DRAFT REPORT

Estimates of Potential Emission Reductions For the Nashville Ozone Early Action Compact Area

Prepared for

The Nashville Area MPO
And
The Tennessee Department of Transportation
Division of Transportation Planning
And
The Tennessee Department of Environment and Conservation
Division of Air Pollution Control

By

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Department of Civil and Environmental Engineering

September 11, 2003
(Draft Version 1)

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1.0 INTRODUCTION AND PURPOSE

The University of Tennessee in cooperation with the TDEC Division of Air Pollution Control and the Tennessee Department of Transportation (TDOT) has prepared this draft report to assist the Nashville Area MPO (Metropolitan Planning Organization) and the state in making decisions regarding potential emission control measures that might be considered in meeting the 8-hr ozone standard by 2007. The work was requested by Jeanne Stevens of the Nashville Area MPO. The project was funded through contracts with TDOT and TDEC. The work was coordinated with the Nashville Air Pollution Control Department.

The report includes information on the existing emissions for 1999 and baseline projections for 2007 (see Chapter 2) for the 8-county Nashville EAC (Early Action Compact) area. Twenty-one possible control measures have been evaluated (see Chapter 3) in order to estimate the potential emissions that might be achieved for each. Emission reductions have been estimated for nitrogen oxides (NOx), volatile organic compounds (VOC), carbon monoxide (CO) and particulate matter 2.5 micrometers or less in diameter (PM-2.5). Also included in each section are estimates of the cost to achieve the emission reductions per ton of pollutant. This information is intended to help prioritize the selection of control measures on the basis of cost effectiveness.

Another purpose of the report is to provide estimates of the emission reductions achievable in the Nashville EAC by 2007 for purposes of modeling future ozone concentrations. A summary of the emission reductions achievable by each of the 21 control measures considered is given in Table 1.0 (see Executive Summary of Results). Baseline ozone modeling for the area is currently being performed by SAI, Inc. as part of the ATMOS (Arkansas, Tennessee, and Mississippi Ozone Study) project. If projected baseline emissions for 2007 do not show attainment of the 8-hour National Ambient Air Quality Standard (NAAQS) for ozone, then additional emission reductions will be needed.

1.1 EXECUTIVE SUMMARY OF RESULTS

Table 1.0 lists 21 control measures that were evaluated and shows the estimated tons per day of emission reductions achievable for each of four pollutants. At the bottom of the table is the total emissions reduction achievable if all 21 controls measures are implemented. The total emission reductions achievable are 40.8 tons/day of NOx, 20.5 tons/day of VOC, 196 tons/day of CO and 14.4 tons/day of PM-2.5. Also shown is the proportional reduction in 2007 baseline emissions achievable. If all the control measures were implemented the potential emission reductions would be equivalent to a 14.6%

reduction in NOx emissions, a 9.0% in VOC emissions, a 17.8% reduction in CO emissions, and a 29.4% reduction in PM-2.5 emissions. These estimates assume that each control measure could be fully implemented, which in many cases will not be either possible or practical. For this reason, actual emission reductions from these measures are likely to be less than the values shown in Table 1.0.

The control measures are numbered in Table 1.0. Each number corresponds to the section number in Chapter 3, which includes details on the calculations of emission reductions and costs achievable by each control measure.

Reducing the emissions of NOx and VOC are most important for effecting ozone concentrations, as these pollutants are precursors to ozone production. Estimates of the reductions of CO and PM-2.5 were included in order to indicate any additional air quality benefit that might be achieved from the proposed control measure. The cost of controlling the emissions shown in Table 1.0 is calculated as the cost (in dollars) per ton of reduction in all four pollutants combined. In most cases the cost to control a single pollutant would be higher than shown in Table 1.0. Estimates of the control cost per pollutant are given in Chapter 3.

As stated above, the most important emission reductions are in NOx and VOC. Table 1.0 shows that some control measures may achieve a significant reduction in emissions while some control measures are likely to achieve very little emission reduction. Among the potentially most effective control measures in reducing NOx and VOC emissions are lowering the speed limit by 10 mph on rural interstates, a more restrictive I/M program, a RACT rule affecting point sources with greater than 50 tons/year of NOx emissions, truck electrification, a ban on open burning, cetane additives to diesel fuel, a lower Reid vapor pressure for gasoline, traffic signal synchronization, reduced travel on AQADs (Air Quality Action Days), and requiring contractors to use low-emission construction equipment. Not all these control measures are likely to be popular, especially with those being asked to reduce emissions. It will be up to each community to decide on the control measures they are willing to adopt in order to improve air quality. Some of the control measures will require voluntary action by the public, while others will require new regulations by state and local agencies. Some may even require legislative action.

Table 1.0 List of Potential Emission Control Measures
For the Nashville EAC Counties (Draft 9/11/03)

Control Measure	Estimate of Potential Emission Reductions NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)	COST ($/ton)
1. New RACT Rule for >50 Tons/Year NOx Sources					
A. Fossil Fueled Boilers	6.0	0.025	0.76	0.31	500
B. Gas Compressors	3.9	-	-	-	1,800
C. Glass Plants	3.2	-	-	-	1,400
2. Open Burning Ban					
A. Residential Garbage and Refuse	0.26	0.31	3.66	1.27	3,300
B. Yard Waste (Brush)	0.03	0.18	0.95	0.21	3,300
C. Construction Land Clearing	2.07	7.9	96.	12.1	360
3. More Stringent Vehicle Inspection & Maintenance	2.7	4.3	50.5	0	980
4. Lower Reid Vapor Pressure of Gasoline	0.18	3.4	6.1	0	4,300
5. Smoking Vehicle Ban	0.09	0.11	1.2	0.01	-
6. Stage I Controls in Cheatham, Dickson, & Robertson Co.	0	1.3	0	0	23
7. Lower Speed Limits on Rural Interstates	10.2	-0.22	11.6	0	-
8. HOV Lane Expansion	0.024	0.031	0.35	0.0003	180,000
9. Trip Reduction Plans	0.053	0.068	0.77	0.0007	180
10. Rideshare Programs	0.0076	0.01	0.1	0.0001	1,700
11. ITS Improvements					
A. Traffic Signal Synchronization	1.2	1.4	8.9	0	150
B. Roadside Assistance Programs	0.031	0.031	0.25	0.0004	2,600
12. New Greenways & Bikeways	0.039	0.049	0.56	0.0005	4,200
13. Low Emission Vehicle Fleets (On-Road)	0.32	0.01	0.20	0.005	11,500
14. Idling Engine Reductions					
A. Truck Stop Electrification	1.86	0.18	1.56	0.03	860
B. Reduce School Bus Idling	0.02	0.0012	0.0044	0.0011	0
15. Improve Transit					
A. Improve Bus Ridership	0.01	0.012	0.14	0.00013	0
B. New Rail Service	0.041	0.074	0.84	0	-

Control Measure	Estimate of Potential Emission Reductions NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)	COST ($/ton)
16. Reduce Bus Fares on Air Quality Action Days (AQAD)	0.10	0.12	1.4	0.0013	16,700
17. Construction Equipment Emission Reductions					
A. For TDOT Contractors	0.87	0.11	0.39	0.08	6,000
B. For All Contractors	3.44	0.42	1.53	0.32	6,000
18. New Airport Service Vehicles	0.04	0.003	0.026	0.002	4,700
19. Cetane Additives to Diesel Fuel	2.3	0	0	0	4,100
20. Land Use Controls to Reduce VMT	0.61	0.24	2.89	0.01	-
21. AQAD Measures	1.22	0.47	5.79	0.022	-
Total Potential Reductions	40.8	20.5	196.	14.4	
Projected 2007 Emissions w/o Control Measures	280	231	1114	49	
Percent Reduction in Emissions	**14.6%**	**8.9%**	**17.6%**	**29.4%**	

2.0. BASELINE EMISSIONS FOR THE NASHVILLE EAC AREA

2.1 INTRODUCTION

Before discussing potential emission control strategies that may be employed in the Nashville Early Action Compact (EAC) area it is useful to recognize the existing emission levels and projected baseline emissions without additional controls for the proposed attainment year of 2007. Table 2.1 below shows the tons per day of emissions of NOx, VOC, CO and PM-2.5 for the 8-county area for 1999 and projected for 2007.

Table 2.1 Baseline Emissions Without Additional Control Measures For the Eight County Nashville EAC Area

Pollutant	1999 Daily Emissions (tons/day)	2007 Projected Daily Emissions (tons/day)	Percent Change
NOx	341	280	-18%
VOC	244	231	-5%
CO	1292	1114	-14%
PM-2.5	47	49	4%

As shown in Table 2.1, emissions of NOx are projected to decrease by 18%, VOC emissions are projected to decrease 5%, and CO emissions are projected to decrease 14% over this 8-year period. Most of the emission reductions come from lower emissions from on-highway vehicles due to the lower allowable emissions from new vehicles under the Federal Motor Vehicle Control Program and the planned availability of cleaner burning low sulfur gasoline and diesel fuels. It is possible that dispersion modeling being performed as part of the ATMOS project by SAI, Inc. will show that this reduction in emissions is sufficient to achieve attainment of the ozone NAAQS. This is not likely, however, such that additional emission reductions may be necessary. Estimates of the additional emission reductions potentially achievable by 21 different control measures are presented in Chapter 3 of this report.

2.2 EMISSIONS BY COUNTY AND BY SOURCE TYPE

Emissions for 1999 for each of the 8 counties in the Nashville EAC are summarized in Tables 2.2 to 2.5. Separate tables are shown for each pollutant. Emissions are also shown for 10 source categories.

Emission estimates for the Nashville EAC area were taken from the U.S. EPA website: www.epa.gov/air/data. The information included at the website is the NEI99 Version2, Tier 1 and Tier 2 emission inventories reported for Tennessee counties for 1999. The emission inventory was modified to incorporate the MOBILE6-based on-road emissions, taken from the report, “Effects of Growth in VMT and New Mobile Source Emission Standards on NO_x and VOC Emissions in Tennessee 1999-2030” dated March 12, 2002 and prepared by the University of Tennessee for TDOT.

In 1999, sources in Davidson County accounted for 40% of the NOx and VOC emissions in the 8-county area. Highway vehicles accounted for 63.9% of CO emissions, 55% of the NOx emissions and 28.9% of anthropogenic VOC emissions in the 8-county area. The largest source category of VOC emissions (accounting for 35.3%) was from “solvent utilization” which consist mostly of surface coating and degreasing operations. The largest source category of PM-2.5 emissions is “miscellaneous” which includes fugitive emissions from construction activities, mining and quarrying, and paved and unpaved road dust resuspension.

2.3 EMISSION PROJECTIONS TO 2007

Projections of baseline emissions for 2007 are shown by county and source category in Tables 2.6 to 2.9. Emission projection methods are different for different source categories. Electric utility emissions are not expected to change from 1999 – 2007 because TVA plans no changes at the Gallatin Steam Plant which is the only “electric utility” source in the 8-county area. Highway vehicle emissions were predicted using the USEPA’s MOBILE6 emissions model and are expected to decrease due to lower emission standards for new vehicles and lower sulfur gasoline and diesel fuels that should be available in the area by 2006. Highway vehicle emissions are expected to decrease even with a projected increase of ~3% growth in vehicle miles of travel (VMT) per year. Off-Highway emissions of NOx and VOC are also expected to decrease 3% and 15% respectively, based on the USEPA Non-Road Emissions Model that accounts for new emission standards for gasoline and diesel engines used in off-road vehicles and construction equipment. All other source categories show projected increases in emissions based on an assumed 10% growth (over the 8-year period) in the activities that cause these emissions.

Tables 2.6 to 2.9 show the emission projections for 2007. The largest source category of NOx and CO emissions is still expected to be highway sources. The largest source category for anthropogenic VOC emissions is still “solvent utilization”. The largest source of PM-2.5 emissions is projected to be from miscellaneous sources of fugitive emissions from construction activities, mining and quarrying, and paved and unpaved road dust resuspension.

Table 2.2 1999 Nashville Area NOx Emissions in Tons/day

Source	Cheatham	Davidson	Dickson	Robertson	Rutherford	Sumner	Williamson	Wilson	Total	Percent
Elec. Util.						38.92			38.92	11.4
Ind comb	0.12	7.22	0.66	0.60	2.55	18.55	0.87	2.20	32.77	9.6
Other comb	0.09	16.31	0.14	0.15	0.50	0.72	0.38	0.27	18.55	5.4
Petrol Ind		0.01							0.01	0.0
Other Ind	0.03	9.08	0.01		0.06				9.19	2.7
Solvent							0.003		0.00	0.0
Waste Disp	0.11	0.91	0.12	0.11	0.46	0.26	0.41	0.19	2.58	0.8
Highway Vehicles	8.82	79.60	9.46	18.21	25.75	13.02	16.12	16.84	187.82	55.0
Off-Highway	2.03	23.20	2.28	3.00	6.77	3.88	7.51	2.68	51.35	15.0
Misc.	0.02	0.02	0.03	0.01	0.02	0.01	0.02	0.02	0.15	0.0
	11.22	136.35	12.70	22.08	36.12	75.35	25.32	22.20	341.34	100.0

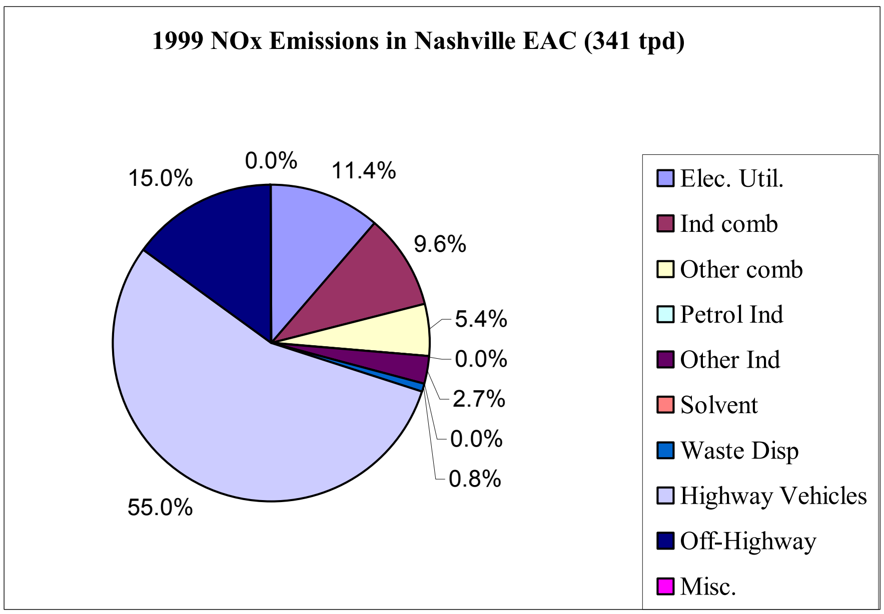


Table 2.3 1999 Nashville Area VOC Emissions in Tons/day

Source	Cheatham	Davidson	Dickson	Robertson	Rutherford	Sumner	Williamson	Wilson	Total	Percent
Elec. Util.						0.53			0.53	0.2
Ind comb	0.02	0.20	0.02	0.03	0.12	0.82	0.05	0.08	1.34	0.5
Other comb	0.37	3.29	0.50	0.64	0.68	1.65	0.53	0.98	8.64	3.5
Chem Prod		0.24			0.16	0.01	0.03		0.45	0.2
Petro Ind		0.01							0.01	0.0
Other Ind	0.02	2.78	0.02	0.03	2.18	0.25	0.26	0.05	5.60	2.3
Solvent	2.33	31.17	6.71	3.63	16.40	14.43	7.65	3.81	86.13	35.3
Storage & Transport	0.48	8.47	0.89	1.20	3.74	2.44	2.85	2.60	22.67	9.3
Waste Disp	0.61	2.86	1.67	1.27	3.83	2.39	2.42	1.76	16.81	6.9
Highway Vehicles	3.37	32.56	4.61	4.76	8.71	5.48	5.92	5.14	70.53	28.9
Off-Highway	0.75	13.82	0.84	0.62	3.19	2.02	4.20	2.96	28.39	11.6
Misc.	0.14	0.07	0.15	1.32	0.42	0.46	0.33	0.11	3.01	1.2
	8.08	95.45	15.41	13.49	39.43	30.48	24.25	17.50	244.10	100.0

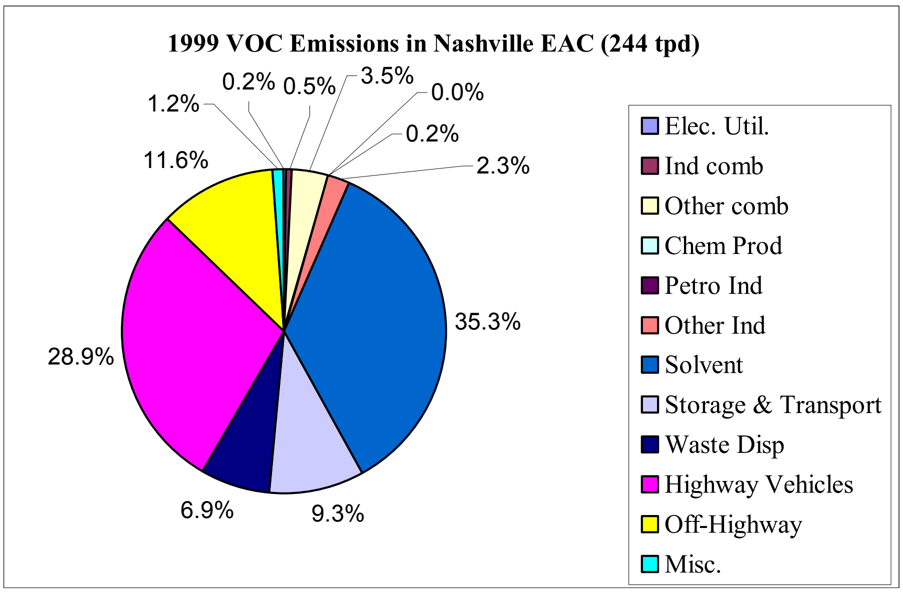


Table 2.4 1999 Nashville Area CO Emissions in Tons/day

Source	Cheatham	Davidson	Dickson	Robertson	Rutherford	Sumner	Williamson	Wilson	Total	Percent
Elec. Util.						3.24			3.24	0.3
Ind comb	0.10	1.93	0.21	0.32	1.43	1.16	0.52	0.59	6.27	0.5
Other comb	1.25	9.00	1.68	1.45	1.61	3.74	1.23	3.32	23.29	1.8
Chem Prod		10.39							10.39	0.8
Metal Proc		0.13				2.11			2.24	0.2
Petrol Ind		0.01							0.01	0.0
Other Ind	0.01	0.64			0.01				0.66	0.1
Waste Disp	2.65	30.61	2.96	2.39	11.95	6.24	11.26	4.56	72.62	5.6
Highway Vehicles	40.21	376.95	51.77	61.49	101.81	60.15	71.44	62.07	825.89	63.9
Off-Highway	5.13	176.94	8.36	8.50	37.67	18.90	57.13	26.67	339.29	26.3
Misc.	0.95	1.01	1.40	0.43	1.29	0.76	1.18	0.82	7.85	0.6
	50.30	607.60	66.39	74.59	155.78	96.30	142.75	98.03	1291.74	100.0

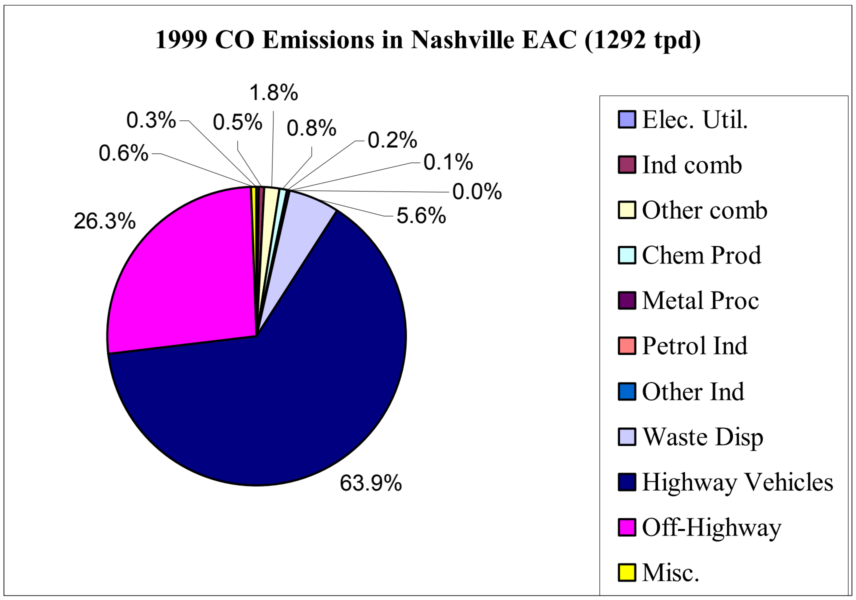


Table 2.5 1999 Nashville Area PM2.5 Emissions in Tons/day

Source	Cheatham	Davidson	Dickson	Robertson	Rutherford	Sumner	Williamson	Wilson	Total	Percent
Elec. Util.						1.23			1.23	2.6
Ind comb	0.01	0.21	0.01	0.01	0.03	0.02	0.02	0.01	0.31	0.7
Other comb	0.18	2.53	0.24	0.22	0.25	0.51	0.21	0.47	4.60	9.7
Metal Proc		0.07					0.26		0.32	0.7
Petrol Ind		0.01							0.01	0.0
Other Ind	0.01	0.16	0.01	0.01	0.02	0.25			0.46	1.0
Storage & Transport		0.05							0.05	0.1
Waste Disp	0.48	3.08	0.51	0.47	1.74	0.96	1.54	0.77	9.56	20.2
Highway Vehicles	0.14	1.49	0.15	0.29	0.45	0.25	0.28	0.30	3.34	7.1
Off-Highway	0.11	1.51	0.12	0.19	0.50	0.29	0.63	0.24	3.60	7.6
Misc.	0.96	8.52	1.12	2.02	3.44	2.69	2.89	2.13	23.77	50.3
	1.88	17.63	2.16	3.20	6.43	6.20	5.82	3.92	47.26	100.0

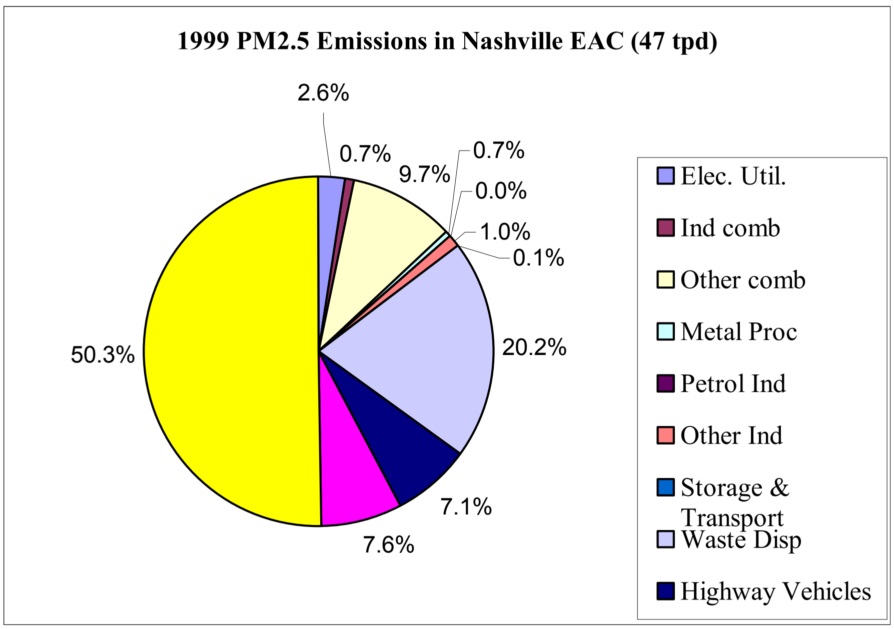


Table 2.6 2007 Nashville Area NOx Emissions in Tons/day

Source	Cheatham	Davidson	Dickson	Robertson	Rutherford	Sumner	Williamson	Wilson	Total	Percent
Elec. Util.						38.92			38.92	13.9
Ind comb	0.14	7.94	0.73	0.66	2.81	20.40	0.96	2.42	36.04	12.9
Other comb	0.10	17.94	0.15	0.17	0.55	0.79	0.42	0.30	20.41	7.3
Petrol Ind		0.01							0.01	0.0
Other Ind	0.04	9.99	0.01		0.07				10.11	3.6
Solvent							0.003		0.00	0.0
Waste Disp	0.12	1.00	0.13	0.12	0.51	0.29	0.46	0.21	2.84	1.0
Highway Vehicles	5.92	51.43	6.15	11.81	17.07	8.40	10.81	10.79	122.38	43.7
Off-Highway	1.98	22.59	2.24	2.92	6.47	3.78	6.93	2.57	49.48	17.6
Misc.	0.02	0.02	0.03	0.01	0.03	0.02	0.02	0.02	0.17	0.1
	8.31	110.93	9.45	15.69	27.50	72.58	19.59	16.31	280.36	100.0

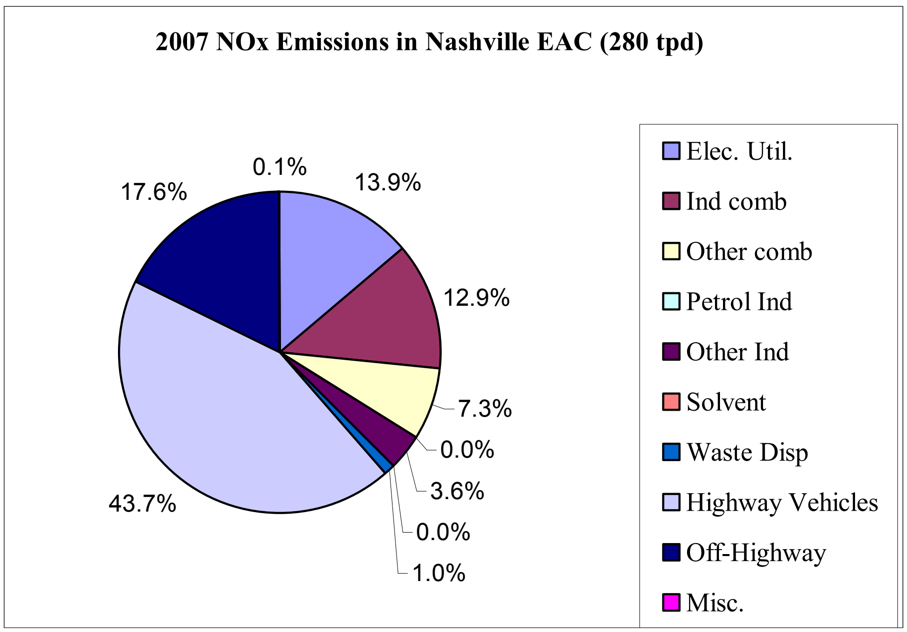


Table 2.7 2007 Nashville Area VOC Emissions in Tons/day

Source	Cheatham	Davidson	Dickson	Robertson	Rutherford	Sumner	Williamson	Wilson	Total	Percent
Elec. Util.						0.53			0.53	0.2
Ind comb	0.02	0.22	0.02	0.03	0.13	0.91	0.05	0.09	1.47	0.6
Other comb	0.41	3.62	0.55	0.71	0.75	1.82	0.58	1.07	9.51	4.1
Chem Prod		0.27			0.17	0.02	0.04		0.49	0.2
Petro Ind		0.01							0.01	0.0
Other Ind	0.02	3.05	0.03	0.03	2.40	0.28	0.29	0.05	6.16	2.7
Solvent	2.56	34.28	7.38	3.99	18.04	15.87	8.42	4.20	94.74	41.0
Storage & Transport	0.53	9.31	0.98	1.32	4.12	2.68	3.14	2.86	24.94	10.8
Waste Disp	0.68	3.14	1.84	1.39	4.22	2.62	2.66	1.94	18.49	8.0
Highway Vehicles	2.39	21.63	3.11	3.25	5.91	3.58	4.03	3.40	47.30	20.5
Off-Highway	0.78	11.39	0.82	0.48	2.73	1.75	2.99	2.95	23.88	10.3
Misc.	0.15	0.08	0.17	1.45	0.46	0.51	0.37	0.12	3.31	1.4
	7.54	87.01	14.89	12.65	38.92	30.56	22.57	16.68	230.82	100.0

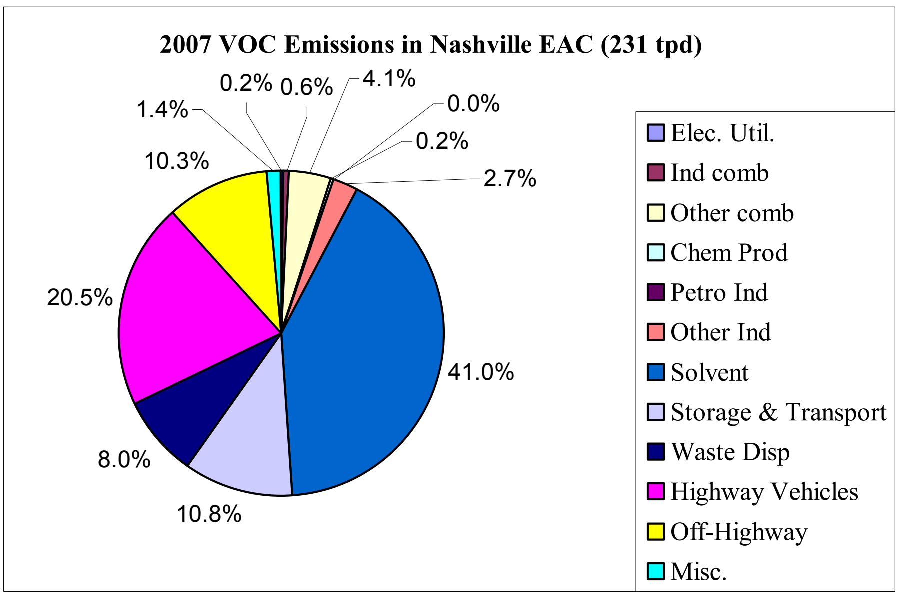


Table 2.8 2007 Nashville Area CO Emissions in Tons/day

Source	Cheatham	Davidson	Dickson	Robertson	Rutherford	Sumner	Williamson	Wilson	Total	Percent
Elec. Util.						3.24			3.24	0.3
Ind comb	0.11	2.12	0.24	0.35	1.58	1.27	0.57	0.65	6.89	0.6
Other comb	1.38	9.90	1.85	1.60	1.78	4.11	1.36	3.65	25.62	2.3
Chem Prod		11.43							11.43	1.0
Metal Proc		0.14				2.32			2.46	0.2
Petrol Ind		0.01							0.01	0.0
Other Ind	0.01	0.71			0.01				0.73	0.1
Waste Disp	2.92	33.67	3.25	2.63	13.14	6.87	12.38	5.02	79.88	7.2
Highway Vehicles	26.99	267.87	32.86	42.92	72.49	41.34	51.09	42.96	578.51	51.9
Off-Highway	5.86	209.48	9.75	9.45	42.81	21.26	66.52	31.77	396.89	35.6
Misc.	1.05	1.11	1.54	0.48	1.42	0.83	1.30	0.90	8.63	0.8
	38.31	536.43	49.49	57.42	133.23	81.25	133.22	84.95	1114.30	100.0

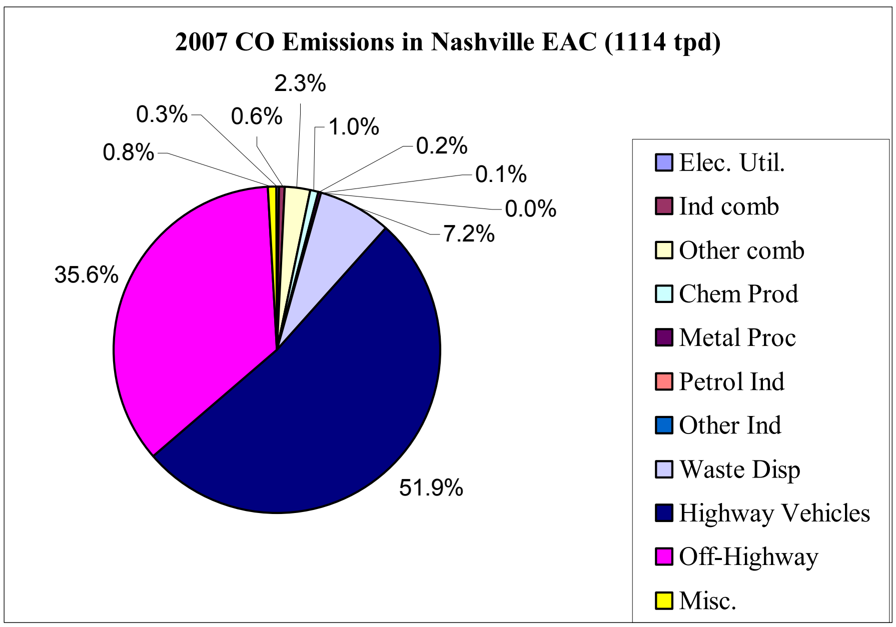
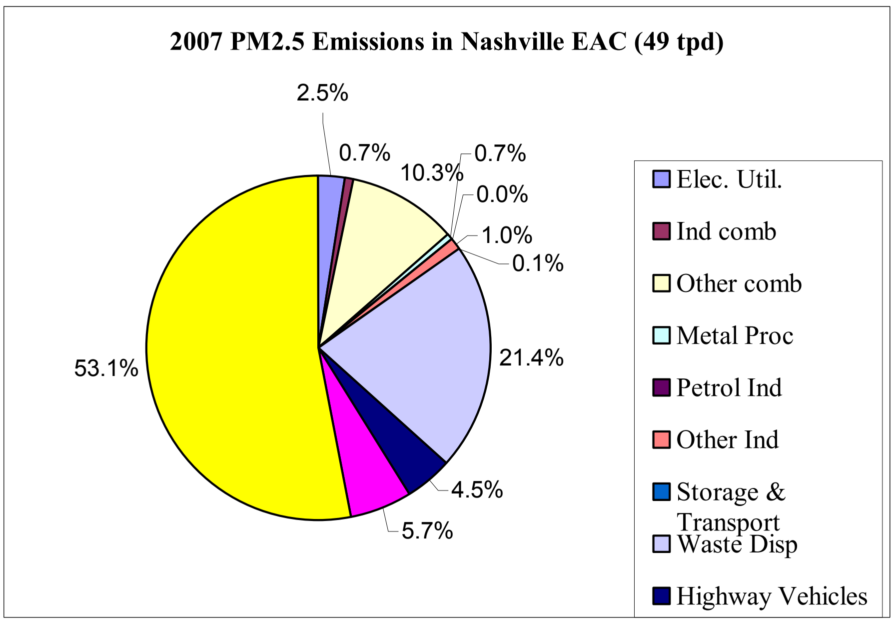


Table 2.9 2007 Nashville Area PM2.5 Emissions in Tons/day

Source	Cheatham	Davidson	Dickson	Robertson	Rutherford	Sumner	Williamson	Wilson	Total	Percent
Elec. Util.						1.23			1.23	2.5
Ind comb	0.01	0.23	0.01	0.01	0.04	0.02	0.02	0.01	0.34	0.7
Other comb	0.20	2.78	0.27	0.24	0.28	0.56	0.23	0.52	5.06	10.3
Metal Proc		0.07					0.28		0.36	0.7
Petrol Ind		0.01							0.01	0.0
Other Ind	0.01	0.18	0.01	0.02	0.02	0.27			0.50	1.0
Storage & Transport		0.06							0.06	0.1
Waste Disp	0.53	3.39	0.56	0.51	1.92	1.06	1.70	0.85	10.52	21.4
Highway Vehicles	0.09	0.98	0.09	0.18	0.30	0.17	0.19	0.19	2.20	4.5
Off-Highway	0.09	1.23	0.10	0.15	0.37	0.21	0.48	0.19	2.83	5.7
Misc.	1.06	9.37	1.23	2.22	3.78	2.96	3.18	2.34	26.14	53.1
	1.97	18.30	2.27	3.33	6.70	6.48	6.07	4.11	49.25	100.0



3.0 ESTIMATES OF POTENTIAL EMISSION REDUCTIONS

Twenty-one different control measures were identified by the Nashville Area MPO for possible inclusion in a plan for reducing emissions for the Nashville EAC area.
Each control measure has been evaluated herein to determine how much of a reduction in emissions might be achievable and at what cost. Each control method is discussed in a separate section of the report that contains details describing how the emission reductions were estimated. Emission reductions were estimated for nitrogen oxides (NOx), volatile organic compounds (VOC), carbon monoxide (CO) and particulate matter 2.5 micrometers or less in diameter (PM-2.5). Included in each section are estimates of the cost to achieve the emission reductions in dollars per ton of pollutant. This information is intended to help prioritize the selection of control measures on the basis of cost effectiveness.

Listed below are the 21 control measures that were evaluated along with the section number in this report where the details of the analysis are described. A summary of the emissions reductions achievable by each control measure is presented in Table 1.0 of Chapter 1 "Executive Summary of Results".

Section Number	Control Measure
3.1	New RACT Rule for >50 Tons/Year NOx Sources
3.2	Open Burning Ban
3.3	More Stringent Vehicle Inspection and Maintenance Programs
3.4	Lower Reid Vapor Pressure Gasoline
3.5	Smoking Vehicle Ordinance
3.6	Stage I Controls in Cheatham, Dickson & Robertson Counties
3.7	Lower Speed Limits on Rural Interstates
3.8	HOV Lane Expansions
3.9	Trip Reduction Plans
3.10	Rideshare Programs
3.11	ITS Improvements
3.12	New Greenways and Bikeways
3.13	Low Emission Vehicle Fleets
3.14	Idling Engine Reductions
3.15	Improve Transit
3.16	Reduce Bus Fares on Air Quality Action Days
3.17	Construction Equipment Emission Reductions
3.18	New Airport Service Vehicles
3.19	Cetane Additives to Diesel Fuel
3.20	Land Use Controls to Reduce VMT
3.21	Air Quality Action Day (AQAD) Measures

3.1 NEW RACT RULE FOR >50 TON/YEAR NOx SOURCES

TDEC is considering adopting a new regulation requiring all sources of >50 tons/day of NOx to control emissions to meet RACT (reasonable available control technology) requirements. Each source emitting more than 50 ton/day of NOx would have to submit an analysis of their emissions and show that (1) their emissions either currently meet RACT requirements or (2) identify what methods could be used to reduce NOx emissions to RACT requirements. RACT emission reductions are less stringent than NSPS (New Source Performance Standards) or BACT (Best Available Control Technology) standards. Actual emission reductions achievable by the rule can only be determined after sources submit their RACT analyses. In the Nashville EAC there were only three types of industrial processes that emit more than 50 tons/year of NOx, and would be required to undertake the RACT review. These sources are: fossil fueled boilers, natural gas compressors, and glass manufacturing plants. This chapter attempts to estimate the emission reductions that might be possible if each source implements new controls under the proposed RACT Rule.

3.1.A. FOSSIL FUELED BOILERS

3.1.1.A. OVERVIEW OF FOSSIL FUELED BOILERS

Combustion boilers are designed to use the chemical energy in fuel to raise the energy content of water so that it can be used for heating and power applications. Many fossil and nonfossil fuels are fired in boilers, but the most common types of fuel include coal, oil, and natural gas[1].

Coal that is used as fuel for the boilers can be further classified into bituminous, sub-bituminous, anthracite and lignite. Each class of coal has distinct characteristics which can influence NOx emissions. NOx emissions are also affected by the various types of fossil fuel fired boilers such as tangentially-fired, single and opposed wall-fired, cell burner, cyclone, stoker, and fluidized bed combustion. Each type of furnace has specific design characteristics which can influence NOx emissions levels. These include heat release rate, combustion temperatures, residence times, combustion turbulence, and oxygen levels[2].

3.1.2.A. FOSSIL FUEL BOILERS WITH NOX EMISSIONS 50+ TON/YEAR

Nashville area contains five companies that emit more than 50 tons of NOx per year. These companies are:

1) EI Dupont De Nemours & Co Inc. (Davidson County) – 3 boilers (will fire coal and gas).
2) Vanderbilt University (Davidson County) – 3 boilers (2 fire gas, 1 fires coal only).
3) Nashville Thermal Transfer Corp. (Davidson County) – has switched its boilers from solid waste to natural gas or propane. Currently, there are 4 boilers in operation, although the available data shows one boiler that utilizes solid waste.

4) Nissan North America, Inc. (Rutherford County) – 2 boilers (one fires natural gas, the other boiler uses coal).
5) TVA Gallatin Fossil Plant (Sumner County) – 4 boilers (coal).

NOx emissions result from these companies utilizing boilers that use coal, distillate oil, or natural gas as fuel, or a combination of these fuels. Boilers that utilize oil as a fuel did not result in NOx emissions in excess of 50 tons/year.

3.1.3.A. ALTERNATIVE CONTROL TECHNOLOGIES

NOx emissions from boilers can be controlled through one of two methods, or in conjunction with one another. One method is known as combustion control. Low NOx Burners (LNBs), Flue Gas Recirculation (FGR), Overfire Air (OFA), Ultra Low NOx Burners (ULNBs) are control technologies that will reduce NOx emissions and are classified as combustion control technologies. These technologies are among those most likely to qualify as RACT. Switching from coal to gas also reduces NOx emissions.

The other method of controlling NOx emission is known as post-combustion control. Selective Catalytic Reduction (SCR) and Selective Noncatalytic Reduction (SNCR) are the two technologies that fall under this particular method. Nonetheless, these technologies can be used jointly with combustion control to increase the NOx removal efficiency. SCR and SNCR technologies are generally considered to meet BACT or higher requirements.

3.1.4.A. ANALYSIS OF RESULTS

Table 3.1.1.A shows current NOx emissions from these companies as well as emissions from the boilers if certain reduction technologies (i.e. LNB, FGR, SCR) are used. The emission reductions are based on reduction technologies installed on boilers burning coal and/or natural gas. Lowest NOx removal efficiency is achieved with a Flue Gas Recirculation (FGR) technique that results in a 45% decrease in pollution, on average. Selective Catalytic Reduction (SCR) is a post combustion control technology that yields on average, 85% reductions in NOx emissions when applied to boilers that burn bituminous coal[3]. This table also shows current total emissions for each company in the Nashville area as well as total emissions per company that will result from installing a control technology.

Table 3.1.2.A shows NOx emissions from the companies named above. “Current Emissions” indicate emissions from existing boilers using respective fuels. Also, the table lists emissions that could be achieved through firing natural gas at all boilers concurrent with control technologies. One boiler of Vanderbilt University steam plant (Emission Unit ID “EU” 209) and one boiler of Nissan North America, Inc. (EU 01) cannot switch fuels to natural gas due to their stoker design for the boilers, thus, no emission reductions are shown for these units in table 3.1.2.A. Reduction technologies applied to boilers that fire natural gas as a fuel, will have lower NOx emissions than the same technology applied to boilers that burn coal. The most efficient control method is SCR when used jointly with an LNB. On average, a 94% decrease in NOx emissions is possible[4].

Table 3.1.1.A. NOx Emissions Based On Existing Fuel

State County FIPS	State Facility ID	Emission Unit ID	Facility Name	Description of Fuel	Current Emissions (Tons/Year)	Current Emissions (Tons/Day)	Emissions Based on NOx Control Measures (Tons/Day)			
							LNB	FGR	SCR	SNCR
47037	470370000	009	E I DUPONT DE NEMOURS & CO INC	Bituminous Coal	614.070	1.682	0.841	0.925	0.252	0.673
47037	470370000	009	E I DUPONT DE NEMOURS & CO INC	Natural Gas	52.480	0.144	0.058	0.065	0.007	0.086
47037	470370000	010	E I DUPONT DE NEMOURS & CO INC	Bituminous Coal	353.300	0.968	0.484	0.532	0.145	0.387
47037	470370000	010	E I DUPONT DE NEMOURS & CO INC	Natural Gas	66.640	0.183	0.073	0.082	0.009	0.110
47037	470370000	011	E I DUPONT DE NEMOURS & CO INC	Bituminous Coal	540.900	1.482	0.741	0.815	0.222	0.593
47037	470370000	011	E I DUPONT DE NEMOURS & CO INC	Natural Gas	88.820	0.243	0.097	0.110	0.012	0.146
				Total Emissions	**1716.210**	**4.702**	**2.294**	**2.529**	**0.648**	**1.995**
47037	470370003	207	VANDERBILT UNIVERSITY	Bituminous Coal	186.830	0.512	0.256	0.282	0.077	0.205
47037	470370003	208	VANDERBILT UNIVERSITY	Bituminous Coal	157.500	0.432	0.216	0.237	0.065	0.173
47037	470370003	209	VANDERBILT UNIVERSITY*	Bituminous Coal	195.580	0.536	-	0.295	0.080	0.214
				Total Emissions	**539.910**	**1.479**	**0.472**	**0.814**	**0.222**	**0.592**
47037	470370005	002	NASHVILLE THERMAL TRANSFER**	Solid Waste	457.800	1.254	0.081	0.091	0.010	0.122
				Total Emissions	**457.800**	**1.254**	**0.081**	**0.091**	**0.010**	**0.122**
47149	0155	65	NISSAN NORTH AMERICA, INC.	Natural Gas	61.500	0.168	0.067	0.076	0.008	0.101
47149	0155	01	NISSAN NORTH AMERICA, INC.	Bituminous Coal	81.300	0.223	0.111	0.123	0.033	0.089
				Total Emissions	**142.800**	**0.391**	**0.179**	**0.198**	**0.042**	**0.190**
47165	0025	004	TVA-GALLATIN FOSSIL PLANT	Bituminous Coal	3425.000	9.384	9.384	-	1.408	3.753
47165	0025	003	TVA-GALLATIN FOSSIL PLANT	Bituminous Coal	3609.000	9.888	9.888	-	1.483	3.955
47165	0025	002	TVA-GALLATIN FOSSIL PLANT	Bituminous Coal	2805.000	7.685	7.685	-	1.153	3.074
47165	0025	001	TVA-GALLATIN FOSSIL PLANT	Bituminous Coal	3143.000	8.611	8.611	-	1.292	3.444
				Total Emissions	**12982.000**	**35.567**	**35.567**		**5.335**	**14.227**

* Vanderbilt University uses one boiler (Emission Unit ID 209) that is a spreader stoker design. As such, LNBs can not be installed on stoker design boilers.

** Nashville Thermal Transfer Corp has switched its boilers from solid waste to natural gas as a fuel as of 2002. "Current Emissions" represent NOX pollution from boilers utilizing solid waste as a fuel. Emissions with control technologies are based on NOx emissions of 74.04 tons/year that are emitted when the boiler is switched from burning solid waste to natural gas.

Efficiency[3]:

- Low NOx Burners (LNB): 50% avg.(Coal)
- Flue Gas Recirculation (FGR): 45% avg. (Coal)
- Selective Catalytic Reduction (SCR): 85% avg. (Coal)
- Selective Noncatalytic Reduction (SNCR): 60% avg. (Coal)

NOTE: These effciencies are achieved when the appropriate technology is used in conjuction with coal as fuel for the boilers. For efficiencies on boilers with natural gas as fuel, see the footnote for Table 3.2.

Table 3.1.2.A. NOx Emissions: Current Fuel vs. Natural Gas Fuel

State County FIPS	State Facility ID	Emission Unit ID	Facility Name	Description of Fuel	Current Emissions (Tons/Day)	Emissions When Burning Natural Gas as Fuel (Tons/Day)					
						No Controls$	LNB	ULNB	FGR	SCR+LNB	SNCR+LNB
47037	470370000	009	E I DUPONT DE NEMOURS & CO INC	Bituminous Coal	1.682	0.920	0.368	0.184	0.414	0.055	0.552
47037	470370000	009	E I DUPONT DE NEMOURS & CO INC	Natural Gas	0.144	0.144	0.058	0.029	0.065	0.009	0.086
47037	470370000	010	E I DUPONT DE NEMOURS & CO INC	Bituminous Coal	0.968	0.629	0.252	0.126	0.283	0.038	0.378
47037	470370000	010	E I DUPONT DE NEMOURS & CO INC	Natural Gas	0.183	0.183	0.073	0.037	0.082	0.011	0.110
47037	470370000	011	E I DUPONT DE NEMOURS & CO INC	Bituminous Coal	1.482	0.771	0.308	0.154	0.347	0.046	0.462
47037	470370000	011	E I DUPONT DE NEMOURS & CO INC	Natural Gas	0.243	0.243	0.097	0.049	0.110	0.015	0.146
				Total Emissions	**4.702**	**2.890**	**1.156**	**0.578**	**1.300**	**0.173**	**1.734**
47037	470370003	207	VANDERBILT UNIVERSITY *	Bituminous Coal	0.512	0.075	0.030	0.015	0.034	0.004	0.045
47037	470370003	208	VANDERBILT UNIVERSITY	Bituminous Coal	0.432	0.063	0.025	0.013	0.028	0.004	0.038
47037	470370003	209	VANDERBILT UNIVERSITY	Bituminous Coal	0.536	-	-	-	-	-	-
				Total Emissions	**1.479**	**0.137**	**0.055**	**0.027**	**0.062**	**0.008**	**0.082**
47037	470370005	002	NASHVILLE THERMAL TRANSFER**	Solid Waste	1.254	0.203	0.081	0.041	0.091	0.012	0.122
				Total Emissions	**1.254**	**0.203**	**0.081**	**0.041**	**0.091**	**0.012**	**0.122**
47149	0155	65	NISSAN NORTH AMERICA, INC.	Natural Gas	0.168	0.168	0.067	0.034	0.076	0.010	0.101
47149	0155	01	NISSAN NORTH AMERICA, INC.***	Bituminous Coal	0.223	-	-	-	-	-	-
				Total Emissions	**0.391**	**0.168**	**0.067**	**0.034**	**0.076**	**0.010**	**0.101**
47165	0025	004	TVA-GALLATIN FOSSIL PLANT****	Bituminous Coal	9.384	-	3.749	-	-	0.225	2.250
47165	0025	003	TVA-GALLATIN FOSSIL PLANT	Bituminous Coal	9.888	-	3.223	-	-	0.193	1.934
47165	0025	002	TVA-GALLATIN FOSSIL PLANT	Bituminous Coal	7.685	-	2.989	-	-	0.179	1.793
47165	0025	001	TVA-GALLATIN FOSSIL PLANT	Bituminous Coal	8.611	-	2.847	-	-	0.171	1.708
				Total Emissions	**35.567**		**12.808**			**0.769**	**7.685**

* Vanderbilt University uses 1 spread stoker boiler that fires coal (Emission Unit ID 209). This boiler can not be modified to burn natural gas.

** Nashville Thermal Transfer Corp has switched to using natural gas as a fuel instead of solid waste as 2002. "Current Emissions" represent NOX pollution from boilers utilizing solid waste as a fuel.

*** Nissan North America, Inc. has not reported Actual Throughput. An approximate Actual Throughput value is calculated from the AP-42 emission factor (11 lbNOx/ton) for Spreader Stoker boilers with bituminous coal. Emission Unit ID 01, boiler, is an overfeed stoker boiler and as such it can not burn natural gas.

**** TVA Gallatin uses Low NOx Burners in all 4 coal fired units. Thus, no uncontrolled emissions exist.

$ "No Controls " emissions are calculated based on AP-42 emission factors for natural gas combustion.

Efficiency[4]:

- Low NOx Burners (LNB): 60%
- Ultra Low NOx Burners (ULNB): 80%
- Flue Gas Recirculation (FGR): 55%
- Selective Catalytic Reduction (SCR)+LNB: 94% avg.
- Selective Noncatalytic Reduction (SNCR)+LNB: 40%

NOTE: These efficiencies are achieved when the particular technology is used in boilers firing natural gas as fuel.

Table 3.1.3.A lists current emissions in tons per day, and controlled emissions achievable by firing natural gas in boilers that are currently multi-fuel, and installing LNBs. In case of Vanderbilt University steam plant, boilers (EU 207, 208) could operate on natural gas in combination with an LNB, or run on coal but with an FGR modification. The table shows the NOx reductions (in percent) potentially achievable by individual companies when modifications made to the current systems. Since TVA already has LNBs installed, they are not expected to control their emissions any further due to their compliance with the RACT rule. TVA reductions are expected to be equal to zero. Other companies in the Nashville area might reduce their NOx emissions 75 percent (EI Dupont De Nemours) to 84 percent (Nashville Thermal Transfer Corp.) by switching to gas and installing low NOx burners. This may or may not be achievable depending in part on the availability of natural gas.

Table 3.1.4.A shows emission reductions achievable by county. Companies in Davidson County (EI Dupont De Nemours Inc., Vanderbilt University, and Nashville Thermal Transfer Corp.) may have the potential to reduce NOx emissions by 5.726 tons/day, whereas, Nissan North America Inc., in Rutherford County may only reduce its NOx emissions by 0.324 tons/day. As a side benefit of burning gas instead of coal, CO and PM2.5 emissions will be decrease by 80 and 99.7 percent, respectively[5]. However, VOC emissions would likely increase by 26 percent when burning gas.

Table 3.1.5.A lists estimated capital costs for emission control technologies applied to boilers. The cost per ton of NOx removed depends on the type of technology applied as well as on boiler classification, according to a study by MPR[3]. Installing LNBs on oil or gas firing boilers will cost between $125-250 based on literature values (3). This cost is higher when modifying coal-firing boilers with LNBs, $300-500. It will cost $300-500 to install FGR in coal-fired boilers.

3.1.5.A. BOILER DATA

EI Dupont De Nemours & CO Inc. has three boilers that emit more than 50 tons NOx/year. These boilers are dual-fuel. Boilers with EU 009, 010, and 011, burn natural gas instead of coal 7.97, 14.78, and 16.10 percent of time, respectively. Ambiguously, NOx emission factors (lb/MMBtu) for boilers are higher when they operate on natural gas than on coal. Referring to AP-42 emissions factors, it can be concluded that for boilers that use natural gas as a fuel, NOx emissions will always be less than when running on coal. If boilers are to use natural gas instead of coal and have LNBs, NOx emissions decrease from 4.702 tons/day to 1.156 tons/year (75%).

Table 3.1.3.A. Current Emissions vs. Controlled Emissions

State County FIPS	State Facility ID	Facility Name	Current Total Emissions (ton/day)	Controlled Emissions (Tons/Day)	% Reduction
47037	4703700002	E I DUPONT DE NEMOURS & CO INC.[1]	4.702	1.156	75
47037	4703700039	VANDERBILT UNIVERSITY[2]	1.479	0.350	76
47037	4703700050	NASHVILLE THERMAL TRANSFER[3]	1.254	0.203	84
47149	0155	NISSAN NORTH AMERICA, INC.[4]	0.391	0.067	83
47165	0025	TVA-GALLATIN FOSSIL PLANT[5]	35.567	35.567	0
		Total	**43.394**	**37.343**	**14**

EU = Emission Unit ID

1. EI Dupont De Nemours & Co Inc. operates multi-fuel boilers (EU 009, 010, 011) that emit more than 50 tpy of NOx. "Controlled Emissions" represent the emissions achieved by firing only natural gas and installing LNBs at these three units.

2. Vanderbilt University steam plant operates three boilers with emissions greater than 50 tpy. "Controlled Emissions" represent the emissions achieved by firing natural gas and installing LNBs at two of its boilers (EU 207, 208), and installing FGR at the other boiler (EU 209), since it's a spreader stoker, and it can not switch to natural gas nor be modified for LNBs.

3. Nashville Thermal Transfer Corp has switched to using natural gas as a fuel instead of solid waste, as of 2002. "Current Emissions" represent NOx pollution from boilers utilizing solid waste as a fuel. "Controlled Emissions" represent emissions achieved by burning natural gas instead of solid waste. It is unlikely that Nashville Thermal Transfer Corp. will have additional NOx control measures at this time.

4. Nissan North America Inc.operates two boilers with emissions greater than 50 tpy. "Controlled Emissions" represent annual emissions achieved by installing a LNB at boiler (EU 65). Nissan operates only one boiler (EU 65) during the summer season.

5. TVA Gallatin uses Low NOx Burners in all 4 coal fired units. Thus, there will be no further controls and emissions will remain the same.

Table 3.1.4.A. Emission Reductions Achieved by "LNB+Natural Gas/FGR'

County		NOx*** (tons/day)	VOC* (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson		5.726	0.015	0.661	0.309
Rutherford		0.324	0.010	0.101	0.003
Sumner**		NR	NR	NR	NR
Williamson		N/A	N/A	N/A	N/A
Wilson		N/A	N/A	N/A	N/A
Cheatham		N/A	N/A	N/A	N/A
Dickson		N/A	N/A	N/A	N/A
Robertson		N/A	N/A	N/A	N/A
TOTAL		**6.050**	**0.025**	**0.762**	**0.312**

EU = Emission Unit ID

NR = No Reductions

N/A = Not Available

* VOC emissions INCREASE when switching from coal to natural gas.

** Since TVA Gallatin already uses LNBs with its coal-fired boilers, it is very unlikely that they will switch to natural gas as fuel. As such no reductions will take place in the Sumner County.

*** The reduction value is based on switching fuel to natural gas and installing LNBs. For companies within counties that operate stoker boilers, value used is for emissions from boilers burning coal and FGR as a control measure.

Table 3.1.5.A. Estimated Cost of Emission Reductions by "LNB/FGR"

County		NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties		125-250[1] 300-500[2] 300-500[3]	NA	NA	NA	NA

1. Installation of LNBs for boilers on oil or gas.
2. Installation of LNBs for boilers on coal.
3. Installation of FGR for spreader stoker boilers on coal.

Vanderbilt University steam plant uses two multi-fuel boilers and one overfeed stoker boiler, which makes it impossible to burn natural gas. The steam plant operates three boilers that emit NOx in excess of 50 tons/year, individually. One method of controlling NOx emissions would be installation of LNBs and firing natural gas during summer season for boilers (EU 207, 208), and modify boiler (EU 209) with FGR. The reduction efficiency would be 76 percent, thus emissions from the three boilers might be reduced from 1.479 to 0.350 tons/day.

Nashville Thermal Transfer Corporation (NTTC) has switched it boilers from burning solid waste to natural gas after a major fire that occurred at the facility in May of 2002. NTTC utilizes four boilers that can burn natural gas or propane. The guaranteed unit emissions are 0.062 lb NOx/MMBtu when burning propane or natural gas[5]. When NTTC was using solid waste as fuel, there were 1.254 tons/day (457.8 tons/year) of NOx emissions. If steam production remains at levels prior to switching fuels, NOx emissions will decrease to 0.203 tons/day with new fuel firing. NTTC would likely meet the RACT rule burning natural gas instead of solid waste.

Nissan North America, Inc. has two boilers that emit more than 50 tons/year of NOx. One boiler fires coal on a spreader stoker design, whereas the second boiler burns natural gas. Due to the stoker design of the boiler, it may be impractical to convert to firing natural gas. During summer season, Nissan operates boiler (EU 65), which fires natural gas. The coal-fired boiler (EU 01) is not operational during summer. If the natural gas firing boiler is modified with a LNB, then emissions during the summer season might be reduced from 0.391 to 0.067 tons/day. Note: The 0.391 tons/day is an annual average emission rate for both boilers. The 0.067 tons/day is the emissions from one gas fired boiler with LNB reducing NOx by 60%.

TVA Gallatin Plant already employs four coal-fired boilers with low NOx burners. As such, it is very unlikely that TVA will consider installing additional controls (i.e. SCR) or that it will replace coal with natural gas as fuel. Emissions will remain at 35.567 tons/day (12,982 tons/year). Considering the presence of LNB control technologies at the plant, TVA Gallatin should already comply with the RACT rule.

3.1.6.A. RECOMMENDATIONS

This study briefly outlines the emission reductions that are achievable by installing NOx control technologies and/or switching fuels from firing coal to natural gas. Companies have several control technologies at their disposal to decrease NOx emissions. Not all control technologies were considered for this analysis. It is expected that RACT may be achieved through the use of LNB control technologies and/or replacement of coal with natural gas as fuel. Those companies that cannot fire natural gas at some of their boilers (Vanderbilt University, Nissan North America, Inc.) may consider the option of installing FGR or other technologies.

While natural gas is more costly as fuel than coal, the use of gas not only reduces NOx, it also greatly decreases the emissions of CO, CO2, SO2, PM. It is not know, however, whether sufficient natural gas will be available during the summer months.

3.1.7.A. REFERENCES

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3.1.B NATURAL GAS COMPRESSORS

3.1.B.1 Introduction. Gas compressors are used in the natural gas industry to compress and transport natural gas, and they are used for the auxiliary production of electricity. This category includes reciprocating internal combustion engines (RICE) and stationary gas turbines, which are sometimes referred to as combustion turbines (CT). These engines are almost always fueled by pipeline grade natural gas. Reciprocating engines can be separated into three classes: 2-cycle (stroke) lean-burn (2SLB), 4-stroke lean-burn (4SLB) and 4-stroke rich-burn (4SRB). Two piston strokes are required for a single crankshaft revolution, thus to complete the power cycle, one crankshaft revolution is required for 2-stroke engines, and two crankshaft revolutions are required for 4-stroke engines. Rich and lean-burn refers to the relative air/fuel ratio. Lean-burn engines operate with more air relative to the fuel, and rich burn engines operate with less air relative to the fuel.

Natural gas-fueled engines typically emit nitrogen oxides (NOx), carbon monoxide (CO), volatile organic carbons (VOC) and particulate matter (PM). However, control technologies for natural gas-fueled engines are primarily aimed at reducing only NOx emissions. Three general types of NOx emission controls are in use for CT (wet controls, dry controls and post-combustion controls), and three types exist for RICE (parametric controls, combustion modification and post-combustion controls).

Wet controls use steam or water injection to reduce combustion temperatures for NOx control. Usually water or steam injection is accompanied by an efficiency penalty (typically 2 to 3 percent). In addition, both CO and VOC emissions are increased by water injection. Dry controls use advanced engine design to suppress NOx formation by lowering combustor temperature using lean mixtures of air and/or staging the fuel to decrease the residence time of gases in the combustion area. Staged combustion is identified through a variety of names, including Dry-Low NOx (DLN), Dry-Low Emissions (DLE) or SoLoNOx.

Parametric controls use engine spark timing and/or operating the engine at leaner air/fuel ratios. Combustion modifications are aimed at improving the mixing of fuel-air and promoting staged combustion. Examples include clean burn engine head designs and pre-stratified charge combustion. Post-combustion controls involve catalytic NOx reduction, i.e., selective catalytic reduction (SCR) for stationary gas turbines and nonselective catalytic reduction (NSCR) for lean-burn reciprocating engines.

Lean-burn engines typically have lower oxides of nitrogen (NO_x) emissions than rich-burn engines. In general, NOx emissions increase with increasing load and intake air temperature, and decrease with increasing absolute humidity and air/fuel ratio.

3.1.B.2 Summary of Emissions. Table 3.1.B.1 summarizes the sources in Tennessee emitting NOx that are greater than 50 tons/year as listed on the 1999 EPA website

Table 3.1.D.1. Emissions for Tennessee, Reporting Year 1999, SIC 4922 - Natural Gas Transmission, Sources > 50 ton year NOx

Facility	ID No.	County	NOx (ton/yr)	%	VOC (ton/yr)	%	CO (ton/yr)	%	PM25 (ton/yr)	%
Tenneco Gas	165-0008	Sumner	6257	22.7	99	12.0	346	10.0	NA	NA
Tennessee Gas Pipeline (#79)	135-0001	Perry	4340	15.8	73	8.8	279	8.1	NA	NA
Tenneco Gas / Environmental Department	081-0002	Hickman	3631	13.2	101	12.2	1191	34.5	NA	NA
Tenneco Gas	181-0001	Wayne	2616	9.5	43	5.2	212	6.1	NA	NA
American Natural Resources Co.	079-0024	Henry	2221	8.1	129	15.6	203	5.9	NA	NA
ANR Pipeline Company	075-0053	Haywood	2068	7.5	44	5.3	287	8.3	NA	NA
Columbia Gulf Transmission Company	119-0095	Maury	1996	7.3	48	5.8	308	8.9	NA	NA
Texas Gas Transmission Corporation	167-0067	Tipton	1722	6.3	69	8.3	242	7.0	32.0	68.1
East Tennessee Natural Gas	163-0110	Sullivan	709	2.6	4	0.5	26	0.8	7.0	14.9
Texas Gas Transmission Corp	131-0101	Obion	643	2.3	9	1.1	131	3.8	8.0	17.0
Texas Eastern Gas Pipeline Gladeville	189-0093	Wilson	604	2.2	19	2.3	81	2.3	NA	NA
Tenneco Gas/Midwestern Gas Transmission	165-0014	Sumner	451	1.6	186	22.5	57	1.7	NA	NA
Tenneco Gas / Environmental Department	071-0061	Hardin	212	0.8	4	0.5	81	2.3	NA	NA
East Tennessee Natural Gas Co.	051-0080	Franklin	58	0.2	NA	NA	9	0.3	NA	NA
Total (for Natural Gas Transmission > 50 ton year NOx) =			**27528**	**100.0**	**828**	**100.0**	**3453**	**100.0**	**47.0**	**100.0**
Total (for all Reporting Tennessee Counties) =			**286098**	**9.6**	**120999**	**0.7**	**108040**	**3.2**	**27252**	**0.2**
Summary (SIC 4922 - Natural Gas Transmission Only)		**Sumner County =**	**6708**	**2.3**	**285**	**0.2**	**403**	**0.4**	**NA**	**NA**
		Wilson County =	**604**	**0.2**	**19**	**0.0**	**81**	**0.1**	**NA**	**NA**
		Total (for Nashville Area) =	**7312**	**2.6**	**304**	**0.3**	**484**	**0.4**	**NA**	**NA**

www.epa.gov/air/data for the SIC 4922 - Natural Gas Transmission. The VOC, CO and PM25 emissions for these source are also listed in Table 3.1.B.1 for these sources for comparisons. Total NOx emissions for the SIC 49220 category are approximately 25,728 tons/year (70.5 tons/day). The Nashville Area includes Sumner and Wilson Counties. Two natural gas transmission facilities are located in Sumner County and one natural gas transmission facility is located in Wilson County. The NOx emissions for Sumner County are 6,708 tpy (18.4 tpd) and for Wilson County, NOx emissions are 604 tpy (1.7 tpd). The NOx emissions for the total Nashville area are 7,312 tpy (20 tpd), which represents about 2.6% of the total NOx emissions for Tennessee (i.e., 2.34% for Sumner County and 0.21 % for Wilson County).

Tennessee Gas Pipeline Company - Station 87 (i.e., Tenneco Gas in Sumner County)[7,8,9] operates 33 Cooper-Bessemer two-cycle lean-burn reciprocating engines with a total of 49,700 hp and seven Ingersoll-Rand four-cycle rich-burn auxiliary generators with a total of 2,704 hp. The permit requires that a clean-burn retrofit modification be applied to one Cooper-Bessemer engine limiting the NOx emission rate to 3.6 g/hp-hour hr (0.00793 lb/hp-hr). Also, the permit requires that parametric controls be used on two additional Cooper-Bessemer engines to limit the NOx emission rate to 37.3 g/hp-hour (0.0821 lb/hp-hr) for each engine. During 1996, the facility received a RACT permit to reduce NOx emissions 90% by requiring non-selective catalytic reduction (NSCR) on two of the Ingersoll-Rand auxiliary generators.

Midwestern Gas Transmission Company - Station 2101 (i.e., Tenneco/Midwestern Gas Transmission in Sumner County)[8,9] operates one Cooper-Bessemer two-cycle lean-burn reciprocating engine (2,700 hp) and four Ingersoll-Rand four-cycle lean-burn reciprocating engines with a total 9,000 hp. The operating permit requires a clean-burn retrofit to be utilized on the Cooper-Bessemer engine and on one of the Ingersoll-Rand engines limiting the NOx emission rates to 8.55 g/hp-hr (0.0188 lb/hp-hr) and 18.01 g/hp-hr (0.0397 lb/hp-hr), respectively.

Texas Eastern Gas Pipeline - (Gladeville in Wilson County)[9] operates a single General Electric regenerated gas turbine (18,500 hp). The operating permit sets the NOx RACT rate limitation at 52.2 kg/hr (115 lb/hr).

3.1.B.3 Summary of Emission Factors. Tables 3.1.B.2 and 3.1.B.3 list criteria pollutant emission factors for RICE and CT engines. Close inspection of the emission factors for the uncontrolled conditions reveal that NOx emissions factors are generally larger for the lean-burn RICE and CT engines when they are operating at higher load. The percent reduction for instance between RICE uncontrolled at 90-105% load for 2SLB and 4SLB and RICE uncontrolled at less than 90% load for 2SLB and 4SLB are approximately 38.8% and 79.2%, respectively. Note: there is basically no difference between low and high load NOx emission factors for 4SRB engines.

The percent reduction is not as large (about 8.5%) between CT uncontrolled at greater than or equal to 80% load (high load) and CT uncontrolled for all load conditions (low load). However, when based on the fuel input emission factor (lb/MMscf), the CT engine has a lower NOx emission factor when compared with any type RICE. For instance when comparing the uncontrolled lower load conditions CT engine versus any RICE, the percent reduction in NOx emissions are approximately 84.8%, 65.2% and 87.0% for 2SLB, 4SLB and 4SRB, respectively.

3.1.B.4 Emission Reduction Estimates and Control Measure Costs. This section will first explain two current strategies that have already been considered in Tennessee to take advantage of the differences in NOx emissions at reduced engine load (see Case 1) and between reciprocating and turbine engines (see Case 2).

Case 1: The Texas Gas Transmission Company in Tipton County (Facility ID number 167-0067)[10] has orally committed to the Memphis and Shelby County Health Department to make programming changes on eight reciprocating natural gas compressors to operate at 90% of rated load during the ozone season, which would achieve NOx emission reductions of 140 tpy. It is believe that other similar NOx reductions of 83 tpy can be achieved in the Memphis-Shelby Metropolitan area applying a similar strategy, which would achieve NOx emission reductions of approximately 235 tpy (1.09 tpd).

Case 2: The Tennessee Gas Pipeline Company in Sumner County (Facility ID number 163-0008)[7] requested a change in their Title V operating permit to replace 13 reciprocating (2SLB) engines total 14,935 hp with two reciprocating (4SLB) engines total 15,400 hp. The 4SLB technology will result in a 157.4 tpy (0.43 tpd) NOx reduction or approximately 19% facility wide NOx reduction.

Tables 3.1.B.4 and 3.1.B.5 show sample calculations for a combination of NOx reductions strategies for the natural gas transmission company in Sumner and Wilson County, respectively. Only one large gas turbine is located in Wilson County. However, a mixture of reciprocating engines is located in Sumner County. Thus, a

Table 3.1.D.2. Criteria Emission Factors for Natural Gas-Fired Reciprocating Internal Combustion Engines [a]

Pollutant	Control Method	2-Stroke Lean-Burn		4-Stroke Lean-Burn		4-Stroke Rich-Burn		~ Cost of Emission Reduction
		(lb/hp-hr) [1]	(lb/MMscf) [2]	(lb/hp-hr) [1]	(lb/MMscf) [2]	(lb/hp-hr) [1]	(lb/MMscf) [2]	$/ton [3]
NOx	Uncontrolled < 90% Load	-	1979	-	864	-	2315	-
	Uncontrolled 90-105% Load	0.027	3233	0.033	4161	0.046	2254	-
	LEC [3]	0.00721	-	-	-	-	-	-
	SCR	ND	ND	0.0076	-	-	-	1,800
	NSCR	ND	ND	-	-	0.0051	-	-
VOC	Uncontrolled	0.0021	-	0.00069	-	0.00048	-	-
CO	Uncontrolled 90-105% Load	0.0027	394	0.0027	323	0.0160	3794	-
	Uncontrolled < 90% Load	-	360	-	568	-	3580	
	SCR	ND	ND	ND	ND	-	-	-
	NSCR	ND	ND	ND	ND	0.0050	-	-
PM-10 Total	Uncontrolled	ND	ND	0.000080	-	0.000098	-	-
PM-10 Filterable	Uncontrolled	ND	ND	0.00000062	-	0.0000055	-	-

[a] Emission factors for (lb/MMscf) were calulated from units of (lb/MMBtu) using 1020 Btu/scf.

Table 3.1.D.3. Criteria Emission Factors for Natural Gas-Fired Combustion Turbines [4]

Pollutant	Control Method	All Loads		High Loads (greater than or equal to 80 %)		~ Cost of Emission Reduction
		(lb/MMBtu)	(lb/MMscf)	(lb/MMBtu)	(lb/MMscf)	$/ton [5,6]
NOx	Uncontrolled	0.295	301	0.323	329	-
	Water-steam Injection	0.126	128	0.128	130	1,650
	Lean Pre-mix	0.111	113	0.0991	101	2,000
	SCR	0.013	13.1	0.0128	13.1	6,270
VOC	Uncontrolled	0.002	2.09	0.0021	2.09	-
CO	Uncontrolled	0.177	180	0.0823	83.9	-
	Water-steam Injection	0.033	34.1	0.0295	30.1	-
	Lean Pre-mix	1.270	1300	0.0151	15.4	-
PM Condensable	Water-steam Injection	0.005	4.82	0.0047	4.82	-
PM Filterable	Water-steam Injection	0.002	1.93	0.0019	1.93	-
PM Total	Water-steam Injection	0.007	6.76	0.0066	6.76	-

percentage of the available engines (i.e., a fraction of the total facility horsepower) was used to calculate the NOx reduction strategy. A fraction reduction method was also used for the control strategy. Fraction reduction here was determined by subtracting the ratio of the emission factors (EF) from unity (i.e., 1 - control EF /uncontrolled EF).

Assuming that 50% of the gas compressors could be run at low-load for the Tenneco Gas Company, and 20% of the compressors at the Midwestern Gas Company could be run at low-load, then the reduction for Sumner County would be approximately 3.9 tpd. With the addition of 0.14 tpd from Wilson County, the total NOx emission reduction for the Nashville Area would be approximately 4.0 tpd for the Low-load control method..

It may be possible to achieve a reduction of about 3.8 tpd in Sumner County with the Low Emission Combustion (LEC) technology if only 25% of the 2SLB engines at Tenneco Gas are retrofitting with LEC. The cost associated with the retrofitting would be about $1,800/ton.

Table 3.1.D.4. Sample calculations for predicting NOx reduction in Sumner County

Company Name (Facility ID #)	Reciprocating Engines		2-Stroke Lean-Burn		4-Stroke Lean-Burn		4-Stroke Rich-Burn	
	Fraction reduction >>>		0.388	0.733	0.792	0.770	ND	0.889
	Uncontrolled		Low-load	LEC	Low-load	SCR	Low-load	NSCR
	ton/yr	ton/day	ton/day	ton/day	ton/day	ton/day	ton/day	ton/day
Tenneco Gas (165-0008)	6257	17.14						
Fraction of facility's total 52,404 horsepower			0.50	0.25			0.05	0.05
Facility Reduction			3.33	3.14			ND	0.76
Midwestern Gas Transmission (165-00014)	451	1.24						
Fraction of facility's total 11,700 horsepower			0.20	0.20	0.50	0.50		
Facility Reduction			0.10	0.18	0.49	0.48		
Summary for Low-load condition	County Reduction		3.91					
	County Total		14.47					
Summary for LEC condition	County Reduction			3.80				
	County Total			14.58				

Table 3.1.D.5. Sample calculations for predicting NOx reduction in Wilson County

Company Name (Facility ID #)	Combustion Turbine (CT)					
	Fraction reduction >>>		0.085	0.573	0.624	0.957
	Uncontrolled		Low-load	Water-steam injection	Lean pre-mix	SCR
	ton/yr	ton/day	ton/day	ton/day	ton/day	ton/day
Texas Eastern Gas Pipeline (189-0093)	604	1.65				
Fraction facility's total 18,500 horsepower			1	1	1	1
Summary for all conditions	County Reduction		0.14	0.95	1.03	1.58
	County Total		1.51	0.71	0.62	0.07

Table 3.1.D.6. Emission Reductions Achievable by Low-load Control Measure

County		NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson					
Rutherford					
Sumner		1.89			
Williamson					
Wilson		0.14			
Cheatham					
Dickson					
Robertson					

Table 3.1.D.7. Estimated Cost of Emission Reductions by Low-load Control Measure

County		NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties		0				#DIV/0!

Table 3.1.D.6. Emission Reductions Achievable by LEC Control Measure

County		NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson					
Rutherford					
Sumner		3.8			
Williamson					
Wilson		0.14			
Cheatham					
Dickson					
Robertson					

Table 3.1.D.7. Estimated Cost of Emission Reductions by LEC Control Measure

County		NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties		1,800	0	0	0	#DIV/0!

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3.1C NEW RACT RULE FOR GREATER THAN 50 TONS PER YEAR NOx SOURCES – GLASS PLANTS

3.1C.1 Uncontrolled NOx Emissions. Most NOx emissions are emitted from the melting furnace in the glass plants. Nitrogen oxides form when nitrogen and oxygen react in the high temperatures of the furnace[1]. Uncontrolled NOx emissions can vary considerably based on furnace type, furnace age, fuel firing rate, fuel used, and raw materials.

Visteon Corporation is an automotive glass plant that was spun off from Ford Motor Corporation in 2000 in Nashville, Tennessee. This company is one of the biggest producers of flat glass in the United States. Uncontrolled NOx emissions are generated from two glass melting furnaces emitting 834 tons per year and 772 tons per year, respectively. This is equivalent to 2.28 tons/day and 2.12 tons/day, respectively.

Table 3.1C.1 shows the summary of uncontrolled NOx emissions from Visteon glass manufacturing in Nashville. According to the AP-42 report [1], uncontrolled NOx emissions from flat glass range from 5.6 to 10.4 lb NOx per ton of glass. The average emission factor based on AP-42 is 8 lb NOx per ton of glass. The emission factor reported by this company is 8.0 – 8.8 lb NOx per ton of glass which would indicate emissions are uncontrolled.

3.1C.2 Controlled NOx Emissions. Since 1990, when Congress enacted the Clean Air Act, a primary focus of the glass industry has been toward low NOx technologies to meet the increasingly stringent regulations on furnace emissions [2]. Low NOx technologies include cullet preheating, electric boosting, SNCR, SCR, OEAS, oxy fuel combustion and 3R process (Reaction and Reduction in Regenerators). Most low NOx technologies such as electronic boosting and oxy fuel combustion offer significant NO reductions but at increased production costs.

The OEAS (Oxygen Enriched Air Staging) technology is advanced combustion modification technique that reduces NOx formation by decreasing the oxygen in the flame's high temperature zone. However, the OEAS (Oxygen-enriched air staging) technology is not acceptable for flat glass to reduce NOx emissions.[3] SNCR (Selective non-catalytic reduction) technology offers significant NOx reductions[4]. SCR (Selective Catalytic Reduction) technology also shows high NOx reductions (up to 70%) but at increased costs.

According to IPPC (Integrated Pollution Prevention and Control)[5] documents, the 3R process is based on the addition of a hydrocarbon fuel (e.g. natural gas or oil) to the waste gas stream at the regenerator entrance. The fuel dissociates and acts to chemically reduce the NOx formed in the furnace. The technology is designed for use in regenerative furnaces. The process called "3R" stands for "Reaction and Reduction in Regenerators." Hydrocarbons (CHx) are formed mainly by thermal decomposition (pyrolysis) which occurs very quickly as the fuel enters the regenerator.

Table 3.1C.1. Summary of NOx Emissions from Visteon Glass Manufacturing Company in Nashville EAC Area

Company Name	EU ID	SIC	SCC	Emission Process Description	Flat Glass used (ton/day)	NOx Emissions (ton/yr)	NOx Emissions (tons/day)	E.F Used (lb/ton)
VISTEON CORP - NASHVILLE GLASS	4	3211	30501403	MELTING FURNACE #2	520 (189771 ton/yr)	834	2.28	8.79
VISTEON CORP - NASHVILLE GLASS	6	3211	30501403	MELTING FURNACE #3	530 (193604 ton/yr)	772	2.12	7.98

The main reactions are below.

$CH_4 + OH/O/O_2 \rightarrow CHx + H_2O$
$CH_4 \rightarrow CHx$
$CHx + NO \rightarrow HxCN + O$
$CHx + NO \rightarrow HxCNO + H$

3R is an innovative technology and is acceptable as BACT for NOx emissions from the Main furnace.[3] Table 3.1C.2 shows the relative costs and NOx reductions of some available low NOx technologies.[4,5] According to Table 3.1C.3 and Figure 3.1C.1, 3R is chosen as the most appropriate technology to reduce NOx emissions for the flat glass manufacturing.

3.1C.3 Calculations Of NOx Reduction Emissions And Costs For NOx Reductions From Two Melting Furnaces. NOx reduction for 3R is 75 percent, based on the reference[5]. The emission factor for 3R is 2.2 lb NOx per tons of glass[5]. For melting furnace#4 and #6 at this company, NOx emissions employing 3R would be:

Furnace #2: (8.79 - 2.2 lb NOx /ton of Glass) x (520 tons of glass/day) x (ton/2000lb) = 1.71 ton/day
Furnace #3: (7.98 - 2.2 lb NOx /ton of Glass) x (530 tons of glass/day) x (ton/2000 lb) = 1.53 ton/day

Annual operating and capital costs are $301,000 and $512,000 for 3R,[5] respectively. The costs per ton of NOx reductions ($/ton NOx reductions) for furnace #4 and 6 are calculated below:

For the furnace #2: ($813,000/yr) / (624.15 ton/yr) = $1,303/ton NOx removed
For the furnace #3: ($813,000/yr) / (558.45 ton/yr) = $1,456/ton NOx removed

Table 3.1C.2. Summary of NOx Reductions and Capital and Annual Costs

Technology	NOx Reduction (%)	Capital Cost ($1000) ***	Annual Operating Cost ($1000/yr)***
Low NOx burners	40	1340	621
Oxy-firing	85	9810	3590
Cullet preheat	25	NF*	NF*
Electric boost	10	NA**	525
SCR	75	2690	1200
SNCR	40	1560	660
3R	75	512	301

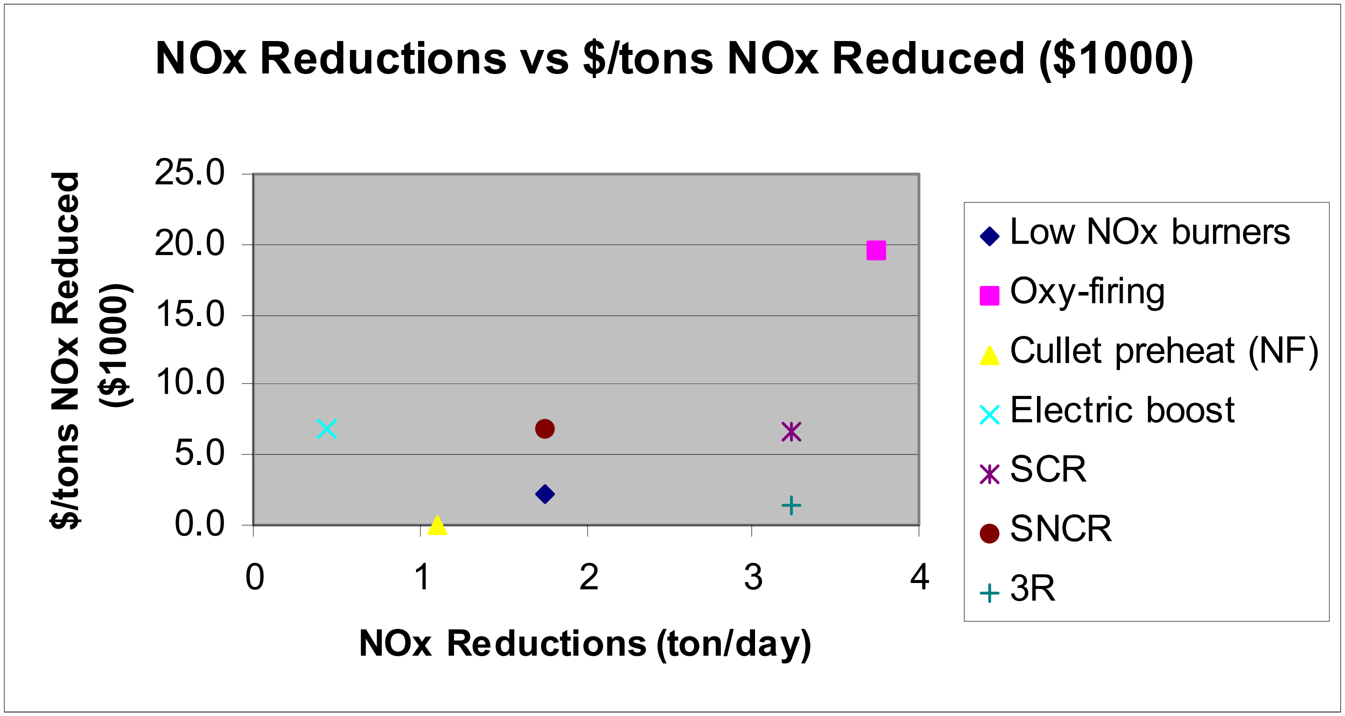
* Not Feasible ** Not Available
*** Capital & Annual Costs are for a 750 ton/day flat glass plant.[4] Capital & Annual Costs for 3R are for a 600 ton/day float glass plant [5].

Technology	NOx Reductions (ton/day)		Total NOx Reductions (ton/day)	Furnace #2 (520 ton/day)		Furnace #3 (530 ton/day)		Total ($million)	$/tons NOx Reduced ($1000)
	Furnace #2 (520 ton/day)	Furnace #3 (530 ton/day)		Annualized Capital Cost ($million)*	Annual Operating Cost ($million)	Annualized Capital Cost ($million)*	Annual Operating Cost ($million)		
Low NOx burners	0.91	0.85	1.76	0.134	0.621	0.134	0.621	1.5	2.3
Oxy -firing	1.94	1.8	3.74	9.810	3.590	9.810	3.590	26.8	19.6
Cullet preheat	0.57	0.53	1.1	NF**	NF**	NF**	NF**	NF**	NF**
Electric boost	0.23	0.21	0.44	NA***	0.525	NA***	0.525	1.1	NA***
SCR	1.71	1.53	3.24	2.690	1.200	2.690	1.200	7.8	6.6
SNCR	0.91	0.85	1.76	1.560	0.660	1.560	0.660	4.4	6.9
3R	1.71	1.53	3.24	0.512	0.301	0.512	0.301	1.6	1.4

Table 3.1C.3. Comparison to Annual Operating and Capital Costs with those Control Technologies

*Annualized Capital cost estimated as capital cost divided by 10 year life.
** Not Feasible *** Not Available

Figure. 3.1C.1. Nox Reductions and $ /tons of NOx Reductions ($1000)



3.1C4 Summary Of NOx Reductions And Costs For Glass Plants. Table 3.1C.4 summaries NOx reductions and costs for 3R from two melting furnaces in Vieston glass manufacturing plants in Nashville EAC area.

Table 3.1C.4. Summary of NOx reductions and costs for 3R

Company Name	Emission Process Description	E.F (lb Nox/ tons of glass)	NOx Reductions (Ton/day)	$/tons NOx reduced	NOx Removed %
VISTEON CORP - NASHVILLE GLASS	MELTING FURNACE #2	2.2	1.71	1303	76
VISTEON CORP - NASHVILLE GLASS	MELTING FURNACE #3	2.2	1.53	1456	74

NOx emissions would be reduced by average 75% from the original NOx emissions for using 3R technology. Therefore, 0.57 tons of NOx/day from the melting furnace #2 and 0.59 tons of NOx/day from the melting furnace #3 would be emitted for using 3R technology. The estimated cost of NOx redustions by 3R is $1,400 per tons of NOx reduced.

Table 3.1C.5 and Table 3.1C.6 show the emission reductions achievable and estimated cost of emission reductions by 3R in Nashville EAC project. Because there is no information about VOC, CO, and PM2.5 reductions for using 3R technology[5], N/A are given for them in the Table 3.1C.5.

Table 3.1E.5 Emission Reductions Achievable by "3R"

County		NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson		3.24	N/A	N/A	N/A
Rutherford		N/A	N/A	N/A	N/A
Sumner		N/A	N/A	N/A	N/A
Williamson		N/A	N/A	N/A	N/A
Wilson		N/A	N/A	N/A	N/A
Cheatham		N/A	N/A	N/A	N/A
Dickson		N/A	N/A	N/A	N/A
Robertson		N/A	N/A	N/A	N/A
Total (tons/day)		3.24	N/A	N/A	N/A

N/A : Not Available

Table 3.1E.6 Estimated Cost of Emission Reductions by "3R"

County		NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties		1,400	N/A	N/A	N/A	1,400

References

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3.2.0 OPEN BURNING BAN

3.2.1 INTRODUCTION

This control measure proposes to ban open burning. Open burning is currently used to dispose of some solid waste and yard waste at private residences in rural areas of the Nashville EAC, and to dispose of trees and brush from land clearing at construction sites. The emission reductions possible from banning open burning from each of these three sources is discussed in this section.

3.2.2 RESIDENTIAL MUNICIPAL SOLID WASTE BURNING (RMSWB)

RMSWB refers to non-hazardous refuse produced by households. Activity data for RMSWB burning can be estimated from the total amount of waste generated. The amount of waste generated for each county was estimated using a national average per capita waste generated factor of 4.51 lbs/person/day, as reported in *Municipal Solid Waste in The United State: 2000* [1]. To better reflect the actual amount of household residential waste subject to being burned, non-combustible (glass and metals) waste factor of 0.6 lbs/person/day was subtracted out. In addition, since yard waste is considered a separate open burning category, it was subtracted out also, where its factor is of 0.54 lbs/person/day. Thus, the latest total RMSWB without yard waste, called entire refuse waste, was 3.97 lbs/person/day and the latest available per capita waste generation factor, called actually burned, was 3.37 lbs/person/day. These factors were then applied to the portion of the county's total population that is considered rural based on *1990 Census data* [2] on rural and urban population, and the information given by *Nashville Metro Air Pollution Control Department 2003* [3], since open burning is generally not practiced in urban areas. The percentage of total waste generated that is burned was estimated from survey data as reported in *Emission Characteristics of Burn Barrels* [4]. This study estimated that for a rural population a median value of 28 percent of the municipal waste generated is burned. This value was used for the following rural counties: Wilson, Cheatham, Dickson, and Robertson. The *Nashville Metro Air Pollution Control Department* suggested a value of 5 percent for the following urbanized counties: Davidson, Williamson, Sumner, and Rutherford.

The emission factors were obtained from the *Emission Inventory Improvement Program, Open Burning, EPA 2001* [5].

Table 3.2.1 RMSWB Emission Factors

Pollutant	lb/ ton entire refuse weight	lb/ ton actually burned
PM10		38
PM2.5		34.8
CO	85	
VOC		8.556
NOX	6	

The 2007 population for each county was estimated using annual 1995-2025 Tennessee projections given by the *Census Bureau* [6], interpolating in a graph the 2007 Tennessee population. The 2007 population was allocated to counties using the county contribution percentage based on Census Bureau 2000 [7]. This population is shown in the table 3.2.2.

The equation for estimating emissions from RMSWB is [8].

$$\text{Ecty} = (\text{Pcty x Rfrac}) * \text{W} * \text{Bfrac} * (\text{EF})\left(\frac{\text{ton}}{2000\ \text{lbs}}\right)\left(\frac{\text{ton}}{2000\ \text{lbs}}\right)$$

Where

Ecty : County-level emissions, tons per day
Pcty : Total population in county
Rfrac : Fraction of county population that is rural
W : Per capita waste generated 3.37 lbs/person/day
Bfrac : Waste generated fraction that is burned, 5 or 28% depending on the county.
EF : Emission factor in lbs/ton

Table 3.2.2 Counties population of 2000 and 2007, and rural percentage.

Location	2000	2007	Rural
Davidson	569,891	605,323	32%*
Rutherford	182,023	193,340	44.4%
Sumner	130,449	138,559	38.4%
Williamson	126,638	134,511	50.0%
Wilson	88,809	94,330	55.0%
Cheatham	35,912	38,145	90.6%
Dickson	43,156	45,839	74.9%
Robertson	54,433	57,817	61.9%
Total	1,231,311	1,307,865	

* General Services Area

Thus, the total RMSWB for 2007 are shown in the table 3.2.3

Table 3.2.3 Total RMSWB 2007

County	Actually burned (tons/day)	Entire refuse weight (tons/day)
Davidson	16.32	19.23
Rutherford	7.23	8.52
Sumner	4.48	5.28
Williamson	5.67	6.68
Wilson	4.37	5.15
Cheatham	16.30	19.21
Dickson	16.20	19.08
Robertson	16.89	19.89
Total	**87.46**	**103.03**

Therefore, the total open burning emission for RMSWB 2007 are shown in the table 3.2.4

Table 3.2.4 RMSWB 2007 emissions by county.

County	PM10 (tons/day)	PM2.5 (tons/day)	CO (tons/day)	VOC (tons/day)	NOX (tons/day)
Davidson	0.3101	0.2840	0.8171	0.0698	0.0577
Rutherford	0.1374	0.1258	0.3621	0.0309	0.0256
Sumner	0.0852	0.0780	0.2244	0.0192	0.0158
Williamson	0.1077	0.0986	0.2837	0.0242	0.0200
Wilson	0.0830	0.0761	0.2188	0.0187	0.0155
Cheatham	0.3098	0.2837	0.8163	0.0698	0.0576
Dickson	0.3078	0.2819	0.8110	0.0693	0.0572
Robertson	0.3208	0.2938	0.8454	0.0722	0.0597
Total	**1.6617**	**1.5218**	**4.3789**	**0.3742**	**0.3091**

3.2.3 RESIDENTIAL YARD WASTE

Yard residential waste refers to materials such as grass clippings, leaves, and trimmings from trees and shrubs. Similar to RMSWB a national per capita waste generation value was used as the basis for yard waste emissions for 2000. EPA reports an average daily generation rate of 0.54 lbs yard waste/person/day [1]. Of the total amount of yard waste generated, the yard waste composition is 25% leaves, 25% brush, and 50% grass by weight [8], however, open burning of grass clippings is not typically practiced by homeowners, and as such only estimates for leaf and brush burning were developed [14]. It was assumed that 28% of the total yard waste generated is burned and that burning occurs only in rural areas of the following counties: Wilson, Cheatham, Dickson, Robertson, Williamson, Sumner, and Rutherford. The *Nashville Metro Air Pollution Control Department* [3] recommended a value of 5 % for Davidson County.

The emission factors were obtained from the *Emission Inventory Improvement Program, Open Burning, EPA 2001* [5].

Table 3.2.5 Yard Waste Emission Factors

Yard Waste Type	Yard Waste Burning, [lb/ton]				
				TOC	
	PM	NOx	CO	Methane	Nonmethane
Leaf Species Unspecified	38.00	4.00	112.00	12.00	28.00
Forest Residues Unspecified	17.00	4.00	140.00	5.70	19.00
Weeds, Unspecified	15.00	4.00	85.00	3.00	9.00

The 2007 population for each county was estimated using the *Census Bureau Population Projections* [6] for Tennessee (1995-2025), interpolating the 2007 Tennessee population and estimating the county contribution based on the county population of the 2000 Tennessee-Census [7]. This population is shown in the table 3.2.2.

The equation for estimating emissions from Yard Waste is [8].

$$\text{Ecty} = (\text{Pcty x Rfrac}) * (\text{YW} * \text{YWfrac}) * \text{Bfrac} * (\text{EF}) \left(\frac{\text{ton}}{2000\ \text{lbs}} \right) \left(\frac{\text{ton}}{2000\ \text{lbs}} \right)$$

Where

Ecty : County-level emissions, tons per day
Pcty : Total population in county
Rfrac : Fraction of county population that is rural
YW : Per capita yard waste generation, 0.54 lbs/person/day
YWfrac: Fraction of yard waste that is burned.
Bfrac : Waste generated fraction that is burned, 5% (Davidson), and 28% (others).
EF : Emission factor in lbs/ton

Thus, the total yard waste for 2007 are shown in the table 3.2.6

Table 3.2.6 Total yard waste 2007

County	Brush (tons/day)	Leaf (tons/day)
Davidson	0.65	0.65
Rutherford	1.62	1.62
Sumner	1.01	1.01
Williamson	1.27	1.27
Wilson	0.98	0.98
Cheatham	0.65	0.65
Dickson	0.65	0.65
Robertson	0.68	0.68
Total	7.51	7.51

Then, the total open burning emission for Yard Waste 2007 are shown in the table 3.2.7

Table 3.2.7 Yard Waste emissions 2007.

County	PM (tons/day)	CO (tons/day)	NOX (tons/day)	Methane (tons/day)	No-Methane (tons/day)
Davidson	0.0180	0.0824	0.0026	0.0058	0.0154
Rutherford	0.0446	0.2044	0.0065	0.0144	0.0381
Sumner	0.0277	0.1267	0.0040	0.0089	0.0236
Williamson	0.0350	0.1602	0.0051	0.0112	0.0299
Wilson	0.0270	0.1236	0.0039	0.0087	0.0230
Cheatham	0.0180	0.0823	0.0026	0.0058	0.0153
Dickson	0.0178	0.0818	0.0026	0.0057	0.0152
Robertson	0.0186	0.0852	0.0027	0.0060	0.0159
Total	**0.2066**	**0.9465**	**0.0300**	**0.0665**	**0.1765**

3.2.4 CONSTRUCTION LAND CLEARING

Land clearing debris refers to the clearing of land for new construction and the burning of organic material (i.e., trees, shrubs and other vegetation). Debris may be burned in place, but it is usually collected in piles for burning. Emissions for this category were based on an estimate of the acres cleared, multiplied by a fuel loading factor, and multiplied by an emission factor. National or state data on the number of acres are not available from any known data sources. As such, a value for the acres disturbed by construction activity was estimated using surrogate data, which was then converted to acres using USEPA conversion factors [9]. Three general types of construction are accounted for to estimate land clearing activities [8]: a) residential construction; b) non-residential construction;

and c) roadway construction. It is assumed that all land clearing debris that is cleared is then burned. [8].

The formula for calculating the county-level emissions from land clearing debris was [8]:

$$\text{Ecty} = \text{Acres} * \text{LF} * \text{EF}\left(\frac{\text{ton}}{2000\,\text{lbs}}\right)\left(\frac{\text{year}}{365\,\text{days}}\right)$$

Where
Ecty : County-level emissions, tons per day
Acres : Total acres disturbed by construction per year
LF : Weighted loading factor to convert acres to tons of available fuel.
EF : Emission factor in lbs/ton

The loading factors were obtained from the *Emission Inventory Improvement Program, Open Burning, EPA 2001* [5]. Table 3.2.8.

Table 3.2.8 Loading Factors

Fuel Type	**Fuel loading [Ton/acre]**
Unspecified forest residues	**70**
Hardwood slash	66
Long-needle pine slash	21
Mixed conifer slash	54
Grassland	4.5

Unspecified forest residues fuel type was used on this study.

The emission factors were obtained from the *Emission Inventory Improvement Program, Open Burning, EPA 2001* [5]. Table 3.2.9.

Table 3.2.9 Emission Factors for Land Clearing Debris

Fuel Type	Material Burned	Pollutants, lb/ton						
		PM	PM10	PM2.5	CO	Methane	NMHC	NOX
Piled	Coniferous Slash	20.40		10.80	153.20	11.40	8.00	4.00
Piled	**Woody Debris**	**36.40**		**23.40**	**185.40**	**21.72**	**15.20**	**4.00**
Piled	Logging Slash	12.00	8.00	8.00	74.00	3.60		4.00
Broadcast	Logging Slash Hardwood	36.00	24.00	22.00	224.00	12.20	12.80	4.00
Broadcast	Logging Slash Conifer-Short Needle	34.00	26.00	24.00	350.00	11.20	7.00	4.00
Broadcast	Logging Slash Conifer-Long Needle	40.00	26.00	26.00	254.00	11.40	8.40	4.00
Unspecified	Forest Residues	16.00			140.00	5.60	18.00	4.00

Wood debris material burned was used on this study.

The total acres disturbed by construction are estimated by applying conversion factors to the available activity data for each category as follows:

3.2.4.1 Residential Construction

For residential construction, housing permit data for single-family units, two-family units, 3 and 4 family units, and 5 and more family units were obtained at the county level from the U.S. Department of Commerce's (DOC) Bureau of the Census [10]. Once the number of buildings in each category was estimated, the total acres disturbed by construction was calculated by applying conversion factors to the housing start data for each category as follow [8].

- ✓ Single-family : 1/4 acre/building
- ✓ Two-family : 1/3 acre/building
- ✓ 3 and 4 family : 1/2 acre/building
- ✓ 5 and more family : 1/2 acre/building

The 2007 building permits was estimated using the 2000-2007 population factor for each county estimated in table 3.2.10

Table. 3.2.10 2007 residential building permits.

Location	Singly Family	2 Family	3 or 4 Family	5 or more Family
Davidson	2,524	46	12	40
Rutherford	682	0	0	0
Sumner	899	0	2	0
Williamson	1,280	0	0	0
Wilson	805	7	10	3
Cheatham	202	3	0	5
Dickson	302	16	0	0
Robertson	633	0	1	2
Total	**7,326**	**72**	**24**	**51**

Thus, the acres of the 2007 residential construction were:

Table 3.2.11 Acres of the 2007 Residential Construction

County	Acres
Davidson	672
Rutherford	170
Sumner	226
Williamson	320
Wilson	210
Cheatham	54
Dickson	81
Robertson	160
Total	**1,893**

3.2.4.2 <u>Non-residential Construction</u>

Non-residential construction represents building construction, including commercial, institutional, industrial, government, and public works. The nationwide acres for non-residential construction was calculated using the value of construction put in place [11] multiplied by a conversion factor of 1.6 acres/10^6 dollars [8], see Table 3.2.12. The emissions were allocated to counties calculating an acres factor for non-residential and residential construction nationwide shown in table 3.2.12, and multiplying this factor by the acres due to residential construction for each county estimated as in letter (a). The 2007 acres were estimated using the 2000-2007 population factor for each county.

Table 3.2.12. Value of construction put in place and nationwide acres factor

Nationwide Non-Residential (million of dollars)	401,319
Acres/million dollars	1.6
Acres No-Residential US. Construction	642,110
Acres Residential US. Construction	491,511
Non-Residential - Residential Acres factor	1.31

Thus, the acres of the 2007 non-residential construction were:

Table 3.2.13 Acres of the 2007 Non-residential Construction

County	Acres
Davidson	878
Rutherford	223
Sumner	295
Williamson	418
Wilson	275
Cheatham	71
Dickson	105
Robertson	209
Total	**2,473**

3.2.4.3 <u>Road Construction</u>

The emissions produced by road construction were estimated using an emission factor for heavy construction and Tennessee capital outlay for new road construction [8]. To estimate the acres disturbed by road construction, Federal Highway Administration State expenditure data for capital outlay was obtained for the following six classifications [12]:

- ✓ Interstate, urban;
- ✓ Interstate, rural;
- ✓ Other principal arterial, urban;
- ✓ Other principal arterial, rural;
- ✓ Minor arterial, urban;
- ✓ Minor arterial, rural;
- ✓ Collector, urban; and
- ✓ Collector, rural.

For interstate expenditures, an average of $ 4 million/mile was assumed for freeways and interstate projects and for other arterial and collectors an average of $1.9 million/mile was assumed for all projects except freeways and interstate projects, next, miles were converted to acres using the following estimates of acres disturbed per mile [8].

- ✓ Interstate, urban and rural; Other arterial, urban : 15.2 acres/mile
- ✓ Other arterial, rural : 12.7 acres/mile
- ✓ Collectors, urban : 9.8 acres/mile
- ✓ Collectors, rural : 7.9 acres/mile

The emissions were allocated to counties using the VMT of 2000 and 2007 for each county and Tennessee [13], calculating a county-State factor for each year and multiplying this factor by the State acres of road construction.

Thus, the acres of the 2007 road construction were:

Table. 3.2. 14 Acres of the 2007 Road Construction

County	Acres
Davidson	386
Rutherford	212
Sumner	100
Williamson	105
Wilson	106
Cheatham	33
Dickson	41
Robertson	53
Total	**1,037**

Therefore, the total acres due to the construction land clearing were.

Table 3.2.15 Total Construction Land Clearing Acres

County	Acres
Davidson	1,936
Rutherford	605
Sumner	621
Williamson	843
Wilson	591
Cheatham	158
Dickson	227
Robertson	422
Total	**5,403**

Thus, the total emissions for Land Clearing Debris were.

Table 3.2.16 Land Clearing Debris Emissions

County	**PM2.5** (tons/day)	**CO** (tons/day)	**Methane** (tons/day)	**NMHC** (tons/day)	**NOX** (tons/day)
Davidson	4.3457	34.4311	4.0337	2.8228	0.7429
Rutherford	1.3570	10.7518	1.2596	0.8815	0.2320
Sumner	1.3928	11.0352	1.2928	0.9047	0.2381
Williamson	1.8911	14.9837	1.7554	1.2284	0.3233
Wilson	1.3263	10.5082	1.2311	0.8615	0.2267
Cheatham	0.3551	2.8138	0.3296	0.2307	0.0607
Dickson	0.5108	4.0472	0.4741	0.3318	0.0873
Robertson	0.9452	7.4887	0.8773	0.6140	0.1616
Total	**12.1240**	**96.0596**	**11.2536**	**7.8754**	**2.0725**

3.2.5 COST ESTIMATE

To estimate the costs, it was assumed $ 40/ton waste for construction and $ 20/month (pickup/disposal) for the total residential solid waste including yard, metals, and glass for a family of 4 persons [15,16]. The cost per ton of pollutants reduced by banning open burning of MSW is $1,300/ton. The cost per ton of pollutants reduced by banning the burning of brush from land clearing is $360/ton.

Table 3.2.17 MSW Pickup/Disposition Cost

County	$/day
Davidson	1,592
Rutherford	706
Sumner	437
Williamson	553
Wilson	426
Cheatham	1.591
Dickson	1,580
Robertson	1,647
Total	**8,532**

Table 3.2.18 Land Clearing Debris Disposition Cost

County	$/day
Davidson	14,852
Rutherford	4,641
Sumner	4,764
Williamson	6,467
Wilson	4,534
Cheatham	1,212
Dickson	1,741
Robertson	3,237
Total	**41,448**

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3.3 EFFECT OF A STRINGENT I/M PROGRAM ON ON-ROAD MOBILE SOURCE EMISSIONS

3.3.1. Introduction. As part of the Ozone Early Action Compact (EAC) program, the participating agencies need to identify potential emission reduction actions that might be used to meet the emissions budget for the year 2007. For the on-road mobile source sector, one of the options proposed is the enforcement of a stringent vehicle inspection and maintenance (I/M) program, including an anti-tampering program (ATP), in the Nashville EAC area. This section summarizes a possible combination of inspection programs that might be considered as a "stringent" I/M Program, the emission reductions that might be achieved in the year 2007 and the associated cost analysis.

3.3.2. Current I/M Program in the Nashville EAC area and its implications. Only five counties in the Nashville EAC area currently have an I/M program in place. They include Davidson, Rutherford, Sumner, Williamson and Wilson counties. The other three counties, namely, Cheatham, Dickson and Robertson do not have an I/M program. Although specific parameters of the I/M program may differ between the five counties to a certain extent, the basic type of inspection that is conducted at all these locations is an idle test. Based on calculations done by the University of Tennessee (Davis et al., 2002), it is shown that the implementation of an I/M program similar to that in place at Davidson County, would yield about a 6% reduction in NO_x emissions and a 22% reduction in VOC emissions in the year 2007, compared to a situation without an I/M program in place.

3.3.3. Proposed "Stringent" I/M Program. The on-road emission factor model, MOBILE6.2, was used to identify the emissions reductions associated with an I/M program. A series of MOBILE6.2 runs were done in an effort to determine the best option of a combination of evaporative and exhaust inspections that might be considered "stringent". All the MOBILE6.2 model runs were done for the analysis year 2007. A base-case run for each of these counties represented a scenario modeled in an earlier report to the Tennessee Department of Transportation (TDOT) (Davis et al., 2002). The base case consisted of runs with assumptions and programs currently projected to be in place in 2007. The combination of I/M and ATP tests that is proposed will be referred to as the "stringent I/M" in further discussions in this report. Table 3.3.1 lists the input parameters that were used in the model runs.

The proposed stringent I/M program consists of a combination of the exhaust and evaporative inspections. It is assumed that these programs would begin in the year 2004 and would be a "test-only" program. The exhaust I/M program consists of an enhanced I/M program, namely the IM240, applied to all light duty gasoline vehicles and the lightest category of heavy duty (HDGV2B) gasoline vehicles for model years older than 1996. The cutpoints which determine whether a vehicle has passed or failed the IM240 test is shown in Table 3.3.1. Since the on-board diagnostics (OBD) were supposed to be on all light duty gasoline vehicles and trucks for model years 1996 and newer, and on all heavy duty gasoline vehicles for model years 2007 and newer, those vehicles which are 1996 and newer would be subjected to an OBD I/M program. Since OBD would be present in HDGV only after 2006, the HDGV2B would be subjected to IM240 program for model years 1996 -2006. In this stringent I/M program, the 1996 and newer vehicles for LDGV and LDGT, and 2007 and newer for HDGV2B, are not subject to IM240, because it is hoped that the OBD inspection would "catch" any problem with the vehicle and would be a more simplistic and an efficient way of inspection. The evaporative I/M program consists of a fill-pipe pressure (FP) test, gas cap (GC) inspection and an evaporative OBD check. The FP and GC tests would be applied to all gasoline vehicles for model years prior to 1996. LDGV and LDGT of model years 1996 and later, and HDGV2B of model years 2007 and later would be subjected to OBD and GC tests. Due to the limitation of the maximum number of I/M programs that can be modeled simultaneously in MOBILE6.2, the effect of GC inspections on HDGV2B of model years 1996-2006 could not be modeled. However, it is felt that this effect would be negligible on VOC emissions, and none on CO and NO_x emissions, and hence would not be a major concern for evaluation purposes. The proposed anti-tampering program would consist of an annual inspection and would cover all the available inspections, so as to estimate the maximum reductions that are likely to be achieved.

3.3.4. Implications of Stringent I/M Program – Emissions Reduction and Cost Analysis.

Emissions Reduction: The MOBILE6.2 model lists the emission factors in terms of grams of pollutant per vehicle mile traveled. The model results are shown in Table 3.3.2. The results clearly indicate that the implementation of the proposed stringent I/M program would provide a reduction of about 4 to 6% in NO_x and about 25% in VOC emissions for those counties that do not have an I/M and a reduction of about 1 to 2% in NOx and about 4 to 7% in VOC emissions for those counties that already have an I/M program planned for 2007.

Emissions calculations conducted for Davidson County as per current projections (Davis et al., 2002) provide an overview of the nature of reductions that might be expected over the next 30 years. Figures 3.3.1 and 3.3.2 illustrate this concept. It is evident that the emissions from on-road mobile sources continue to decrease until about 2025. It is also clear that, although the emissions reduction from implementation of the I/M is only about 6% in NO_x and about 22% in VOC in the year 2007, the emissions reduction estimated to be achieved by the year 2030 is far greater (42% in NO_x and 39% in VOC).

Among the counties that currently have I/M programs, Davidson County has the least emission reduction, probably due to the fact that their currently planned I/M program already has a higher compliance rate and lower waiver rate relative to the other four counties. Hence, the benefit that is projected for Davidson County (4.4% reduction in VOC and 1.2% reduction in NOx) may be considered to be primarily due to shifting to an IM240 program and inclusion of additional tests in the ATP.

Table 3.3.1. Input Parameters used in MOBILE6.2 model runs

Parameter	**Value**
Analysis Year	2007
Min/Max Temperature (deg F)	66/93
Evaluation Month	7
Fuel RVP (psi)	7.8 with I/M
Proposed I/M Vehicles subject to I/M & ATP	IM-240 LDGV, LDGT1234, HDGV2B
I/M Stringency for pre-1981 model years	50%
I/M & ATP Compliance	100%
Exemption Age	25 years (MOBILE6 default)
Grace Period	1 year (MOBILE6 default)
Cut Points for IM240 inspection (g/mi)	HC:0.8, CO:15, NO_x:2
I/M Waiver Rates	0% waiver for both, pre and post 1981 model years.
ATP start model year	1975
ATP final model year	2030
ATP inspections	Check air pump system disablement, catalyst removal, fuel inlet restrictor disablement, tailpipe lead deposit test, EGR disablement, evaporative system disablement, PCV system disablement, missing gas cap
Current Davidson County I/M Program	Idle Test for model years until 1995 and exhaust OBD test since 2002, for model years 1996 and later. Evaporative OBD and GC since 2002. Stringency of 30%, Compliance of 98% and waiver rate of 0%. Applied to LDGV and LDGT1234.
Current I/M in other 4 counties	Idle Test for model years until 1995 and exhaust OBD test since 2002, for model years 1996 and later. Evaporative OBD and GC since 2002. Stringency of 30%, Compliance of 95% and waiver rate of 5%. Applied to LDGV and LDGT1234.
Current ATP	ATP starting with 1975 model year, compliance rate same as I/M compliance, applied to LDGV and LDGT1234, check for catalyst removal, fuel inlet restrictor disablement and missing gas cap.

Table 3.3.2. Model Results – Effect of Stringent I/M and ATP on Emissions

County	Pollutant	Currently Projected 2007 As Is	Proposed measure - Stringent I/M	Reduction in Emissions	% Reduction
		tons/day	tons/day	tons/day	%
Cheatham	VOC	2.3850	1.7848	0.60	25.17
	CO	26.9108	19.4924	7.42	27.57
	NOx	5.8989	5.5854	0.31	5.31
	PM2.5	0.0879	0.0879	0.00	0.00
Davidson	VOC	21.5991	20.6484	0.95	4.40
	CO	267.4346	257.8859	9.55	3.57
	NOx	51.3587	50.7060	0.65	1.27
	PM2.5	0.9802	0.9802	0.00	0.00
Dickson	VOC	3.1123	2.3072	0.81	25.87
	CO	32.8449	23.5806	9.26	28.21
	NOx	6.1493	5.7471	0.40	6.54
	PM2.5	0.0929	0.0929	0.00	0.00
Robertson	VOC	3.2460	2.4334	0.81	25.03
	CO	42.9107	31.8856	11.03	25.69
	NOx	11.8118	11.3441	0.47	3.96
	PM2.5	0.1827	0.1827	0.00	0.00
Rutherford	VOC	5.8931	5.4902	0.40	6.84
	CO	72.3532	67.7445	4.61	6.37
	NOx	17.0421	16.7446	0.30	1.75
	PM2.5	0.3032	0.3032	0.00	0.00
Sumner	VOC	3.5852	3.3349	0.25	6.98
	CO	41.4465	38.7481	2.70	6.51
	NOx	8.4199	8.2416	0.18	2.12
	PM2.5	0.1656	0.1656	0.00	0.00
Williamson	VOC	4.0352	3.7575	0.28	6.88
	CO	51.0871	47.8719	3.22	6.29
	NOx	10.8111	10.6056	0.21	1.90
	PM2.5	0.1917	0.1917	0.00	0.00
Wilson	VOC	3.4038	3.1744	0.23	6.74
	CO	43.0598	40.3470	2.71	6.30
	NOx	10.8164	10.6457	0.17	1.58
	PM2.5	0.1942	0.1942	0.00	0.00

It is evident that the emission reduction achieved from the proposed stringent I/M program is not far greater than that obtained through the basic I/M program (idle test and OBD) in Davidson County, realizing that differences in input parameters do exist. Discussions with personnel at the I/M testing stations also indicate that the basic I/M program may produce results as good as the enhanced I/M (IM240) program, based on their experience with emissions testing at different locations in the US. Hence, an IM240 program may not necessarily produce much more emission reduction than that seen with a basic I/M program.

Cost Analysis: A simple cost analysis was done to evaluate the cost involved per ton of pollutant reduction. Supporting information for cost analysis was obtained from the article by Harrington et al. (1999). The article described the enhanced I/M program in Arizona and provided information on the failure rate and the costs associated with testing and repair, which were used as starting values for the cost analysis in this section. Table 3.3.3 shows the failure rate and the repair costs recorded in the IM240 program in Arizona. (Harrington et al., 1999).

Since the reported costs and inspection failure rates varied by model year, a weighted mean repair cost ($123) and a weighted mean stringency (26%) was calculated as shown in the table. The inspection cost in Arizona during 1995-1996 was $16.75. These costs were adjusted to a 2002 dollar value based on the conversion factors reported by Robert Sahr (2003). On conversion, the inspection cost and the mean repair cost evaluated to $19.21 and $141.08 respectively. This calculation used an inspection cost of $20 per vehicle and a mean repair cost of $145. The mean repair cost when multiplied by the failure rate (number of vehicles that failed the test/total number of vehicles that went through the test) resulted in the repair cost per vehicle tested. Based on these values, the total cost per vehicle tested is $57.70. These are tabulated in Table 3.3.4.

The cost per ton of pollutant reduced was calculated collectively for all the counties in the Nashville EAC area. The cost per vehicle was multiplied by an estimated number of vehicles in the EAC area to arrive at a total cost for the whole Nashville EAC area. The number of LDV and LDT were calculated from the 2000 registration data obtained from the Tennessee Department of Safety, Title and Registration Division. The 2000 vehicle counts were grown to the year 2007 using a growth rate of 6% between 2000 and 2007 following the population growth for the same time period Use the default ratio of the HDV2B to all light duty vehicles (EPA, 1999) of 0.038, the 2007 HDGV2B vehicle counts were determined. Once the total number of vehicles in the Nashville EAC area was estimated, the total cost for the I/M program was determined. The estimation of vehicle counts is shown in Table 3.3.5.

Arizona's I/M program experienced a waiver rate of about 4%. The assumed I/M program uses a 0% waiver rate and includes HDGV2B, while the Arizona I/M program didn't. Although the assumed I/M program is not exactly comparable to the Arizona I/M program, it could be used to give an idea of the cost that might be involved in the I/M program, given the fact that limited cost data are available.

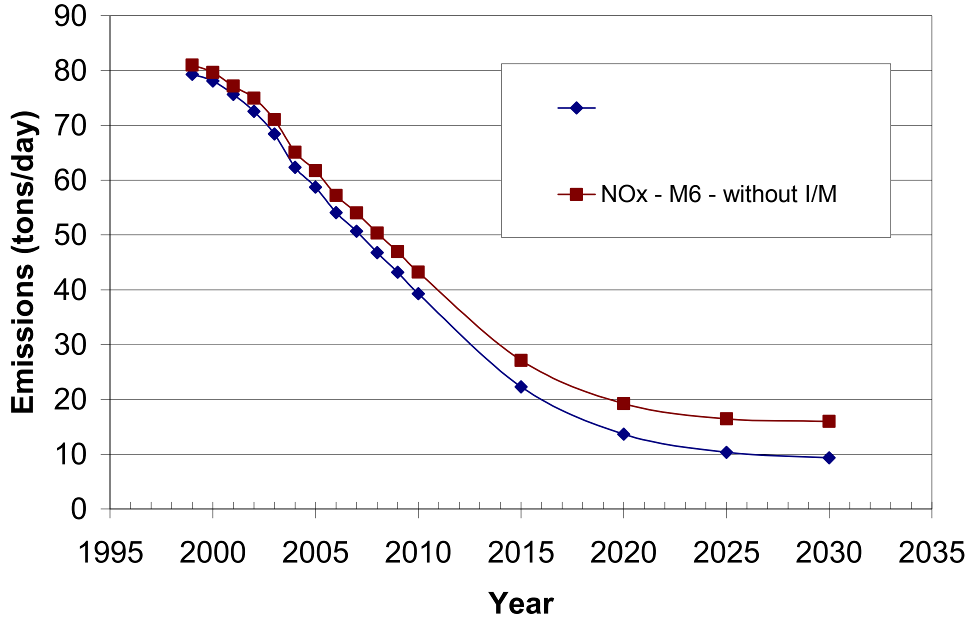

Figure 3.3.1. Davidson County - NO_x Emissions with and without I/M Program

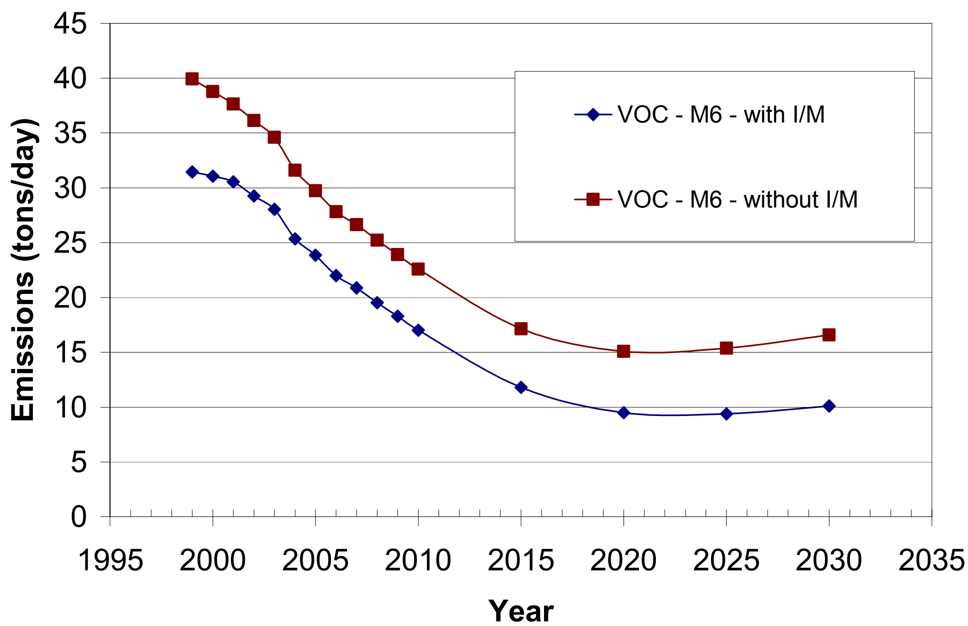

Figure 3.3.2. Davidson County - VOC Emissions with and without I/M Program

Table 3.3.3. Failure Rates and Mean Repair Costs in Arizona's IM240 Program

	Model Year	**Number of Vehicles**	**Mean Repair Costs***	**Failure Rate**	**No. Veh * Mean Repair Cost**	**No. Veh * Failure Rate**
Cars	81-82	10,320	123	50	1,269,360	516,000
	83-85	24,067	135	38	3,249,045	914,546
	86-88	14,696	128	17	1,881,088	249,832
	89-90	4,121	120	7	494,520	28,847
	91-92	3,254	128	5	416,512	16,270
	93-95	1,101	72	1	79,272	1,101
Trucks less than 6000 lbs	81-82	2,458	67	26	164,686	63,908
	83-85	4,855	113	26	548,615	126,230
	86-88	3,442	100	15	344,200	51,630
	89-90	4,691	129	10	605,139	46,910
	91-92	2,061	124	8	255,564	16,488
	93-95	1,184	114	2	134,976	2,368
Trucks greater than 6000 lbs	81-82	1,252	77	40	96,404	50,080
	83-85	1,863	121	33	225,423	61,479
	86-88	1,422	120	21	170,640	29,862
	89-90	1,106	113	9	124,978	9,954
	91-92	568	122	10	69,296	5,680
	93-95	325	76	3	24,700	975
Sum =		82,786			10,154,418	2,192,160
					Weighted Mean Repair Cost =	*Weighted Mean Stringency (%)=*
Weighted Average =					$123	26

* Mean Repair Costs include actual reported costs plus estimated costs when repairs were done but zero cost reported.

Hence, the cost per ton estimated using data from Harrington et al. (1999) might be considered as the lower end of the cost. The ton/day emission reduction and the associated cost are summarized in Tables 3.3.6 and 3.3.7 respectively. The costs shown in Table 3.3.7 reflect the cost of an I/M program as a whole and not just the incremental I/M improvement cost. That is, for those counties that already have an I/M program, the costs calculated would reflect the cost of implementing the "stringent I/M" program versus no I/M program and not just the incremental cost of upgrading from current I/M to the "stringent I/M". Based on the calculations, the cost of implementing a stringent I/M program is around $19,500/ton of NOx. When looking at the cost effectiveness collectively for all pollutants, the cost per ton of all pollutants reduced is estimated to be around $980.

Table 3.3.4. Cost Estimate Per Vehicle

	From Arizona Document	Conversion factor to convert 1996 dollars to 2002 dollars	Dollars in 2002	Value Used in this calculation
Inspection Cost per vehicle[1]	$ 16.75	1.147	$ 19.21	$ 20.00
Mean Repair Costs[2]	$ 123.00	1.147	$ 141.08	$ 145.00
Assumed Stringency	26.00%			26%
Mean Repair Costs per vehicle = Stringency*Repair cost				$ 37.70
Total cost per vehicle				$ 57.70

1. Inspection cost does not include waiting and travel time costs

2. Mean Repair Costs include imputed costs (Costs estimated when the vehicle showed repairs, but didn't report any cost)

Table 3.3.5. Projected 2007 Vehicle Counts in Nashville EAC Area

County	Vehicle Counts based on 2000 reg data		Projected 2007 Vehicle Counts		Estimated HDGV2B counts	Total 2007 vehicles
	LDV	LDT	2007 LDV	2007 LDT	2007 HDGV2B	
Davidson	291,343	105,047	308,824	111,350	15967	436,140
Rutherford	61,522	36,022	65,213	38,183	3929	107,326
Sumner	52,330	32,921	55,470	34,896	3434	93,800
Williamson	59,811	31,529	63,400	33,421	3679	100,500
Wilson	36,021	25,447	38,182	26,974	2476	67,632
Cheatham	14,937	12,918	15,833	13,693	1122	30,648
Dickson	17,994	15,123	19,074	16,030	1334	36,438
Robertson	22,079	16,911	23,404	17,926	1571	42,900

2007 LDV, LDT = 1.06 * 2000 counts
1.06 based on population growth from 2000 to 2007 for those counties
2007 HDGV2B = 0.038 *(LDV+LDT)
0.038 based on ratio of projected vehicle counts in 2007 as in Mobile6 report M6.FLT.007

Table 3.3.6. Emission Reductions Achievable by Implementation of Stringent I/M

County	NOx tons/day	VOC tons/day	CO tons/day	PM2.5 tons/day
Davidson	0.65	0.95	9.55	0.00
Rutherford	0.30	0.40	4.61	0.00
Sumner	0.18	0.25	2.70	0.00
Williamson	0.21	0.28	3.22	0.00
Wilson	0.17	0.23	2.71	0.00
Cheatham	0.31	0.60	7.42	0.00
Dickson	0.40	0.81	9.26	0.00
Robertson	0.47	0.81	11.03	0.00
Total	2.69	4.33	50.49	0.00

Table 3.3.7. Estimated Cost of Emission Reductions by Implementation of Stringent I/M

	NOx $/ton	VOC $/ton	CO $/ton	PM2.5 $/ton	Combined $/ton
Nashville EAC area – all 8 counties	19,500	15,800	1,100	n/a	980

3.3.5. Conclusions. Although the cost per ton of NO_x reduced seems prohibitive, this might be an option worth pursuing due to the facts noted below:

- This option reduces emissions of other pollutants in addition to just NO_x.
- Implementation of I/M program promises a far greater reduction in the emissions compared to a case with no I/M program, as shown by Figures 3.3.1 and 3.3.2.

For those locations that already have a basic I/M program and choose to upgrade to the proposed stringent I/M program, the percent reduction gained may not be significant. The costs shown are for the scenario of I/M program versus no I/M program. The incremental cost of upgrading to the stringent I/M may be higher than shown.

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1. W.T. Davis, T.L. Miller, G.D. Reed, A.M.Y. Tang, P. Doraiswamy and P.Sanhueza, Effects of Growth in VMT and New Mobile Source Emission Standards on NO_x and VOC Emissions in Tennessee, 1999-2030 (Based on MOBILE6-Final Version), Report submitted to the Tennessee Department of Transportation, March 14, 2002.

2. Winston Harrington, Virginia McConnell and Amy Ando, "The Enhanced I/M Program in Arizona: Costs, Effectiveness, and a Comparison with Pre-regulatory Estimates", Discussion Paper 99-37, *Resources For the Future*, Washington DC, June 1999. Obtained from the internet at http://www.rff.org/environment/air.htm, accessed March 20th, 2003.

3. Robert C. Sahr, Consumer Price Index (CPI) *Conversion Factors 1800 to estimated 2013 to Convert to Dollars of 2002*, Oregon State University, OR. Feb 2003. Obtained from the internet at http://oregonstate.edu/Dept/pol_sci/fac/sahr/sahr.htm, accessed March 20th, 2003.

4. EPA, Fleet Characterization Data for MOBILE6: Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates and Projected Vehicle Counts for Use in MOBILE6, EPA420-P-99-011, M6.FLT.007, April 1999

3.4 EFFECT OF LOWERING REID VAPOR PRESSURE OF GASOLINE

3.4.1. Introduction. The Reid vapor pressure (RVP) of gasoline is indicative of the volatility of the fuel. The higher the RVP, the greater is the volatility. A reduction in the fuel RVP would reduce its volatility, resulting primarily in lower evaporative VOC emissions. This section summarizes the effects of reducing the fuel RVP to 7.0 psi in the year 2007 and the associated emissions reductions that can be achieved in the Nashville EAC area.

3.4.2. Current Fuel RVP Requirements in the Nashville EAC Area. The fuel RVP requirements in an area is specified by the ASTM guidance (D 4814 – 96: Standard Specification for Automotive Spark-Ignition Engine Fuel) which incorporates the US EPA fuel volatility regulations. The five counties in the Nashville EAC area that currently have an I/M program in place, namely, Davidson, Rutherford, Sumner, Williamson and Wilson counties use fuel with an RVP of 7.8 psi in the ozone season, while the other three counties (Cheatham, Dickson and Robertson) use fuel with an RVP of 9.0 psi.

3.4.3. Lower Fuel RVP – Effect on Emissions and Associated Cost Analysis.
Emission Reduction: The on-road emission factor model, MOBILE6.2, was used to identify emissions reductions associated with lowering the fuel RVP. The MOBILE6.2 runs were done with an RVP of 7.0 psi for the ozone season for the analysis year 2007. A base case run represented a scenario with currently projected fuel programs as modeled in the TDOT report (Davis et al., 2002).

Table 3.4.1 shows the emissions in tons/day for the base case and for the scenario when the fuel RVP is lowered to 7.0 psi. For those counties that use a fuel with 7.8 psi RVP, lowering the RVP to 7.0 psi showed an estimated reduction of about 5.8 % in VOC emissions with a negligible effect on other pollutants. For those counties that use a 9.0 RVP fuel, lowering the RVP to 7.0 psi showed about 14% reduction in VOC emissions, around 6% reduction in CO emissions, and a negligible effect on other pollutants.

Cost Analysis: EPA has estimated that the implementation of low RVP gasoline would result in a cost increase of about \$0.01 to \$0.02 per gallon when compared to the conventional gasoline (Korotney, 1996). Based on gasoline tax revenue data for the state of TN, an average gasoline consumption for the state of TN was estimated. The statewide gasoline consumption was apportioned to each of the 8 counties based on the ratio of the respective county DVMT to the statewide DVMT. The DVMT values used were the projected 2007 DVMT values (Davis et al., 2002). These calculations are shown in Tables 3.4.2 through 3.4.4.

Table 3.4.1. Model Results and Emissions Reduction due to Lower RVP

County	Pollutant	Currently Projected 2007 As Is	Proposed measure - 2007 - RVP 7.0	Reduction in Emissions	% Reduction
		tons/day	tons/day	tons/day	%
Cheatham	VOC	2.3850	2.0515	0.33	13.98
	CO	26.9108	25.3226	1.59	5.90
	NOx	5.8989	5.8821	0.02	0.28
	PM2.5	0.0879	0.0879	0.00	0.00
Davidson	VOC	21.5991	20.3373	1.26	5.84
	CO	267.4346	267.3916	0.04	0.02
	NOx	51.3587	51.2926	0.07	0.13
	PM2.5	0.9802	0.9802	0.00	0.00
Dickson	VOC	3.1123	2.6597	0.45	14.54
	CO	32.8449	30.8901	1.95	5.95
	NOx	6.1493	6.1263	0.02	0.37
	PM2.5	0.0929	0.0929	0.00	0.00
Robertson	VOC	3.2460	2.8174	0.43	13.20
	CO	42.9107	40.4042	2.51	5.84
	NOx	11.8118	11.7862	0.03	0.22
	PM2.5	0.1827	0.1827	0.00	0.00
Rutherford	VOC	5.8931	5.5535	0.34	5.76
	CO	72.3532	72.3356	0.02	0.02
	NOx	17.0421	17.0253	0.02	0.10
	PM2.5	0.3032	0.3032	0.00	0.00
Sumner	VOC	3.5852	3.3714	0.21	5.96
	CO	41.4465	41.4394	0.01	0.02
	NOx	8.4199	8.4096	0.01	0.12
	PM2.5	0.1656	0.1656	0.00	0.00
Williamson	VOC	4.0352	3.8043	0.23	5.72
	CO	51.0871	51.0772	0.01	0.02
	NOx	10.8111	10.7986	0.01	0.12
	PM2.5	0.1917	0.1917	0.00	0.00
Wilson	VOC	3.4038	3.2122	0.19	5.63
	CO	43.0598	43.0501	0.01	0.02
	NOx	10.8164	10.8063	0.01	0.09
	PM2.5	0.1942	0.1942	0.00	0.00

Table 3.4.2. Gasoline Consumption in TN during the summer season (June-August)

	Gasoline Tax Rate	Gasoline Tax Collected for the month	Gasoline Consumption
	$/gal	$/month	Million gal/day
June	0.20	54,279,852	9.05
July	0.20	50,299,055	8.11
August	0.20	54,178,751	8.74
3-month Average	0.20	52,919,219	8.63

Source: TN Department of Revenue, Tax collections and Statistics, 2002. http://www.state.tn.us/revenue/collections/index.htm, 2003.

Table 3.4.3. Ratio of Countywide DVMT to Statewide DVMT

County	2007 Projected DVMT	Ratio
	miles/day	
Tennesee	225,137,190	
Davidson	26,366,179	0.1171
Rutherford	7,376,382	0.0328
Sumner	4,409,238	0.0196
Williamson	5,088,076	0.0226
Wilson	4,335,843	0.0193
Cheatham	1,552,713	0.0069
Dickson	1,935,542	0.0086
Robertson	2,989,960	0.0133

Table 3.4.4. Estimated Cost Increase Due to Switching to Low RVP Fuel

County	Gasoline Consumption	Cost Increase
	million gal/day	$/day
Davidson	1.01	20,220
Rutherford	0.28	5,657
Sumner	0.17	3,381
Williamson	0.20	3,902
Wilson	0.17	3,325
Cheatham	0.06	1,191
Dickson	0.07	1,484
Robertson	0.11	2,293
Total	2.07	41,453

Table 3.4.5. Emission Reductions Achievable by Lowering Fuel RVP to 7.0 psi

County	NOx tons/day	VOC tons/day	CO tons/day	PM2.5 tons/day
Davidson	0.07	1.26	0.04	0.00
Rutherford	0.02	0.34	0.02	0.00
Sumner	0.01	0.21	0.01	0.00
Williamson	0.01	0.23	0.01	0.00
Wilson	0.01	0.19	0.01	0.00
Cheatham	0.02	0.33	1.59	0.00
Dickson	0.02	0.45	1.95	0.00
Robertson	0.03	0.43	2.51	0.00
Total	0.18	3.45	6.14	0.00

Table 3.4.6. Estimated Cost of Emission Reductions by Lowering Fuel RVP to 7.0 psi

	NOx $/ton	VOC $/ton	CO $/ton	PM2.5 $/ton	Combined $/ton
Nashville EAC area – all 8 counties	230,000	12,000	6,800	n/a	4,300

The cost calculations assume a cost increase of 2 cents per gallon of fuel. The calculated costs represent the increase in cost involved in switching to lower RVP gasoline. The calculations do not make a distinction in the assumed cost increase between those counties that have a 7.8 psi fuel and those that use 9.0 psi fuel.

Table 3.4.5 summarizes the ton/day reduction that might be achieved in each of those counties in the Nashville EAC area by lowering the fuel RVP to 7.0 psi. Table 3.4.6 lists the cost per ton of pollutant reduced.

3.4.4. Conclusions. Lowering the fuel RVP to 7.0 psi targets primarily VOC emissions. As shown above, the percent reduction obtained through use of a lower RVP fuel depends on the current fuel RVP. For those counties that use a 9.0 psi fuel, the percent reductions are substantial for VOC emissions. The use of a lower RVP fuel does not result in significant reductions in NOx emissions. The model also does not show any effect on particulate emissions.

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3.5 EFFECT OF SMOKING VEHICLE BAN

3.5.1. Introduction. High-emitting vehicles or smoking vehicles are those vehicles that have excessive emissions with a visible smoke. The exact definition of a smoking vehicle varies between different studies. This section summarizes the possible emissions reduction that might be achieved by imposing a ban on operation of smoking vehicles in the Nashville EAC area.

3.5.2. Emissions From Smoking Vehicles. The emission factor for smoking light duty vehicles and trucks was obtained from section 3.2 of the technical documentation for the EMFAC2000 model (EMFAC2000, 2001). The reference shows plots of emission factors predicted by the EMFAC2000 model as a function of vehicle model year for hydrocarbons, NOx and CO. The emission factors for purposes of this analysis were chosen by extending the flat portion of the curve towards the old model year vehicles. For PM2.5, the emission factor was chosen from a research article (Durbin et al., 1999). The article by Durbin et al., reports a study done at California on the measurement of emissions from smoking vehicles. The study shows emission factors obtained from two different test procedures for non-methane hydrocarbons (NMHC), NOx, CO and PM. The average emission factor chosen for this analysis for VOC and CO fall in the range reported by Durbin et al. The emission factor for NOx, however, is twice that reported by Durbin et al. The following are the emission factors that were used in this analysis: 3.9 g/mile for NOx, 4.8 g/mile for VOC, 52 g/mile for CO, and 0.4 g/mile for PM (93.4% is less than 2.5 microns on average, as per Durbin et al). Since no data was found for heavy duty gasoline vehicles, it was assumed that the emissions from a smoking heavy duty gasoline vehicle would be twice that of the smoking light duty vehicle.

It was assumed that a typical smoking vehicle would drive about 40 miles per day. Based on data obtained from Davidson County (Higgins, 2003), on average, 160 vehicles are cited each year for excessive smoking exhaust in Davidson County and that about 50% of those are heavy duty gasoline vehicles. For the other counties in the Nashville EAC area, the number of smoking vehicles was estimated based on the ratio of population data for that county to the population in Davidson County projected for the year 2007.

Based on the calculations, it is estimated that the effect of banning smoking vehicles may have negligible effect on emissions of the pollutants considered. A reduction of about 1 ton/day is estimated for CO, while being negligible for NOx. This is probably because the percent of smoking vehicles considered is very small.

Tables 3.5.1 and 3.5.2 tabulate the emission factor and the assumptions used. Table 3.5.3 summarizes the emissions associated with smoking vehicles in the Nashville EAC area. These emissions associated with smoking vehicles would be the emission reduction that would be obtained by imposing a ban on smoking vehicles.

Table 3.5.1. Smoking Vehicle Emission Factor and Assumptions

Pollutant	LDV Emission Factor	Source of EF	Assumed Travel	LDV + HDGV emissions*	# smoking vehicles in Davidson Co**
	g/mile/vehicle		miles/day	ton/day/veh	#/yr
NOx	3.9	EMFAC document	40	0.00052	160
VOC	4.8	EMFAC document	40	0.00063	160
CO	52	EMFAC document	40	0.0069	160
PM2.5	0.37	J.AWMA, v49	40	0.000049	160

* HDGV Emission Factor = 2*LDV Emission Factor; Hence, LDV+HDGV emission factor = 3*LDV emission factor
** 50% of vehicles are light duty and 50% are heavy duty gasoline vehicles

Table 3.5.2. Estimate of Smoking Vehicles in the Nashville EAC Area

County	Population, 2007 projection	Ratio to Davidson Co Population	Estimated # smoking vehicles (veh/yr)
Davidson Co	605,323	1.00	160
Rutherford	193,340	0.32	51
Sumner	138,559	0.23	37
Williamson	134,511	0.22	36
Wilson	94,330	0.16	25
Cheatham	38,145	0.06	10
Dickson	45,839	0.08	12
Robertson	57,817	0.10	15
Total			346

Table 3.5.3. Emission Reductions Achievable by Banning Smoking Vehicles

County	LDGV, LDGT & HDGV			
	NOx	VOC	CO	PM2.5
	tons/day	tons/day	tons/day	tons/day
Davidson Co	0.04	0.05	0.55	0.00
Rutherford	0.01	0.02	0.18	0.00
Sumner	0.01	0.01	0.13	0.00
Williamson	0.01	0.01	0.12	0.00
Wilson	0.01	0.01	0.09	0.00
Cheatham	0.00	0.00	0.03	0.00
Dickson	0.00	0.00	0.04	0.00
Robertson	0.00	0.00	0.05	0.00
Total	0.09	0.11	1.19	0.01

<u>3.5.3. Conclusions</u>. Although smoking vehicles emit excessive amounts, their contribution to the overall emissions is negligible due to their extremely small fraction in the vehicle population. Imposing a ban on smoking light duty and heavy duty gasoline vehicles would render less than one-tenths of a ton per day reduction on NOx.

REFERENCES

1. EMFAC2000 Technical Support Documentation, Section 3.2, "High Emitter Correction Factors", California Air Resources Board, Feb 6, 2001. Obtained from the internet at http://www.arb.ca.gov/msei/on-road/downloads/tsd/High_Emitters.pdf, accessed on Aug 28, 2003.

2. Durbin, Thomas D., Smith, Matthew R., Norbeck, Joseph M. and Truex, Timothy J., "Population Density, Particulate Emission Characterization and Impact on the Particulate Inventory of Smoking Vehicles in the South Coast Air Quality Management District", *J. Air & Waste Management Association*, Volume 49, pp 28-38, Jan 1999.

3. Huggins, Fred, Personal Communications, Jul 2003.

3.6 EFFECT OF A STAGE I VAPOR CONTROL

3.6.1 Introduction. Stage I vapor control is a vapor balance system designed to reduce VOC emissions from underground tank filling operations at service stations. The vapor balance system employs a hose that returns gasoline vapors displaced from the underground tank to the tank truck cargo compartments being emptied. The implementation of Stage I control in those areas that do not currently have Stage I control will result in reduced VOC emissions. This section summarizes the reductions that might be achieved through Stage I control in Cheatham, Dickson and Robertson counties.

3.6.2 Stage I Controls – Calculations. The methodology used for estimating gasoline distributed in Tennessee was based on Tennessee gasoline sales tax data. Countywide estimates could then be made by apportioning the statewide total by the ratio of countywide VMT to statewide VMT.

First, the gasoline tax rate was multiplied by gasoline tax collected to obtain Tennessee daily gasoline consumption amounts during June-August 2002, as shown in table 3.6.1. The gasoline tax rate and the amount of gasoline tax collected were obtained from *Tennessee Department of Revenue* [1].

Table 3.6.1: Daily gasoline consumption in Tennessee during June-August 2002

	Gasoline Tax Rate ($/gal)	Gasoline Tax Collected ($/day)	Gasoline Consumption (million gal/day)
June	0.2	1.81	9.05
July	0.2	1.62	8.11
August	0.2	1.75	8.74
3-month Average	0.2	1.73	8.63

$ millions

Next, using the daily VMT data for the year 2002 from *Tennessee Department of Transportation* [2], the ratios of countywide daily VMT to Tennessee daily VMT were calculated as shown in table 3.6.2.

Table 3.6.2: Ratio of countywide daily VMT and Tennessee daily VMT for 2002

	Daily VMT_{2002} (million mile)	Ratio
Tennesee	187.17	1.0000
Cheatham	1.22	0.0065
Dickson	1.67	0.0089
Robertson	2.39	0.0128

In the next step, the countywide daily VOC emissions were calculated by multiplying the county ratio by Tennessee's 3-month average gasoline consumption and the emission factor, obtained from *AP-42, EPA 1995* [3]. The results are shown in table 3.6.3.

	Gasoline Consumption (million gal/day)	Emission Factor (lb/1000 gal)	VOC emission (ton/day)
Cheatham	0.06	11.5	0.32
Dickson	0.08	11.5	0.44
Robertson	0.11	11.5	0.63
Total	0.24	11.5	1.40

The potential reductions in countywide VOC emissions as a result of Stage I vapor control were then calculated and shown in table 3.6.4, using 93% control efficiency obtained from *AP-42, EPA 1995* [3].

Table 3.6.4: Countywide daily VOC emission during June-August 2002 with Stage I Control

	Control Efficiency (%)	Reduction in VOC (ton/day)	Uncontrolled VOC (ton/day)
Cheatham	93	0.30	0.02
Dickson	93	0.41	0.03
Robertson	93	0.59	0.04
Total	93	1.30	0.10

The estimated costs of emission reductions achieved by implementation of Stage I controls were estimated as shown in table 3.6.5. An example calculation is shown below:

Assumptions:
Underground tank volume = 10,000 gal/tank
Stage I control cost = 400 $/tank
Tanks are refilled every 3 weeks
Tank life = 20 years

Example calculation:

Estimated number of tanks in Cheatham	=	60000 gal/day * 3 week * 7 days/week * 1 tank/10000 gal
	=	126 tanks
Stage I control cost for Cheatham	=	[126 tanks * 400 $/tank] / [365 days/year 20 years] / [0.30 tons/day]
	=	23.0 $/ton of VOC

Table 3.6.5 Estimated Cost of Emission Reductions by Stage I Control

County		NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
Cheatham		-	23.0	-	-	23.0
Dickson		-	22.5	-	-	22.5
Robertson		-	21.5	-	-	21.5
3 Counties Avg		-	22.3	-	-	22.3

<u>3.6.3 Conclusions</u>. Implementation of Stage I control targets only the VOC emissions in Cheatham, Dickson and Robertson. As shown in table below, the potential reductions in VOC emissions, obtained through Stage I control alone, are about 0.30, 0.41 and 0.59 for Cheatham, Dickson and Robertson, respectively. There is no significant reduction in NO_x, CO and $PM_{2.5}$ as a result of Stage I control.

Table 3.6.6 Emission Reductions Achievable by Stage I Control

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	-	-	-	-
Rutherford	-	-	-	-
Sumner	-	-	-	-
Williamson	-	-	-	-
Wilson	-	-	-	-
Cheatham	-	0.30	-	-
Dickson	-	0.41	-	-
Robertson	-	0.59	-	-
Total	-	1.30	-	-

Reference

1. TN Department of Revenue, Tax collections and Statistics, 2002. http://www.state.tn.us/revenue/collections/index.htm, 2003.

2. TN Department of Transportation, Vehicle miles of travel by counties, 2002.

3. U.S. Environmental Protection Agency, AP-42, 5th edition, Volume I: Chapter 5; Petroleum industry, January 1995.

3.7 EFFECT OF LOWER SPEED LIMITS ON RURAL INTERSTATES

3.7.1. Introduction. The emissions from on-road mobile sources vary greatly as a function of speed. The NOx emissions are lowest around 35 mph and increase for both lower and higher average speeds. The VOC emissions, on the other hand, decrease with increase in speed. The draft EAC report by Davis et al. (Davis et al., 2003) presented a table of emission factors as a function of speed. This section summarizes the effects of lowering the speed limit for all vehicles on rural interstates by 10 mph in the year 2007 and the associated emissions reductions that can be achieved in the Nashville EAC area.

3.7.2. Lower Speed Limit on Rural Interstates – Effect on Emissions. The on-road emission factor model, MOBILE6.2, was used to identify emissions reductions associated with lowering the speed by 10 mph. It was assumed that a lowering of speed limit by 10 mph would result in the average speed on the highway being lowered by an equivalent 10 mph. Hence, the MOBILE6.2 runs were done for an average speed of 54 mph, a reduction of 10 mph from the earlier modeled 64 mph speed on rural interstates. A base case run represented a scenario with currently projected emissions as modeled in the TDOT report (Davis et al., 2002). At the time the TDOT report was prepared (Davis et al., 2002), it was assumed that Davidson County did not have any rural interstates. However, based on information obtained from TDOT, speed limits on those sections of interstates in Davidson County that fell outside the old city limits were recently increased to 65-70 mph. Thus, this section of interstates may be modeled as "rural interstates" given the higher speed limit. Since the base case run for Davidson County performed earlier for the TDOT report does not account for this higher speed limit, emissions were recalculated for the base case with the assumption of a higher speed limit on those sections of interstates outside the old city limits. The VMT on those sections of the interstates is about 38% of the DVMT on all sections of the interstates in Davidson County and about 16.7% of the total DVMT in Davidson County.

Table 3.7.1 shows the emissions in tons/day for the base case and for the scenario when the speed on rural interstates is lowered by 10 mph. The model predicts a significant effect on NOx emissions from on-road mobile sources. A 10 mph reduction in speed is estimated to decrease NOx emissions by 4 to 16%, while increasing VOC emissions by a maximum of about 1.3%. The CO emissions are projected to decrease by a maximum of about 5%, while the PM2.5 emissions are unaffected. The emissions reduction in Sumner County is lower than that estimated for the other counties. This is probably due to the fact that in Sumner County, only 6.4% of the total DVMT is on Rural Interstates, while it ranges from 15% to 53% for the other counties in the Nashville EAC area.

Lowering the speed limit would require an act of the state legislature. The emission reductions projected here are for the ozone season only and the implementation of lower speed limits might be restricted for the same period.

Table 3.7.1. Model Results – Effect of Reducing Speed Limit on Rural Interstates from 65-70 mph to 55 mph (10 mph speed decrease)

County	Pollutant	Currently Projected 2007 As Is	Proposed measure - 2007 – lower speed by 10 mph on rural ins.	Reduction in Emissions	% Reduction
		tons/day	tons/day	tons/day	%
Cheatham	VOC	2.3850	2.4155	-0.03	-1.28
	CO	26.9108	25.9495	0.96	3.57
45% VMT on rural ins	NOx	5.8989	5.0569	0.84	14.27
	PM2.5	0.0879	0.0879	0.00	0.00
Davidson	VOC	21.7076	21.7896	-0.08	-0.38
	CO	274.5198	270.1628	4.36	1.59
16.7% VMT on rural ins	NOx	55.3602	52.3532	3.01	5.43
	PM2.5	0.9986	0.9986	0.00	0.00
Dickson	VOC	3.1123	3.1392	-0.03	-0.86
	CO	32.8449	31.9958	0.85	2.59
32% VMT on rural ins	NOx	6.1493	5.4056	0.74	12.09
	PM2.5	0.0929	0.0929	0.00	0.00
Robertson	VOC	3.2460	3.2886	-0.04	-1.31
	CO	42.9107	40.9328	1.98	4.61
53.6% VMT on rural ins	NOx	11.8118	9.8863	1.93	16.30
	PM2.5	0.1827	0.1827	0.00	0.00
Rutherford	VOC	5.8931	5.9101	-0.02	-0.29
	CO	72.3532	70.8451	1.51	2.08
19% VMT on rural ins	NOx	17.0421	15.4323	1.61	9.45
	PM2.5	0.3032	0.3032	0.00	0.00
Sumner	VOC	3.5852	3.5887	0.00	-0.10
	CO	41.4465	41.1412	0.31	0.74
6.4% VMT on rural ins	NOx	8.4199	8.0660	0.35	4.20
	PM2.5	0.1656	0.1656	0.00	0.00
Williamson	VOC	4.0352	4.0445	-0.01	-0.23
	CO	51.0871	50.2656	0.82	1.61
15% VMT on rural ins	NOx	10.8111	9.9591	0.85	7.88
	PM2.5	0.1917	0.1917	0.00	0.00
Wilson	VOC	3.4038	3.4126	-0.01	-0.26
	CO	43.0598	42.2757	0.78	1.82
16.7% VMT on rural ins	NOx	10.8164	9.9120	0.90	8.36
	PM2.5	0.1942	0.1942	0.00	0.00

The cost of lowering the speed limit for all vehicles on rural interstates is difficult to assess. The speed limit signs would have to be replaced adding to the costs. Lower speed limits would probably increase fuel economy, thus lowering the costs. The cost to the truckers would be primarily the extra travel time to deliver the cargo. One noticeable effect of reducing the speed limit would be the increase in travel time.

Table 3.7.2 summarizes the ton/day reduction that might be achieved in each of those counties in the Nashville EAC area by lowering the speed limit on rural interstates by 10 mph.

Table 3.7.2. Emission Reductions Achievable by Lowering Speed Limit on Rural Interstates by 10 mph

County	NOx tons/day	VOC tons/day	CO tons/day	PM2.5 tons/day
Davidson	3.01	-0.08	4.36	0.00
Rutherford	1.61	-0.02	1.51	0.00
Sumner	0.35	0.00	0.31	0.00
Williamson	0.85	-0.01	0.82	0.00
Wilson	0.90	-0.01	0.78	0.00
Cheatham	0.84	-0.03	0.96	0.00
Dickson	0.74	-0.03	0.85	0.00
Robertson	1.93	-0.04	1.98	0.00
Total	10.24	-0.22	11.56	0.00

3.7.3. Conclusions. A reduction in the speed limit on rural interstates shows a significant reduction in NOx emissions from on-road mobile sources in the Nashville EAC area. Although, it increases the VOC emissions slightly, it is insignificant. It must be noted that for Davidson County, the base case run is different from the run modeled earlier. Hence, while the emission reduction shown for Davidson County would be real, it may not be possible to take it as a credit because of the already projected base case emissions with a lower speed limit on the interstates. Counties with larger fraction of the VMT on rural interstates would benefit significantly from this measure.

REFERENCES

1. W.T. Davis, T.L. Miller, G.D. Reed, A.M.Y. Tang, P. Doraiswamy and P.Sanhueza, Effects of Growth in VMT and New Mobile Source Emission Standards on NO_x and VOC Emissions in Tennessee, 1999-2030 (Based on MOBILE6-Final Version), Report submitted to the Tennessee Department of Transportation, March 14, 2002.

2. Davis et al., Draft Report: Emission Inventories and Potential Emission Control Strategies For Ozone Early Action Compact Areas in Tennessee, Report prepared for Tennessee Department of Transportation and Tennessee Department of Environment and Conservation, April 13, 2003.

3.8 HOV LANE EXPANSIONS

3.8.1 Introduction. High Occupancy Vehicle (HOV) lanes are designated lanes of freeways requiring two or more occupants for legal use. HOV lanes are designed to encourage ridesharing to increase vehicle occupancy and reduce vehicle miles of travel (VMT). The Nashville area already has HOV lanes on portions of the freeways in the area. The current TIP (Transportation Improvement Plan) for the area includes expanding current HOV lanes. Three specific projects are planned for completion in 2006. They are 8 miles of new HOV lanes on I-40/I-24 to Old Hickory Blvd, 7 miles of new HOV lanes on I-24/SR-840 to US-231 and 9 miles of new HOV lanes on I-65 from Trinity Lane to SR-386. HOV lanes will be constructed in both directions. The Nashville Area MPO estimates that 1000 vehicles/day will utilize the new HOV lanes with an average increase in occupancy from 1.2 to 2.2 persons/vehicle *(1)*. This represents an increase in HOV lane usage of 24,000 vehicle-miles per day. The expected increase in vehicle occupancy of 1 person per vehicle should eliminate another 24,000 vehicle-miles per day of travel by an SOV (single occupant vehicle).

3.8.2 Emission Reductions. Emission reductions achievable by new HOV lane use can be estimated assuming that 24,000 vehicle miles of SOV travel will be eliminated because of the required higher occupancy rate required by vehicles using the HOV lanes. Table 3.8.1 below shows the composite emission factors taken from the MOBILE6.2 model *(2)* for the composite national default fleet of light duty gasoline cars, vans, and light trucks (including SUVs) for 2007. The emission factors were multiplied times 24,000 vehicle-miles of travel per day for SOV trips eliminated by the higher occupancy rates of vehicles using the HOV lanes.

Table 3.8.1 Emissions Reduction From New High Occupancy Vehicle (HOV) Lanes.

Pollutant	Emission from Light Duty Vehicles		
	(g/mile)	(miles/day)	(tons/day)
NOx	0.909	24,000	0.024
VOC	1.181	24,000	0.031
CO	13.241	24,000	0.35
PM-2.5	0.012	24,000	0.0003

The emission reductions from new HOV lanes are expected to occur only in the Nashville EAC area, so all the emission reduction credits are assigned to Davidson County as shown in Table 3.8.2 below.

3.8.3 Costs. The cost of emission reductions obtained from constructing new HOV lanes can be estimated from the cost of building the HOV lanes and the estimated reduction in emissions resulting from the program. Freeway construction costs can be estimated at $4 million per lane mile. The proposed HOV projects involve a total of 48 new lane miles (24 miles each way). The total construction cost can be estimated at $192 million. The NOx emission reduction is estimated in Table 3.8.1 using 0.024 tons/day, 5 days/week, 52 weeks/year. The HOV lane should last at least 10 years without significant maintenance cost. The emission reduction over 10 years would be 62.4 tons NOx. The cost per ton reduced is then $3 million/ton NOx. The cost per ton for other pollutants is shown in Table 3.8.3. These costs are the costs to the agency building the HOV lanes. The users of the HOV lanes should actually save money, since their travel cost per person will be reduced by ridesharing and higher vehicle occupancy rates.

Table 3.8.2 Emission Reductions Achievable for New HOV Lanes.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.024	0.031	0.35	0.0003
Rutherford	0	0	0	0
Sumner	0	0	0	0
Williamson	0	0	0	0
Wilson	0	0	0	0
Cheatham	0	0	0	0
Dickson	0	0	0	0
Robertson	0	0	0	0
Total	0.024	0.031	0.35	0.0003

Table 3.8.3 Estimated Cost of Emission Reductions from New HOV Lanes.

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties	3,000,000	2,300,000	200,000	-	180,000

References for Section 3.8:

(1) HOV data provided by Matt Meservy of the Nashville Area MPO.
(2) MOBILE6.2 Emission Factor Model, U.S. Environmental Protection Agency, available on the web at www.epa.gov/otaq/m6.htm

3.9 EMPLOYER BASED TRIP REDUCTION PLANS

3.9.1 Introduction. Employer based trip reduction plans include work schedule changes designed to reduce peak demand and generally involve flexible employee schedules where employees can alter the normal 9 am to 5 pm work shift to fit their own preferences. Some occupations do not work well with flexible employee schedules, while others may. Coming to work unusually early and leaving early help reduce peak hour traffic, but do not necessarily reduce trip distance and VMT. In order to accomplish a reduction in air pollution emissions, a change in work schedule that has the potential to reduce VMT is needed. Examples of work changes that may reduce VMT are working four 10-hour shifts per week instead of five 8-hour shifts; or working at home 2 or 3 days per week (sometimes called telecommuting). Working 4 days per week instead of 5 may reduce VMT by eliminating one home to work and back commute each week. Telecommuting more than one day per week has the potential to reduce the number of weekly commutes even more. However, there is some evidence that people working at home may tend to do more non-work related driving (especially at the end of the work day) than those who spend the day at the office or factory.

3.9.2 Emission Reductions. In order to estimate the emission reductions achievable by rescheduling work, an estimate of the VMT reduction that results is needed. It can be estimated that one commute-to-work-and-back can be eliminated per day for each person participating in the program. A distance of 26.3 miles each way is typical in the Nashville EAC area based on data provided by the Nashville Area MPO *(1)*. People choosing to reschedule work (or take the day off) will save 52.6 vehicle-miles of travel each day they work at home (i.e. telecommute) or take off. For every 1000 people participating, 52,600 vehicle miles of travel (VMT) could be eliminated from area highways each workday. It is likely that only light-duty gasoline vehicle trips would be eliminated. Table 3.9.1 below shows the composite emission factors taken from the MOBILE6.2 model *(2)* for the composite national default fleet of light duty gasoline cars, vans, and light trucks (including SUVs) for 2007. The emission factors were multiplied times 52,600 vehicle-miles of travel per day of trips eliminated by 1000 people not commuting to work per day.

Table 3.9.1 Emissions Reduced From Rescheduling 1000 Commuter Trips/Day to Work.

Pollutant	Emission from Light Duty Vehicles (g/mile)	(miles/day)	(tons/day)
NOx	0.909	52,600	0.053
VOC	1.181	52,600	0.068
CO	13.241	52,600	0.77
PM-2.5	0.012	52,600	0.0007

The emission reductions will occur throughout the Nashville EAC area, but it is difficult to determine exactly where they occur. Most of the trips are expected to occur in Davidson County, so all the emission reduction credits are assigned to Davidson County as shown in Table 3.9.2 below.

<u>3.9.3 Costs.</u> The cost of NOx emission reductions obtained from a program to promote work schedule changes is difficult to estimate. One crude estimate would be to approximate the cost to operate and maintain a small staff and purchase advertising to promote work schedule changes, along with an assumed success rate or participation rate. If $40,000 was spent each year to promote work schedule changes, and if eventually 1,000 people participate each work day, then $40,000/yr will be spent to achieve 0.053 tons/day of NOx reduction, 250 days per year. This cost is equal to $3,020 per ton of NOx. The cost per ton for other pollutants is shown in Table 3.9.3. These costs are the costs to the agency promoting the program. The participants in the program will actually save money, since their travel cost will be reduced by $0.32/mile x 52.6 miles/day = $16.80 for each day they don't commute to work (not counting parking costs).

Table 3.9.2 Emission Reductions Achievable for 1000 Less Trips/Day to Work.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.053	0.068	0.77	0.0007
Rutherford	0	0	0	0
Sumner	0	0	0	0
Williamson	0	0	0	0
Wilson	0	0	0	0
Cheatham	0	0	0	0
Dickson	0	0	0	0
Robertson	0	0	0	0
Total	0.053	0.068	0.77	0.0007

Table 3.9.3 Estimated Cost of Emission Reductions for Trip Reduction Plans.

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties	3,020	2,350	210	230,000	180

References for Section 3.9:

(1) Transit data provided by Matt Meservy of the Nashville Area MPO.
(2) MOBILE6.2 Emission Factor Model, U.S. Environmental Protection Agency, available on the web at www.epa.gov/otaq/m6.htm

3.10 EXPAND RIDESHARE PROGRAMS

3.10.1 Introduction. Ridesharing programs are currently promoted in the Nashville area to reduce the number of private vehicles used for commuting to work and encourage the use of passenger vans (vanpooling) serving 10 to 15 riders each. Each van carrying 13 passengers potentially reduces the number of vehicle-trips by private vehicles by 12. The emissions from the 12 vehicles not used represent a reduction in emissions attributable to ridesharing or vanpooling programs. The emission reductions achievable should be equal to the emissions from cars, vans and light trucks (including SUVs) that would otherwise have been used instead of riding passenger vans. The cost of this control measure would be equal to the capital and operating cost of the vans, however this is offset by the savings from not using private vehicles.

3.10.2 Existing Vanpooling. Vanpooling data was provided by the Nashville Area MPO *(1)*. There are an estimated 1464 riders from the RTA, plus another 110 riders from the TMA vanpool programs in the Nashville area (a total of 1574 riders per day). Each of these programs utilizes 15-passenger vans, traveling an estimated 52.6 miles/day (i.e. 26.3 miles each way to and from work). Total riders per day times 52.6 miles each yields 82,792 passenger miles per day by vanpooling. Assuming an average of 13 passengers per van, there are 121 vans involved in the program traveling 6370 vehicle-miles per day. The vehicle-miles of travel by private vehicles offset by the program is 12 times 6370 miles, equal to 76,440 vehicle-miles per day. The Nashville Area MPO estimates that future programs could increase vanpool ridership by 10%. The increase in private vehicle use diverted to vanpooling would then be 7,644 vehicle-miles per day (diverted).

3.10.3 Emission Reductions. Emission reductions achievable through an increase in vanpooling have been estimated as follows. The daily increase in vanpool use is estimated to reduce private vehicle travel by 7,644 vehicle-miles per day. Table 3.10.1 below shows the composite emission factors taken from the MOBILE6.2 model *(2)* for the composite national default fleet of light duty gasoline cars, vans, and light trucks (including SUVs) for 2007. The emission factors were multiplied times 7,644 vehicle-miles of travel per day of new trips diverted to vanpool travel to estimate the daily tons/day of emission reduction. It is assumed that van emissions are no higher than the emissions from light duty gasoline vehicles.

Table 3.16.1 Emissions From Light Duty Vehicle Trips Diverted to New Vanpooling.

Pollutant	Emission from Light Duty Vehicles (g/mile)	(miles/day)	(tons/day)
NOx	0.909	7,644	0.0076
VOC	1.181	7,644	0.01
CO	13.241	7,644	0.11
PM-2.5	0.012	7,644	0.0001

The emission reductions will occur throughout the Nashville EAC area, but it is impossible to determine exactly where they occur. Most of the trips are expected to occur in Davidson County, so all the emission reduction credits are assigned to Davidson County as shown in Table 3.10.2 below.

3.10.4 Costs. The cost of achieving this reduction in emissions is estimated assuming an average capital and operating cost for the vans equal to \$0.32/mile. Daily costs for use of the vans would be \$0.32/mile times 52.6 miles/day times 12 new vans. The daily cost is \$202. The cost per ton of NOx emissions reduced would be \$202/0.0076 tons NOx, equal to \$26,600/ton NOx. The cost per ton for other pollutants is shown in Table 3.10.3. These costs are the costs to the van owner/operator. The vanpool users will actually save money, since their travel cost will be less than if they used their own vehicles.

Table 3.10.2 Emission Reductions Achievable by a 10% Increase in Vanpooling.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.0076	0.01	0.11	0.0001
Rutherford	0	0	0	0
Sumner	0	0	0	0
Williamson	0	0	0	0
Wilson	0	0	0	0
Cheatham	0	0	0	0
Dickson	0	0	0	0
Robertson	0	0	0	0
Total	0.0076	0.01	0.1	0.0001

Table 3.10.3 Estimated Cost of Emission Reductions for Vanpooling.

County	NOx (\$/ton)	VOC (\$/ton)	CO (\$/ton)	PM2.5 (\$/ton)	Combined (\$/ton)
All Counties	26,600	20,200	2,020	2,020,000	1,700

References for Section 3.10:

(1) Transit data provided by Matt Meservy of the Nashville Area MPO.
(2) MOBILE6.2 Emission Factor Model, U.S. Environmental Protection Agency, available on the web at www.epa.gov/otaq/m6.htm

3.11 ITS IMPROVEMENTS

3.11A. TRAFFIC FLOW IMPROVEMENT PROGRAMS

Intelligent Transportation Systems (ITS) can be used to reduce air pollution emissions through improvements in traffic flow and reductions in travel time. Traffic flow improvement programs generally involve traffic signal synchronization designed to minimize stop-and-go travel thereby shortening delays and increasing average route speeds. These projects are applicable only on arterial roads with many traffic lights. Using the MOBILE6 model to estimate the change in emissions due to traffic flow improvements may result in a predicted increase in NOx emissions (especially if speeds are increased above 35 mph). Two papers (1, 2) presented at the Transportation Research Board annual meeting in Washington, D.C. in January 2003 presented a different finding. Both these papers showed that NOx and VOC emissions can be reduced as a result of traffic signal synchronization. One paper presented the results of research with computer models that predict the effects of traffic flow improvements at three sites in Illinois (2). The other paper (1) presented the results of research using on-board tailpipe exhaust monitoring equipment on vehicles traveling a corridor in North Carolina with and without traffic signal synchronization. A research report from North Carolina State University (3) also showed significant reductions in emissions were achieved when traffic flow was uncongested versus congested. Conclusions from the study (3) state: "A reduction in emissions of approximately 50 percent for each of NO, CO and HC could be achieved if traffic flow could be improved from congested to uncongested. However, it is clear that traffic signal timing and coordination alone cannot achieve such an improvement during peak time periods on this particular corridor." The TRB paper (1) states "the magnitude of the percentage decrease in travel time was typically comparable to the magnitude of the percentage decrease in emissions."

The results of the North Carolina study (1) showed average reductions of 9.8 % in VOC, 8.5% in NO, and 6.3% in CO for an arterial after signal coordination. A 15% reduction in travel time was also achieved. The Illinois study (2) showed an average 3.5% reduction in NOx and 13% reduction in VOC's for 3 corridors studied. In general, significant emission reductions were not achieved on highly congested roadways where the effects of traffic signal synchronization were not fully realized (i.e. roads so congested that traffic signal synchronization did not improve traffic flow). The emission reductions were greatest when traffic volumes were moderate so that the full effect of traffic signal synchronization was realized.

For the purpose of the Nashville EAC analysis, the average reduction in emissions achieved or predicted from these studies was used to estimate the emission reductions achievable with traffic flow improvements in the Nashville area. The average reductions were 6% for NOx, 11% for VOC and 6% for CO. No results were given for reductions in particulate matter emissions. Interstates and local streets have few or no traffic lights. Therefore, only urban arterials (with many traffic signals) are candidates for flow improvements by traffic signal synchronization and coordination.

Table 3.11A.1 below shows the estimated emissions from urban arterials in 2007 in the 8 counties of the Nashville EAC without traffic flow improvements. Emission projections for urban arterials were obtained from the MOBILE6 emissions modeling analysis performed by the University of Tennessee (4) for TDOT in 2002. Table 3.11A.2 shows the estimated reduction in emissions assuming that traffic flow improvements are implemented on all urban arterials in the 8-county area.

Table 3.11A.1 Projected Emissions on Urban Arterials in 2007 Without Traffic Flow Improvements.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	11.59	7.56	87.05	0.25
Rutherford	2.54	1.78	20.33	0.05
Sumner	2.24	1.32	14.98	0.05
Williamson	1.19	0.83	9.51	0.03
Wilson	0.99	0.62	7.00	0.02
Cheatham	0.00	0.00	0.00	0.00
Dickson	0.55	0.58	5.41	0.01
Robertson	0.36	0.31	3.41	0.01
Total	19.5	13.0	147.7	0.4

Table 3.11A.2 Emission Reductions Possible With Traffic Flow Improvement.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.70	0.83	5.22	0.00
Rutherford	0.15	0.20	1.22	0.00
Sumner	0.13	0.15	0.90	0.00
Williamson	0.07	0.09	0.57	0.00
Wilson	0.06	0.07	0.42	0.00
Cheatham	0.00	0.00	0.00	0.00
Dickson	0.03	0.06	0.32	0.00
Robertson	0.02	0.03	0.20	0.00
Total	1.2	1.4	8.9	0.0

Nashville is currently planning to implement traffic signal synchronization projects on 431 miles of urban arterials at a cost of $1.8 million. This covers almost all the urban arterials in Davidson County. If the $1.8 million is amortized over 5 years, the cost per ton of emissions reduced over 5 can be estimated. These values are given the Table 3.11A.3.

Table 3.11A.3 Estimated Cost of Emission Reductions by Traffic Flow Improvement

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties	1,418	1,186	189		146

It is not likely that all urban arterials in the Nashville EAC would be candidates for traffic signal synchronization. It is also likely that some traffic flow improvement projects may have already been undertaken and do not represent a potential for future emission reductions. The actual potential emission reductions from traffic flow improvement may be somewhat less than estimated above.

EPA's Transportation Air Quality Web Site www.epa.gov/otaq/transp/traqmodl.htm contains a report on the emission reductions and costs of 24 CMAQ projects. A table summarizing the costs per ton of NOx emissions reduced is presented in the appendix of this report. One project in Pennsylvania involved "arterial street signal interconnecting" was estimated to have achieved 2.01 tons/yr reduction in NOx emissions at a cost of $102,000 per ton. The costs for other signal synchronization projects were not given.

References for Section 3.11A:

(1) *"Effect of Arterial Signalization and Level of Service on Measured Vehicle Emissions"* by U. Alper, N. Rouphail, and C. Frey, North Carolina State University, TRB Paper No. 03-2884, Transportation Research Board Meeting, Washington, D.C., Jan 12-16, 2003.

(2) *"Evaluation of Simulation Models for Project-Level Emissions Analysis",* by S. Hallmark, and S Poska, Iowa State University and K. Kosman LSC Transportation Consultants, TRB Paper No. 03-3925, Transportation Research Board Meeting, Washington, D.C., Jan 12-16, 2003.

(3) **Final Report – Emission Reduction Through Better Traffic Management: An Empirical Evaluation Based Upon On-Road Measurements Stage**, by C. Frey, R. Nagui, A. Unal, and J. Colyer; North Carolina State University, Dept. of Civil

Engineering, Raleigh, NC 27695-7908, December 2001. Available on the web at itre.ncsu.edu/cte/rip_airqqlty.html (9/4/03)

(4) **Effects of Growth in VMT and New Mobile Source Emission Standards on NOx and VOC Emissions in Tennessee 1999-2030 (Based on MOBILE6 – Final Version)**, by W. Davis, T. Miller, G. Reed, A. Tang, P. Doraiswamy, and P. Sanhueza, Department of Civil and Environmental Engineering and UT Center for Transportation Research, University of Tennessee, Knoxville, TN. Contract Report for the Tennessee Department of Transportation, March 14, 2002.

3.11B ROADSIDE ASSISTANCE PROGRAM

The greatest benefits of an effective incident management program are achieved through the reduction of incident duration. Substantial reductions in response and clearance of incidents can be achieved through the implementation of policies and procedures that are understood and agreed upon by each player in the incident management process. No consistent standard has been identified that can be uniformly applied to evaluate the quantifiable benefits of an effective incident management program. In part, this results from the relatively diverse structure and operations of incident management programs. Each program is developed to meet the unique identified needs of the region and is generally developed to fit within the existing institutional framework[1]. In an effort to quantify the emission reduction benefits of the Nashville Area Incident Management Program, we will use other programs from other cities that have published results as a guide.

3.11.B.1 CALCULATION OF REDUCED EMISSIONS AS A RESULT OF INCIDENT MANAGEMENT PROGRAM

The Nashville Area Incident Management Program operates five trucks per day that are constantly patrolling area interstates. On an average day each truck can be expected to respond to 10 incidents[2]. This results in 50 incidents per day.

5 trucks x 10 incidents/truck-day = 50 incidents/day

The Traffic Incident Program in place along the Gowanus Expressway in Brooklyn, New York has been attributed with reducing the time required to aid disabled vehicles by 19 minutes[3]. Likewise, the program "Highway Helper" in St. Paul, Minnesota reduces the duration of stalled vehicles by 8 minutes[4]. If we conservatively estimate that the Nashville program reduces incident time by 10 minutes and assume an average of 240 vehicles are affected by each incident, then 2000 vehicle hours per day of delay is avoided.

50 incidents/day x 10 minutes x 240 vehicles/incident x 1 hr/60 min = 2000 vehicle-hours/day

As a comparison, the Washington DC/Baltimore CHART program claims two million vehicle-hours per year, or 5500 vehicle-hours per day, of delay avoided[5]. The population of the Washington DC/Baltimore MSA is about three times greater than the population of the Nashville MSA.

To calculate the reduction in emissions achieved, the Mobile 6 All National Defaults for 2007 were used. These values are 2.77grams/mile for VOC, 22.4 grams/mile for CO and 2.78 grams/mile for NO_X. Using 5 miles per hour we can estimate the emissions to be 14 grams/hour, 112 grams/hour and 14 grams/hour for VOC, CO and NO_X respectively. As a result of the 2000 vehicle hours per day obviated by the incident program, we can estimate emission reductions of 0.031 tons per day for VOC and NO_X, and 0.25 tons per day for CO. These results and an example calculation for NO_X are summarized in the table below. It should also be noted that emissions from the five program trucks were not included in the emission determinations.

Table 3.11.B.1 Emissions Reductions

Pollutant	2007 Mobile6 All National Defaults (grams/mile) @ 5 mph	Idling Emissions (grams/hour)	Emissions Reduction (tons/day)
VOC	2.77	14	0.031
CO	22.4	112	0.25
NO_X	2.78	14	0.031
$PM_{2.5}$		0.2	4.4×10^{-4}

Example calculation for NO_X:

$$\text{Idling Emissions} = 2.78 \text{ g/mi} \times 5 \text{ mph} = 13.9 \text{ grams/hour}$$

$$NO_X \text{ reduced} = 2000 \text{ veh-hrs/day} \times 14 \text{ g/hr} \times 1.1\text{x}10^{-6} \text{ g/ton} = 0.0308 \text{ tons/day}$$

Though we cannot estimate the cost for the Nashville Area Incident Management Program, the Incident Management Program in place in the Atlanta, Georgia area does offer some estimates. The total annual project cost is reported as $841,309. Annual emissions reductions for 2010 for VOC and NO_X are 165 tons per year and 158 tons per year, respectively[6]. This results in an emission reduction cost of $5100 per ton of VOC and $5300 per ton of NO_X.

Example for VOC:

Cost per ton of VOC emission reduction = $841,309 per year/165 tons/yr = $5099/ton

References:

1. Traffic Incident Management Handbook, FHWA Office of Travel Management, November 2000. The URL is: http://www.ops.fhwa.dot.gov/Travel/IncidentMgmt/traffic_incident_management.htm
2. Information from phone conversation with Mr. Bill Jacobs of Tennessee Department of Transportation, August 25, 2003
3. Traffic Incident Management Handbook, FHWA Office of Travel Management, November 2000 http://www.ops.fhwa.dot.gov/Travel/IncidentMgmt/traffic_incident_management.htm

4. Traffic Incident Management Handbook, FHWA Office of Travel Management, November 2000 http://www.ops.fhwa.dot.gov/Travel/IncidentMgmt/traffic_incident_management.htm
5. Summary Review of Caosts and Emissions Information for 24 CMAQ Projects, US EPA, September 28, 1999

3.12 NEW GREENWAYS AND BIKEWAYS

3.12.1 Introduction. A significant program has been approved by the Nashville Area MPO for upgrading sidewalks and constructing greenways and bikeways in the Nashville area. It is hoped that improved greenways and sidewalks will encourage walking and bicycling as an alternative to traveling in private vehicles. The Nashville Metro MPO has performed travel demand modeling that shows an expected 20,000 people per day will use the greenways and sidewalks with an average trip distance of 1.91 miles. The Nashville Area MPO has estimated that 38,234 person-miles/day of travel by walking and bicycling *(1)* is achievable when these programs are completed by 2007. To estimate the effect this has on emissions, it can be assumed that each mile traveled by walking or bicycling offsets or replaces a mile that would have been traveled by private vehicle. Emission and cost calculations are given below.

3.12.2 Emission Reductions. Given the estimate that 38,234 person-miles/day of travel in the Nashville area will be by walking or bicycling, emission reductions can be estimated assuming the trips would otherwise be taken by private vehicle. Table 3.12.1 below shows the composite emission factors taken from the MOBILE6.2 model *(2)* for the composite national default fleet of light duty gasoline cars, vans, and light trucks (including SUVs) for 2007. The emission factors were multiplied times 38,234 vehicle-miles of travel per day to estimate the emissions that would have occurred from private vehicles.

Table 3.12.1 Emissions Reduced From Walking or Bicycling Per Day in 2007.

Pollutant	Emission from Light Duty Vehicles		
	(g/mile)	(miles/day)	(tons/day)
NOx	0.909	38,234	0.039
VOC	1.181	38,234	0.049
CO	13.241	38,234	0.56
PM-2.5	0.012	38,234	0.0005

The emission reductions will occur throughout the Nashville EAC area, but it is difficult to determine exactly where they occur. Most of the trips are expected to occur in Davidson County, so all the emission reduction credits are assigned to Davidson County as shown in Table 3.12.2 below.

3.12.3 Costs. The cost of emission reductions obtained from a program to promote work schedule changes is difficult to estimate. One estimate would be to approximate the annualized cost to build and maintain the greenways and sidewalks and divide by the annual reduction in emissions. If the annualized cost to build and maintain greenways and sideswalks is estimated at $1,000,000 per year, then the cost per ton of NOx emissions reduced is $1,000,000/14.2 tons NOx reduced per year. This cost is equal to $70,040 per ton of NOx. The cost per ton for other pollutants is shown in Table 3.12.3.

Table 3.12.2 Emission Reductions From Bikeways and Greenways.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.039	0.049	0.56	0.0005
Rutherford	0	0	0	0
Sumner	0	0	0	0
Williamson	0	0	0	0
Wilson	0	0	0	0
Cheatham	0	0	0	0
Dickson	0	0	0	0
Robertson	0	0	0	0
Total	0.039	0.049	0.56	0.0005

Table 3.12.3 Estimated Cost of Emission Reductions for Bikeways & Greenways.

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties	70,040	55,900	4,900	5,500,000	4,200

References for Section 3.12:

(1) Transit data provided by Matt Meservy of the Nashville Area MPO.
(2) MOBILE6.2 Emission Factor Model, U.S. Environmental Protection Agency, available on the web at www.epa.gov/otaq/m6.htm

3.13 LOW EMISSION VEHICLE FLEETS

3.13.1 Introduction. Lower emissions from on-road mobile sources can be achieved by replacing a older high-emitting vehicles with new low-emitting vehicles. EPA classifies low emission vehicles as either low emission vehicles (LEVs), ultralow emission vehicles (ULEVs) or zero emission vehicles (ZEVs). Most new conventional vehicles meet LEV standards even today. ULEVs are usually hybrid vehicles using a small efficient engine to generate electricity to run electric motors. ZEVs are electric vehicles that run on batteries. Most ULEVs and ZEVs are light-duty vehicles. Heavy-duty vehicles can sometimes achieve lower emissions by burning cleaner fuels. The more low emission vehicles that can be purchased to replace older high emission vehicles, the lower area emissions will be. Commercial fleets of buses, trucks, and cars are often the best candidates for utilizing these newer technologies since they tend to drive vehicles longer distances each day, and they have the maintenance personnel to operate special refueling stations and troubleshoot vehicle problems.

3.13.2 Alternative Fuels. Some fuels can be substituted for conventional gasoline and diesel fuel to achieve a reduction in mobile source emissions. These alternative fuels include biodiesel, ethanol, liquefied natural gas (LNG), compressed natural gas (CNG), and propane. Biodiesel is a fuel containing vegetable oil (corn, soy, canola, etc) either 20% by weight in B20 (80% diesel) or 100% biodiesel called B100. EPA has tested emissions from vehicles utilizing these alternative fuels and published "Fact Sheets" summarizing the emission reductions achievable and the estimated costs. These Fact Sheets are available on EPA's "Alternative Fuels Web Site" at www.epa.gov/altfuels/altfuels.htm. The percent reduction in emissions reported by EPA for several alternative fuels is summarized in the table below.

Fuel	**Percent Reduction in Emissions Reported**			
	NOx	**CO**	**VOC**	**PM**
Biodiesel B20	2	10	10	15
Biodiesel B100	9	50	40	70
Ethanol E85	10	40	varies	20
Liquified Natural Gas	50	NA	50	50
Compressed Natural Gas	45	94	65	NA
Propane (Rich Adjust)	lower	higher	higher	NA
Propane (Lean Adjust)	higher	lower	lower	NA

Use of these alternative fuels requires new fueling stations as well as modifications to the vehicles burning the fuels. In some cases the alternative fuels have higher costs per equivalent heat value of gasoline or diesel. B100 biodiesel is typically \$2 to \$3 per gallon, 33% to 100% higher than diesel fuel. B20 is \$.20 to \$.30 per gallon higher than diesel fuel. Propane cost is typically \$.30 per equivalent gallon higher cost than diesel fuel not including highway taxes which are currently \$.38/gal of gasoline. CNG and LNG costs are generally about the same as diesel (not including highway taxes).

Modifications required to vehicles burning alternative fuels can be minimal or quite extensive depending on the fuel and the vehicle. The largest NOx emission reduction comes from burning LNG. LNG fueled heavy-duty trucks and buses can cost an additional $30,000 to $50,000. Fuel dispensing and fuel storage required for LNG typically costs $15,000 to $22,000 per vehicle.

Tons per day of NOx emission reductions can be estimated for LNG and CNG fueled buses. A new (2006 model) diesel fueled bus in 2007 will have NOx emissions of 9.5 g/mile (under National default conditions) and travel an average 124 miles/day *(1)*. An LNG fueled bus should have 50% lower NOx emissions (i.e. 4.75 g/mile). The emission reduction per bus is 4.75 g/mile x 124 miles/day = 589 g/day. If 100 buses in the study area are converted to LNG, the emission reduction will be 58.9 kg/day or 0.065 tons/day. Emission reductions possible for the other pollutants are shown in Table 3.13.1 below.

Table 3.13.1 Emission Reductions Achievable From 100 Low Emission Buses.

Pollutant	Model 2006 Transit Bus Emissions (gm/mile)	Percent Reduction With LNG or CNG Vehicle	Average Daily VMT Per Vehicle (veh-miles/day)	Daily Emission Reduction Per 100 LNG or CNG Buses (tons/day)
NOx	9.5	50	124	0.065
VOC	0.24	65	124	0.002
CO	3.1	94	124	0.040
PM-2.5	0.14	50	124	0.001

In order to estimate emission reductions achievable for the Nashville EAC area some estimate is needed as to the number of low emissions vehicles that will be purchased in the area by 2007. Local government agencies and utility companies are the most likely to be interested in participating in a program of low emission vehicle use. For purposes of this report, it is assumed that at least 100 low emission buses or heavy-duty trucks will be acquired in each of the 5 largest counties in the area. Light-duty low emission vehicles also can reduce area wide emissions, but it requires replacing many more vehicles (10 times more for NOx) to achieve the same emission reduction. A summary of the estimated emission reductions for each county is shown in Table 3.13.2.

3.13.3 Costs. The cost of the 0.065 ton/day emission reduction can be estimated from the higher cost of an LNG modified vehicle. Ignoring the fuel dispensing and storage costs, the added capital cost of $40,000 per bus can be amortized over the life of the bus. If the bus service life is 400,000 miles, the added capital cost of the vehicle is $.10/mile. For 100 buses, each traveling 124 miles/day, the total cost is $.10/mile x 100 buses x 124 miles/day = \$1240/day. The cost per ton of emission reduction is \$1240/0.065 tons = \$19,000 per ton NOx. Cost estimates for the other pollutants are shown in Table 3.13.3.

Table 3.13.2 Emission Reductions Achievable With Low Emission Vehicles.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.065	0.002	0.04	0.001
Rutherford	0.065	0.002	0.04	0.001
Sumner	0.065	0.002	0.04	0.001
Williamson	0.065	0.002	0.04	0.001
Wilson	0.065	0.002	0.04	0.001
Cheatham	0	0	0	0
Dickson	0	0	0	0
Robertson	0	0	0	0
Total	0.325	0.01	0.20	0.005

Table 3.13.3 Estimated Cost of Emission Reductions from Low Emission Vehicles.

County	NOx (\$/ton)	VOC (\$/ton)	CO (\$/ton)	PM2.5 (\$/ton)	Combined (\$/ton)
All Counties	19,000	620,000	31,000	1,200,000	11,500

Emission reductions are greatest for CNG and LNG alternative fuel vehicles, but the NOx emission reductions for the other alternative fuels are less. For this reason, additional analyses for the other fuels were not undertaken.

References for Section 3.13:

(1) MOBILE6.2 Emission Factor Model, U.S. Environmental Protection Agency, available on the web at www.epa.gov/otaq/m6.htm

3.14. IDLING ENGINE REDUCTIONS

3.14.A Truck Stop Electrification (TSE), an Alternative to Idling

3.14.A.1 Introduction

Long haul truck drivers generally idle their heavy-duty diesel vehicle engines while parked at travel centers during required rest periods. The engines are operated in the idling mode to keep the engines warm during cold weather and to provide on board electrical power for appliances and to provide heat and air conditioning for the truck cab and sleeper compartment.

Up to one gallon of diesel fuel per hour is used by a typical diesel truck while idling, due to the fact that the truck must be maintained in a high idle mode to minimize damage to the engine. This results in as much as 2,400 gallons of fuel burned every year per truck. In addition, idling increases engine wear and contributes to emissions of major pollutants. On average, each idling truck produces about 21 tons of carbon dioxide (CO_2) and 0.3 tons of nitrogen oxides (NO_x) annually[1].

The fuel consumed during idling can be saved and air emissions reduced by installing "idle reduction technology," a technology that allows the truck driver to avoid idling the engine. One alternative is Truck Stop Electrification (TSE), which saves fuel and reduces emissions. One local example of TSE technology is that provided by IdleAire, Inc. that provides a connection to the truck cab through the passenger side window. The connection includes thermostatically controlled heat and air conditioning, electricity and cable TV at each truck parking space via an overhead rack that spans the parking area. The electrification devices allow drivers to power heat or air conditioning appliances, without running their engines. Once installed, the system is operated on a fixed fee per visit basis (typically $1.25/hour) that essentially pays for itself in that the cost is offset by the savings in fuel.

3.14.A.2 Methodology & Assumptions

Based on discussion with IdleAire and estimates used in a recent CMAQ grant made by Knox County TN to IdleAire, the initial capital cost of electrification parking spaces for 100 heavy-duty diesel trucks is approximately $1,000,000 and the equipment life is expected to be 20 years. For purposes of calculation in this report, each space is assumed to have an occupancy rate of 16 hours/day or two-thirds of a day (or 0.667).

The emissions (grams/hour/truck) for idling conditions for heavy-duty diesel vehicles (truck category HDDV 8b) were estimated using the EPA-recommended procedure of obtaining the emissions by running the MOBILE6 model for a speed of 2.5 mph for the arterial roadways category. All other parameters were set to default national fleet settings.

A brief literature review was also conducted to confirm that the emission estimate using the above approach was reasonable based on reported emissions from idling diesel trucks. The literature review revealed that actual testing of truck idling emissions in the 1990's showed average idling NOx emission rates of 155 grams/hour/truck (ranging from 95 to 225 grams/hour/truck). This value is greater than the 47 grams/hour/truck value obtained from MOBILE6 for 2007, however this is probably reasonable, since emissions from diesel engines will decrease in the future due to improved technologies and low sulfur diesel fuel programs. While the 2007 value of 47 g/h was used in the calculations, it should be noted that the actual emission reduction achievable may be greater if TSE is implemented earlier than 2007 or if the emissions end up being greater than that predicted by MOBILE6. In that case, the estimated cost per ton of reduction may also be lower.

3.14.A.3 Calculations

The cost per ton of emission reduction is calculated as follows:

1. The emission factor in grams/mile/truck is converted to grams/hour/truck by multiplying by 2.5miles/hour.

2. The gram of pollutant per hour for a single truck is changed to gram of pollutant per day for 100 trucks by multiplying by 24 and 100.

3. The calculated grams of pollutant is converted to tons and an occupancy factor of 0.667 is applied to take into account the assumed occupancy at the TSE travel center.

4. Multiply the resulting quantity by the number of days in a year, this will result in tons/year/100 trucks.

5. The cost per ton of emission reduction is obtained by dividing the cost per annum by tons of emission/year/100 trucks.

The emission reduction and cost estimate are summarized in Table 3.14.A.1. As shown in the table, the estimated cost of the strategy is approximately \$1660/ton of NO_x reduced, if the entire cost is based on NO_x reduction and it is assumed that there is no net expense to the driver once it is installed due to the savings in fuel. The cost is lower if one looks at the cost per ton of all pollutants, or if one looks at the current emissions from diesel trucks.

3.14.A.4 Reduction Achievable

The amount of NO_x reduction that could be achieved out of 1000 truck spaces is 0.82 tons/day (Table 3.14.A.1). The number of truck spaces in eight counties is 2265 as listed in Table 3.14.A.2[2] and the reduction achievable if all of these spaces are electrified is 1.86 tons/day.

Table 3.14.A.1 Truck Electrification Emission Reduction and Cost

MOBILE6 Model Inputs:

Calendar Year:	2007
Month:	July
Altitude:	Low
Minimum Temperature:	60.0 (F)
Maximum Temperature:	93.0 (F)
Absolute Humidity:	75. grains/lb
Diesel Sulfur Content:	112.0 ppm

Intial cap Costs/100 trucks ($)	1,000,000					
Eqp life (Years)	20					
Per annum costs/100 trucks ($)	50000					
Utilization Factor	0.66					
Vehicle Type	**HDDV 8b**					
Emission Factors	**gms/mile**	**Miles/hr**	**gms/hr**	**Tons/day/100 Trucks**	**Tons/year/100 Trucks**	**$/Ton Emission Reduction**
Composite VOC	1.7	2.5	4.47925	0.007820913	2.9	17515.4
Composite CO	15.8	2.5	39.652	0.069233651	25.3	1978.6
Composite NO_X	18.8	2.5	47.167	0.082355079	30.1	1663.4
$PM_{2.5}$	0.3	2.5	0.756	0.00132	0.5	103777.5
NO_x Emission from truck in 1990s			225	0.392857143	143.4	348.7

ASSUMPTIONS

Assume the utilization factor for Electricfication Slot as 0.66 (used effectively two-third of a day).

Assume the Initial cap costs of Electricfication Slot for 100 Trucks is $1,000,000.

Assume the equipment life to be around 20 years.

CALCULATION

Therefore the cost involved in E.S/annum for 100 trucks is 50,000$.

Emission factor (gms/mile) is calculated by running the model for National settings with 2.5 mph.

Emission Factor (gms/mile) * Speed (miles/hr) = **gms of pollutant/hour/truck.**

Convert **gms/hour/truck** to **Tons/day/100 trucks.**

Tons/day/100 trucks = ((gms/hour/truck)*24*0.66*100)/90700.

Convert **Tons/day/100 trucks** to **Tons/year/100 trucks.**

Cost involved / Ton Emission Reduction = (50,000$/Tons/year/100 trucks).

Table 3.14.A.2 Number of Truck Spaces in Nashville EAC Counties

County	Route	Spaces	Miles	Spaces/Mile
Cheatam	I -24	0	3	0.00
	I - 40	150	6	25.00
Davidson	I -24	630	32	19.69
	I - 40	15	32	0.47
	I - 65	300	23	13.04
Dickson	I - 40	150	18	8.33
Robertson	I -24	50	10	5.00
	I - 65	150	17	8.82
Rutherford	I -24	130	35	3.71
Sumner	I - 65	15	6	2.50
Williamson	I - 40	150	4	37.50
	I - 65	165	21	7.86
Wilson	I - 40	360	28	12.86
Total		2265	235	144.79

Table 3.14.A.3 Emission Reduction Achievable by Truck Stop Electrification

County	**NO_x tons/day**	**VOC tons/day**	**CO tons/day**	**$PM_{2.5}$ tons/day**
Davidson	0.77	0.07	0.65	0.012
Rutherford	0.11	0.01	0.09	0.002
Sumner	0.01	0.00	0.01	0.000
Williamson	0.26	0.02	0.22	0.004
Wilson	0.30	0.03	0.25	0.005
Cheatham	0.12	0.01	0.10	0.002
Dickson	0.12	0.01	0.10	0.002
Robertson	0.16	0.02	0.14	0.003
Total	1.86	0.18	1.56	0.030

Table 3.14.A.4 Estimated Cost of Emission Reductions by Truck Stop Electrification

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	$PM_{2.5}$ ($/ton)	Combined ($/ton)
All Counties	1671	17562	1985	103778	856

3.14.A.5 References:

[1]. http://www.epa.gov/otaq/retrofit/idling.htm browsed April 1, 2003.

[2]. http://www.dieselboss.com/truckstops.asp browsed August 26, 2003.

3.14.B.REDUCE SCHOOL BUS IDLING EMISSIONS

3.14.B.1.Basic Information

Each day, approximately 24 million students ride in 600,000 school buses in the US[1]. Most of the school buses use diesel fuel. The exhausts from the diesel engines are believed to be carcinogens. Results have shown that diesel bus emits more PM2.5 at idling than when it is moving[2]. Diesel emissions contain a far higher concentration of particulates. It's been the routine practice for school buses to idle for 2 main reasons:

1. Idling at loading and unloading areas to drop off or pick up the children.

2. Idling more than needed during warm-up and in colder climates.

Pollutions from school bus are in high during periods of peak use—early mornings and afternoons[2].

3.14.B.2.EPA Suggestions

EPA developed a program known as "Clean School Bus" to implement various strategies to control the emissions from school buses. One among them is Anti idling. Anti idling is the most popular way to improve the air quality in and around where children learn and play. In addition to improving the air quality, reducing the idling time will lead to less consumption of fuel thereby saving money. EPA prefers this technique as it is easier to implement. EPA is planning to require that each bus attempt to reduce its idling time by 30 minutes per day.

3.14.B.3.Reduction achievable

Calculations have been performed to determine amount of emission reduction achievable by reducing the idling time. The emissions (grams/hour/bus) for idling conditions for diesel and gasoline school buses were estimated using the EPA-recommended procedure of obtaining the emissions by running the MOBILE6 model for a speed of 2.5 mph for the arterial roadways category. Rest of the parameters is set as follow:

Year	=	2007.
Month	=	July.
Minimum Temperature	=	60 F.
Maximum Temperature	=	93 F.
Sulfur in diesel	=	112 ppm.

Table 3.14.B.1 shows the number of school buses by age in TN. Using the diesel sales fraction for each age vehicle in MOBILE6, the ratio of diesel bus to gasoline bus (weighed by age) was found to be 0.92:0.08 for Tennessee, 2002 [3].

Table 3.14.B.1 Number of Buses in Operation In TN 2001 – 2002 State Totals

Model Year	Age	Total Number of Buses	Mobile 6 Diesel Sales Fraction	Number of Diesel buses	Number of Gasoline buses
2002	1	593	0.958	568	25
2001	2	624	0.958	598	26
2000	3	618	0.958	592	26
1999	4	670	0.958	642	28
1998	5	594	0.958	569	25
1997	6	505	0.958	484	21
1996	7	515	0.958	493	22
1995	8	539	0.885	477	62
1994	9	602	0.852	513	89
1993	10	542	0.879	476	66
1992	11	528	0.990	523	5
1991	12	584	0.910	531	53
1990	13	527	0.876	462	65
1989	14	362	0.771	279	83
1988	15	210	0.750	158	53
1987	16	26	0.734	19	7
1986	17	2	0.673	1	1
Total		8,041		7,385	656

TN Diesel Fraction (7385/8041)	0.92
TN Gasoline Fraction (656/8041)	0.08

Table 3.14.B.2 lists the number of buses in each county in the Nashville EAC area. The diesel fraction of 92% determined from Table 3.14.B.1 was used to calculate the number of diesel and gasoline buses in each county.

Table 3.14.B.2 Number of School Buses, 2002[4]

County	Type - I	Type - II	Total
CHEATHAM CO.	73	7	80
DAVIDSON CO.	515	0	515
	80	0	80
ROBERTSON CO.	85	0	85
RUTHERFORD CO.	161	0	161
MURFREESBO	16	1	17
SUMNER CO.	190	1	191
WILLIAMSON CO.	169	0	169
WILSON CO.	115	0	115

Table **3.14.B.3A and B** shows the emission reductions achievable by reducing the idling time by 30 minutes for all the 8 counties. An example calculation is shown below:

Total number of buses in Cheatham county	=	80		
Number of diesel buses	=	80*0.92	=	74 bus.
Number of gasoline buses	=	80*0.08	=	6 bus.
Emission factor * Vehicle Speed (VOC, for example)	=	0.67 gm/mile * 2.5 mph		
	=	1.68 gm/hr/bus		
Rate of emissions from the diesel fleet	=	1.68gm/hr/bus*74bus		
	=	123.67gm/hr VOC		

Reducing the idling time by 30 minutes per day (0.5 hour/day) reduction achievable =

123.67 gm/hr * 0.5 hr/day = 61.83 gm/day (0.00007 tons/day) VOC.

Table 3.14.B.3A.Diesel school Bus

Speed	2.5	mph
Reducing Idling by	0.5	hr/day

CHEATHAM

					Reduction Achivable	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	0.67	1.68	74	123.67	**61.83**	**0.00007**
CO	2.48	6.20	74	456.01	**228.00**	**0.00025**
NO_x	11.16	27.89	74	2052.52	**1026.26**	**0.00113**
$PM_{2.5}$	0.62	1.55	74	113.75	**56.87**	**0.00006**

DICKSON

					Reduction Achivable	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	0.67	1.68	74	123.67	**61.83**	**0.00007**
CO	2.48	6.20	74	456.01	**228.00**	**0.00025**
NO_x	11.16	27.89	74	2052.52	**1026.26**	**0.00113**
$PM_{2.5}$	0.62	1.55	74	113.75	**56.87**	**0.00006**

DAVIDSON

					Reduction Achivable	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	0.67	1.68	474	796.10	**398.05**	**0.00044**
CO	2.48	6.20	474	2935.55	**1467.77**	**0.00162**
NO_x	11.16	27.89	474	13213.10	**6606.55**	**0.00728**
$PM_{2.5}$	0.62	1.55	474	732.26	**366.13**	**0.00040**

ROBERTSON

					Reduction Achivable	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	0.67	1.68	78	131.40	**65.70**	**0.00007**
CO	2.48	6.20	78	484.51	**242.25**	**0.00027**
NO_x	11.16	27.89	78	2180.80	**1090.40**	**0.00120**
$PM_{2.5}$	0.62	1.55	78	120.86	**60.43**	**0.00007**

RUTHERFORD

					Reduction Achivable	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	0.67	1.68	164	275.16	**137.58**	**0.00015**
CO	2.48	6.20	164	1014.62	**507.31**	**0.00056**
NO_x	11.16	27.89	164	4566.86	**2283.43**	**0.00252**
$PM_{2.5}$	0.62	1.55	164	253.09	**126.55**	**0.00014**

SUMNER

					Reduction Achivable	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	0.67	1.68	176	295.25	**147.63**	**0.00016**
CO	2.48	6.20	176	1088.72	**544.36**	**0.00060**
NO_x	11.16	27.89	176	4900.39	**2450.20**	**0.00270**
$PM_{2.5}$	0.62	1.55	176	271.58	**135.79**	**0.00015**

WILLIAMSON

					Reduction Achivable	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	0.67	1.68	155	261.25	**130.62**	**0.00014**
CO	2.48	6.20	155	963.32	**481.66**	**0.00053**
NO_x	11.16	27.89	155	4335.95	**2167.97**	**0.00239**
$PM_{2.5}$	0.62	1.55	155	240.29	**120.15**	**0.00013**

WILSON

					Reduction Achivable	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	0.67	1.68	106	177.77	**88.89**	**0.00010**
CO	2.48	6.20	106	655.51	**327.76**	**0.00036**
NO_x	11.16	27.89	106	2950.50	**1475.25**	**0.00163**
$PM_{2.5}$	0.62	1.55	106	163.51	**81.76**	**0.00009**

Table 3.14.B.3B.Gasoline school Buses

Speed	2.5	mph
Reducing Idling by	0.5	hr/day

CH ATHAM							**DICKSON**						
					Reduction Achivable							**Reduction Achivable**	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**	POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	7.73	19.34	6	123.74	**61.87**	**0.0001**	VOC	7.73	19.34	6	123.74	**61.87**	**0.0001**
CO	95.15	237.87	6	1522.40	**761.20**	**0.0008**	CO	95.15	237.87	6	1522.40	**761.20**	**0.0008**
NO_x	8.18	20.45	6	130.87	**65.44**	**0.0001**	NO_x	8.18	20.45	6	130.87	**65.44**	**0.0001**
$PM_{2.5}$	0.12	0.30	6	1.91	**0.95**	**0.0000**	$PM_{2.5}$	0.12	0.30	6	1.91	**0.95**	**0.0000**
DAVIDSON							**ROBERTSON**						
					Reduction Achivable							**Reduction Achivable**	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**	POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	7.73	19.34	41	796.60	**398.30**	**0.0004**	VOC	7.73	19.34	7	131.48	**65.74**	**0.0001**
CO	95.15	237.87	41	9800.42	**4900.21**	**0.0054**	CO	95.15	237.87	7	1617.54	**808.77**	**0.0009**
NO_x	8.18	20.45	41	842.48	**421.24**	**0.0005**	NO_x	8.18	20.45	7	139.05	**69.52**	**0.0001**
$PM_{2.5}$	0.12	0.30	41	12.29	**6.14**	**0.0000**	$PM_{2.5}$	0.12	0.30	7	2.03	**1.01**	**0.0000**
RU RFORD							**SUMNER**						
					Reduction Achivable							**Reduction Achivable**	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**	POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	7.73	19.34	14	275.33	**137.67**	**0.0002**	VOC	7.73	19.34	15	295.44	**147.72**	**0.0002**
CO	95.15	237.87	14	3387.33	**1693.66**	**0.0019**	CO	95.15	237.87	15	3634.72	**1817.36**	**0.0020**
NO_x	8.18	20.45	14	291.19	**145.59**	**0.0002**	NO_x	8.18	20.45	15	312.45	**156.23**	**0.0002**
$PM_{2.5}$	0.12	0.30	14	4.25	**2.12**	**0.0000**	$PM_{2.5}$	0.12	0.30	15	4.56	**2.28**	**0.0000**
WILLIAMSON							**WILSON**						
					Reduction Achivable							**Reduction Achivable**	
POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**	POL	gm/mile	gm/hr/vehi	No. of Vehicles	gm/hr	**(gm/day)**	**Tons/day**
VOC	7.73	19.34	14	261.41	**130.70**	**0.0001**	VOC	7.73	19.34	9	177.88	**88.94**	**0.0001**
CO	95.15	237.87	14	3216.06	**1608.03**	**0.0018**	CO	95.15	237.87	9	2188.44	**1094.22**	**0.0012**
NO_x	8.18	20.45	14	276.46	**138.23**	**0.0002**	NO_x	8.18	20.45	9	188.13	**94.06**	**0.0001**
$PM_{2.5}$	0.12	0.30	14	4.03	**2.02**	**0.0000**	$PM_{2.5}$	0.12	0.30	9	2.74	**1.37**	**0.0000**

Table 3.14.B.4 summaries the emission reduction achievable in each of eight counties in the Nashville EAC area. The Table shows the total emission reduction obtained by reducing idling in diesel and gasoline buses.

Table 3.14.B. 4.Total Reduction Achievable in Nashville EAC area.

County	NO_x tons/day	VOC tons/day	CO tons/day	$PM_{2.5}$ tons/day
Davidson	0.0073	0.0009	0.0070	0.0004
Rutherford	0.0027	0.0003	0.0024	0.0001
Sumner	0.0029	0.0003	0.0026	0.0002
Williamson	0.0025	0.0003	0.0023	0.0001
Wilson	0.0017	0.0002	0.0016	0.0001
Cheatham	0.0012	0.0001	0.0011	0.0001
Dickson	0.0012	0.0001	0.0011	0.0001
Robertson	0.0013	0.0001	0.0012	0.0001
Total	0.0208	0.0024	0.0193	0.0011

Encouraging the anti-idling program in Diesel school buses could reduce NOx by 0.02 tons/day. Though it's a small reduction that we can achieve, it may improve air quality in and around the schools.

3.14.B.4.References:

1.http://www.epa.gov/otaq/schoolbus/index.htm browsed August 12, 2003.

2.John Wargo, Ph.D. "Children's Exposure to Diesel Exhaust on School Buses", Connecticut, February 2002. Obtained from the Internet at http://www.ehhi.org/diesel/pr_diesel1.html, accessed August 12, 2003.

3.http://www.epa.gov/otaq/schoolbus/basicinfo.htm browsed August 12, 2003.

4.http://www.k-12.state.tn.us/asr0102/ browsed August 12, 2003.

3.15 IMPROVE TRANSIT

Transit service in the Nashville area currently consists of bus service provided by the MTA (Metro Transit Authority). A new commuter rail service is planned to begin in 2005 providing transit service between Lebanon and downtown Nashville. Current emission estimates from on-road mobile sources for the 8-county Nashville EAC area are based on a projected increase in VMT from 45.5 million vehicle-miles/day in 2002 to 53.0 million vehicle-miles/day in 2007. This is an average 16.6% increase over the 5-year period. Expanding transit service can serve to divert many of these trips from automobiles, vans and light trucks to buses and the new commuter rail service. Estimates of emission reductions expected from improved transit service are given below.

3.15A Improve Bus Ridership. The existing bus service is provided by 107 transit buses, serving 40 routes in the Nashville area *(1)*. In May 2003 a total of 482,365 passengers utilized bus service, providing $421,677 of revenue to the MTA. Passenger-miles per day were 96,029 and vehicle revenue miles per day were 13,643 *(1)*. The average number of passengers per day is 16,000. Each passenger rides an average of 6 miles. The average number of passengers per revenue mile was 7. The average bus travels 128 miles per day. The Nashville Area MPO estimates that transit ridership could be increased by 10% by 2007 *(1)*. This increase in ridership could be accommodated without adding new buses.

Emission reductions achievable through increased bus ridership has been estimated based on a 10% increase in passenger-miles of travel on buses, and assuming that an equal number of vehicle miles of travel is diverted from automobiles, vans, and light trucks. The daily increase in bus use is estimated to be 9,600 passenger-miles. Table 3.15A.1 below shows the composite emission factors taken from the MOBILE6.2 model *(2)* for the composite national default fleet of light duty gasoline cars, vans, and light trucks (including SUVs) for 2007. The emission factors were multiplied times 9,600 vehicle-miles of travel per day diverted to bus travel to estimate the daily tons/day of emission reduction. It is assumed that bus emissions will not increase since no new buses or routes are to be added.

Table 3.15A.1 Emissions From Light Duty Vehicle Trips Diverted to Bus Travel.

Pollutant	Emission from Light Duty Vehicles (g/mile)	(miles/day)	(tons/day)
NOx	0.909	9600	0.01
VOC	1.181	9600	0.012
CO	13.241	9600	0.14
PM-2.5	0.012	9600	0.00013

The emission reductions will occur throughout the Nashville EAC area, but it is impossible to determine exactly where they occur. Most of the additional transit trips are expected to occur in Davidson County, so all the emission reduction credits are assigned to Davidson County as shown in Table 3.15A.2 below.

The cost of achieving this reduction in emissions is assumed to be zero (See Table 3.15A.3). There should actually be a cost savings to the bus riders. Bus service cost to riders is $1.25 per trip. The average trip is 6 miles, equal to an average cost of $0.20 per mile (not including parking costs). The cost to operate an automobile is typically $0.32 per mile, so bus users should save money by using the bus.

Table 3.15A.2 Emission Reductions Achievable by Improved Bus Ridership

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.01	0.012	0.14	0.00013
Rutherford	0	0	0	0
Sumner	0	0	0	0
Williamson	0	0	0	0
Wilson	0	0	0	0
Cheatham	0	0	0	0
Dickson	0	0	0	0
Robertson	0	0	0	0
Total	0.01	0.012	0.14	0.00013

Table 3.15A.3 Estimated Cost of Emission Reductions for Improved Bus Ridership

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties	0	0	0	0	0

References for Section 3.15A:

(1) Transit data provided by Matt Meservy of the Nashville Area MPO.
(2) MOBILE6.2 Emission Factor Model, U.S. Environmental Protection Agency, available on the web at www.epa.gov/otaq/m6.htm

3.15B NEW RAIL SERVICE

Potential emission reductions as a result of the new Nashville to Lebanon commuter rail system (in Davidson and Wilson counties) were calculated as follows.

First, using the data provided by the *Regional Transportation Authority* [1], the commuter rail ridership and passenger mile projections for 2007 were calculated as shown in table 3.15b.1.

ile Projections for 2007

From Station	To Station	Distance between Stations (mile)	2007 Daily Ridership (passenger)	2007 Inbound Passengers on Each Leg (passenger)	2007 Inbound Passengers-Miles on Each Leg (mile)
Lebanon	Martha Station	9.2	191	191	1,757
Martha Station	Mount Juliet	8.0	223	414	3,312
Mount Juliet	Chandler Road	6.4	384	798	5,107
Chandler Road	Donelson Pike	4.8	434	1232	5,914
Donelson Pike	Riverfront	8.0	369	1601	12,808
Totals		36.4	1601		28,898
Total Daily Passenger Miles (inbound and outbound) =				2 x 28,898 =	57,796

Next, the emissions from light duty vehicle were estimated in units of gram/mile, using the national default MOBILE6 inputs. Those emission numbers were multiplied times the total daily passenger miles to yield the emissions from light duty vehicles that would otherwise have traveled an equivalent distance if there were no rail services (see table 3.15b.2).

The emissions from the locomotives were estimated, assuming 3,000 bhp-hr/day for one locomotive. The locomotive emission factors were taken from *EPA* [2].

Table 3.15b.2 Emissions from Light Duty Vehicles and Locomotives

	Emissions from Light Duty Vehicles		Emissions from Locomotives	
	(g/mile)	(ton/day)	(g/bhp-hr)	(ton/day)
NO_X	0.909	0.058	5.000	0.017
VOC	1.181	0.075	0.260	0.001
CO	13.241	0.843	1.280	0.004
PM	0.012	0.001	0.170	0.001

The potential emission reductions achievable by the new rail service were then estimated by subtracting the emissions from locomotives from the emissions from light duty vehicles. The results are summarized in table 3.15b.3. No estimates of costs were made for diverting auto trips to the commuter train.

Table 3.15b.3 Emission Reductions Achievable by New Rail Service

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Rutherford	-	-	-	-
Sumner	-	-	-	-
Williamson	-	-	-	-
Cheatham	-	-	-	-
Dickson	-	-	-	-
Robertson	-	-	-	-
Davidson and Wilson	0.041	0.074	0.839	0.000
Total	0.041	0.074	0.839	0.000

Reference

1. Regional Transportation Authority, Financial Plan, May 2003.
2. U.S. Environmental Protection Agency, Office of Mobile Sources, Emission Factors for Locomotives, December 1997.

3.16 REDUCE BUS FARES ON AIR QUALITY ACTION DAYS

3.16.1 Introduction. Reducing bus fares on Air Quality Action Days (AQADs) might be used to encourage additional bus use and eliminate an equivalent number of trips using private vehicles. The concept evaluated herein assumes that if bus service were free on AQADs, then bus ridership might double. The emission reductions achievable would be equal to the emissions from cars, vans and light trucks (including SUVs) that would otherwise have been used instead of riding the bus. The cost of this control measure would be equal to the lost fares from the existing riders plus the "new" riders that would be using the service only on AQADs. Estimates of emission reductions expected from the measure and costs are given below.

3.16.2 Existing Bus Service. The existing bus service is provided by 107 transit buses, serving 40 routes in the Nashville area *(1)*. In May 2003 a total of 482,365 passengers utilized bus service, providing $421,677 of revenue to the MTA. Passenger-miles per day were 96,029 and revenue per day was $13,600 *(1)*. The average number of passengers per day is 16,000. Each passenger rides an average of 6 miles. The average number of passengers per revenue mile was 7. The average bus travels 128 miles per day. This analysis assumes that transit ridership could be increased by 100% on AQADs without adding new buses.

Emission reductions achievable through free bus fares has been estimated based on a 100% increase in passenger-miles of travel on buses, and assuming that an equal number of vehicle miles of travel is diverted from automobiles, vans, and light trucks. The daily increase in bus use is estimated to be 96,000 passenger-miles. Table 3.16.1 below shows the composite emission factors taken from the MOBILE6.2 model *(2)* for the composite national default fleet of light duty gasoline cars, vans, and light trucks (including SUVs) for 2007. The emission factors were multiplied times 96,000 vehicle-miles of travel per day diverted to bus travel to estimate the daily tons/day of emission reduction. It is assumed that bus emissions will not increase since no new buses or routes are to be added.

Table 3.16.1 Emissions From Light Duty Vehicle Trips Diverted to Bus Travel.

Pollutant	Emission from Light Duty Vehicles		
	(g/mile)	(miles/day)	(tons/day)
NOx	0.909	96,000	0.10
VOC	1.181	96,000	0.12
CO	13.241	96,000	1.4
PM-2.5	0.012	96,000	0.0013

The emission reductions will occur throughout the Nashville EAC area, but it is impossible to determine exactly where they occur. Most of the additional transit trips are expected to occur in Davidson County, so all the emission reduction credits are assigned to Davidson County as shown in Table 3.16.2 below.

The cost of achieving this reduction in emissions is estimated as two times the normal daily revenues, divided by the tons of emissions reduced (See Table 3.16.3). Daily revenues are currently $13,600. If fares are free on AQADs, then revenue from existing riders will be lost as well as the revenue from "new" riders. The daily revenue loss would be $27,400. The cost per ton of NOx emissions reduced would be $27,000/0.1 tons NOx, equal to $270,000/ton NOx. The cost per ton for other pollutants is shown in Table 3.16.3. These costs are the costs to the transit operator. The bus users will actually save money, since their travel cost will be free on AQADs. The cost to the transit operator may be closer to half the value shown below, since the increase in ridership may not increase the cost of bus operations significantly above the normal daily cost.

Table 3.16.2 Emission Reductions Achievable by Doubling Bus Transit Use on Air Quality Action Days.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.1	0.12	1.4	0.0013
Rutherford	0	0	0	0
Sumner	0	0	0	0
Williamson	0	0	0	0
Wilson	0	0	0	0
Cheatham	0	0	0	0
Dickson	0	0	0	0
Robertson	0	0	0	0
Total	0.1	0.12	1.4	0.0013

Table 3.16.3 Estimated Cost of Emission Reductions for Free Bus Service on Air Quality Action Days.

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties	270,000	225,000	19,300	20,700,000	16,700

References for Section 3.16:

(1) Transit data provided by Matt Meservy of the Nashville Area MPO.
(2) MOBILE6.2 Emission Factor Model, U.S. Environmental Protection Agency, available on the web at www.epa.gov/otaq/m6.htm

3.17 CONSTRUCTION EQUIPMENT EMISSION REDUCTION

EPA's NONROAD model was used to estimate the emission reduction that might be achieved from construction equipment in Cheatham, Davidson, Dickson, Robertson, Rutherford, Sumner, Williamson and Wilson counties. The NONROAD model contains inventories of all types of construction equipment and emission factors for that equipment. Construction equipment includes bulldozers, loaders, etc. that are powered by gasoline and diesel engines. A lot of construction equipment is old and has much higher emissions than new equipment. Replacing old construction equipment with new equipment was considered as a 'control method' for reducing emissions from construction equipment. Model runs were performed for the analysis year of 2007. The proposed non-road gasoline fuel sulfur content of 33 ppm and diesel fuel sulfur content of 500 ppm for year 2007 were used while running the model. Non-road diesel fuel currently has sulfur levels of about 3,400 ppm on average. Starting in 2007, fuel sulfur levels in non-road diesel fuel will be limited to a maximum of 500ppm, the same as the current highway diesel fuel sulfur content and this diesel sulfur content will further be reduced to 15 ppm by year 2010. On the other hand the sulfur level of on-road diesel fuel will be reduced to a maximum level of 112 ppm by the year 2006 from its current level of 500 ppm and will further be reduced to a level of 15 ppm by year 2010. The proposed on-road and off-road sulfur fuel contents are shown in the following graph.

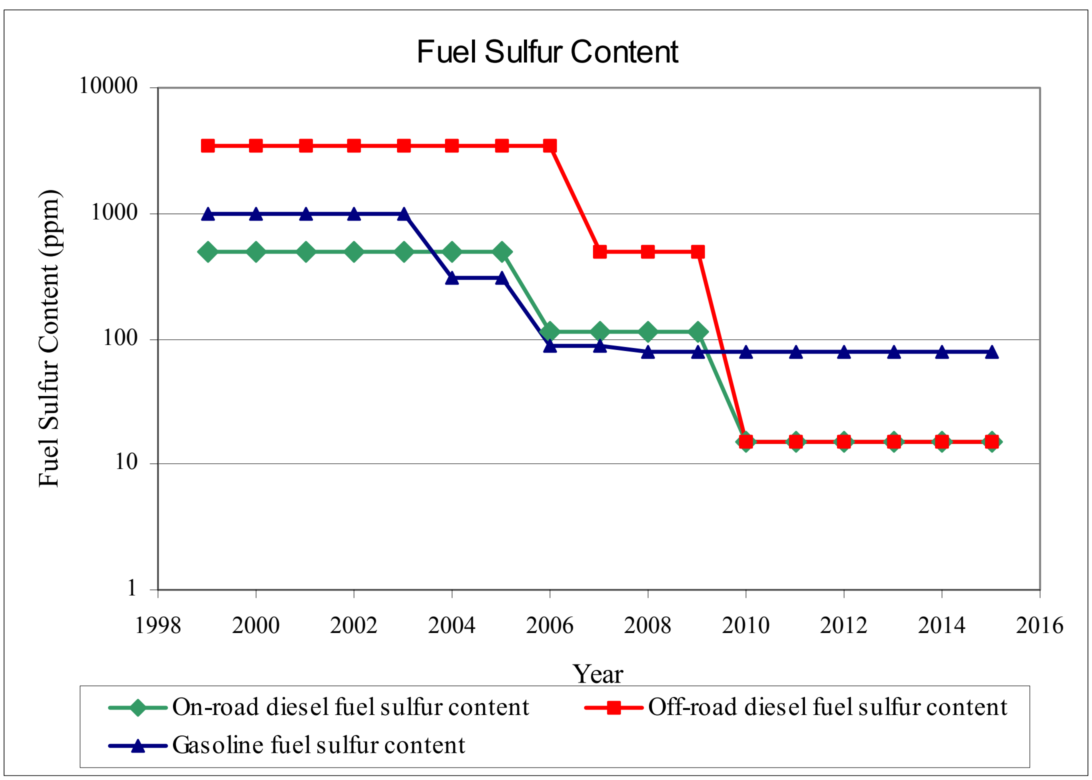

Figure 3.17.1 Fuel sulfur contents

For the base case, emissions from a population of equipment that has both old and new construction equipment were calculated using the NONROAD model. For the "new equipment" scenario emissions were calculated by taking out all old construction equipment and replacing them with new construction equipment while running the NONROAD model. Calculated emissions from the "new equipment" scenario were lower than the base case since new equipment will have lower emission factors. The achievable emission reduction is the difference in emissions between the base case and the "new equipment" scenario. The table below shows input parameters used to run the NONROAD model.

Table 3.17.1 Input parameters for NONROAD model.

Parameters	Values
Analysis Year	2007
Max/Min/Avg. Temperature	60/93/82
Oxygen Weight %	0.0
Gas Sulfur %	0.0033
Diesel Sulfur %	0.05
CNG/LPG Sulfur %	0.003
Stage II Control %	0.0

The following total emission reductions in NOx, VOC, CO and $PM_{2..5}$ can be achieved from construction equipment by replacing all old construction equipment with new equipment.

Table 3.17.2 Total emission reduction achievable by 'New Equipment' in 2007

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	$PM_{2.5}$ (tons/day)
Davidson	1.805	0.219	0.804	0.167
Rutherford	0.720	0.087	0.321	0.066
Sumner	0.295	0.036	0.131	0.027
Williamson	1.003	0.121	0.447	0.093
Wilson	0.250	0.030	0.112	0.023
Cheatham	0.095	0.012	0.042	0.009
Dickson	0.076	0.009	0.034	0.007
Robertson	0.068	0.008	0.030	0.006
SUM	4.312	0.522	1.921	0.398

The above emission reductions are 32.4% of NOx, 28.5% of VOC, 8.6% of CO and 39.7% of $PM_{2.5}$ emissions from construction equipment in each county.

After determining the total emission reduction from the eight counties, the calculated reductions were split into emission reduction from TDOT contractors and emission reduction from all other contractors. The allocation was based on the ratio of the projected area of land that will be used for construction of roads and area of land that will be used for all other constructions in year 2007.

Table 3.17.3 Total acres of land for all construction and acres of land for road construction in 2007

County	Total acres of land for all construction	Acres of land for road construction
Davidson	1936	386
Rutherford	605	212
Sumner	621	100
Williamson	843	105
Wilson	591	106
Cheatham	158	33
Dickson	227	41
Robertson	422	53

<u>3.17.1 For TDOT Contractors</u>. Emission reductions allocated to TDOT contractors based on the fraction of area of land that will be used for construction of roads is shown in table 3.17.1.1.

Table 3.17.1.1 Emission reduction achievable by 'New Equipment' from TDOT contractors

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	$PM_{2.5}$ (tons/day)
Davidson	0.360	0.044	0.160	0.033
Rutherford	0.252	0.031	0.112	0.023
Sumner	0.048	0.006	0.021	0.004
Williamson	0.125	0.015	0.056	0.012
Wilson	0.045	0.005	0.020	0.004
Cheatham	0.020	0.002	0.009	0.002
Dickson	0.014	0.002	0.006	0.002
Robertson	0.009	0.001	0.004	0.001
SUM	0.872	0.105	0.388	0.080

3.17.2 For All Contractors. Emission reduction allocated to all contractors other than TDOT contractors based on the fraction of area of land that will be used for all construction work other than road construction is shown in table 3.17.2.1

Table 3.17.2.1 Emission reduction achievable by 'New Equipment' from all contractors

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	$PM_{2.5}$ (tons/day)
Davidson	1.445	0.175	0.644	0.133
Rutherford	0.468	0.057	0.209	0.043
Sumner	0.247	0.030	0.110	0.023
Williamson	0.878	0.106	0.391	0.081
Wilson	0.205	0.025	0.092	0.019
Cheatham	0.075	0.009	0.033	0.007
Dickson	0.062	0.008	0.028	0.006
Robertson	0.060	0.007	0.027	0.006
SUM	3.44	0.416	1.533	0.317

Replacing all old equipment with new equipment may not be a cost effective policy for reducing emissions. Instead of replacing all old equipment with new equipment contractors could retrofit existing equipment with particulate traps and NOx catalysts. The Voluntary Diesel Retrofit Program developed by EPA is designed to get emission reductions from construction equipment. The program addresses pollution from diesel non-road equipment in addition to heavy-duty vehicles that are currently on the road. The diesel retrofit program is expected to reduce emissions from non-road diesel equipment by up to 58% for CO and 20% for NOx. NOx reductions that can be achieved from replacing old equipment with new equipment are greater than could be achieved from retrofitting diesel engines, but the cost will also be higher.

3.17.3 Cost Analysis. The Texas Commission on Environmental Quality (TCEQ) reported that the average estimated cost effectiveness of approved projects for the Texas Emission Reduction Plan (TERP) emission reduction incentive grant on the purchase of new construction equipment for fiscal years of 2002 and 2003 is $10,000/tons of NOx. This corresponds to a cost of $43,000/day for the purchase of new equipment to get a reduction of 4.312 tons of NOx/day from the eight counties. Calculating the cost of emission reductions for other pollutants gave the following values.

Table 3.17.3.1 Estimated Cost of Emission Reductions from Replacing Old Construction Equipment With New Equipment

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	$PM_{2.5}$ ($/ton)	Combined ($/ton)
All Counties	10,000	82,000	22,000	108,000	6,000

3.18 AIRPORT SERVICE EQUIPMENT EMISSION REDUCTION

3.18.1 New Airport Service Vehicles. According to the USEPA's NONROAD model, airport service vehicles exist in three out of the eight counties considered in this study. Those three counties are Davidson, Rutherford and Wilson.

EPA's NONROAD model was run for the year 2007 for those three counties with and without the control measure. Here again replacing all old airport service equipment with new equipment was considered as a control measure and the two NONROAD model runs were performed to determine the resulting emissions. The base case included old and new airport service equipment for running the NONROAD model while the scenario with the 'control measure' considered the case where all old airport service equipments are replaced by new airport service vehicles. The difference in emission between the base case and the 'control measure' scenario provides an estimate of achievable emission reductions from airport service equipment in year 2007. Input parameters used to run the NONROAD model are the same as those shown in table 3.17.1. Total emission reductions from airport service equipment that can be achieved by replacing old airport service equipment with new equipment are shown below.

Table 3.18.1.1 Total Emission Reduction Achievable From Airport Service Equipment by Replacing All Old Equipment With New Equipment

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	$PM_{2.5}$ (tons/day)
Davidson	0.0392	0.00313	0.0234	0.00191
Rutherford	0.0034	0.00027	0.0020	0.00017
Wilson	0.0003	0.00002	0.0002	0.00001
SUM	0.0429	0.00343	0.0256	0.00209

The above emissions from airport service equipment reflect a 38.6% reduction in NOx , 29.1% reduction in VOC, 13.0% reduction in CO, and a 32.1% reduction in $PM_{2.5}$ emissions.

3.18.2 Cost Analysis. According to the Texas Commission on Environmental Quality (TCEQ) report on projects approved for the Texas Emission Reduction Plan (TERP) emission reduction incentive grant for fiscal year of 2002, estimated average cost effectiveness on the purchase of new airport service equipment is $8200/tons of NOx. This corresponds to a cost of $ 350/day for the purchase of new equipment to get a reduction of 0.0429 tons of NOx/day from the three counties. Calculating the cost of emission reductions for the other pollutants gave the following values.

Table 3.18.2.1 Estimated Cost of Emission Reduction from Airport Service Equipment by Replacing Old Equipment

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	$PM_{2.5}$ ($/ton)	Combined ($/ton)
All Counties	8,200	102,000	13,700	167,000	4,700

Reference

1. Calculation of Age Distributions in the NONROAD Model: Growth and Scrappage, NR-007a, EPA420-P-02-017, June 2002

2. Exhaust and Crankcase Emission Factors for NONROAD Engine Modeling - Compression-Ignition, NR-009b, EPA420-P-02-016, November 2002

3. Exhaust Emission Factors for NONROAD Engine Modeling - Spark-Ignition, NR-010c, EPA420-P-02-015, November, 2002

4. Texas Commission on Environmental Quality (TCEQ), Texas Emissions Reduction Plan (TERP) emission reduction incentive grants approved projects at http://www.tnrcc.state.tx.us/oprd/sips/grants.html#projects_selected

5. Federal Register, Part V, 40 CFR Parts 69, 80, 86, January 18, 2001

6. Federal Register, Part II, 40 CFR Parts 69, 80, 86, May 23, 2003

3.19 DIESEL CETANE ADDITIVES

A program has been initiated for the summer of 2004 in the East Tennessee area led by Mr. Ben Henneke of Clean Air Action Corporation (Tulsa OK) to introduce a diesel fuel cetane additive into the diesel fuel delivered to diesel refueling stations. The cetane additive requires no infrastructure as it is introduced directly into the fuel at the regional fuel storage and distribution point. The additive increases the cost of the fuel by approximately one cent per gallon. The pilot program is being funded by TVA to provide NOx emission reduction credits for use in a NOx emission trading program. The pilot program is expected to achieve a 3% reduction in NOx emissions from diesel-fueled vehicles (1). Ten percent of the estimated NOx reduction is being retired (no longer able to be used as an allowable credit), whereas the remainder (2.7%) is providing useable NOx credits for use by electric generating utilities.

Assuming a cost of $.01/gallon, a fuel usage of 6 mpg, a speed of 55 mph, 673 g NOx/hour, and a 3% reduction in NOx emissions due to the cetane additive, the cost of this control measure is estimated to be $4100/ton. The effect on particulate matter is minimal.

The actual reduction in NOx is a function of the specific year of application, the fraction of HDDV with exhaust gas recirculation, the average cetane number of the diesel fuel and the amount of cetane additive (which affects the cetane number). EPA estimates (1) a reduction of 3 % in NOx emissions with an increase of 5 to 6 points in cetane number from a base cetane number of 45. Cetane number of diesel fuel is similar to octane number in gasoline. An octane number of 93 means the fuel burns like a fuel containing 93% octane. A cetane number of 50 means the fuel burns like it contains 50% cetane. Some engines require high-octane fuel to retard fuel ignition and prevent knocking. Like high octane numbers, a higher cetane number means the fuel burns more slowly avoiding excessive combustion chamber temperatures and pressures. Lower combustion chamber temperatures and pressures reduce NOx formation.

Discussions are being held at the national level (U.S. EPA and others) to determine how such a program would be credited to local areas given the fact that fuel purchased in East TN, particularly with respect to diesel fuel, would be only partially consumed within the local area. Thus the question arises as to whether the 3% reduction can be claimed for the local area or only the fraction that is used in the local area.

Aside from the uncertainty as to what area gets the credit, it would appear that the cetane program is a viable approach for reducing NOx emissions and could be utilized as an NOx reduction strategy. Table 3.19.1 shows the estimated tons/day of emission reductions achievable for each of the 8 counties in the Nashville EAC, assuming a 3% reduction would be achieved from all diesel fueled on-road vehicles projected to occur in 2007. Table 3.19.2 shows the estimated cost associated with the emission reduction in dollars per ton of NOx emissions reduced.

Table 3.19.1 Emission Reductions Achievable by Cetane Additives

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.88	0	0	0
Rutherford	0.33	0	0	0
Sumner	0.15	0	0	0
Williamson	0.20	0	0	0
Wilson	0.22	0	0	0
Cheatham	0.12	0	0	0
Dickson	0.11	0	0	0
Robertson	0.26	0	0	0
Total	2.27	0	0	0

Table 3.19.2 Estimated Cost of Emission Reductions by Cetane Additives

County	NOx ($/ton)	VOC ($/ton)	CO ($/ton)	PM2.5 ($/ton)	Combined ($/ton)
All Counties	4,100	0	0	0	4,100

The political issues associated with the cetane additive program are as follows. First, the additive would likely need to be provided and required of all suppliers within a region, thus the requirement crosses over jurisdictional boundaries. For example, the pilot program encompasses all of East Tennessee due to the central location of major distributors. Legal requirements would need to be implemented much like the current requirements for low RVP gasoline used in current areas requiring I/M, so there is precedence within the state for fuel requirements. Second, the question of how much credit can be claimed by the local area, due to the fact that some vehicles would leave the local area, must be resolved. At minimum, areas should be able to utilize the fraction of the benefit that is estimated to occur within the area. Third, the current pilot program in East Tennessee is being conducted for the primary purpose of creating useable emission credits, with only a small fraction being retired. This allowable emission credit program would need to be eliminated, if the reductions are to be used as an emission reduction for attainment purposes.

References

(1) The Effect of Cetane Number Increases Due to Additives on NOx Emissions from Heavy Duty Highway Engines—EPA420-S-02-012, June 2002

3.20 LAND USE CONTROLS TO REDUCE VMT

3.20.1 Introduction. Land use controls can be used to reduce the growth in vehicle miles of travel (VMT) by zoning regulations and planning goals designed to reduce urban sprawl and encourage spatially compact urban development. Uncontrolled growth can lead to longer trips and more VMT growth than higher density, multiuse development where shorter trips and trips taken by walking, bicycling or transit can reduce highway VMT. The Nashville Area MPO is committed to a strategy of using land use controls, to the extent feasible, to reduce future VMT. Current estimates are that a 0.5% reduction in VMT growth may be achievable by 2007 through land use controls *(1)*.

3.20.1 Emission Reductions. The emission reductions achievable by land use controls designed to reduce VMT have been estimated based on the anticipated 0.5% reduction in VMT for 2007. The emission reduction for each pollutant is assumed to be equal to an equivalent proportional reduction of 0.5% in on-highway emissions. It is assumed that land use controls will reduce heavy-duty truck emissions as well as automobile, van, and light-truck emissions. As a result the emission reduction for 2007 for each pollutant is simply equal to 0.5% of the highway vehicle emissions shown in the emission tables in chapter 2. The emission reductions estimated for each county for NOx, VOC, CO and PM-2.5 is shown in Table 3.20.1. The cost of these reductions could not be determined.

Table 3.20.1 Emission Reductions From Land Use Controls to Reduce VMT.

County	NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson	0.26	0.11	1.34	0.0049
Rutherford	0.09	0.03	0.36	0.0015
Sumner	0.04	0.02	0.21	0.0009
Williamson	0.05	0.02	0.26	0.0010
Wilson	0.05	0.02	0.21	0.0010
Cheatham	0.03	0.01	0.13	0.0005
Dickson	0.03	0.02	0.16	0.0005
Robertson	0.06	0.02	0.21	0.0009
Total	0.61	0.24	2.89	0.01

References for Section 3.20:

(1) Data and estimates provided by Jeanne Stevens of the Nashville Area MPO August, 2003.

3.21. AIR QUALITY ACTION DAYS

3.21.1 Introduction. The concept of Air Quality Action Days (AQADs) is that AQADs will be declared on high ozone days, so actions can be taken to reduce precursor emissions. In order to be effective it is necessary that ozone levels be forecast at least one day in advance. Radio and television announcements can then be made stating that certain actions should be curtailed on the AQAD in order to reduce emissions. Actions that may be effective in reducing emissions include:

- Lower speed limits (e.g. "Drive 55")
- Ridesharing
- Diversion of private vehicle trips to transit, bicycle or walking
- Free transit service to encourage bus & train use
- Minimize vehicle idling (cars & trucks)
- Mow lawns and fill vehicle fuel tanks only after noon
- Ask people to refrain from unnecessary trips.

All these actions are voluntary and will only be as effective as participation in the program. Vigorous participation by media outlets will be necessary to notify the public of AQADs and encourage participation.

3.21.1 Emission Reductions. The emission reduction achievable on AQADs is difficult to estimate. Emission reductions for most of the actions listed above have already been estimated and included in previous sections of the report. It is anticipated that some or all of these actions will be taken on all days during the ozone season, not just on air quality action days. The only two actions listed above that have not been previous analyzed are "mow lawns and fill vehicle fuel tanks only after noon" and "ask people to refrain from unnecessary trips". Mowing lawns and filling fuel tanks after noon will not eliminate emissions, but will transfer the emissions to the afternoon or evening. It takes several hours for emission precursors to cause peak ozone concentrations. Lower morning peak-hour emissions may therefore reduce afternoon peak ozone levels.

Potentially the most effective action is to request people to refrain from unnecessary trips. People might be willing to defer a shopping trip, carpool to work, walk to work, bicycle to work, telecommute, postpone deliveries, or otherwise reduce private vehicle and truck trips. If 1% of all trips could be eliminated on AQADs, then a 1% reduction in VMT should be achieved. The emission reduction for each pollutant is assumed to be equal to an equivalent proportional reduction of 1.0% in on-highway emissions for 2007. It is assumed that AQAD participation will reduce heavy-duty truck emissions as well as automobile, van, and light-truck emissions. As a result the emission reduction for 2007 for each pollutant is simply equal to 1.0% of the highway vehicle emissions shown in the emission tables in chapter 2. The emission reductions estimated for each county for NOx, VOC, CO and PM-2.5 are shown in Table 3.21.1. The cost of these reductions could not be determined.

Table 3.21.1 Emission Reductions on Air Quality Action Days (AQADs).

County		NOx (tons/day)	VOC (tons/day)	CO (tons/day)	PM2.5 (tons/day)
Davidson		0.51	0.22	2.68	0.0098
Rutherford		0.17	0.06	0.72	0.0030
Sumner		0.08	0.04	0.41	0.0018
Williamson		0.11	0.04	0.51	0.0020
Wilson		0.11	0.03	0.43	0.0020
Cheatham		0.06	0.02	0.27	0.0010
Dickson		0.06	0.03	0.33	0.0010
Robertson		0.12	0.03	0.43	0.0018
Total		1.22	0.47	5.79	0.022