SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

Goods Movement

2016 AQMP WHITE PAPER

OCTOBER 2015

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT
GOVERNING BOARD

CHAIRMAN:
WILLIAM A. BURKE, Ed.D.
Speaker of the Assembly Appointee

VICE CHAIRMAN:
DENNIS YATES
Mayor, Chino
Cities of San Bernardino County

MEMBERS:
MICHAEL D. ANTONOVICH
Supervisor, Fifth District
County of Los Angeles

BEN BENOIT
Mayor, Wildomar
Cities of Riverside County

JOHN J. BENOIT
Supervisor, Fourth District
County of Riverside

JOE BUSCAINO
Councilmember, 15th District
City of Los Angeles Representative

MICHAEL A. CACCIOTTI
Councilmember, South Pasadena
Cities of Los Angeles County/Eastern Region

JOSEPH K. LYOU, Ph.D.
Governor's Appointee

JUDITH MITCHELL
Councilmember, Rolling Hills Estates
Cities of Los Angeles County/Western Region

SHAWN NELSON
Supervisor, Fourth District
County of Orange

DR. CLARK E. PARKER, SR.
Senate Rules Appointee

MIGUEL A. PULIDO
Mayor, Santa Ana
Cities of Orange County

JANICE RUTHERFORD
Supervisor, Second District
County of San Bernardino

South Coast Air Quality Management District

Barry R. Wallerstein, D.Env.
Executive Officer

Matt Miyasato, Ph.D.
Deputy Executive Officer
Science and Technology Advancement

Philip M. Fine, Ph.D.
Deputy Executive Officer
Planning, Rule Development & Area Sources

Henry Hogo
Assistant Deputy Executive Officer
Mobile Source Division
Science and Technology Advancement

Dean Saito
Planning and Rules Manager
On-Road Strategies Section

Authors

David Coel – Program Supervisor
Richard Carlson – Air Quality Specialist

Reviewers

Barbara Baird, J.D. – Chief Deputy Counsel
Patti Whiting – Staff Specialist

Table of Contents

INTRODUCTION 1
Purpose and Objective 1
Document Outline 2

BACKGROUND 2
Attainment Challenge 3
Climate Challenge 4
Air Quality Impacts of Goods Movement Sources 7
Emissions Reduction Progress to Date 11
On-Road Heavy-Duty Truck Emissions 11
Off-Road Goods Movement Emission Sources 14

NOX EMISSION REDUCTION SCENARIOS 15
Equal Share Scenario 19
100 Percent Existing Standards 19
90 Percent Cleaner Combustion Technologies 20
Advanced Technology Penetration Scenarios 20

INITIAL OBSERVATIONS 20
Emission Reduction Scenarios 20
Advanced Technologies 22
Efficiency Measures 23

RECOMMENDATIONS 23
Technology-Related and Vehicle Deployment Recommendations 24
Operational Efficiency Recommendations 25

REFERENCES 26

APPENDIX A – CURRENT EMISSIONS CONTROL PROGRAMS

APPENDIX B – POTENTIAL EMISSION REDUCTION TECHNOLOGIES AND EFFICIENCY MEASURE

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 goods movement sector, which includes (for the purposes of this paper) on-road heavy-duty trucks; freight locomotives; aircraft; marine vessels such as oceangoing vessels and commercial harbor craft; and cargo handling equipment.

To illuminate policy choices relevant to the AQMP, the paper describes a number of potential scenarios for reducing emissions from the goods movement sector to support attainment of 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 vehicles that have emission levels below the emission standards established in existing state and federal regulations, advanced emission control technologies, use of alternative and renewable fuels, and the use of operational efficiency measures such as intelligent transportation systems, connected trucks, enhanced routing efficiencies, and vessel sharing.

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 goods movement 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 needed 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 and 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.

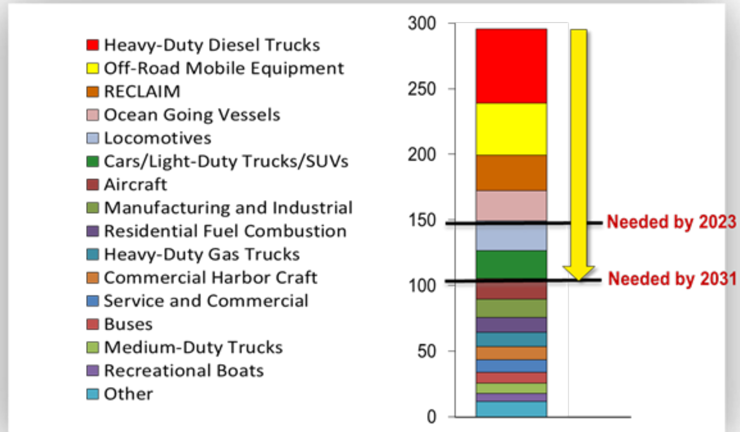
BACKGROUND

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.

The SCAQMD region includes approximately 21,000 miles of highways and arterials, 450 miles of passenger rail, and six commercial airports. It is estimated that about 90% of trips in the SCAQMD make use of the highway/arterial system, utilizing various transportation modes including automobile, transit, and active transportation. (SCAG, 2012). The nation's largest marine ports are located in the South Coast Air Basin. Close to 40% of the containerized goods that enter the Ports of Los Angeles and Long Beach are destined to areas outside of the South Coast Air Basin. As such, South Coast Air Basin residents are the recipients of the emissions associated with the movement of goods across the region that benefits the rest of the nation.

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. Since many mobile sources have already achieved over a 90% reduction in NOx emissions, attainment of the ozone standards will require wide-scale deployment of not only new vehicles 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 specifically target goods movement 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 goods movement 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 goods movement sector.

Clearly, aggressive and coordinated technology development and deployment efforts are needed in the goods movement sector 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 transportation 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 transportation technologies are needed to more widely deploy hybrid and electric vehicles as well as increased renewable sources of energy for electricity production.

GOODS MOVEMENT RELATED EMISSIONS SOURCE CATEGORIES

Tables 1 and 2 provide a list of goods movement related emissions source categories for discussion purposes in this white paper. The on-road emissions source categories shown in Table 1 include light heavy-duty vehicles with gross vehicle weight rating (GVWR) from 8,501 lbs to 14,000 lbs, medium heavy-duty vehicles (14,001 to 33,000 lbs GVWR), and heavy heavy-duty vehicles with gross vehicle weight ratings greater than 33,000 lbs. Examples of light heavy-duty vehicles include cargo vans and heavier pickup trucks. Medium heavy-duty vehicles include single unit trucks, box trucks, vocation vehicles such as solid waste collection vehicles, crew trucks, and delivery trucks. Heavy heavy-duty vehicles include over the road tractor/trailer combinations. To provide greater insight into the emissions contributions of each source categories, the emissions are further disaggregated by weight category. For example, light heavy-duty trucks are separated into two categories: LHT1 (up to 8,501 to 10,000 lbs GVWR) and LHT2 (10,001 to 14,000 lbs GVWR).

TABLE 1

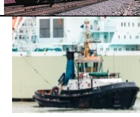
On-Road Goods Movement Vehicle Categories

Description/ Weight Class (lbs)	
Light Heavy-Duty Trucks 1 (8,501 – 10,000)	
Light Heavy-Duty Trucks 2 (10,001 – 14,000)	
Medium Heavy-Duty Trucks (14,001 – 33,000)	
Heavy Heavy-Duty Vehicles (Greater than 33,000)	

Table 2 shows the various off-road emissions source categories that are part of the goods movement sector. These categories include freight rail, ocean-going vessels, commercial harbor craft, and cargo handling equipment. For the purposes of this white paper, airport ground support equipment and transportation refrigeration units are discussed in the Off-Road Equipment White Paper.

TABLE 2

Off-Road Goods Movement Categories

Description/ Weight Class (lbs)	
Ocean-Going Vessels	
Freight Locomotives	
Commercial Harbor Craft	
Cargo Handling Equipment	

Air Quality Impacts of Goods Movement Sources

The adoption and implementation of control strategies specific to the goods movement 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 goods movement sector and their contribution to the total emissions for 2014, 2023, and 2032. For 2014, goods movement sources contribute approximately 4 and 42% to the total VOC and NOx emissions inventory. The percent contribution from goods movement sources to total VOC and NOx emissions in 2032 are 4 and 40%, respectively. Goods movement related emissions are more significant contributors to the total overall NOx emissions than to total VOC emissions.

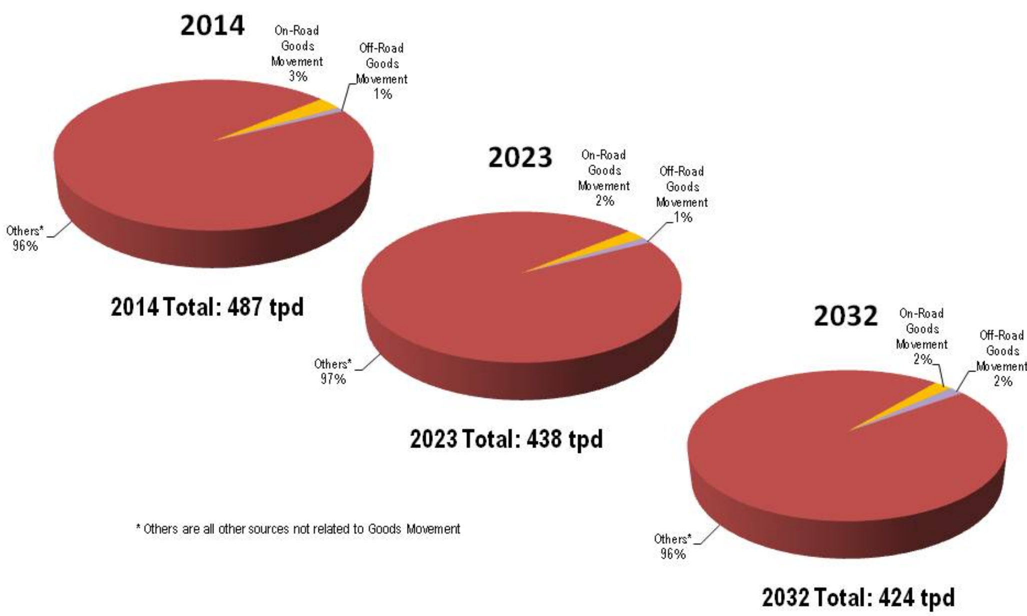


FIGURE 2

Goods Movement Sector VOC Emissions Contribution to the Total VOC Emissions for 2014, 2023, and 2032 (Source: 2012 AQMP)

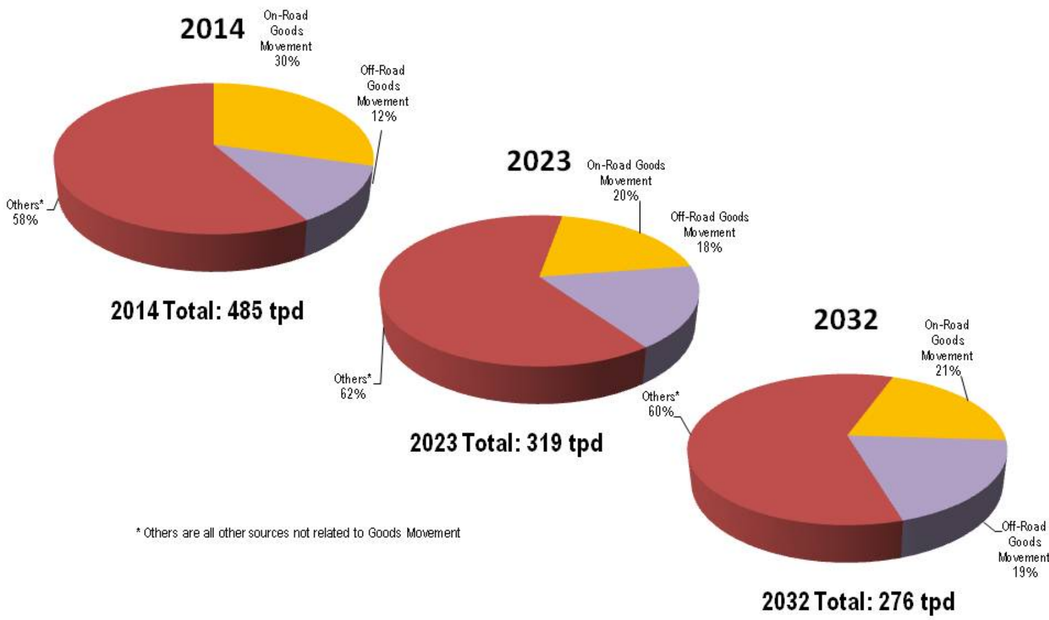


FIGURE 3

Goods Movement Sector NOx Emissions Contribution to the Total NOx Emissions for 2014, 2023, and 2032 (Source: 2012 AQMP)

Tables 3, 4, and 5 provide VOC and NOx emissions for the various emissions source categories in the goods movement sector for calendar years 2014, 2023, and 2032, respectively. In addition, the vehicle population and vehicle miles travelled are provided.

TABLE 3

VOC and NOx Emissions from On-Road Mobile Sources in the Goods Movement Sector for Calendar Year 2014 (Source: 2012 AQMP)

Source Category	Population	VMT (miles/day)	VOC (tons/day)	NOx (tons/day)
Light HD Gas Trucks-1 (8501-10000 lb.)	274,553	11,988,596	6.58	15.01
Light HD Gas Trucks-2 (10001-14000 lb.)	29,078	1,261,404	0.66	1.49
Medium HD Gas Trucks (14001-33000 lb.)	23,181	960,000	1.18	2.43
Heavy HD Gas Trucks (>33000 lb.)	1,585	186,000	0.19	1.02
Light HD Diesel Trucks-1 (8501-10000 lb.)	86,598	3,679,455	0.56	17.48
Light HD Diesel Trucks-2 (10001-14000 lb.)	29,299	1,231,545	0.19	5.69
Medium HD Diesel Trucks (14001-33000 lb.)	80,061	4,101,000	0.94	23.30
Heavy HD Diesel Trucks (>33001 lb.)	72,411	8,216,000	3.29	76.43
Total	**596,766**	**31,624,000**	**13.59**	**142.85**

TABLE 4

VOC and NOx Emissions from On-Road Mobile Sources in the
Goods Movement Sector for Calendar Year 2023 (Source: 2012 AQMP)

Source Category	Population	VMT (miles/day)	VOC (tons/day)	NOx (tons/day)
Light HD Gas Trucks-1 (8501-10000 lb.)	315,011	13,400,938	4.76	10.93
Light HD Gas Trucks-2 (10001-14000 lb.)	32,770	1,407,062	0.39	1.00
Medium HD Gas Trucks (14001-33000 lb.)	26,017	1,046,000	0.54	1.08
Heavy HD Gas Trucks (>33000 lb.)	1,776	173,000	0.09	0.86
Light HD Diesel Trucks-1 (8501-10000 lb.)	101,566	4,150,710	0.39	9.74
Light HD Diesel Trucks-2 (10001-14000 lb.)	33,579	1,360,290	0.14	3.19
Medium HD Diesel Trucks (14001-33000 lb.)	89,766	4,609,000	0.40	4.99
Heavy HD Diesel Trucks (>33001 lb.)	90,511	10,412,000	3.06	31.39
Total	**690,995**	**36,559,000**	**9.77**	**63.18**

TABLE 5

VOC and NOx Emissions from On-Road Mobile Sources in the
Goods Movement Sector for Calendar Year 2032 (Source: 2012 AQMP)

Source Category	Population	VMT (miles/day)	VOC (tons/day)	NOx (tons/day)
Light HD Gas Trucks-1 (8501-10000 lb.)	350,806	14,536,676	3.80	7.82
Light HD Gas Trucks-2 (10001-14000 lb.)	36,613	1,547,324	0.31	0.77
Medium HD Gas Trucks (14001-33000 lb.)	29,088	1,128,000	0.47	0.71
Heavy HD Gas Trucks (>33000 lb.)	2,038	188,000	0.09	0.93
Light HD Diesel Trucks-1 (8501-10000 lb.)	112,978	4,531,254	0.28	4.73
Light HD Diesel Trucks-2 (10001-14000 lb.)	37,402	1,496,746	0.12	1.61
Medium HD Diesel Trucks (14001-33000 lb.)	100,084	4,998,000	0.45	5.42
Heavy HD Diesel Trucks (>33001 lb.)	108,911	12,278,000	3.57	34.41
Total	**777,921**	**40,704,000**	**9.09**	**56.40**

Tables 6 through 8 show the VOC and NOx emissions associated with the off-road emissions source categories in the goods movement sector for 2014, 2023, and 2032, respectively.

TABLE 6

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

Source Category	VOC (tons/day)	NOx (tons/day)
Ocean Going Vessels (Except Cruise Ships)	1.86	29.23
Freight Locomotives	1.47	17.27
Harbor Craft (Except Ferries/Excursion Vessels)	0.66	7.80
Cargo Handling Equipment	0.33	3.40
Aircraft (Estimated Air Cargo Portion)	0.46	1.81
Total	**4.78**	**59.51**

TABLE 7

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

Source Category	VOC (tons/day)	NOx (tons/day)
Ocean Going Vessels (Except Cruise Ships)	3.02	28.51
Freight Locomotives	1.03	17.77
Harbor Craft (Except Ferries/Excursion Vessels)	0.62	5.89
Cargo Handling Equipment	0.42	2.23
Aircraft (Estimated Air Cargo Portion)	0.59	2.03
Total	**5.68**	**56.43**

TABLE 8

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

Source Category	VOC (tons/day)	NOx (tons/day)
Ocean Going Vessels (Except Cruise Ships)	4.92	27.33
Freight Locomotives	0.74	14.72
Harbor Craft (Except Ferries/Excursion Vessels)	0.63	6.68
Cargo Handling Equipment	0.61	2.38
Aircraft (Estimated Air Cargo Portion)	0.72	2.25
Total	**7.62**	**53.36**

Emissions Reduction Progress to Date

On-Road Heavy-Duty Truck Emissions

As shown in Figure 4, on-road truck emissions of VOC, NOx, and PM have experienced reductions ranging from 46% to 89% from 1990 levels. (Note that during the 1990s NOx emissions increased since the first on-road heavy-duty engine exhaust emissions standard for NOx became effective in 1996.) These reductions have primarily relied upon development and commercialization of technologies that control emissions from internal combustion engines with most of the trucks meeting 2010 emissions standards equipped with aftertreatment control technologies such as selective catalytic reduction (SCR) and diesel particulate filters. 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.

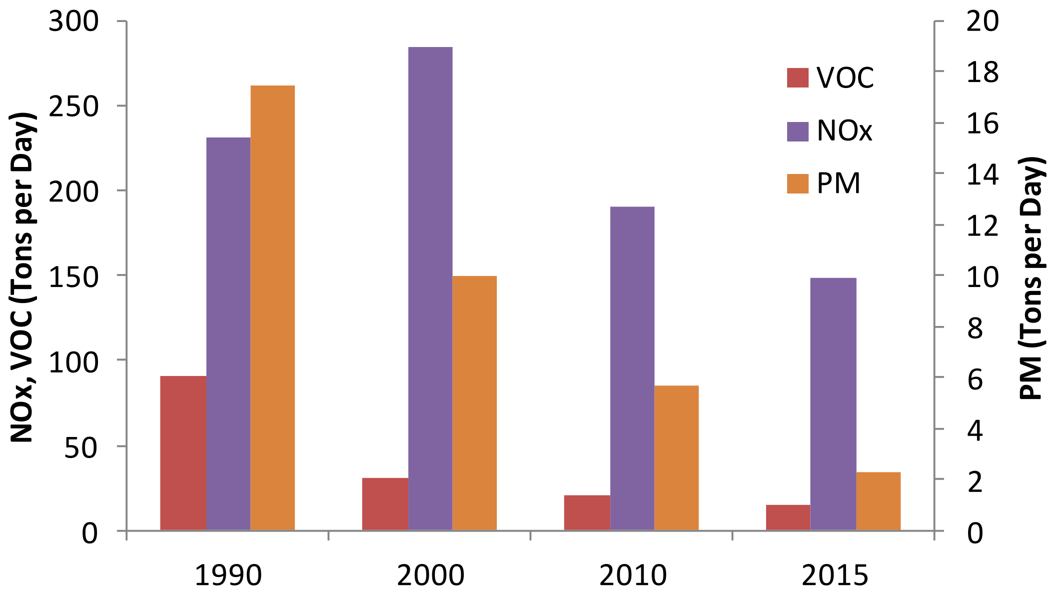


FIGURE 4

On-Road Heavy-Duty Truck Emissions in the South Coast Air Basin
(Source: EMFAC2011 with Vehicle Miles Traveled information from the 2012 AQMP)

The on-road heavy-duty trucks NOx and VOC emissions provided in Tables 3, 4, and 5 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 specific weight categories of heavy-duty trucks. 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 vehicle/fleet owners, as well as monetary incentive programs that promote the market penetration of lower-emitting vehicles. These emission reductions have occurred despite the general increase in the population of on-road heavy-duty trucks over time, as illustrated in Figure 7. It is also important to note that while the heavy heavy-duty truck population represents 12 to 15% of the total heavy-duty truck population (Figure 7), its contribution to the total NOx emissions ranges from around 50 to 60% of the total NOx emissions (Figure 5).

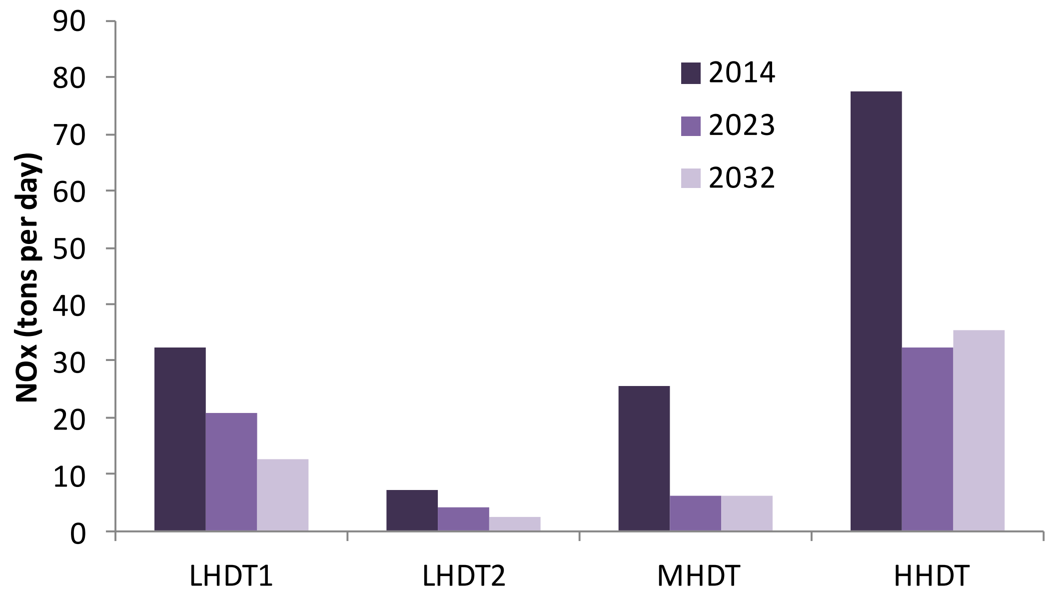


FIGURE 5

NOx Emissions for Specific On-Road Heavy-Duty Vehicles
(Source: 2012 AQMP; LHDT1 AND LHDT2 – Light Heavy-Duty Trucks; MHDT – Medium Heavy-Duty Trucks; HHDT – Heavy Heavy-Duty Trucks)

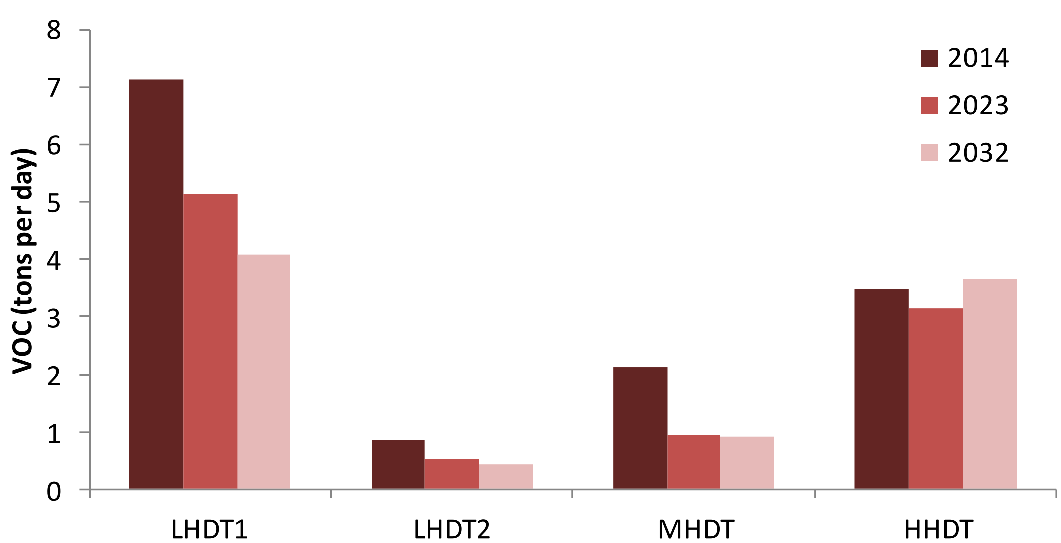


FIGURE 6

VOC Emissions for Specific On-Road Heavy-Duty Vehicles (Source: 2012 AQMP)

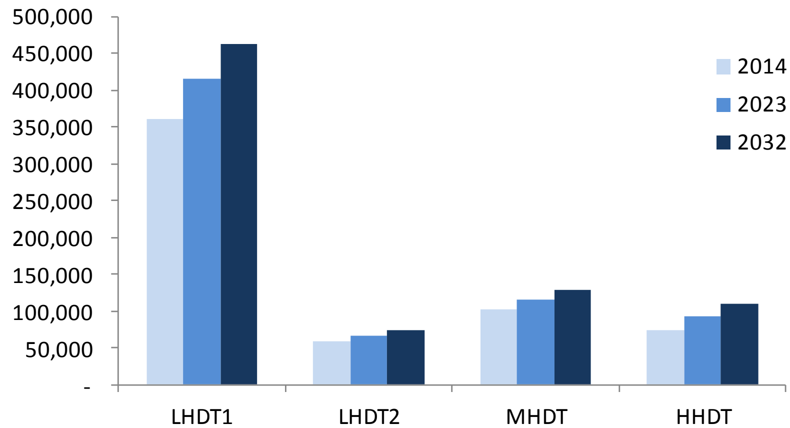


FIGURE 7

Populations for Specific On-Road Heavy-Duty Vehicles (Source: 2012 AQMP)

Off-Road Goods Movement Emission Sources

Off-road goods movement source emissions of NOx and VOC provided in Tables 6, 7, and 8 are shown graphically in Figures 8 and 9 for 2014, 2023, and 2032 calendar years to illustrate the trend in emissions and the impact of regulatory programs on emissions for specific sources. There is generally a small decrease in NOx emissions over time due to current regulations. However, air cargo related aircraft emissions increase slightly. Relative to VOC emissions, ocean-going vessel, cargo handling equipment, and air cargo related aircraft VOC emissions increase over time whereas VOC emissions from freight locomotives decrease from 2014 to 2032. Commercial harbor craft VOC emissions are at about the same levels from 2014 to 2032.

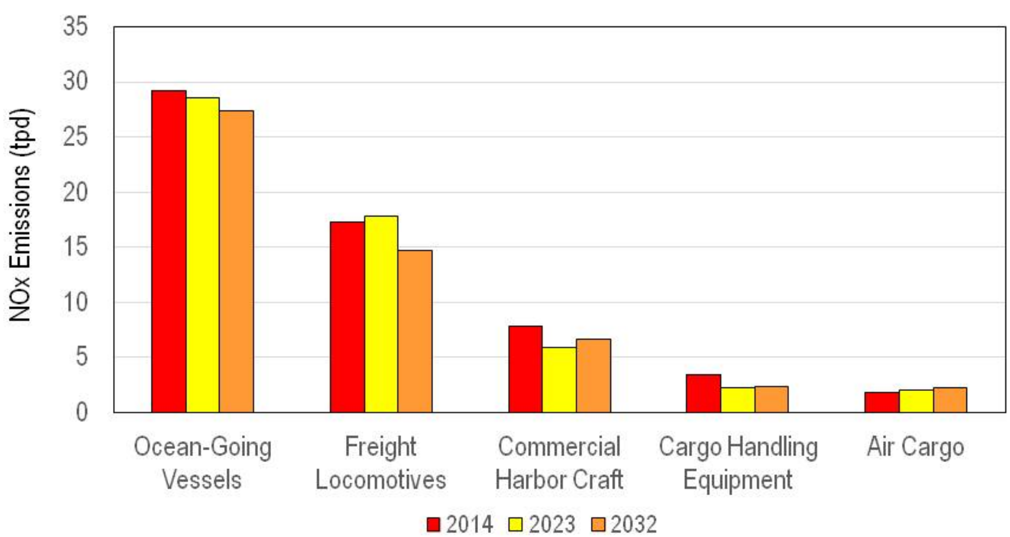


FIGURE 8

NOx Emissions for Specific Off-Road Goods Movement Sources (Source: 2012 AQMP)

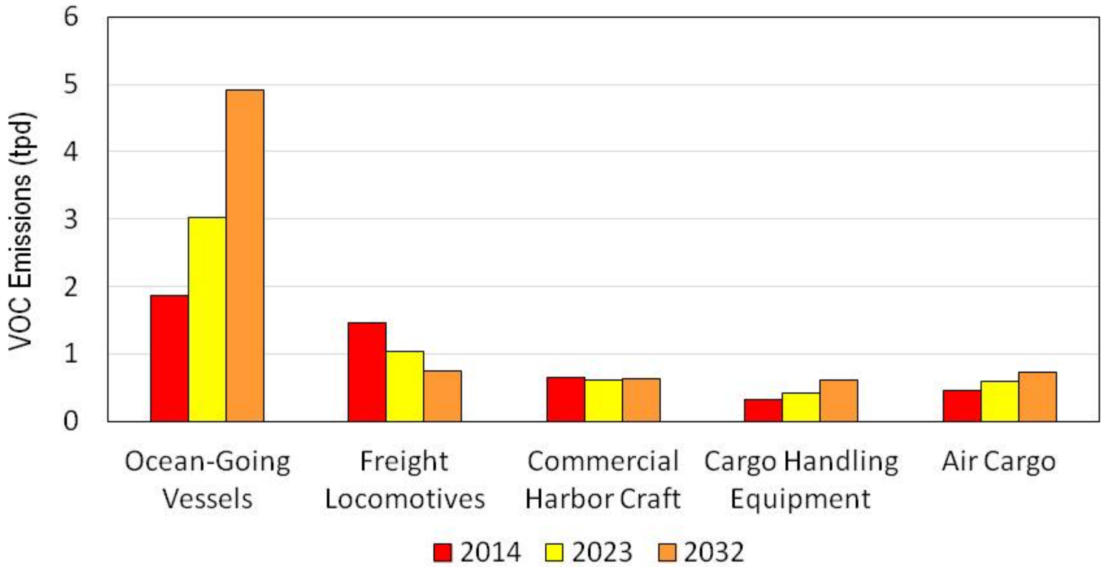


FIGURE 9

VOC Emissions for Specific Off-Road Goods Movement Sources (Source: 2012 AQMP)

NOx EMISSION REDUCTION SCENARIOS

Various NOx emission reduction scenarios were developed to assess the amount of NOx emission reductions and levels of technology deployment that may be necessary across the various emissions source categories in the goods movement sector to achieve regional NOx carrying capacities in attainment deadline years. In addition, these scenarios serve to provide insight into the various emission tradeoffs associated with different technology penetration rates. The emission scenarios are intended to help provide perspective on the challenging task to achieve necessary emission reductions in compressed timeframes to meet air quality attainment goals. The scenarios do not represent any specific strategies to meet the emission reductions associated with the various scenarios. As such, the scenarios do not do not take into consideration potential need for new advanced technologies, socioeconomic impacts, or the regulatory agency authority to regulate each of the emission source categories in this sector. 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.

The scenarios were developed using the latest approved CARB emissions inventory model, EMFAC2011, as provided in the Final 2012 AQMP. These scenarios and underlying assumptions are described below.

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

- Equal Share Reduction in NOx
  Under this scenario, all of the goods movement source category baseline emissions are reduced by 65 percent for 2023 and 75 percent for 2032 (from the 2023 baseline emissions).
- 100 Percent Existing Standards
  Under this scenario, all vehicles and equipment NOx emissions are assumed to be at the greatest level of control based on current exhaust emissions standards.
- 90 Percent Cleaner Combustion Technologies
  On-road heavy-duty truck NOx emissions are assumed to achieve additional 90 percent or cleaner emission levels beyond the existing 2010 NOx emission standard. Freight locomotives and ocean-going vessels are assumed to achieve some additional level of NOx reductions beyond Tier 4.
- Varying Penetration of Zero-Emission Technologies (Three Scenarios)
  Three scenarios were developed analyzing the potential to have 25 percent, 50 percent, and 75 percent penetration of zero-emission technologies.

Tables 9 and 10 provide the results of the emissions analysis for each scenario for 2023 and 2032, respectively.

TABLE 9

Remaining NOx Emissions (tons/day) in 2023
(Baseline and Equal Share Emissions from the 2012 AQMP)

(a) On-Road Heavy-Duty Trucks

Source	Baseline	Equal Share	100% Existing Standards	90% Cleaner	ATP1 - 25% Zero / 75% Near-Zero	ATP2 - 50% Zero / 50% Near-Zero	ATP3 - 75% Zero / 25% Near-Zero
Light HD Gas Trucks-1	10.93	3.83	4.22	4.22	3.17	2.11	1.06
Light HD Gas Trucks-2	1.00	0.35	0.48	0.48	0.36	0.24	0.12
Medium HD Gas Trucks	1.08	0.38	0.38	0.04	0.03	0.02	0.01
Heavy HD Gas Trucks	0.86	0.30	0.74	0.07	0.06	0.04	0.02
Light HD Diesel Trucks-1	9.74	3.41	2.12	2.12	1.59	1.06	0.53
Light HD Diesel Trucks-2	3.19	1.12	0.79	0.79	0.59	0.39	0.20
Medium HD Diesel Trucks	4.99	1.75	4.73	0.47	0.35	0.24	0.12
Heavy HD Diesel Trucks	31.39	10.99	28.80	2.88	2.16	1.44	0.72
Total	**63.18**	**22.11**	**42.25**	**11.07**	**8.30**	**5.53**	**2.77**

(b) Off-Road Goods Movement

Source	Baseline	Equal Share	Existing Standard	90% Cleaner	ATP 1 - 25% Zero/ 75% Near-Zero	ATP 2 - 50% Zero/ 50% Near-Zero	ATP 3 - 75% Zero/ 25% Near-Zero
Ocean-Going Vessels	28.51	9.98	13.27	8.80	8.80	8.80	8.80
Freight Locomotives	17.77	6.22	5.48	0.55	0.41	0.28	0.14
Cargo Handling Equipment	2.23	0.78	1.20	0.12	0.09	0.06	0.03
Harbor Craft	5.89	2.06	1.62	1.39	1.39	1.39	1.39
Aircraft	2.03	0.71	0.51	0.51	0.51	0.51	0.51
Total	**56.42**	**19.75**	**22.07**	**11.37**	**11.20**	**11.04**	**10.87**

(c) Total On-Road and Off-Road Goods Movement

All Sources	Baseline	Equal Share	Existing Standard	90% Cleaner	ATP 1 - 25% Zero/ 75% Near-Zero	ATP 2 - 50% Zero/ 50% Near-Zero	ATP 3 - 75% Zero/ 25% Near-Zero
Total	**119.60**	**41.86**	**64.32**	**22.44**	**19.50**	**16.57**	**13.64**

TABLE 10

Remaining NOx Emissions (tons/day) in 2032
(Baseline and Equal Share Emissions from the 2012 AQMP)

(a) On-Road Heavy-Duty Trucks

Source	Baseline	Equal Share	100% Existing Standards	90% Cleaner	ATP1 - 25% Zero / 75% Near-Zero	ATP2 - 50% Zero / 50% Near-Zero	ATP3 - 75% Zero / 25% Near-Zero
Light HD Gas Trucks-1	7.82	2.74	4.58	4.58	3.44	2.29	1.15
Light HD Gas Trucks-2	0.77	0.25	0.52	0.52	0.39	0.26	0.13
Medium HD Gas Trucks	0.71	0.27	0.45	0.05	0.03	0.02	0.01
Heavy HD Gas Trucks	0.93	0.21	0.84	0.08	0.06	0.04	0.02
Light HD Diesel Trucks-1	4.73	2.41	2.31	2.31	1.73	1.15	0.58
Light HD Diesel Trucks-2	1.61	0.8	0.87	0.87	0.65	0.43	0.22
Medium HD Diesel Trucks	5.42	1.25	5.31	0.53	0.40	0.27	0.13
Heavy HD Diesel Trucks	34.41	7.92	33.15	3.32	2.49	1.66	0.83
Total	**56.40**	**15.85**	**48.04**	**12.26**	**9.19**	**6.13**	**3.06**

(b) Off-Road Goods Movement

Source	Baseline	Equal Share	Existing Standard	90% Cleaner	ATP 1 - 25% Zero/ 75% Near-Zero	ATP 2 - 50% Zero/ 50% Near-Zero	ATP 3 - 75% Zero/ 25% Near-Zero
Ocean Going Vessels	27.33	7.65	19.71	13.19	13.19	13.19	13.19
Freight Locomotives	14.72	4.12	6.53	0.65	0.49	0.33	0.16
Cargo Handling Equipment	2.38	0.71	1.89	0.19	0.14	0.10	0.05
Harbor Craft	6.68	1.53	1.94	1.26	1.26	1.26	1.26
Aircraft	2.25	0.52	1.13	1.13	1.13	1.13	1.13
Total	**53.36**	**14.54**	**31.19**	**16.39**	**16.12**	**15.91**	**15.70**

(c) Total On-Road and Off-Road Goods Movement

All Sources	Baseline	Equal Share	Existing Standard	90% Cleaner	ATP 1 - 25% Zero/ 75% Near-Zero	ATP 2 - 50% Zero/ 50% Near-Zero	ATP 3 - 75% Zero/ 25% Near-Zero
Total	**109.76**	**30.39**	**79.23**	**28.65**	**25.31**	**22.04**	**18.21**

Equal Share Reduction in NOx Scenario

For the 2023 attainment year, an overall 65 percent NOx reduction for all source categories in the South Coast Air Basin was determined 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 goods movement source categories, resulting in an overall decrease of NOx emissions from 63.18 tons/day to 22.11 tons/day for on-road heavy-duty trucks, and NOx emissions decrease from 56.42 to 19.75 tons/day for off-road sources [Tables 9(a) and 9(b)]. The total remaining NOx emissions combining on-road and off-road emissions are 41.86 tons/day [Table 9(c)].

For the 2032 attainment year, an overall 75 percent 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 goods movement sources as applied to 2023 baseline emission inventories, with remaining inventories applied to the 2032 attainment year. 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. Reflecting all on-road heavy-duty trucks, the on-road NOx emissions are reduced from 56.4 tons/day to 15.85 tons/day in 2032 [Table 10(a)]. Off-road NOx emissions are reduced from 53.36 tons/day to 14.54 tons/day [Table 10(b)]. The total remaining NOx emissions combining on-road and off-road emissions are 30.39 tons/day [Table 10(c)].

100 Percent Existing Standards Scenario

This scenario assumes full implementation of existing adopted emission standards. For on-road heavy-duty trucks, this scenario assumes that all trucks meet the 2010 model year on-road heavy-duty engine exhaust emissions standard of 0.2 g/bhp-hr for NOx. To incorporate emission deterioration, for the 2023 and 2032 calendar year scenarios, EMFAC2011 was used to calculate in-use fleet average NOx emissions for the 2010 to 2023 calendar year timeframe and 2010 to 2032 calendar year timeframe, respectively. Similarly, the off-road sources are assumed to meet the most stringent existing emissions standards. For example, cargo handling equipment and locomotives are assumed to be at 100% Tier 4 NOx emissions levels and ocean-going vessels are at the Tier 3 NOx emissions standard. Aircraft are assumed to meet the current U.S. EPA NOx emission standards. Again, the analysis provided here does not reflect how these levels are achieved. The total NOx emissions were reduced from 119.6 tons/day to 64.32 tons/day in 2023, and 109.76 tons/day to 79.23 tons/day in 2032 [Table 9(c) and 10(c)].

90 Percent Cleaner Combustion Technologies Scenario

For this scenario, on-road heavy-duty trucks are assumed to meet a 90 percent cleaner combustion technology from the 2010 NOx exhaust emissions standard or 0.02 g/bhp-hr. For off-road sources, locomotives are assumed to reach a 90% cleaner level, NOx emissions from ocean-going vessels would be further reduced through reduction of emissions from auxiliary engines and boilers while at-berth, and cargo handling equipment and harbor craft emissions would be further reduced through deployment of cleaner engines and hybrid systems. No additional reductions were assumed for the aircraft sector. The resulting remaining emissions shown in Tables 9(c) and 10(c), are 22.44 tons/day (from 119.6 tons/day) in 2023 and 28.65 tons/day (from 109.76 tons/day) in 2032.

Varying Penetration of Zero-Emission Technologies Scenarios

The varying penetration scenarios assume various in-use penetrations of zero-emission technologies to achieve emission reductions beyond the 90 percent cleaner combustion scenario. Three specific in-use fleet penetration scenarios were evaluated corresponding to 25% ZEV/75% near-ZEV, 50% ZEV/50% near-ZEV, and 75% ZEV/25% near-ZEV. Note that "near-ZEV" corresponds to the vehicle technologies incorporated into the 90% cleaner combustion scenario. As expected, these scenarios result in the largest emission reductions for all scenarios evaluated, reducing the remaining NOx inventory in 2023 to 19.5 tons/day, 16.57 tons/day, and 13.64 tons/day, respectively, from a baseline inventory of 119.6 tons/day. In 2032, the remaining NOx inventories are reduced to 25.31 tons/ day, 22.04 tons/day, and 18.21 tons/day, respectively, from a baseline inventory of 109.76 tons/day.

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 goods movement sector. As such, any analysis performed does not imply that the federal ozone air quality standards will be attained without further reductions 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 trucks and off-road equipment were turned over to meet the lowest emissions standards established in current international (IMO, ICAO), U.S. EPA, and CARB exhaust emission standards, the goods movement sector would not achieve the 65% or 75% "equal share" NOx emissions reductions needed to attain the federal ozone air quality standards.

- On-road heavy-duty trucks remain the largest contributor to the total NOx emissions inventory. While on-road heavy heavy-duty trucks (with gross vehicle weight ratings over 33,000 lbs) represent around 15 percent of the total heavy-duty truck population in 2032, the on-road heavy-duty truck NOx emissions are over half of the total heavy-duty trucks emissions (see Table 5).

- 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 vehicles or equipment, and the timeframe to turn over older vehicles to meet air quality standards.

- Additional NOx reductions are needed from federal transportation sources (i.e., locomotives, marine vessels, and aircraft).

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

- If the goods movement 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 goods movement sector do not achieve needed NOx reductions, there will be a need for the goods movement 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 are needed. New heavy-duty exhaust emissions standards must be established as early as possible. 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 vehicles.

- The most effective set of strategies will consist of a combination of accelerated advanced technology deployment, incentives programs to accelerate replacement of older trucks and 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 a near-zero or zero-emission vehicle or equipment.

- There is a nexus with the passenger transportation sector. On certain freeways and arterial roads, heavy-duty truck traffic is shared with passenger cars and transit buses during the morning and evening commute hours. In addition, commuter rail operate on rail tracks shared with freight rail. The reader is referred to the companion Passenger Transportation White Paper for more information.

Advanced Technologies

The following are observations on the availability of zero- and near-zero emission technologies for the goods movement sector. For some sectors (e.g., aircraft), 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.

- Federal transportation sources (locomotives, ocean-going vessels, and aircraft) are not required to use the cleanest technologies when transporting goods in and out of California. As such, there is a need to develop mechanisms or incentives for rail operators, vessel operators, and air cargo transportation operators to use the cleanest equipment when transporting goods through California.

- Many of the equipment used in the goods movement 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 trucks are currently in development and are being demonstrated in the port area. However, there is a need to complete the field demonstrations and develop a commercial market base for the zero-emission trucks. Similar efforts will be needed for near-zero emission trucks. In addition, zero-emission yard tractors are being demonstrated at the Ports.

- As the Class I railroads begin purchasing Tier 4 line-haul locomotives, there is a need to deploy as many Tier 4 locomotives in the Southern California region as early as possible. If nearly all freight locomotives operating in California were at the Tier 4 emissions level, freight locomotives would achieve the overall 65% reduction in NOx needed by 2023. However, in the longer term, even cleaner locomotives will need to be developed and deployed. The use of liquefied natural gas, hybrid systems, and external electrical power can lead to NOx emission levels lower than the current Tier 4 emissions standard. However, research and demonstration of the technologies described must be initiated as soon as possible to help meet ozone air quality standards in the 2032 timeframe.

- The FAA CLEEN Program plays an important role in developing lower NOx emitting aircraft engines with an objective to have new aircraft engines 60% cleaner in NOx emissions.

Efficiency Measures

While greater penetration of zero- and near-zero emission technologies are needed to attain air quality standards, operational efficiencies in the roadway network and best practices at marine ports, warehouse distribution centers, and intermodal yards can potentially provide criteria pollutant and greenhouse gas emission reduction benefits. Some initial observations are:

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

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

- Operational efficiencies in goods delivery routing will help reduce road congestion and reduce emissions. Potential criteria pollutant emission reductions resulting from implementing operational efficiency strategies need to be quantified and recognized as part of the development of the 2016 AQMP.

RECOMMENDATIONS

The emission reduction scenario analysis for the goods movement sector 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 in the goods movement sector, existing funding programs such as the Carl Moyer Program and Proposition 1B, need to continue to help accelerate deployment of zero- and near-zero emission technologies. There is also a need to continue development of cleaner combustion engine technologies for federal transportation sources. The following are some key recommendations to consider during the development of the 2016 AQMP.

Technology-Related and Vehicle Deployment Recommendations

As mentioned earlier, on-road zero-emission trucks are currently being demonstrated. However, to commercialize the zero-emission trucks, new and innovative approaches must be developed. Implementing the following recommendations will help accelerate deployment of cleaner vehicles.

- The U.S. EPA and CARB need to establish a new NOx emissions standard for on-road heavy-duty engines that is 90 percent cleaner than current on-road heavy-duty engine exhaust emissions standard as soon as possible. As part of this effort, new certification test procedures should be developed for on-road heavy-duty trucks that take into account hybridization that provides for zero-emission miles operation.

- The appropriate international organizations and U.S. EPA need to establish new exhaust emission standards that are substantially lower than the existing emission standards for locomotives, ocean-going vessels, and aircraft. In addition, sustained incentives 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, initiate research and demonstration projects should be initiated to develop new engines meeting the lower emission standards.

- Sustained public funding assistance will benefit all emission source categories in the goods movement sector to maximize deployment of zero- and near-zero emission technologies.

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

- Develop mechanisms for greater deployment of "emissions capture systems" at marine ports and at freight rail maintenance facilities to reduce emissions from ocean-going vessels while at berth and freight rail locomotives during maintenance.

- Support the FAA CLEEN Program in the development of cleaner, more fuel-efficient aircraft engines.

- 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. Improvements to the existing transportation infrastructure have potential criteria pollutant co-benefits. The following recommendations can potentially help to further reduce criteria pollutant emissions and greenhouse gas emissions.

- Work with stakeholders in the goods movement sector to develop industry best practice examples for others to implement where appropriate.
- Conduct studies to assess intelligent transportation systems' (ITS) potential to reduce truck and traffic congestion and criteria pollutant emissions.
- Promote deployment of ITS in key congestion areas and in implementation of best practices in goods delivery to help further reduce emissions and reduce congestion.
- Where dedicated truck lanes are being proposed in freeway expansion projects, dedicated truck lanes should give preferential treatment to zero- and near-zero emission trucks.

REFERENCES

CARB (2013a). EMFAC2011, *California Air Resources Board*, January 2013

CARB (2013b). Staff Report: Initial Statement of Reasons, Proposed Amendments to California Exhaust and Evaporative Emission Standards and Test Procedures for Passenger Cars, Light-Duty Trucks and Medium-Duty Vehicles, California Air Resources Board "LEV II", *California Air Resources Board*, September 1998.

CARB (2014). Lower NOx Heavy-Duty Diesel Engines Technology Assessment, *California Air Resources Board*, September 2014.

MECA (2013). LEV III and Tier 3 Exhaust Emission Control Technologies for Light-Duty Gasoline Vehicles, *Manufacturers of Emissions Controls Association*, April 2013.

MECA (2014). Technology Details Heavy-Duty Trucks and Buses, *Manufacturers of Emissions Controls Association*, http://www.meca.org/technology/technology-details?id=22&name=Heavy-Duty Trucks and Buses, February 2014.

SCAG (2012). Regional Transportation Plan and Sustainable Community Strategies, *Southern California Association of Governments*, Adopted – 2012.

APPENDIX A

CURRENT EMISSION CONTROL PROGRAMS

CURRENT EMISSION CONTROL PROGRAMS

Current regulatory programs and other planning efforts affecting the goods movement sector are provided in this appendix.

GOODS MOVEMENT SECTOR EMISSION SOURCES

On-Road Heavy-Duty Trucks

The on-road heavy-duty truck category includes diesel and spark-ignition heavy-duty trucks and contributes 53% of goods movement NOx emissions in 2023 (Tables 4 and 7). The current heavy-duty NOx engine exhaust standard of 0.2 g/bhp-hr NOx was phased-in beginning in 2007 with full implementation beginning in 2010, and became mandatory in 2008 for spark ignition engines and 2010 for diesel engines. CARB recently adopted a set of optional low-NOx engine exhaust emissions standards at 0.1, 0.5, and 0.02 g/bhp-hr. Engine manufacturers are not required to produce engines that meet the optional NOx emission standards. However, heavy-duty engines certified to the lower optional NOx standards can be eligible for public funding since the lower emissions from these engines would be considered surplus to the mandatory standard.

In 2023, spark ignition (gasoline and natural gas) trucks emissions are estimated around 14 tons/day of NOx representing approximately 22% of truck emissions and 12% of all goods movement NOx emissions. Heavy-duty diesel trucks are subject to CARB's Truck and Bus Regulation, which requires turnover of nearly all heavy-duty diesel trucks to at least the 0.2 g/bhp-hr NOx emissions standard by 2023. Heavy-duty spark ignition engine vehicles do not have an in-use CARB fleet rule.

Freight Locomotives

A substantial fraction of international goods moving through the South Coast Air Basin is carried by freight trains pulled by diesel-electric locomotives. Diesel-electric locomotives have a large diesel engine (main traction engine) for generating electric power which in turn drives electric motors in each axle. Goods movement-related locomotives are forecast to contribute approximately 18 tons per day of NOx emissions to the South Coast Air Basin in 2023. There are two Class I railroads that operate in the South Coast Air Basin. The two railroads are subject to the 1998 Memorandum of Understanding (MOU) with CARB to reach a NOx fleet average emission rate to meet the U.S. EPA Tier 2 locomotive emissions standard by 2010. In 2008, U.S. EPA adopted new locomotive emission standards establishing a NOx emissions level of 0.13 g/bhp-hr for locomotive engines produced beginning in 2015.

Ocean-Going Vessels

Ocean-going vessels (OGVs) contribute a significant portion of NOx, PM, greenhouse gas, and toxic emissions particularly in coastal regions in and around shipping ports. These emissions contribute to on-shore air quality problems representing approximately 9% of total NOx emissions in the South Coast Air Basin for 2023. NOx emissions produced by main propulsion and auxiliary engines when the vessels are transiting within the South Coast Air Basin and the auxiliary engines, when the vessels are anchored or docked at a port in the South Coast Air Basin, are included in the emission inventory. CARB has established low sulfur content fuel standards for marine fuels that took effect since 2009 with the lowest maximum sulfur content limit of 0.1% taking effect beginning 2014. The use of lower sulfur content marine fuels primarily reduced PM and SOx emissions with some reductions in NOx. The International Maritime Organization (IMO) has established lower NOx emission standards for Category 3 propulsion and auxiliary engines. Ocean-going vessels built today must meet a Tier 2 NOx emissions standard, while vessels built beginning in 2016 must meet the Tier 3 standard of 3.4 g/bhp-hr if the vessel will be calling at marine ports located in an Emissions Control Area (ECA) established by IMO. Currently, the North American ECA is in effect, which requires ocean-going vessels to use 0.1% sulfur content marine fuels when transiting within 200 nautical miles off the North American coast.

Aircraft

Passenger aircraft carry cargo as well as passengers. Commercial aircraft emission inventories combine passenger aircraft and dedicated cargo aircraft. CARB estimates that 13% of aircraft emissions are attributable to air cargo (CARB, 20313), which includes mail, express packages, and freight. Based on the South Coast Air Basin aircraft NOx emission forecast for 2023, 2 tons/day of NOx are attributed to air cargo. Aircraft engine emissions are regulated by U.S. EPA, which harmonized emission standards in 2005 with the International Civil Aviation Organization's Committee on Aviation Environmental Protection (ICAO-CAEP). Aircraft have a long service life (typically, greater than 30 years) although there is an economic incentive to retire older aircraft due to better fuel efficiency from new aircraft. The most stringent currently adopted standard took effect in 2014 and provides approximately 50% cleaner NOx emissions than engines manufactured before 2005.

Commercial Harbor Craft

There are approximately 750 commercial harbor craft operating within the South Coast Air Basin. Commercial harbor craft NOx emissions are estimated to be around 6 tons/day in 2023. Commercial harbor craft related to goods movement activities include barges, crew/supply vessels, dredges, pilot vessels, tow/push boats for barges, tug boats for assisting ocean-going vessels, and work boats for harbor construction and maintenance activities. Commercial harbor craft generally have multiple propulsion and auxiliary engines per vessel with total power between several hundred and several thousand horsepower. Essentially all commercial harbor craft are currently diesel powered. Work activity varies significantly with some vessels spending most time within the port harbor and adjacent waters, while others leave the local port for adjacent ports, Catalina Island, or off-shore platforms. Harbor craft are subject to new engine regulations that now require meeting Tier 3 exhaust emission standards for engines less than 800 hp and Tier 4 standards, the most stringent currently adopted, for engines greater than 800 hp. In addition, crew and supply vessels, dredges, tow/push boats, tug boats, and work boats are also subject to the CARB Commercial Harbor Craft regulation which specifies turnover of older marine engines for new engines on a schedule that will leave essentially all regulated harbor craft with Tier 2 or cleaner engines by 2023.

Cargo Handling Equipment

There are approximately 5,700 pieces of diesel powered cargo handling equipment (CHE) operated at marine ports, intermodal freight facilities, and warehouse distribution centers in the South Coast Air Basin. Cargo handling equipment includes forklifts, yard hostlers (i.e., top picks, side picks, etc), cranes, excavators, tractors, loaders, and other cargo or material handling equipment used to load or unload cargo from vessels, trucks, and rail cars. Based on the emissions projections in the 2012 AQMP, cargo handling equipment NOx emissions are around 2 tons/day in 2023. Tier 4 off-road emission standards, currently the most stringent emissions standard for diesel powered equipment, took effect in 2014 and required greater than 90% reduction in NOx and PM emissions for new engines compared to uncontrolled engines. CARB also adopted a Cargo Handling Equipment regulation to accelerate reduction in emissions from 2006 and older equipment by specifying an equipment retrofit or replacement schedule. With full implementation of the rule, all cargo handling equipment will be at Tier 3 emissions levels or cleaner by 2023. Zero emission and alternative fueled cargo handling equipment are also becoming available and are being deployed in a number of demonstration projects. In addition, funding assistance is available for the deployment of zero-emission and alternative fuel cargo handling equipment.

OTHER PLANNING EFFORTS AFFECTING THE GOODS MOVEMENT SECTOR

SCAG Regional Transportation Plan

The Southern California Association of Governments (SCAG) prepares the Regional Transportation Plans (RTP), with the primary goal of increasing mobility in the region. An additional goal includes increasing the region's sustainability, officially incorporated into the RTP as the Sustainable Communities Strategies (SCS). The most recent RTP/SCS is the 2012 – 2035 RTP/SCS, and was adopted by SCAG on April 12, 2012. It can be accessed at the following link: http://www.scagrtp.net.

The 2012 RTP/SCS includes a freight element that provides near-term actions to further emission reductions in the region Specifically, the 2012 RTP incorporates widespread utilization of zero- and near-zero emission transportation technologies in the 2023 to 2035 timeframe and various mechanisms to incrementally achieve this objective. This approach is intended to generate numerous co-benefits, including greater energy security and cost certainty, increased public support for infrastructure, GHG reduction, and economic development.

San Pedro Bay Ports Clean Air Action Plan (CAAP)

The CAAP was adopted in late 2006 by the Ports of Los Angeles and Long Beach and outlines a path for the San Pedro Bay Ports to reduce criteria pollutant emissions from Port facilities. Port-related emission sources included heavy-duty drayage trucks, freight locomotives, ocean-going vessels, commercial harbor craft, and cargo handling equipment. The CAAP was initially a 5-year plan, beginning with fiscal year (FY) 2006/2007, and ending with FY 2010/2011. In 2010, the CAAP was updated reflecting new emission inventories and longer-term emission reduction goals.

The CAAP involves investments by the two ports for air quality programs to reduce PM, NOx, and SOx. The CAAP commits the Ports to develop policies, standards, specifications, and incentives to accelerate the introduction of low emission technologies, operational changes such as vessel speed reduction programs, and fuels that reduce emissions. The CAAP encompasses 11 specific control measures including two for heavy-duty drayage trucks, five for ocean-going vessels, three for locomotives and near-dock railyards, and one each for cargo handling equipment and commercial harbor craft. Additional commitments by the Ports include working with air quality regulatory agencies (SCAQMD, CARB, and U.S. EPA) to establish San Pedro Bay Air Quality Standards as well as tracking improvements in air quality compared to 2005 through annual emission inventories. The goals set forth in the CAAP include the following, and for 2014, have been met:

- by 2014, reduce emissions of DPM, NOx, SOx by 72%, 22%, 93%
- by 2023, reduce emissions of DPM, NOx, SOx by 77%, 59%, 93%
- by 2020, reduce population-weighted cancer risk by 85%

Federal Surface Transportation Legislation

Every five years the federal government usually adopts legislation broadly categorized as "federal surface transportation legislation" that authorizes and funds transportation related infrastructure, impacting the federal highway system, transit systems, and related local infrastructure projects. The latest federal surface transportation legislation enacted by Congress was named "Moving Ahead for Progress in the 21st Century", known as MAP-21. It was adopted in 2012 with expiration at the end of 2014. The short expiration date resulted from lack of funding primarily due to shortfalls in vehicle fuel taxes ($/gallon), imposed at the pump, that were established approximately 20 years ago and have not increased over time to offset the effects of lower gasoline consumption from increased fuel economy. At the end of 2014, MAP-21 was extended to May 2015 as a temporary measure, and federal surface transportation legislation targeting up to a six-year time frame is currently being developed. As a result of the authorization and funding components, surface transportation legislation establishes policy on the priority of highway and related infrastructure projects that are federally supported. This legislation provides a mechanism by which the federal government can participate in the funding of critical infrastructure projects, that support the widespread deployment of near-zero and zero-emission vehicle technologies in the SCAQMD region. As identified previously, the deployment of these technologies is critical for ambient air quality standard attainment as reflected in the 2012 AQMP.

MAP-21 includes a number of provisions to improve the condition and performance of the national freight network and support investment in freight-related surface transportation projects. Some of the provisions include having the U.S. Department of Transportation (DOT) establish a national freight network to assist States in strategically directing resources toward improved movement of freight on highways and allowing a maximum federal share of 95% for an interstate system project (or of 90% for a non-interstate system project) if the project makes a demonstrable improvement in the efficiency of freight movement and is identified in a State freight plan. U.S. DOT would also lead efforts on the national level for future freight planning.

California Freight Mobility Plan (CFMP)

The California State Transportation Agency (CalSTA) and the California Department of Transportation (Caltrans) developed the California Freight Mobility Plan (CFMP) in partnership with stakeholders representing other state agencies such as CARB, local government agencies such as SCAG and

SCAQMD, private industries, and public interest groups. The CFMP is a plan that governs the immediate and long-range planning activities, provides a comprehensive inventory of transportation infrastructure, volume and value of goods moved, facilities, identifies potential improvements to the transportation system, and guides the state's capital investments with respect to the movement of freight. The CFMP complies with the relevant provisions of the federal Moving Ahead for Progress in the 21st Century Act (MAP-21), which encourages each state to develop a freight plan.

CARB Sustainable Freight Strategy Discussion Draft

CARB is developing the California Sustainable Freight Strategy with the goal of describing CARB's vision and options for a clean freight system that meets the needs of diverse goods movement stakeholders. The strategy document, expected to be released in 2015, will identify both regulatory and voluntary levers to accomplish a near-zero or zero emission freight system, taking into consideration the current and anticipated state of commercialization of various technologies that can achieve very large reductions in criteria pollutant and GHG emissions.

More specific information is contained in each of the above documents. The reader is referred to those documents for further detailed information.

APPENDIX B

POTENTIAL EMISSION REDUCTION TECHNOLOGIES AND EFFICIENCY MEASURES

POTENTIAL EMISSION REDUCTION TECHNOLOGIES AND EFFICIENCY MEASURES

Provided in this Appendix are discussions on emission control technologies that have led to criteria pollutant emission reductions in the goods movement sector historically and potential technologies to further reduce emissions including greater deployment of zero-emission and near-zero emission advanced technologies. 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 California Air Resources Board is currently conducting a comprehensive technology assessment for goods movement related sources, which includes the emission sources identified in this document and in addition, transportation refrigeration units and fuels. The reader is referred to CARB's website (www.arb.ca.gov) for further information. 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.

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 20-25%. 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 has found higher levels of NOx emissions from diesel vehicles when the vehicles operate in shorter trips where exhaust temperatures are below the level needed for the SCR system to work effectively. There are on-going 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 the engine performance to address potential increase in fuel usage.

Engine Modifications

Engine modifications are performed on heavy-duty engines and change the engine 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 measurements of NOx emissions from modern diesel and natural gas engines typically, 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 Power Sources

Alternative power sources include engine-electric hybrids, engine-hydraulic hybrids, fuel cells, and battery systems. Hybrid systems provide emission reductions of criteria and GHG emissions of 20 to 30% when used in applications with opportunities for energy recovery such as trucks driving in "stop and go" conditions or for power demand leveling such as with tugboats, loaders, or cranes. Hybrid systems have been commercialized for light-duty vehicles and are available for a variety of smaller commercial trucks. Fuel cell and battery systems reduce criteria and GHG emissions 100% at point of use. Light-duty battery electric vehicles have been commercialized and prototype commercial vehicles are being demonstrated. Prototype fuel cell systems are being demonstrated in light duty-vehicles and commercial trucks up to Class 8 vehicles.

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 cargo handling automation, reduced handling steps, improved vehicle-vehicle and vehicle-infrastructure communication, and improved scheduling/coordination of ground with marine/air cargo handling and movement. These steps are intended to reduce queuing or wait times and inefficient utilization of logistics resources which can reduce traffic congestion, emissions, and energy consumption.

Another form of efficiency is "vessel sharing". This practice described by the Pacific Merchant Shippers Association, is where shippers share the movement of goods in one common vessel instead of multiple vessels; thus, reducing the number of vessel calls at the Ports of Los Angeles and Long Beach. In addition, to be more efficient and further reduce fuel costs, newer container vessels can carry more containers than older smaller vessels, thus reducing the number of vessel calls.

CONTROL TECHNOLOGY APPLICATION BY EMISSIONS SOURCE CATEGORY

On-Road Heavy-Duty Trucks

Since the 2010 model year, on-road heavy-duty diesel engines have been equipped with diesel oxidation catalysts, cooled EGR, high pressure fuel injection, variable geometry turbochargers, urea-based SCR and catalyzed DPFs in order to meet the current emission standards of 0.2 g/bhp-hr NOx and 0.01 g/bhp-hr PM. The following additional enhancements may be required to achieve additional NOx reduction to reach a 90% level of 0.02 g/bhp-hr with combustion engines: improved air and fuel control, reduced cylinder to cylinder and cycle to cycle variation, shortened catalyst light-off time to better control cold start conditions, and improved low temperature catalyst activity or thermal management to maintain catalyst temperature above 250°C. Hybrid technologies are commercially available in light and medium heavy-duty trucks. Current commercial hybrid technologies will reduce greenhouse gas emissions on the order of 10 to 30% depending on duty cycle. However, many of the current hybrid technologies have limited reductions in NOx emissions. In addition to hybrid technologies, zero emission technologies such as battery electric are commercially available for smaller size trucks.

Research is now being conducted to further reduce NOx levels of current diesel and natural gas-powered heavy-duty vehicles to near-zero levels, specifically targeting a 90% NOx reduction from the current level of 0.2 g/bhp-hr. This research is being conducted separately by SCAQMD, CARB, California Energy Commission, Southern California Gas Company, U.S. Department of Energy (DOE), and other stakeholders. CARB is sponsoring a study focused on the development of emission control technologies for both diesel and natural gas engines to determine the feasibility of reaching a 90% reduction in NOx emissions. 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. The SCAQMD's research focuses on a natural gas engine's ability to achieve a 90% reduction in NOx emissions. The 90% cleaner natural gas engine will be deployed in various vocations as part of the field demonstration efforts of the SCAQMD's program. 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 other fuels of interest (e.g., renewable biofuels) to further address criteria pollutant and GHG goal attainment.

In addition to the research on the next-generation of heavy-duty combustion engines, zero emission technologies are being demonstrated. Dedicated battery electric trucks and fuel cell trucks are being developed and demonstrated at the Ports. Dedicated battery electric trucks are envisioned to provide drayage to the existing and planned near-dock railyards, which are around five miles from the marine terminals to the nearest railyard. Fuel cell trucks have the potential to travel up to 200 miles before refueling. As such, fuel trucks may potentially make several trips to intermodal yards and warehouse distribution centers located farther away from the ports. Another demonstration project is the use of catenary systems to provide external electrical power to the electric motor equipped on the truck. When external power is not available, the truck will run on the internal combustion engine. This configuration provides flexibility for the truck to be used beyond the region where external power is available.

Freight Locomotives

The most stringent locomotive standard is Tier 4 and takes effect in 2015. This standard is expected to be met through engine modifications and without aftertreatment technologies. Potential engine modifications include high-rate cooled EGR, two-stage turbochargers, and improved fuel injection systems. Also, due to the long service life of locomotives, modification of in-use engines (remanufacturing) should also be considered. In-use engine modifications may include addition of dual fuel systems, engine overhaul kits (injectors, fuel pumps, cylinder heads, turbochargers, manifolds, etc.) or reprogrammed engine management computers that reduce emissions. Modified in-use engines are unlikely to meet Tier 4 standards unless required and the emission reduction from these modifications will vary depending on the technology utilized and the original engine design.

Further emission reductions beyond Tier 4 could be achieved using aftertreatment technologies such as oxidation or three-way catalysts, diesel particulate filters, and selective catalytic reduction (SCR) systems incorporated into Tier 4 engines. SCR systems can potentially reduce NOx by up to 90% compared to the current Tier 4 NOx emissions standard using a reductant such as urea, commercially available as Diesel Exhaust Fluid, and in some cases, can provide moderate reductions in particulate emissions. Diesel oxidation catalysts do not reduce NOx, but can reduce hydrocarbons by 50% and particulates by 20 to 25%. 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. These technologies may also be retrofitted to in-use engines where technically feasible.

Other potential approaches to reducing NOx and PM emissions include electric hybrid, fuel cell, battery-electric with tender car, and catenary electric systems. Hybrid systems provide emission reductions of criteria and greenhouse gas emissions typically, on the order of 20 to 30% when used in applications with opportunities for energy recovery such as service with multiple stops and/or hilly terrain.

More recently, the Class I railroads are investigating the feasibility of using natural gas for locomotive operations. The use of natural gas has the potential to further reduce NOx emissions with appropriate engine development similar to their on-road counterparts. The use of natural gas would also reduce particulate emissions compared to diesel usage.

Note: The following information (shown in italics) was provided by Sempra Energy Utilities.

It has been reported that Class 1 railroad companies are currently evaluating the technical, economic and logistical feasibility of deploying natural gas fueled locomotives system wide.[1] *If a decision is made to integrate natural gas fuel, it may be deployed trans-continentally, with natural gas fueling infrastructure installed at appropriate intervals along the specific route. Natural gas locomotives operating on this route could be either a Tier 4 new build or an older locomotive converted to achieve NOx emission rates comparable to a Tier 3 or cleaner locomotive.*

If LNG fueling infrastructure and capacity was readily available at intermodal port facilities, such as OGV bunkering facilities, it would be an incentive for Class 1 railroad companies to initiate any potential LNG conversion with Southern California railroad lines.

There are opportunities for combining technologies to gain greater emission reductions. GE Transportation (one of the two leading locomotive manufacturers) has developed a diesel hybrid locomotive concept that achieves a nominal level of "zero emission track miles" (i.e., the locomotive is operating solely on the electric motor).

Ocean-Going Vessels

Control technologies for main propulsion engines of ocean-going vessels (OGVs) include engine modifications such as common rail injection, electronic engine monitoring/control, slide valve injectors, advanced injector orifice design, turbocharging, and EGR. In addition, water emulsification and seawater scrubber technologies, can reduce NOx and PM emissions. SCR systems have been used in ocean-going vessels and are able to meet the IMO Tier 3 NOx emissions standard. Lastly, heat recovery systems being implemented on newer vessels can potentially reduce NOx emissions as well as greenhouse gas emissions. Some of the control technologies can be combined to meet the IMO Tier 3 NOx emissions standard.

[1] Kemp, John, "Next energy revolution will be on roads and railroads," Reuters, August 12, 2014, http://www.reuters.com/article/2014/08/12/us-lng-railways-kemp-idUSKBN0GC11K20140812, accessed July 2015.

More recently, natural gas as a transportation fuel (in particular, liquefied natural gas) is being used on ocean-going vessels with NOx emissions levels at the IMO Tier 3 emissions standard.

Note: The following information (shown in italics) was provided by Sempra Energy Utilities.

There is a global trend towards the use of liquefied natural gas (LNG) as a propulsion fuel in ocean going vessels driven by a combination of factors which include projected natural gas price advantage[2] over bunker fuel as IMO fuel sulfur reduction regulations kick in. Coincidentally a synergy exists between natural gas as a marine transport fuel and NOx emissions. OGV classed LNG engines are currently commercially available that emit NOx at rates as much as 54% lower than IMO Tier 3 regulations. This is an additional driver for the adoption of natural gas by marine fleets servicing North America. In the U.S., positive movement towards LNG exists foremost in the Pacific Northwest[3] and Caribbean[4] where fleets servicing domestic North American ECA trade routes out of these ports have made commitments to introduce LNG fueled vessels. Fuel suppliers have stepped forward to introduce LNG bunkering infrastructure to meet demand.

Globally, there is a strong association between the existence of LNG fueling infrastructure and the use of LNG powered ships, the highest concentration occurring in Northern Europe, where IMO fuel sulfur regulations and existing natural gas import facilities have stimulated the adoption and deployment of natural gas ship propulsion technology (Figure B-1). In the Pacific Rim, there is evidence that Asian ports are either planning or proposing the installation of LNG bunkering infrastructure. LNG bunkering exists in Incheon, South Korea and Gaolan, China (Figure B-2). For example, Korea's Ministry of Trade, Industry & Energy (MOTI) signed an agreement with 50 organizations to advance the development of LNG fueled shipping and bunkering infrastructure, [5] *State-owned shipyards in China are laying plans for the building of 20 LNG ready very large ore carriers (Valemax) for charter to Vale, Brazil*[6] *and the Port of Singapore issued its first Request for Proposal for interested parties to apply for LNG bunker supplier license in July 2015.* [7] *Table B-1 describes the current state of Pacific Rim Ports that have the most advanced plans for installing LNG*

[2] "Cost and Benefits of LNG as a Ship Fuel for Container Vessels," Germanisher Lloyd, MAN

[3] Totem Ocean Trailer Express (TOTE), Matson and Pasha Hawaii have all indicated they will operate LNG fueled vessels out of the Port of Tacoma; Washington State Ferries is investigating operating their Seattle fleet on LNG, fueling at Port of Tacoma.

[4] TOTE and Crowley Maritime have indicated they will operate an LNG powered fleet out of the Port of Jacksonville.

[5] "Ulsan Plans LNG-Fuelled Ship-Building Dominance," NGV Global News, July 19, 2015, http://www.ngvglobal.com/blog/ulsan-plans-lng-fuelled-ship-building-dominance-0719#more-36375, accessed July 2015.

[6] "LNG-ready Stumbling Block as Cosco Pushes for Priority," TradeWinds, Volume 26, Number 28, July 17, 2015, p. 3.

[7] "Port of Singapore Issues RFP for LNG Bunkering," NGV Global News, July 30, 2015, http://www.ngvglobal.com/blog/port-of-singapore-issues-rfp-for-lng-bunkering-0730#more-36432, accessed July 30, 2015.

infrastructure. Evaluation of shipping line schedules indicate that the Ports of Los Angeles and Long Beach are on ship trade routes that include the ports of Seattle, Busan and Singapore. [8]

All of these factors are indicative of an opportunity for Southern California to reduce regional NOx, however a mechanism would be required to attract these vessels to the region, namely the ability to refuel vessels at the regional ports. If LNG powered ships are attracted to Southern California, a higher proportion of newest technology IMO Tier 3 vessels would service the region, displacing older, higher emitting ships. Furthermore, a mechanism for incentivizing the construction of ships that utilize the lowest NOx emission technologies has the potential to yield even more NOx reductions.

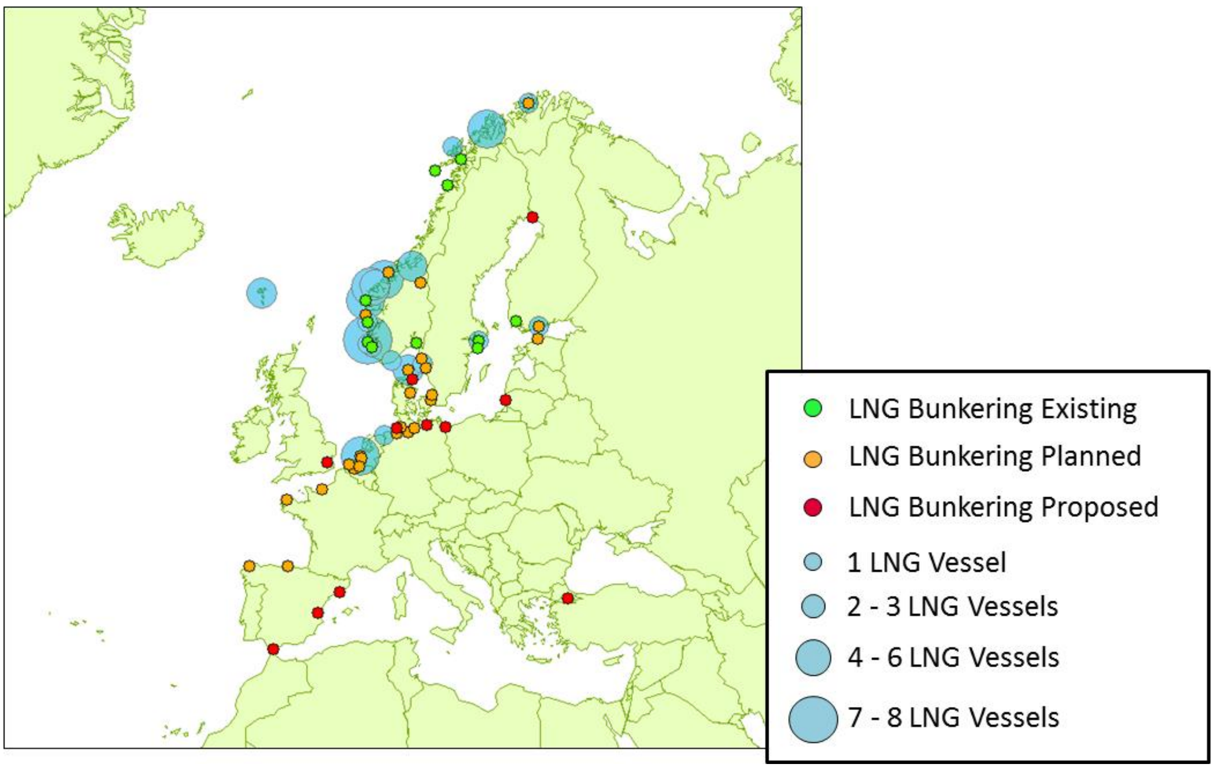


FIGURE B-1

European LNG ship deployment correlated with existing LNG bunkering

[8] COSCO Container Lines Americas, HPSX, MD1, PSW2, http://www.cosco-usa.com/fpdb/Services/schedules.aspx; accessed July 22, 2015.

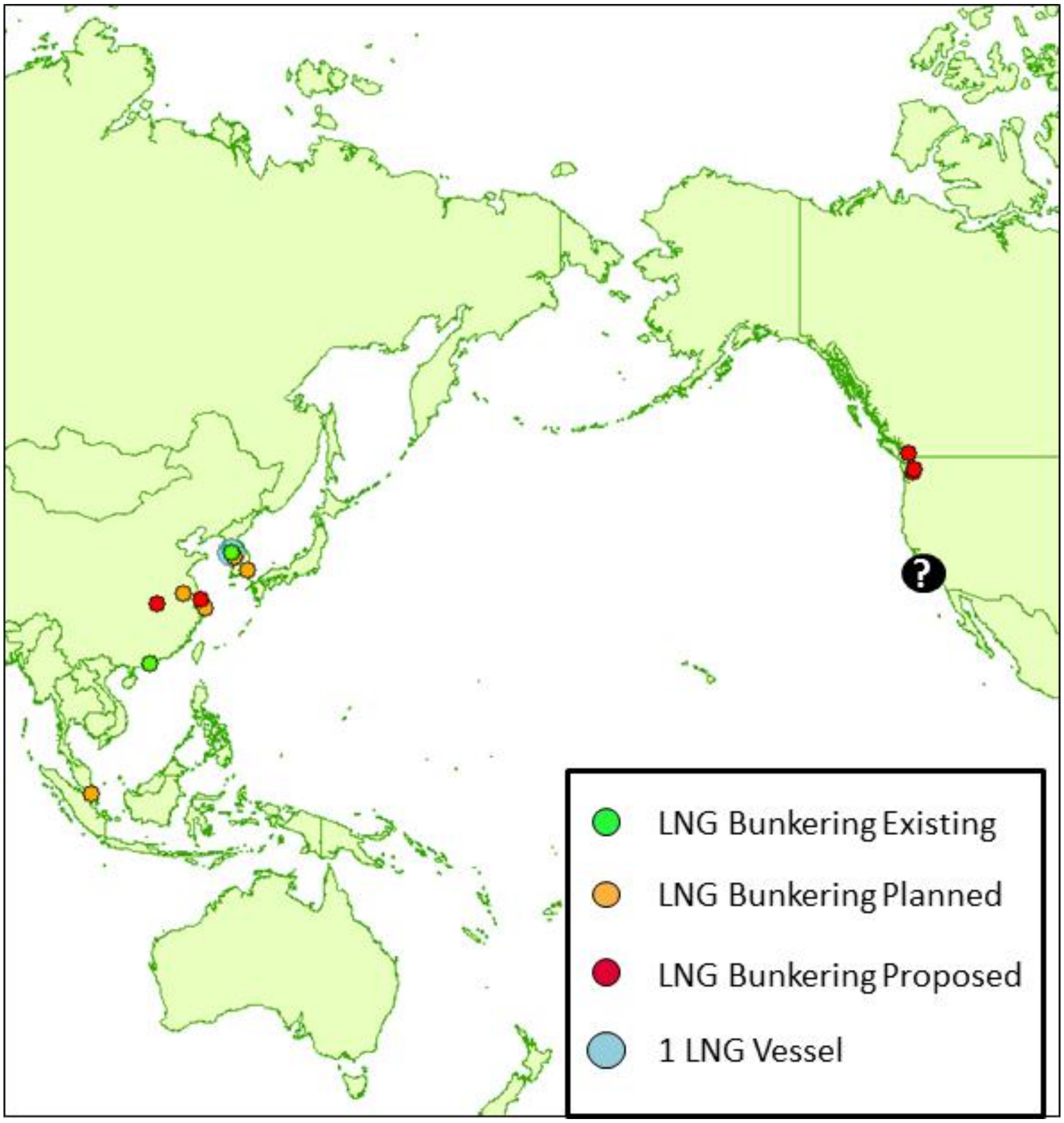


FIGURE B-2

Emerging Pacific Rim LNG bunkering sites.

TABLE B-1

Pacific Rim ports' activity in establishing LNG bunkering facilities.

Country	City LNG Bunkering Status		
	Existing	Planned	Proposed
China	Gaolan	Nanjing Zhoushan	Wuhan Shanghai
South Korea	Incheon	Busan Pyeongtaek	-
Singapore	-	Singapore	-
Canada	-	-	Vancouver
U.S.A.	-	-	Tacoma

IMO standards require 30% improvement in vessel fuel efficiency by 2025 as a means of reducing greenhouse gas emissions from ocean-going vessels. Several alternative technologies besides heat recovery systems mentioned above can contribute to that goal including the use of fuel cells, wind power, hull coatings, and propeller optimization. Vessel trip optimization and vessel speed reduction also contribute to reduced fuel consumption and emissions.

Ocean-going vessels also have auxiliary engine emissions which have similar technology solutions as propulsion engines. In addition, the CARB At-Berth Regulation requires certain vessels to use shorepower for shipboard power requirements while at berth. However, boiler emissions may still occur. As such, the use of emissions capture systems can capture boiler emissions as well as auxiliary engine emissions. Two companies are demonstrating emissions capture systems at the Ports of Los Angeles and Long Beach. The systems have the potential to capture over 90% of the NOx, SOx, and PM emissions from vessels while at berth. In addition, both companies are constructing the emissions capture system on barges to provide the flexibility of moving the systems to vessels as they call at different berths.

Commercial Harbor Craft

Commercial harbor craft used in goods movement related activities include barges, crew and supply boats, dredges, tow/push boats, tug boats, and workboats. The boats operate primarily at the Ports of Los Angeles and Long Beach. Commercial harbor craft have long useful life and turnover to newer engines or boats is slow. Most commercial harbor craft have engines less than 800 horsepower, for which the most stringent emissions standard is Tier 3 (5.4 g/bhp-hr) for Category 1 and 2 marine engines. Engines greater than 800 horsepower (found almost exclusively in tugs and tow boats) are subject to the Tier 4 standard (1.3 g/bhp-hr) for Category 1 and 2 marine engines, which may need SCR and possibly a DPF. Promising alternative technologies include fuel cells and hybrid-diesel or hybrid-natural gas engines. Hybrid vessels have been shown to reduce emissions by around 30%. Fuel cells and battery systems have been demonstrated in a few commercial vessels.

Cargo Handling Equipment

Cargo handling equipment includes specialized container handling equipment (top-picks, side picks, rubber tired gantry cranes, etc), yard trucks, and conventional material handling equipment (excavators, loaders, forklifts.etc). Engines used in new cargo handling equipment must meet Tier 4 emission standards, the most stringent off-road diesel engine standard which generally requires use of DPF and SCR after treatment systems to reach 0.3 g/bhp-hr NOx. Lower emission technologies include diesel-electric hybrid engines and battery electric systems which are being deployed in demonstration projects for yard trucks, forklifts, and cranes.

Commercial Aircraft

Air cargo is carried in dedicated freight aircraft and also in passenger aircraft. CARB estimates that 13% of commercial aircraft emissions are related to air cargo. Technology improvements in air cargo movement will depend on technological advances for aircraft. These advances will include progressively lower NOx emissions and fuel consumption through improved jet engine combustor, turbine, and air frame designs. The improvements are driven by international and U.S. EPA emission standards for aircraft engines. Research supporting these improvements is guided by the Federal Aviation Administration (FAA) Continuous Lower Energy, Emissions, and Noise (CLEEN) Program. In efforts to reduce fuel consumption, many airports provide landside electrical power to run the auxiliary power units (APUs) on aircraft. In addition, several airlines are testing biofuels to reduce particulate, GHG emissions, and potentially, NOx emissions. Fuel cell technologies are also being investigated for auxiliary power as are wing and airframe designs to improve flight efficiency.

EFFICIENCY MEASURES

The regional goods movement system has a number of inefficiencies involving multiple handling stages, and rail or road congestion. The benefits from reducing these inefficiencies vary by emission source category and specific improvements include trip reduction, reduced queuing time, fewer intermodal transfers, and better utilization of logistics resources.

Multiple Transfers of Goods

On-dock rail capability at the ports is an example of reducing intermodal transfers. Rather than unloading cargo containers from ocean-going vessels, trucking it to an intermodal facility, and then loading onto rail cars, the rail cars would be loaded directly at the docks. This eliminates the need for the container to be loaded onto a truck and transferred to the nearby railyards. Effective use of on-dock rail depends on proper staging of rail cars and containers.

Choke Points

There are a number of choke points in the transportation network that cause travel delays and increased emissions. The 2012 SCAG Regional Transportation Plan contains a list of road and rail improvements that increase capacity or provide alternate routes at specific sites throughout the South Coast Air Basin. These include grade separations of rail/road crossings, double/triple tracks for selected mainline rail segments, bridge improvements, and dedicated truck lanes with limited access.

Operational Changes

Operational changes include such measures as off-peak hours of operation, automated cargo handling, internet-aided trip planning/congestion avoidance, and platooning (close-coupled convoys of trucks) to reduce wind drag on individual trucks. The effect of these changes is relatively small per vehicle but can have a significant effect on basinwide emissions if implemented on a system-wide basis. As trucks enter the ports and intermodal yards, automated gate systems can improve truck movement and reduce idling.

Category-Specific Efficiency Strategies

Besides the operational efficiency strategies discussed above, there are additional emissions source category-specific strategies that could be considered. For example, trip/queuing reduction through better coordination/scheduling of drayage trucks with staged cargo container handling can also reduce criteria pollutant and greenhouse gas emissions.

Other emissions source category-specific examples include the use of larger container vessels and longer train consists (i.e., lineups). New ocean-going container vessels are being constructed with a capacity to transport a larger number of container resulting in fewer vessel trips. As mentioned earlier, in order to reduce fuel costs, shippers have formed partnerships to share ocean-going vessels resulting in fewer number of vessel calls. The Class I railroads have been specifying larger horsepower locomotives to move longer consists, resulting in a smaller number of train trips.

Greater use of wide-span electric gantry cranes can potentially reduce the number of yard tractor movements and use of other cargo handling equipment while improving container movement efficiency.

The Ports of Los Angeles and Long Beach implemented a policy to allow harbor craft to dock at or near the berths that they plan to be operating the next day instead of having to travel back to their home base. Recognition of the emissions related and fuel related activities from all sources can potentially provide further emission reduction.

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

SOUTH COAST AQMD • 21865 COPLEY DR • DIAMOND BAR, CA 91765 • (909) 396-2000 • 800-CUT-SMOG (288-7664)