South Coast AQMD

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

Off-Road Equipment

2016 AQMP WHITE PAPER

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South Coast Air Quality Management District

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Table of Contents

INTRODUCTION

Purpose and Objective

Despite the significant progress made in reducing emissions that has resulted in substantial improvements in air quality, additional emission reductions will be necessary to attain state and federal ambient air quality standards for ozone and fine particulate matter in the South Coast Air Basin. This white paper is intended to assist the public, stakeholders, and the SCAQMD in understanding key facts and policy issues related to the development of the 2016 South Coast Air Quality Management Plan (AQMP). The paper includes information regarding criteria pollutant emissions that are associated with the off-road equipment sector, which includes a wide variety of equipment ranging from smaller equipment such as residential and commercial lawn and garden equipment, to larger equipment such as industrial and commercial equipment, transportation refrigeration units, cargo handling equipment, airport ground support equipment, and construction and mining equipment. In addition, there is equipment used in various activities such as portable engines that are included in this sector. For the purposes of this white paper, the focus will be on the largest emission source categories in this sector. In addition, cargo handling equipment is discussed in the Goods Movement White Paper.

To illuminate policy choices relevant to the AQMP, the paper provides a couple of emission reduction scenarios to illustrate the need for additional emission reductions within this sector to support attainment of the state and federal ozone and particulate matter standards. The emission reduction scenarios highlight emission source categories where emission reductions could potentially be achieved more readily compared to other emission source categories in this sector. In addition, if some emissions source categories are able to go beyond the overall emission reduction target needed for attainment of the air quality standard, the additional reductions would help compensate for other emissions source categories where reductions are more challenging to achieve. The scenarios do not reflect any control strategies or suggest any control approach. As such, this paper does not propose specific rules or other control measures, but provides information to assist in crafting control measures as part of the 2016 AQMP development process. This paper does discuss the potential for achieving additional emission reductions through greater deployment of cleaner equipment that has emission levels below the emission standards established in existing state and federal regulations, advanced emission controls technologies, use of alternative and renewable fuels, and the use of operational efficiency measures.

In a separate effort, the SCAQMD staff has been working with the California Air Resources Board (CARB) and the Southern California Association of Governments (SCAG) to prepare updated emissions inventories for the attainment demonstration of the federal ozone and fine particulate air quality standards. However, the new emission inventories were not available to perform the analyses described above. Therefore, in order to develop this white paper to help illuminate policy choices in the development of the 2016 AQMP, the emission inventories from the 2012 AQMP are used to perform the analyses described above. The initial observations and recommendations in this white paper are relevant regardless if a newer set of emissions inventories are used since the analyses examine the relative differences between the various emissions reduction scenarios since it is not the intent of this white paper to propose specific emissions control levels to meet federal air quality standards. That objective is part of the overall development of the 2016 AQMP.

Document Outline

This white paper provides background information on the base year and future year volatile organic compounds (VOC) and oxides of nitrogen (NOx) emissions inventories associated with the various off-road equipment emissions source categories. The following sections present brief descriptions of the associated air quality impacts, emission reduction progress, attainment challenges, and connections to climate change programs. Emission reduction scenario analyses were conducted to examine the range of emission reductions that could occur for each source category to help meet the ozone air quality standards by 2023 and 2032. The results of the scenario analysis are presented with initial observations of the issues/questions raised from the analysis. In addition, operational efficiencies are discussed. Finally, recommendations are provided to help frame the discussions in the development of the 2016 AQMP.

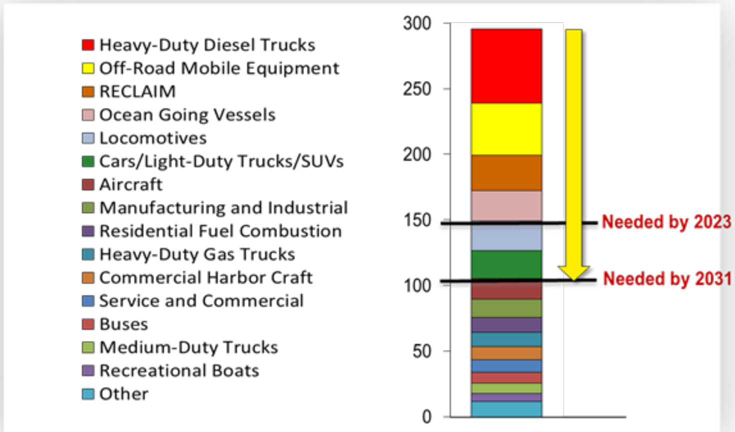
A discussion of current regulatory programs and other planning efforts is provided in Appendix A. Information on potential emission reduction technologies and efficiency measures is discussed in Appendix B.

BACKGROUND

The South Coast Air Quality Management District (SCAQMD or District) consists of an area of approximately 10,743 square miles consisting of the South Coast Air Basin, and the Riverside County portion of the Salton Sea Air Basin (SSAB) known as the Coachella Valley Planning Area. The South Coast Air Basin, which is a subregion of the District's jurisdiction, is bounded by the Pacific Ocean to the west and the San Gabriel, San Bernardino, and San Jacinto mountains to the north and east. It includes all of Orange County and the non-desert portions of Los Angeles, Riverside, and San Bernardino Counties. The region is inhabited by more than 16 million people, representing about half of California's population. In addition, the SCAQMD region is projected to grow to approximately 18 million people by 2030, and this growth is expected to occur primarily in Riverside and San Bernardino Counties. This situation is expected to lead to a greater imbalance of jobs and housing in the region, increasing transportation mobility and air quality challenges because of increased travel demand requirements and economic growth.

Attainment Challenge

Meeting U.S. Environmental Protection Agency (EPA) national ambient air quality standards for ozone and fine particulate matter will require additional NOx emission reductions in the South Coast Air Basin. Meeting state standards will be even more challenging. Preliminary ozone air quality analysis currently underway in the development of the 2016 AQMP indicates that NOx emissions will need to be reduced by approximately 50 percent in 2023 and 65 percent in 2031 (beyond projected 2023 baseline emissions). Note that the percentages will likely change slightly as the emission inventories are updated with more recent economic and demographic forecast information from the Southern California Association of Governments (SCAG) as part of the development of the 2016 AQMP. Figure 1 shows graphically the overall NOx emission reductions needed to attain the 8-hour ozone air quality standards in 2023 and 2031 and the major NOx emission sources contributing to the ozone air quality problem. This is especially challenging given that among the largest contributors to NOx emissions are mobile sources that are primarily regulated by the state and/or federal governments. The off-road equipment sector is the second largest contributor to total NOx emissions. Since many types of off-road equipment have already achieved over a 90% reduction in NOx emissions, attainment of the ozone standards will require wide-scale deployment of not only new equipment meeting the tightest tailpipe emissions standards, but also commercialization and deployment of technologies that achieve zero- or near-zero emissions.



(Source: Preliminary Draft 2023 Baseline NOx Emissions Inventory, July 2015)

FIGURE 1

Needed NOx Emission Reductions to Achieve
Federal 8-Hour Ozone Ambient Air Quality Standards

Climate Challenge

The SCAQMD Governing Board (Board) has recognized the nexus between technologies that minimize climate impacts and technologies that reduce criteria pollutant emissions, since many of the same technologies simultaneously address both of these challenges. As such, the SCAQMD Governing Board has developed policies and guiding principles which include the coordinated development of criteria air pollutant strategies that have co-benefits in reducing greenhouse gas emissions to make the most efficient use of limited resources and the time needed to deploy the necessary cleaner technologies. In September 2011, the Board adopted the SCAQMD Air Quality-Related Energy Policy. This policy was developed to integrate air quality, energy issues, and climate change in a coordinated manner. Various policies and actions were identified as part of this effort, some of which would affect off-road equipment emission sources. These include policies to promote zero- and near-zero emission technologies to the fullest extent feasible. Action items include studies to identify measures that reduce emissions from the off-road equipment sector, including incentivizing the early introduction of zero- and near-zero emission measures and identification of potential new funding mechanisms to support widespread penetration of such technologies within the off-road equipment sector.

Clearly, aggressive and coordinated technology development and deployment efforts are needed for off-road equipment over the next eight to twenty years to meet ozone ambient air quality standards in 2023 and 2032, as well as greenhouse gas reduction goals between 2020 and 2050. To this end, in 2012, the SCAQMD, California Air Resources Board (CARB), and San Joaquin Valley Unified Air Pollution Control District jointly prepared a document titled: "Vision for Clean Air: A Framework for Air Quality and Climate Planning." This document evaluated various technology scenarios in the off-road equipment sector that provide direction on future control strategies to concurrently achieve criteria pollutant standards and climate change goals. Major conclusions from that effort are that significant changes in technologies are needed to more widely deploy hybrid and significantly cleaner combustion equipment.

OFF-ROAD EQUIPMENT RELATED EMISSIONS SOURCE CATEGORIES

Table 1 shows the major emission source categories in the off-road equipment sector. The off-road equipment sector includes airport ground support equipment, construction and mining equipment, industrial and commercial equipment, oil drilling/workover equipment, transportation refrigeration units (TRUs), lawn/garden equipment, cargo handling equipment, and other miscellaneous portable equipment including military tactical equipment. Cargo handling equipment is addressed in the Goods Movement White Paper. Off-road equipment typically operates on gasoline or diesel fuel. Some commercial and industrial equipment operate on alternative fuels such as propane or natural gas. Other equipment operates on electricity such as lawn and garden equipment and airport ground support equipment.

TABLE 1

Off-Road Equipment Emission Source Categories

Emissions Source Categories	Examples
Airport Ground Support Equipment	Tugs, Baggage Handling, Food Service and Maintenance Trucks
Construction/Mining	Tractors, Bulldozers, Excavators, Off-Road Trucks
Cargo Handling Equipment	Yard Tractors, Side Picks, Top Picks, Cranes
Commercial	Generators, Compressors, Pumps

TABLE 1 (concluded)

Off-Road Equipment Emission Source Categories

Industrial	Forklifts, Aerial Lifts, Sweepers
Lawn and Garden Equipment (Commercial and Residential)	Lawn Mowers, Edgers, Trimmers, Blowers, Chainsaws
Transportation Refrigeration Units	Refrigerated Containers, Trucks, Truck Trailers, Railcars
Oil Drilling Equipment	Oil Drilling Rigs, Workover Rigs (mobile)
Miscellaneous	Portable Generators, Military Tactical Equipment

Air Quality Impacts of Off-Road Equipment Sources

The adoption and implementation of control strategies specific to the off-road equipment sector have resulted in significant emissions reductions. However, additional emission reductions are needed in order to achieve federal ambient air quality standards for ozone and fine particulate matter.

NOTE: For the purposes of this white paper, the emissions inventories provided in this section and the subsequent sections are from the 2012 AQMP. The 2016 AQMP will contain updated emission inventories for use in demonstrating attainment of the federal ozone and fine particulate air quality standards.

Figures 2 and 3 show the VOC and NOx emissions in tons/day from the off-road equipment sector and their contribution to the total emissions for 2014, 2023, and 2032. For 2014, off-road equipment sources contribute approximately 11 and 13% to the total VOC and NOx emissions inventory. The percent contribution from off-road equipment sources to total VOC and NOx emissions in 2032 is 9% for VOC and 13% for NOx. The largest contributor to VOC emissions among the off-road equipment categories is the lawn and garden equipment category.

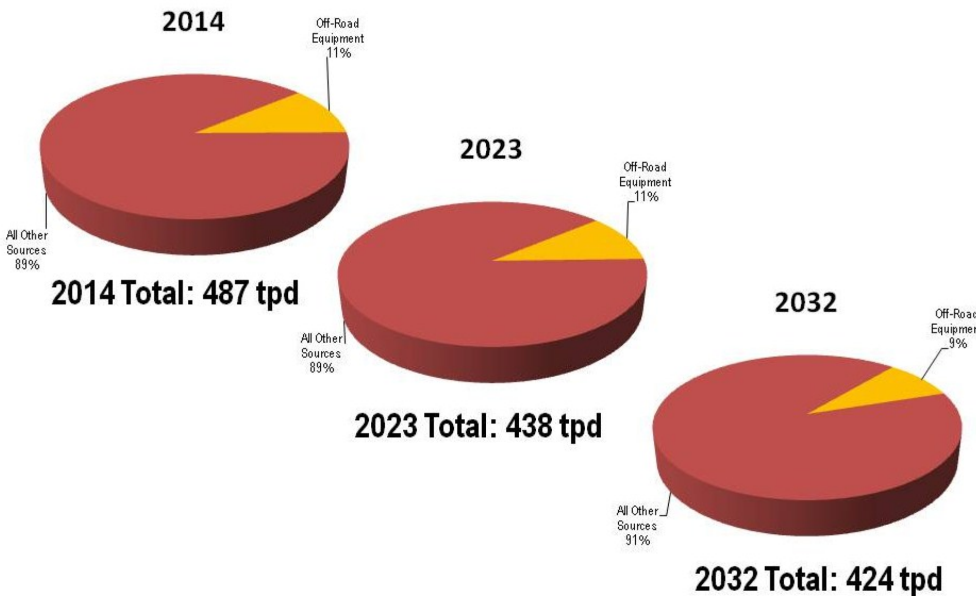


FIGURE 2

Off-Road Equipment Sector VOC Emissions Contribution to the Total VOC Emissions for 2014, 2023, and 2032 (Source: 2012 AQMP)

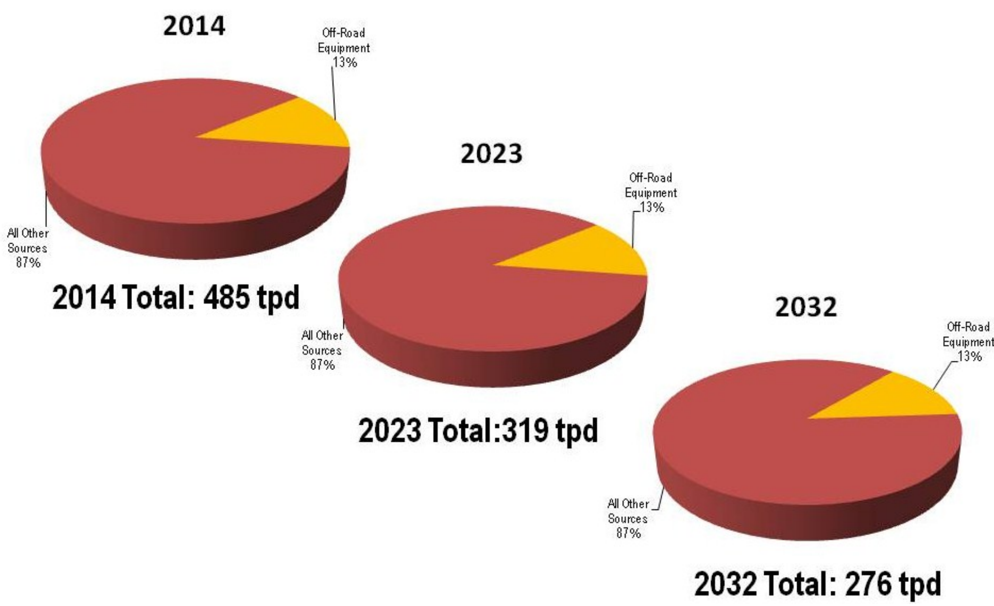


FIGURE 3

Off-Road Equipment Sector NOx Emissions Contribution to the Total NOx Emissions for 2014, 2023, and 2032 (Source: 2012 AQMP)

Tables 2, 3, and 4 provide VOC and NOx emissions and the equipment population for the various emissions source categories in the off-road equipment sector for calendar years 2014, 2023, and 2032, respectively.

TABLE 2

VOC and NOx Emissions from Emission Sources in the Off-Road Equipment Sector for Calendar Year 2014 (Source: 2012 AQMP)

Source Category	Population	VOC (tons/day)	NOx (tons/day)
Construction and Mining	86,607	3.45	25.54
Commercial	219,190	7.84	11.41
Industrial	34,070	1.97	10.01
Transportation Refrigeration Units	51,553	0.51	5.07
Cargo Handling Equipment	3,365	0.33	3.39
Lawn and Garden	6,801,314	38.50	4.62
Airport Ground Support Equipment	4,559	0.56	2.67
Oil Drilling Equipment	519	0.13	1.43
Other (Generators, Military Tactical Equipment)	521	0.02	0.26
Total	**7,201,698**	**53.31**	**64.40**

TABLE 3

VOC and NOx Emissions from Emission Sources in the Off-Road Equipment Sector for Calendar Year 2023 (Source: 2012 AQMP)

Source Category	Population	VOC (tons/day)	NOx (tons/day)
Construction and Mining	103,259	2.59	15.11
Commercial	225,228	5.32	6.79
Industrial	48,958	1.58	7.55
Transportation Refrigeration Units	59,690	0.44	4.05
Cargo Handling Equipment	5,697	0.42	2.23
Lawn and Garden	7,638,328	35.97	4.82
Airport Ground Support Equipment	6,349	0.40	1.41
Oil Drilling and Equipment	494	0.08	0.73
Other (Generators, Military Tactical Equipment)	522	0.01	0.11
Total	**8,088,525**	**46.81**	**42.80**

TABLE 4

VOC and NOx Emissions from Emission Sources in the Off-Road Equipment Sector for Calendar Year 2032 (Source: 2012 AQMP)

Source Category	Population	VOC (tons/day)	NOx (tons/day)
Construction and Mining	111,213	1.86	8.35
Commercial	235,261	3.75	5.09
Industrial	53,007	1.10	6.37
Transportation Refrigeration Units	73,577	0.64	4.87
Cargo Handling Equipment	6,521	0.61	2.37
Lawn and Garden	8,612,866	29.25	6.44
Airport Ground Support Equipment	5,986	0.30	0.99
Oil Drilling and Equipment	416	0.10	0.92
Other (Generators, Military Tactical Equipment)	522	0.00	0.03
Total	**9,099,369**	**37.61**	**35.43**

Emissions Reduction Progress to Date

As shown in Figure 4, off-road equipment emissions of VOC, NOx, and PM have experienced reductions of from 73%, 58%, and 68% from 2002 levels. These reductions have primarily relied upon development and commercialization of technologies that control emissions from internal combustion engines and accelerated equipment turnover resulting from CARB fleet rules for diesel-fueled equipment. Some categories (industrial, transportation refrigeration units, and airport ground support equipment) have also had turnover to zero- or partially zero-emission equipment. While directly emitted PM emissions affect PM air quality and are associated with local air toxic exposure, directly emitted PM emissions do not have a direct impact on ozone formation. However, NOx and VOC emissions are precursors to both ozone and fine particulates.

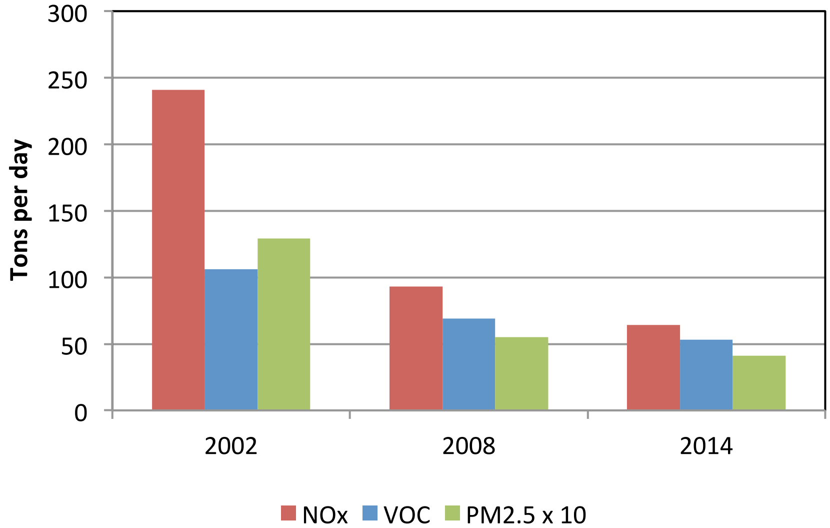


FIGURE 4

Off-Road Equipment Emissions in the South Coast Air Basin (Source: 2007 AQMP (for 2002) and 2012 AQMP (for 2008 and 2014))

The off-road equipment NOx and VOC emissions provided in Tables 2, 3, and 4 are shown graphically in Figures 5 and 6 for 2014, 2023, and 2032 calendar years to illustrate the projected trend in NOx and VOC emissions due to the impact of regulatory programs for the various off-road equipment categories. Regulatory programs include a combination of command and control programs, such as more stringent emission standards applicable to original equipment manufacturers and in-use compliance programs applicable to equipment/fleet owners, as well as monetary incentive programs that promote the market penetration of lower-emitting vehicles and equipment. These emission reductions have occurred despite the general increase in the population of off-road equipment over time, as described in Tables 2 through 4.

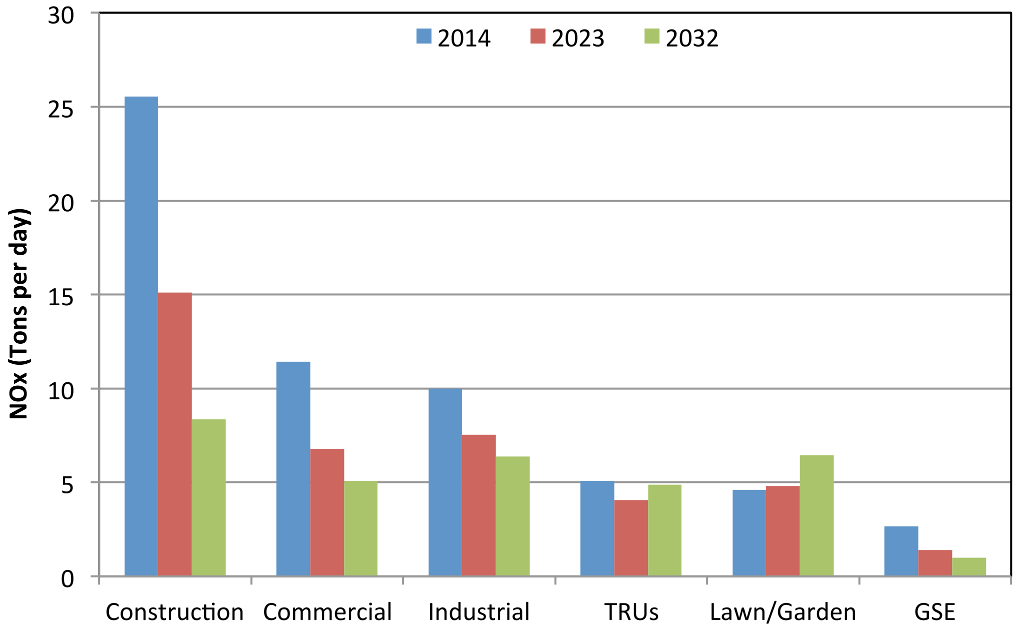


FIGURE 5

NOx Emissions for Specific Off-Road Equipment Source Categories (TRUs – Transportation Refrigeration Units; GSE – Airport Ground Support Equipment)
(Source: 2012 AQMP)

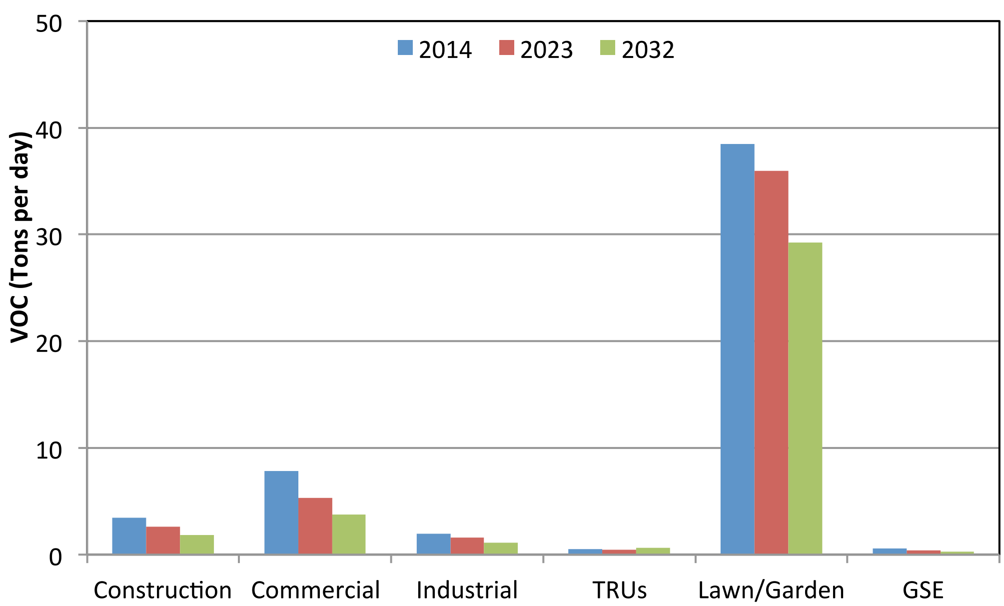


FIGURE 6

VOC Emissions for Specific Off-Road Equipment Emission Source Categories (Source: 2012 AQMP)

NOx EMISSION REDUCTION SCENARIOS

NOx emission reduction scenarios were developed to illustrate the amount of NOx emission reductions that may be necessary across the various emissions source categories in the off-road equipment sector to achieve regional NOx carrying capacities for criteria pollutants and their precursors in attainment deadline years. The scenarios are intended to help provide perspective on the challenging task to achieve necessary emission reductions in compressed timeframes to meet air quality attainment standards. The scenarios do not represent any specific strategies to meet the emission reductions associated with the various scenarios. Specific strategies will be developed as part of the 2016 AQMP development process.

As noted in the beginning of this white paper, the emissions inventories used for the emissions reduction scenarios are from the 2012 AQMP. The 2012 AQMP calls for 65 and 75 percent reduction in NOx emissions to attain the federal 8-hr ozone air quality standards in 2023 and 2032, respectively. However, preliminary analysis as part of the development of the 2016 AQMP indicates that the needed NOx emission reductions are approximately 50 and 65 percent for 2023 and 2031, respectively. The initial observations and recommendations would not change due to differences in the emissions inventories since the analysis are based on relative changes among the various emissions source categories.

For the two attainment years 2023 and 2032, two scenarios were developed and analyzed. The two scenarios are:

- Equal Share Reduction in NOx
  Under this scenario, all of the off-road equipment source category baseline emissions are reduced by 65% for 2023 and 75% for 2032 (from the 2023 baseline emissions).
- 100 Percent Existing Standards
  Under this scenario, all off-road equipment NOx emissions are assumed to be at the greatest level of control based on current exhaust emissions standards.

Tables 5 and 6 provide the results of the emissions analysis for each scenario for 2023 and 2032, respectively.

TABLE 5

Remaining NOx Emissions (tons/day) in 2023

(Baseline and Equal Share Emissions from the 2012 AQMP)

Source	Baseline	Percent of Equipment at Most Stringent Level of Existing Standard (%)	Equal Share	100% Existing Standards
Construction and Mining	15.11	81	5.29	4.43
Commercial Equipment	6.79	86	2.38	4.70
Industrial Equipments	7.55	85	2.65	6.84
Lawn and Garden Equipment	4.82	87	1.69	3.95
Transportation Refrigeration Units	4.05	97	1.42	4.01
Airport Ground Support Equipment	1.41	83	0.49	0.94
Oil Drilling/Workover Equipment	0.73	68	0.26	0.15
Total	**40.46**	**--**	**14.18**	**25.02**

TABLE 6

Remaining NOx Emissions (tons/day) in 2032

(Baseline and Equal Share Emissions from the 2012 AQMP)

Source	Baseline	Percent of Equipment at Most Stringent Level of Existing Standard (%)	Equal Share	100% Existing Standards
Construction and Mining	8.35	94	2.34	4.41
Commercial Equipment	5.09	99	1.43	5.09
Industrial Equipments	6.37	97	1.78	6.05
Lawn and Garden Equipment	6.44	98	1.81	6.19
Transportation Refrigeration Units	4.87	100	1.36	4.87
Airport Ground Support Equipment	0.99	96	0.28	0.86
Oil Drilling/Workover Equipment	0.92	82	0.26	0.35
Total	**33.03**	**--**	**9.26**	**27.82**

Equal Share Reduction in NOx Scenario

For the 2023 attainment year, an overall 65% NOx reduction for all source categories in the South Coast Air Basin was determined in the 2012 AQMP beyond already adopted rules to be needed for attainment of the 80 ppb federal 8-hour ozone air quality standard. This is reflected in a straight 65% reduction across all off-road equipment source categories, resulting in an overall decrease of NOx emissions from 40.46 tons/day to 14.18 tons/day (Table 5).

For the 2032 attainment year, an overall 75% NOx reduction in all source categories based on 2023 baseline emission inventories was determined to be needed for attainment of the 75 ppb Federal 8-hour ozone standard. This is reflected in a straight 75% reduction across all off-road equipment sources as applied to 2023 baseline emission inventories, and adjusted by the 2032 baseline emissions to reflect growth. The calculation was performed in this manner to provide the incremental emission reductions by source category in "2023 currency" necessary to meet the more stringent Federal 8-hour ozone air quality standard in 2032. The total remaining NOx emissions are 9.26 tons/day from the baseline NOx emissions of 33.03 tons/day (Table 6).

100 Percent Existing Standards

This scenario assumes all equipment meet existing adopted emission standards. For each category in the off-road equipment sector, this scenario assumes that all equipment meet the highest level of controls (or the cleanest exhaust emission standards) for NOx. For example, construction and mining equipment and commercial and industrial equipment are assumed to be at 100% Tier 4 NOx emissions levels. The total NOx emissions were reduced from 40.46 tons/day to 25.02 tons/day in 2023, and 33.03 tons/day to 27.82 tons/day in 2032 (Tables 5 and 6). In addition to the emission changes for the two scenarios, Tables 5 and 6 show the percentage of the equipment population that are projected to be at the highest level of control (based on existing emission standards) in the baseline emissions for 2023 and 2032. As shown in Tables 5 and 6, significant numbers of equipment are projected to be at the highest level of control. As such, having the remaining equipment at the highest level of control does not provide sufficient NOx emission reductions to meet the "equal share" target levels.

INITIAL OBSERVATIONS

Emission Reduction Scenarios

The emission reduction scenario analysis provides insights into the development of control strategies needed to attain the federal 8-hour ozone air quality standards in 2023 and 2032. Some of the initial observations are provided below.

- The analysis conducted for this white paper focuses on specific emissions source categories related to the off-road equipment sector. As such, any analysis performed does not imply that the federal ozone air quality standards will be attained without further reduction from all emission source categories that contribute to the ozone air quality problem. That analysis will be conducted as part of the development of the 2016 AQMP. However, the scenarios analyzed as part of this white paper provide information on areas to focus on for the development of the 2016 AQMP.

- If all off-road equipment were turned over to meet the lowest emissions standards established in current U.S. EPA, and CARB exhaust emission standards, the off-road equipment sector will not achieve the 65% or 75% "equal share" NOx emissions reduction needed to attain the federal ozone air quality standards.

- Construction and mining equipment remain the largest contributor to the total off-equipment NOx emissions inventory.

- In general, almost all off-road equipment will be operating at the most stringent existing U.S. EPA exhaust emission standards in the early 2020s (as shown in Tables 5 and 6). By 2032, off-road equipment in nearly all emission source categories is at the highest level of emissions control. As such, further emission reductions in these emission categories can potentially be achieved through a combination of regulatory actions such as new emission standards, accelerated research and demonstration of new control technologies or advanced zero-emission technologies, and incentives programs.

- There is a general recognition that not all emission sources will be able to achieve an "equal share" reduction in NOx emissions for a variety of reasons, including, but not limited to, availability of cleaner technologies, cost-effectiveness, sheer number of equipment, and the timeframe to turn over older equipment to meet air quality standards.

- Accelerated deployment of commercially available zero-emission equipment in the off-road equipment sector will be needed to help meet the "equal share" reduction levels in 2023 and 2032.

- If the off-road equipment sector does not achieve the needed NOx reductions, emission sources in other sectors must achieve greater NOx reductions to make up the difference. Conversely, if emission sources other than the off-road equipment sector do not achieve needed NOx reductions, there will be a need for the off-road equipment sector to achieve greater levels of NOx reductions to make up the difference.

- While significant emission reductions have occurred in this sector, new exhaust emission standards need to be established. Given the low pollutant levels of such standards, innovative approaches will be needed in setting them and in maximizing the deployment of zero- and near-zero emission equipment.

- The most effective set of strategies will consist of a combination of accelerated advanced technology deployment, incentive programs to accelerate replacement of older off-road equipment, infrastructure enhancements, and funding incentives. Regarding funding incentives, there is a need to develop funding mechanisms that will allow operators complying with the lowest emissions standards to help recoup their investments when considering acquisition of near-zero or zero-emission equipment.

Advanced Technologies

The following are observations on the availability of zero- and near-zero emission technologies for the off-road equipment sector. For some sectors, if zero- or near-zero technologies are not feasible, cleaner combustion technologies are needed. In addition, advancing cleaner fuels and renewable fuels will help reduce criteria pollutant and greenhouse gas emissions.

- Many of the equipment used in the off-road equipment sector have long remaining useful lives. As such, new acquisitions should be at the cleanest levels of emissions and there is a need to commercialize near-zero and zero-emission technologies as early as possible.

- Zero-emission off-road equipment is currently commercially available for smaller equipment. However, there is a need to conduct research and demonstration programs for larger off-road equipment.

- To the extent that a large number of airport ground support equipment are already operating on electricity, hybridization and alternative fuels will have a significant role in reducing emissions further from airport ground support equipment.

Efficiency Measures

While greater penetration of zero- and near-zero emission technologies are needed to attain air quality standards, best practices to reduce fuel costs and increase operational efficiencies will play an important role to help meet air quality standards. Based on discussions with the Off-Road Equipment White Paper Working Group, some initial observations are:

- Operational efficiency enhancements can be made relative to industry best practices to reduce fuel costs and improve operational efficiencies in the delivery of goods.

- Intelligent transportation systems (ITS) and connected vehicles/equipment (i.e., equipped for wireless communication) can potentially provide additional environmental benefits not only in improving operational efficiencies and fuel savings, but also reduced criteria pollutant and greenhouse gas emissions.

- Potential criteria pollutant emission reductions resulting from implementing operational efficiency strategies should be quantified to the greatest extent possible and recognized as part of the development of the 2016 AQMP.

RECOMMENDATIONS

The emission reduction scenario analysis for the off-road equipment sector (Tables 5 and 6) shows a need for greater penetration of zero- and near-zero emission technologies in order to attain air quality standards. Given the long remaining useful life of off-road emission sources, existing funding programs, such as the Carl Moyer Program, Federal Aviation Administration Voluntary Airport Low Emission (VALE) Program, and the SCAQMD Lawnmower and Commercial Leaf Blower Exchange Programs, will be beneficial to help accelerate deployment of zero- and near-zero emission technologies. The following are some key recommendations to consider during the development of the 2016 AQMP.

Technology-Related and Equipment Deployment Recommendations

There is a need to develop new off-road engines and equipment that will be at zero- and near-zero emission levels. Implementing the following recommendations will help accelerate deployment of cleaner off-road equipment.

- Further research, demonstration, and deployment programs need to be initiated to develop cleaner off-road engines. Funding for such programs needs to be identified as early as possible to foster the research and demonstration programs.

- The U.S. EPA and CARB need to establish as soon as possible new NOx emissions standards for off-road engines that can potentially achieve significantly cleaner than current off-road engine exhaust emissions standards. As part of this effort, new certification test procedures should be developed for off-road engines that take into account hybridization that provides for zero-emission operational load hours or zero-emission miles.

- Sustained incentive programs (monetary and non-monetary) are needed for operators to deploy the cleanest equipment in the South Coast Air Basin. As part of this effort, research and demonstration projects should be initiated to develop new engines meeting the lower emission standards. In addition, research and demonstration of aftermarket emissions reduction equipment and retrofit technologies should continue to be promoted to provide a viable and cost effective alternative to meet compliance of new emission standards.

- Sustained public funding assistance will benefit all emission source categories in the off-road equipment sector to maximize deployment of zero- and near-zero emission technologies. Near-zero technologies that rely on alternative and renewable fuels, and where feasible, solar power, should be considered.

- New mechanisms must be developed to significantly increase deployment of zero- and near-zero technology equipment. Such mechanisms may take the form of regulations or monetary and non-monetary incentives.

- Renewable fuels may potentially provide criteria pollutant emission reduction benefits along with greenhouse gas emissions benefits. The use of renewable fuels should be supported, such as renewable gasoline, renewable diesel, renewable natural gas, and other biofuels, to help reduce fine particulate emissions and to some extent NOx emissions. [Note: The reader is referred to the Energy Outlook White Paper for further discussions of renewable fuels and infrastructure development.]

Operational Efficiency Recommendations

Operational efficiency improvements currently in practice and new strategies to further reduce fuel costs need to be quantified in terms of criteria pollutant emission benefits as part of the 2016 AQMP. The following recommendations can potentially help to further reduce criteria pollutant emissions and greenhouse gas emissions.

- Work with stakeholders in the off-road equipment sector to develop industry best practice examples for others to implement where appropriate.

- Work with stakeholders to identify technologies that help improve operations at construction and mining sites, warehouse distribution centers, and ports, rail, and intermodal yards where off-road equipment (in addition to cargo handling equipment) are used, that provide criteria pollutant emission reduction co-benefits.

- Develop methodologies to quantify emission reductions from the implementation of best practices. Such quantification methodologies can be used in the 2016 AQMP and future

AQMPs as well as CEQA for purposes of tracking and reporting criteria pollutant and greenhouse gas emission reduction benefits.

The following recommendations were provided at the June 26, 2015 meeting of the Off-Road Equipment White Paper Working Group.

- As new incentive programs are developed, administration of the programs should be streamlined as much as possible in recognition that many fleets, especially smaller fleets, do not have sufficient resources to manage the projects.
- As new emissions inventories are being developed, there is a need to reflect the most up-to-date information regarding activity and future year projections.
- Given that there may be multiple compliance requirements from different regulations that may affect the same piece of equipment, there is a desire that the regulations be as consistent as possible.
- Similar to the desire for regulatory consistency, there is a desire that the various incentive programs have a consistent set of provisions.
- Quantifying the emission benefits from operational efficiency strategies will be challenging. There is a need to develop a process to evaluate strategies for each vocation.

APPENDIX A

CURRENT EMISSION CONTROL PROGRAMS

CURRENT EMISSION CONTROL PROGRAMS

Current regulatory programs affecting the off-road equipment sector are provided in this appendix.

OFF-ROAD EQUIPMENT SECTOR EMISSION SOURCES

Off-road equipment emission sources addressed in this paper include diesel and spark ignition equipment in the construction and mining, commercial/portable, industrial, transportation refrigeration units (TRU), lawn/garden, and airport ground support equipment (GSE) source categories. Emission control programs include U.S. EPA and CARB exhaust emission standards for new diesel and spark ignition engines as well as CARB in-use equipment regulations. In-use regulations require accelerated turnover of older engines to newer lower emission engines and have been established by CARB for the following types of equipment: diesel-fueled self-propelled mobile equipment greater than 25hp, spark ignition forklifts and certain other industrial equipment greater than 25hp, portable equipment, and TRUs. The U.S. Federal Aviation Administration (FAA) provides grants under the Voluntary Airport Low Emission (VALE) Program to airports to finance low emission vehicles, refueling and recharging stations, gate electrification, and other airport air quality improvements to help meet air quality standards. In addition, the SCAQMD provides incentives for repowering or replacing construction equipment through the Carl Moyer and Surplus Off-Road Opt-In for NOx (SOON) programs and replacing residential lawn mowers with electric mowers through the Lawn Mower Exchange Program.

Diesel Construction and Industrial Equipment

In January 2015, the final stage of the Tier 4 off-road (or non-road) engine exhaust emission standards became effective and nearly all newly manufactured engines will be Tier 4 compliant. Most new equipment in 2015 and later will be built with Tier 4 engines. However, due to the long useful life of construction and industrial equipment, some older equipment including uncontrolled Tier 0 equipment will remain in service for many years. To require replacement, repower, or retirement of older equipment, CARB adopted the Regulation for In-Use Off-Road Diesel-Fueled Fleets. This regulation required registration and labeling of diesel-fueled engines 25hp and larger, established fleet average emission targets in 2014 and future years, and required mandatory turnover of old equipment if fleets do not meet the emission targets. The regulation provides later implementation schedules for small fleets. The implementation schedule is fully implemented by 2023 for large and medium fleets and 2028 for small fleets. The final emission targets are equivalent to an average of Interim Tier 4 standards. However, the regulation allows for some older engines to remain in the fleet including equipment with Tier 0 engines.

Large Spark Ignition Equipment

Large spark ignition (LSI) engines are defined as engines equal or larger than 25hp or 19kw in maximum power rating. CARB adopted off-road engine emission standards for LSI engines and the Large Spark Ignition Fleet Regulation, which established recordkeeping requirements and fleet average emissions targets for industrial LSI forklifts, and non-forklift LSI fleets (e.g., sweepers/scrubbers, industrial tugs, and airport ground support equipment). Fleets with three or fewer pieces of regulated LSI equipment are exempt from the regulation. The rule accelerated turnover of regulated LSI and encouraged introduction of electric forklifts as they could be counted in the fleet average as zero emission. New engine exhaust emission standards were fully implemented in 2010 and fleet average requirements were fully implemented in 2013. The fleet emission standards are approximately midway between the 2007 and 2010 standards and the regulation allows some pre-2010 engines to remain in the fleet.

Transportation Refrigeration Units

Transportation refrigeration units (TRU) are small refrigeration units mounted on trucks, trailers, containers, and railcars to provide refrigerated or frozen storage of perishable goods. CARB adopted emission standards for diesel and spark ignition engines less than 25 hp. These standards were fully implemented by 2010 for spark ignition engines and 2013 for diesel engines. TRUs are powered primarily by diesel engines which emit diesel particulate matter (PM). CARB adopted the Airborne Toxic Control Measure for In-Use Diesel-Fueled Transport Refrigeration Units (TRU) and TRU Generator Sets, and Facilities Where TRUs Operate in 2004 with amendments in 2011. The TRU regulation applies to TRUs that operate in California and established registration and reporting requirements and an accelerated turnover schedule such that in-use TRUs had to be repowered, retrofitted or replaced after seven years. TRUs that do not operate in California and transit through the state to other destinations are exempt from the regulation. The mandatory turnover schedule ends in 2019, seven years after 2012, which is the last year that non-Tier 4 TRU engines were manufactured. By 2020, essentially all TRUs that operate in California will be Tier 4 final compliant.

Portable Equipment

Portable equipment includes pumps, generators, compressors, and other specialized construction and industrial portable equipment. Portable equipment is mounted on trucks, trailers, containers, and skids and the engine powering the equipment does not also propel the equipment. CARB adopted emission standards for diesel and spark ignition engines less than 25 hp (small off-road engine standards) and 25hp and above (large engine standards). These standards were fully implemented by 2010 for spark ignition engines and 2015 for diesel engines. Small portable equipment is usually powered by spark ignition engines, but most portable equipment over 25hp is powered by diesel engines. Portable engines may have long remaining useful lives. CARB adopted the Portable Diesel-Fueled Engines Regulation in 2010 and the regulation became effective in February 2011. The portable engine regulation provides that at the time of registration of an engine subject to the regulation that the engine meets the most stringent emission standards in effect at the time of the registration application. The regulation applies to diesel-fueled portable equipment with engines rated at 50hp and higher and established registration, recordkeeping, and reporting requirements.

Lawn and Garden Equipment

This source category includes equipment used by both professional gardeners and homeowners. As a result, it is the largest category in terms of number of equipment and includes a diverse population of engine sizes, fuel types, and handheld, portable, and self-propelled equipment. CARB adopted regulations establishing exhaust emission standards for diesel and spark ignition engines less than 25 hp (Small Off-Road Engines). Engines with 25 hp and above are subject to the LSI Regulation discussed above. In addition, CARB adopted evaporative emission standards for small off-road engines in 2004. These standards were fully implemented by 2010 for spark ignition engines and 2015 for diesel engines. There are no emission control programs specifically applied to lawn and garden equipment. Portable lawn and garden equipment with diesel-fueled engines equal or greater than 50 hp are subject to the Portable Diesel-Fueled Engines Regulation. Riding mowers and other self-propelled mobile equipment with diesel-fueled engines equal or greater than 25 hp are subject to the Regulation for In-Use Off-Road Diesel-Fueled Fleets.

Ground Support Equipment

Ground service equipment (GSE) move and load baggage, tow aircraft, and provide electrical power, engine starting, air conditioning, fueling, maintenance, food service, and lavatory service for aircraft at airports. Due to their specialized design and use, GSEs have long useful lives. As a group, GSE largely comprise off-road types of equipment fueled by either gasoline or diesel. Diesel fueled GSE are subject to the Regulation for In-Use Off-Road Diesel-Fueled Fleets. Spark ignition forklifts and certain other equipment are subject to the Off-Road Large Spark-Ignition Fleet Regulation. In addition, zero emission GSEs are commercially available and grid power is used for some aircraft support functions (auxiliary power, fueling) previously provided by diesel-fueled mobile equipment.

Incentive Programs

Given the wide variety of off-road equipment, there are several funding programs that apply to various off-road equipment types. The SCAQMD administers several incentive programs to repower, retrofit, or replace off-road equipment.

The Carl Moyer Memorial Air Quality Standards Attainment Program provides funding based on cost-effectiveness criteria proportional to the emission reduction benefit of projects to repower, retrofit, or replace equipment. The Carl Moyer Program can fund projects for diesel and spark ignition equipment that are not required for compliance with in-use fleet rules.

The SCAQMD has been implementing the Surplus Off-Road Opt-In for NOx (SOON) provision of the CARB In-Use Off-Road Diesel-Fueled Fleet Regulation. The SOON program provides funding to operators subject to the regulation for projects to repower or replace Tier 0 and Tier 1 diesel construction and industrial equipment including ground support equipment.

As mentioned earlier, the U.S. FAA provides grants under the VALE Program to airports for the replacement of ground support equipment. In addition, the SCAQMD may receive U.S EPA funds for emission reduction projects for off-road equipment and ground support equipment.

The SCAQMD has been providing funding for zero-emission lawnmowers as part of the residential and commercial lawnmower exchange program. The exchange program provides a new electric lawn mower at a substantial discount in exchange for an older working gasoline-powered mower, which is scrapped. In addition, the SCAQMD conducts a commercial leaf blower exchange program to replace older gasoline-powered leaf blower with new leaf blowers that meet existing emission standards or cleaner.

APPENDIX B

POTENTIAL EMISSION REDUCTION TECHNOLOGIES AND EFFICIENCY MEASURES

POTENTIAL EMISSION REDUCTION TECHNOLOGIES AND EFFICIENCY MEASURES

Discussions on emission control technologies that have led to criteria pollutant emission reductions in the off-road equipment sector historically and the potential technologies to further reduce emissions including greater deployment of zero-emission and near-zero emission advanced technologies are provided in this Appendix. In addition, operational efficiency measures will have an important role in reducing criteria pollutant and greenhouse gas emissions.

OVERVIEW - TYPES OF CONTROL TECHNOLOGIES AND EFFICIENCY MEASURES

The following sections summarize some of the control technologies that can potentially further reduce criteria pollutant combustion emissions. Specific control technologies by emissions source are provided in the next section.

Cleaner Combustion Engines

Cleaner combustion engines may use advanced engine designs, improved engine management controls, or aftertreatment control systems. Most of the cleaner combustion technologies were developed for on-road engines and were adapted to off-road engines. The current off-road diesel emission standards for 75 to 750 hp engines (Tier 4 final) require high pressure common rail fuel injection, multi-stage turbochargers with charge air cooling, cooled EGR, selective catalytic reduction (SCR), and diesel particulate filters to reach NOx and PM emission levels of 0.3 g/bhp-hr and 0.01 g/bhp-hr, respectively. Tier 4 represents a 90% reduction from Tier 3 standards and even higher reduction from less stringent standards. However, cleaner combustion engines are needed to reach future ozone air quality standards.

Research is now being conducted to further reduce NOx levels of current diesel and natural gas-powered heavy-duty on-road vehicles to near-zero levels, specifically targeting a 90 percent NOx reduction from the current level of 0.2 g/bhp-hr. This research is being conducted separately by CARB under a contract with Southwest Research Institute. Under funding from the SCAQMD, California Energy Commission, and Southern California Gas Company, several natural gas engine manufacturers are developing next-generation natural gas engines to meet a 0.02 g/bhp-hr exhaust emissions level in the next several years. CARB research efforts focus on the development of emission control technologies for both diesel and natural gas engines, and SCAQMD's research solely focuses on natural gas engine technology at this time. Further improvements in engine and aftertreatment control technologies will be investigated as part of these research projects. It may be possible to extrapolate the results of this research for application with off-road equipment applications.

The following sections provide an overview of technologies that can further reduce criteria pollutant emissions.

Aftertreatment Emissions Control Technologies

Aftertreatment technologies to reduce NOx and particulate emissions include oxidation or three-way catalysts, selective catalytic reduction (SCR) systems, exhaust gas recirculation, and diesel particulate filters. These technologies may be retrofitted to in-use engines where technically feasible or may be incorporated in certified engines as originally manufactured.

Diesel oxidation catalysts do not reduce NOx, but can reduce hydrocarbons by 50% and particulates by 20 to 25%. Three-way catalysts for spark ignition engines can reduce hydrocarbon, carbon monoxide, and NOx by 90%, but are not effective on particulates.

SCR systems can reduce NOx by 90% using a reductant such as urea, commercially available as Diesel Exhaust Fluid, and in some cases, can provide moderate reductions in particulate emissions. However, SCR performance and efficiency is highly dependent on the exhaust temperature. In-use measurements of NOx emissions from heavy-duty vehicles found higher levels of NOx emissions from diesel vehicles when the vehicles operate in shorter trips where the exhaust temperatures are below the level needed for the SCR system to work effectively. There are ongoing investigations to address this performance issue.

Diesel particulate filters do not reduce NOx, but can reduce particulate emissions by more than 90% by mass and, depending on design, may also reduce hydrocarbons.

Aftertreatment systems do not generally reduce CO2 emissions and in some instances, may increase CO2 emissions due primarily to increased fuel usage.

Exhaust Gas Recirculation

Exhaust gas recirculation (EGR) is another technology that reduces NOx emissions. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. The presence of exhaust gas in the engine cylinders reduces the fraction of cylinder volume available for combustion, thus reducing combustion temperature and corresponding NOx formation. The EGR valve sits between the exhaust and intake manifolds on a vehicle engine and regulates the amount of spent exhaust gas that is mixed into the intake stream. Diesel engines relied on EGR to reduce

NOx to meet NOx emissions standards prior to 2010. Since 2010, almost all on-road diesel engines rely on SCR to meet the 2010 on-road heavy-duty exhaust NOx emissions standard as discussed above. Alternative fueled engines, which are typically spark ignited engines, also rely on EGR to reduce NOx. "Supercooled" EGR systems have been developed to meet 2010 NOx emissions standards for most alternative fueled engines.

The use of EGR systems may lead to greater fuel use. Engine manufacturers have been combining other engine technologies or modifying engine performance to address potential increase in fuel usage.

Engine Modifications

Engine modifications are performed on heavy-duty engines and change the calibration, configuration, or operation of an existing engine. Modifications may include addition of dual fuel systems, engine overhaul kits (injectors, fuel pumps, cylinder heads, turbochargers, manifolds, etc.) that reduce emissions or reprogrammed computers that reduce emissions. The emission reduction of these changes varies depending on the technology and original engine design. More advanced engine modifications such as variable valve timing and homogeneous combustion compression ignition can provide additional NOx reductions.

Alternative Fuels

Alternative fuels include dedicated natural gas, high pressure direct injection and dual fuel systems (diesel ignition with natural gas), propane, and hydrogen. These fuels have the potential to significantly reduce NOx emissions. In-use emissions measurements of NOx emissions from modern diesel and natural gas engines generally show NOx emissions levels from engines running on alternative fuels to be half as much as their diesel engine counterparts. In addition, these fuels generally reduce particulate and CO2 exhaust emissions compared to exhaust emissions from diesel engines. Alternative fuels are used in smaller industrial equipment such as forklifts. In addition, there is a commercially available LNG powered mining truck.

Hybrid Systems

Hybrid systems include a smaller than typical engine with an electric motor and energy storage system such as batteries, capacitors, or hydraulic systems. Some hybrid systems may use diesel-electric drive for energy savings rather than energy storage devices. These systems often have a high fraction of idling or low power operation where engine accessory loads (hydraulic pumps, air compressors, air conditioning, etc) are parasitic loads and can be replaced by electric motors. Hybrid systems provide emission reductions of criteria and GHG emissions of 20-30% when used in applications with opportunities for energy recovery such as loaders or cranes. Energy savings up to

10% have been reported for diesel-electric bulldozers. Hybrid systems have been commercialized for loaders (batteries), excavators (capacitors), and bulldozers (diesel-electric). Currently, Caterpillar offers a diesel-electric dozer that reduces fuel usage and meets interim Tier 4 emission standards. CO2 emission reductions would be proportional to the fuel savings. Criteria pollutant emission reduction would be expected as co-benefits.

Plug-in Hybrid Systems

Plug-in hybrid systems are similar to conventional electric hybrid systems, but can recharge batteries using grid power. Plug-in hybrid systems can achieve greater fuel savings and emission reductions than conventional hybrids but require access to grid power when not being used. Plug-in hybrid technology is commercialized in light-duty on-road vehicles and in demonstration projects for heavy-duty trucks.

Fuel Cells

Fuel cells reduce criteria and GHG emissions 100% at point of use. Fuel cell systems may include battery storage for load transients and peaking power. Most on-road fuel cells use hydrogen as fuel and react it with oxygen in the air. Similar systems are being evaluated as range extenders for electric off-road equipment. Fuel cell powered equipment can be used where battery electric equipment does not have access to grid power. Fuel cell powered vehicles and trucks are currently in development and being demonstrated in on-road applications. Smaller fuel cell powered forklifts are commercially available for use in applications where conventional and alternative fueled forklifts cannot be used such as the food service industry. Fuel cell technologies are under development for other off-road equipment such as airport ground support equipment and transportation refrigeration units.

Battery Electric

Battery powered equipment also reduces criteria and GHG emissions 100% at point of use. Battery powered equipment is recharged from grid power. Battery systems have been commercialized for lawn and garden equipment as well as industrial equipment such as forklifts, aerial lifts, and sweepers as well as certain airport ground support equipment. The SCAQMD is conducting research and demonstration of larger commercial zero-emission lawn and garden equipment.

Technology Combination

There are opportunities for combining technologies to gain greater emission reductions. For example, natural gas plug-in hybrids combine the low emissions of natural gas engines, the energy savings of hybrids, and grid power for battery charging.

Efficiency Measures

Efficiency measures include improved vehicle-to-vehicle and vehicle-to-infrastructure communications. These technologies are intended to reduce queuing or wait times and inefficient utilization of resources, which will reduce emissions and energy consumption. Caterpillar has a commercial offering for the Cat Connect system using GPS positioning and machine guidance technology to improve efficiency of graders and dozers so that less machine and operator time is required for a given job. This increase in machine productivity can reduce energy consumption per job up to 50% with criteria pollutant and GHG reductions as co-benefits.

CONTROL TECHNOLOGY APPLICATION BY EMISSIONS SOURCE CATEGORY

Construction/Mining and Commercial Equipment.

Engines used in new equipment must meet the current, most stringent U.S. EPA nonroad (or off-road) Tier 4 Final exhaust emission standards, which generally requires use of SCR and DPF aftertreatment systems to reach 0.3 g/bhp-hr NOx and 0.01 g/bhp-hr PM. Short term reductions can best be obtained by incentivizing turn-over of Tier 0 and Tier 1 equipment to Tier 4 Final equipment. The emission reduction from Tier 0 or Tier 1 to Tier 4 Final is over 95% for NOx and over 80% for VOC.

Since many pieces of diesel powered equipment are subject to the CARB In-Use Off-Road Diesel-Fueled Fleets Regulation, longer term NOx emission reductions will require widespread adoption of near-zero and zero emission systems for mobile construction and commercial (portable) equipment. Mobile construction equipment is best suited to cleaner combustion engines and hybrid systems. Alternative fuels such as natural gas will facilitate reaching near-zero emissions with combustion engines. Commercial equipment also needs cleaner combustion engines as well as zero-emission systems such as fuel cells, particularly for portable equipment with relatively constant loads such as generators, pumps, and fans.

Industrial Equipment

Industrial equipment is generally used inside or adjacent to buildings. Approximately 70% of the industrial equipment population operates with spark-ignition engines. Due to the relatively short life of most industrial equipment, the fleet will be turned over to the lowest current standards by 2023. The LSI engine certification regulation includes lower optional standards, which could be incentivized or mandated to reduce LSI fleet emissions approximately 80% (0.6 to 0.1 g/bhp-hr) if fully implemented.

Industrial equipment is also uniquely suited to zero-emission technologies such as batteries and fuel cells since the equipment generally operates at fixed facilities. Battery-electric versions of most types of industrial equipment are already commercialized. Fuel cell powered forklifts are also commercialized and other fuel cell powered industrial equipment is in development.

Transportation Refrigeration Units

Almost all TRUs are powered by diesel engines. By 2023, the TRU regulation will result in turnover of the regulated fleet to Tier 4 final engines. Further reductions will require new lower emission standards or replacing engine powered TRUs with zero emission technologies. Plug-in TRUs are currently commercialized such that the TRUs can be plugged in while parked at warehouses and the engine only operates when the TRU is in transit. Other zero-emission technologies are being investigated including fuel cells and cryogenic cooling using liquid nitrogen or CO2.

Lawn and Garden

This category includes a small number of high-use commercial equipment and a large number of low-use residential equipment. Residential equipment is almost exclusively powered by small spark ignition engines less than 25 hp. This equipment can be replaced with battery electric equipment through incentive programs such as the SCAQMD lawn mower exchange program. Commercial equipment includes the full range of small handheld equipment up to large riding mowers and small tractors. Commercial equipment, although representing approximately 11% of the population, produces 53% of the NOx emissions from the lawn and garden source category. Reductions in emissions are best obtained by incentivizing replacement of commercial equipment with the cleanest available equipment and, where feasible, with zero-emission equipment.

Ground Support Equipment

Ground service equipment (GSE) move and load baggage, tow aircraft, and provide electrical power, engine starting, air conditioning, fuel, food, and lavatory service for aircraft at airports. Due to their specialized design and use, GSEs have long useful lives. Most GSEs can be electrified to operate in battery electric configurations. In addition, new GSEs are available in diesel, propane, and natural gas configurations meeting Tier 4 emissions standards. Diesel engines will generally use EGR, SCR, and DPFs to meet Tier 4 emission standards. Natural gas and propane engines will generally use EGR, three-way catalysts, and fuel injection to meet current LSI standards. Ground support equipment generally runs for short periods under load and is then shut off. Plug-in hybrid systems can provide NOx emission reductions proportional to the percent of time running in all electric mode and maintain mission critical availability. Alternative fuels and biofuels can also provide NOx and GHG reductions that vary by fuel type.

Los Angeles World Airports reported that in its 2013 GSE inventory, 37% of the GSEs at Los Angeles International Airport operate on electricity, 16% operate on natural gas, and 47% operate on conventional diesel fuel. Since GSEs remain on airport property and generally in a given terminal area, converting the 63% of combustion equipment to plug-in hybrid systems could potentially achieve near-zero emission levels since the equipment would be recharged with grid power.

EFFICIENCY MEASURES

The benefits from reducing operational inefficiencies such as work/equipment scheduling and improving equipment/operator productivity vary by emission source category and equipment type and function. Specific benefits include fewer machine and labor hours per job resulting in more efficient utilization of off-road equipment, lower fuel consumption, and reduced GHG and criteria pollutant emissions.

Operational changes include such measures as automated package and goods handling at warehouse distribution centers that eliminate the use of conventionally fueled equipment, GPS-aided construction and mining equipment during grading operations, and more efficient routing of airline services. As an example, airlines are continually evaluating air flights to fill as many seats as possible on each flight. Such actions may result in fewer flights and in turn, result in fewer emissions and lower fuel use not only for aircraft activity, but also reduce the use of landside ground support equipment usage. Such best practices will be explored further as part of the 2016 AQMP.

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