Final Report
Potential Emission Control Strategies Available for Evaluation by the City of San Antonio

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EXECUTIVE SUMMARY

The purpose of this study is to assist the City of San Antonio (CoSA) to develop an objective list of control measures that that can be evaluated by the CoSA in partnership with the Alamo Area Council of Government's (AACOG's) regional pollution control efforts. ENVIRON identified emission control measures that have the potential to reduce ozone in the CoSA, including its Extra-Territorial Jurisdiction (ETJ). We focused on controls of ozone precursors, nitrogen oxides (NOx) and volatile organic compounds (VOCs).

To identify potential emission control measures for the CoSA, we reviewed air quality plans for other regions in Texas to identify recently adopted emission control measures in those areas, EPA guidance documents, and other available resources. In addition, we analyzed the Texas Commission on Environmental Quality (TCEQ) emission inventories to determine the amount of emissions available for control in each source category. This report describes the methodology used to develop two top ten lists of control measures for the CoSA prioritized by potential emission reductions and cost effectiveness. For the measures included on the two top ten lists, this report describes each potential control measure, estimates the potential for reduction of ozone precursor emissions in the CoSA area and reports estimates of each measure's cost-effectiveness.

The control strategies analyzed in this report target emission reductions from mobile sources (i.e. on-road mobile and non-road mobile sources) and area sources. The emission inventory analysis showed that mobile sources, which include on-road vehicles and non-road equipment, are the largest contributor to CoSA area NOx emissions and point sources are the second largest contributor to CoSA area NOx emissions. Power plants and cement kilns are the two largest contributors to point source emissions, together accounting for 94% of point source NOx emissions. Power plants are operated by the CoSA-owned CPS Energy while cement kilns are outside of the purview of CoSA authority. Further control of power plants and cement kiln point sources was not investigated as part of this study due to the expected early retirement of two older power plant units (Deely 1 and Deely 2) and the current high level of control on the remaining power plant and cement kiln facilities. All other point sources (i.e. point sources that are not power plants or cement kilns) account for only 6% of point source NOx emissions; due to their small contributions to the emission inventory any associated emission control strategies are expected to result in limited emissions control. For the aforementioned reasons, point sources emission control measures are not included on either the top ten list prioritized by cost effectiveness or the top ten list prioritized by emission reductions.

Table ES-1 shows the top ten control measures, prioritized by (1) cost effectiveness and (2) emission reduction. The top ten list by cost effectiveness includes seven measures targeting emission reductions from non-road mobile sources, two measures targeting emission reductions from on-road mobile sources, and one measure targeting emission reductions from area sources. The top ten list by emission reductions includes five measures targeting emission reductions from non-road mobile sources, four measures targeting emission reductions from on-road mobile sources, and one measure targeting emission reductions from area sources.

There were eight measures that were common to both lists, and two measures on each list that were unique.

Table ES - 1. Top ten control measures by (1) cost effectiveness and (2) emission reduction (measures in bold text are common to both top ten lists).

Cost Effectiveness Top Ten List		Emission Reduction Top Ten List	
ID No.	**Measure**	**ID No.**	**Measure**
N8	**Locomotives Idling Reduction within City Limit**	**A5**	**VOC Content Limits for Surface Coatings**
N5	**Alternative Fuels – compressed natural gas (CNG)/liquid petroleum gas (LPG) for City-owned fleet**	O10	Restrict Long Term Idling
N3	**Diesel Retrofits and Engine Rebuilds for City-owned Construction Equipment**	**N8**	**Locomotives Idling Reduction within City limit**
N12	**City-owned Construction Equipment Replacement Program (replace Tier 0 and Tier 1 with Tier 4)**	**O17**	**Commuter Trip Reduction Programs (vanpool, carpool)**
N13	**City-owned Construction Equipment Replacement Program (replace Tier 0, Tier 1, and Tier 2 with Tier 4)**	O19	Increased Use of Non-Motorized Travel (Bike)
A5	**VOC Content Limits for Architectural, Traffic, and Industrial Maintenance Coatings**	**N13**	**City-owned Construction Equipment Replacement Program (replace Tier 0, Tier 1, and Tier 2 with Tier 4)**
O17	**Commuter Trip Reduction Programs (vanpool, carpool)**	**N3**	**Diesel Retrofits and Engine Rebuilds for City-owned Construction Equipment**
N9	Airport Terminal Gate Electrification	**N12**	**City-owned Construction Equipment Replacement Program (replace Tier 0 and Tier 1 with Tier 4)**
N11	Emission Specifications in Contracts	**O7**[1]	**On-road Vehicle Electrification for City-owned fleet**
O7[1]	**On-road Vehicle Electrification for City-owned fleet**	**N5**	**Alternative Fuels - CNG/LPG for City-owned fleet**

* The first letter of the measure ID indicates the applicable emission source: A: area sources, N: non-road mobile sources, O: on-road mobile sources

[1] Revised from non-road equipment to on-road vehicle focused measure in consultation with TCEQ and CoSA.

The most effective control measures for reducing emissions are commuter trip reduction programs (O17) which are estimated to reduce 354 tons per year (tpy) NOx and 245 tpy VOC, heavy duty truck long term idling reductions (O10) which is estimated to reduce 150 tpy NOx, and the city-owned construction equipment replacement program (N13) which is estimated to reduce 93.3 tpy NOx. Control measures that are most cost effective are locomotive idling reduction (N8), long term heavy duty truck idling restrictions (O10), alternative fuel engine replacements for city-owned equipment fleets (N5), and VOC content limits on surface coatings for city projects (A5), all with a cost effectiveness estimate of $6,400 or less.

1.0 INTRODUCTION

1.1 Background

In a letter dated April 16, 2014, on behalf of the City of San Antonio (CoSA), Councilman Ray Lopez requested that the Texas Commission on Environmental Quality (TCEQ) assist the CoSA in developing a list identifying potential air quality control measures available for evaluation by the CoSA. ENVIRON was contracted to conduct an objective third-party study to develop two shortlists of control measures that will be effective, viable, and can be utilized in partnership with the Alamo Area Council of Government's (AACOG's) regional pollution control efforts based on potential emission reductions and cost-effectiveness of the measures. This report, documenting the study, will be a useful reference or tool for many stakeholders as emission control strategies are being considered and implemented to improve air quality in the San Antonio area.

The TCEQ operates three Continuous Air Monitoring Stations (CAMS) in the San Antonio Area[1]. As of the end of 2014, the Camp Bullis monitor (CAMS 58) in northern San Antonio had a design value of 80 parts per billion (ppb), the San Antonio Northwest monitor (CAMS 23) had a design value of 75 ppb, and the Calaveras Lake monitor (CAMS 59) in southeastern San Antonio had a design value of 67 ppb.

Under the Clean Air Act, the United States Environmental Protection Agency (EPA) is required to review the National Ambient Air Quality Standards (NAAQS) periodically. On November 26, 2014, the EPA announced their intention to lower the ozone NAAQS from 75 ppb to a value in the 65-70 ppb range and to finalize the NAAQS by October 2015. Designations of attainment status are anticipated by October 2017 and will likely be based on monitored ozone levels in the 2014-2016 timeframe. Depending on where the NAAQS is set, the San Antonio area could potentially exceed the NAAQS. Because failure to comply with the health based NAAQS carries significant economic impacts, ozone air quality planning is important for San Antonio, and ozone precursor emission control strategies are a key component of air quality planning.

1.2 Objective

The objective of this study is to assist the CoSA to develop an objective list of control measures that can be evaluated by the CoSA in partnership with the AACOG's regional pollution control efforts. Two lists identifying and evaluating potential air quality control measures available for evaluation by the CoSA have been developed, with one list that prioritizes emission reductions and a second list that prioritizes cost effectiveness. For control strategies identified on these two potential project lists, estimates of nitrogen oxides (NOx) and volatile organic compound (VOC) emission reductions, and cost per ton of emissions reductions for each control strategy have been estimated. In addition, control factor files that can be used in the Comprehensive Air Quality Model with extensions (CAMx) have also been developed for each control measure identified on either of the two potential project lists.

[1] http://www.tceq.state.tx.us/cgi-bin/compliance/monops/8hr_attainment.pl

1.3 Relationship to Other Programs

There are a number of existing and in-development programs which are designed to reduce emissions and pollution in the San Antonio area. Below is a listing of such programs. The emission control measures analyzed in this study are based on specific measures that can be taken by the CoSA in coordination with current programs.

- **City of San Antonio Metropolitan Health District, Draft City Ordinance**: The proposed ordinance would require registration of businesses that are sources of air pollution within the CoSA and adopt the rules and regulations of the Texas Clean Air Act, Chapter 382 of the Texas Health and Safety Code. This registration program would provide information that can be used in determining strategies to lower ozone levels in San Antonio.[2]
- **AACOG** is participating in the **EPA's Ozone Advance Program** (OAP) which was started by the EPA to give agencies a pathway to work with cities that are on the cusp of nonattainment. The program encourages application of emission reductions to help these areas continue to meet the NAAQS.
- **AACOG Air Quality Health Alert (AQHA) Program**: Upon notification from TCEQ that high ozone is forecast, AACOG distributes an alert to media, schools, local governments and businesses along with information on steps that can be taken to minimize ozone precursor emissions. AACOG also has a banner program that encourages schools and organizations to display their AQHA banners on high ozone days.[3]
- **AACOG** sponsors the **NuRide Program** in the Greater San Antonio area (Atascosa, Bandera, Bexar, Comal, Guadalupe, Kendall, Medina, and Wilson Counties). The NuRide Program is an online carpool matching, alternative transportation tracking, and reward system. NuRide data available for the City of San Antonio area[4] indicates that in 2014, a total of 18.7 tons per year (tpy) of NOx emissions and 13.6 tpy of VOC emissions were reduced and $131K of NuRide rewards were redeemed as part of the program. Table 1-1 shows estimates of trip and VMT reductions from the NuRide program in 2014[4].

[2] Email communication from the City of San Antonio Metropolitan Heath District Staff, Kyle Cunningham, January 28 2015.
[3] Email communication from AACOG Staff, Brenda Williams, January 15, 2015.
[4] Email communication from AACOG Staff, Annette Prosterman, February 25, 2015.

Table 1-1. 2014 estimates of car trips and VMT reduced in the NuRide Program for the City of San Antonio.

Mode	Reduced Car Trips (1000s of trips)	Reduced VMT (1000s of miles)
Carpool	417	7,760
Transit	215	2,619
Vanpool	196	6,298
Telecommute	91	3,374
Walk	60	88
Bike	59	274
Compressed work week	4	70
Totals	**1,042**	**20,483**

- As part of its **Clean Fleet & Fuel Program, VIA Metropolitan Transit** (VIA) has taken a number of steps to control emissions. VIA replaced its paratransit fleet with propane vehicles.[5] All VIA buses are equipped with anti-idling controls and exhaust treatment systems.[5] 107 older diesel bus engines have been repowered with reduced emissions engines.[5] VIA recently purchased three all-electric buses that are in service in the downtown area.[6] In May 2010, VIA introduced four buses that run on compressed natural gas.[6] VIA also acquired 30 new diesel-electric hybrid buses that are in service along VIA's express routes to help daily commuters reduce the city's overall fuel consumption while cutting back on emissions.[6]
- **City of San Antonio Programs**:
  - **Linear Creekway Parks Program** provides expansion for bike and pedestrian connectivity while protecting San Antonio's creekways and watersheds. Accomplishments include: 46 miles of trails constructed, 40 miles of trail in design or construction with total funds allocation at $110M.[7]
  - **City vehicle fleet alternative fuel vehicles.** Approximately 10% of the city's on-road vehicle fleet is comprised of alternative fuel vehicles (propane or compressed natural gas), electric, or electric hybrid vehicles.[7]
  - **Use of low VOC content asphalt:** CoSA contractors and operations use warm-mix asphalt emulsion; cut-back asphalt is not used. The warm-mix asphalt is generally produced in a lower temperature range than cut-back asphalt which allows for lower VOC emissions associated with asphalt production and application.
  - **Traffic calming measures.** The CoSA has allocated $40M in bond funding to traffic calming project improvements within the downtown area from 2012-2017. Approximately 1/5 of that funding is allocated annually to bike and pedestrian facilities/amenities ($8M annually). An additional $1M annual allocation from Advanced

[5] Presentation to Citizen's Environmental Advisory Committee by VIA Metropolitan Transit, December 2013.
[6] http://www.viainfo.net/Planning/OtherInitiatives.aspx
[7] Email communication from City of San Antonio Office of Sustainability Staff, Liza Meyer, January 28, 2015.

Transportation District (sales-tax) funding is allocated for dedicated bike lanes/paths for areas outside of the downtown's 36 square mile area.

- **CPS Energy** (CPS) is a CoSA-owned, not-for-profit energy utility company. CPS owns a number of power plants in the San Antonio area and to the extent feasible and economical has installed emission controls on their electrical generating units (EGUs) as follows:
  - Induced Flue Gas Recirculation (IFGR) has been installed on a few older natural gas units to achieve a small amount of NOx reduction. CPS has installed all feasible and economical NOx controls at older natural gas units; additional NOx control is not expected due to the low capacity factors and expected retirement dates for the older natural gas units. It is not economical to install selective catalytic reduction (SCR) technology on older natural gas units, which only run at peak times and are currently projected for retirement in 7-15 years.[8]
  - The newest coal unit, Spruce 2, as well as Deely 2 and CPS' newer peaking turbines and combined cycle unit all already have SCR technology.
  - The Deely 1 and Deely 2 coal-fired units, which have been in-service since the late 1970s, will be indefinitely suspended by the end of 2018.[8]
  - CPS' current budget plans include installation of an SCR on the Spruce 1 unit at an estimated cost of $107M. Based on expected regulatory requirements and rate-case funding, the project is projected to be online in 2019.[8]
  - Low NOx coal & air nozzle with cross coupled and separated over fire air (SOFA) technology has been installed on all of units that it applies to (i.e. where SCR has not been installed); these units are operated at optimum levels to get the most NOx reduction possible. This is a relatively inexpensive technology compared to SCR, but produces marginal NOx reductions compared to SCR.[8]
  - CPS' overall generation strategy is referred to as the New Energy Economy (NEE). The NEE includes emission reductions due to renewables such as solar and wind, the early deactivation of the Deely 1 and Deely 2 units, and implementation of energy efficiency measures with the STEP (Save for Tomorrow Energy Plan).[8]
- **TCEQ Programs:** TCEQ, the Texas state environmental agency, has a comprehensive air quality program. The TCEQ's **Texas Emissions Reduction Program (TERP)** provides financial incentives to eligible individuals, businesses, or local governments to reduce emissions from polluting vehicles and equipment.[9] The TERP program is comprised of the following incentive grant programs[10]:
  - Diesel Emissions Reduction Incentive (DERI) Program:
    - Emissions Reduction Incentive Grants Program

[8] "CPS Energy Air Emission Control Strategies" (CPS Energy Air Emission Control Strategies for COSA Air Quality Group Feb 26 2014.pdf). Provided in email communication from City of San Antonio Office of Sustainability Staff, Liza Meyer, December 15, 2014.
[9] http://www.tceq.state.tx.us/airquality/terp
[10] Source: Texas Emissions Reduction Plan Biennial Report (2013-2014), TCEQ publication SFR-079/14, December 2014

    - Rebate Grants Program
    - Third-Party Grants Program
- Texas Clean Fleet Program (TCFP)
- Texas Natural Gas Vehicle Grant Program (TNGVGP)
- Drayage Truck Incentive Program (DTIP)
- Clean Transportation Triangle (CTT) Grant Program
- Alternative Fueling Facilities (AFFP) Program
- Texas Clean School Bus Program (TCSB)
- Light-Duty Motor Vehicle Purchase or Lease Incentive (LDPLI) Program
- New Technology Implementation Grants (NTIG) Program

Additional TERP programs include[10]:

- Energy Efficiency Programs:
    - Goal for Energy Efficiency
    - Energy Efficiency Programs in Institutions of Higher Education and Certain Government Entities
    - Texas Building Energy Performance Standards
- Regional Air Monitoring Program
- Health Effects Study
- Air Quality Research Support Program

1.4 Report Organization

This report presents the results of the study for each step in the analysis. Following this introduction section, Section 2 summarizes the NOx and VOC emission contributions by source for Bexar County, and presents the results of the qualitative screening analysis. Section 3 presents the results of the technical and economic analyses of the selected control measures. Section 4 presents key recommendations and limitations of the study. Section 5 lists the references used in the study.

2.0 SCREENING ANALYSIS OF CONTROL MEASURES

2.1 Emission Inventory

ENVIRON analyzed the NOx and VOC emission inventory for Bexar County, Texas to determine the magnitude of emissions by source sector in the CoSA and its Extra-Territorial Jurisdiction (ETJ). The Bexar County emission inventory was used as a surrogate for CoSA emissions based on relatively good agreement between CoSA (including ETJ) boundaries and Bexar County boundaries (see Figure 2-1). Point source locations were also analyzed in Bexar and surrounding Counties and it was determined that with the exception of a few small airports (not shown in Figure 2-1), there were no point sources that were either (1) in Bexar County, but not in the CoSA (including ETJ) area or (2) outside of Bexar County, but within the CoSA (including ETJ) area. The Bexar County emission inventory analysis informed the development and selection of emission control measures for the CoSA. All Bexar County anthropogenic emissions data were obtained from the TCEQ. Area, on-road, and non-road[11] inventories were acquired from the TCEQ's 2018 ozone air quality modeling emission input files[12], while point source emissions were obtained from TCEQ's 2012 point source database[13].

2.1.1 Analysis of Bexar County Emissions

The Bexar County emission inventory was used to identify major NOx and VOC emission sources in the CoSA (including the ETJ area). Area, on-road, and non-road emissions inventories were developed by TCEQ using county specific 2011 emission factor and activity data which was then projected to 2018 by applying growth and control factors[12]. On-road vehicle emissions were developed using the EPA MOVES2010b model[14]; non-road sector aircraft emissions were estimated using the Federal Aviation Administration (FAA) Emission Dispersion Modeling System (EDMS)[15], other non-road equipment emissions were estimated using the TexN model[16], while area source and non-road locomotive emissions were estimated using accepted emissions estimation protocol. Point source emissions were compiled from an annual survey of chemical plants, refineries, electric utility plants and other industrial sites that meet TCEQ point source reporting criteria[13].

[11] Non-road mobile sources include locomotives, aircraft, and other off-road equipment
[12] TCEQ, 2014. Email communication from Eddy Lin, October 15, 2014.
[13] 2012 Point Source data obtained from the State of Texas Air Reporting System (STARS) on September 23, 2014. The data collected was for sources reporting 1 ton per year and greater. Emissions data reported by sites that met the TCEQ reporting requirements as stated in 30 Texas Administrative Code, Section 101.10 for the 2012. The data is subject to revisions or updates.
[14] http://www.epa.gov/otaq/models/moves/moves-docum.htm
[15] http://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/edms_model/
[16] https://www.tceq.texas.gov/airquality/airmod/overview/am_ei.html/#nonroad

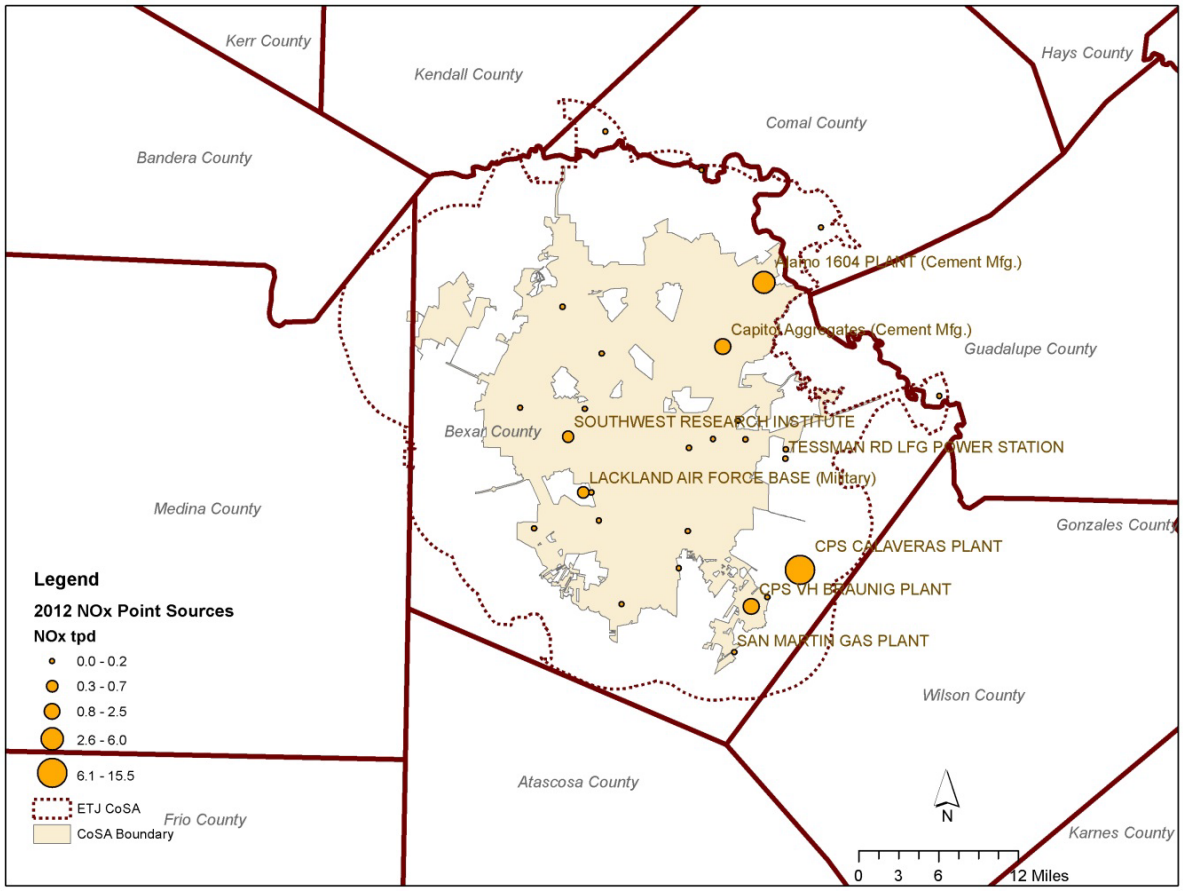

Figure 2-1. CoSA ETJ and Bexar County Boundaries with major NOx point sources.

According to the inventory data compiled (i.e. 2018 emissions for area, on-road, and non-road sources, and 2012 for point sources), total emissions in Bexar County are 73.1 tons per day (tpd) and 104 tpd of NOx and VOC emissions, respectively. Contributions by sector are shown in Figure 2-2. Mobile sources, including on-road vehicles and non-road equipment, is the largest contributor to NOx emissions (52%), point sources account for 38% of NOx emissions, and area sources account for 10% of NOx emissions. In contrast, a majority of VOC emissions (70%) come from area sources.

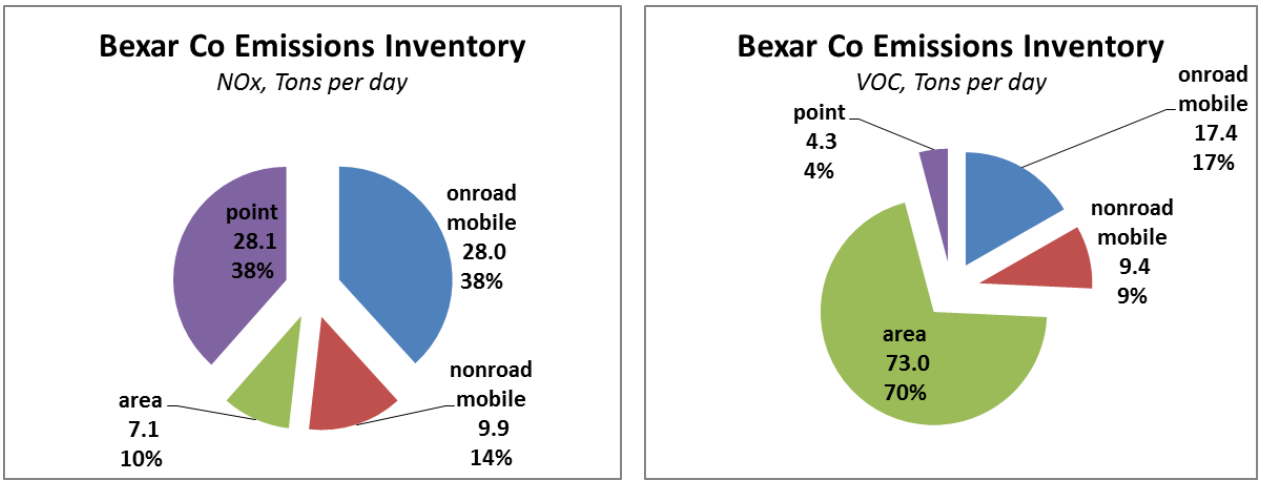

Figure 2-2. Bexar County NOx (left) and VOC (right) anthropogenic emission in tons per day by sector (2018 emissions for area, on-road, and non-road sources, and 2012 for point sources).

2.1.1.1 NOx Emissions

Table 2-1 shows a tabular summary of NOx emissions in Bexar County by sector and major source category. This section describes the major sources of NOx emissions in each source sector. In this section, the mobile source sector on-road vehicle and non-road equipment emissions are discussed separately.

On-road: On-road vehicles are the second largest contributor to NOx emissions, accounting for 38% of Bexar County anthropogenic NOx emissions. The emissions are dominated by light duty gasoline vehicles and trucks (53%) and heavy duty diesel vehicles (30%).

Non-road: Non-road mobile sources are the third largest contributor to NOx emissions, accounting for 14% of anthropogenic NOx emissions. The three largest non-road NOx emission sources are construction and mining equipment, locomotives, and aviation.

Area Sources: Area sources constitute the smallest NOx emissions of any anthropogenic sector in Bexar County, comprising approximately 10% of total anthropogenic NOx emissions. NOx area source emissions are primarily from the combustion of various fuel types in residential, commercial, and industrial settings and from the oil and gas sector.

Point sources: Point sources are the largest contributor to NOx emissions, accounting for 39% of Bexar County anthropogenic NOx emissions. A vast majority of point source NOx emissions in Bexar County are from two source categories: electric services and electric generating units (64%) and cement manufacturing plants (30%). There are two major power plant locations in the Bexar County area; both sites are operated by CPS Energy and located in the southeast part of the CoSA and CoSA ETJ. The Calaveras Lake Generating Station is the largest emitter (15.5 tpd NOx) and includes the coal-fired Deely and Spruce units and natural gas-fired Sommers unit,

with total facility-wide capacity of 3,129 MW. The Deely 1 and Deely 2 units are expected to be retired indefinitely beginning in late 2018; the Deely 1 and Deely 2 unit electricity generation will be replaced by the Rio Nogales Power Plant, a natural gas-fired facility located outside of CoSA ETJ in Seguin, Texas[17]. The Braunig Power Station is a natural-gas fired power plant with a total capacity of 1,415 MW and emissions of 2.1 tpd NOx. There are two major cement manufacturing plants in Bexar County, the Alamo 1604 Plant (6.0 tpd NOx) and the Capitol Aggregates Plant (2.5 tpd NOx); both are located in the northeastern part of the CoSA. Further control of electric sector and cement manufacturing point source facilities was not investigated as part of this study because of the expected retirements of Deely 1 and Deely 2 and the current level of controls on these facilities which are the extent feasible at this time.

Table 2-1. Ranked contributions to Bexar County NOx emissions by sector and source category.

NOx (tpd)	Percent of Sector NOx	Source Description
Point Sources		
17.9	64%	Electric Services
8.4	30%	Cement, Hydraulic
0.7	3%	National Security
0.5	2%	Noncommercial Research Organizations
0.6	2%	Other Source Categories
28.1	**100%**	**Point Subtotal**
On-road Vehicles		
8.7	31%	Light duty Gasoline Vehicles (LDGV)
8.4	30%	Heavy Duty Diesel Vehicles (HDDV)
6.0	21%	Light duty Gasoline Trucks (LDGT)
3.3	12%	Heavy Duty Gasoline Vehicles (HDGV)
0.8	3%	Light Duty Diesel Trucks (LDDT)
0.7	2%	Heavy Duty Diesel Buses (HDD Bus: School & Transit)
<0.1	0%	Light Duty Diesel Vehicles (LDDV)
<0.1	0%	Motorcycles (MC)
<0.1	0%	Heavy Duty Gasoline Bus (HDG Bus)
28.0	**100%**	**On-road Subtotal**
Non-road Mobile		
3.1	31%	Construction and Mining Equipment
2.4	24%	Locomotives
1.5	15%	Aviation (Aircraft and Ground Support Equip.)
1.0	10%	Commercial Equipment
0.7	8%	Industrial Equipment
0.6	6%	Agricultural Equipment
0.6	6%	Other Source Categories
9.9	**100%**	**Off-road Subtotal**

[17] http://newsroom.cpsenergy.com/blog/policy/coal-plant-operations-suspended-2018/

Area Sources		
2.0	28%	Fuel Comb - Residential
1.8	25%	Fuel Comb – Commercial
1.6	23%	Fuel Comb - Industrial Boilers
1.7	23%	Oil & Gas Production
<0.1	0%	Other Source Categories
7.1	**100%**	**Area Subtotal**
73.1		**Grand Total**

Table 2-2 shows major NOx point source emissions in Bexar County ranked by point source NOx emission contribution. Figure 2-1 depicts major NOx point sources in the CoSA ETJ region.

Table 2-2. Top NOx emitting point source facilities in Bexar County.

Bexar County Major NOx Facilities	NOx (tpd)	Percent of Point Source NOx
CPS Calaveras Plant (Electric Services)	15.5	55%
Alamo 1604 Plant (Cement Mfg.)	6.0	21%
Capitol Aggregates (Cement Mfg.)	2.5	9%
CPS VH Braunig Plant (Electric Services)	2.1	7%
Lackland Air Force Base (Military)	0.7	3%
Southwest Research Institute (Research)	0.5	2%
Tessman RD LFG Power Station (Electric Services)	0.2	1%
All Other Sources (<1% individual contribution)	0.8	3%
Total	**28.1**	**100%**

2.1.1.2 VOC Emissions

Table 2-3 shows a tabular summary of VOC emissions in Bexar County by sector and major source category. This section describes the major sources of VOC emissions in each source sector. In this section, the mobile source sector on-road vehicle and non-road equipment emissions are discussed separately.

Area Sources: Area sources emit 73.0 tpd of VOC and constitute 70% of all anthropogenic VOC emissions in Bexar County. 27.3 tpd (37%) of VOC emissions are from solvent utilization activities, surface coating operations account for 17.2 tpd (24%), gas stations account for 11.2 tpd (15%), and oil and gas production accounts for 8.0 tpd (11%).

On-road: On-road vehicle emissions account for 17% of Bexar County anthropogenic VOC emissions (17.4 tpd). Light duty gasoline vehicles (LDGV) and light duty gasoline trucks (LDGT) account for more than 80% (14.2 tpd) of on-road VOC emissions. Heavy duty gasoline vehicles constitute approximately 10% of on-road VOC emissions.

Non-road: Non-road mobile sources constitute 9% (9.4 tpd) of overall anthropogenic VOC emissions in the Bexar County. The largest non-road VOC sources are gasoline fueled equipment fleets including lawn and garden equipment, recreational equipment, and pleasure craft.

Point Sources: Point sources in Bexar County contribute slightly more than 4% of the total anthropogenic VOC emissions. Motor vehicles and car body facilities are the largest point source VOC emission sources, accounting for one quarter of point source VOC emissions.

Table 2-3. Ranked contributions to Bexar County VOC emissions by sector and source category.

VOC (tpd)	Percent of Sector VOC	Source Description
Point Sources		
1.1	25%	Motor Vehicles And Car Bodies
0.6	14%	Wood Kitchen Cabinets
0.5	13%	Petroleum Bulk Stations & Terminals
0.5	11%	Petroleum Refining
0.4	9%	Electric Services
0.4	9%	Cement, Hydraulic
0.2	5%	National Security
0.6	14%	Other Source Categories
4.3	**100%**	**Point Subtotal**
On-road		
9.6	55%	Light Duty Gasoline Vehicles (LDGV)
4.6	26%	Light Duty Gasoline Trucks (LDGT)
1.7	10%	Heavy Duty Gasoline Vehicles (HDGV)
0.8	4%	Motorcycles (MC)
0.6	3%	Heavy Duty Diesel vehicles (HDDV)
0.1	0%	Light Duty Diesel Trucks (LDDT)
<0.1	0%	Heavy Duty Diesel Buses (HDD Bus: School & Transit)
<0.1	0%	Light Duty Diesel Vehicles (LDDV)
<0.1	0%	Heavy Duty Gasoline Bus (HDG Bus)
17.4	**100%**	**On-road Subtotal**
Non-road Mobile		
3.1	33%	Lawn and Garden Equipment
1.8	19%	Recreational Equipment
1.5	16%	Pleasure Craft
1.4	15%	Commercial Equipment
0.8	8%	Construction and Mining Equipment
0.5	5%	Aviation (Aircraft and Ground Support Equip.)
0.3	3%	Other Source Categories
9.4	**100%**	**Off-road Subtotal**
Area Sources		
27.3	37%	Solvent Commercial Use
17.2	24%	Surface Coating
11.2	15%	Gas Stations
8.0	11%	Oil & Gas Production
2.2	3%	Miscellaneous Non-Industrial

VOC (tpd)	Percent of Sector VOC	Source Description
2.0	3%	Degreasing
2.0	3%	Industrial Processes
1.3	2%	Landfills
1.2	2%	Fuel Comb - Residential
0.5	1%	Other Source Categories
73.0	**100%**	**Area Subtotal**
104.0		**Grand Total**

Table 2-4 lists the largest VOC point source facilities in Bexar County.

Table 2-4. Top VOC emitting point source facilities in Bexar County.

Bexar County Major VOC Facilities	VOC (tpd)	Percent of Point Source VOC
Toyota Vehicle Assembly Plant	1.1	25%
Calumet San Antonio Refining LLC	0.5	11%
Cardell Cabinetry San Antonio Main Facility	0.3	7%
Capitol Aggregates Portland Cement	0.3	7%
Cardell Cabinetry San Antonio Timco Facility	0.3	6%
CPS Calaveras Plant	0.2	5%
Nustar Logistics San Antonio South Terminal	0.2	4%
Lackland Air Force Base	0.1	3%
Tessman Road Landfill	0.1	3%
Flint Hills/ Exxonmobile San Antonio Terminal	0.1	3%
Southwest Research Institute	0.1	3%
The Boeing Company - San Antonio	0.1	3%
CPS VH Braunig Plant	0.1	3%
Alamo Cement Company 1604 Plant	0.1	2%
Motiva San Antonio Market Terminal	0.1	2%
Other (< 0.1 tpd)	0.5	12%
Total	**4.3**	**100%**

2.2 Qualitative Screening Analysis

As part of the screening analysis, ENVIRON identified and compiled a master list of control measures. The objective of the screening analysis was to refine and reduce the master list to two shorter lists, with one listing the top ten control measures by emission reduction potential and a second listing the top ten control measures by cost effectiveness. Those measures included in the two top ten lists would be subject to further technical and economic analyses.

The screening assessment was performed on more than 59 emission control measures listed in the preliminary master list in Appendix A. To the extent that data and/or information were available, ENVIRON estimated preliminary potential emission benefits for the control strategies based on their control effectiveness or efficiency, and potential emission impacts based on the emission benefits and estimated ranges of penetration rates. Section 3 of this report presents

the results of the technical and economic analyses that provide refined emission reduction benefit estimates for the selected control measures.

The screening evaluation for these control measures was based on three components (1) preliminary potential estimates of achievable emission reductions, (2) literature estimates of cost-effectiveness, and (3) whether the measure could be implemented under CoSA authority.

Literature-based information on each of the control measures included in the master list was based on a variety of reports and studies. These include the EPA Menu of Control Measures for NAAQS Implementation[18], AACOG Potential Control Strategy List[19], Austin 2008 Eight-Hour Ozone Flex Plan, Potential Emission Reduction Strategies for Northeast Texas (ENVIRON, 2013), EPA Airport Emission Reduction Guidance (EPA, 2004), EPA Update of the Control Measures Database for On-road Sources with MOVES (EPA, 2011), Northeast Diesel Collaborative (NEDC) emission control guidance[20], the FAA Voluntary Airport Low Emissions Program (VALE)[21], Ozone Early Action Compacts (EACs) for San Antonio and Austin as well as other relevant references or studies.

2.3 Screening Results

ENVIRON ranked and prioritized the control measures in the master list based on preliminary estimates of emission reduction potential and cost effectiveness for each control measure. In consultation with project stakeholders, ENVIRON developed the final lists of the top ten control measures by (1) potential emission reduction and (2) cost effectiveness. A summary of the screening results prioritized by (1) the highest potential emission reductions or (2) lowest cost-effectiveness values is shown in Table 2-5. Those selected control measures that are top-ten ranked in both potential emission reductions and cost effectiveness are bolded.

[18] http://www.epa.gov/air/criteria.html
[19] Potential Control Strategies List. Provided in email communication from AACOG Staff, Brenda Williams, October 28, 2014.
[20] htt://northeastdiesel.org
[21] http://www.faa.gov/airports/environmental/vale/

Table 2-5. Top ten control measures by (1) cost effectiveness and (2) emission reduction (measures in bold text are common to both top ten lists).*

Cost Effectiveness Top Ten List		Emission Reduction Top Ten List	
ID No.	**Measure**	**ID No.**	**Measure**
N8	**Locomotives Idling Reduction within City Limit**	**A5**	**VOC Content Limits for Surface Coatings**
N5	**Alternative Fuels - CNG/LPG for City-owned fleet**	O10	Restrict Long Term Idling
N3	**Diesel Retrofits and Engine Rebuilds for City-owned Construction Equipment**	**N8**	**Locomotives Idling Reduction within City limit**
N12	**City-owned Construction Equipment Replacement Program (replace Tier 0 and Tier 1 with Tier 4)**	**O17**	**Commuter Trip Reduction Programs (vanpool, carpool)**
N13	**City-owned Construction Equipment Replacement Program (replace Tier 0, Tier 1, and Tier 2 with Tier 4)**	O19	Increased Use of Non-Motorized Travel (Bike)
A5	**VOC Content Limits for Architectural, Traffic, and Industrial Maintenance Coatings**	**N13**	**City-owned Construction Equipment Replacement Program (replace Tier 0, Tier 1, and Tier 2 with Tier 4)**
O17	**Commuter Trip Reduction Programs (vanpool, carpool)**	**N3**	**Diesel Retrofits and Engine Rebuilds for City-owned Construction Equipment**
N9	Airport Terminal Gate Electrification	**N12**	**City-owned Construction Equipment Replacement Program (replace Tier 0 and Tier 1 with Tier 4)**
N11	Emission Specifications in Contracts	**O7**[1]	**On-road Vehicle Electrification for City-owned fleet**
O7[1]	**On-road Vehicle Electrification for City-owned fleet**	**N5**	**Alternative Fuels - CNG/LPG for City-owned fleet**

* The first letter of the measure ID indicates the applicable emission source: A: area sources, N: non-road sources, O: on-road sources

[1] Revised from non-road to on-road focused measure in consultation with TCEQ

3.0 TECHNICAL AND ECONOMIC ANALYSIS OF SELECTED CONTROL MEASURES

As discussed in Section 2, measures identified on top ten lists by (1) emission reductions and (2) cost effectiveness were selected for further technical and economic analyses based on the screening analysis.

Detailed descriptions of these selected measures or measure groups are presented in this section. Each measure description includes a description of the control measure; estimates of emission reductions, costs and cost-effectiveness; and issues related to implementation.

3.1 Measures N12 & N13: City-owned Diesel Construction Equipment Replacement (Modernization) Program

3.1.1 Description

The most widely employed method for reducing emissions from non-road diesel engines is replacing older engines with newer lower-emitting engines or replacing the entire piece of equipment with equipment that has a lower-emitting diesel engine, including replacement with both new and remanufactured engines. The expected percentage emission reduction from this approach depends upon the engine model year to be replaced and the emission standard that the new engine meets.

This measure focuses on non-road construction equipment which accounts for more than 30% of off-road mobile source NOx emissions in Bexar County. Specifically, this control strategy targets city-owned construction equipment certified to Tier 0, Tier 1 and Tier 2 engine standards for modernization.

The EPA adopted the first Tier 1 emission standards for non-road compression-ignition (CI) engines at or above 50 horsepower (hp) (37 kilowatts (kW)) in June 1994. Subsequently in October 1998, the EPA adopted Tier 1 emission standards for non-road CI engines below 50 hp, as well as Tier 2 and Tier 3 emission standards for all engine sizes of these non-road CI engines. CI engines were required to meet Tier 1 standards beginning in 1996. Tier 2 standards were phased in from 2001 to 2004, depending on horsepower range, while Tier 3 standards were phased in from 2006 to 2008 depending on horsepower range. In June 2004, the EPA adopted Tier 4 emission standards that further reduce NOx emissions, as well as particulate matter (PM) emissions, from non-road diesel engines. These NOx+ non-methane hydrocarbon (NMHC) emission standards, along with Tier 0 uncontrolled emission levels, are summarized in Table 3-1.

Table 3-1. NOx+NMHC emission standards and uncontrolled levels for non-road diesel engines.

Engine Power (hp)	Model Year	Regulation	NOx+NMHC Emission Standard (g/hp-hr)
75 to < 100	Pre-1998	Tier 0 (uncontrolled)	8.8
	1998 – 2003	Tier 1	6.9
	2004 – 2007	Tier 2	5.6
	2008 -2011	Tier 3	3.5
	2012-2013	Tier 4A	3.5
	2014 +	Tier 4B	0.44
100 to < 175	Pre-1997	Tier 0 (uncontrolled)	9.5
	1997 – 2002	Tier 1	6.9
	2003 – 2006	Tier 2	4.9
	2007 – 2011	Tier 3	3.0
	2012-2013	Tier 4A	3.0
	2014 +	Tier 4B	0.44
175 to < 300	Pre-1996	Tier 0 (uncontrolled)	9.3
	1996 – 2002	Tier 1	6.9
	2003 – 2005	Tier 2	4.9
	2006 – 2010	Tier 3	3.0
	2011-2013	Tier 4A	3.0
	2014 +	Tier 4B	0.44
300 to < 600	Pre-1996	Tier 0 (uncontrolled)	9.5
	1996 – 2000	Tier 1	6.9
	2001 – 2005	Tier 2	4.8
	2006 – 2010	Tier 3	3.0
	2011-2013	Tier 4A	3.0
	2014 +	Tier 4B	0.44
600 to < 750	Pre-1996	Tier 0 (uncontrolled)	9.7
	1996 – 2001	Tier 1	6.9
	2002 – 2005	Tier 2	4.8
	2006 – 2011	Tier 3	3.0
	2011 - 2013	Tier 4A	3.0
	2014 +	Tier 4B	0.44

This control measure consists of replacing an engine or an entire piece of equipment with a new engine meeting the final Tier 4 emission standard (Tier 4B), or a remanufactured engine that meets the final Tier 4 emission standard (Tier 4B). The actual emission reduction realized will depend upon the actual engine replaced. Like any scrappage program, the scrapped engine should be in good working order and would otherwise be used for many years to come if not replaced under this program. The life of the emission credit generated will be equivalent to the remaining life of the engine to be replaced.

For this non-road construction equipment modernization program, two scenarios were evaluated, (1) replacing Tier 0 and Tier 1 baseline engines with Tier 4 engines, and (2) replacing Tier 0, Tier 1, and Tier 2 baseline engines with Tier 4 engines.

3.1.2 Emissions

Specific city-owned construction applications included in the Texas NONROAD model (TexN)[22] (Municipal-owned and City and County Road Construction) were chosen for estimating potential emission reductions from this program; candidate equipment types (listed in Table 3-2) were chosen based on their contributions to NOx emissions. City-owned construction equipment types with highest emission contribution to Construction and Mining category in Bexar County were selected for the analysis.

To estimate emission reductions, the NOx emission standards by Tier level were used with average load factors, annual hours of use, and equipment population extracted from TexN.

Table 3-2. Largest emissions contributing equipment types for Municipal-owned and City and County Road Construction and associated emissions for Bexar County.

SCC	HP range	Equipment Type	NOx Emissions (tpd)	Percent of Total[1] NOx
2270002066	50-75	Tractors/Loaders/Backhoes	0.17	27%
2270002048	100-175	Graders	0.07	11%
2270002069	100-175	Crawler Tractors	0.06	10%
2270002069	175-300	Crawler Tractors	0.06	10%
2270002066	75-100	Tractors/Loaders/Backhoes	0.04	7%
2270002060	100-175	Rubber Tire Loaders	0.04	6%
2270002015	50-75	Rollers	0.02	4%
2270002036	175-300	Excavators	0.02	3%

[1] Includes only Municipal-owned and City and County Road Construction equipment

3.1.3 Cost

ENVIRON estimated that Tier 4 engines cost about $500 per horsepower yielding a range of Tier 4 engine costs of about $31K to $119K for construction equipment, depending on the horsepower range (this is the cost for engine replacement, not equipment replacement). This is consistent with TERP[23] projects for which the average cost for excavator replacement was $88K and the average cost for rubber tire loader replacement was $123K over the 2004 to 2013 period[24].

3.1.4 Emission Reductions

Emission reductions depend on the technology group (i.e., Tier 0, Tier 1, Tier 2), equipment type, annual hours or use, and horsepower range of the engine replaced. The emission reduction values for equipment modernization are summarized in Table 3-3 (detailed emission reduction calculation data are presented in Appendix B, Tables B1 through B6). The highest

[22] https://www.tceq.texas.gov/airquality/airmod/overview/am_ei.html/#nonroad

[23] The TERP program, established by the Texas legislature in 2001, is a program aimed at improving air quality in Texas by reducing emissions of oxides of nitrogen (NOx) from both on-road and non-road high-emitting internal combustion engines.

[24] TERP Project List File, personal communication with TCEQ staff, Steve Dayton, December, 2013.

equipment populations available for retrofit are rollers while the largest per unit emission reductions are for excavators. Per unit emissions for excavators are higher than other equipment types based on the higher annual horsepower-hours of work performed by excavators relative to other equipment based on TexN model estimates of activity, horsepower, and load factor. The largest emission reductions are from tractors/loaders/backhoes and graders.

Table 3-3. Emission reduction estimates for Municipal-owned equipment modernized with Tier 4 engines.

Equipment Type	Horsepower Range	Tier 0	Tier 1	Tier 2	Tier 0 & Tier 1 Total	Tier 0, Tier 1, & Tier 2 Total
Available Equipment Population						
Graders	100-175 HP	22	44	28	**66**	**94**
Rollers	50-75 HP	51	58	34	**109**	**143**
Rubber Tire Loaders	100-175 HP	3	10	14	**13**	**27**
Excavators	175-300 HP	0	1	1	**1**	**2**
Crawler Tractors/Dozers	100-175 HP	13	34	22	**47**	**69**
Crawler Tractors/Dozers	175-300 HP	5	17	10	**22**	**32**
Tractors/Loaders/Backhoes	50-75 HP	5	42	62	**47**	**109**
Tractors/Loaders/Backhoes	75-100 HP	1	11	17	**12**	**29**
Totals		**100**	**217**	**188**	**317**	**505**
NOx Emission Reduction Per Unit (tons per year (tpy)/unit)						
Graders	100-175 HP	0.35	0.25	0.17	**0.28**	**0.25**
Rollers	50-75 HP	0.04	0.02	0.01	**0.03**	**0.03**
Rubber Tire Loaders	100-175 HP	0.43	0.31	0.20	**0.34**	**0.27**
Excavators	175-300 HP	1.52	1.12	0.74	**1.12**	**0.93**
Crawler Tractors/Dozers	100-175 HP	0.45	0.32	0.21	**0.36**	**0.31**
Crawler Tractors/Dozers	175-300 HP	0.76	0.56	0.37	**0.61**	**0.53**
Tractors/Loaders/Backhoes	50-75 HP	0.19	0.12	0.07	**0.13**	**0.10**
Tractors/Loaders/Backhoes	75-100 HP	0.41	0.32	0.24	**0.33**	**0.28**
Total Emission Reduction (tpy)						
Graders	100-175 HP	7.7	11.0	4.6	**18.7**	**23.4**
Rollers	50-75 HP	1.9	1.4	0.5	**3.3**	**3.8**
Rubber Tire Loaders	100-175 HP	1.3	3.1	2.9	**4.4**	**7.2**
Excavators	175-300 HP	-	1.1	0.7	**1.1**	**1.9**
Crawler Tractors/Dozers	100-175 HP	5.9	11.0	4.7	**16.9**	**21.6**
Crawler Tractors/Dozers	175-300 HP	3.8	9.5	3.7	**13.3**	**17.0**
Tractors/Loaders/Backhoes	50-75 HP	0.9	5.2	4.3	**6.1**	**10.4**
Tractors/Loaders/Backhoes	75-100 HP	0.4	3.5	4.1	**3.9**	**8.0**
Totals		**21.9**	**45.9**	**25.5**	**67.8**	**93.3**

Bexar County emission reduction percentages were estimated based on estimated emission reductions relative to the total emissions from all construction equipment applications by source classification code (SCC). Table 3-4 shows Bexar County NOx emission reduction factors by SCC for (1) Tier 0 and Tier 1 engine replacement and (2) Tier 0, Tier 1, and Tier 2 engine replacement.

Table 3-4. Emission reduction factor by SCC.

SCC	Description	Tier 0 & Tier 1	Tier 0, Tier 1, & Tier 2
2270002048	Diesel Graders	31%	39%
2270002015	Diesel Rollers	8%	9%
2270002060	Diesel Rubber Tire Loaders	7%	11%
2270002036	Diesel Excavators	1%	2%
2270002069	Diesel Crawler Tractors	17%	22%
2270002066	Diesel Tractors/Loaders/Backhoes	8%	15%

3.1.5 Cost-Effectiveness

The cost-effectiveness of the engine or equipment replacement depends on the emissions available from the engine replaced and the cost associated with the engine replacement. The cost effectiveness estimates for city-owned construction equipment fleet modernization are summarized in Table 3-5 (detailed cost effectiveness calculation data are presented in Appendix B, Tables B1 through B6). Excavators comprise the most cost-effective equipment for modernization.

Table 3-5. Average cost effectiveness for fleet modernization by option.

Equipment Type	Horsepower Range	Cost Effectiveness ($/ton)			Average for Tier 0 & Tier 1	Average for Tier 0, Tier 1, & Tier 2
		Tier 0	Tier 1	Tier 2		
Graders	100-175 HP	$23,050	$32,130	$48,693	**$28,401**	**$ 32,426**
Rollers	50-75 HP	$98,081	$150,207	$269,169	**$120,294**	**$ 138,508**
Rubber Tire Loaders	100-175 HP	$18,692	$26,056	$39,488	**$23,884**	**$ 30,039**
Excavators	175-300 HP	$9,147	$12,474	$18,904	**$12,474**	**$ 15,030**
Crawler Tractors/Dozers	100-175 HP	$17,819	$24,839	$37,644	**$22,399**	**$ 25,720**
Crawler Tractors/Dozers	175-300 HP	$18,215	$24,839	$37,644	**$22,943**	**$ 26,132**
Tractors/Loaders/Backhoes	50-75 HP	$19,438	$29,768	$53,344	**$28,175**	**$ 38,511**
Tractors/Loaders/Backhoes	75-100 HP	$12,520	$16,125	$21,200	**$15,747**	**$ 18,543**
Average		**$26,711**	**$30,129**	**$43,495**	**$29,024**	**$32,974**

3.1.6 Technical Implementation Feasibility and Public Acceptance

The measure is feasible, as the emission reductions are based on available certified lower emission engines or equipment. Similar fleet modernization programs have already been implemented in many states in the U.S. (e.g. California, Texas etc.). Guidelines for such a modernization program, especially eligibility criteria, and emission credit life, should be clearly defined to avoid potential issues related to surplus emissions versus normal turnover rates.

3.2 Measure N3: City-owned Diesel Construction Equipment NOx Retrofit Technologies

3.2.1 Description

This control measure includes retrofit of city-owned non-road construction equipment with emission-reduction devices to reduce diesel exhaust NOx emissions.

This measure focuses on diesel construction equipment which accounts for more than 30% of total non-road NOx emissions in the Bexar County area. Specifically, this control strategy targets city-owned construction equipment certified to Tier 0, Tier 1 and Tier 2 engine standards.

Technologies available to reduce NOx emissions from diesel engines include retarded engine timing modification, exhaust gas recirculation (EGR), lean NOx catalyst (LNC), and selective catalytic reduction (SCR). Examples of verified and demonstrated emission reduction effectiveness are shown in Table 3-6. NOx control retrofits will not reduce PM emissions by themselves and may increase PM emissions. Often a NOx control device is accompanied in a package offered by the vendor by a particulate control device such as a Diesel Particulate Filter (DPF).

Table 3-6. NOx retrofit control technologies.

Emission Control Device	NOx Control Efficiency[1]
Lean NOx reduction catalyst + Diesel particulate filter (Example Vendor: ESW CleanTech Longview)	25%
EGR+DPF (Example Vendor: Johnson Matthey EGRT)	40%
SCR+DPF (Example Vendor:NETT GreenTRAP DPF)	85%

[1] source: ARB certification, http://www.arb.ca.gov/diesel/verdev/vt/cvt.htm

This analysis focuses on SCR and LNC retrofit technology. While EGR technology is commonly used by engine manufacturers as a method to comply with stringent emission standards; it is not as practical for retrofits since EGR systems may require major engine integration[26]. Therefore, the use of EGR as a retrofit technology was not evaluated.

3.2.2 Emissions

Specific city-owned construction applications included in TexN[25] (Municipal-owned and City and County Road Construction) were chosen for estimating potential emission reductions from this program; candidate equipment types (listed in Table 3-7) were chosen based on their contributions to NOx emissions. City-owned construction equipment types with the highest emission contribution to Construction and Mining category in Bexar County were selected for analysis.

[25] https://www.tceq.texas.gov/airquality/airmod/overview/am_ei.html/#nonroad

To estimate baseline emissions, the NOx emission standards by Tier level were used with average load factors, annual hours of use, and equipment population extracted from TexN. Emission reductions from baseline levels were estimated based on control efficiencies listed in Table 3-6. The useful life for these retrofit technologies was assumed to be 10 years.

Table 3-7. Largest emissions contributing equipment types for Municipal-owned and City and County Road Construction and associated emissions for Bexar County.

SCC	HP Range	Equipment Type	NOx Emissions (tpd)	Percent of Total[1] NOx
2270002066	50-75	Tractors/Loaders/Backhoes	0.17	27%
2270002048	100-175	Graders	0.07	11%
2270002069	100-175	Crawler Tractors	0.06	10%
2270002069	175-300	Crawler Tractors	0.06	10%
2270002066	75-100	Tractors/Loaders/Backhoes	0.04	7%
2270002060	100-175	Rubber Tire Loaders	0.04	6%
2270002015	50-75	Rollers	0.02	4%
2270002036	175-300	Excavators	0.02	3%

[1] Includes only Municipal-owned and City and County Road Construction equipment

3.2.3 Cost

The major costs for these NOx retrofit systems include both capital and operational costs. The average capital costs for installation of the SCR is estimated to be $305 per horsepower[26], yielding an incremental capital cost ranging from $19K to $72K, depending on the horsepower of the engine being retrofit. It was assumed that the SCR associated urea consumption was equivalent to about 2% of the fuel consumption. According to the EPA[27], cost of the LNC equipment runs between $6.5k and $10k (the average of this range was assumed for this analysis).

3.2.4 Emission Reductions

Emission reductions depend on the technology group (i.e. Tier 0, Tier 1, Tier 2), equipment type, annual hours or use, horsepower range, and retrofit technology. The emission reduction estimates for retrofits are summarized in Table 3-8 (SCR) and Table 3-9 (LNC). Detailed emission reduction calculation data are presented in Appendix B, Tables B7 through B18. The largest equipment populations available for retrofit are rollers while the largest per unit emission reductions for both SCR and LNC retrofits are for excavators. Per unit emissions for excavators are higher than other equipment types based on the higher annual horsepower-hours of work performed by excavators relative to other equipment types based on TexN model estimates of activity, horsepower, and load factor. The largest emission reductions are from tractors/loaders/backhoes and crawler tractors/dozers for both SCR and LNC retrofits.

[26] http://www.arb.ca.gov/msprog/aqip/demo/demo%20final%20reports/final_report_hug_scr_dpf_072914.pdf
[27] http://www.epa.gov/cleandiesel/technologies/retrofits.htm

Bexar County emission reduction percentages were estimated based on estimated emission reductions relative to the total emissions from all construction equipment applications by SCC. Table 3-10 (SCR) and Table 3-11 (LNC) show Bexar County NOx emission reduction factors by SCC for both (1) Tier 0 and Tier 1 engine retrofits and (2) Tier 0, Tier 1, and Tier 2 engine retrofits.

Table 3-8. Potential emission reductions for SCR retrofits by equipment type.

Equipment Type	Horsepower Range	Tier 0	Tier 1	Tier 2	Tier 0 & Tier 1 Totals	Tier 0, Tier 1, & Tier 2 Totals
Available Equipment Population						
Graders	100-175 HP	22	44	28	66	94
Rollers	50-75 HP	51	58	34	109	143
Rubber Tire Loaders	100-175 HP	3	10	14	13	27
Excavators	175-300 HP	0	1	1	1	2
Crawler Tractors/Dozers	100-175 HP	13	34	22	47	69
Crawler Tractors/Dozers	175-300 HP	5	17	10	22	32
Tractors/Loaders/Backhoes	50-75 HP	5	42	62	47	109
Tractors/Loaders/Backhoes	75-100 HP	1	11	17	12	29
Totals		**100**	**217**	**188**	**317**	**505**
NOx Emission Reduction Per Unit (tpy/unit)						
Graders	100-175 HP	0.18	0.13	0.09	0.15	0.13
Rollers	50-75 HP	0.05	0.04	0.03	0.05	0.04
Rubber Tire Loaders	100-175 HP	0.38	0.27	0.19	0.30	0.24
Excavators	175-300 HP	1.34	0.99	0.67	0.99	0.83
Crawler Tractors/Dozers	100-175 HP	0.25	0.18	0.19	0.20	0.20
Crawler Tractors/Dozers	175-300 HP	0.67	0.50	0.34	0.54	0.47
Tractors/Loaders/Backhoes	50-75 HP	0.26	0.20	0.16	0.21	0.18
Tractors/Loaders/Backhoes	75-100 HP	0.36	0.28	0.22	0.29	0.25
Total Emission Reduction (tpy)						
Graders	100-175 HP	3.9	5.7	2.4	9.6	12.1
Rollers	50-75 HP	2.6	2.3	1.0	4.9	6.0
Rubber Tire Loaders	100-175 HP	1.1	2.7	2.6	3.9	6.5
Excavators	175-300 HP	-	1.0	0.7	1.0	1.7
Crawler Tractors/Dozers	100-175 HP	3.3	6.2	4.3	9.5	13.8
Crawler Tractors/Dozers	175-300 HP	3.4	8.5	3.4	11.8	15.2
Tractors/Loaders/Backhoes	50-75 HP	1.3	8.5	9.7	9.8	19.4
Tractors/Loaders/Backhoes	75-100 HP	0.4	3.1	3.7	3.5	7.2
Totals		**15.9**	**38.1**	**27.8**	**54.0**	**81.8**

Table 3-9. Potential emission reductions for LNC retrofits by equipment type.

Equipment Type	Horsepower Range	Tier 0	Tier 1	Tier 2	Tier 0 & Tier 1 Totals	Tier 0, Tier 1, & Tier 2 Totals
Available Equipment Population						
Graders	100-175 HP	22	44	28	66	94
Rollers	50-75 HP	51	58	34	109	143
Rubber Tire Loaders	100-175 HP	3	10	14	13	27
Excavators	175-300 HP	0	1	1	1	2
Crawler Tractors/Dozers	100-175 HP	13	34	22	47	69
Crawler Tractors/Dozers	175-300 HP	5	17	10	22	32
Tractors/Loaders/Backhoes	50-75 HP	5	42	62	47	109
Tractors/Loaders/Backhoes	75-100 HP	1	11	17	12	29
Totals		**100**	**217**	**188**	**317**	**505**
NOx Emission Reduction Per Unit (tpy/unit)						
Graders	100-175 HP	0.05	0.04	0.03	0.04	0.04
Rollers	50-75 HP	0.02	0.02	0.01	0.02	0.02
Rubber Tire Loaders	100-175 HP	0.11	0.08	0.05	0.09	0.07
Excavators	175-300 HP	0.39	0.29	0.20	0.29	0.24
Crawler Tractors/Dozers	100-175 HP	0.12	0.08	0.06	0.09	0.08
Crawler Tractors/Dozers	175-300 HP	0.20	0.15	0.10	0.16	0.14
Tractors/Loaders/Backhoes	50-75 HP	0.08	0.06	0.05	0.06	0.05
Tractors/Loaders/Backhoes	75-100 HP	0.11	0.08	0.06	0.09	0.07
Total Emission Reduction (tpy)						
Graders	100-175 HP	1.2	1.7	0.7	2.8	3.5
Rollers	50-75 HP	1.1	1.0	0.4	2.0	2.5
Rubber Tire Loaders	100-175 HP	0.3	0.8	0.8	1.1	1.9
Excavators	175-300 HP	-	0.3	0.2	0.3	0.5
Crawler Tractors/Dozers	100-175 HP	1.5	2.9	1.3	4.4	5.7
Crawler Tractors/Dozers	175-300 HP	1.0	2.5	1.0	3.5	4.5
Tractors/Loaders/Backhoes	50-75 HP	0.4	2.5	2.8	2.9	5.7
Tractors/Loaders/Backhoes	75-100 HP	0.1	0.9	1.1	1.0	2.1
Totals		**5.5**	**12.5**	**8.3**	**18.1**	**26.4**

Table 3-10. SCR retrofit emission reductions by SCC.

SCC	Description	Tier 0 & Tier 1	Tier 0, Tier 1, & Tier 2
2270002048	Diesel Graders	16%	20%
2270002015	Diesel Rollers	12%	14%
2270002060	Diesel Rubber Tire Loaders	6%	10%
2270002036	Diesel Excavators	1%	2%
2270002069	Diesel Crawler Tractors	12%	17%
2270002066	Diesel Tractors/Loaders/Backhoes	11%	22%

Table 3-11. LNC retrofit emission reductions by SCC.

SCC	Description	Tier 0 & Tier 1	Tier 0, Tier 1, & Tier 2
2270002048	Diesel Graders	5%	6%
2270002015	Diesel Rollers	5%	6%
2270002060	Diesel Rubber Tire Loaders	2%	3%
2270002036	Diesel Excavators	0%	1%
2270002069	Diesel Crawler Tractors	5%	6%
2270002066	Diesel Tractors/Loaders/Backhoes	3%	7%

3.2.5 Cost-Effectiveness

Retrofit cost-effectiveness depends on the emissions available from the engine being retrofit and the cost associated with the engine retrofit along with increased fuel use. The cost effectiveness estimates for city-owned construction equipment retrofits are summarized in Table 3-12 (SCR) and Table 3-13 (LNC). Detailed emission reduction calculation data are presented in Appendix B, Tables B7 through B18. Excavators comprise the most cost-effective equipment for both SCR and LNC retrofits.

Table 3-12. SCR Cost-effectiveness (including fuel cost) for Municipal-owned construction equipment.

Equipment Type	Horsepower Range	Cost Effectiveness ($/ton)			Average for Tier 0 & Tier 1	Average for Tier 0, Tier 1, & Tier 2
		Tier 0	Tier 1	Tier 2		
Graders	100-175 HP	$28,074	$38,652	$57,293	$34,339	$38,992
Rollers	50-75 HP	$44,337	$56,545	$73,339	$50,092	$54,175
Rubber Tire Loaders	100-175 HP	$13,495	$18,580	$27,541	$17,094	$21,279
Excavators	175-300 HP	$6,868	$9,257	$13,722	$9,257	$11,056
Crawler Tractors/Dozers	100-175 HP	$12,889	$17,745	$26,303	$16,070	$19,243
Crawler Tractors/Dozers	175-300 HP	$13,166	$17,745	$26,303	$16,445	$18,627
Tractors/Loaders/Backhoes	50-75 HP	$10,653	$13,587	$17,622	$13,200	$15,398
Tractors/Loaders/Backhoes	75-100 HP	$10,461	$13,341	$17,303	$13,042	$15,243
Average		**$21,621**	**$21,795**	**$26,405**	**$21,744**	**$23,326**

Table 3-13. LNC Cost-effectiveness (including fuel cost) for Municipal-owned construction equipment.

Equipment Type	Horsepower Range	Cost Effectiveness ($/ton)			Average for Tier 0 & Tier 1	Average for Tier 0, Tier 1, & Tier 2
		Tier 0	Tier 1	Tier 2		
Graders	100-175HP	$20,267	$27,903	$41,360	$24,790	$28,149
Rollers	50-75HP	$48,158	$61,419	$79,660	$54,409	$58,844
Rubber Tire Loaders	100-175HP	$10,457	$14,397	$21,340	$13,245	$16,488
Excavators	175-300HP	$4,227	$5,697	$8,445	$5,697	$6,804
Crawler Tractors/Dozers	100-175HP	$10,049	$13,835	$20,507	$12,529	$14,303
Crawler Tractors/Dozers	175-300HP	$6,680	$9,004	$13,346	$8,344	$9,451
Tractors/Loaders/Backhoes	50-75HP	$19,562	$24,948	$32,357	$24,238	$28,274
Tractors/Loaders/Backhoes	75-100HP	$15,236	$19,431	$25,202	$18,995	$22,200
Average		**$19,707**	**$20,862**	**$29,014**	**$20,507**	**$23,182**

3.2.6 Technical Implementation Feasibility and Public Acceptance

These NOx retrofit strategies are feasible, as they have already been implemented in California, Texas and elsewhere in the U.S.

3.3 Measure N8: Locomotives Idling Reduction within City limit

3.3.1 Description

The EPA estimates that idling accounts for about 60 percent of switch yard locomotive operating time and 12.5 percent of line-haul locomotive operating time. In 2008, EPA adopted standards that required new and remanufactured locomotives to meet increasingly stringent emission standards; the most stringent emission standard (Tier 4) is required on locomotive engines manufactured beginning in 2015. Recently, EPA required that all new and remanufactured engines include idling reduction technology. This control measure will thus be most efficient as a retrofit to older locomotives. EPA[28] has provided guidance for quantifying switch yard locomotive idle emission reductions.

ENVIRON's experience performing rail yard emission inventories has indicated that locomotives dedicated for use at switching yards (switching locomotives) are often older, retired line-haul locomotives. Given the propensity for the use of older models for switching locomotives and the larger share of emissions in idling mode for these locomotives, switching locomotives are good candidates to target for idling emission reductions.

In the San Antonio area, there have been reports of switching locomotives emission reductions through the use of new technology switching locomotive engine purchases. Alamo Gulf Coast Railroad purchased a Tier 2 (generator set) switch locomotive for its operations at Beckmann, Texas in 2005 with TERP funding. In addition, Union Pacific has touted its use of such locomotives in the San Antonio area. (*"Union Pacific (NYSE: UNP) invested in 98 new 2,000-horsepower Generator Set locomotives for use in the company's rail facilities in the Dallas/Fort Worth, Houston and San Antonio metro areas."*[29]*)*

3.3.2 Emissions

According to TCEQ's emissions inventory, switching locomotives in Bexar County contribute almost a ton per day of NOx emissions (0.8 tpd). There is uncertainty associated with the switching locomotive emission estimate in the TCEQ inventory because switching locomotive activity in San Antonio is not based on local activity or emission factor data. Switching locomotive activity as described in ERG (2010) is based on the assumption that two locomotives operate at each attainment area switchyard; emission rates do not vary from yard-to-yard (ERG, 2010). Realistically, switchyards are expected to have varying levels of activity, with specific emission rates for the switching locomotives at each yard; for these two reasons there is considerable uncertainty associated with the switching locomotive emission estimates.

[28] http://www.epa.gov/cleandiesel/documents/420b09037.pdf
[29] http://www.bizjournals.com/sanantonio/stories/2007/12/10/daily26.html?t=printable

Additional information related to switchyard activity and emission estimation methodology is available in ERG (2010).

3.3.3 Cost and Cost Effectiveness

Cost will vary by the locomotive outfitted and special circumstances for each project; however Kim Hotstart[30] (the primary supplier of idle shut off devices for locomotives) quoted the cost of $40,000 per locomotive in 2009. An alternative vendor of a verified idle reductions device[31] is available from Power Drives Inc.[32]

According to the EPA[33], locomotive-idle-reduction technology cost effectiveness ranges from $1,500 to $5,000 per ton of NOx on average. Additional cost savings are expected from reduced fuel consumption, and additional benefits of lower PM and VOC are expected as well making this measure even more cost effective.

3.3.4 Emission Reductions

EPA[34] reported emissions by mode for several locomotive models of which two were typical of switch locomotive engines (EMD 12 cylinder and 16 cylinder engines 12/16-645 of 1500 hp and 2000 hp) and idling represented 20-21% of the total NOx emissions for the switch duty cycle. Applying 20% to 0.8 tpd of NOx emissions results in 0.16 tpd NOx emission reduction from switching locomotives (SCC 2285002010).

3.3.5 Technical Implementation Feasibility and Public Acceptance

This measure has been successfully implemented in other areas in the U.S., such as in Chicago[35].

3.4 Measure A5: VOC Content Limits for Surface Coatings

3.4.1 Description

Architectural and industrial maintenance (AIM) surface coating operations consist of applying a thin layer of coating such as paint, paint primer, varnish, or lacquer to surfaces, and the use of solvents as thinners and for cleanup. VOCs that are used as solvents in the coatings are emitted during application of the coating and as the coating dries.

The EPA published the AIM coatings rule on September 11, 1998 (40 CFR Part 59 Subpart D). The AIM coatings rule limits the amount of VOC that can be used in coating products. VOC

[30] ftp://ftp.ci.missoula.mt.us/DEV%20ftp%20files/Transportation/Clean%20Diesel/Appendix/C_Appendix_Hotstart_Letter.pdf
[31] http://www.epa.gov/smartway/forpartners/technology.htm
[32] http://www.dieselwarming.com/
[33] "Talking Freight Seminar", Paul Bubbosh, EPA 2004, http://www.fhwa.dot.gov/planning/freight_planning/talking_freight/04talking.cfm, Accessed Jan, 2015.
[34] Regulatory Support Document, EPA-420-R-98-101, April 1998, http://www.epa.gov/otaq/documents/420r98101.pdf
[35] http://www.epa.gov/smartway/forpartners/documents/rail/documents/420r04003.pdf

content limits in the national rule have been in effect since September 11, 1999. The Federal AIM rule is estimated to result in VOC reductions of 20 percent from pre-regulation levels.

This measure proposes adoption of VOC limits more stringent than required under the national AIM coatings rule based on VOC limits from the Ozone Transport Commission (OTC) Model Rule or South Coast Air Quality Management District (SCAQMD) Phase III VOC limits for surface coating operations that take place under CoSA authority (e.g. painting of city-owned buildings, traffic markings applied to city streets). The VOC content limits for select coatings are provided in Table 3-14 for the federal rule (40 CFR Part 59 Subpart D), SCAQMD Rule 1113, and OTC Model Rule. Comprehensive listings of the VOC content limits are available in 40 CFR Part 59 Subpart D[36], the SCAQMD Rule 1113[37], and the OTC Model Rule[38].

Table 3-14. Select AIM surface coating VOC content limits.

Coating Type	VOC Content Limit (grams/liter)		
	Federal 40 CFR Part 59 Subpart D	SCAQMD Rule 1113	OTC Model Rule
Bond Breakers	600	350	350
Concrete-Curing Compounds	350	100[a]	350
Floor Coatings	400	50	100
Industrial Maintenance Coatings	450	100	250
Primer, Sealers and Undercoaters	450	100	100
Traffic marking coatings	150	100	100

[a] 350 grams/liter for Roadways and Bridges compounds

3.4.2 Emissions

Most VOC released into the air by AIM surface coating use are from the evaporation of the VOC contained in the coating, coating thinners, and thinners used for cleanup. According to 2018 emissions inventory projection developed by TCEQ, AIM coatings are estimated to contribute almost a quarter of total anthropogenic VOC in Bexar County (17.2 tpd), with contributions of 27% from architectural coating, 2% from traffic markings, and 71% from industrial coatings. For the purposes of this measure, we assume that (1) the CoSA controlled traffic marking activity accounts for 100% of the traffic marking emissions, though it is understood that this is an overestimate as state and federal highways in CoSA would also have associated traffic marking activity, (2) lacking a better estimate, the CoSA controlled architectural coating projects are assumed account for 16% of all architectural coating activity consistent with the estimate of the fraction of construction equipment NOx emissions from city-owned equipment (see Section 3.8.2) , and (3) that CoSA controlled industrial coatings account for a negligible fraction of

[36] http://www.gpo.gov/fdsys/granule/CFR-2012-title40-vol6/CFR-2012-title40-vol6-part59-subpartD-app1
[37] SCAQMD, Rule 1113. Architectural Coatings (Amended September 6, 2013). http://www.aqmd.gov/home/regulations/rules/scaqmd-rule-book/regulation-xi
[38] OTC, MODEL RULE 2009-12 - AIM Coatings Update, 2011, v15. http://www.otcair.org/upload/Documents/Model%20Rules/OTC_model%20rule_AIM_2010_v15.pdf

industrial coating activity. Based on the aforementioned assumptions, 1.09 tpd of VOC emissions are emitted from CoSA controlled surface coating activities.

3.4.3 Cost and Cost Effectiveness

According to the Lake Michigan Air Directors Consortium (LADCO) study[39], adoption of the OTC model rule would cost $6,400 per ton of VOC reduced. CoSA specific cost effectiveness is expected to be determined by the actual incremental costs associated with the usage of low VOC reactivity coatings.

3.4.4 Emission Reductions

The adaptation of SCAQMD Phase III VOC limits is estimated to yield 11% of additional reduction from the existing national limits. An 11% control efficiency (CE) over the baseline yields an emissions reduction of 0.10 tpd of VOC, assuming 80% rule effectiveness.

3.4.5 Technical Implementation Feasibility and Public Acceptance

The usage of low VOC surface coatings is feasible because it has been adopted in other areas of the U.S. The SCAQMD AIM Rule (Rule 1113) is the most stringent rule on AIM coatings in the U.S. and covers Los Angeles and the surrounding air basin. Rule 1113 is generally the model that other jurisdictions consider when writing their own rules. The CoSA would have to work with local vendors to address the specific costs and requirements that would be needed to use low VOC surface coatings on all CoSA controlled projects.

3.5 Measures N9: Airport Terminal Gate Electrification

3.5.1 Description

Airport terminal gate electrification includes the replacement of fossil fuel-powered aircraft gate operations and airport ground support equipment (GSE) with electric-powered models. Some notable airport electrification measures are described as part of the Federal Airport Improvement Program (AIP) and FAA's Voluntary Airport Low Emission (VALE) program[40] which includes success stories for the Dallas-Fort Worth International Airport, Albuquerque International Sunport, Chicago O'Hare International Airport, Hartsfield-Jackson Atlanta International, Seattle-Tacoma International Airport and Yeager Airport in West Virginia.

An auxiliary power unit (APU) is usually a small turbine engine onboard a large aircraft and a ground power unit (GPU) is a vehicle mounted generator that provides power to aircraft at the gate. When airplanes stop at terminals for loading and unloading, they use their APU and/or a GPU to provide power for preconditioned air (PCA) and other onboard electrical components. As planes have become larger, plane docking time has become longer and as fuel prices have increased, the use of electricity in place of fossil fuel to power gate operations has become more economical.

[39] "Identification and Evaluation of Candidate Control Measures, Phase II Final Report", LADCO, 2006
[40] http://www.faa.gov/airports/environmental/vale/

3.5.2 Emissions

The San Antonio International Airport (SAIA) GSE and APUs contribute almost 50 tpy of NOx and 15 tpy of VOC emissions (see Table 3-15).

Table 3-15. 2018 SAIA GSE and APU emissions inventory.

SAIA Airport Equipment	NOx (tpy)	VOC (tpy)	CO (tpy)
Aircraft Auxiliary Power Units (APU)	1.4	0.2	2.5
GSE, Gasoline	7.6	2.4	68.9
GSE, LPG	0.7	0.2	6.8
GSE, CNG	0.6	0.2	5.4
GSE, Diesel[1]	35.9	11.4	327.4
Grand Total	**46.1**	**14.4**	**411.0**

[1]Note: more than two thirds of all APU and GSE NOx emissions at SAIA can be attributed to diesel powered GSE.

3.5.3 Emission Reductions

Equipment electrification is an effective way to completely eliminate direct emissions from GSE and APUs. Since APU emissions at SAIA represent only 3% of total airport non-road equipment NOx emissions, the effect of electrification on APUs was not evaluated. However, it is important to note that terminal gates equipped with electrified equipment such as PCA or GPUs may be able to reduce additional NOx emissions through reduced usage of APUs.

The 2018 TCEQ emissions inventory, presented in Table 3-15 for SAIA, is aggregated by fuel type. We disaggregated the 2018 GSE emissions inventory by using detailed SAIA Emissions Inventory report[41], prepared by AACOG. The report provides detailed SAIA airport GSE information for key emission inventory inputs such as age distribution, equipment population, and annual use. 2018 GSE emissions were disaggregated by GSE type according to emission contributions estimated in the AACOG report.

According to the AACOG's SAIA report, a majority of NOx emissions come from GSE such as air start units, baggage tugs, air conditioners, ground power units and belt loaders. There are mature electric alternatives for belt loaders, baggage tugs, fixed-GPUs and bridge-mounted-AC units, but not for air start units[42]. As noted above, over three quarters of the GSE emissions are from diesel engines.

The GSE types shown in Table 3-16 account for almost 50% (~18 tpy) of total diesel GSE NOx emissions in 2018. In this measure, we assume that all of these sources are electrified. Table 3-17 shows SAIA airport electrification measure emission reduction factors by SCC.

[41] "Emission Inventory San Antonio International Airport - Technical Report" http://www.aacog.com/DocumentCenter/View/6544
[42] "Austin Airport Electrification: Landside and Airside Operations", EPRI 2011; http://content.abia.org/environmental/pdfs/electric_vehicle.pdf

Table 3-16. Airport terminal gate electrification emission reduction potential.

GSE Type	# of Units	2018 NOx (tpy)	% of Airport GSE NOx Emissions
Air Cond. (Diesel)	14	8.0	17%
Ground Power Unit (Diesel)	27	7.3	16%
Baggage Tug (Diesel)	29	2.1	5%
Belt Loader (Diesel)	34	1.8	4%
Grand Total	**104**	**19.2**	**42%**

Table 3-17. Airport terminal gate electrification emission reduction by SCC.

Applicable SCCs	SCC Description	Emission Reduction %		
		NOx	VOC	CO
2270008005	Airport Ground Support Equipment, Diesel	53.4%	6.9%	54.7%

3.5.4 Cost-Effectiveness

Cost effectiveness was calculated by ENVIRON using TERP methodology which does not include operational or maintenance costs. Since operational costs of electric equipment are typically smaller than diesel equipment alternatives (i.e. annualized cost of battery versus annual fuel use)[43], cost effectiveness may be even lower than presented. Table 3-18 shows estimated cost effectiveness for GSE electrification at SAIA.

The annualized cost is based on the total replacement project costs and the expected equipment life cycle (assumed 10 years). The average cost effectiveness is an emission-weighted average estimated based on TERP methodology.

Table 3-18. Cost effectiveness of electric powered GSE and APU equipment.

GSE Type	New Diesel Equipment Cost ($/unit)	New Electric Equipment Cost ($/unit)	No. of Units	Fleet-wide Cost ($)	Cost Effectiveness ($/ton)
Baggage Tug (Diesel)	$19,000[1]	$24,000[1]	29	$696,000	$38,854
Belt Loader (Diesel)	$27,000[1]	$30,000[1]	34	$1,020,000	$66,431
GPU (Diesel)	$20,000[2]	$30,000[2]	27	$810,000	$13,008
Aircraft Air Conditioners (Diesel)	$40,000[2]	$60,000[2]	14	$840,000	$12,309
Average Cost Effectiveness ($/ton)					$20,552

[1] ARB, "Draft Airport Ground Support Equipment Project Criteria", http://www.arb.ca.gov/msprog/moyer/historic/gsecrit.pdf
[2] http://www.trade-a-plane.com/

Additional costs, including maintenance facility upgrades, training, and charging station costs may also be required depending on existing SAIA infrastructure. Such costs may not be insignificant.

[43] "Austin Airport Electrification: Landside and Airside Operations", EPRI 2011; http://content.abia.org/environmental/pdfs/electric_vehicle.pdf

3.5.5 Technical Implementation Feasibility and Public Acceptance

The measure is feasible, as the emission reductions are based on available technology by utilizing electric powered motors instead of internal combustion engines at other airports.

3.6 Measure O19: Increased Use of Non-Motorized Travel (Bike)

3.6.1 Description

Non-motorized travel improvements, in a typical urban area can reduce the number of automobile trips from 5 to 10%[44]. In combination with driving disincentives such as high parking prices or vehicle emission taxation, this measure can reduce automobile travel even more, causing a shift from automobile driving to walking and cycling, reducing on-road vehicle emissions in an urban area. Many ozone nonattainment areas take emission credits through a variety of transportation control measures (TCM), which include measures such as non-motorized travel improvement. For example, the City of Austin included a list of non-motorized travel improvements measures in the Early Action Compact (EAC)[45]. In addition, nonattainment areas such as Dallas-Fort Worth and Houston-Galveston-Brazoria also include TCMs and take emission credits in their SIP for similar measures.

The focus of this analysis is on bicycle travel improvements. The analysis of pedestrian travel improvements is more complex and requires many more parameters which are not easily estimated without detailed project specific data[46]. On the other hand, bicycle travel is a closer alternative to automobile travel as commute distances in San Antonio Area are estimated to average more than 20 miles[47] and are thus more relevant.

It is recognized that CoSA has already undertaken significant efforts to improve non-motorized travel:

- The CoSA has allocated $40M in bond funding is dedicated to traffic calming project improvements within the downtown area from 2012-2017. Approximately 1/5 of that funding is annually allocated to bike and pedestrian facilities/amenities ($8M annually). An additional $1M annual allocation from Advanced Transportation District (sales-tax) funding is allocated for dedicated bike lanes/paths for areas outside of the downtown's 36 square mile area.[48]
- The CoSA's Linear Creekway Parks Program provides expansion for bike and pedestrian connectivity while protecting San Antonio's creekways and watersheds. Accomplishments

[44] "How to Reduce the Number of Short Trips by Car", European Transport Conference, Centre for Transport Studies, University College London, http://www.vtpi.org/tdm/tdm25.htm
[45] Austin/Round Rock MSA Emissions Reduction Strategies, Austin, Texas, March 2004, https://www.tceq.texas.gov/assets/public/implementation/air/sip/sipdocs/2004-06-AUS/04086sipapk_pro.pdf
[46] Multi-Pollutant Emissions Benefits of Transportation Strategies-FHWA, https://www.fhwa.dot.gov/environment/air_quality/conformity/research/mpe_benefits/mpe03.cfm
[47] Strategy Effectiveness Analysis, AACOG, 2010, https://www.aacog.com/DocumentCenter/Home/View/193
[48] Email communication from City of San Antonio Office of Sustainability Staff, Liza Meyer, January 28, 2015.

include: 46 miles of trails constructed, 40 miles of trail in design or construction with total funds allocation at $110M.[48]

- The CoSA includes 4,766 miles of sidewalks, 301 miles of roadways with exclusive bike lanes, and 109 miles of bike paths.[48]

3.6.2 Emissions

This measure aims to reduce emissions from light duty vehicles by displacing vehicle trips to bicycle trips through infrastructure improvements. Table 3-19 shows a breakdown of on-road mobile emissions in Bexar County. Vehicle trips are expected to be displaced from the following vehicle types: gasoline and diesel light duty vehicles (LDV), gasoline and diesel light duty trucks (LDT), and motorcycles (MC).

Table 3-19. On-road mobile emissions (2018) by vehicle category, Bexar County.

Vehicle Category	NOx (tpd)	% of Total
Light duty Gasoline Vehicles (LDGV)	8.7	31%
Heavy Duty Diesel Vehicles (HDDV)	8.4	30%
Light duty Gasoline Trucks (LDGT)	6	21%
Heavy Duty Gasoline Vehicles (HDGV)	3.3	12%
Light Duty Diesel Trucks (LDDT)	0.8	3%
Heavy Duty Diesel Buses (HDD Bus: School & Transit)	0.7	2%
Light Duty Diesel Vehicles (LDDV)	<0.1	0%
Motorcycles (MC)	<0.1	0%
Heavy Duty Gasoline Bus (HDG Bus)	<0.1	0%
On-road Total	**28**	**100%**

3.6.3 Emission Reductions

Emission reduction due to the addition of bicycle lanes would be due to a shift in vehicle traffic to bicycle trips, which is expected to directly affect passenger vehicle miles travel (VMT) and the number of cold starts that a vehicle would have otherwise made. Local estimates are not readily available, however, according to the Federal Highway Administration (FHWA) and California Air Resource Board (CARB), average daily traffic in the area where bicycle lanes are added, is reduced by approximately 1.1%[49].

3.6.3.1 Example Calculation

If the average bicycle trip is assumed to be 1.8 miles[1] and average daily traffic (ADT) over the area is for example 10,000 vehicles, total annual reductions in VMT (VMT_r) are estimated as follows:

Auto Trips Reduced = (ADT; e.g. 10,000) x (mode shift, e.g. 1%) x (operating days; e.g. 200)

Auto Trips Reduced = 20,000 annual trips

[49] Multi-Pollutant Emissions Benefits of Transportation Strategies-FHWA, https://www.fhwa.dot.gov/environment/air_quality/conformity/research/mpe_benefits/mpe03.cfm

VMT_r = (Auto Trips Reduced) x (average length of bike trip; 1.8 miles) = 360,000 miles

According to a recent AACOG study[50], average NOx and VOC commuter emission factors in Bexar county area are 0.84 g/mile and 0.58 g/mile, respectively. Notably, the emission reductions from this measure are expected to be derived from emission reductions associated with reductions to both in-transit and start mode emissions and the aforementioned emission factors include both modes. The expected reduction from a measure that adds new bicycle lanes in a city area with average of 10,000 daily vehicle trips reduced is 0.33 tpy NOx and 0.23 tpy VOC.

3.6.4 Cost and Cost Effectiveness

Cost effectiveness is highly dependent on each City's road infrastructure and average daily traffic patterns. University of North Carolina Highway Safety Research Center and Federal Highway Administration[51] estimates of the average cost of bikeways projects are listed in Table 3-20.

Table 3-20. Cost of bicycle improvement projects.

Infrastructure	Description	Average	Cost Unit
Bikeway	Bicycle Lane	$133,177	Mile
Bikeway	Signed Bicycle Route	$25,070	Mile
Bikeway	Signed Bicycle Route with Improvements	$239,440	Mile
Bicycle Parking	Bicycle Rack	$660	Each

Assuming that a road section with new bicycle lanes which affects 10,000 daily vehicle trips has a length of 1.8 miles, and using the emission reduction estimates from the example above and the cost estimates from Table 3-20, we estimate cost effectiveness to range from $7,500 per ton (signed bicycle route) to $75,000/ton (signed bicycle route with improvements) over the 10 year period, depending on capital investment.

3.6.5 Technical Implementation Feasibility and Public Acceptance

This measure is widely used across the U.S. and therefore is feasible and publically acceptable.

3.7 Measures O17: Commuter Trip Reduction Programs (Vanpool, Carpool)

3.7.1 Description

This measure seeks to enhance existing programs such as the NuRide Program that reduce employee vehicle commuting through a) provision of alternative commute infrastructure such as bike racks, showers, preferential carpool/vanpool parking; b) carpool or alternative transportation programs, including a dedicated parking cashout program, subsidized transit

[50] Strategy Effectiveness Analysis, AACOG, 2010, https://www.aacog.com/DocumentCenter/Home/View/193
[51] Cost of Pedestrian and Bicyclist Infrastructure Improvements, http://katana.hsrc.unc.edu/cms/downloads/Countermeasure%20Costs_Report_Nov2013.pdf

passes, or other incentives (such as administrative leave or regular prize drawings) for employees to take alternative commutes; c) compressed work weeks in which an employee does not have to travel to work at least one day every two weeks; d) flexible work schedules; and e) teleworking; among others.

AACOG sponsors the NuRide Program in the Greater San Antonio area. The NuRide Program is an online carpool matching, alternative transportation tracking, and reward system. Additional information about the San Antonio Area NuRide Program is available in Section 1.3.

3.7.2 Emissions

This measure targets emission reductions from on-road mobile vehicle emissions. In particular, it affects commuter behavior and thus reduces emissions from light duty personal vehicles. Overall, light duty vehicles contribute almost one third of all on-road vehicle NOx emissions. Table 3-21 shows NOx emissions by vehicle type in Bexar County.

Table 3-21. On-road mobile emissions (2018) by vehicle category, Bexar County.

Vehicle Category	NOx (tpd)	% of Total
Light duty Gasoline Vehicles (LDGV)	8.7	31%
Heavy Duty Diesel Vehicles (HDDV)	8.4	30%
Light duty Gasoline Trucks (LDGT)	6	21%
Heavy Duty Gasoline Vehicles (HDGV)	3.3	12%
Light Duty Diesel Trucks (LDDT)	0.8	3%
Heavy Duty Diesel Buses (HDD Bus: School & Transit)	0.7	2%
Light Duty Diesel Vehicles (LDDV)	<0.1	0%
Motorcycles (MC)	<0.1	0%
Heavy Duty Gasoline Bus (HDG Bus)	<0.1	0%
On-road Total	**28**	**100%**

3.7.3 Cost and Cost Effectiveness

Carpooling and/or vanpooling typically save money for participants, however programmatic costs can be associated with incentives used to motivate ridership. Cost effectiveness estimates will depend on whether such incentives are offered and, if so, the monetary value of those incentives as well as the cost of program administration and marketing. In the case of vanpool programs, there may be additional costs associated with van insurance, maintenance, and roadside assistance.

One carpool program in California (Riverside County) offers financial incentives in the form of gift certificates and discounts at local retailers. Including marketing, administration, and financial incentives; a cost effectiveness of $32K per ton of VOC and NOx emissions reduced was estimated for this program.[52] Another carpool program in California (Contra Costa County), which included an incentive of a $40 dollar gas card for each participant forming or joining a

[52] http://www.fhwa.dot.gov/environment/air_quality/cmaq/research/cmaq_cost.cfm

carpool, estimated a cost effectiveness of $10,081 per ton of emissions reduced.[53] A vanpool program in California (Contra Costa County), which included an incentive of half off of rider fees for the first three months of ridership and $1K for drivers who keep a van on the road for one year, estimated a cost effectiveness of $17K per ton of emissions reduced.

The Houston Metro Star vanpool program has been successfully operating for 20 years and in 2011 it was estimated that 48 tons of NOx were reduced as a result of this program.[54] The program provides passenger vans or mini-vans to participants along with insurance, maintenance, roadside assistance and administrative coordination for van pools in Houston area counties.

3.7.4 Emission Reductions

Commuter trip reduction program measures, which include carpooling and vanpooling are effective ways to reduce on-road mobile vehicle emissions, especially during peak emission hours. The specific programs implemented and the level of participation is key information needed to estimate emission reduction potential. The following calculation is an example how emission reductions can be estimated using federal highway administration methodology[55]. Emission reduction estimates from carpooling and vanpooling are provided below.

3.7.4.1 Carpooling Reduction

The first step is to estimate the number of commuters that will have access to and utilize new commuter options. This information is typically obtained from a survey. Next, the total change in vehicle trips and VMT are estimated. The associated emission reduction can be estimated by using typical commuter trip distance in San Antonio area and number of trips reduced according to the following equations:

$$N_{trips} = (N_p/n_r) \times (n_r-1)$$

$$VMT_r = N_{trips} \times ACD \text{ (miles)}$$

$$ER = VMTr \text{ (miles)} \times EF \text{ (g/mile) } (/454 \text{ g/lbs} / 2000 \text{ lbs/ton})$$

Where,

N_p: Number of participants
n_r: Average ridership (including a driver)
N_{trips}: Number of trips reduced
VMT_r: VMT Reduction
ACD: Average commute distance (miles)
EF: Emission Factor (g/mile)
ER: Emission reduction (tons)

[53] "TDM Cost Effectiveness: How VMT Reduction Translates to Congestion Mitigation and Improved Air Quality" White Paper Presented at ACT International Conference - September 2003.
[54] Air Quality Initiatives, Houston-Galveston Area Council, 2011. http://www.h-gac.com/taq/airquality/documents/HGAC_AirQuality_Initiatives_v7.pdf
[55] Federal Highway Administration, Air Quality, https://www.fhwa.dot.gov/environment/air_quality/conformity/research/mpe_benefits/mpe03.cfm

3.7.4.1.1 Example Calculation

For example, if 100,000 employees use a carpool program and average ridership is two (driver + passenger), using emission factors and emission reduction estimates from a recent AACOG study[56] (EF_{NOx} = 0.84 g/mile, EF_{VOC} = 0.58 g/mile; ACD_{Bexar} = 21 miles), the estimated VMT and emission reductions would be:

N_{trips} = (100,000/2)x(2-1) = 50,000 trips
VMT_r = 50,000 x 21 miles = 1,050,000 miles
ER_{NOx} = 1,050,000 miles x 0.84 g/mile / 907185 g/ton) = 0.97 tpd
Similarly, ER_{VOC} = 0.67 tpd

3.7.4.2 Vanpooling Reductions

Similar to carpooling, emission reductions for vanpooling can be estimated using simple steps as in carpooling examples. Vanpooling typically utilizes larger vehicles (with typically higher emission factors) and thus emissions from vanpooling trips are higher than from a same number of personal car trips, however, because vanpools typically have from 5-15 riders per trip, emission reductions can be greater on a per trip basis. Vanpooling tends to have higher ridership compared to carpooling resulting in larger number of reduced trips and therefore higher VMT reduction, which leads to more reduced NOx and VOC. For example, the Houston-Galveston Area Council estimated that in 2011, the Star Vanpool Program reduced close to 60 million vehicle miles traveled and 48 tons of NOx emissions while the NuRide program in the same area indicated that the rideshare (i.e. carpool) program in 2011 reduced about 11 million vehicle miles traveled and approximately 10 tons of NOx.[54]

3.7.5 Technical Implementation Feasibility and Public Acceptance

This measure is widely used across the US, and has been successfully implemented in Austin and San Antonio. Increasing the level of commuter trip program participation in the San Antonio area is both feasible and publically acceptable.

3.8 Measure N11: Emission Specifications in Contracts

3.8.1 Description

This measure aims to reduce emissions associated with construction equipment that is operated as part of projects to fulfill CoSA contracts. The goal of this measure is to adopt an ordinance that includes provisions to control emissions from non-road equipment and on-road vehicles which may include the usage of best available technology for limiting NOx emissions and idle-reduction policies. Example contract language can be found in Northeast Diesel Collaborative (NEDC)[57] guidance.

[56] Strategy Effectiveness Analysis, AACOG, 2010, https://www.aacog.com/DocumentCenter/Home/View/193
[57] EPA, "Diesel Emission Controls in Construction Projects", http://www.epa.gov/cleandiesel/documents/cl-nedc-model-2010rev.pdf

3.8.2 Emissions

This measure mainly affects non-road sector and specifically the diesel construction equipment category. Table 3-22 shows the Bexar County construction equipment NOx emissions contributions by TexN model[58] grouping. There is no way to accurately account for the fraction of emissions from construction equipment that is used to fulfill CoSA contracts based on readily available data from the TexN model; it is likely that portions of a number of different construction equipment groupings would be affected by this measure. In the Dallas-Fort Worth area, it was estimated that 20% to 25% of NOx emissions were estimated to be from equipment owned by, operated by or on behalf of, or leased by a local government/public agency. Assuming that 16% of NOx emissions in Bexar County are from city-owned construction equipment (based on TexN model estimates of emission from municipal-owned and city and county road construction equipment), we assume that 5% to 10% of construction equipment NOx emissions (0.15 tpd and 0.31 tpd) are from construction activity associated with the fulfillment of CoSA contracts.

[58] Sources of Air Emissions, TCEQ; https://www.tceq.texas.gov/airquality/areasource/Sources_of_Air_Pollution.html/#NonRoad

Table 3-22. Percent of NOx emissions by TexN construction equipment grouping.

TexN Construction Equipment Grouping	% of NOx
Skid Steer Loaders	15%
Municipal-Owned Construction Equipment	7%
Off-Road Tractors, Misc. Equipment, and all Equipment < 25 hp	5%
Trenchers	5%
Commercial Construction	6%
Rough Terrain Forklifts	5%
Transportation/Sales/Services	4%
Residential Construction	4%
Cranes	4%
Mining and Quarry Operations	4%
TxDOT Construction Equipment	4%
Landscaping Activities	3%
Utility Construction	2%
City and County Road Construction	2%
Boring and Drilling Equipment	1%
Heavy Highway Construction	1%
County-Owned Construction Equipment	1%
Concrete Operations	1%
Agricultural Activities	<1%
Manufacturing Operations	<1%
Scrap Recycling Operations	<1%
Landfill Operations	<1%
Brick and Stone Operations	<1%
Special Trades Construction	<1%

3.8.3 Cost and Cost Effectiveness

The implementation of this measure may cause additional costs to the CoSA if contractor bids are higher overall due to the requirement to meet more stringent Tier 4 standards, or if the city opts to share with contractors the cost of equipment upgrades that would be required. Detailed estimates of costs and cost effectiveness associated with upgrades to Tier 4 engines and diesel engine retrofits are provided above in the Sections 3.1 and Section 3.2. Cost effectiveness varies by equipment type, the technology of the engine being upgraded, and the emission control modality choice (i.e. Tier 4 engine replacement, SCR retrofit, or LNC retrofit). We note that part of the cost may be leveraged through opportunities to improve: (a) occupational exposure, (b) community health, (c) company image, (d) community concerns including environmental justice issues, and (e) cost savings for idle reductions.

3.8.4 Emission Reductions

It is estimated that more than one third (35%) of diesel construction equipment in Bexar County currently in use are estimated to be certified to Tier 2 or less stringent emission standards. This offers a potential for significant reductions in emissions by adopting contract language that for

example, limits using old engines on site, restricts long term idling, requires best operation practices, requires regular equipment maintenance, and/or specifies use of clean fuels.

Emission reductions will vary depending on specific actions and contract agreements. Based on the assumption that (a) 48% of construction and mining emissions are from Tier 2 and older equipment, (b) emissions reductions in the range of 25% to 85% or an average of 55% reductions, and (c) 5% to 10% of construction equipment NOx emissions (0.15 tpd and 0.31 tpd) are from construction activity associated with the fulfillment of CoSA contracts, we estimate emission reductions in the range of 0.04 tpd and 0.08 tpd NOx (or an overall reduction in NOx emissions across all diesel construction equipment of 0.9% to 2%).

3.8.5 Technical Implementation Feasibility and Public Acceptance

This measure is feasible and widely accepted. It is commonly used to improve air quality around local construction sites. Many government agencies (e.g. Texas Department of Transportation (TxDOT)[59]), local organizations, businesses and institutions have attempted to use contract specifications in sensitive areas to require the use of cleaner diesel equipment. A comprehensive guidance[57] for this measure has been developed by NEDC and EPA.

3.9 Measures N5: Alternative Fuels - CNG/LPG for City-owned Fleet (Airport Ground Support Equipment)

3.9.1 Description

Alternative fuels are transportation fuels other than gasoline and diesel, including natural gas, propane, methanol, ethanol, electricity, and biodiesel. The use of alternative fuels such as compressed natural gas (CNG) or liquid petroleum gas (LPG) can significantly reduce emissions from airport GSE that otherwise burn gasoline or diesel fuel. Both liquid or compressed natural gas and LPG fuels have lower NOx emission rates compared to diesel fueled engines and therefore have the potential to lower exhaust emissions from GSE. The SAIA is the commercial aviation hub of the San Antonio area and is where a vast majority, if not all, airport GSE in the San Antonio area is located.

3.9.2 Emissions

Annual emissions from GSE at SAIA for calendar year 2018 are shown by fuel type in Table 3-23.

Table 3-23. 2018 SAIA GSE emissions by fuel type.

Fuel Type	NOx (tpy)	VOC (tpy)	CO (tpy)
Gasoline	7.6	2.4	68.9
LPG	0.7	0.2	6.8
CNG	0.6	0.2	5.4
Diesel	35.9	11.4	327.4
Totals	**44.7**	**14.2**	**408.4**

[59] "Standard Specification for Construction and Maintenance of Highways, Streets, and Bridges", TxDOT, 2004, http://ftp.dot.state.tx.us/pub/txdot-info/des/specs/specbook.pdf

Diesel operated GSE engines account for 80% of NOx emissions from GSE at the SAIA in the TCEQ inventory. The AACOG conducted GSE surveys and compiled a detailed GSE emission inventory for calendar year 2006 in a study released in 2012[60]. We have disaggregated the 2018 TCEQ diesel engine emission estimates to the equipment type level (Table 3-24) based on emission contributions by equipment type from the AACOG study.

Table 3-24. 2018 SAIA GSE diesel engine emissions by equipment type.

GSE Type	Fuel	No. of Units	NOx (tpy)	VOC (tpy)	CO (tpy)
Diesel - Total	**Diesel**	**221**	**35.9**	**11.4**	**327.4**
Air Cond.	Diesel	14	8.0	2.0	72.0
Air Start Unit	Diesel	14	8.6	1.3	79.2
Aircraft Pushback Tractor	Diesel	33	2.5	2.7	10.8
Baggage Tug	Diesel	29	2.1	1.3	32.4
Belt Loader	Diesel	34	1.8	0.7	10.8
Cargo Loader	Diesel	20	1.0	0.7	21.6
Catering Truck	Diesel	4	1.0	-	3.6
Conveyor	Diesel	2	0.1	-	-
Deicing Unit	Diesel	1	-	-	-
Fuel Truck	Diesel	31	2.7	0.7	14.4
Ground Power Unit	Diesel	27	7.3	2.0	72.0
Lavatory Truck	Diesel	1	0.1	-	-
Lift	Diesel	1	0.1	-	3.6
Lift Platform	Diesel	2	0.4	-	7.2
Light Cart	Diesel	3	-	-	-
Light Plant	Diesel	2	-	-	-
Portable Air Stairs	Diesel	1	-	-	-
Service Truck	Diesel	2	-	-	-

3.9.3 Emission Reductions

Potential emission reductions due to the replacement of diesel-fueled engines with CNG and LPG-fueled models will vary depending on emission standards to which the new engine and the engine being replaced are certified. VOC and CO emission changes are expected to be marginal while NOx reductions are estimated to range from 50% to 60% based on NONROAD model estimates of emission rates for CNG and LPG engines certified to 2007 standards versus fleet average diesel-fueled engine GSE emission rates. An average NOx reduction of 55% was assumed for this measure; associated emission reductions are shown in Table 3-25.

[60] "Emission Inventory San Antonio International Airport - Technical Report" http://www.aacog.com/DocumentCenter/View/6544

Table 3-25. Airport terminal gate electrification emission reduction potential.

GSE Type	NOx (tpy)
Diesel – Total	**19.7**
Air Cond.	4.4
Air Start Unit	4.7
Aircraft Pushback Tractor	1.4
Baggage Tug	1.1
Belt Loader	1.0
Cargo Loader	0.6
Catering Truck	0.6
Conveyor	0.1
Deicing Unit	-
Fuel Truck	1.5
Ground Power Unit	4.0
Lavatory Truck	0.1
Lift	0.1
Lift Platform	0.2
Light Cart	-
Light Plant	-
Portable Air Stairs	-
Service Truck	-

Replacing diesel-fueled GSE with alternative fuel models becomes more effective when applied to older equipment (assuming that the older equipment has a usage profile similar to newer equipment). AACOG conducted detailed surveys of SAIA GSE circa-2006[60]; population by model year (see Figure 3-1) showed that over one-quarter of diesel GSE engines had a model year prior to 1996. These pre-1996 model year engines are not expected to be captured under EPA non-road diesel engine emission standards.

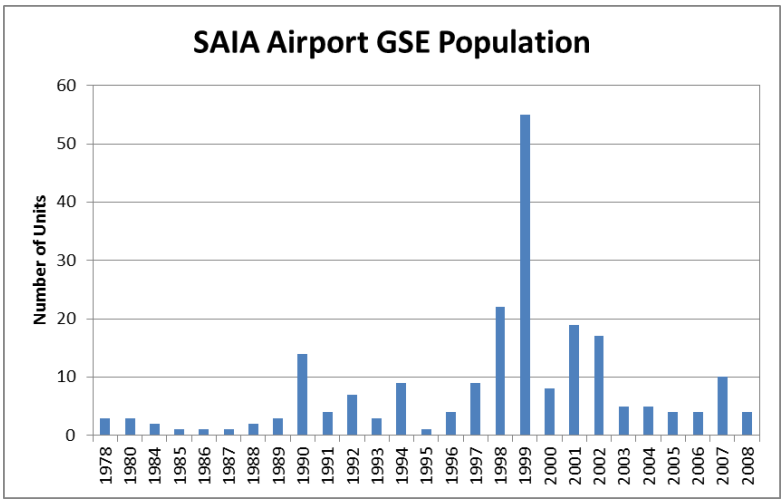

Figure 3-1. SAIA GSE population by model year circa-2006 (source: AACOG, 2012[60]).

3.9.4 Cost-Effectiveness

Using data from various literature sources[61,62], cost effectiveness of switching from diesel to alternative fuels such as CNG or LPG appears to be consistently below $5,000/ton (NOx) for non-road engines. Cost effectiveness can be even lower when the cost of CNG or LPG fuel relative to diesel fuel is considered. For example, according to the U.S. Department of Energy[63], CNG fuel (in gallon equivalents) is around 57% cheaper than a gallon of diesel (as of October 2014). For example, an average internal combustion baggage tractor burns between six and eight gallons of fuel per day[64]; additional savings of approximately $4,000/year can be expected for a typical GSE conversion from diesel to CNG fuel. Depending on GSE type, fuel savings can offset incremental capital cost.

Additional costs, including maintenance facility upgrades, training, and refueling station costs may also be required depending on existing SAIA infrastructure. Such costs may not be insignificant. For example, while refueling infrastructure capital cost is expected to be determined based on site specific demand, site conditions, and other factors, a station with a dispensing capacity of 100 to 200 gasoline gallon equivalents per day is estimated to cost between $400,000 to $600,000 for a fast-fill station and $250,000 to $500,000 for a time-fill station[65].

3.9.5 Technical Implementation Feasibility and Public Acceptance

This measure is feasible and publicly acceptable and is being implemented in many major airports across the U.S.[66]. The FAA's VALE initiative, through the Airport Improvement Program (AIP) among other measures targets airport GSE for emission reductions and actively funds such measures.

3.10 Measure O10: Restrict Long Term Idling (Truck Stops)

3.10.1 Description

The goal of this measure is to reduce emissions from long term heavy duty diesel truck idling within the CoSA (including the ETJ area). Long term idling of heavy duty diesel trucks involves the use of a diesel engine or APU to provide power to the cabin for heating, air conditioning, electronic devices and other equipment that is typically used while a truck is at a truck stop or rest stop in hoteling mode. Long term idling emission reductions can be achieved by equipping trucks with automatic idling shut-off devices or by truck stop electrification (TSE).

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[61] NESCAUM, July 2003: "Controlling Airport-Related Air Pollution"
[62] ARB - Carl Moyer Program, http://www.arb.ca.gov/regact/cargo2005/appf.pdf
[63] U.S. DOE, Energy Efficiency & Renewable Energy: "Clean Cities Alternative Fuel Price Report", October, 2014.
[64] EPRI, "Austin Airport Electrification: Landside and Airside Operations ", http://content.abia.org/environmental/pdfs/electric_vehicle.pdf
[65] U.S. DOE, Energy Efficiency & Renewable Energy: "Costs Associated with Compressed Natural Gas Vehicle Fueling Infrastructure: Factors to consider in the implementation of fueling stations and equipment", September, 2014.
[66] Voluntary Airport Low Emissions Program (VALE), http://www.faa.gov/airports/environmental/vale/

The focus of this measure is on the application of TSE based on a potential city ordinance limiting long term idling throughout, or in certain areas of the CoSA, or an incentive program to support TSE. TSE has already been implemented in the Houston-Galveston-Brazoria area through the TERP program[67]. Similarly, a truck stop in Northeast Texas is also electrified.

Since IH-35, IH-10, and other major highways converge in San Antonio, truck drivers frequently use truck stops and rest areas in the San Antonio area[68]. Figure 3-2 shows truck stop locations in the San Antonio area. Figure 3-3 shows rest stop locations in the San Antonio area; there are no rest stops in Bexar County. While trucks may carry out long term idling operations away from truck or rest stops, it is estimated that idling activity outside of truck and rest stops is relatively minor.

This emission reductions estimated for this measure do not account for emission reductions associated with short term truck idling, i.e. idling that occurs during deliveries, or at other times when a vehicle is stopped, but is not in long-term idling hoteling mode at a truck stop, rest stop, or picnic area. However, it is important to note that short-term idling emissions are also a source of NOx emissions that can be controlled.

3.10.1.1 Anti-idling Rule (30 TAC 114, Subchapter J, Division 2)

The TCEQ has an anti-idling rule that applies to all local jurisdictions in Texas that have signed an agreement with the TCEQ (30 TAC 114, Subchapter J, Division 2)[69]. This rule places idling limits on gasoline and diesel-powered engines of motor vehicles; the primary propulsion engine of any heavy-duty motor vehicle may not idle for more than five consecutive minutes when the vehicle is not in motion. The TCEQ's website[69] indicates that 41 cities and counties in Texas have signed an agreement for this rule. The CoSA does not have an agreement with TCEQ that would allow for implementation of this rule and the benefits of the expected associated NOx emission reductions.

In the Dallas-Fort Worth SIP, emission reductions resulting from the application of the TCEQ anti-idling rule (30 TAC 114, Subchapter J, Division 2) were taken credit for as part of the voluntary mobile emission reduction program (VMEP)[70]. It was assumed that this measure would reduce 25% of idling emissions from Class 4 Heavy-Duty Diesel Vehicles (14,001-16,000 pounds gross vehicle weight rating) and heavier. If a similar 25% reduction is assumed for all extended idling in Bexar County, an emission reduction of 0.28 tpd NOx is estimated from this anti-idling program.

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[67] TCEQ, 2007, "Houston-Galveston-Brazoria Eight-Hour Ozone Nonattainment Area" https://www.tceq.texas.gov/assets/public/implementation/air/sip/hgb/hgb_sip_2007/06027SIP_COMPLETE_DOCS.pdf

[68] AACOG, 2011, "Heavy-Duty Vehicle Idle Activity and Emissions, San Antonio-New Braunfels MSA", http://www.aacog.com/DocumentCenter/View/6543

[69] https://www.tceq.texas.gov/airquality/mobilesource/vehicleidling.html

[70] North Central Texas State Implementation Plan Voluntary Mobile Emission Reduction Program (VMEP) http://www.nctcog.org/trans/air/sip/future/VMEP2009_090506.pdf

3.10.2 Emissions

According to the TCEQ emissions inventory for calendar year 2018, long term idling activity accounts for more than 1.1 ton per day of NOx emissions in Bexar County.

According to the AACOG long term idling survey, there are 18 truck stops in the CoSA (including the ETJ area) with 1,390 parking stalls and no rest areas[2]. Table 3-26 shows the number of parking spaces and location of Bexar County truck stops.

3.10.3 Cost and Cost Effectiveness

Idle reduction technologies typically require initial capital expenditures, however, according to the CARB, it is expected that operators will recover their costs over time through fuel and maintenance savings. CARB estimates that cost recovery times will range between 8 months and 3 years, depending on the idling-reduction equipment and the amount of time spent in idling mode[71].

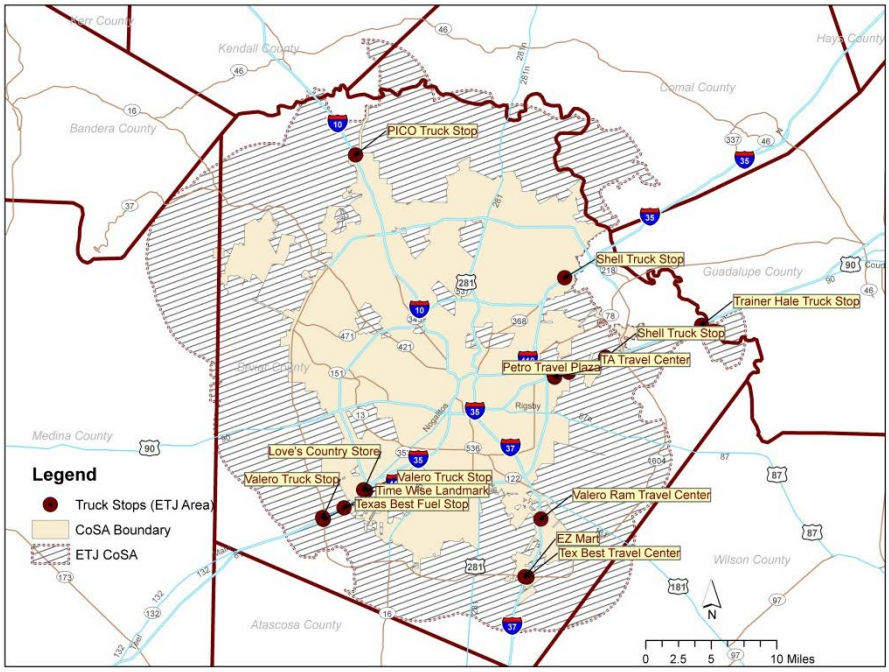

Figure 3-2. Truck stops in the CoSA (including ETJ area) (KMZ and shapefiles data provided by AACOG and CoSA).

[71] http://www.arb.ca.gov/msprog/cabcomfort/cabcomfort.htm

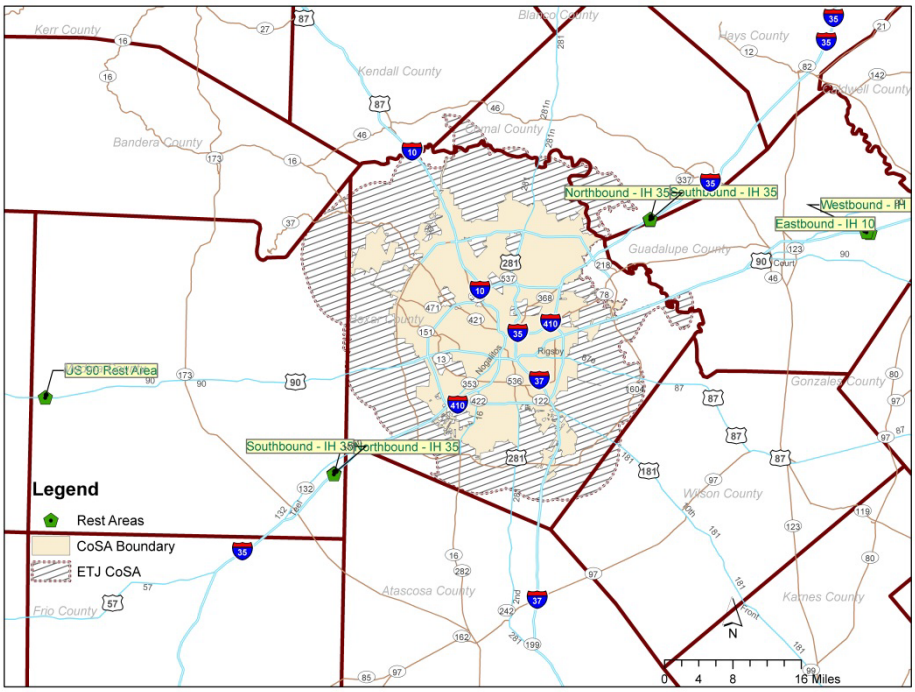

Figure 3-3. Rest stops in the San Antonio Area (KMZ and shapefiles data provided by AACOG and CoSA).

Table 3-26. Truck stop locations in the CoSA (including ETJ area) (source: AACOG, 2011)[68].

Truck Stop	Address	Parking Spaces
EZ Mart	15537 IH 37, Elmendorf	25
Tex Best Travel Center	20290 IH 37, Elmendorf	30
Valero Ram Travel Center	IH 37, Elmendorf	12
Texas Best Fuel Stop (Exxon)	14650 IH 35, Von Ormy	15
Valero AAA Travel Center	14555 IH 35, Von Ormy	70
Shell Time Wise Landmark	13437 IH 35, Von Ormy	24
Love's Country Store	11361 IH 35, S Von Ormy	108
Valero	IH 35, S Von Ormy	50
Shell Truck Stop	11607 N IH 35, San Antonio	45
PICO	25284 IH 10, San Antonio	15
Petro Travel Plaza	1112 Ackerman Rd, San Antonio	320
Pilot Travel Center	5619 IH 10 E, San Antonio	50
Flying J Travel Plaza	1815 Foster Rd., San Antonio	283
TA Travel Center	6170 IH 10 E, San Antonio	258
Shell Truck Stop	8755 IH 10 E, Converse	60
Trainer Hale Truck Stop	14462 IH 10, Converse	25
Total		**1,390**

There are two general TSE modalities, (1) on-board power infrastructure which requires retrofit of individual trucks and (2) off-board power infrastructure which does not require individual truck retrofits. It is expected that a significant fraction of long-term idle trucks in San Antonio may not be based locally; therefore, for this measure we explore the off-board power option that does not require additional truck modifications. An off-board infrastructure system would typically provide 110V of AC electrical power for on-board appliances, an externally mounted, individual controlled heating and air conditioning unit and hook-ups for basic telephone, internet and television (access to cable/satellite) services at each truck parking space. According to CARB, the cost of such infrastructure is approximately $8,000 per parking space[72].

As indicated in Table 3-26, it is estimated that there are 16 active truck stops in the CoSA (including the ETJ area) with 1,390 parking places. The total cost of equipping all truck stops with off-board TSE infrastructure is estimated to be approximately $11 million dollars. Obtaining participation from drivers will be necessary to yield the greatest emission reductions from this measure; we have assumed a participation rate of 80%.

Table 3-27 shows estimated costs and cost effectiveness in the case that 100% or 50% of truck stops in Bexar County were outfitted with TSE infrastructure. As a comparison, a recent ENVIRON study (ENVIRON, 2013) conducted for The North East Texas Air Care (NETAC) , estimated TSE cost effectiveness of $1,000/ton over the project life (15 years), though off-board and on-board infrastructure projects were not differentiated.

Table 3-27. Idle reduction truck stop electrification cost effectiveness.

Number of Parking Spaces	1,390	695
TSE Infrastructure Cost (per truck stop)	$8,000	$8,000
Project Cost	$11,120,000	$5,560,000
Rule Effectiveness	80%	80%
NOx Emissions Reductions (tpd)	0.82	0.41
Cost Effectiveness ($/ton)	$3,113	$3,113

3.10.4 Emission Reductions

Long term idling emissions at the truck stops may be reduced significantly when using idle-reduction technologies such as onboard APUs or truck-stop hookups that provide heating, cooling, electricity, hence eliminating the need for idling at the stop. The TSE option would completely eliminate the need for long-term idling where implemented.

Emission reductions will depend on the long term idling activity able to be displaced by TSE. Here, we assume that half of the truck stops in ETJ Area would be retrofitted with TSE, removing approximately 0.41 tpd NOx. Note, this measure has the potential to control a very

[72] CARB, Truck Idling Reduction Workshop, http://www.arb.ca.gov/msprog/truck-idling/workshop-notice-05-09-2003.pdf

high percentage of truck idling emissions, depending on the number of truck stops equipped with TSE technology and driver participation.

3.10.5 Technical Implementation Feasibility and Public Acceptance

Several TSE projects have been funded in Texas through the TERP. As indicated above, truck stop electrification has already been implemented at truck stops in the Houston-Galveston-Brazoria area and in Northeast Texas through the TERP program.

3.11 Measure O7: Electrification of City-owned Vehicle Fleet

3.11.1 Description

Fleet vehicle electrification programs are becoming more and more popular as on-road emission reduction options, as prices of conventional hybrid, plug-in hybrid electric, and dedicated electric vehicles continue to decline. As of 2015, CoSA already has 398 conventional hybrid electric and five plug-in electric vehicles in its fleet.[7]

As a part of Mission Verde Sustainability Plan[73] and other adopted policies to remain in attainment of the EPA's air quality standards, CoSA is committed to reducing emissions from city-owned mobile sources by 30% by year 2020 (from 2009 baseline)[74]. This vehicle electrification measure will help achieve that goal.

3.11.2 Emissions

The CoSA owns approximately 5,000 on-road and off-road vehicles[7]. According to a 2010 AACOG study[74], there were at that time 2,186 on-road gasoline vehicles certified to Tier 2 standards, 889 on-road gasoline vehicles certified to pre-Tier 2 standards, and 557 on-road pre-2007 model year diesel vehicles. This measure is specifically targeted at the subset of on-road passenger gasoline vehicles that can be electrified. For purposes of estimating emission reductions, we assume that (1) 1,500 Tier 2 conventional gasoline vehicles are replaced by 500 conventional hybrid vehicles, 500 plug-in hybrid vehicles, and 500 dedicated electric vehicles and (2) 450 pre-Tier 2 conventional gasoline vehicles are replaced by 150 conventional hybrid vehicles, 150 plug-in hybrid vehicles, and 150 dedicated electric vehicles. Based on MOVES default estimates of on-road emissions for Bexar County, Table 3-28 shows the estimate of annual emissions from 1,500 Tier 2 conventional gasoline vehicles and 450 pre-Tier 2 conventional gasoline vehicles. Per vehicle emission estimates by model year are provided in Appendix C for reference.

[73] San Antonio Mission Verde, http://www.alamo.edu/main.aspx?id=10966
[74] "Strategy Effectiveness Analysis", 2010, https://www.aacog.com/DocumentCenter/Home/View/193

Table 3-28. On-road vehicle (gasoline passenger car) emissions.

Vehicle Technology	Number of Vehicles	Emissions (tpy)[c]		
		NOx	VOC	CO
Pre-Tier 2[a]	450	2.12	2.02	11.86
Tier 2[b]	1,500	0.55	0.53	10.72
Totals		**2.67**	**2.55**	**22.59**

[a] model years 1988-2004
[b] model years 2005-2014
[c] based on assumption of 5,000 annual miles traveled per vehicle

3.11.3 Emission Reductions

Emission reductions were estimated based on the following assumptions (1) 2015 model year fleet average emission rates are assumed for conventional hybrid vehicles, (2) 2015 model year fleet average emission rates reductions of 30% are assumed for plug-in hybrid vehicles (30% of travel is assumed in all electric mode), and (3) all electric vehicles are assumed to have zero emissions. It is important to note that plug-in electric vehicles will use electricity which would cause indirect emissions at power plants; incremental emissions from nearby power plants are not considered in this analysis.

Table 3-29 shows emission reduction estimates based on replacement of (1) 1,500 Tier 2 conventional gasoline vehicles with 500 conventional hybrid vehicles, 500 plug-in hybrid vehicles, and 500 dedicated electric vehicles and (2) 450 pre-Tier 2 conventional gasoline vehicles with 150 conventional hybrid vehicles, 150 plug-in hybrid vehicles, and 150 dedicated electric vehicles. Per vehicle emission reduction estimates by model year are provided in Appendix C for reference; Appendix Table C1 shows that emission reductions are far greater on a per vehicle basis from older vintage vehicles.

Table 3-29. On-road vehicle (gasoline passenger car) emission reductions (tpy) associated with city-owned fleet electrification.

Model Year Grouping	Emission Reductions (tpy) for Conventional Hybrid Vehicles			Emission Reductions (tpy) for Plug-in Hybrid Vehicles			Emission Reductions (tpy) for Dedicated Electric Vehicles		
	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO
Pre-Tier 2[a]	2.07	1.96	10.81	2.09	1.97	11.12	2.12	2.02	11.86
Tier 2[b]	0.38	0.33	7.21	0.43	0.39	8.27	0.55	0.53	10.72
Totals	**2.46**	**2.29**	**18.02**	**2.52**	**2.37**	**19.39**	**2.67**	**2.55**	**22.59**

[a] model years 1988-2004
[b] model years 2005-2014
[c] based on assumption of 5,000 annual miles traveled per vehicle

3.11.4 Cost and Cost-Effectiveness

There are currently many different conventional hybrid, plug-in hybrid, and dedicated electric vehicles available. The prices of several popular examples (shown in Table 3-30) were used to develop cost effectiveness estimates.

Table 3-30. Electric vehicle prices for select models (circa February 2015).

Vehicle Type	Model	Price
All electric	Nissan Leaf	$ 29,000
	Ford Focus Electric	$ 29,170
Plug-in Hybrid Electric	Chevy Volt	$ 34,345
	Toyota Prius Plug-in	$ 29,990
Conventional Hybrid	Toyota Prius	$ 24,200

Assuming the average price of conventional vehicle to be approximately $22,000[75], the average incremental cost for vehicle replacement is approximately $7,500 per vehicle. Annualized cost and cost effectiveness estimated using TERP methodology with and without fuel economy savings is provided for plug-in vehicles in Table 3-31. Average fuel consumption was estimated from U.S. Energy Information Administration estimates: (1) average consumption in 2018 of a conventional fuel vehicle is expected to be 35 miles per gallon (mpg), compared to 75 mpg and 130 mpg (equivalent) for plug-in and dedicated electric vehicles, respectively. Average fuel cost is assumed to be $3/gallon.

Table 3-31. Cost effectiveness for the electrification of select vehicles in the city-owned vehicle fleet.

Model Year Grouping	Cost Effectiveness (without fuel savings) [$/ton]			Cost Effectiveness (with fuel savings) [$/ton]		
	Conventional Hybrid	Plug-in Hybrid	Dedicated Electric	Conventional Hybrid	Plug-in Hybrid	Dedicated Electric
MY 1988-2004	$9,602	$53,448	$30,470	*	$46,062	$26,287
MY 2005-2014	$179,398	$874,048	$388,290	*	$753,258	$334,988
Totals	**$35,310**	**$192,392**	**$104,660**	*	**$165,804**	**$90,293**

* conservatively assumed no fuel savings for conventional hybrid vehicles

It is important to note that the cost effectiveness estimates above do not include the cost of charging infrastructure. Capital outlay for AC charging infrastructure in a parking garage is expected to be approximately $6,000 while a fast charging station is expected to be $50,000 to $100,000.[76] Cost can vary significantly depending on local constraints, e.g. distance to the breaker box is an important cost factor. Station maintenance costs are estimated to be relatively minor ($300 per year) relative to initial capital cost.[76]

3.11.5 Technical Implementation Feasibility and Public Acceptance

Electric and hybrid electric technology is readily available; hence this emission measure is highly feasible for light duty passenger fleet vehicles. The CoSA is already implementing a clean fleet program that includes electric vehicles.

[75] http://www.eia.gov/todayinenergy/detail.cfm?id=17211
[76] http://blog.rmi.org/blog_2014_04_29_pulling_back_the_veil_on_ev_charging_station_costs

3.12 Summary of Analyzed Control Measures

Table 3-32 presents a summary of emission reductions and cost effectiveness by control measure. Those selected measures that are top-ten ranked in both potential emission reductions and cost effectiveness are bolded. The most effective control measures for reducing emissions are commuter trip reduction programs which are estimated to reduce 354 tpy NOx and 245 tpy VOC and the heavy duty truck long term idling reduction measure which is estimated to reduce 150 tpy NOx. Control measures that are most cost effective are locomotive idling reduction, long term heavy duty truck idling restrictions, alternative fuel engine replacements for city-owned equipment fleets, and VOC content limits on surface coatings for city projects, all with a cost effectiveness of $6,400 or less.

ENVIRON prepared an EPS3 model-ready “cntlem” file for each control measure analyzed and provided these files to TCEQ electronically. Each “cntlem” file includes the SCC and pollutant emissions reduction factors for a given control measure. These files are capable of being used with existing EPS3 modeling setups to develop CAMx model-ready files for a chosen suite of control measures.

Table 3-32. Summary of estimated emission reductions and cost effectiveness (sorted by emission reduction)*.

Emissions Control Measure Descriptive Information				Estimated 2018 Emission Reduction [tpy]		
ID No.	Emission Sector	Measure		NOx	VOC	Estimated Cost Effectiveness [$/ton]
O17	**on-road**	**Commuter Trip Reduction Programs (vanpool, carpool)**		354	245	$10,000 - $32,000
O10	on-road	Restrict Long Term Idling		150	-[a]	$3,113
N13	**non-road**	**City-owned Construction Equipment Replacement Program (replace Tier 0, Tier 1, and Tier 2 with Tier 4)**		93.3	-[a]	$32,974
N3	**non-road**	**Diesel Retrofits and Engine Rebuilds for City-owned Construction Equipment**	**SCR**	81.8[b]	-[a]	$23,326[d]
			LNC	26.4[c]	-[a]	$23,182[e]
N12	**non-road**	**City-owned Construction Equipment Replacement Program (replace Tier 0 and Tier 1 with Tier 4)**		67.8	-[a]	$29,024
N8	**non-road**	**Locomotives Idling Reduction within City limit**		58.4	-[a]	$1,500 - $5,000
N5	**non-road**	**Alternative Fuels - CNG/LPG for City-owned fleet**		19.7	-[a]	$5,000
A5	**area/nonpoint**	**VOC Content Limits for Architectural, Traffic, and Industrial Maintenance Coatings**		-[a]	34.9	$6,400
N11	non-road	Emission Specifications in Contracts		14.6 - 29.2	-[a]	[f]
N9	non-road	Airport Terminal Gate Electrification		19.2	-[a]	$20,552
O7	**on-road**	**Electrification of City-owned Vehicle Fleet**		**7.65**	**7.21**	**$35,310 -$192,392**
O19	on-road	Increased Use of Non-Motorized Travel (Bike)		0.33	0.23	$7,500 - $75,000

* It should be noted that ENVIRON relied on data that was readily available for use in this analysis, and that actual emission reductions that are achievable and associated costs and cost effectiveness depend on a number of input parameters that will need to be evaluated during implementation planning.

[a] not target pollutant for given measure, emission reductions assumed negligible

[b] 81.8 tpy NOx reduction for SCR retrofit of Tier 0, Tier 1, and Tier 2 engines, 54.0 tpy NOx reduction for SCR retrofit of Tier 0 and Tier 1 engines

[c] 26.4 tpy NOx reduction for LNC retrofit of Tier 0, Tier 1, and Tier 2 engines, 18.1 tpy NOx reduction for LNC retrofit of Tier 0 and Tier 1 engines

[d] $23,326/ton NOx cost effectiveness for SCR retrofit of Tier 0, Tier 1, and Tier 2 engines, $21,744/ton NOx cost effectiveness for SCR retrofit of Tier 0 and Tier 1 engines

[e] $23,182/ton NOx cost effectiveness for LNC retrofit of Tier 0, Tier 1, and Tier 2 engines, $20,507/ton NOx cost effectiveness for LNC retrofit of Tier 0 and Tier 1 engines

[f] expected to be consistent with cost effectiveness estimated for N3, N13, and N12, depending on mitigation strategy chosen

4.0 RECOMMENDATIONS AND LIMITATIONS

The pertinent accomplishments, shortfalls, and limitations of this work are as follows:

- As a result of this study, two lists identifying and evaluating potential air quality control measures available for evaluation by the CoSA have been developed, with one list that prioritizes emission reductions and a second list that prioritizes cost effectiveness.

- It is recommended that this report be used as a reference for many stakeholders when considering the selection and implementation of emission control strategies in the San Antonio area.

- ENVIRON relied on data that was readily available for use in this analysis. We note that actual emission reductions that are achievable and associated costs and cost effectiveness depend on a number of input parameters that will need to be evaluated during implementation planning. Some examples of assumptions that should be revisited during the implementation planning stage are as follows:

    - Measure A5: VOC Content Limits for Architectural and Industrial Coatings – before implementing this measure, CoSA may consider compiling a revised emission inventory estimate based on its surface coating usage based on a survey of CoSA-wide surface coating usage on CoSA controlled projects.

    - Generally, technology cost estimates were based on vendor data and relatively current market conditions, to the extent that this information was available. These estimates will need to be revisited based on the specific control strategies being considered.

    - CoSA emission estimates and emission reduction estimates are based on a 2018 emission forecasts for on-road, non-road, and area sources (and a 2012 inventory for point sources). Depending on the emission source category, there may be considerable uncertainty associated with the emissions estimates. For example, the switching locomotive emission inventory was noted as a particular area of uncertainty with respect to Measure N8: Locomotives Idling Reduction within City limits.

5.0 REFERENCES

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Environmental Protection Agency. (EPA). 2004. "Guidance on Airport Emission Reductions Credits for Early Measures through Voluntary Airport Low Emission Programs". September 2004.

APPENDIX A

Control Measure Master List

Appendix A. Control Measure Master List

Top Ten List Inclusion, or Reason for Exclusion	Emissions Control Measure Descriptive Information						Preliminary Cost Effectiveness [$/ton]	Preliminary Emission Reduction [tons/day]	
	ID No.	Measure	Sector	City Authority	Applicable Emission Source Category	Target Pollutant		NOx	VOC
Emission Reduction, Cost Effectiveness	A5	VOC Content Limits for Architectural, Traffic, and Industrial Maintenance Coatings	nonPoint	Y (city projects)	Architectural, Traffic, and Industrial Maintenance Coatings	VOC	$6,612	[a]	1.17
Emission Reduction	O10	Restrict Long Term Idling	On-road	Y	Heavy Duty Diesel Vehicles (Idling)	NOx	not available	0.858	[a]
Emission Reduction, Cost Effectiveness	N8	Locomotives Idling Reduction within City limit	Non-road	Y	Locomotives	NOx	$1,500	0.116	[a]
Emission Reduction, Cost Effectiveness	O17	Commuter Trip Reduction Programs (vanpool, carpool)	On-road	Y	Light Duty Vehicles	NOx, VOC	$11,253	0.044	0.042
Emission Reduction	O19	Increased Use of Non-Motorized Travel (Pedestrian/Bike)	On-road	Y	Light Duty Vehicles	NOx, VOC	not available	0.044	0.042
Emission Reduction, Cost Effectiveness	N13	City-owned Construction Equipment Replacement Program (replace Tier 0, Tier 1, and Tier 2 with Tier 4)	Non-road	Y	Construction Equipment (City-owned only)	NOx	$5,627	0.084	[a]
Emission Reduction, Cost Effectiveness	N3	Diesel Retrofits and Engine Rebuilds for City-owned Construction Equipment	Non-road	Y	Diesel Construction Equipment	NOx	$4,500	0.063	[a]
Emission Reduction, Cost Effectiveness	N12	City-owned Construction Equipment Replacement Program (replace Tier 0 and Tier 1 with Tier 4)	Non-road	Y	Construction Equipment (City-owned only)	NOx	$5,627	0.055	[a]
Emission Reduction, Cost Effectiveness	N7	Equipment Electrification for city-owned fleet	Non-road	Y	Gasoline and Diesel Aircraft Ground Support Equipment (GSE)	NOx	$2,973	0.024	0.008

Top Ten List Inclusion, or Reason for Exclusion	Emissions Control Measure Descriptive Information						Preliminary Cost Effectiveness [$/ton]	Preliminary Emission Reduction [tons/day]	
	ID No.	Measure	Sector	City Authority	Applicable Emission Source Category	Target Pollutant		NOx	VOC
Emission Reduction, Cost Effectiveness	N5	Alternative Fuels - CNG/LPG for city-owned fleet	Non-road	Y	Gasoline and Diesel Aircraft Ground Support Equipment (GSE)	NOx	$2,218	0.016	0.005
Cost Effectiveness	N11	Emission Specifications in Contracts	Non-road	Y	Diesel Construction Equipment	NOx	not available	0.02	[a]
Cost Effectiveness	N9	Airport Terminal Gate Electrification	Non-road	Y	Aircraft Auxiliary Power Units	NOx, VOC	not available	0.003	<0.001
Program already in place for residential mowers, lack of demonstrated programs for commercial mowers	N10	Electric Lawn Mower Replacement Program	Non-road	N	Residential and Commercial Lawn and Garden Equipment	NOx, VOC	$16,000	0.01	0.08
Spruce 1 SCR expected to be online in 2019, Deely units may be taken offline from 2018	P9	Selective Catalytic Reduction for City-owned EGU	Point	Y	EGU: Utility Boiler - Coal	NOx	$2,852	8.66	[a]
Technology already implemented on all possible units	P8	Natural Gas Reburn Technology for City-owned EGU	Point	Y	EGU: Utility Boiler - Coal	NOx	$776	5.29	[a]
Technology already implemented on all possible units	P11	Low NOx Burner for City-owned EGU	Point	Y	EGU: Utility Boiler - Coal	NOx	$570	5.00	[a]

Top Ten List Inclusion, or Reason for Exclusion	Emissions Control Measure Descriptive Information						Preliminary Cost Effectiveness [$/ton]	Preliminary Emission Reduction [tons/day]	
	ID No.	Measure	Sector	City Authority	Applicable Emission Source Category	Target Pollutant		NOx	VOC
SCR used wherever possible	P10	Selective Non-Catalytic Reduction for City-owned EGU	Point	Y	EGU: Utility Boiler - Coal	NOx	$3,054	4.81	[a]
COSA does not use cutback asphalt	A1	Cutback Asphalt VOC Content Restrictions	nonPoint	Y	Commercial Solvent Use, Cutback Asphalt	VOC	$24	[a]	0.66
Applicable roadways not in CoSA juristiction	O20	High Occupancy Vehicle (HOV) Lanes	On-road	Y	Light Duty Vehicles	NOx, VOC	not available	0.20	0.19
Program already in place	O13	Ozone Action Days - Education and promotion campaigns	On-road	Y	All	NOx, VOC	not available	0.22	0.139
Comprehesive Program Already in Place	O27	Add more Clean Buses to VIA Metropolitan Transit Fleet	On-road	Y	Buses	NOx	$22,000	0.15	[a]
TCEQ Program already in place	O16	Clean School Bus Program - Diesel Retrofit	On-road	Y	School Buses	NOx	$5,950	0.02	[a]
Applicable roadways not in CoSA juristiction	O26	Speed limit reduction	On-road	Y	Light Duty Vehicles	NOx, VOC	not available	-	-
Not under CoSA authority	A2	Add-on Controls, Work Practices, and Material Reformulation / Substitution.	nonPoint	N	Commercial Solvent Use, Graphic Arts (flexible package printing)	VOC	$17	11	-
Not under CoSA authority	A3	Low VOC Cleaning Materials and Improved Work Practices	nonPoint	N	Solvent Cleaning / Degreasing	VOC	$40	21	-
Not under CoSA authority	A4	Automotive Coating VOC Content Limits	nonPoint	N	Mobile Equipment Repair and Refinishing	VOC	$35	32	-
Not under CoSA authority	A6	VOC Content Limits for Consumer Products	nonPoint	N	Consumer Products (e.g. adhesives, general purpose cleaners, etc.)	VOC	$9	16	-

Top Ten List Inclusion, or Reason for Exclusion	Emissions Control Measure Descriptive Information						Preliminary Cost Effectiveness [$/ton]	Preliminary Emission Reduction [tons/day]	
	ID No.	Measure	Sector	City Authority	Applicable Emission Source Category	Target Pollutant		NOx	VOC
Not under CoSA authority	A7	Reasonably Available Control Technology (RACT) (Low NOx Burner)	nonPoint	N	Industrial Fuel Combustion (Residual Oil, Distillate Oil, Kerosene)	NOx	$14	49	38
Not under CoSA authority	A8	Reasonably Available Control Technology (RACT) (Low NOx Burner)	nonPoint	N	Industrial Fuel Combustion (Natural Gas, Liquefied Petroleum Gas)	NOx	-	37	29
Not under CoSA authority	A9	Water and Space Heater Replacement (Low NOx Burners)	nonPoint	N	Residential/Commercial Fuel Combustion	NOx	$11	18	13
Not under CoSA authority	A10	Repower/replace artificial lift equipment (pumpjacks)	nonPoint	N	Oil and Gas Artificial Lift Engines	NOx	$37	28	19
Not under CoSA authority	A11	Low Bleed Pneumatic Devices	nonPoint	N	Oil and Gas Pneumatic Devices	VOC	$1	15	-
Not under CoSA authority	N1	Clean Fuel Specifications in Contracts	Non-road	N	Construction Equipment	NOx	-	46	35
Not under CoSA authority	N2	Low RVP Gasoline	Non-road	N	Gasoline Vehicles	VOC	$31	13	-
Not under CoSA authority	N4	Diesel Retrofits and Engine Rebuild Incentives	Non-road	N	Diesel Construction Equipment	NOx	$24	51	40
Not under CoSA authority	N6	Equipment Electrification	Non-road	N	Gasoline and Diesel Forklifts	NOx	$20	56	47
Not under CoSA authority	N10	Electric Lawn Mower Replacement Program	Non-road	N	Residential and Commercial Lawn and Garden Equipment	NOx, VOC	$41	42	48
Not under CoSA authority	N14	Equipment Replacement Incentive (replace Tier 0 and Tier 1 with Tier 4)	Non-road	N	Construction Equipment	NOx	$27	39	30
Not under CoSA authority	N15	Equipment Replacement Incentives (replace Tier 0, Tier 1, and Tier 2 with Tier 4)	Non-road	N	Construction Equipment	NOx	$27	35	27

Top Ten List Inclusion, or Reason for Exclusion	Emissions Control Measure Descriptive Information						Preliminary Cost Effectiveness [$/ton]	Preliminary Emission Reduction [tons/day]	
	ID No.	Measure	Sector	City Authority	Applicable Emission Source Category	Target Pollutant		NOx	VOC
Not under CoSA authority	O1	Diesel Retrofit: Retrofitting engines with verified technologies (i.e. SCR, ERG, LNC)	On-road	N	Heavy Duty Diesel Vehicles (Class 8)	NOx	$38	25	17
Not under CoSA authority	O1	Diesel Retrofit: Retrofitting engines with verified technologies (i.e. SCR, ERG, LNC)	On-road	N	Heavy Duty Diesel Vehicles (Class 6,7)	NOx	$45	47	36
Not under CoSA authority	O2	Diesel Retrofit: Repowering (replacing old engines with new, cleaner engines) for city-owned fleets	On-road	N	Heavy Duty Diesel Vehicles (Class 6 and above)	NOx	$32	23	15
Not under CoSA authority	O3	Diesel Replacement: Replacing older vehicles with new low emission models	On-road	N	Heavy Duty Diesel Vehicles (Class 6 and above)	NOx	$32	23	15
Not under CoSA authority	O6	Reduce Long Duration Idling Emissions with Auxiliary Power Units (APUs)	On-road	N	Heavy Duty Diesel Vehicles (Class 8)	NOx	$26	34	24
Not under CoSA authority	O7	Reduce Long Duration Idling with Truck Stop Electrification (TSE)	On-road	N	Heavy Duty Diesel Vehicles (Class 8)	NOx	$13	33	23
Not under CoSA authority	O8	Heavy Duty Vehicle Inspection Program (HDVIP)	On-road	N	Heavy Duty Vehicles	NOx	$16	31	22
Not under CoSA authority	O11	Alternative Fuel Programs	On-road	N	Heavy Duty Vehicles	NOx	-	29	20
Not under CoSA authority	O12	Travel Efficiency Strategies	On-road	N	Light Duty Vehicles	NOx, VOC	-	20	18
Not under CoSA authority	O14	Opt into Reformulated Gasoline (RFG) standards	On-road, Non-road	N	Gasoline vehicles and gasoline powered equipment	NOx, VOC	$23	30	21

Top Ten List Inclusion, or Reason for Exclusion	Emissions Control Measure Descriptive Information						Preliminary Cost Effectiveness [$/ton]	Preliminary Emission Reduction [tons/day]	
	ID No.	Measure	Sector	City Authority	Applicable Emission Source Category	Target Pollutant		NOx	VOC
Not under CoSA authority	O18	Continuous Inspection and Maintenance - On-board Diagnostics	On-road	N	Light Duty Vehicles	NOx, VOC	-	6	9
Not under CoSA authority	O24	Implementation of Inspection and Maintenance Program	On-road	N	Light Duty Vehicles	NOx	$43	7	10
Not under CoSA authority	O25	Vehicle Buy Back Program (extend LIRAP)	On-road	N	Light Duty Vehicles	NOx, VOC	$44	38	34
Not under CoSA authority	P1	Biosolid Injection Technology	Point	N	Cement Kilns	NOx	$4	10	8
Not under CoSA authority	P2	Changing Feed composition	Point	N	Cement Kilns	NOx	$7	8	6
Not under CoSA authority	P3	Process Control Systems	Point	N	Cement Kilns	NOx	-	12	11
Not under CoSA authority	P4	Low NOx Burner	Point	N	Cement Manufacturing - Dry Process or Wet Process	NOx	$6	14	12
Not under CoSA authority	P5	Mid-Kiln Firing	Point	N	Cement Kilns	NOx	$3	9	7
Not under CoSA authority	P6	Selective Catalytic Reduction	Point	N	Cement Kilns	NOx	$18	3	3
Not under CoSA authority	P7	Selective Non-Catalytic Reduction - Urea	Point	N	Cement Kilns	NOx	$10	40	31

APPENDIX B

Fleet Modernization and Retrofits Detailed Data

Appendix B. Fleet Modernization and Retrofits Detailed Data

Table B1. Detailed Diesel Construction Equipment Fleet Modernization Data, Tractors/Loaders/Backhoes.

	50-75 HP		75-100 HP		50-75 HP		75-100 HP		50-75 HP		75-100 HP	
Tractors/Loaders/Backhoes	Tier 0	Tier 4	Tier 0	Tier 4	Tier 1	Tier 4	Tier 1	Tier 4	Tier 2	Tier 4	Tier 2	Tier 4
	Baseline	Engines	Baseline	Engines	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine
NOx Emission Std (g/bhp-hr)	8.80	3.325	8.80	0.30	6.90	3.33	6.90	0.30	5.32	3.33	5.32	0.30
Average Horsepower (hp)	63	63	88	88	63	63	88	88	63	63	88	88
Load Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Activity (hr/yr)	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379
Incremental Capital Cost		$ 31,250		$ 43,750		$ 31,250		$ 43,750		$ 31,250		$ 43,750
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$3,663		$5,129		$3,663		$5,129		$3,663		$5,129
NOx Emission Factor (g/hr)	115	44	162	6	91	44	127	6	70	44	98	6
NOx (tons/year)	0.30	0.11	0.42	0.01	0.24	0.11	0.33	0.01	0.18	0.11	0.26	0.01
NOx Reduction (tons/year)		0.19		0.41		0.12		0.32		0.07		0.24
Cost-Effectiveness ($/ton)		$19,438		$12,520		$29,768		$16,125		$53,344		$21,200
One-Year Cost-Effectiveness		$165,808		$106,800		$253,930		$137,545		$455,038		$180,837

Table B2. Detailed Diesel Construction Equipment Fleet Modernization Data, Crawler Tractors/Dozers.

	100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP	
Crawler Tractors/Dozers	Tier 0	Tier 4	Tier 0	Tier 4	Tier 1	Tier 4	Tier 1	Tier 4	Tier 2	Tier 4	Tier 2	Tier 4
	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine	Baseline	Engines	Baseline	Engine
NOx Emission Std (g/bhp-hr)	9.5	0.3	9.3	0.3	6.9	0.3	6.9	0.3	4.66	0.3	4.655	0.3
Average Horsepower (hp)	138	138	238	238	138	138	238	238	138	138	238	238
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	550	550	550	550	550	550	550	550	550	550	550	550
Incremental Capital Cost		68,750		118,750		68,750		118,750		68,750		118,750
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$8,060		$13,921		$8,060		$13,921		$8,060		$13,921
NOx Emission Factor (g/hr)	771	24	1303	42	560	24	967	42	378	24	652	42
NOx (tons/year)	0.47	0.01	0.79	0.03	0.34	0.01	0.59	0.03	0.23	0.01	0.40	0.03
NOx Reduction (tons/year)		0.45		0.76		0.32		0.56		0.21		0.37
Cost-Effectiveness ($/ton)		17,819		18,215		24,839		24,839		37,644		37,644
One-Year Cost-Effectiveness		$152,003		$155,381		$211,883		$211,883		$321,109		$321,109

Table B3. Detailed Diesel Construction Equipment Fleet Modernization Data, Excavators.

	175-300 HP		175-300 HP		175-300 HP	
Excavators	**Tier 0**	**Tier 4**	**Tier 1**	**Tier 4**	**Tier 2**	**Tier 4**
	Baseline	**Engine**	**Baseline**	**Engine**	**Baseline**	**Engine**
NOx Emission Std (g/bhp-hr)	9.3	0.3	6.9	0.3	4.655	0.3
Average Horsepower (hp)	238	238	238	238	238	238
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1,095	1,095	1,095	1,095	1,095	1,095
Incremental Capital Cost		$ 118,750		$ 118,750		$ 118,750
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$13,921		$13,921		$13,921
NOx Emission Factor (g/hr)	1303	42	967	42	652	42
NOx (tons/year)	1.57	0.05	1.17	0.05	0.79	0.05
NOx Reduction (tons/year)		1.52		1.12		0.74
Cost-Effectiveness ($/ton)		$9,147		$12,474		$18,904
One-Year Cost-Effectiveness		$2,340,892		$2,340,892		$2,340,892

Table B4. Detailed Diesel Construction Equipment Fleet Modernization Data, Rubber Tire Loaders.

	100-175 HP		100-175 HP		100-175 HP	
Rubber Tire Loaders	**Tier 0**	**Tier 4**	**Tier 1**	**Tier 4**	**Tier 2**	**Tier 4**
	Baseline	**Engine**	**Baseline**	**Engine**	**Baseline**	**Engine**
NOx Emission Std (g/bhp-hr)	9.5	0.3	6.9	0.3	4.7	0.3
Average Horsepower (hp)	138	138	138	138	138	138
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	524	524	524	524	524	524
Incremental Capital Cost		$ 68,750		$ 68,750		$ 68,750
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$8,060		$8,060		$8,060
NOx Emission Factor (g/hr)	771	24	560	24	378	24
NOx (tons/year)	0.45	0.01	0.32	0.01	0.22	0.01
NOx Reduction (tons/year)		0.43		0.31		0.20
Cost-Effectiveness ($/ton)		$ 18,692		$ 26,056		$ 39,488
One-Year Cost-Effectiveness		$159,448		$222,261		$336,837

Table B5. Detailed Diesel Construction Equipment Fleet Modernization Data, Rollers.

	50-75 HP		50-75 HP		50-75 HP	
Rollers	**Tier 0**	**Tier 4**	**Tier 1**	**Tier 4**	**Tier 2**	**Tier 4**
	Baseline	**Engines**	**Baseline**	**Engines**	**Baseline**	**Engines**
NOx Emission Std (g/bhp-hr)	8.8	3.325	6.9	3.325	5.32	3.325
Average Horsepower (hp)	62.5	62.5	62.5	62.5	62.5	62.5
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	168	168	168	168	168	168
Incremental Capital Cost		$ 31,250		$ 31,250		$ 31,250
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$ 3,663		$ 3,663		$ 3,663
NOx Emission Factor (g/hr)	324	123	254	123	196	123
NOx (tons/year)	0.06	0.02	0.05	0.02	0.04	0.02
NOx Reduction (tons/year)		0.04		0.02		0.01
Cost-Effectiveness ($/ton)		$ 98,081		$ 150,207		$ 269,169
One-Year Cost-Effectiveness		$ 836,647		$1,281,299		$ 2,296,062

Table B6. Detailed Diesel Construction Equipment Fleet Modernization Data, Graders.

	100-175 HP		100-175 HP		100-175 HP	
Graders	**Tier 0**	**Tier 4**	**Tier 1**	**Tier 4**	**Tier 2**	**Tier 4**
	Baseline	**Engine**	**Baseline**	**Engine**	**Baseline**	**Engine**
NOx Emission Std (g/bhp-hr)	9.5	0.3	6.9	0.3	4.655	0.3
Average Horsepower (hp)	138	138	138	138	138	138
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	425	425	425	425	425	425
Incremental Capital Cost		$ 68,750		$ 68,750		$ 68,750
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$ 8,060		$ 8,060		$ 8,060
NOx Emission Factor (g/hr)	771	24	560	24	378	24
NOx (tons/year)	0.36	0.01	0.26	0.01	0.18	0.01
NOx Reduction (tons/year)		0.35		0.25		0.17
Cost-Effectiveness ($/ton)		$ 23,050		$ 32,130		$ 48,693
One-Year Cost-Effectiveness		$ 196,619		$ 274,074		$ 415,359

Table B7. Detailed Diesel Construction Equipment Fleet SCR Retrofit Data, Tractors/Loaders/Backhoes.

	50-75 HP		75-100 HP		50-75 HP		75-100 HP		50-75 HP		75-100 HP	
Tractors/Loaders/Backhoes	**Tier 0**	**SCR**	**Tier 0**	**SCR**	**Tier 1**	**SCR**	**Tier 1**	**SCR**	**Tier 2**	**SCR**	**Tier 2**	**SCR**
	Baseline		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**	
NOx Emission Std (g/bhp-hr)	8.8	1.32	8.8	1.32	6.9	1.04	6.9	1.04	5.32	0.80	5.32	0.80
Average Horsepower (hp)	63	63	88	88	63	63	88	88	63	63	88	88
Load Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Activity (hr/yr)	2379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379	2,379
Energy Consumption Factor (bhp-hr/gal)	14.8	14.8	16.4	16.4	14.8	14.8	16.4	16.4	14.8	14.8	16.4	16.4
Fuel Usage (gal/yr)	10,048	10,249	12,695	12,949	10,048	10,249	12,695	12,949	10,048	10,249	12,695	12,949
Urea Fuel Cost ($/yr)	25,422	25,930	32,118	32,760	25,422	25,930	32,118	32,760	25,422	25,930	32,118	32,760
Incremental Urea Fuel Cost/yr		$ 508		$ 642		$ 508		$ 642		$ 508		$ 642
Incremental Capital Cost		$19,063		$26,688		$19,063		$26,688		$19,063		$26,688
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,235		$3,129		$2,235		$3,129		$2,235		$3,129
NOx Emission Factor (g/hr)	115	17	162	24	91	14	127	19	70	10	98	15
NOx (tons/year)	0.30	0.05	0.42	0.06	0.24	0.04	0.33	0.05	0.18	0.03	0.26	0.04
NOx Reduction (tons/year)		0.26		0.36		0.20		0.28		0.16		0.22
Cost-Effectiveness ($/ton)		$8,679		$8,679		$11,069		$11,069		$14,356		$14,356
CE Including Fuel ($/ton)		$10,653		$10,461		$13,587		$13,341		$17,622		$17,303
One-Year Cost-Effectiveness		$74,032		$74,032		$94,417		$94,417		$122,459		$122,459

Table B8. Detailed Diesel Construction Equipment Fleet SCR Retrofit Data, Crawler Tractors/Dozers.

	100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP	
Crawler Tractors/Dozers	**Tier 0**	**SCR**	**Tier 0**	**SCR**	**Tier 1**	**SCR**	**Tier 1**	**SCR**	**Tier 2**	**SCR**	**Tier 2**	**SCR**
	Baseline		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**	
NOx Emission Std (g/bhp-hr)	9.5	1.425	9.3	1.40	6.9	1.035	6.9	1.04	4.655	0.70	4.655	0.70
Average Horsepower (hp)	87.5	87.5	238	238	87.5	87.5	238	238	137.5	137.5	238	238
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	550	550	550	550	550	550	550	550	550	550	550	550
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	2519	2569	6,836	6,973	2519	2569	6,836	6,973	3,958	4,037	6,836	6,973
Urea Fuel Cost ($/yr)	6,372	6,499	17,295	17,641	6,372	6,499	17,295	17,641	10,013	10,213	17,295	17,641
Incremental Urea Fuel Cost/yr		$127		$ 346		$127		$ 346		$ 200		$ 346
Incremental Capital Cost		$26,688		$72,438		$26,688		$72,438		$41,938		$72,438
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$3,129		$8,492		$3,129		$8,492		$4,916		$8,492
NOx Emission Factor (g/hr)	490	74	1303	195	356	53	967	145	378	57	652	98
NOx (tons/year)	0.297	0.0446	0.79	0.12	0.22	0.03	0.59	0.09	0.23	0.03	0.40	0.06
NOx Reduction (tons/year)		0.2526		0.67		0.18		0.50		0.19		0.34
Cost-Effectiveness ($/ton)		$12,384		$12,651		$17,051		$17,051		$25,274		$25,274
CE Including Fuel ($/ton)		$12,889		$13,166		$17,745		$17,745		$26,303		$26,303
One-Year Cost-Effectiveness		$105,640		$107,912		$145,446		$145,446		$215,591		$215,591

Table B9. Detailed Diesel Construction Equipment Fleet SCR Retrofit Data, Excavators.

	175-300 HP		175-300 HP		175-300 HP	
Excavators	**Tier 0**	**SCR**	**Tier 1**	**SCR**	**Tier 2**	**SCR**
	Baseline		**Baseline**		**Baseline**	
NOx Emission Std (g/bhp-hr)	9.3	1.40	6.9	1.04	4.655	0.70
Average Horsepower (hp)	238	238	238	238	238	238
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1095	1095	1095	1095	1095	1095
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.10	19.1	19.10	19.1
Fuel Usage (gal/yr)	13,613	13,885	13,613	13,885	13,613	13,885
Urea Fuel Cost ($/yr)	34,440	35,129	34,440	35,129	34,440	35,129
Incremental Urea Fuel Cost/yr		$ 689		$ 689		$ 689
Incremental Capital Cost		$72,438		$72,438		$72,438
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$8,492		$8,492		$8,492
NOx Emission Factor (g/hr)	1303	195	967	145	652	98
NOx (tons/year)	1.57	0.24	1.17	0.18	0.79	0.12
NOx Reduction (tons/year)		1.34		0.99		0.67
Cost-Effectiveness ($/ton)		$6,353		$8,563		$12,692
CE Including Fuel ($/ton)		$6,868		$9,257		$13,722
One-Year Cost-Effectiveness		$54,191		$73,041		$108,266

Table B10. Detailed Diesel Construction Equipment Fleet SCR Retrofit Data, Rubber Tire Loaders.

	100-175 HP		100-175 HP		100-175 HP	
Rubber Tire Loaders	**Tier 0**	**SCR**	**Tier 1**	**SCR**	**Tier 2**	**SCR**
	Baseline		**Baseline**		**Baseline**	
NOx Emission Std (g/bhp-hr)	9.5	1.425	6.9	1.04	4.655	0.70
Average Horsepower (hp)	138	138	138	138	138	138
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	524	524	524	524	524	524
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.10	19.1	19.10	19.1
Fuel Usage (gal/yr)	3773	3848	3,773	3,848	3,773	3,848
Urea Fuel Cost ($/yr)	9,546	9,737	9,546	9,737	9,546	9,737
Incremental Urea Fuel Cost/yr		$191		$ 191		$ 191
Incremental Capital Cost		$41,938		$41,938		$41,938
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$4,916		$4,916		$4,916
NOx Emission Factor (g/hr)	771	116	560	84	378	57
NOx (tons/year)	0.45	0.07	0.32	0.05	0.22	0.03
NOx Reduction (tons/year)		0.38		0.27		0.19
Cost-Effectiveness ($/ton)		$12,991		$17,886		$26,512
CE Including Fuel ($/ton)		$13,495		$18,580		$27,541
One-Year Cost-Effectiveness		$110,814		$152,570		$226,151

Table B11. Detailed Diesel Construction Equipment Fleet SCR Retrofit Data, Rollers.

Rollers	50-75 HP		50-75 HP		50-75 HP	
	Tier 0	SCR	Tier 1	SCR	Tier 2	SCR
	Baseline		Baseline		Baseline	
NOx Emission Std (g/bhp-hr)	8.8	1.32	6.9	1.04	5.32	0.80
Average Horsepower (hp)	63	63	63	63	63	63
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	168	168	168	168	168	168
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	549	560	549	560	549	560
Urea Fuel Cost ($/yr)	1,390	1,417	1,390	1,417	1,390	1,417
Incremental Urea Fuel Cost/yr		$ 28		$ 28		$ 28
Incremental Capital Cost		$19,063		$19,063		$19,063
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$2,235		$2,235		$2,235
NOx Emission Factor (g/hr)	324	49	254	38	196	29
NOx (tons/year)	0.06	0.01	0.05	0.01	0.04	0.01
NOx Reduction (tons/year)		0.05		0.04		0.03
Cost-Effectiveness ($/ton)		$43,792		$55,851		$72,438
CE Including Fuel ($/ton)		$44,337		$56,545		$73,339
One-Year Cost-Effectiveness		$373,555		$476,418		$617,911

Table B12. Detailed Diesel Construction Equipment Fleet SCR Retrofit Data, Graders.

Graders	100-175 HP		100-175 HP		100-175 HP	
	Tier 0	SCR	Tier 1	SCR	Tier 2	SCR
	Baseline		Baseline		Baseline	
NOx Emission Std (g/bhp-hr)	9.5	1.43	6.9	1.04	4.655	0.70
Average Horsepower (hp)	138	138	138	138	138	138
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	247	247	247	247	247	247
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,778	1,813	1,778	1,813	1,778	1,813
Urea Fuel Cost ($/yr)	4,498	4,588	4,498	4,588	4,498	4,588
Incremental Urea Fuel Cost/yr		$ 90		$ 90		$ 90
Incremental Capital Cost		$41,938		$41,938		$41,938
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$4,916		$4,916		$4,916
NOx Emission Factor (g/hr)	771	116	560	84	378	57
NOx (tons/year)	0.21	0.03	0.15	0.02	0.10	0.02
NOx Reduction (tons/year)		0.18		0.13		0.09
Cost-Effectiveness ($/ton)		$27,569		$37,958		$56,264
CE Including Fuel ($/ton)		$28,074		$38,652		$57,293
One-Year Cost-Effectiveness		$235,171		$323,786		$479,940

Table B13. Detailed Diesel Construction Equipment Fleet LNC Retrofit Data, Tractors/Loaders/Backhoes.

	50-75 HP		75-100 HP		50-75 HP		75-100 HP		50-75 HP		75-100 HP	
Tractors/Loaders/Backhoes	**Tier 0**	**LNC**	**Tier 0**	**LNC**	**Tier 1**	**LNC**	**Tier 1**	**LNC**	**Tier 2**	**LNC**	**Tier 2**	**LNC**
	Baseline		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**	
NOx Emission Std (g/bhp-hr)	8.8	6.60	8.8	6.60	6.9	5.18	6.9	5.18	5.32	3.99	5.32	3.99
Average Horsepower (hp)	63	63	88	88	63	63	88	88	63	63	88	88
Load Factor	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Activity (hr/yr)	2379	2,379	2379	2,379	2379	2,379	2379	2,379	2379	2,379	2379	2,379
Energy Consumption Factor (bhp-hr/gal)	14.8	14.8	16.4	16.4	14.8	14.8	16.4	16.4	14.8	14.8	16.4	16.4
Fuel Usage (gal/yr)	10,048	10,249	12,695	12,949	10,048	10,249	12,695	12,949	10,048	10,249	12,695	12,949
Fuel Cost ($/yr)	25,422	25,930	32,118	32,760	25,422	25,930	32,118	32,760	25,422	25,930	32,118	32,760
Incremental Fuel Cost/yr		$ 508		$ 642		$ 508		$ 642		$ 508		$ 642
Incremental Capital Cost		$8,300		$8,300		$8,300		$8,300		$8,300		$8,300
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$973		$973		$973		$973		$973		$973
NOx Emission Factor (g/hr)	115	87	162	121	91	68	127	95	70	52	98	73
NOx (tons/year)	0.30	0.23	0.42	0.32	0.24	0.18	0.33	0.25	0.18	0.14	0.26	0.19
NOx Reduction (tons/year)		0.08		0.11		0.06		0.08		0.05		0.06
Cost-Effectiveness ($/ton)		$12,848		$9,177		$16,386		$11,704		$21,252		$15,180
CE Including Fuel ($/ton)		$19,562		$15,236		$24,948		$19,431		$32,357		$25,202
One-Year Cost-Effectiveness		$109,596		$78,283		$139,775		$99,839		$181,287		$129,491

Table B14. Detailed Diesel Construction Equipment Fleet LNC Retrofit Data, Crawler Tractors/Dozers.

	100-175 HP		175-300 HP		100-175 HP		175-300 HP		100-175 HP		175-300 HP	
Crawler Tractors/Dozers	**Tier 0**	**LNC**	**Tier 0**	**LNC**	**Tier 1**	**LNC**	**Tier 1**	**LNC**	**Tier 2**	**LNC**	**Tier 2**	**LNC**
	Baseline		**Baseline**		**Baseline**		**Baseline**		**Baseline**		**Baseline**	
NOx Emission Std (g/bhp-hr)	9.5	7.125	9.3	6.98	6.9	5.175	6.9	5.18	4.655	3.49	4.655	3.49
Average Horsepower (hp)	137.5	137.5	238	238	137.5	137.5	238	238	137.5	137.5	237.5	237.5
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	549.770	550	549.770	550	549.770	550	549.770	550	549.770	550	549.770	550
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1	19.10	19.1	19.1	19.1	19.10	19.1
Fuel Usage (gal/yr)	3958	4037	6,836	6,973	3958	4037	6,836	6,973	3,958	4,037	6,836	6,973
Fuel Cost ($/yr)	10,013	10,213	17,295	17,641	10,013	10,213	17,295	17,641	10,013	10,213	17,295	17,641
Incremental Fuel Cost/yr		$200		$ 346		$200		$ 346		$ 200		$ 346
Incremental Capital Cost		$8,300		$8,300		$8,300		$8,300		$8,300		$8,300
Useful Life (years)	10	10	10	10	10	10	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$973		$973		$973		$973		$973		$973
NOx Emission Factor (g/hr)	771	578	1303	977	560	420	967	725	378	283	652	489
NOx (tons/year)	0.467	0.3503	0.79	0.59	0.34	0.25	0.59	0.44	0.23	0.17	0.40	0.30
NOx Reduction (tons/year)		0.1168		0.20		0.08		0.15		0.06		0.10
Cost-Effectiveness ($/ton)		$8,333		$4,928		$11,474		$6,643		$17,007		$9,846
CE Including Fuel ($/ton)		$10,049		$6,680		$13,835		$9,004		$20,507		$13,346
One-Year Cost-Effectiveness		$71,086		$42,040		$97,872		$56,662		$145,073		$83,990

Table B15. Detailed Diesel Construction Equipment Fleet LNC Retrofit Data, Excavators.

	175-300 HP		175-300 HP		175-300 HP	
Excavators	**Tier 0**	**LNC**	**Tier 1**	**LNC**	**Tier 2**	**LNC**
	Baseline		**Baseline**		**Baseline**	
NOx Emission Std (g/bhp-hr)	9.3	6.98	6.9	5.18	4.655	3.49
Average Horsepower (hp)	238	238	238	238	238	238
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	1095	1095	1095	1095	1095	1095
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.10	19.1	19.10	19.1
Fuel Usage (gal/yr)	13,613	13885	13,613	13,885	13,613	13,885
Fuel Cost ($/yr)	34,440	35,129	34,440	35,129	34,440	35,129
Incremental Fuel Cost/yr		$689		$ 689		$ 689
Incremental Capital Cost		$8,300		$8,300		$8,300
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$973		$973		$973
NOx Emission Factor (g/hr)	1303	977	967	725	652	489
NOx (tons/year)	1.57	1.18	1.17	0.88	0.79	0.59
NOx Reduction (tons/year)		0.39		0.29		0.20
Cost-Effectiveness ($/ton)		$2,475		$3,336		$4,945
CE Including Fuel ($/ton)		$4,227		$5,697		$8,445
One-Year Cost-Effectiveness		$21,112		$28,455		$42,178

Table B16. Detailed Diesel Construction Equipment Fleet LNC Retrofit Data, Rubber Tire Loaders.

	100-175 HP		100-175 HP		100-175 HP	
Rubber Tire Loaders	**Tier 0**	**LNC**	**Tier 1**	**LNC**	**Tier 2**	**LNC**
	Baseline		**Baseline**		**Baseline**	
NOx Emission Std (g/bhp-hr)	9.5	7.125	6.9	5.18	4.655	3.49
Average Horsepower (hp)	138	138	138	138	138	138
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	524	524	524	524	524	524
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.10	19.1	19.10	19.1
Fuel Usage (gal/yr)	3773	3848	3,773	3,848	3,773	3,848
Fuel Cost ($/yr)	9,546	9,737	9,546	9,737	9,546	9,737
Incremental Fuel Cost/yr		$191		$ 191		$ 191
Incremental Capital Cost		$8,300		$8,300		$8,300
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$973		$973		$973
NOx Emission Factor (g/hr)	771	578	560	420	378	283
NOx (tons/year)	0.45	0.33	0.32	0.24	0.22	0.16
NOx Reduction (tons/year)		0.11		0.08		0.05
Cost-Effectiveness ($/ton)		$8,742		$12,036		$17,840
CE Including Fuel ($/ton)		$10,457		$14,397		$21,340
One-Year Cost-Effectiveness		$74,567		$102,665		$152,178

Table B17. Detailed Diesel Construction Equipment Fleet LNC Retrofit Data, Rollers.

Rollers	50-75 HP		50-75 HP		50-75 HP	
	Tier 0	LNC	Tier 1	LNC	Tier 2	LNC
	Baseline		Baseline		Baseline	
NOx Emission Std (g/bhp-hr)	8.8	6.60	6.9	5.18	5.32	3.99
Average Horsepower (hp)	88	88	88	88	88	88
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	168	168	168	168	168	168
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	769	784	769	784	769	784
Fuel Cost ($/yr)	1,945	1,984	1,945	1,984	1,945	1,984
Incremental Fuel Cost/yr		$ 39		$ 39		$ 39
Incremental Capital Cost		$8,300		$8,300		$8,300
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$973		$973		$973
NOx Emission Factor (g/hr)	454	341	356	267	275	206
NOx (tons/year)	0.08	0.06	0.07	0.05	0.05	0.04
NOx Reduction (tons/year)		0.02		0.02		0.01
Cost-Effectiveness ($/ton)		$46,307		$59,058		$76,598
CE Including Fuel ($/ton)		$48,158		$61,419		$79,660
One-Year Cost-Effectiveness		$395,006		$503,776		$653,394

Table B18. Detailed Diesel Construction Equipment Fleet LNC Retrofit Data, Graders.

Graders	100-175 HP		100-175 HP		100-175 HP	
	Tier 0	LNC	Tier 1	LNC	Tier 2	LNC
	Baseline		Baseline		Baseline	
NOx Emission Std (g/bhp-hr)	9.5	7.13	6.9	5.18	4.655	3.49
Average Horsepower (hp)	138	138	138	138	138	138
Load Factor	0.59	0.59	0.59	0.59	0.59	0.59
Activity (hr/yr)	247	247	247	247	247	247
Energy Consumption Factor (bhp-hr/gal)	19.1	19.1	19.1	19.1	19.1	19.1
Fuel Usage (gal/yr)	1,778	1,813	1,778	1,813	1,778	1,813
Fuel Cost ($/yr)	4,498	4,588	4,498	4,588	4,498	4,588
Incremental Fuel Cost/yr		$ 90		$ 90		$ 90
Incremental Capital Cost		$8,300		$8,300		$8,300
Useful Life (years)	10	10	10	10	10	10
Annualized Capital Cost ($/yr)		$973		$973		$973
NOx Emission Factor (g/hr)	771	578	560	420	378	283
NOx (tons/year)	0.21	0.16	0.15	0.11	0.10	0.08
NOx Reduction (tons/year)		0.05		0.04		0.03
Cost-Effectiveness ($/ton)		$18,551		$25,542		$37,860
CE Including Fuel ($/ton)		$20,267		$27,903		$41,360
One-Year Cost-Effectiveness		$158,248		$217,878		$322,955

APPENDIX C

On-road Vehicle Electrification Detailed Data

Appendix C. On-road Vehicle Electrification Detailed Data

Table C1. On-road vehicle by model year emissions and electrification associated emission reductions per vehicle.

Model Year	Annual Miles per Vehicle	Annual Emissions per Vehicle (lb/vehicle)			Annual Conventional Hybrid Emission Reductions (lb/vehicle)			Annual Plug-in Hybrid Emission Reductions (lb/vehicle)			Annual Dedicated Electric Emission Reductions (lb/vehicle)		
		NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO
1988	5,000	39.9	48.5	284.9	39.2	47.7	270.8	39.4	47.9	275.0	39.9	48.5	284.9
1989	5,000	39.5	48.4	282.4	38.8	47.6	268.4	39.0	47.9	272.6	39.5	48.4	282.4
1990	5,000	40.8	43.0	213.7	40.2	42.2	199.6	40.4	42.4	203.8	40.8	43.0	213.7
1991	5,000	40.8	42.5	213.3	40.2	41.7	199.3	40.4	41.9	203.5	40.8	42.5	213.3
1992	5,000	40.8	41.8	213.1	40.2	41.0	199.0	40.4	41.3	203.3	40.8	41.8	213.1
1993	5,000	40.8	41.1	212.8	40.2	40.3	198.7	40.4	40.5	203.0	40.8	41.1	212.8
1994	5,000	37.8	40.3	175.5	37.2	39.5	161.4	37.4	39.8	165.7	37.8	40.3	175.5
1995	5,000	37.7	39.6	174.7	37.1	38.8	160.6	37.3	39.1	164.8	37.7	39.6	174.7
1996	5,000	27.2	26.1	137.9	26.6	25.3	123.8	26.7	25.5	128.0	27.2	26.1	137.9
1997	5,000	27.0	24.0	137.2	26.4	23.2	123.1	26.6	23.4	127.4	27.0	24.0	137.2
1998	5,000	26.9	17.9	136.5	26.2	17.1	122.5	26.4	17.4	126.7	26.9	17.9	136.5
1999	5,000	23.5	11.7	118.4	22.8	10.9	104.4	23.0	11.1	108.6	23.5	11.7	118.4
2000	5,000	23.3	11.4	117.4	22.6	10.6	103.4	22.8	10.9	107.6	23.3	11.4	117.4
2001	5,000	10.7	6.2	71.2	10.1	5.4	57.2	10.3	5.6	61.4	10.7	6.2	71.2
2002	5,000	10.0	5.7	68.9	9.4	4.9	54.9	9.6	5.2	59.1	10.0	5.7	68.9
2003	5,000	9.3	5.4	69.2	8.6	4.6	55.2	8.8	4.8	59.4	9.3	5.4	69.2
2004	5,000	4.8	3.4	61.4	4.1	2.6	47.4	4.3	2.9	51.6	4.8	3.4	61.4
2005	5,000	3.7	3.2	58.0	3.1	2.4	43.9	3.3	2.7	48.1	3.7	3.2	58.0
2006	5,000	3.5	3.1	55.8	2.8	2.3	41.7	3.0	2.5	45.9	3.5	3.1	55.8
2007	5,000	2.8	2.9	52.6	2.2	2.1	38.6	2.4	2.4	42.8	2.8	2.9	52.6
2008	5,000	2.6	2.8	51.9	2.0	2.0	37.8	2.2	2.3	42.1	2.6	2.8	51.9
2009	5,000	2.1	1.9	40.3	1.4	1.1	26.3	1.6	1.4	30.5	2.1	1.9	40.3
2010	5,000	1.9	1.9	39.8	1.2	1.1	25.8	1.4	1.3	30.0	1.9	1.9	39.8
2011	5,000	1.5	1.5	36.4	0.8	0.7	22.3	1.0	1.0	26.5	1.5	1.5	36.4
2012	5,000	1.5	1.5	36.1	0.8	0.7	22.1	1.0	1.0	26.3	1.5	1.5	36.1
2013	5,000	1.2	1.2	29.1	0.5	0.4	15.0	0.7	0.7	19.3	1.2	1.2	29.1
2014	5,000	1.2	1.2	28.9	0.5	0.4	14.9	0.7	0.6	19.1	1.2	1.2	28.9
2015	5,000	0.7	0.8	14.2	na	na	na	na	na	na	na	na	na
2016	5,000	0.7	0.8	14.2	na	na	na	na	na	na	na	na	na
2017	5,000	0.7	0.8	14.1	na	na	na	na	na	na	na	na	na
2018	5,000	0.7	0.8	14.0	na	na	na	na	na	na	na	na	na

Table C2. On-road vehicle by model year annual emissions and electrification associated cost effectiveness.

Model Year	Annual Miles per Vehicle	Annual Emissions per Vehicle (lb/vehicle)			NOx+VOC Cost Effectiveness ($/ton)		
		NOx	VOC	CO	Conventional Hybrid	Plug-in Hybrid	Dedicated Electric
1988	5,000	39.9	48.5	284.9	$5,935	$33,139	$19,025
1989	5,000	39.5	48.4	282.4	$5,966	$33,311	$19,123
1990	5,000	40.8	43.0	213.7	$6,264	$34,965	$20,061
1991	5,000	40.8	42.5	213.3	$6,304	$35,184	$20,185
1992	5,000	40.8	41.8	213.1	$6,352	$35,455	$20,339
1993	5,000	40.8	41.1	212.8	$6,412	$35,789	$20,528
1994	5,000	37.8	40.3	175.5	$6,725	$37,521	$21,508
1995	5,000	37.7	39.6	174.7	$6,796	$37,917	$21,733
1996	5,000	27.2	26.1	137.9	$9,954	$55,392	$31,557
1997	5,000	27.0	24.0	137.2	$10,402	$57,860	$32,935
1998	5,000	26.9	17.9	136.5	$11,902	$66,123	$37,531
1999	5,000	23.5	11.7	118.4	$15,287	$84,687	$47,764
2000	5,000	23.3	11.4	117.4	$15,527	$85,997	$48,481
2001	5,000	10.7	6.2	71.2	$33,403	$182,289	$99,495
2002	5,000	10.0	5.7	68.9	$35,998	$196,028	$106,510
2003	5,000	9.3	5.4	69.2	$39,062	$212,183	$114,678
2004	5,000	4.8	3.4	61.4	$76,497	$403,168	$205,082
2005	5,000	3.7	3.2	58.0	$94,044	$488,831	$242,264
2006	5,000	3.5	3.1	55.8	$100,588	$520,183	$255,399
2007	5,000	2.8	2.9	52.6	$119,199	$607,614	$290,768
2008	5,000	2.6	2.8	51.9	$129,536	$655,101	$309,237
2009	5,000	2.1	1.9	40.3	$201,733	$967,004	$419,105
2010	5,000	1.9	1.9	39.8	$224,153	$1,057,348	$447,647
2011	5,000	1.5	1.5	36.4	$324,541	$1,428,901	$552,339
2012	5,000	1.5	1.5	36.1	$331,152	$1,451,640	$558,158
2013	5,000	1.2	1.2	29.1	$555,605	$2,121,003	$705,569
2014	5,000	1.2	1.2	28.9	$575,138	$2,171,169	$715,031
2015	5,000	0.7	0.8	14.2	na	na	na
2016	5,000	0.7	0.8	14.2	na	na	na
2017	5,000	0.7	0.8	14.1	na	na	na
2018	5,000	0.7	0.8	14.0	na	na	na