SCR	Tier 0 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 2 Baseline	With SCR	Tier 3 Baseline	With SCR	Tier 3 Baseline	With SCR
NOx (g/bhp-hr)	9.5	2.38	9.3	2.33	6.9	1.73	6.9	1.73	4.655	1.16	4.655	1.16	2.85	0.71	2.85	0.71
Average Horsepower (hp)	138	138	238	238	138	138	238	238	138	138	238	238	138	138	238	238
Load Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Activity (hr/yr)	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362	1,362
Energy Consumption Factor (bhp-hr/gal)	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4
Fuel Usage (gal/yr)	11,419	11,648	19,724	20,119	11,419	11,648	19,724	20,119	11,419	11,648	19,724	20,119	11,419	11,648	19,724	20,119
Urea Fuel Cost ($/yr)	24,266	24,751	41,914	42,752	24,266	24,751	41,914	42,752	24,266	24,751	41,914	42,752	24,266	24,751	41,914	42,752
Incremental Urea Fuel Cost/yr		$ 485		$ 838		$ 485		$ 838		$ 485		$ 838		$ 485		$ 838
Incremental Capital Cost		$27,500		$27,500		$27,500		$27,500		$27,500		$27,500		$27,500		$27,500
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$3,224		$3,224		$3,224		$3,224		$3,224		$3,224		$3,224		$3,224
NOx Emission Factor (g/hr)	274	69	464	116	199	50	344	86	134	34	232	58	82	21	142	36
NOx (tons/year)	0.41	0.10	0.70	0.17	0.30	0.07	0.52	0.13	0.20	0.05	0.35	0.09	0.12	0.03	0.21	0.05
NOx Reduction (tons/year)		0.31		0.52		0.22		0.39		0.15		0.26		0.09		0.16
Cost-Effectiveness ($/ton)		$10,437		$6,173		$14,370		$8,320		$21,301		$12,332		$34,791		$20,142
CE Including Fuel ($/ton)		$12,009		$7,778		$16,534		$10,483		$24,507		$15,539		$40,029		$25,380
One-Year Cost-Effectiveness		$89,033		$52,654		$122,582		$70,968		$181,700		$105,195		$296,777		$171,818

Off-Highway Trucks	750+ HP		750+ HP		750+ HP	
	Tier 0 Baseline	With SCR	Tier 1 Baseline	With SCR	Tier 2 Baseline	With SCR
NOx (g/bhp-hr)	9.1	2.28	6.9	1.73	4.56	1.14
Average Horsepower (hp)	1360	1360	1360	1360	1360	1360
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,969	1,969	1,969	1,969	1,969	1,969
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	140,159	142,962	140,159	142,962	140,159	142,962
Urea Fuel Cost ($/yr)	297,838	303,795	297,838	303,795	297,838	303,795
Incremental Urea Fuel Cost/yr		$ 5,957		$ 5,957		$ 5,957
Incremental Capital Cost		$157,426		$157,426		$157,426
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$18,455		$18,455		$18,455
NOx Emission Factor (g/hr)	7300	1825	5535	1384	3658	914
NOx (tons/year)	15.84	3.96	12.01	3.00	7.94	1.98
NOx Reduction (tons/year)		11.88		9.01		5.95
Cost-Effectiveness ($/ton)		$1,553		$2,048		$3,099
CE Including Fuel ($/ton)		$2,054		$2,709		$4,100
One-Year Cost-Effectiveness		$13,249		$17,473		$26,439

Measure 46c: SCR Retrofit

Cost of Diesel:	2.13
Urea Cost (equivalent to % fuel)	2%
NOx Reduction	75%

	MY1989 & Earlier		MY 1990		MY 1991 - 1997		MY 1998 - 2001		MY 2002 - 2006	
	Baseline	SCR	Baseline	SCR	Baseline	SCR	Baseline	SCR	Baseline	SCR
Annual mileage	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000	50,000
Incremental Capital Cost		$ 27,500		$ 27,500		$ 27,500		$ 27,500		$ 27,500
Useful Life (years)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Annualized Capital Cost ($/yr)		$3,918		$3,918		$3,918		$3,918		$3,918
Diesel mpg	5.35	5.35	5.54	5.54	5.54	5.54	5.54	5.54	5.54	5.54
Fuel Cost/mile	$0.40	$0.40	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38	$0.38
Fuel Cost/year	$19,878	$19,878	$19,179	$19,179	$19,179	$19,179	$19,179	$19,179	$19,179	$19,179
Urea Cost/year		$398		$384		$384		$384		$384
Emission Std (g/bhp-hr)	10.7		6		5		4		2.4	
Coversion Factor (bhp-hr/mi)	3.11		3.05		2.95		2.90		2.90	
NOx g/mile	33.24	8.31	18.30	4.58	14.75	3.69	11.58	2.90	6.95	1.74
NO tons/year	1.83	0.46	1.01	0.25	0.81	0.20	0.64	0.16	0.38	0.10
NOx Reduction tons/year		1.37		0.76		0.61		0.48		0.29
Cost-Effectiveness ($/ton)		$2,850		$5,178		$6,426		$8,183		$13,638
CE Including Urea Cost ($/ton)		$3,139		$5,685		$7,055		$8,984		$14,973
One-Year Cost-Effectiveness		$20,008		$36,347		$45,106		$57,440		$95,733