BOARD MEETING DATE: October 2, 2015 AGENDA NO. 32

PROPOSAL: 2016 Air Quality Management Plan White Papers

SYNOPSIS: Eight of ten 2016 AQMP white papers were released for final public review at the September 2015 Board meeting. An opportunity for public comments is being provided today. In addition, the draft final Energy Outlook White Paper is being released today for a final public review, and the Board will receive public comments at the November 6, 2015 Board Meeting.

COMMITTEE: Committee reviews as per topic, various dates

RECOMMENDED ACTION:
Receive and file.

Barry R. Wallerstein, D.Env.
Executive Officer

PF:AFM:MK

Background
At the April 10, 2014 AQMP Advisory Group meeting, the SCAQMD introduced the concept of developing a series of white papers to provide for better integration of major planning issues regarding air quality, climate, energy, transportation, and business needs during the development of the 2016 AQMP. The White Papers covered the following key topics:

- Blueprint for Clean Air
- VOC Controls
- Particulate Matter (PM) Controls
- Passenger Transportation
- Goods Movement
- Off-Road Equipment
- Residential and Commercial Energy Use
- Energy Outlook
- Industrial Facility Modernization
- A Business Case for Clean Air Strategies

White Paper Overview

Blueprint for Clean Air
The Blueprint for Clean Air is a preface white paper that provides general background information about the 2016 AQMP, air quality standards, key challenges, and a synopsis of each of the other White Papers.

VOC Controls
The VOC Controls white paper describes the role that VOCs play in the ozone and PM2.5 attainment strategy. The contributions of intermediate-volatility and semi-volatile organic compounds are also explored. A wide range of ozone reduction strategies are evaluated and a tiered approach to reducing VOC emissions is proposed.

Particulate Matter (PM) Controls
The PM Controls White Paper continues the evaluation of potential control approaches for the emission reductions from commercial cooking, residential and open burning, fugitive dust, and ammonia sources. Modeling assists in demonstrating the benefits from implementing strategies targeting directly emitted PM2.5 sources as well as precursor gas emission sources.

Passenger Transportation
The Passenger Transportation white paper describes a number of potential scenarios for reducing emissions from the passenger transportation sector to support attainment of federal ozone and particulate matter standards. Such emission reductions could be achieved through use of operational efficiency measures such as intelligent transportation systems, mode choice, active transportation, technological emission controls, or alternative fuel vehicles. The 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.

Goods Movement
The Goods Movement white paper describes a number of potential scenarios for reducing emissions from the goods movement sector to support attainment of federal ozone and particulate matter standards. Such emission reductions could be achieved through greater deployment of zero- and near-zero emission technologies and quantification of co-benefits associated with operational efficiencies being implemented in goods movement industry. The 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.

Off-Road Equipment
The Off-Road Equipment white paper provides a set of emission reduction scenarios to illustrate the need for additional emission reductions within this sector to support attainment of the state and federal ozone and particulate matter standards. The emission reduction scenarios highlight emission source categories where emission reductions could potentially be achieved more readily compared to other emission source categories in this sector. The scenarios do not reflect any control strategies or suggest any control approach. As such, the 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. The paper discusses the potential for achieving additional emission reductions through greater deployment of cleaner equipment that has emission levels below the emission standards established in existing state and federal regulations, advanced emission controls technologies, use of alternative and renewable fuels, and the use of operational efficiency measures.

Residential and Commercial Energy Use
The Residential and Commercial Energy Use white paper examines energy efficiency, load shifting, and renewable energy sources. The paper reviews the impacts past policies and regulations implemented in California and the Basin have had on reducing the energy needs in the residential and commercial sectors. The white paper also reviews the large potential for further energy reductions within existing buildings in the Basin and reviews the emissions benefits that might result from increasing residential and commercial building energy efficiency 50% and implementing 50% renewable power generation by 2030.

Energy Outlook
The Energy Outlook white paper reviews the Basin’s energy uses (e.g. renewables, liquid fuels) and the associated emissions resulting from energy use. The paper also reviews the past and current policies impacting energy use within California and the Basin followed by a detailed discussion on the current issues impacting the different energy sectors. The potential emission reduction resulting from new energy policies and technologies within the energy sector as a result of increases in efficiency, renewable power generation, and reduced liquid fuel use are reviewed in relation to meeting the future ozone attainment goals.

Industrial Facility Modernization
The Industrial Facility Modernization white paper will identify potential hurdles that may be preventing an owner to replace older, higher-emitting equipment and incentives that can better encourage a business owner to replace an older piece of equipment sooner, as well as encourage ultra clean facilities to site in the Basin and incentivize technologies that are needed to meet attainment goals.

A Business Case for Clean Air Strategies

A Business Case for Clean Air Strategies white paper develops planning concepts that can be used to evaluate potential AQMP control strategies which can support a business case for deployment of needed technologies and efficiency measures, in order to achieve upcoming air quality standards. A control strategy that supports a business case will reduce emissions and also improve energy efficiency, reduce fuel or maintenance costs, create new job opportunities, or have other cost savings and economic benefits.

Working Groups and Public Participation

The AQMP Advisory Group members were encouraged to participate in working groups that will address the specific policy topics or invited a technical expert to participate in lieu of their attendance. The Working Groups for the respective papers met at various times from July 2014 to September 2015 during the development of each of the white papers. The meeting dates, times, agenda, presentations and any available material was provided online at http://www.aqmd.gov/home/about/groups-committees/aqmp-advisory-group/2016-aqmp-white-papers for public access. Table 1 outlines the working group meeting dates that took place as well as when noticing occurred and material was released.

TABLE 1

White Paper Working Group Meetings and Noticing Dates

White Paper Topic	Working Group #	Meeting Dates	Meeting Noticing Dates	Material Release Date
Blueprint for Clean Air	17	June 24, 2014	June 6, 2014	June 24 (Presentation)
		Aug. 13, 2014	July 25, 2014	July 2 (WP Outline) July 25 (WP Outline Comments)
		April 15, 2015	April 2, 2015	April 2 (Draft WP)
VOC Controls	19	June 25, 2014	June 19, 2014 (*Reminder June 20)*	June 25 (Presentations)
		Aug.19, 2014	July 17, 2014 (*Reminder August 6 & 19*)	July 31 (Presentations) – *re-sent August 6th*
		Oct.15, 2014	Sept 24, 2014 *(Reminder Oct 15)*	Sept 25 (WP Outline)
		April 14, 2015	April 2, 2015 *(Reminder April 14)*	April 2 (Draft WP)
PM Controls[1]	20	July 18, 2014	June 18, 2014	July 18 (Scope of WP)
		Sept. 24, 2014	Aug 27, 2014 *(Reminders Sept 18 & 24)*	Sept 18 (WP Outline)
		April 16, 2015	April 2, 2015 *(Reminder April 16)*	April 2 (Draft WP) April 16 (Presentations) June 5 (Revised Draft WP)
Passenger Transportation	34	July 8, 2014	June 16, 2014	July 2 (Presentations)
		Aug. 5, 2014	July 18, 2014	August 5 (Presentations)
		Sept. 4, 2014	August 12, 2014	Sept. 2 (Presentations)
		Feb. 4, 2015	January 23, 2015	Jan. 30 (Presentations) Feb.3 (CARB Info)
		July 1, 2015	June 23, 2015	June 5 (Draft WP) June 30 (Presentations)
Goods Movement	49	July 8, 2014	June 16, 2014	July 2 (Presentations)
		Aug. 5, 2014	July 18, 2014	August 5 (Presentations)
		Sept. 4, 2014	August 12, 2014	Sept. 2 (Presentations)
		Feb. 4, 2015	January 23, 2015	Jan. 30 (Presentations) Feb.3 (CARB Info)
		July 1, 2015	June 23, 2015	June 5 (Draft WP) June 30 (Presentations)
Off-Road Equipment	21	Feb. 24, 2015	Feb. 18, 2015	Feb 20 (Presentations)
		April 1, 2015	March 26, 2015	March 31(Presentations)
		April 29, 2015	April 21, 2015	April 29 (Outside Presentations)
		June 26, 2015	June 19, 2015	June 5 (Draft WP) June 24 (Presentations)

[1] Provided opportunity for written comments but none were received.

TABLE 1 (Concluded)
White Paper Working Group Meetings and Noticing Dates

White Paper Topic	Working Group #	Meeting Dates	Meeting Noticing Dates	Material Release Date
Residential and Commercial Energy Use	29	June 26, 2014	June 12, 2014	June 26 (Presentations)
		Sept. 10, 2014	Aug 27, 2014 *(Reminder Sept 10)*	Sept 9 (Presentations, WP Outline)
		June 25, 2015	June 10, 2015 (*Reminder June 18*)	June 10 (Draft WP) June 25 (Presentation)
Energy Outlook	37	July 23, 2014	June 12, 2014	July 22 (Presentation)
		April 15, 2015	April 3, 2015	April 15 (Outside Presentations)
		Sept. 15, 2015	August 27, 2015 (*Reminders Sept 9 & 11& 15*)	Sept. 11 (Draft WP) Sept. 15 (Presentation)
Industrial Facility Modernization	28	Aug. 13, 2014	July 23, 2014 (*Reminders July 25 & 30*)	Aug 13 (Presentation) Sept 24 (WP Outline)
		Sept. 23, 2015	Aug 25, 2015 *(Reminder Sept 9, 11 & 15)*	TBD (Draft WP)
A Business Case for Clean Air Strategies	33	June 26, 2014	June 20, 2014	June 20 (Agenda)
		Aug. 13, 2014	July 31, 2014	Aug.7 (Agenda) Aug.12 (Presentations)
		Sept. 30, 2014	Aug. 28, 2014	Sept. 29 (Agenda & WP Outline)
		Oct. 31, 2014	Oct. 9, 2014	Oct. 23 (Agenda)
		March 11, 2015	Feb. 20, 2015	March 4 (Agenda)
		June 23, 2015	June 16, 2015 (*Reminder June 19*)	June 16 (Agenda) June 19 (Draft WP) June 23 (Presentation)

Attachments*

1. Revised Draft Final Blueprint for Clean Air White Paper
2. Revised Draft Final PM Controls White Paper
3. Revised Draft Final VOC Controls White Paper
4. Revised Draft Final Passenger Transportation White Paper
5. Revised Draft Final Goods Movement White Paper
6. Revised Draft Final Off-Road Equipment White Paper
7. Revised Draft Final Residential/Commercial Energy Use White Paper
8. Revised Draft Final A Business Case for Clean Air Strategies White Paper
9. Draft Final Energy Outlook White Paper

*These White Papers are also available online at http://www.aqmd.gov/home/about/groups-committees/aqmp-advisory-group/2016-aqmp-white-papers

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

Blueprint for Clean Air

2016 AQMP WHITE PAPER

OCTOBER 2015

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT GOVERNING BOARD

South Coast Air Quality Management District

Barry R. Wallerstein, D.Env.
Executive Officer

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

Jill Whynot
Assistant Deputy Executive Officer
Planning, Rule Development & Area Sources

Joe Cassmassi
Planning and Rules Director
Planning, Rule Development & Area Sources

Authors

Susan Nakamura – Director of Strategic Initiatives
Sam Atwood – Media Manager
Ed Eckerle – Program Supervisor

Contributor

Elaine Chang, DrPH – Deputy Executive Officer (retired)

Reviewers

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

Table of Contents

Introduction

The South Coast Air Quality Management District (SCAQMD) is preparing the 2016 Air Quality Management Plan (AQMP) to demonstrate how the region will reduce air pollution emissions to meet federal health-based standards for ground-level ozone and fine particulates (PM2.5). As part of this process, SCAQMD staff in conjunction with stakeholders' input has prepared a series of 10 white papers on key topics to provide a policy framework and better integration of major planning issues regarding air quality, climate, energy, transportation, and business needs. The Blueprint for Clean Air provides background information regarding the 2016 AQMP as well as introductory discussions relevant to the other white papers.

Setting the Scene

Southern California is unique in many ways. The South Coast Air Basin (Basin) is bounded by the Pacific Ocean on the southwest and surrounded by mountains to the north and east. The warm sunny weather associated with persistent high-pressure systems is conducive to the formation of ozone and PM2.5. The pollution levels are exacerbated by frequent low inversion heights and stagnant air conditions. There are also natural, and increasingly, international man-made pollution that contribute to background ozone levels entering the Basin. All these factors act to trap pollutants in the Basin near ground level where people breathe.

This region contributes significantly to the state-wide and national economy. For example, 40% of all containerized cargo that enters the country comes through the twin ports of Los Angeles and Long Beach. The two San Pedro Bay Ports anticipate cargo volumes will grow to 43 million containers annually by 2035, more than tripling today's levels[1]. As a result, the goods movement sector is an integral part of the Basin's economy. However, goods movement – the transportation of goods by ship, railroad, truck and aircraft – is a major source of regional oxides of nitrogen (NOx) and thus contributes significantly to ozone and PM2.5 levels. The 2012 AQMP emissions inventory for goods movement from port-related sources such as heavy-duty trucks, freight locomotives, cargo- handling equipment, commercial harbor craft, and commercial ocean-going vessels was estimated to be 51 tons per day of NOx for the year 2014.[2]

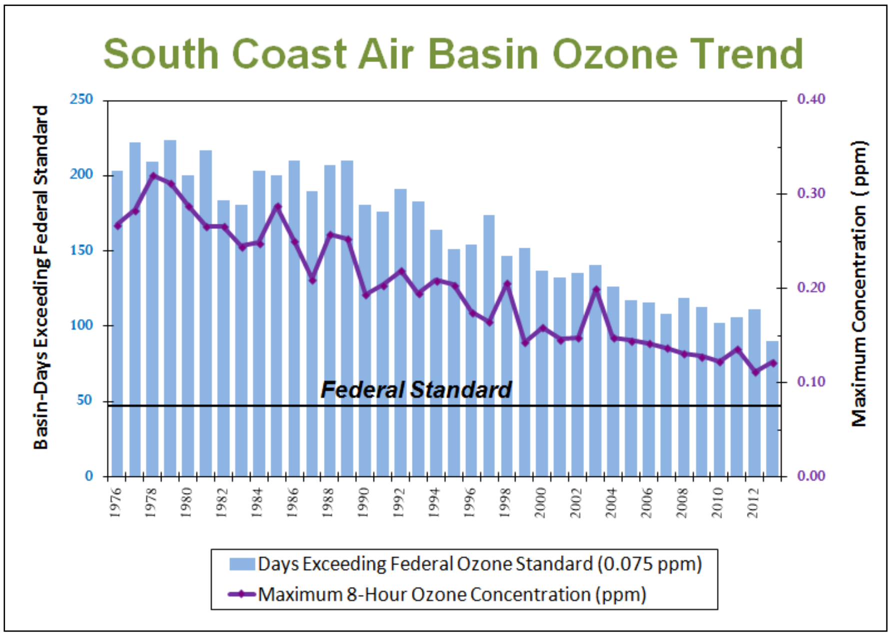
> The San Pedro Bay Ports anticipate cargo volumes to grow to 43 million containers annually by 2035: more than tripling from today's levels[1].

The Basin's air is much cleaner today than it was 20 years ago. Air pollution has improved despite significant long-term growth of the population, the regional economy, and vehicle miles traveled. The number of days exceeding standards has greatly declined, the area of the Basin experiencing exceedances has diminished, and the percentage of the population exposed to exceedances has decreased. This progress is due to decades of programs and regulations at the local, state and federal levels designed to significantly reduce

[1] SCAG, Regional Transportation Plan 2012-2035, Goods Movement Appendix, pg. 7, April 2012.

[2] Final 2012 Air Quality Management Plan, Appendix IV-A, pp IV-A-39, December 2012.

emissions. However, significant challenges remain and much more must be done to meet the current ozone standard of 75 parts per billion (ppb) by 2032, and the previous ozone standard of 80 ppb by 2024. Given, the approximately 17 million people in our region, the over 11 million vehicles serving them and the nation, the presence of the goods movement and other industries, and the natural factors described above result in the Basin still having some of the worst air quality in the nation. The region fails to meet federal health-based standards for ground-level ozone on more than 90 days each year.



Health Benefits of Clean Air

Air pollution has serious health repercussions. Exposure to fine particulate pollution and ozone causes myriad health impacts, particularly to the respiratory and cardiovascular systems. Exposure to fine particulates and ozone aggravates asthma attacks and can amplify other lung ailments such as emphysema and chronic obstructive pulmonary disease. A broad body of scientific research has also linked PM2.5 exposure to cardiovascular diseases.[3] According to the most recent calculations from the California Air Resources Board (CARB), exposure to current levels of PM2.5 is responsible for an estimated 4,300 cardiopulmonary-related deaths per year in the South Coast Air Basin.[4] Improving our air quality will save lives. In addition, University of

[3] U.S. EPA. Integrated Science Assessment for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F, 2009; See: http://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=216546.

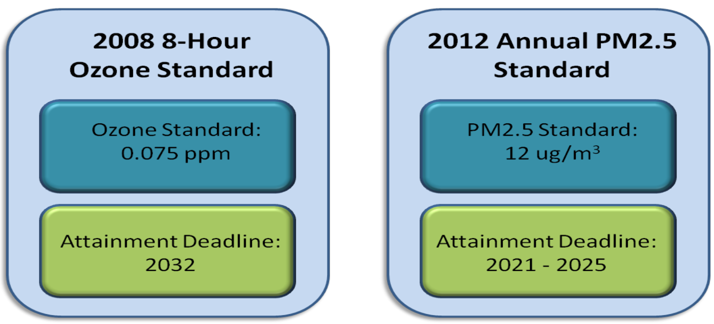
[4] "Estimated cardiopulmonary mortality by air basin associated with PM2.5 exposure." California Air Resources Board, Health and Exposure Branch. February 3, 2015.

Southern California (USC) scientists responsible for the landmark Children's Health Study found that lung growth improved as air pollution declined for children aged 11 to 15 in five communities in the Basin.[5]

Ongoing medical research continues to indicate that the health effects of air pollution have been previously underestimated. As a result, the U.S. Environmental Protection Agency (U.S. EPA) has lowered air quality standards for the PM2.5 standard and is planning to do the same this year for the ozone air quality standard. The U.S. EPA has proposed to lower the ozone standard to a level between 65-70 ppb, which would need to be met by 2037.

The 2016 AQMP

The 2016 AQMP will represent a regional blueprint for achieving the federal air quality standards and thus, healthful air. It will focus on demonstrating attainment of the NAAQS for 8-hour ozone levels (0.075 parts per million or ppm, set in 2008) and the annual PM2.5 standard (12 μg/m^3 set in 2012). It will also update previous plans for additional ozone and PM2.5 NAAQS that have not yet been met. In general, the AQMP is updated every three to four years. However, the air quality planning process for the AQMP is continuous and each iteration is an update of the previous plan.



2008 8-hour Ozone Standard

On March 12, 2008, U.S. EPA revised its national ambient air quality standards for ground-level ozone to a level of 0.075 ppm from the previous standard of 0.08 ppm, set in 1997. Under U.S. EPA's implementation rule released in May 2012, the Basin was classified as Extreme non-attainment and as such, the U.S. EPA required that all areas with an Extreme classification meet the 2008 ozone standard by 2032 (emissions reductions in place by 2031 for purposes of demonstrating attainment).

2012 Annual PM2.5 Standard

In 2012, U.S. EPA revised the NAAQS for the annual PM2.5 standard from 15.0 μg/m^3 to 12.0 μg/m^3. The PM2.5 standard is attained when the 3-year average of the annual arithmetic means does not exceed 12.0 μg/m^3. States would have until 2021 to meet the new 2012 PM2.5 standard as moderate non-attainment areas, and if necessary, up to 4 additional years if the area is classified as serious non-attainment.

[5] "Association of Improved Air Quality with Lung Development in Children," W.J. Gauderman et al, New England Journal of Medicine, Vol. 372, No. 10, March 5, 2015.

Additional Analysis Needed for 2016 AQMP

The 2016 AQMP will also provide updates to the attainment demonstrations of the federal NAAQS for 24-hour PM2.5 (35 μg/m^3), 1-hour ozone (0.12 ppm), and 8-hour ozone (0.08 ppm) standards. In addition to federal standards, there are state ambient air quality standards that the 2016 AQMP will address as well. The state annual standards are 0.09 ppm and 0.07 ppm for 1-hour ozone and 8-hour ozone, respectively. Progress has been made over the years such that the 1-hour ozone concentrations has decreased by about 50 percent since 1990, and by about 30 percent for the 8-hour standard. However, continued progress is needed, and the 2016 AQMP will seek further reductions necessary to meet the California Clean Air Act (CCAA) requirements.

Nonattainment areas such as the Basin also still have some continuing obligations under the 1997 federal 8-hour ozone standard and 1979 1-hour ozone standard. In order to show continued progress towards meeting the 1997 8-hour ozone standard by 2024, the 2016 AQMP will also include additional analysis on the adoption, implementation, and effectiveness of control measures committed to in the approved 8-hour and 1-hour ozone State Implementation Plans (SIPs). As a result, additional analysis will be included in the 2016 AQMP in order to demonstrate continued progress towards meeting the reduction goals by 2022 and 2023 for the 1979 and 1997 ozone standards.

What Will It Take to Achieve the Standards?

In order to realize the emission reductions by the federally mandated deadlines over the next two decades, the SCAQMD, CARB and the U.S. EPA will need to take a detailed look at what is technically and financially feasible as pollution reduction efforts progress. Continuing the Basin's progress toward clean air is a challenging task that combines science, engineering, technology, and public policy while allowing for growth and a healthy economy. Air quality agencies work to understand the complex interactions between emissions, control strategies, resulting air quality, and business impacts and use this information to pursue the most cost-effective set of strategies to improve air quality, while coordinating with other key public policy objectives including transportation, energy and climate goals. The plan is going to require steep emissions reductions to meet these health-based standards. These reductions come on top of decades of successful air pollution controls for both stationary and area sources as well as mobile sources.

Preliminary 2016 AQMP analysis indicates that this air basin will require approximately a 65 percent further reduction in nitrogen oxide (NOx) emissions – above and beyond all currently adopted measures – to meet the 8-hour ozone standards. These reductions will require widespread deployment of existing clean air technology and further commercialization of advanced technologies. Achieving clean air will require help from all stakeholders including businesses, manufacturers, public agencies and the general public.

The 2016 AQMP will include emission control strategies for all categories of emission sources: stationary sources, area sources, and mobile sources. The majority of NOx emission reductions must come from mobile sources, which are generally divided into two main categories: on-road mobile sources, which typically include automobiles, trucks, buses, and other vehicles that operate on public roadways; and off-road mobile sources which include aircraft, ships, trains, and construction equipment that operate off public roadways. The authority to regulate these different emission sources is primarily divided between the California Air Resources Board (CARB) and the U.S. EPA. The SCAQMD does, however, have some limited authority to regulate mobile sources.

General Approach for the 2016 AQMP Control Strategies

The 2016 AQMP will use a variety of implementation approaches such as accelerated deployment of available cleaner technologies, best management practices, incentive programs, as well as development and implementation of zero- and near-zero technologies and control methods. Further demonstration and commercialization projects will be crucial to help deploy near-zero and zero emission technologies. Another key element to plan implementation will be private and public funding to help further the development and deployment of advanced technologies. Many of the same technologies will address both air quality and climate needs, such as those that increase energy efficiency or use renewable fuels. In developing the 2016 control strategies, the SCAQMD staff will consider the following general approach and conceptual framework:

1. **Eliminate Reliance on the "Black Box" to the Maximum Extent Feasible**
   Section 182(e)(5) of the federal Clean Air Act (CAA), authorizes regions classified as extreme nonattainment for ozone to rely on advanced technology measures to meet federal air quality standards; these measures have come to be known as the "Black Box." The 2016 AQMP approach will attempt to eliminate reliance on the "black box" and develop a more definitive pathway to attainment based on specific advanced technology control measures which have quantifiable emission reductions and associated costs. This approach is aided by the fact that the majority of zero and near-zero technologies which will be relied upon for control measure development have already been developed. It will be a matter of accelerating commercialization and deployment of these technologies using existing and new funding and incentive programs.

2. **Fair-Share Emission Reduction Strategy**
   Develop a strategy with fair-share emission reduction commitments at federal, state, and local levels, which includes new federal engine emission standards as well as additional authority provided to the State of California in order to enact additional controls on sources (e.g., locomotives, aircraft, ships) traditionally under the jurisdiction of the federal government.

3. **Incentivize Early Deployment of Zero and Near-Zero Technologies**
   Implement strategies that incentivize early deployment of zero and near-zero technologies, which also include investments in technologies that meet multiple objectives - air quality, climate, toxics, and energy efficiency. The 2016 AQMP will strongly rely on a transition to zero- and near-zero emission technologies in the mobile source sector including automobiles, transit buses, medium- and heavy-duty trucks, and off-road applications to meet the air quality standards. The plan will focus on existing commercialized technologies and energy sources and newer technologies that are nearing commercialization based on demonstration programs and limited test markets, including their supporting infrastructure. To accomplish this, the SCAQMD staff will continue to support technology demonstration and deployment projects for both mobile and stationary sources.

4. **Develop Efficient and Cost-Effective Strategies**

   Select the most efficient and cost-effective path to achieve multi-pollutant and multi-deadline targets. For example, technologies needed for the state's air quality climate goals in GHG emission reductions[6] such as the deployment of zero and near-zero-technologies, as well as increasing the penetration of renewable energy resources and higher energy efficiencies, are "efficient strategies" as they are also needed to attain the air quality goals in the 2016 AQMP. Stationary source measures will include a wide array of advanced low-NOx technologies, low-volatile organic compound (VOC) coatings and processes, and clean energy alternatives, such as fuel cells, solar power, and other renewable energy systems.

5. **Prioritize Win-Win Strategies**

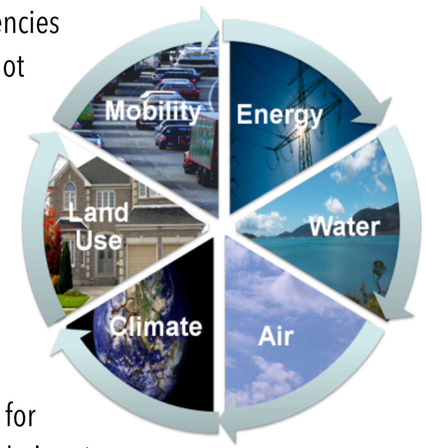
   As shown in the past, air quality standards can be achieved while maintaining a healthy economy. The 2016 AQMP will prioritize non-regulatory, innovative and "win-win" approaches for emission reductions. In designing the control strategy needed to achieve the ozone and PM2.5 air quality standards, there will be special consideration and prioritization of strategies that contribute to the economic vitality of the region and the needs of the public and businesses.

[6] The State's air quality climate goals which require a 30% reduction in GHGs by 2020 to 1990 levels, and the Governor's new executive order mandating a 40% reduction below 1990 levels by 2030.

What Happens if the 2016 AQMP Is Not Approved?

Failure to have an approved plan to meet these health-based standards within the required timeframes would result in sanctions from the federal government. These include: (1) new major stationary sources in the nonattainment area must obtain offsetting emissions reductions at a significantly increased 2-to-1 ratio; (2) restrictions on the state's use of federal highway funds for projects in the nonattainment area; and (3) the U.S. EPA is required to develop its own federal implementation plan (FIP) for the area to ensure improvement of air quality. This outcome not only leads to delayed air quality improvements with associated serious health impacts, but it also has the potential to significantly impact the local economy beyond the impacts of a thoughtful and approvable local plan that has been crafted with input from local stakeholders.

Need for Integrated Planning Process



The 2016 AQMP will need significant integration and coordination with other agencies in order to successfully meet the Basin's clean air goals. This integration should not only include the traditional collaboration between the SCAQMD, CARB, U.S. EPA and the Southern California Association of Governments (SCAG) but should also include at the state level the California Energy Commission (CEC), the California Public Utilities Commission, and the California State Transportation Agency including Caltrans. Regional and local governments, such as counties, cities, coalitions of governments, and regional transportation agencies, also should be a part of the integrated planning process. Such a process would be useful in proposing and implementing strategies that are consistent with the state's Vision for Clean Air and strategies and goals of the 2016 AQMP. In addition to an integrated planning process with other agencies, the 2016 AQMP development process will have to incorporate collaborative efforts by a wide range of non-government stakeholders. These efforts will focus on businesses, environmental and health organizations, community groups, and academia.

2016 AQMP White Papers

As a prelude to the 2016 AQMP, the following white papers were developed to begin the dialogue and frame key policy questions surrounding the development of the plan. These papers are intended to assist the public, stakeholders and the SCAQMD to understand key facts and policy issues related to the development of the 2016 AQMP. The White Papers are also intended to provide for better integration of major planning issues regarding air quality, climate, energy, transportation, and business needs. Below is a brief description of the white paper topics. For more information on each white paper, please visit the SCAQMD website at http://www.aqmd.gov.

Goods Movement

The Goods Movement White Paper will likely be the centerpiece of the 2016 AQMP. Advanced technologies will be needed to achieve clean air goals. This white paper will evaluate all goods movement sectors such as ships, locomotives, and trucks and will analyze a variety of advanced technologies such as hybrid-electric, advanced natural gas, fuel cells, and electric, as well as potential infrastructure needs and commercialization schedules. This white paper will also create scenarios that will assume different future mixes of advanced technologies.

Passenger Transportation

The Passenger Transportation White Paper will examine advanced technologies and operational efficiency opportunities, as well as programs that can help accelerate fleet turnover. Advantages could be gleaned from the implementation of other programs such as SB375.

Energy Outlook

The Energy Outlook White Paper will be evaluating the energy implications of various types of advanced technologies – some of these advanced pollution control technologies for mobile sources will be based on traditional energy sources, while others will rely on alternative energy sources such as electricity or hydrogen. The Energy Outlook White Paper will describe the demand and supply of all energy sources for the Basin and explore how that might change under current and future programs to reduce GHG and pollutant emissions. In addition, this white paper will evaluate the existing and needed infrastructure for various energy sources. This white paper will also evaluate the cost of these energy sources – including cost of distribution of the energy source, cost impact or benefit to the end user, and infrastructure costs, if any.

Residential and Commercial Energy Use

Reducing, managing, and changing the way energy is used in the commercial and residential sectors can provide emission reductions, reduced energy costs, and can provide cross sector benefits such as reduced water consumption. The Residential and Commercial Energy Use White Paper will provide insight and analysis on energy usage while reviewing resulting emissions within the residential and commercial sectors.

Industrial Facility Modernization

The Industrial Facility Modernization White Paper will identify the barriers to and incentives for clean equipment technologies and modernization of industrial stationary sources.

VOC Controls

The VOC Controls White Paper will study the role VOCs play in the ozone and PM2.5 attainment strategy. The potential contribution of intermediate and semi-volatiles will be explored. The need for VOC reductions to achieve clean air goals will be re-examined, along with the requisite quantity and timing of VOC emissions reductions.

PM Controls

The PM Controls White Paper will continue to evaluate feasible control technologies for commercial cooking, fugitive dust, ammonia and SOx sources. Modeling results will assist in demonstrating the benefits from implementing strategies targeting sources of directly emitted PM2.5 as well as precursor emission sources. This white paper will address each of these elements, including source categories for potential control through traditional approaches as well as seasonal, episodic or geographically focused controls.

A Business Case for Clean Air Strategies

This white paper seeks to develop principles and concepts for control measures and related programs to be included in the 2016 AQMP that, to the extent possible, create a business case for deployment of needed technologies and efficiency measures towards attaining upcoming federal air quality standards. A business case could exist where a technology, fuel, or other strategy reduces emissions and also improves energy efficiency, reduces fuel or maintenance costs, creates new job opportunities, or has other economic benefits. In addition to seeking to minimize potentially adverse impacts, the SCAQMD staff, in developing the 2016 AQMP, will explore means to maximize emission control strategies that have a business case for implementation.

Off-Road Equipment

The Off-Road Equipment White Paper will examine advanced technology opportunities as well as programs to accelerate the transition to newer equipment. This category consists of a wide variety of emission sources including construction and mining equipment such as forklifts, cranes, and portable engines. The focus will be on advanced control technologies that go beyond current emission standards and what efforts will be needed to further reduce emissions from these sources.

Participation in the Clean Air Discussion

Public input is an integral part of the planning process and the SCAQMD staff relies on input from all stakeholders. There are a variety of ways to participate in the development of the 2016 AQMP. SCAQMD staff is working with an advisory group which represents over 50 stakeholders from the business community, environmental and community groups, academia, and other agencies. Members of the advisory group generally represent an organization and are approved by the SCAQMD's Governing Board Chairman. Each White Paper has an associated Working Group with members that include representatives from the advisory group as well as other technical experts. The public is invited to attend AQMP Advisory Group and White Paper Working Group meetings.

You can follow the development of the 2016 AQMP on SCAQMD's website at www.aqmd.gov and on social media including Facebook and Twitter. The SCAQMD's website includes meeting dates and information about the AQMP Advisory Group, White Paper Working Groups, public workshops, and public hearings. The website also includes presentations and documents as they become publicly available. In addition, throughout the development of the 2016 AQMP, organizations can request a meeting with or a presentation by SCAQMD staff to receive an update on the 2016 AQMP. This provides the opportunity for SCAQMD staff to have a more inter-active and targeted dialogue with specific groups or organizations. If you are interested in participating in the clean air discussion and would like to be added to the mailing list, have questions or comments, or would like to schedule a meeting with SCAQMD staff to discuss the 2016 AQMP with your organization, please e-mail SCAQMD at aqmp@aqmd

Reaching Further

The SCAQMD staff is looking for ways to conduct further outreach. If you have ideas on additional organizations to participate in the clean air discussion and/or to enhance our 2016 AQMP communication efforts, please let us know at aqmp@aqmd.gov.

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

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

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

PM Controls

2016 AQMP WHITE PAPER

OCTOBER 2015

South Coast Air Quality Management District

Barry R. Wallerstein, D.Env.
Executive Officer

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

Jill Whynot
Assistant Deputy Executive Officer
Planning, Rule Development & Area Sources

Authors

Tracy Goss, P.E. – Planning and Rules Manager

Michael Laybourn – Air Quality Specialist

Jong Hoon Lee, Ph.D. – Air Quality Specialist

Contributors

Kalam Cheung, Ph.D. – Air Quality Specialist

Shoreh Cohanim – Air Quality Specialist

Kevin Durkee – Senior Meteorologist

Scott Epstein, Ph.D. – Air Quality Specialist

Susan Yan – Air Quality Specialist

Elaine Chang, DrPH (retired)

Jean Ospital, DrPH (retired)

Reviewers

Barbara Baird, J.D. – Chief Deputy Counsel

Patti Whiting – Staff Specialist

Table of Contents

LIST OF ACRONYMS AND ABBREVIATIONS

AB	Assembly Bill
APCD	Air Pollution Control District
AQMP	Air Quality Management Plan
Basin	South Coast Air Basin
BC	Black Carbon
CAA	Clean Air Act
CARB	California Air Resources Board
CHC	Commercial Harbor Craft
CMAQ	Community Multi-scale Air Quality model
DPM	Diesel Particulate Matter
EC	Elemental Carbon
GHG	Greenhouse Gas
MATES	Multiple Air Toxics Exposure Study
NAAQS	National Ambient Air Quality Standards
NH_3	Ammonia
NOx	Nitrogen Oxides
OC	Organic Carbon
OGV	Ocean-Going Vessels
PM	Particulate Matter
PM2.5	Particulate Matter with a dynamic diameter less than or equal to 2.5 microns
PM_{10}	Particulate Matter with a dynamic diameter less than or equal to 10 microns
ppm	Parts Per Million
RACM	Reasonably Available Control Measure
RACT	Reasonably Available Control Technology
RECLAIM	REgional CLean Air Incentives Market
SCAQMD	South Coast Air Quality Management District
SIP	Standard Implementation Plan
SOA	Secondary Organic Aerosol
SOx	Sulfur Oxides
SVOC	Semi-Volatile Organic Compound
U.S. EPA	United States Environmental Protection Agency
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
mg/m^3	Micrograms per cubic meter
μm	Micrometers

Preface

The purpose of this 2016 Air Quality Management Plan (AQMP) White Paper on Particulate Matter (PM White Paper) is to provide background technical information and present the policy challenges associated with attaining the National Ambient Air Quality Standards (NAAQS) for fine particulate matter (PM2.5), with a focus on the newly adopted federal annual PM2.5 standard of 12 micrograms per cubic meter ($\mu g/m^3$). Annual PM2.5 concentrations continue to decrease and the South Coast Air Basin (Basin) is projected to be near attainment of the new annual PM2.5 standard once the ozone attainment strategy is fully implemented. Several scientific and policy issues will be described, including the roles of directly emitted PM2.5 emissions and PM2.5 precursor gases, and the PM2.5 co-benefits from the ozone control program. Key to the policy discussion is the potential need for additional measures for PM2.5 given that the attainment strategy cannot rely on the "black box" advanced technology emissions reductions that have been used previously to demonstrate attainment of the ozone standard under federal Clean Air Act (CAA) Section 182(e)(5). Even though the NOx reductions for the ozone strategy will have significant PM2.5 benefits, only specific measures adopted at the time of the 2016 AQMP submittal can be credited towards the PM2.5 attainment demonstration. This PM White Paper will address these issues as well as the science behind PM2.5 formation, followed by potential PM2.5 control approaches that could be developed if additional emission reductions are needed for attainment with the PM2.5 standards. These concepts include control strategies and seasonal, episodic or geographically-focused controls.

1. INTRODUCTION

The Basin has experienced remarkable improvement in air quality since the 1970's as a direct result of a comprehensive, multi-year strategy of reducing air pollution from all sources. Yet the Basin is still not in attainment of current federal and state air quality standards and, in fact, still has the worst air quality in the nation for ozone. Currently, the Basin is not attaining federal ozone standards or the federal annual and 24-hour PM2.5 standards.

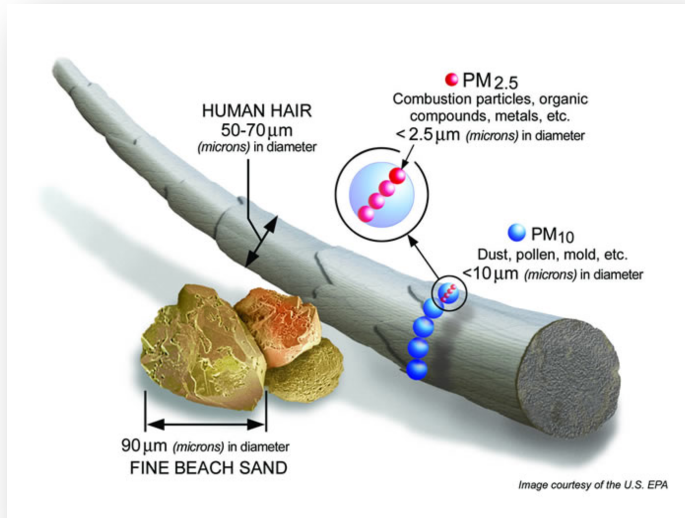
While the 2012 AQMP was designed to bring the Basin into attainment with the 24-hour PM2.5 standard of 35 mg/m^3 by 2015, with additional measures to address the 1997 8-hour ozone standard by 2023, the primary focus of the 2016 AQMP will be to demonstrate attainment of the 2008 ozone standard by 2032 and the annual PM2.5 standard by the 2021-2025 timeframe. Attaining the federal ozone standard will have the added benefit of emission reductions that will further improve PM2.5 levels.

The California State ambient air quality standard is identical to the federal standard for annual PM2.5 and there is no State 24-hour PM2.5 standard. The State has very stringent PM10 standards (annual PM10 of 20 mg/m^3 and 24-hour PM10 of 50 mg/m^3). While there is no effective attainment date for the State PM standards, the State standards must be achieved as soon as practicable to protect the public health and welfare of Southern Californians. Progress towards achieving the federal PM2.5 standards would be the most expeditious approach for attaining both the federal and State PM standards even though State PM10 standards are more stringent than the federal standard. However, a coarse particle control strategy would be very different and beyond the scope of this white paper. The State PM2.5 standard requires Reasonably Available Control Measures (RACM) that will be further evaluated for their feasibility and applicability in the Basin in the 2016 AQMP.

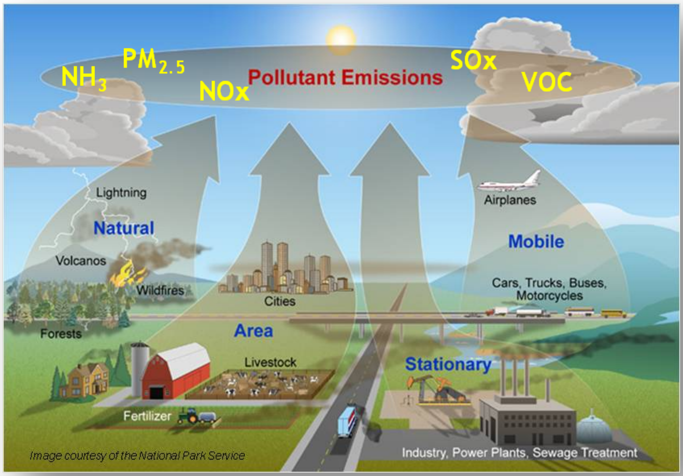
The purpose of this PM White Paper is to provide background technical information and present the policy challenges associated with attaining federal PM air quality standards. The focus will be primarily on the newly adopted federal annual PM2.5 standard of 12 mg/m^3, but some emission control measures that can be implemented sooner will help to ensure attainment of the 24-hour PM2.5 standard of 35 $\mu g/m^3$. This white paper will describe the scientific basis of PM2.5 formation including the major sources of directly emitted PM2.5 and PM2.5 precursor gases. The PM2.5 reduction co-benefits from ozone control programs and climate change strategies will also be described. Finally, potential strategies for further PM2.5 control will be considered, should additional controls be needed.

2. BACKGROUND

PM2.5 and Precursors

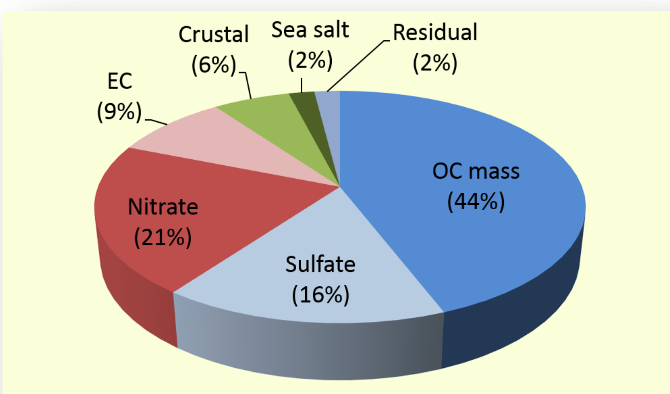


Particulate matter (PM), also known as particle pollution, is a complex mixture of microscopic solid and liquid particles suspended in air. Particles of concern are classified into two categories: inhalable coarse particles (PM10-2.5) and fine particles (PM2.5). Inhalable coarse particles are generally created by mechanical or natural processes, such as grinding, sanding, sea spray, windblown dust, and soil. Coarse particles have sizes larger than 2.5 micrometers (µm) and smaller than 10 µm in diameter. Fine particles, such as those found in smoke and haze, are 2.5 µm in diameter or smaller, and are generally formed by combustion processes or by chemical reactions that occur in the atmosphere. PM2.5 is of primary concern because, once inhaled, it can travel deeply into the respiratory tract, reaching the lungs. Scientific studies have linked increases in daily PM2.5 exposure with increased respiratory and cardiovascular hospital admissions, emergency department visits, and even deaths. Studies also suggest that long-term exposure to PM2.5 may be associated with increased rates of chronic bronchitis, reduced lung function and increased mortality from lung cancer and heart disease. People with breathing and heart problems, children, and the elderly may be particularly sensitive to PM2.5. Recently, an additional particle category known as ultrafine particles (often defined as particles less than 0.1 mm) has been studied and found to have distinct chemical and toxicological properties. However, given that there are no ambient standards for ultrafine particles, and that the purpose of this white paper is to address fine particle standards, issues related to ultrafine and coarse particles are beyond the scope of this discussion.



PM in the atmosphere can be categorized as either primary or secondary particles. Primary particles are directly emitted PM from sources such as construction sites, unpaved roads, sea salt, abrasion, fuel combustion, cooking, or fires. Secondary particles are formed in complex chemical reactions that occur in the atmosphere, often aided by sunlight (known as photochemical reactions). In these reactions, precursor gases, such as volatile organic compounds (VOCs), sulfur oxides (SOx), ammonia (NH_3), and nitrogen oxides (NOx), are transformed into solid or liquid products that contribute to ambient PM levels. NOx and SOx will combine with ammonia to form ammonium sulfate or ammonium nitrate salts, which are generally solids at ambient temperatures and can dissolve into water-containing particles. VOCs react with atmospheric oxidants, producing products with lower volatility that condense and form secondary organic aerosol (SOA), another component of PM. Many combustion processes emit both primary PM and precursor gases that ultimately form PM in the atmosphere. For example, in processes such as motor-vehicle gasoline combustion[1] and wood burning,[2] SOA produced by oxidation of the emitted VOCs can exceed the amount of emitted primary organic PM2.5.

"A large portion of $PM_{2.5}$ in the Basin is formed from precursor gases of anthropogenic origin."



Source: Multiple Air Toxics Exposure Study IV (May 2015)

Secondary particles make up the majority of ambient PM2.5 in the Basin. Basin-wide average ambient PM2.5 speciation profiles[3] measured during the recent Multiple Air Toxics Exposure Study (MATES) IV show that the Basin's PM2.5 mass was comprised of four major chemical components: organic carbon (OC), ammonium nitrate, ammonium sulfates,

[1] Gordon, T.D., et al. Secondary Organic Aerosol Formation Exceeds Primary Particulate Matter Emissions for Light-Duty Gasoline Vehicles, *Atmos. Chem. Phys.* 2014, 14, 4661-4678.

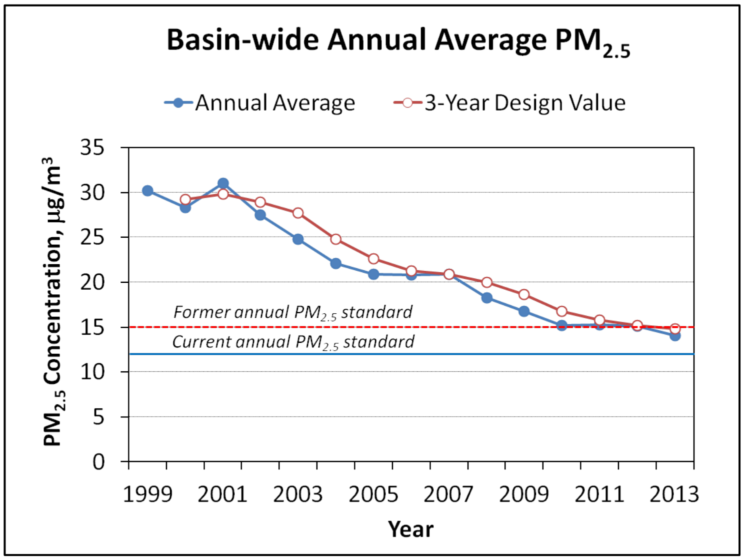
[2] Hennigan, C.J., et al. Chemical and physical transformations of organic aerosol from the photo-oxidation of open biomass burning emissions in an environmental chamber, *Atmos. Chem. Phys.* 2011, 11, 7669-7686.

[3] SCAQMD, Draft Multiple Air Toxics Exposure Study IV, October 3, 2014.

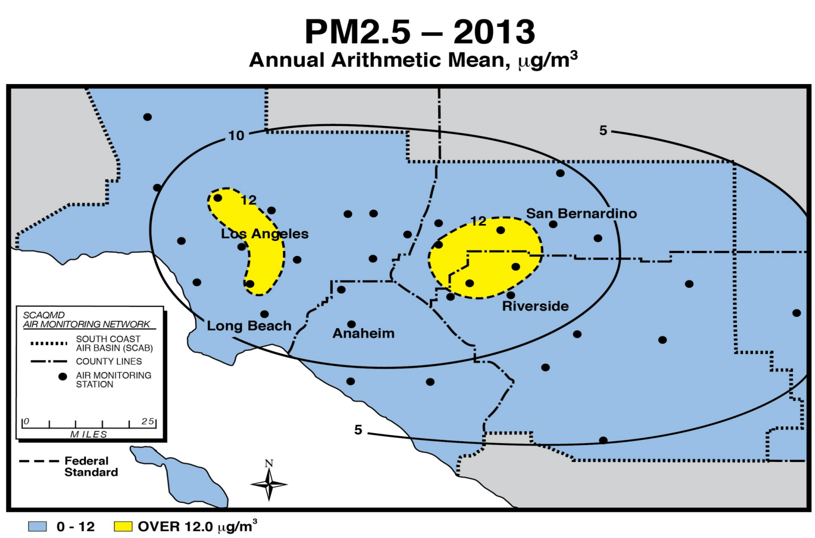
and elemental carbon (EC) with smaller fractions of crustal particles, sea salt, and other trace elements. Elemental carbon (EC), which is similar to the short-lived climate-forcing species Black Carbon (BC), is an important component of directly emitted PM2.5 from internal combustion engines, especially diesel engines. The OC mass portion includes both primary and secondary particle material.

Trends in PM2.5 Levels

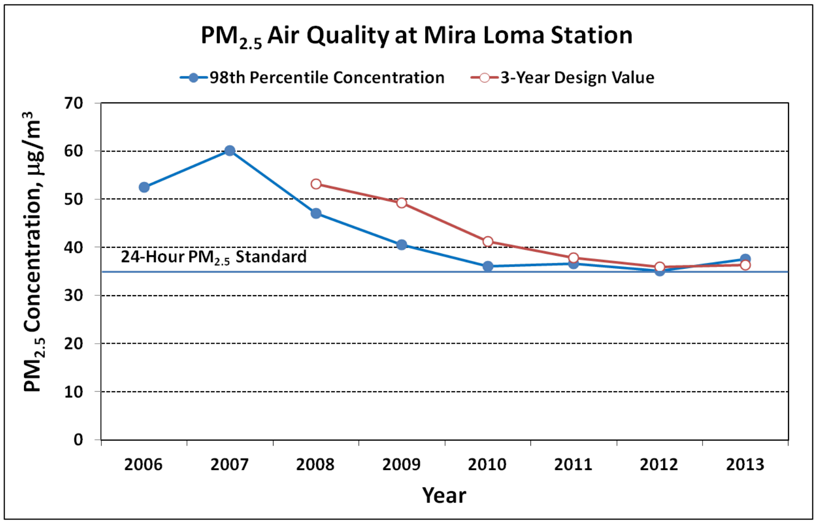
The levels of PM2.5 in the Basin have been continually improving since measurements and standards were initiated in the late 1990s. These improvements occurred over a period of significant growth in the Basin's population, vehicle miles traveled (VMT) and economic activity, and are directly attributable to the region's air quality control program.



Based on measurement data through 2013, no air monitoring station in the Basin violated the previous 1997 federal annual PM2.5 standard (15 mg/m^3 for three years), and in December of 2014, U.S. Environmental Protection Agency (U.S. EPA) proposed a clean data determination finding that the Basin has met the 1997 PM2.5 standards. This is based on the form of the federal standard, known as the *design value*, which is the 3-year average of the annual PM2.5 average, calculated by station.

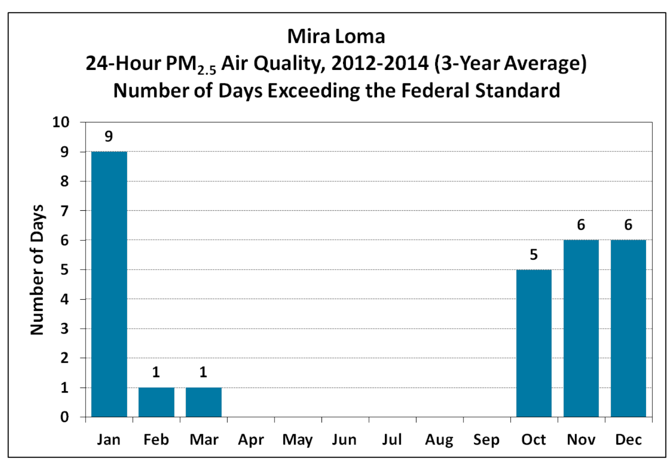


However, exceedances still occur above the new 2012 annual PM2.5 standard of 12 mg/m^3 in the San Bernardino and Riverside County metropolitan areas, with the highest levels in Mira Loma. Los Angeles County also exceeded the new PM2.5 standard in the Central Los Angeles and East San Fernando Valley areas in 2013. This new standard requires additional reductions of directly emitted PM2.5 and PM2.5 precursor gases in order to meet the annual PM2.5 standard by the 2021-2025 statutory timeframe.



Despite significant progress, the Basin remains in nonattainment for the current 24-hour PM2.5 federal standard of 35 mg/m^3. As of 2013, the 24-hour PM2.5 *design value* (in this case, the 3-year average of annual 98th percentile of the monitored 24-hour concentrations by station), exceeds the federal 24-hour PM2.5 standard at only one air monitoring station in Mira Loma in northwestern Riverside County. The 2012 AQMP projected attainment of the 24-hour PM2.5 standard by the end of 2014. However, preliminary monitoring data through June of 2014 indicates that attainment of this standard is not likely to be achieved, largely because of the unanticipated air quality impacts of the severe drought conditions in California. The lack of winter storms and associated rainfall leads to dryer and thus more emissive ground surfaces as well as reduced cleansing and dilution of atmospheric particles. The drought has not only affected PM2.5 levels in Southern California; many areas across the state have experienced this reversal in long-term downward trends of PM2.5 levels.

In addition, a recent court decision has compelled U.S. EPA to implement PM2.5 standards according to the federal CAA, Title 1, Part D, Subpart 4 (hereafter "Subpart 4") planning requirements specific to PM_{10}, rather than the general pollutant planning requirements (Subpart 1). Subpart 4 provides for attainment by 2015, with potential extensions. In February 2015, the South Coast Air Quality Management District (SCAQMD) Governing Board approved a Supplement to the 2012 AQMP 24-hour PM2.5 State Implementation Plan (SIP) for the Basin to comply with Subpart 4 and target attainment in 2015. The Governing Board also directed SCAQMD staff to bring forward early action measures for PM2.5 to ensure progress towards attainment under continuing drought conditions. The Supplement was subsequently approved by California Air Resources Board (CARB) and has been submitted to U.S. EPA for consideration. In Summer of 2015, given the most recent ambient PM2.5 data showing that 2015 attainment was not feasible, the SCAQMD Governing Board approved a request to U.S. EPA for a reclassification of the Basin to "serious" non-attainment area for 24-hour PM2.5 with an attainment date of 2019. The 2016 AQMP will also include a "serious" area plan for PM2.5.



While ozone concentrations peak in the summer months, PM levels can be high at any time of the year, but are typically higher in winter months. These higher winter values are specifically influenced by wintertime temperature inversions and stagnant conditions that reduce atmospheric dilution and trap emissions near ground level. Furthermore, sources such as wood burning have increased emissions during colder weather. Consistent with U.S. EPA guidance, seasonal, episodic, or geographical controls that focus on bringing the Mira Loma station into compliance can continue to be considered as a method to bring the Basin into attainment.

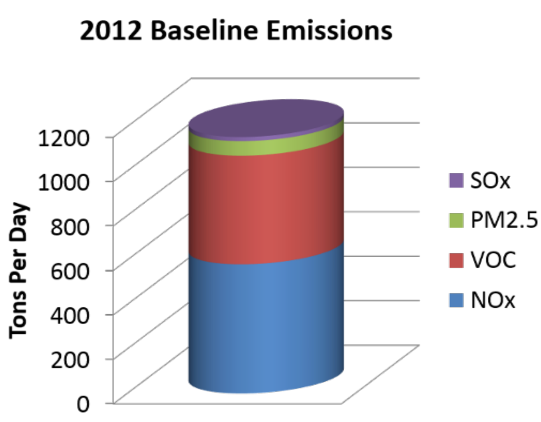
3. ASSESSING FUTURE CONTROL STRATEGIES

"Trucks are the No. 1 source of NOx emissions that form both ground-level ozone and $PM_{2.5}$ in the atmosphere."

Emission Sources of PM2.5

As mentioned above, most PM2.5 in the Basin is formed in the atmosphere, and thus a full picture of the sources of PM2.5 must also consider precursor gases. Based on the preliminary 2016 AQMP emissions inventory for 2012, there were 581 tons of NOx emissions per day, 488 tons of VOC emissions, 66 tons of directly emitted PM2.5 emissions, and 19 tons of SOx emissions. The top 10 emission sources of directly emitted PM2.5 and its precursor gases are contained in Appendix A.

On-road and off-road vehicles emit more than 85% of the total NOx emissions combined. Consumer products solvent evaporation was the single largest contributor to VOC emissions. Mobile (on- and off-road) sources collectively emit more than half of the total VOC emissions. Transportation source categories, including ships, commercial boats, aircraft trucks, and passenger cars account for more than 40% of the total SOx emissions. RECLAIM SOx sources emit more than one-third of the total SOx emissions. Service and commercial fuel combustion and residential fuel combustion are the next largest contributing SOx source categories.



Cooking is the largest emission source of directly emitted PM2.5, followed by residential fuel combustion and paved road dust. These top sources are largely uncontrolled sources of directly emitted PM2.5. The content of particles emitted from cooking, the majority of which comes from commercial under-fired charbroiling of meat, are almost all organic carbon,[4] and studies have shown that commercial meat-cooking contributes more than 20% of the PM2.5 organic carbon fraction in Los Angeles air.[5] Residential fuel

[4] McDonald, J.D., et al. Emissions from charbroiling and grilling of chicken and beef. *JAWMA*, 2003, 53, 185-194.
[5] Norbeck, J. *Standardized Test Kitchen and Screening Tools Evaluation for South Coast Air Quality Management District Proposed Rule 1138;* Prepared under Contract No. S-C95073 for the South Coast Air Quality

combustion is the second largest emission source of directly emitted PM2.5, mostly in the form of wood stove and fireplace wood burning.

Control Effectiveness

In the SCAQMD's 2012 AQMP, a detailed computer air quality model (CMAQ v4.7.1) was used to estimate the regional reductions of ambient PM2.5 concentrations that result from reductions in PM precursor emissions. On a ton-per-ton basis, primary PM2.5 and SOx emissions controls were found to be the most effective in reducing PM2.5 mass concentrations, compared to NOx emissions controls. VOC emissions reductions had the lowest effect on reducing annual PM2.5 mass concentration. As shown, this comparative effectiveness of emissions reductions is different for the 24-hour PM2.5 standard, and may also change with season and location in the Basin.

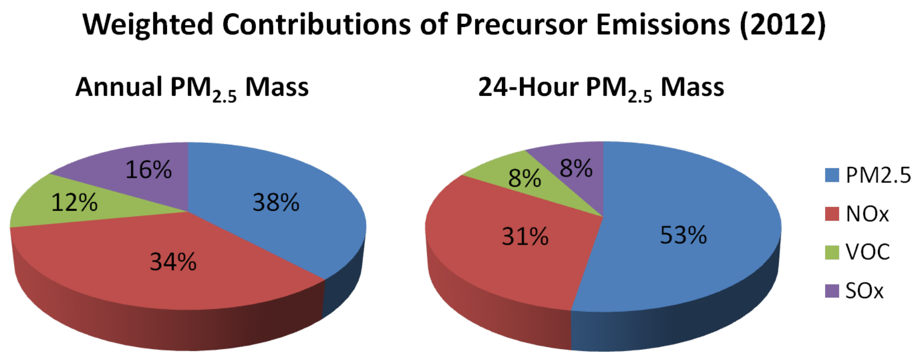
Comparative Effectiveness of Reductions To Achieve Federal PM2.5 Air Quality Standards				
	NOx	**SOx**	**VOCs**	**PM2.5**
Annual PM2.5 Standard	1	15	0.4	10
24-hour PM2.5 Standard	1	8	0.3	15

However, the CMAQ model, while state-of-the-art, has been shown to significantly underestimate SOA formation from VOCs.[6] Future versions of CMAQ will strive to eliminate this underprediction as additional SOA formation processes are better understood and incorporated in the model.

Using 2012 emissions inventories weighted by the relative effectiveness factors, contributions of precursor emissions to achieving both annual and 24-hour PM2.5 standards were estimated. For example, while SOx has a higher relative effectiveness factor than NOx, total emissions of NOx are much greater than those of SOx. Therefore, as shown in the charts below, NOx and PM2.5 contribute more to PM2.5 levels than SOx or VOCs. Controls of NOx emissions will make a significant contribution to reducing annual PM2.5 mass concentrations, and thus meeting the federal annual PM2.5 standard.

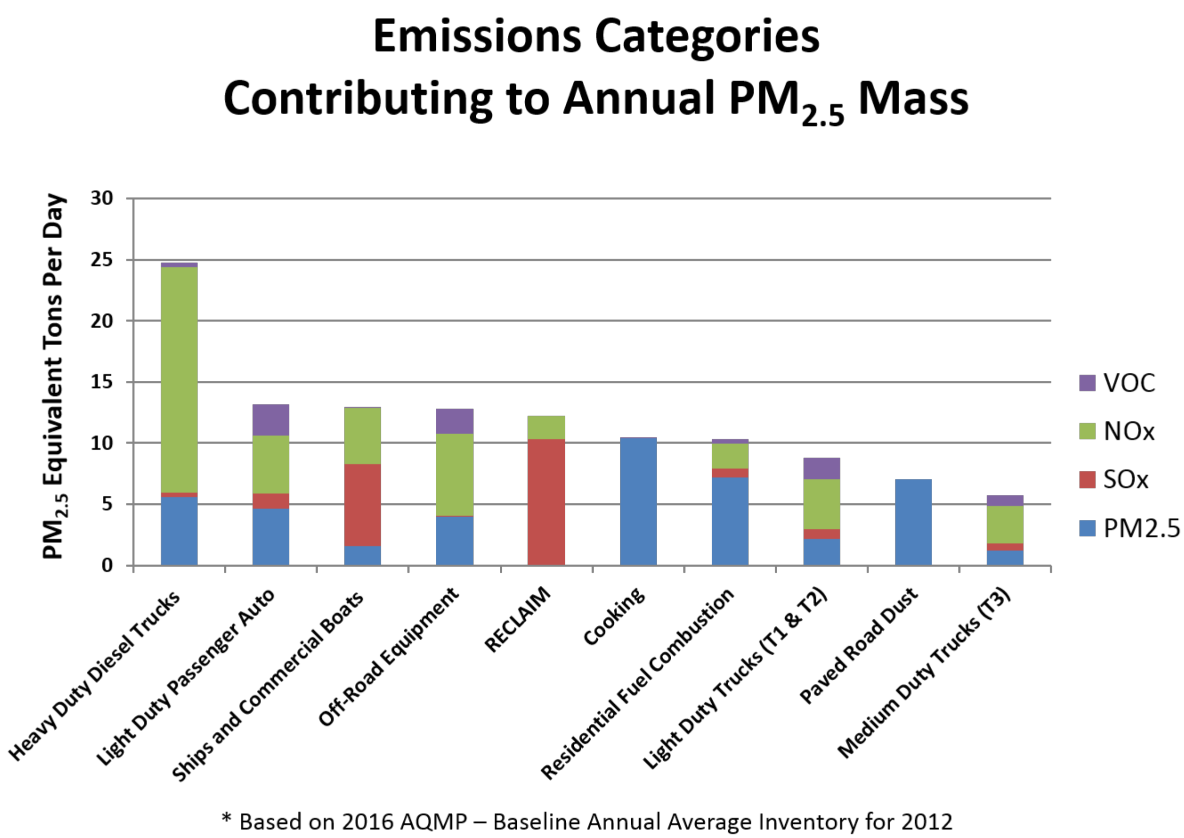
Management District, El Monte, CA, by CE-CERT: University of California, Riverside, CA, 1997.

[6] Carlton, A.G., et al. Model Representation of Secondary Organic Aerosol in CMAQ v4.7, *Environ. Sci. Technol.* 2010, 44, 8553-8560.



Attaining the ozone standards requires significant reductions in emissions of NOx well above and beyond those resulting from current rules, programs, and commercially available technologies. For previous AQMPs, most of these additional reductions relied on the development of new control techniques or improvement of existing control technologies, also known as "black box" measures, as authorized under Section 182(e)(5) of the federal CAA. These "black box" measures, if implemented successfully, will not only allow attainment of the ozone standards, but will also provide significant help in reaching PM2.5 standards. In fact, if NOx emissions reductions designed to meet the former ozone standard in 2023 are achieved, PM2.5 levels in the Basin are projected to be very near, if not meeting, the current 2012 federal annual PM2.5 standard of 12 mg/m^3 by that time. However, attainment of the PM2.5 standard may not rely on Section 182(e)(5) measures.

More detailed analysis of the emissions categories contributing to ambient PM2.5 mass, using the weighting factors for precursors described above, shows what emission sources could be prioritized for a focused and cost-effective PM control program. Area sources, such as commercial cooking, residential fuel combustion, and paved road dust are major contributors to ambient PM2.5, primarily through directly emitted PM2.5 emissions. Mobile sources, both on-road and off-road, are also significant sources of PM2.5, both through directly emitted PM2.5 emissions but also precursors such as NOx.



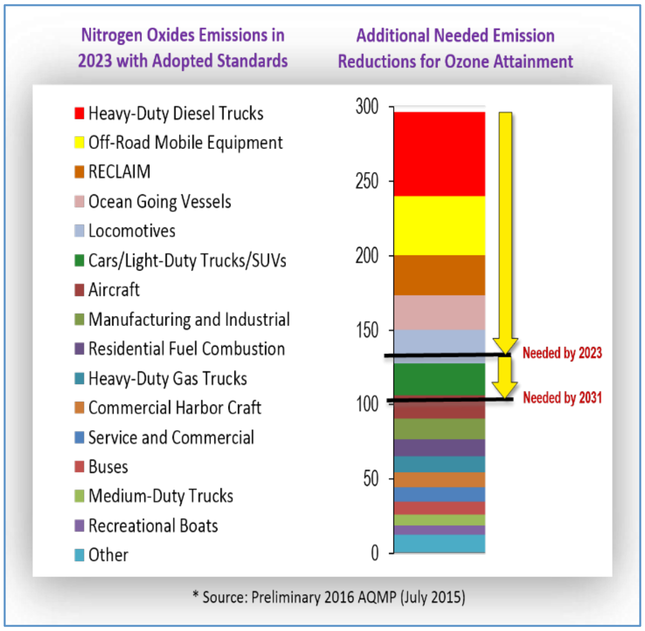
4. RECOMMENDATIONS - PATH TO PM2.5 ATTAINMENT IN THE 2016 AQMP

Control Strategy

Through the 2007 and 2012 AQMPs, it was demonstrated that the previous control strategies employed for the PM_{10} and 1-hour ozone SIPs also benefited PM2.5 and 8-hour ozone reductions. Taking the same multi-pollutant approach to assess strategies for the 2016 AQMP suggests that a NOx-heavy strategy is the most efficient approach for the reduction of fine particulate matter because NOx reductions are needed for the 1-hour and 1997 8-hour ozone standards within approximately the same timeframe for the federal annual PM2.5 attainment demonstration. The PM2.5 strategy can be further augmented with targeted and cost-effective directly emitted PM2.5 and SOx controls if needed, should NOx controls from other control programs be insufficient, not timely, or do not materialize.

Based on the above discussion, several attainment paths can be developed with varying degree of controls among directly emitted PM2.5 and PM precursors. Selecting the most efficient path for PM2.5 attainment takes into consideration many factors, such as the amount of total reductions needed, technology readiness, attainment deadlines, and the inter-relationship with other NAAQS pollutants such that the control strategy does not need to make drastic mid-term adjustments, thus minimizing potential control costs. The following sections describe the staff recommendations for a prioritized approach in the development of a PM2.5 attainment strategy.

1) Co-Benefits from the Ozone NOx Strategy



Many of the most significant directly emitted PM2.5 and PM2.5 precursor emission sources are already well controlled, but additional reductions from implementation of adopted control measures from the 2007 and 2012 AQMPs may still not be adequate for attainment of the new federal annual PM2.5 standard. PM2.5 levels will be further reduced from the additional NOx emissions reductions needed for the ozone control strategy. Preliminary 2016 AQMP analysis shows that approximately another 150 tons per day of NOx reductions needed are to meet the 1997 8-hour ozone standard by 2024. This is within the timeframe of the 2012 annual PM2.5 standard attainment deadline of 2021-2025. Preliminary projections suggest that without any additional PM controls, but with the ozone NOx strategy alone, the Basin's annual PM2.5 design value would be very near the standard of 12 mg/m^3 in 2023.

Given the goal of developing the most efficient and cost-effective path to meeting all clean air standards, and given that these NOx reductions are needed for ozone attainment anyway, the most desirable path is to control NOx emissions, not only from point and area sources, but primarily from mobile sources that fall under state and federal jurisdiction. Significant reductions are needed from on-road vehicles, off-road engines, ships, and locomotives to achieve the necessary NOx reductions to meet the federal ozone standards. The 2016 AQMP will capture the anticipated NOx reductions from the ozone plan, as well as anticipated concurrent reductions of VOCs, SOx, and directly emitted PM2.5 from zero tailpipe emission technologies or efficiency measures that reduce vehicle trips/vehicle miles traveled.

2) Co-Benefits from Climate Change or Air Toxic Control Programs

SCAQMD staff recognizes, to the extent available under the U.S. EPA's PM2.5 implementation rule, that there are several near-term measures that are being pursued by CARB under the AB 32 Scoping Plan, including reductions in short-lived climate forcers such as BC. Comprised of microscopic particles emitted from incomplete combustion of biomass, wood, and fossil fuels, BC is a major contributor to global climate change and also a primary component of diesel particulate matter (DPM). Cutting BC emissions would immediately result in reduction of the rate of warming, as well as PM2.5 benefits. Identifying the most promising control measures or mitigation options to address BC emissions reductions in the areas of stationary and mobile sources, residential wood combustion, and open biomass burning will provide climate change as well as PM2.5 benefits in the near term.

Air toxic control programs reducing DPM or toxic metals would also contribute to PM2.5 reductions. Despite significant decreases in air toxics exposure over the past couple of decades, the recent SCAQMD MATES IV results continue to show unacceptably high risk of exposure to DPM, representing two-thirds of the overall air toxic cancer risk. This result emphasizes that continuous efforts towards reducing DPM emissions are needed at local, state, and federal levels and via cooperation with the ports, airports, and other stakeholders. Alternative fueled vehicles with significant zero emission miles traveled, along with coordinated land use and transportation planning with the goal of reducing VMT, will contribute to reduction of DPM, GHG, as well as NOx emissions. Toxic metals emitted from industrial processes can cause risks to public health and the environment. SCAQMD staff will continue to develop and propose new rules or amend existing rules by strengthening requirements to reduce toxic metal emissions and exposure from various metal industry sources. These measures, although not developed for SIP purposes, will achieve concurrent reductions in directly emitted PM2.5 and can be quantified and credited toward needed SIP reductions.

3) Outreach and Incentive Programs

Other programs supporting PM control measure implementation are also important to ensure expected emission reductions are being realized. These programs include outreach and incentive programs. SCAQMD staff utilizes a variety of tools to raise public awareness and understanding of the significance and health effects of particle pollution and thus, the importance of PM controls to protect public health. Enhanced public outreach should continue to be pursued by various means, including targeted and focused communications campaigns, community workshops, educational brochures and videos, and other digital media formats.

Incentive funding for stationary sources can be pursued and best applied where controls are cost-effective, but not necessarily affordable by the affected sources, especially when controls are considered for smaller businesses. Such incentive funds can be used to subsidize low-emitting equipment purchases either by businesses or the public. Funding for such incentive programs can originate from state and federal grants, penalties/settlements, and other sources.

4) Additional Measures for PM2.5 Attainment

Since the federal CAA does not allow for reliance on future technologies (i.e., "black box," Section 182(e)(5) measures) in the PM2.5 attainment plan, portions of NOx controls that are part of the ozone attainment strategy may be not eligible for inclusion as SIP measures for PM2.5 purposes. For this reason, additional measures to ensure attainment will need to be evaluated and implemented if needed. Potential control concepts based on the Reasonably Available Control Technology (RACT) or RACM analysis for PM2.5 and its precursors as part of the 2016 AQMP will be evaluated for their feasibility and applicability for this air basin. Any additional measures needed to meet the RACT/RACM requirements could be further developed for inclusion in the 2016 AQMP. Based on the PM2.5 formation potentials described above, if additional reductions are still needed for timely PM2.5 attainment demonstration, additional SOx and/or directly emitted PM2.5 measures should be a first priority. Examples of such measures can be found in Appendix B.

In developing the PM2.5 strategy, geographic, seasonal, and episodic controls should also be considered as they minimize compliance costs while targeting emissions reductions when and where they are needed. Examples of these measures are also contained in Appendix B. Such targeted measures will have even greater benefits for avoiding exceedances of the 24-hour PM2.5 standard given that the exceedances are episodic and occur almost exclusively in the colder months. As attainment deadlines for the 24-hour standard are imminent, PM2.5 measures arising from the 2016 AQMP development process that can help to ensure timely attainment of the 24-hour PM2.5 standard should be developed and adopted as early action measures, parallel to the 2016 AQMP development.

5. CONTINUING RESEARCH AND SCIENTIFIC STUDIES

Continuing research and scientific studies are needed to better quantify organic compounds and their contribution to PM2.5 formation. In the Basin, approximately 30-50% of the PM2.5 mass is composed of organic compounds. However, the organic component of PM2.5 in the Basin needs further study as certain semi-volatile organic compounds (SVOC) have not been historically inventoried, controlled or incorporated in regional air quality modeling. Continuing research and scientific studies are required to better quantify SVOC emissions and their contribution to PM2.5 formation.

The role of ammonia emissions will also be examined further in the 2016 AQMP modeling analysis. Some areas within the Basin may be saturated with ammonia now or in the future relative to SOx and NOx, and thus modest ammonia controls may have little effect. Other areas may show that ammonia controls are effective in reducing ambient PM2.5. Even if large ammonia reductions may have benefits, it may not be feasible given the nature of the sources.

SUMMARY

The 2016 AQMP modeling and attainment demonstration analysis will provide refinement to the concepts in this white paper, but it is clear that an integrated approach to multiple air quality challenges will minimize control costs while achieving multiple goals. A NOx-heavy control strategy will not only provide for attainment of the ozone standards, but also provide significant co-benefits for the reduction of fine particulate matter. Concurrent targeted, strategic, and timely reductions in directly emitted PM2.5 and precursors will ensure meeting the federal annual and 24-hour PM2.5 standards by the attainment deadlines.

APPENDIX A

TOP TEN EMISSION SOURCES BY POLLUTANT

Appendix A: Top Ten Emission Sources by Pollutant[1]

1. NOx

Emission Sources	2012 Emissions (Tons/Day)
Heavy Duty Diesel Trucks	184.1
Off-Road Equipment	67.0
Light Duty Passenger Auto (LDA)	46.8
Ships and Commercial Boats (OGV & CHC)	45.9
Light Duty Trucks (T1 & T2)	41.2
Medium Duty Trucks (T3)	30.2
Trains	21.3
Heavy Duty Gasoline Trucks	20.9
Residential Fuel Combustion	20.2
Heavy Duty Diesel Urban Buses (UB)	19.6

2. VOC

Emission Sources	2012 Emissions (Tons/Day)
Consumer Products	86.5
Light Duty Passenger Auto (LDA)	64.4
Off-Road Equipment	51.6
Light Duty Trucks (T1 & T2)	42.9
Petroleum Marketing	34.4
Recreational Boats	30.4
Medium Duty Trucks (T3)	21.2
Coatings and Related Process Solvents	18.9
Heavy Duty Gasoline Trucks	14.4
Architectural Coatings and Related Solvents	13.3

[1] Source: Preliminary 2016 AQMP, July 2015.

3. Directly Emitted PM2.5

Emission Sources	2012 Emissions (Tons/Day)
Cooking	10.4
Residential Fuel Combustion	7.2
Paved Roads Dust	7.1
Heavy Duty Diesel Trucks	5.6
Light Duty Passenger Auto (LDA)	4.6
Off-Road Equipment	4.0
Wood and Paper	2.3
Light Duty Trucks (T1 & T2)	2.2
Mineral Processes	2.1
Construction and Demolition	1.7

4. SOx

Emission Sources	2012 Emissions (Tons/Day)
RECLAIM	6.87
Ships and Commercial Boats (OGV & CHC)	4.46
Aircraft	1.42
Service and Commercial Fuel Combustion	1.15
Light Duty Passenger Auto (LDA)	0.85
Light Duty Trucks (T1 & T2)	0.51
Residential Fuel Combustion	0.49
Manufacturing and Industrial	0.45
Medium Duty Trucks (T3)	0.40
Petroleum Refining	0.36

APPENDIX B

OPPORTUNITIES FOR EMISSION REDUCTIONS TO ACHIEVE PM2.5 STANDARDS

Appendix B: Opportunities for Emission Reductions to Achieve PM2.5 Standards

This appendix describes control concepts toward achieving the federal PM2.5 standards if additional emission reductions are needed after implementation of other measures that achieve PM2.5 co-benefits and incentive programs as outlined in the PM White Paper. Examples of potential control concepts are discussed by sector. If additional reductions are needed for annual PM2.5 standard attainment, some or all of the concepts could be developed as a control measure that can be prioritized for implementation, including time and place controls, such as geographic, seasonal, or episodic controls, as well as incentive programs.

1. Cooking

The SCAQMD has implemented a very successful PM2.5 control program for chain-driven charbroilers (used at quick service restaurants), but PM2.5 emissions from under-fired charbroilers remain relatively uncontrolled, primarily due to the current high capital costs of equipment, and operation and maintenance (O&M) costs. Based on current emissions inventory, approximately 80% of PM2.5 emissions from restaurants are from under-fired charbroilers. SCAQMD is completing a study with University of California Riverside, in partnership with the U.S. EPA and other air agencies in PM2.5 nonattainment areas, to identify cost-effective and more affordable under-fired charbroiler controls. Types of devices being evaluated can be generally described as filter-based equipment, electrostatic precipitators (ESPs), catalysts, scrubbers, and other innovative technologies, some of which are nearing commercial availability. Study results are being evaluated and will be used to develop a detailed technical and economic (cost and affordability) feasibility analysis.

If needed for attainment, emission control programs for under-fired charbroilers could potentially be tiered and require high efficiency (and potentially more expensive) controls for larger restaurants and possibly less efficient, less expensive, yet more affordable equipment for smaller sources. Small business incentive programs could also be explored to help offset purchase and installation costs. For example, an incentive program could be explored to help offset the control device costs to restaurants from what could otherwise be less affordable controls for directly emitted PM2.5 reductions at small business restaurants. The net result could be an overall reduction of PM2.5 pollution at a lower overall cost. SCAQMD continues to work closely with staff from the Bay Area AQMD, San Joaquin Valley APCD, and U.S. EPA Region 9 on research and demonstration projects for these control technologies.

2. Residential and Open Burning

Additional PM2.5 reductions from biomass burning were identified by the SB 656 (Sher) report and control measures were developed and implemented in conjunction with the 2007 and 2012 AQMPs. SCAQMD Rule 445 (Wood-Burning Devices) was adopted in 2008 and subsequently amended in 2013. Rule 445 established a mandatory residential wood-burning curtailment program, beginning in 2011, during winter months (November through the end of February) known as the "Check Before You Burn" program. Amendments in

2013 lowered the curtailment threshold from 35 (federal 24-hour PM2.5 standard) to 30 $\mu g/m^3$ to address forecasting uncertainties and assure a level of protection to remain below the standard. Rule 445 specifies the types of devices that can be installed into new and existing developments, includes moisture content requirements for commercial firewood sellers, and establishes a winter wood burning curtailment program. SCAQMD Rule 444 (Open Burning) has been in place since the formation of the SCAQMD and has been amended many times, most recently in 2013. Rule 444 is applicable to agricultural and prescribed (e.g., forest service) open burning sources and includes requirements to minimize smoke emissions. The 2013 amendments to Rule 444 synchronized the wintertime residential wood-burning control program (Rule 445) with the open burning program such that open burning would not occur during a mandatory residential no-burn day.

A new initiative has been implemented to upgrade wood-burning devices in inland, high PM2.5 areas. Under this program, households in the greater area surrounding the cities of Riverside and San Bernardino can work with participating retailers to choose from a variety of cleaner hearth products, including gas logs, gas/electric inserts, and more efficient wood stoves (if no gas service) for installation. SCAQMD provides incentives to offset purchase and installation costs. The incentives offered have been increased substantially over past programs and even higher incentives (up to $1,600) are available for households that qualify under low-income guidelines. This program has been effective, but to achieve maximum emission reductions, higher incentives could be offered or the geographic area eligible to participate could be expanded. Experience has shown that education and outreach to targeted households is a key program component. Since the current eligible project area is relatively small, direct outreach to individual residences has been the most successful.

Potential additional emission reductions via Rule 445 related residential wood burning could involve further restrictions on the types of devices (e.g., U.S. EPA certified wood burning devices) allowed to be installed into existing developments, such as room additions, remodels, etc.

The highest PM2.5 levels usually occur during late fall and winter months, with the exception of high values reported near the Fourth of July (attributable to smoke from Independence Day firework displays). However, some high levels occur in early fall. If needed for attainment, further burn restrictions could be established for this fall time period by expanding the wintertime curtailment period to include October. The threshold used to forecast no-burn days under either the residential or the open burning programs could also be lowered. Both options could reduce emissions during peak PM periods or episodes.

As previously mentioned, Rule 445 prohibits wood burning in areas where high PM2.5 levels are forecast. If poor PM2.5 air quality is, however, forecast for an area that has documented an exceedance of the federal 24-hour PM2.5 standard, the no-burn day applies to the entire Basin. This is intended to seek the maximum amount of emission reductions feasible in an attempt to prevent the episodic exceedance. The 2016 AQMP will address the annual PM2.5 standard which is less sensitive to these episodes. Currently, the peak PM2.5 monitoring site, or "trigger area", to identify a Basin-wide curtailment day is in the Mira Loma area, part of

Source Receptor Area (SRA) 23 (Metropolitan Riverside County). As part of an enhanced control effort, the trigger area could be expanded to include other SRAs with elevated PM2.5 levels that have not documented exceedances of the federal 24-hour standard (annual 98th percentile concentration, averaged over 3 years). This would likely result in an increase in Basin-wide no-burn days and help to lower annual PM2.5 levels. Alternatively, if air quality modeling supported a truly targeted control program, there could be an increase in the number of no-burn days forecast solely for SRA 23 and immediate upwind areas.

Possible controls for Rule 444 related open burning sources could include mandatory use of chipping/grinding or mulching as alternatives to open burning.

3. Fugitive Dust

PM derived from mechanical disruption (e.g., agriculture, construction, etc.) is primarily in the coarse (PM10-2.5) size fraction; however, entrained road dust is still one of the major directly emitted PM2.5 sources due to the region's large number of roadways and high traffic volumes. In response, SCAQMD has adopted regulations to prevent material from being deposited on roadways and a program for efficient street sweeping equipment. For the street sweeping equipment, a testing protocol was developed and minimum pick-up efficiency and entrainment standards are in place (Rule 1186 – PM_{10} Emissions from Paved and Unpaved Roads, and Livestock Operations). Local jurisdictions must only procure equipment that meets applicable standards and a companion regulation (Rule 1186.1 – Less-Polluting Sweepers) also requires, in most cases, that street sweepers be powered by alternative fuels.

During the development of Rule 1186, SCAQMD staff learned that street sweeping frequencies vary greatly among jurisdictions, from weekly to monthly to, in some cases, not at all. If needed for attainment, minimum street sweeping frequencies could be explored as well as enhanced cleaning on roads with higher silt loadings.

4. Ammonia Control

1) Agricultural Dairies

Livestock waste is the third largest emission source of ammonia in the Basin and is regulated by both SCAQMD Rules 223 (Emission Reduction Permits for Large Confined Animal Facilities) and 1127 (Emission Reductions from Livestock Waste). Recent research found that fresh excreted manure in the animal housing areas is the major source of ammonia emissions and each cow produces approximately 60 kg of manure daily.[2] Prevailing winds push NOx and SOx emissions from industrial and transportation sources in the western Basin to inland areas and these gases mix with ammonia emissions from widespread sources, including approximately 100,000 head of dairy cattle and support stock in western Riverside and San Bernardino counties. Ammonium

[2] Final 2012 Air Quality Management Plan, Appendix IV-A, Control Measure BCM-04 – Further Ammonia Reductions from Livestock Waste, SCAQMD, February 2013.

nitrate is the most prevalent PM compound measured at the Mira Loma air monitoring station, the only station projected to exceed federal 24-hour standard for PM2.5.

If needed for attainment, seasonal or episodic approaches to control ammonia from dairy manure may be beneficial in reducing the secondarily formed air contaminants in the area. One possible approach would be to reduce ammonia emissions from fresh manure using an ammonia-reducing agent. Sodium bisulfate, when dissociated, reduces the pH and protonates ammonia, converting it to ammonium. The ammonium is then bound by sulfate to form ammonium sulfate, which is retained in the manure in its solid form. In California, sodium bisulfate has been used by dairies in northern and southern counties, including San Bernardino and Riverside counties, mainly to prevent cow lameness and nuisance flies. Theoretically, 100 pounds (lbs) of sodium bisulfate would bind 14 lbs of ammonia. This method of control was initially proposed in the 2012 AQMP for an assessment to evaluate the technical and economic feasibility of application, including episodic application.

If deemed feasible and necessary, seasonal or episodic ammonia controls may be considered, for example by applying sodium bisulfate to fresh manure during high PM2.5 months or for days only when higher concentrations occurred or are anticipated to occur based on the past analyses. However, costs associated with sodium bisulfate use can be high and the need to offset the costs through an incentive program would need to be considered.

2) Anaerobic Digestion

The SCAQMD Rule 1133 series establishes requirements for composting of organic waste such as animal manure, biosolids, greenwaste, and foodwaste. As ongoing efforts at the state level for organics diversion to meet AB 32 and landfill diversion goals, AB 341 (Chesbro) has created challenges relative to controlling VOC and ammonia emissions from increased composting of greenwaste, and increasingly from foodwaste. AB 341 was approved by the legislature in 2011 to further reduce GHG emissions by diversion of organic materials away from landfills. This legislation established a goal that 75% of solid waste be reduced, recycled, or composted by 2020. This has created a statewide challenge to develop mechanisms to accommodate the state mandate while not adversely affecting air quality. Inclusive of these challenges are local air quality rules and regulations associated with composting operations/methods, permitting, and off-road vehicle use. Local air districts are working with CARB and California Department of Resources Recycling and Recovery (CalRecycle) to address these issues.

According to the composting industry[3], the majority of the yard trimmings and tree prunings processed (i.e., chipped and ground) in the Basin are not composted but go through a much shorter pathogen reduction process. These organic materials are used as an alternative daily cover (ADC) or for other beneficial uses at landfills or as a ground cover on commercial or public lands. The majority of mobile, point, and area source

[3] Paul Ryan, Inland Empire Disposal Association, E-mail communication, November 13, 2014.

emissions from compostable materials handling through chipping and grinding are not sufficiently controlled to minimize potential emissions in the Basin. Conversely, composting is relatively well regulated through current air quality planning and rulemaking. Two legislative mandates, AB 1594 (Williams) and AB 1826 (Chesbro) approved in 2014 will help the state achieve diversion goals by 2020 through recycling of compostable organic waste materials. AB 1594 closes diversion credit for yard trimmings and prunings, including greenwaste, which is used as an ADC or for other beneficial uses at landfills. AB 1826 will drive the recycling of yard trimmings and food scraps by requiring commercial generators to sign up for composting or anaerobic digestion service for their organic waste. More organic materials are expected to be diverted in the future and consideration must be given to expansion of the organics processing industry and the emissions impact from those processes and associated equipment compared to the overall benefits of diversion.

Anaerobic digestion (AD) has been identified as a technically viable method of organic waste treatment in which organic waste is transformed to renewable biogas, mainly composed of methane (CH_4) and carbon dioxide (CO_2), in an oxygen-free environment. Digesters can minimize emissions of ammonia, VOC, and other odorous pollutants in well-managed operating conditions, which can contribute to reductions of PM2.5 formation. However, air quality permitting, off-road vehicle use, as well as high capital investment and O&M costs, may be a disincentive. CalRecycle is in the process of amending and creating new requirements for California Code of Regulations, Titles 14 and 27 to address these and other implementation issues. As part of this process in particular, a stand-alone set of in-vessel digestion regulations has been proposed to divert compostable organic materials from landfills to reduce GHG generation, while producing biofuels or bioenergy. Use of digesters may bring about air quality benefits (e.g., decreasing GHG, ammonia, and VOC emissions) and co-benefits of PM2.5 reduction in the Basin.

South Coast AQMD

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

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

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

VOC Controls

2016 AQMP WHITE PAPER

OCTOBER 2015

South Coast Air Quality Management District

Barry R. Wallerstein, D.Env.
Executive Officer

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

Jill Whynot
Assistant Deputy Executive Officer
Planning, Rule Development & Area Sources

Elaine Chang, DrPH
Deputy Executive Officer (Retired)
Planning, Rule Development & Area Sources

Joe Cassmassi
Planning and Rules Director
Planning, Rule Development & Area Sources

Naveen Berry
Planning and Rules Manager
Planning, Rule Development & Area Sources

Authors

Scott Epstein, Ph.D. – Air Quality Specialist
Sang-Mi Lee, Ph.D. – Program Supervisor

Contributors

Kalam Cheung, Ph.D. – Air Quality Specialist
Shoreh Cohanim – Air Quality Specialist
Kevin Durkee – Senior Meteorologist
Jean Ospital, DrPH –Health Effects Officer (retired)
Diana Thai – Air Quality Specialist

Reviewers

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

Working Group

Frank Caponi – SCAP
Dave Darling - American Coatings Association
Douglas Fratz - Consumer Specialty Product Asso.
Bill La Marr – Small Business Alliance
Noel Muyco – SoCal Gas
Ravi Ramalingam - Air Resources Board
David Rothbart - SCAP
Patty Senecal – Western States Petroleum Asso.
Lee Wallace – SoCal Gas
Ron Wilkniss- Western States Petroleum Asso.
John DaMassa - Air Resources Board
Dave Edwards - Air Resources Board
Andrew Henderson – SoCal Leadership Council
Rita M. Loof - RadTech
David Pettit – Natural Resources Defense Council
Doug Raymond - Raymond Regulatory Resources
Paul Ryan - California Refuse Recycling Council
Jim Stewart – Sierra Club
Mike Wang - Western States Petroleum Asso.

Table of Contents

Introduction

This white paper evaluates the need for additional volatile organic compound (VOC) controls to achieve more stringent annual fine particulate matter (PM2.5) and 8-hour ozone standards in the South Coast Air Basin (SoCAB). It assesses the role of VOCs in forming ozone and PM2.5 to inform policymakers of the most efficient and effective strategies to attain the federal standards that are the subject of the upcoming 2016 Air Quality Management Plan (AQMP).

The science behind the formation of ozone and particulate matter from VOCs is also summarized. A state-of-the-science numerical modeling system (WRF-CMAQ) is used to estimate the maximum allowable nitrogen oxides (NOx) and VOC emissions that will lead to regional ozone and PM2.5 concentrations that meet the federal standards. Given the results of this modeling, the implications of various NOx and VOC control strategies are analyzed.

What Are VOCs?

VOCs are chemicals containing carbon that readily evaporate. Some VOCs may be gases at room temperature. VOCs are widely used in modern society in fuels, solvents, coatings, cleaning supplies, building products, and many other materials. In addition to evaporation or direct emissions of organic gases, some VOCs are emitted as a byproduct of combustion processes, such as wood burning, power generation, or internal combustion engines. Thus, VOCs are emitted from mobile sources such as cars and trucks, and stationary sources such as refineries, chemical plants, and households. Since VOCs evaporate readily, in the absence of appropriate control measures, these compounds will ultimately end up in the atmosphere. Subsequent chemical reactions of VOCs in the atmosphere can form surface level ozone pollution and particulate matter.

Atmospheric scientists classify VOCs into several subcategories. The degree to which each specific VOC impacts the formation of ozone is a function of its unique chemical reactivity, its atmospheric concentration, and the atmospheric concentrations of other chemicals needed for these complex chemical reactions. VOCs that form ozone at extremely slow rates are considered minimally reactive and are often classified as "exempt" from current VOC rules and regulations. However, toxicity or other potential adverse environmental impacts from these VOCs should also be considered. The ability for a specific VOC to form particulate matter is dependent on how fast it reacts with other atmospheric compounds and the physical and chemical properties of the resulting products.

We can also classify VOCs and their chemical reaction products into three sub-categories dependent on how readily they evaporate and their ability to exist in the gas-phase. VOCs with high volatility evaporate quickly, but are less likely to contribute to particulate matter, because these compounds generally remain as gases once they evaporate. On the other hand, compounds with lower volatilities evaporate at a slower rate, but are more likely to contribute to particulate matter as they or their reaction products may condense (transition from gas to liquid or solid form) once they are in the atmosphere. Compounds that have a significant fraction of their mass in both the gas and particle-phase in the atmosphere are referred to semi-volatile organic compounds (SVOCs). Compounds that have most of their mass in the gas-phase, but can transition to the particle phase under certain atmospheric conditions are classified as intermediate volatility organic compounds (IVOCs). While a direct comparison is difficult, low vapor pressure volatile organic compounds (LVP-VOCs), defined under the California Air Resources Board consumer products regulations, may fall into the SVOC category. In addition, atmospheric reactions can produce products with drastically different volatilities than the parent compounds.

The Role of VOCs in Ozone Formation

Ozone concentrations in the South Coast Air Basin

Atmospheric ozone is a powerful oxidant with significant adverse effects on human health and the environment. While ozone concentrations have declined significantly in the Basin over the past few decades, levels still exceed the current federal or state ozone standards. In addition, the recently proposed federal standard between 65 and 70 ppb will make future attainment even more challenging [1]. In recent years, the significant downward trend in Basin-wide ozone concentrations has begun to level off. FIGURE 1 details the yearly trend in ozone concentrations and the trend in the number of days that exceed the current federal standard.

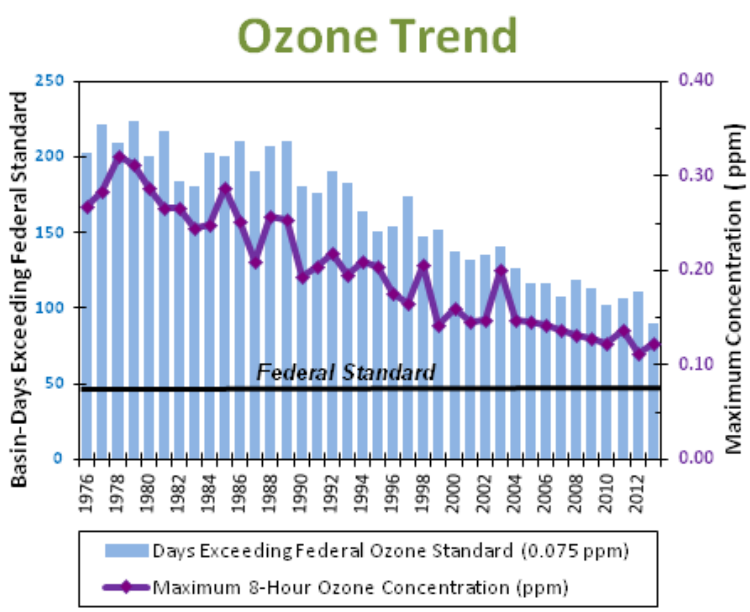


FIGURE 1

Basin-wide maximum 8-hour ozone concentrations and Basin-days exceeding the federal standard.

Certain air quality monitoring stations located in San Bernardino and Riverside counties exceed the current 75 ppb federal ozone standard over 60 days per year (FIGURE 2). Higher local ozone concentrations in these regions can be attributed to the significant upwind O_3, NOx, and VOC precursor emissions transported by the daily sea-breeze in the summer, local emissions, and the timing of the daily emissions and peak sunlight intensity.

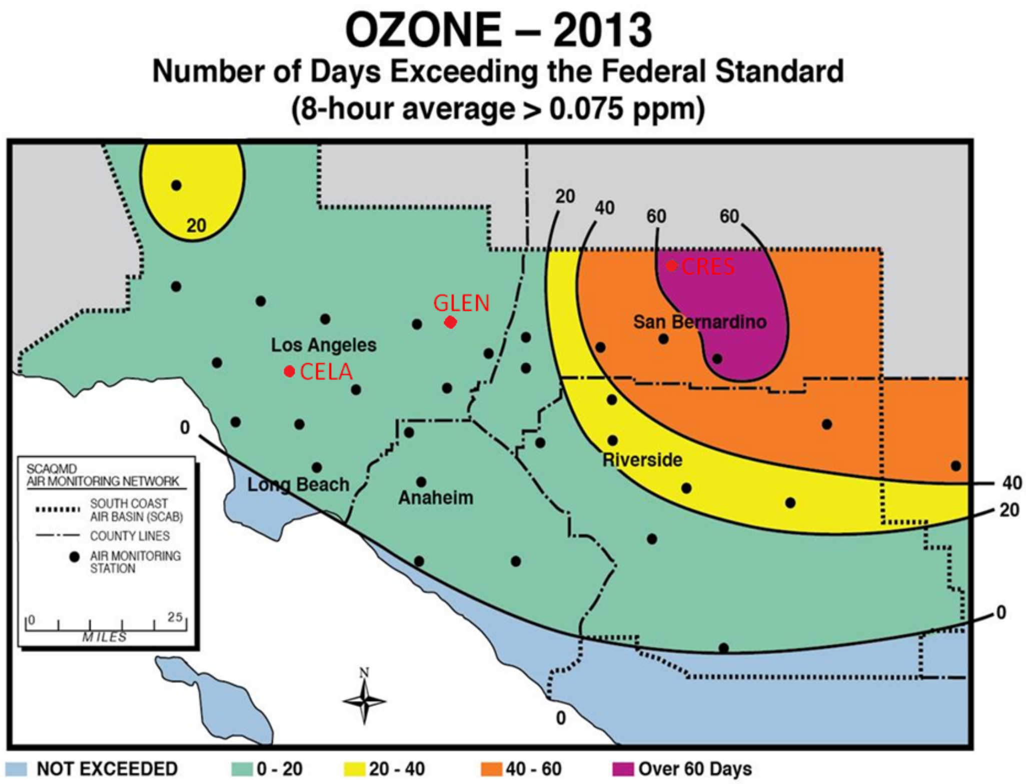


FIGURE 2

Spatial distribution of ozone exceedances in the SoCAB. Central Los Angeles (CELA), Glendora (GLEN), and Crestline (CRES) are highlighted.

How do VOCs form ozone?

Ozone (O_3) is not emitted directly into the atmosphere; near-surface ozone, in contrast to stratospheric ozone, is formed by the reaction of VOCs with NOx in the presence of sunlight. NOx is generated from combustion processes and is emitted in large quantities within the SoCAB. The chemical reactions that form ozone are highly complex and depend not only on NOx and VOC levels, but also on the ratio of VOC to NOx concentrations. NOx emissions can even reduce ozone concentrations in the immediate vicinity of an emission source, but will contribute to ozone formation downwind.

FIGURE 3

Recipe for ozone production

A decrease in ambient VOC concentrations generally leads to a decrease in ozone. However, because of the complex chemistry involved, a decrease in NOx concentrations may lead to a decrease or an increase in ambient ozone depending on the local VOC concentration. The local VOC concentration is a mixture of many distinct compounds, each with unique impacts on ozone formation. This complex dependence on NOx and VOC concentrations leads to interesting policy implications, which can be explored using comprehensive air quality models.

How Do VOCs Form Particulate Matter?

The SoCAB does not currently meet federal and state standards for PM2.5, particles with diameters less than 2.5 μm (FIGURE 4). These particles consist of a myriad of different chemical compounds in both solid and liquid form. While some PM2.5 is emitted directly from sources, the majority of ambient PM2.5 is formed from chemical reactions and processes in the atmosphere. These small particles are particularly dangerous due to their ability to penetrate deep into the lungs. Many studies have linked inhalation of PM2.5 to serious adverse respiratory and cardiovascular affects. In order to develop an effective control strategy, one must consider the composition and by extension, the sources of PM2.5 in the Basin. In the Basin, approximately 30-50% of the PM2.5 mass is composed of organic compounds. The remaining fraction consists of elemental carbon, metals, dust, and inorganic sulfate, nitrate, ammonium, and chloride compounds. The organic fraction, known as organic aerosol (OA), is composed of a complex mixture of organic chemicals that may continue to evolve as it ages in the atmosphere.

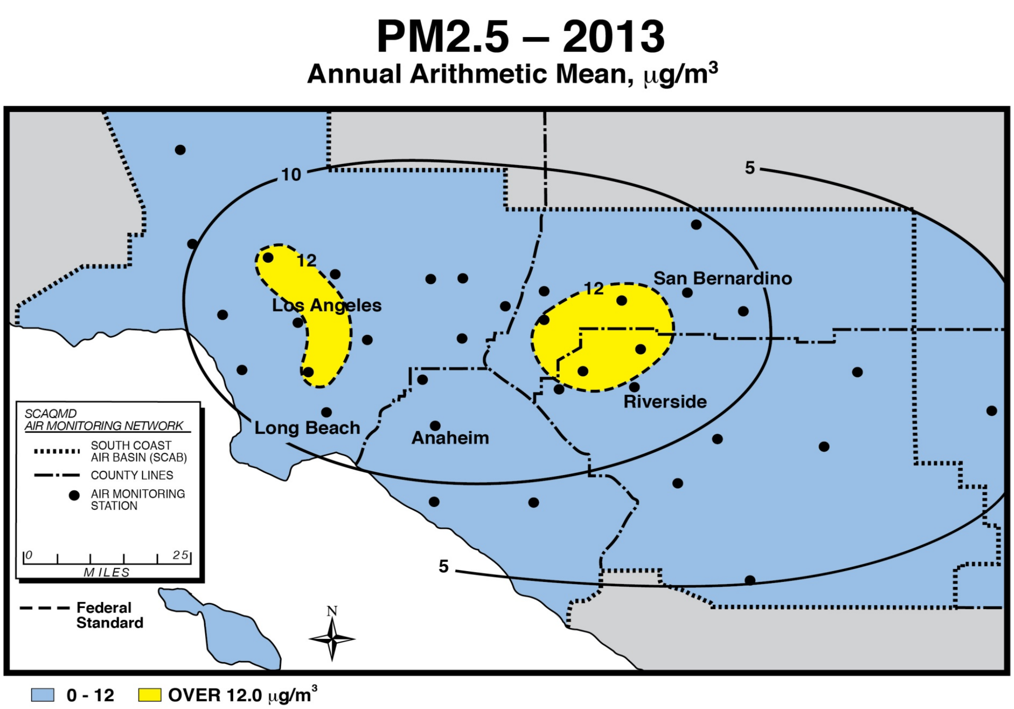


FIGURE 4

Spatial distribution of PM2.5 concentrations in the SoCAB

Different chemical reactions are responsible for the formation of ozone and OA from gaseous organic compounds. Since both ozone and PM2.5 formation are largely dominated by atmospheric reactions, we must consider the potential for a gaseous organic compound to contribute to both ozone and PM2.5 levels. Organic compounds with large ozone formation potentials may or may not contribute significantly to PM2.5 mass. Similarly, many gaseous organic compounds classified as VOCs, IVOCs, or SVOCs that contribute to OA may or may not play a role in the formation of ozone [2].

Ozone Control Modeling Analysis

The Community Multiscale Air Quality (CMAQ) model has been used to investigate the O_3 concentrations as a result of various levels of VOC and NOx emissions under different control strategies. The CMAQ model, which is the U.S. EPA recommended regulatory model, is considered the preeminent, state-of-the-science air quality model for analyzing air quality improvement strategies. Since ozone concentrations are a complex function of both NOx and VOCs concentrations, we use a three-dimensional plot to visualize this dependency. The Empirical Kinetics Modeling Approach (EKMA) ozone "isopleths" diagrams illustrate the outcomes of this complicated chemistry.

The ozone isopleth diagram in FIGURE 5 illustrates how 8-hour ozone concentrations in Crestline (the monitoring station currently with the most ozone exceedances in the Basin) respond to decreases in total Basin-wide anthropogenic VOC and NOx emissions beyond the existing adopted rules and regulations. In ozone isopleths, NOx and VOC emissions are each reduced from base levels equally across all sources; however, sensitivity tests demonstrate that the current cross-the-board reduction approach does not show significant differences from source-specific control scenarios and thus provides a reliable tool to evaluate potential attainment strategies. The corresponding ozone isopleths diagram for Central Los Angeles is presented in FIGURE 6. Estimated VOC and NOx emissions following the continued implementation of adopted rules and regulations in the 2023 timeframe are defined by the upper-right corner of the plot. The federal ozone standard is met within the yellow and green regions of the diagram (corresponding to Air Quality Index levels and colors). Three paths are illustrated on both isopleths diagrams to highlight the potential effects of different control strategies and to aid in policy discussions. Each control scenario on the plot illustrates the effects of reducing VOCs and/or NOx equally across all sources. Path C illustrates the impact of a control scenario that attains the ozone standards with only additional NOx reductions beyond what is required in current rules. In this scenario, additional VOC reductions beyond current requirements are not applied. A control scenario focusing solely on additional VOC control is shown with Path A. A hypothetical control scenario where additional (beyond scheduled reductions) NOx and VOC reductions occur at the same rate is illustrated with Path B. This is provided as an example of the results of a control strategy emphasizing VOC and NOx reductions equally.

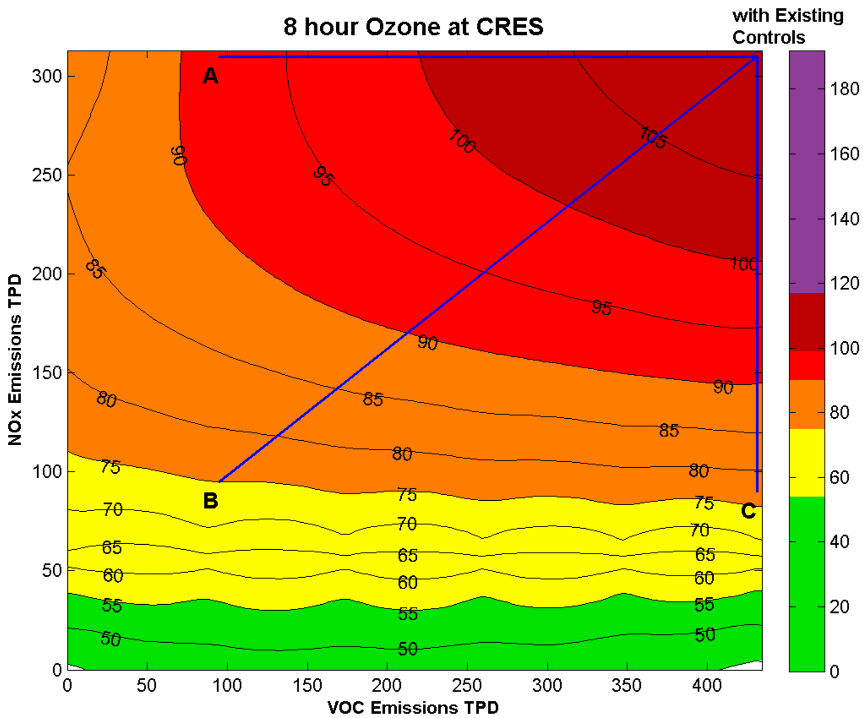


FIGURE 5

Ozone isopleths diagram showing 8-hour ozone isopleth at Crestline. The color shading corresponds to the air quality index (AQI) color code. This analysis is based on the emissions inventory used for the 2012 AQMP using CMAQ version 4.7, and will be updated for the 2016 AQMP analysis.

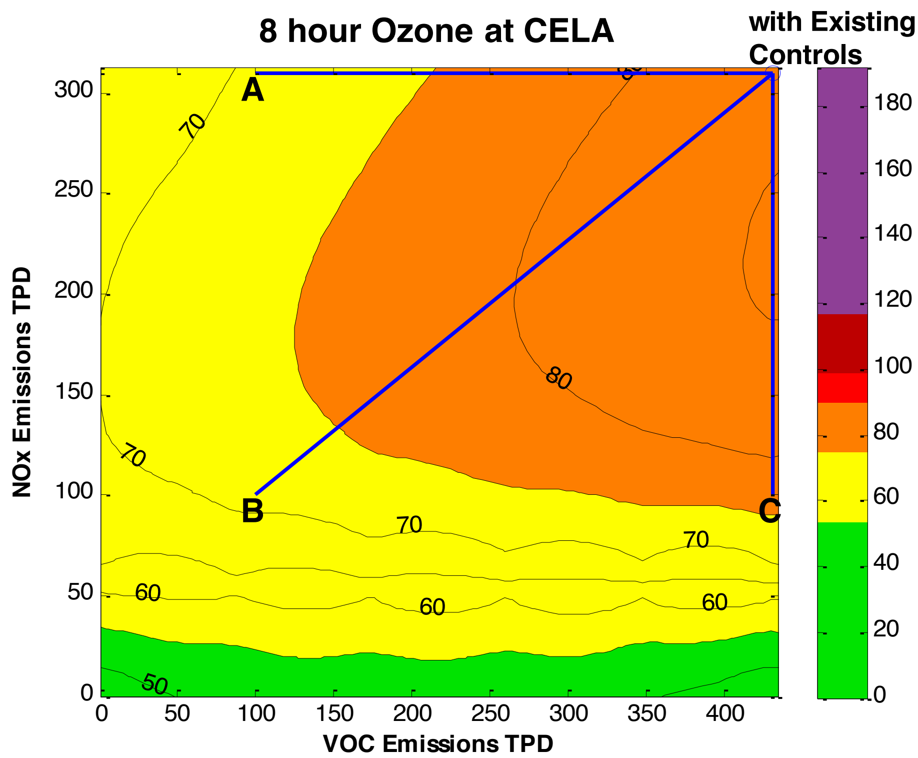


FIGURE 6

Ozone isopleths diagram showing 8-hour ozone isopleth at Central Los Angeles. The color shading corresponds to the air quality index (AQI) color code. This analysis is based on the emissions inventory used for the 2012 AQMP using CMAQ version 4.7, and will be updated for the 2016 AQMP analysis.

It is necessary to understand how ozone concentrations evolve during each of these three control paths at the Crestline and Central L.A. monitoring locations (FIGURE 7).

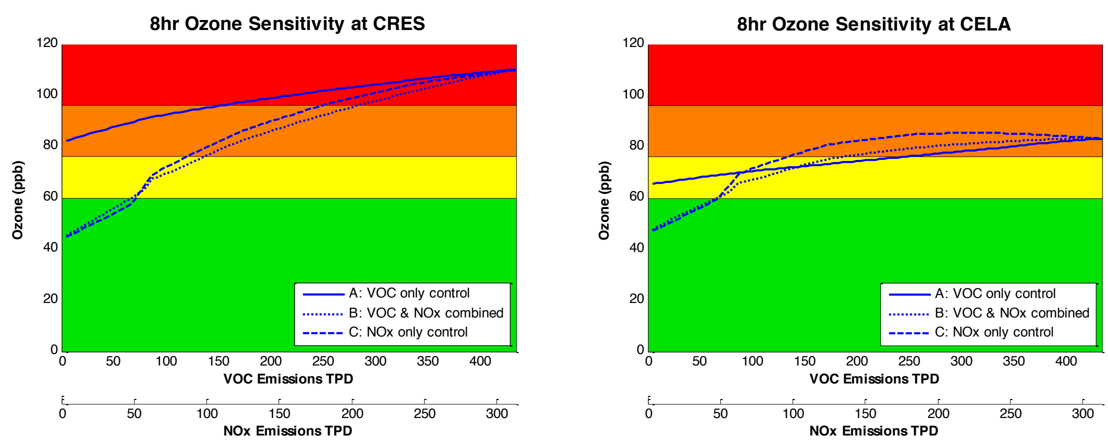


FIGURE 7

Ozone concentrations at Crestline and Central Los Angeles predicted to occur as a result of the specific control strategies (Paths A, B, and C) marked in FIGURE 5 and 6. This analysis is based on the emissions inventory used for the 2012 AQMP using CMAQ version 4.7, and will be updated for the 2016 AQMP analysis.

While the VOC-heavy control strategy (Path A from right to left) reaches attainment at CELA with the minimum amount of emissions reductions, this strategy will not lead to attainment at CRES, and thus the Basin, even with zero anthropogenic VOC emissions. Therefore, additional NOx reductions are required to achieve the ozone standards for both sites. Not only is the achievable endpoint different in each of the scenarios, the ozone concentrations predicted to occur along the path to attainment are also quite different. Moving from right to left in these figures along Path C, the NOx-heavy control strategy suggests that approximately an additional 200 ton per day (TPD) of NOx reductions beyond current regulations is required to attain the federal ozone standard (Note: Preliminary 2016 AQMP analysis suggests approximately 150 TPD is needed for attainment in 2023 rather than the 200 TPD, but the concepts regarding the emissions reduction scenarios are not expected to change). If NOx is reduced without additional VOC reductions beyond what is projected from current rules, as illustrated in Figure 7, there could be up to a 2 ppb increase in ozone in certain parts of the western Basin surrounding central LA along the path to attainment. FIGURE 8 shows the area that would be above the 1997 ozone standard of 80 ppb and how much the potential ozone exposure would increase. Several million people are estimated to be subject to this inadvertent increase of O3. It should be noted that this increased ozone phenomenon attributable to a NOx only reduction strategy is temporary and exists only along the path to attain the 80 ppb standard.

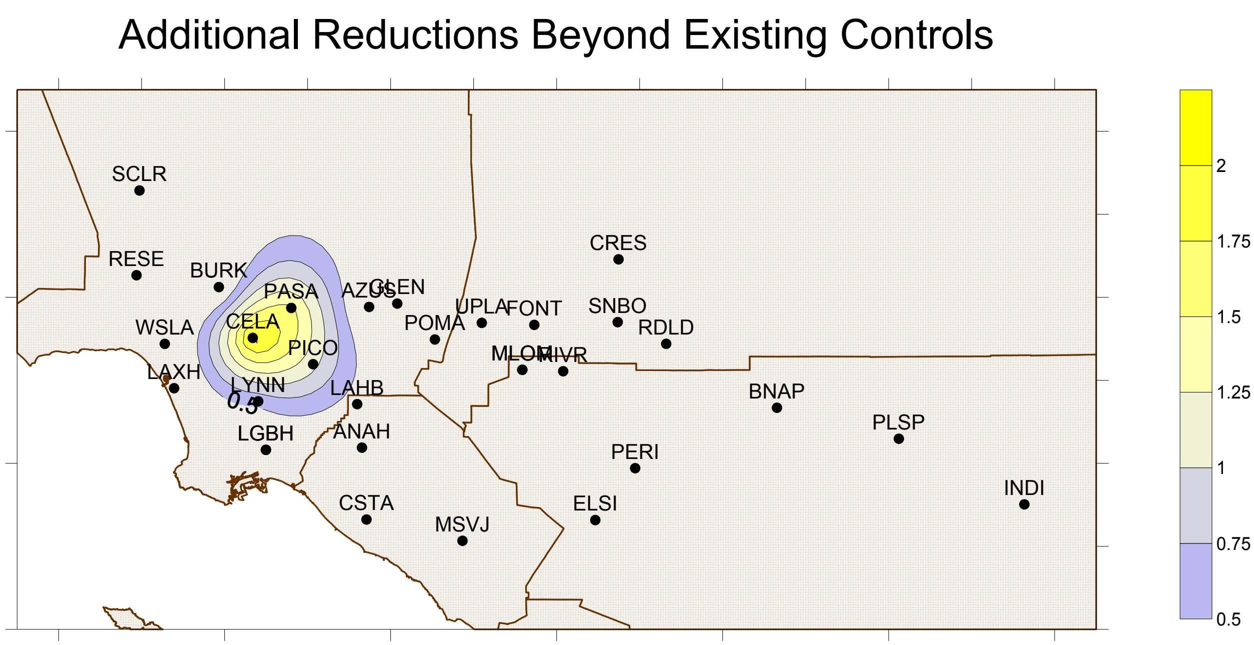


FIGURE 8

Maximum increase in ozone along the path to attainment with a pure NOx control strategy.
This analysis is based on the emissions inventory used for the 2012 AQMP using CMAQ version 4.7, and will be updated for the 2016 AQMP analysis.

Consideration of "Path to Clean Air" Scenarios

There are multiple paths to achieve ozone and PM2.5 standards based on various levels of control among the precursor pollutants. The total required emission reductions, technology readiness, cost-effectiveness, economic impacts, attainment deadlines, and the interaction with other attainment deadlines for other pollutants are all critical considerations in developing an overall multi-pollutant control strategy. Complex atmospheric chemistry and the non-uniform spatial distribution of both sources and the resulting ambient concentrations require a comprehensive analysis that ensures not only that ozone and PM2.5 meet standards, but also that unintended exposure increases are avoided if at all possible. Furthermore, concurrent reductions of other pollutants such as air toxics and greenhouse gases (GHGs) should also be considered in optimizing a path to meeting multiple standards, objectives, and deadlines.

NOx-Only Control Strategy (Path C)

As demonstrated above, a NOx-only approach can lead to attainment for the Basin. This approach does not require additional VOC controls and consequently has the minimum emission reduction tonnage and has commensurate benefits for PM2.5. Based on preliminary 2016 AQMP analysis, the amount of NOx reduction needed is estimated to be approximately 50-65% of total NOx emissions. While a reduction of this magnitude is challenging and will require significant investments, zero- and near zero- NOx emission reduction technologies currently exist, are in limited use, and can potentially be widely deployed in the next 10 to 20 years. Many of the currently available technologies needed for NOx reductions have air toxics and greenhouse gas co-benefits and vice-versa. Reducing NOx emissions will also mitigate adverse health effects associated with inhalation of locally elevated concentrations of NO_2, another criteria pollutant. However, this NOx-only (path C) approach leads to increased ozone and its exposure in the more densely populated western Basin during interim years to attainment. Consequently, millions of residents in the area would experience worse ozone air quality at levels above federal standards under this strategy.

VOC-Only Control Strategy (Path A)

A VOC-heavy control strategy without additional NOx controls, illustrated by Path A in Figure 6, will not lead to attainment of the ozone standards for the eastern Basin, even in the absence of any man-made VOC emissions. Furthermore, zero- and near-zero-VOC technologies for many of the major VOC-emitting categories (e.g. consumer products) may take many years for reformulation and market penetration, and are thus less mature than current low NOx technologies.

Combined NOx and VOC Control Strategies

A VOC and NOx combined strategy would require greater combined tons of reductions with greater associated compliance costs than a single-pollutant approach. However, a combined strategy would aid in mitigating interim increases in ozone, especially in the highly populated western side of the Basin, while potentially providing additional benefits for PM2.5, toxics, and greenhouse gases. Note that Path B in the above figures is provided only as an example, and a combined control strategy could lie anywhere between Path A and Path C that still reaches the ozone attainment.

For example, Figure 9 illustrates two potential scenarios, Paths D and E, designed to avoid the interim increase of ozone especially in the western Basin. Path D provides just enough additional VOC control (30 - 40 tons per day) to avoid any increases in ozone exposure above the 2023 attainment target of 84.5 ppb (this standard has been revoked, but the 2023 target remains with U.S. EPA's anti-backsliding provisions). Path E requires enough early VOC reductions to avoid any increases in ozone exposure in the western Basin. This would require approximately 100 tons per day of additional VOC controls, and for those controls to be timed to occur before the bulk of the NOx controls. In any case, the choice of the optimal path should consider multiple policy goals, including public health, cost-effectiveness, and economic impacts. Note that the isopleth analysis provided in this white paper is based on the 2012 AQMP emissions inventories, modeling methods, and air quality measurements. The 2016 AQMP will provide a complete update to this analysis, with potentially different levels of needed reductions under these varying scenarios.

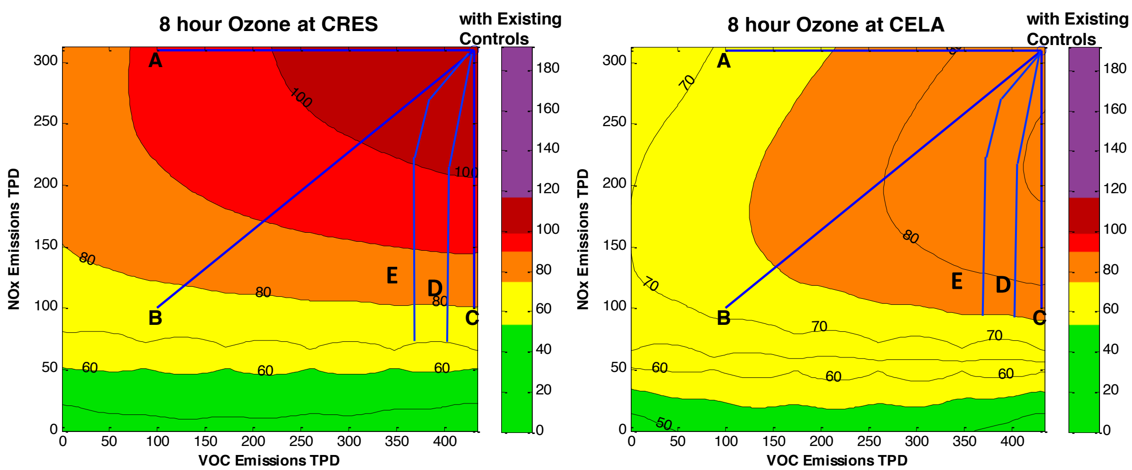


FIGURE 9

Additional emissions reduction options (Paths D and E) mitigating ozone increases in the western Basin (CELA). This analysis is based on the emissions inventory used for the 2012 AQMP using CMAQ version 4.7, and will be updated for the 2016 AQMP analysis.

Recommendations: NOx-Heavy Controls with Strategic and Tiered VOC Reductions

Given the availability of technology, climate and PM2.5 objectives, a desire to minimize control costs, and the lack of a viable path to attainment with VOC reductions only, a NOx-heavy approach with modest VOC controls as shown in Path D is preferred. It continues the path that was taken by both the 2007 and 2012 AQMPs that focuses primarily on NOx reductions, but is augmented with modest VOC reductions to mitigate increased ozone exposures along the path to attainment. According to this 2012 AQMP analysis, approximately 200 tons per day of NOx would be needed by 2023, and mitigating the interim ozone increases would require about 30 to 40 tons per day, or less than 10 percent of total anthropogenic VOC emissions beyond the existing adopted rules and regulations. However, preliminary 2016 AQMP analysis suggests approximately 150 tons per day of NOx reductions are needed by 2023, and will re-analyze the need for and effect of VOC reductions.

Reductions in VOC must occur at the earlier stage of control so that the path goes around the 85 ppb contour line illustrated as Path D and E in the Central Los Angeles (CELA) plot of Figure 9. It should be noted that Path D would also result in concurrent PM2.5 reductions throughout the entire air basin, which are needed to address the current PM2.5 annual standard of 12 μg/m^3.

Therefore, a control strategy that continues to focus on NOx reductions, with additional strategic and cost-effective VOC reductions, is the most desirable way to minimize the general public's exposure to unhealthy ozone pollution not only in the target attainment year, but also during the course of the control effort. The next section discusses a prioritized strategy to achieve cost-effective VOC reductions that maximizes co-benefits and emphasizes non-regulatory approaches.

Note that this analysis is based on the attainment demonstration used in the 2012 AQMP. A new analysis with updated emissions inventory, meteorological parameterizations and photochemical reaction mechanisms will be conducted during development of the 2016 AQMP. The general findings of the control strategies outlined above are expected to be similar, but the amount of reductions needed to attain the standard will be revised based on the most updated science and U.S. EPA attainment guidance (U.S. EPA 2014).

Tiered Approach to VOC Reductions

Based on the above analysis of the overall path to attainment and the role VOCs play in the ozone control program, control strategies continue to focus on significant NOx reductions but include meaningful VOC reductions where appropriate. In order of priority, the following potential strategy considerations are designed to achieve VOC reductions in a cost-effective and targeted fashion considering the co-benefits from and to other air quality objectives:

1. *Maximize co-benefits from NOx, GHG or air toxics controls that produce concurrent VOC reductions*

   Certain zero- or near-zero NOx technologies would also lead to VOC reductions. Given the continued NOx-heavy strategy, policies should promote technologies with these additional VOC co-benefits. For example, electric and hydrogen fuel cell vehicles, efficiency measures, or vehicle miles traveled (VMT) reductions produce both NOx and VOC reductions; many of these strategies also avoid evaporative losses associated with traditional fuels like gasoline. Similarly, control technologies for GHGs and air toxics may also produce concurrent VOC reductions. The 2016 AQMP will aim to better integrate and quantify these VOC reductions into the attainment plan.

2. *Promote pollution prevention at the source with associated cost savings*

   Reducing waste at the source is an efficient and effective way to reduce emissions. This strategy could involve the implementation of more robust leak detection and repair (LDAR) programs, including Smart LDAR using advanced infrared or optical technologies. This approach can lead to cost savings as less product is lost through fugitive emissions. In other cases, this approach could reduce the use of VOC-containing products and/or the reliance on after-treatment control technology. This also can lead to cost savings. Examples of this are incentives and programs promoting the use of higher transfer efficiency spray painting equipment.

3. *Incentivize super-compliant zero- and near-zero VOC materials, especially during peak ozone season*

   Super-compliant zero- and near-zero VOC materials eliminate or drastically reduce emissions during the use of these products. There are several product categories where these materials perform as well as traditional products and are widely available in the market. Incentives to promote the use of super-compliant products containing no or little VOCs during ozone season could reduce ozone concentrations when exceedances are typically experienced.

4. *Maximize reductions from existing regulations via enhanced enforcement actions, removal of potential regulatory loopholes, and expanded reporting programs*

   Enhanced enforcement and the tightening of regulatory exemptions that may be used as loopholes in lieu of compliant technologies can lead to reduced emissions. Additionally, recent sales and emissions reporting programs have led to increased understanding of the VOC inventory, incentivized clean technology through fee structures, and better-focused future enforcement and regulatory actions. These enhancements not only ensure that the reductions assumed in the AQMP are actually occurring, but also allow the plan to capture market trends and compliance margins that go beyond the regulatory requirements.

5. *Prioritize emission reductions of the VOC species that are most reactive for ozone and/or PM2.5 formation and that produce concurrent air toxics or GHG benefits*

   The California Air Resources Board has an active reactivity program to investigate the scientific and policy implications of reactivity-based regulations [3]. Reducing emissions of the most reactive species, considering ozone and PM2.5 formation along with enforceability, toxicity, and climate impacts, may be an efficient method to reduce ambient ozone and PM2.5 concentrations, achieve multiple environmental and health benefits, while minimizing market disruptions. For example, for VOC controls that are equally cost-effective in terms of cost per unit of emissions reduced, controls for higher reactivity VOCs would be more cost-effective in terms of costs per unit of ozone reduced.

6. *Avoid toxicity trade-offs from exempt VOC replacements*

   In recent years more and more manufacturers are formulating their compliant products using exempt VOCs, which are VOCs that do not contribute significantly to ozone formation. However, sometimes these compounds may have or be suspected to have adverse health impacts. Their associated potential toxic risks, in comparison with existing products, are a complex issue in terms of how they are being used by workers or the general public and associated work practices to reduce exposure. In some cases, health impacts may involve different health end points (acute vs. chronic or cancer risks) than existing formulations. SCAQMD staff held a one-day technical symposium on this issue to solicit inputs from experts in the field. Emerging from this and other discussions, is a policy debate as to whether we should treat new chemicals as "innocent until proven guilty" (i.e., not toxic until a risk factor is formally assigned by a health agency). In light of the amount of VOC reductions needed for attainment and other available VOC control opportunities, a precautionary approach is recommended to avoid particular VOC reductions that could potentially lead to the increased use of chemicals that are known or suspected to be toxic until it can be demonstrated that they would not create more toxic risks for workers or the public than the compounds they are replacing.

7. *Further evaluation of the practicality and effectiveness for time and place controls*

Most ozone exceedances occur during the months of May through September (the "ozone season") when higher ambient temperatures and stronger solar radiation intensities accelerate ozone formation rates. In addition, during the ozone season, higher temperatures increase the volatility of organic compounds, leading to accelerated evaporation and larger emissions of precursor compounds. In contrast, PM2.5 concentrations are typically highest during the winter months when stagnant weather and temperature inversions trap emissions close to the ground. The implications of controlling ozone and PM2.5 sources differently based on location and season can be evaluated further through modeling exercises.

8. *Conduct further studies related to VOCs*

Over the years, knowledge of the VOC emissions inventory, speciation profiles, and reactivity has improved significantly. Several topics should be further investigated to build a stronger scientific basis for future VOC control programs. These include optical remote sensing technologies that allow for the detection of emissions in locations where traditional monitoring techniques are not practical. Such fence-line systems could enhance the accuracy of emissions inventories, provide an alarm system in the case of process disruptions, and offer opportunities for real-time feedback for process and emissions control to the facility operator. Furthermore, ongoing and future studies of emissions, evaporation rates, ambient concentrations, ozone formation, and PM2.5 formation from SVOCs, IVOCs, and LVP-VOCs will help determine if controlling these compounds could assist the attainment strategies for ozone and PM2.5.

Conclusions

While air quality has improved considerably in the SoCAB over the past few decades, further emission reductions must be made to attain the federal standards for ozone and PM2.5. The analysis herein indicates that a NOx-heavy strategy accompanied by more modest VOC reductions will help to avoid temporary increases in ozone concentrations in the western side of the Basin. This finding reaffirms the previous NOx-heavy State Implementation Plan (SIP) strategies to meet both PM2.5 and ozone standards, but recognizes that VOC reductions can be given a lower priority. To this end, a strategic VOC control program is recommended for the 2016 AQMP to first maximize co-benefits of NOx, GHG, and air toxic controls, followed by controls that could create a win-win, "business case" for the affected entities, incentives for super-compliant products, while ensuring and capturing benefits from implementation of existing rules. When additional VOC controls are still needed, it is recommended to prioritize controls that will produce co-benefits for air toxics and GHGs, with a focus on VOC species that are most reactive in ozone and/or PM2.5 formation.

References

1. E.P.A., U.S., *National Ambient Air Quality Standards for Ozone: A Proposed Rule by the Environmental Protection Agency*. 79 FR 75233. 2014.
2. Gentner, D.R., et al., *Chemical Composition of Gas-Phase Organic Carbon Emissions from Motor Vehicles and Implications for Ozone Production.* Environmental Science & Technology, 2013. **47**(20): p. 11837-11848.
3. Chen, J. and D. Luo, *Ozone formation potentials of organic compounds from different emission sources in the South Coast Air Basin of California.* Atmospheric Environment, 2012. **55**(0): p. 448-455.

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

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

South Coast AQMD

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Passenger Transportation

2016 AQMP WHITE PAPER

OCTOBER 2015

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

Randall Pasek, Ph.D.
Planning and Rules Manager
Off-Road Strategies Section

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

APPENDIX A – CURRENT EMISSIONS CONTROL PROGRAMS

APPENDIX B – POTENTIAL EMISSION REDUCTION TECHNOLOGIES AND EFFICIENCY MEASURES

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 passenger transportation sector, which includes (for the purposes of this paper) passenger cars, passenger vans, light-duty trucks, and sport utility vehicles; transit and school buses; passenger locomotives; aircraft; and marine vessels such as cruise ships and ferries.

To illuminate policy choices relevant to the AQMP, the paper describes a number of potential scenarios for reducing emissions from the passenger transportation 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, electric power, and the use of operational efficiency measures such as intelligent transportation systems, mode choice, and active transportation.

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 passenger transportation emissions source categories. The following sections present brief descriptions of the current regional passenger system, 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 an initial assessment of the issues and questions raised from the analysis. In addition, operational efficiencies and alternative mobility choices 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 portions 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. [1]

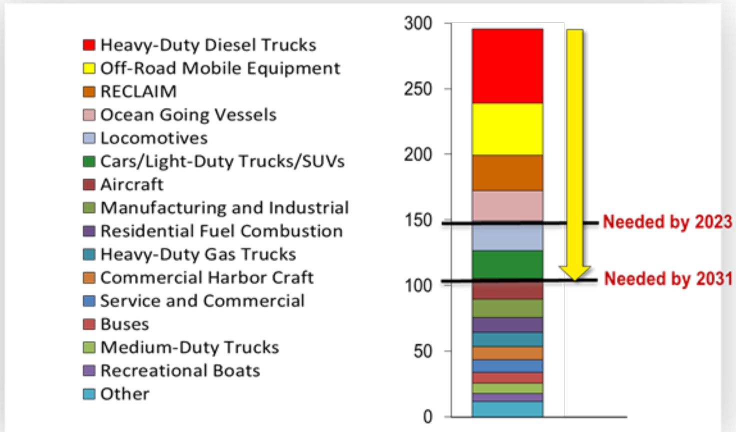
The SCAQMD region includes approximately 21,000 miles of highways and arterials, 450 miles of passenger rail, and six commercial airports. It is estimated that about 90 percent of trips in the SCAQMD make use of the highway and arterial system, utilizing various transportation modes including automobile, public transit, and active transportation (e.g., bicycling on arterial streets).[2]

Attainment Challenge

Meeting 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% in 2023 and 65% 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.

[1] 2012-2035 Regional Transportation Plan, Southern California Association of Governments, April 2012

[2] *Ibid.*



(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 passenger transportation 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 passenger transportation sector, including incentivizing the early introduction of zero- and near-zero emission vehicles and identification of potential new funding mechanisms to support widespread penetration of such technologies within the transportation sector.

Clearly, aggressive and coordinated technology development and deployment efforts are needed in the transportation sector over the next 10 to 20 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.

PASSENGER TRANSPORTATION EMISSIONS SOURCE CATEGORIES

Tables 1 and 2 provide a list of passenger transportation emissions source categories for the discussion purposes of this white paper. The on-road emissions source categories shown in Table 1 include light-duty vehicles up to 5,750 lbs GVWR (gross vehicle weight rating), medium-duty vehicles (5,751 to 8,500 lbs GVWR), and heavy-duty vehicles with gross vehicle weight ratings greater than 8,500 lbs. Examples of light-duty vehicles include passenger cars, light-duty trucks, sport utility vehicles, and minivans. Medium-duty vehicles include heavier pickup trucks and passenger and cargo vans. Heavy-duty vehicles include passenger shuttles, transit buses, school buses, and motor homes. In addition to the vehicles listed above, motorcycles are included in the passenger transportation sector. To provide greater insight into the emissions contributions of each source category, the emissions are further disaggregated by weight category. For example, light-duty trucks are separated into two categories: LDT1 (up to 3,750 lbs GVWR) and LDT2 (3,751 to 5,750 lbs GVWR).

TABLE 1

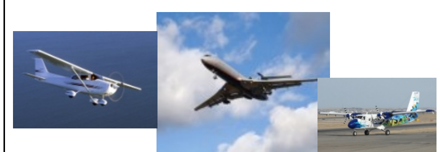
On-Road Transportation Categories

Description/ Weight Class (lbs)	
Passenger Car/Light Duty Automobile (LDA)	
Light-Duty Trucks 1 (LDT-1) (Up to 3,750)	
Light-Duty Trucks 2 (LDT-2) (3,751 – 5,750)	
Medium-Duty Vehicles (MDV) (5,751 – 8,500)	
Motorcycles (MCY)	
School Buses (SBUS)	
Urban Buses (UBUS)	
Other Buses (OBUS)	
Motor Homes (MH)	

Table 2 shows the various off-road emissions source categories that are part of the passenger transportation sector. These categories include passenger rail, passenger and excursion ferries, cruise ships, and commercial and general aviation aircraft.

TABLE 2

Off-Road Transportation Categories

Description	
Ocean-Going Vessels (Cruise Ships)	
Commercial Harbor Craft (Ferries and Excursion Vessels)	
Commuter Rail (Passenger Locomotives)	
Aircraft (Commercial and General Aviation)	

Air Quality Impacts of Passenger Transportation Sources

The adoption and implementation of control strategies specific to the passenger transportation 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. A discussion of the current regulatory programs and other planning efforts in the passenger transportation sector is provided in Appendix A.

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 passenger transportation sector and their contribution to the total emissions for 2014, 2023, and 2032. For 2014, passenger transportation sources contribute approximately 23 and 28% of the South Coast Air Basin's VOC and NOx emissions inventory. The percent contribution from passenger transportation sources to total VOC and NOx emissions in 2032 are 11 and 21%, respectively.

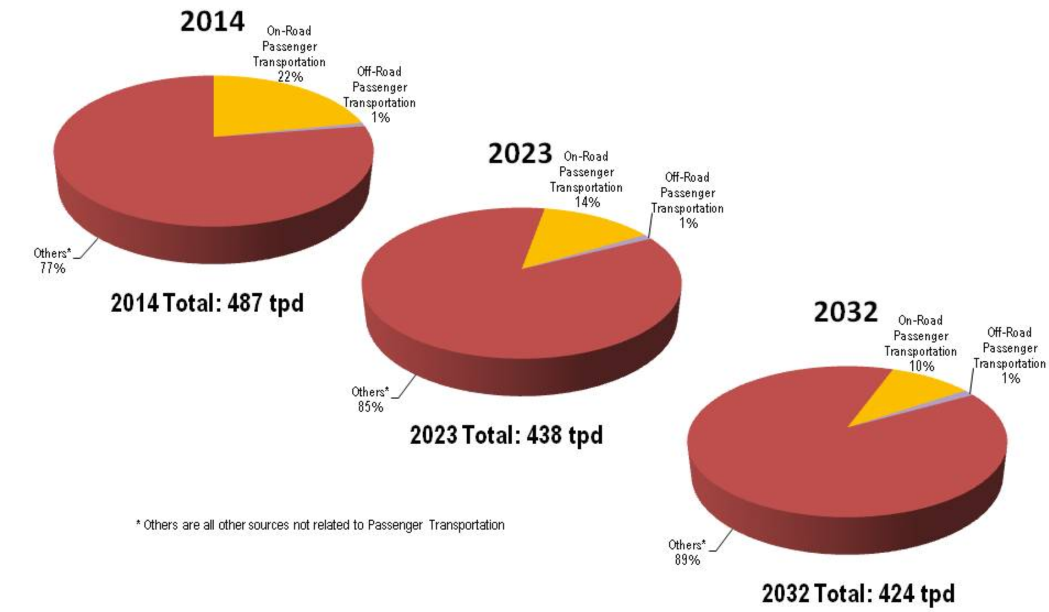


FIGURE 2

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

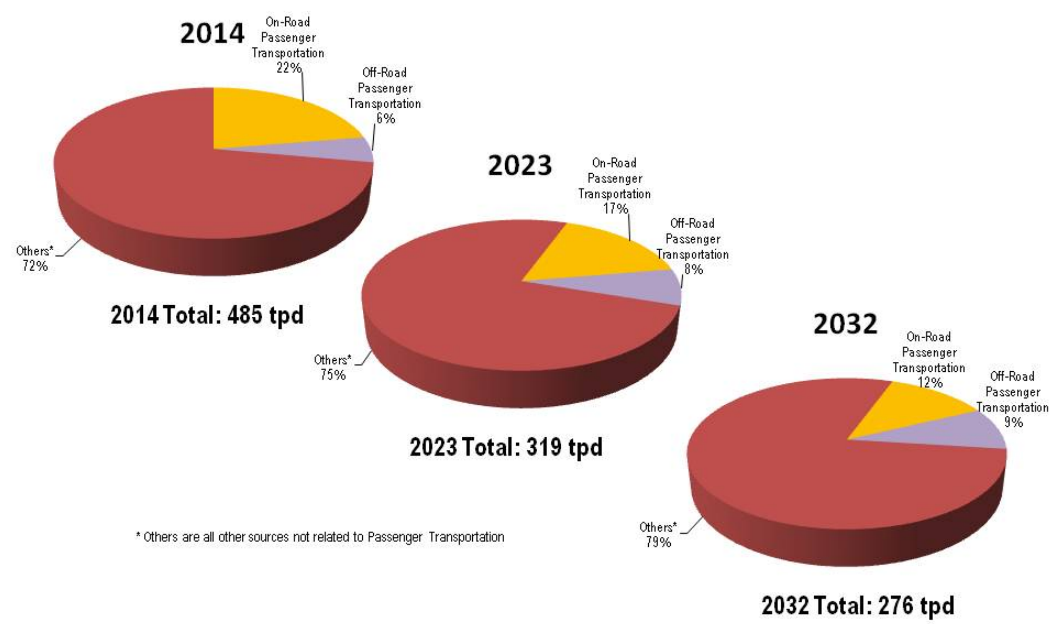


FIGURE 3

Passenger Transportation 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 passenger transportation 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 Passenger Transportation Sector for Calendar Year 2014 (Source: 2012 AQMP)

Source Category	Population	VMT (miles/day)	VOC (tons/day)	NOx (tons/day)
Light Duty Passenger	5,728,985	202,036,463	44.63	31.00
Light Duty Trucks-1 (up to 3750 lb.)	670,990	23,667,541	13.61	9.02
Light Duty Trucks-2 (3751 to 5750 lb.)	1,873,658	70,389,181	19.24	20.33
Medium Duty Trucks (5751-8500 lb.)	1,545,179	54,982,815	19.71	23.84
Heavy Duty Diesel Urban Buses	7,114	762,389	0.5	12.67
Heavy Duty Gas Urban Buses	1,787	191,845	0.32	0.67
School Buses - Gas	1,510	54,279	0.08	0.12
School Buses - Diesel	4,643	172,951	0.04	2.15
Other Buses - Gas	7,024	290,381	0.36	0.86
Other Buses - Diesel	5,499	435,008	0.13	4.21
Motor Homes	70,444	782,786	0.19	1.47
Motorcycles	222,597	1,627,281	7.29	2.06
Total	**10,139,428**	**355,392,919**	**106.10**	**108.40**

TABLE 4

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

Source Category	Population	VMT (miles/day)	VOC (tons/day)	NOx (tons/day)
Light Duty Passenger	6,045,577	202,227,892	18.24	12.34
Light Duty Trucks-1 (up to 3750 lb.)	716,203	24,037,227	7.83	4.33
Light Duty Trucks-2 (3751 to 5750 lb.)	2,036,593	73,251,629	10.91	7.66
Medium Duty Trucks (5751-8500 lb.)	1,703,888	56,678,252	14.93	11.92
Heavy Duty Diesel Urban Buses	7,613	815,970	0.43	10.43
Heavy Duty Gas Urban Buses	1,958	210,257	0.3	0.61
School Buses - Gas	1,683	60,450	0.04	0.07
School Buses - Diesel	4,770	170,017	0.04	1.73
Other Buses - Gas	7,417	277,729	0.28	0.5
Other Buses - Diesel	6,444	528,964	0.1	0.94
Motor Homes	83,646	948,629	0.07	0.97
Motorcycles	239,153	1,734,034	6.58	2.03
Total	**10,854,946**	**360,941,049**	**59.75**	**53.53**

TABLE 5

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

Source Category	Population	VMT (miles/day)	VOC (tons/day)	NOx (tons/day)
Light Duty Passenger	6,198,902	208,469,240	8.88	6.83
Light Duty Trucks-1 (up to 3750 lb.)	774,282	26,511,038	4.69	1.91
Light Duty Trucks-2 (3751 to 5750 lb.)	2,220,575	80,214,386	8.51	4.48
Medium Duty Trucks (5751-8500 lb.)	1,881,310	62,155,336	12.43	6.82
Heavy Duty Diesel Urban Buses	8,234	882,829	0.35	7.85
Heavy Duty Gas Urban Buses	2,159	231,860	0.13	0.54
School Buses - Gas	1,890	67,874	0.02	0.05
School Buses - Diesel	4,808	165,524	0.05	1.07
Other Buses - Gas	7,924	297,772	0.26	0.37
Other Buses - Diesel	7,365	618,352	0.12	1.15
Motor Homes	113,494	1,308,532	0.05	0.92
Motorcycles	242,094	1,732,796	6.85	2.07
Total	**11,463,038**	**382,655,538**	**42.34**	**34.06**

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

TABLE 6

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

Source Category	VOC (tons/day)	NOx (tons/day)
Ocean-Going Vessels (Cruise Ships)	0.22	5.91
Passenger Locomotives	0.21	4.46
Harbor Craft (Ferries and Excursion Vessels)	0.42	4.09
Aircraft (Excluding Air Cargo Transport)	3.05	12.13
Total	**3.90**	**26.59**

TABLE 7

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

Source Category	VOC (tons/day)	NOx (tons/day)
Ocean-Going Vessels (Cruise Ships)	0.24	3.54
Passenger Locomotives	0.26	4.46
Harbor Craft (Ferries and Excursion Vessels)	0.43	3.32
Aircraft (Excluding Air Cargo Transport)	3.93	13.59
Total	**4.86**	**24.92**

TABLE 8

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

Source Category	VOC (tons/day)	NOx (tons/day)
Ocean-Going Vessels (Cruise Ships)	0.38	2.15
Passenger Locomotives	0.27	4.92
Harbor Craft (Ferries and Excursion Vessels)	0.43	3.30
Aircraft (Excluding Air Cargo Transport)	4.62	14.74
Total	**5.70**	**25.11**

Emissions Reduction Progress to Date

The following sections describe the historic emission trends from the on-road and off-road passenger transportation sources.

On-Road Passenger Transportation Emission Sources

As shown in Figure 4, on-road passenger transportation source emissions of VOC, NOx, and PM have experienced reductions ranging from 84 percent to 88 percent from 1990 levels. These reductions have primarily relied upon development and commercialization of technologies that control emissions from internal combustion engines.

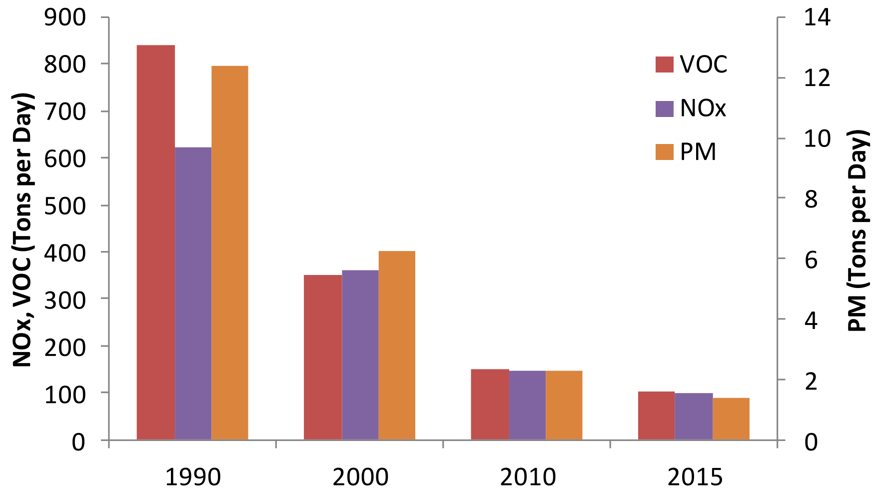


FIGURE 4

On-Road Passenger Transportation Sources
(Source: EMFAC2011 with Vehicle Miles Traveled Information from the 2012 AQMP)

NOx and VOC emissions from on-road passenger transportation emission sources 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 emissions due to the impact of regulatory programs for specific sources of emissions in the passenger transportation sector. 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 passenger transportation emission sources over time, as illustrated in Figure 7.

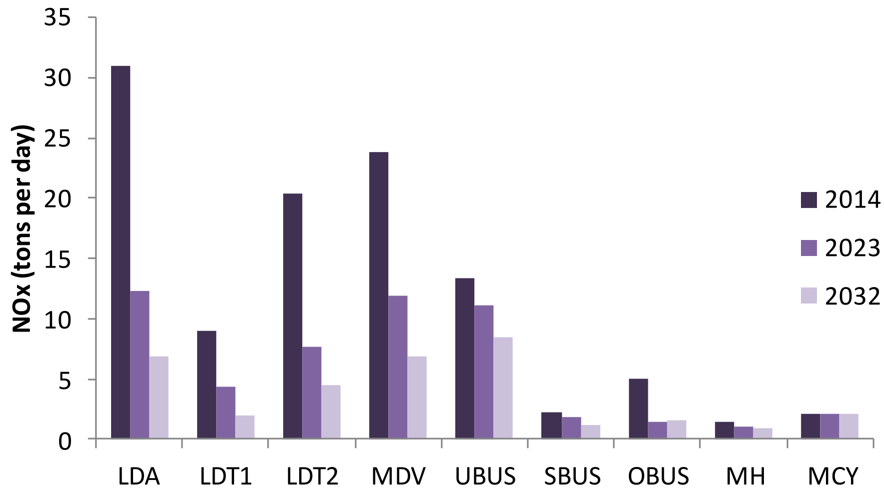


FIGURE 5

NOx Emissions for Specific On-Road Passenger Transportation Sources

(Source: 2012 AQMP)

(LDA – Light Duty Automobile; LDT1 and LDT2 –Light-Duty Trucks;
MDV – Medium-Duty vehicles; UBUS – Urban Buses; SBUS – School Buses:
OBUS – Other Buses; MH – Motorhomes; MCY – Motorcycles)

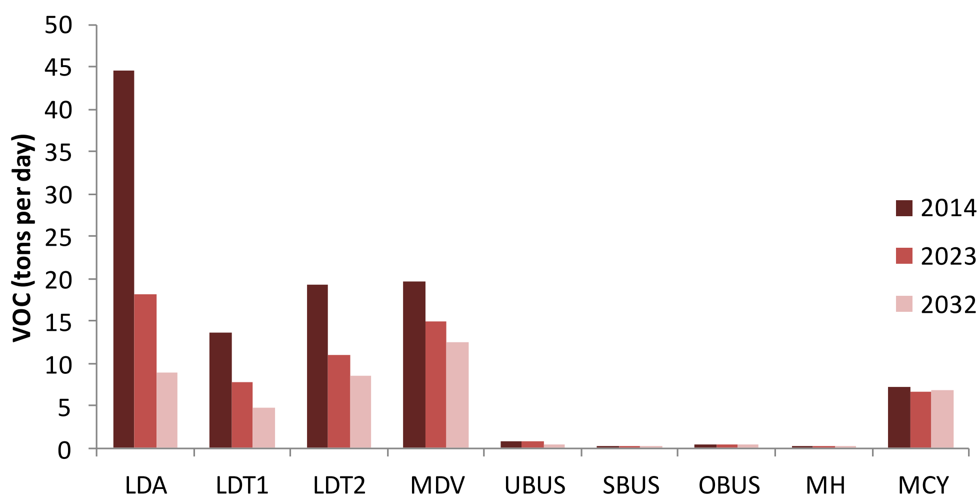


FIGURE 6

VOC Emissions for Specific On-Road Passenger Transportation Sources

(Source: 2012 AQMP)

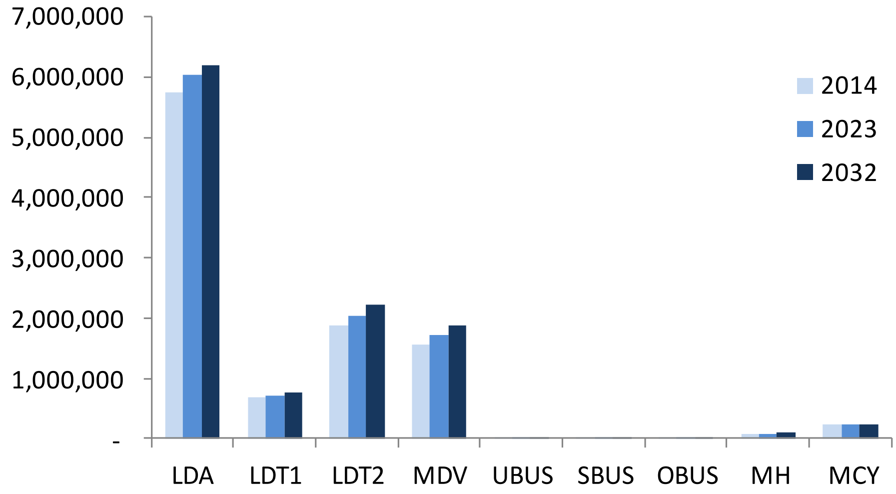


FIGURE 7

Populations for Specific On-Road Passenger Transportation Sources

(Source: 2012 AQMP)

Off-Road Passenger Transportation Emission Sources

NOx and VOC emissions from off-road passenger transportation sources 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 of emissions in the passenger transportation sector. Aircraft and commuter rail emissions of NOx increase over time due to greater activity and no additional regulations. Cruise ship and ferry/excursion vessel NOx emission decrease over time due to state regulations.

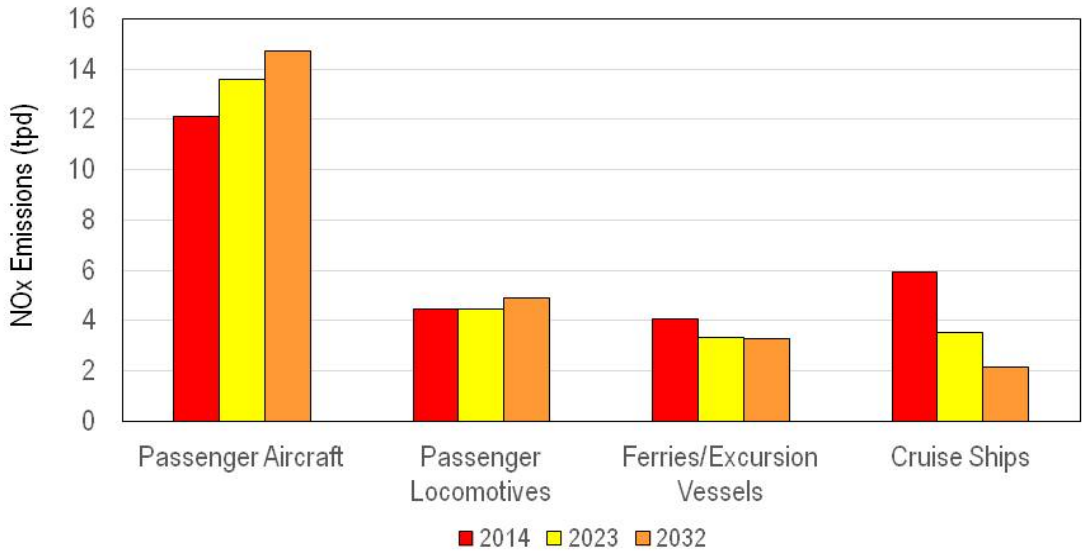


FIGURE 8

NOx Emissions for Specific Off-Road Passenger Transportation Sources

(Source: 2012 AQMP)

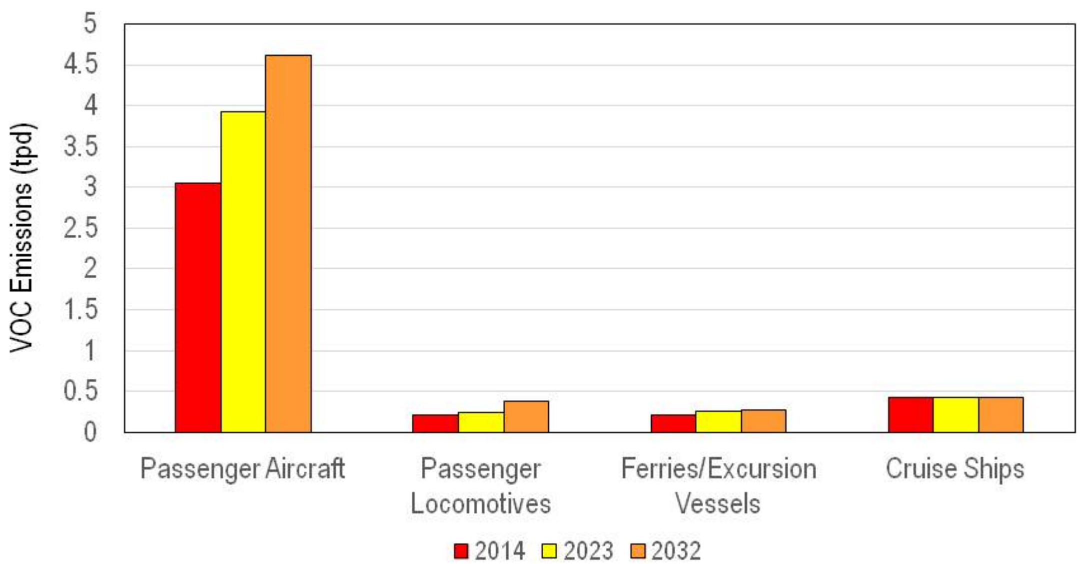


FIGURE 9

VOC Emissions for Specific Off-Road Passenger Transportation 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 passenger transportation emission source categories 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 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 transportation source category baseline emissions are reduced by 65% for 2023 and 75% for 2032 (from the 2023 baseline emissions).
- 100 Percent Existing Standards
  Under this scenario, all vehicle NOx emissions are assumed to be at the greatest level of control based on current exhaust emissions standards.
- 90 Percent Cleaner Combustion Technologies
  Transit and school bus NOx emissions are assumed to achieve additional 90 percent or cleaner emission levels beyond existing emission standards. Passenger locomotives and

marine 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%, 50%, and 75% 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 Passenger Transportation Vehicles

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
LDA	12.34	4.32	5.17	5.17	3.88	2.58	1.29
LDT1	4.33	1.52	0.98	0.98	0.73	0.49	0.24
LDT2	7.66	2.68	2.86	2.86	2.15	1.43	0.72
MDV	11.92	4.17	2.82	2.82	2.11	1.41	0.70
UBUS-DSL	10.43	3.65	0.50	0.05	0.04	0.02	0.01
UBUS-GAS	0.61	0.21	0.08	0.01	0.01	0.00	0.00
SBUS-GAS	0.07	0.02	0.01	0.00	0.00	0.00	0.00
SBUS-DSL	1.73	0.61	0.28	0.03	0.02	0.01	0.01
OBUS-GAS	0.5	0.18	0.18	0.02	0.01	0.01	0.00
OBUS-DSL	0.94	0.33	0.94	0.09	0.07	0.05	0.02
MH	0.97	0.34	0.53	0.05	0.04	0.03	0.01
MCY	2.03	0.71	2.03	2.03	2.03	2.03	2.03
Total	**53.53**	**18.74**	**16.36**	**14.10**	**11.09**	**8.07**	**5.05**

(b) Off-Road Passenger Transportation

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	3.54	1.24	1.32	0.99	0.99	0.99	0.99
Passenger Locomotives	4.46	1.56	1.07	0.11	0.08	0.06	0.03
Harbor Craft	3.32	1.16	0.88	0.57	0.57	0.57	0.57
Aircraft	13.59	4.76	3.40	3.40	3.40	3.40	3.40
Total	**24.92**	**8.72**	**6.67**	**5.07**	**5.04**	**5.01**	**4.98**

(c) Total On-Road and Off-Road Passenger Transportation

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	**78.45**	**27.46**	**23.03**	**19.17**	**16.13**	**13.08**	**10.03**

TABLE 10

Remaining NOx Emissions (tons/day) in 2032

(Baseline and Equal Share Emissions from the 2012 AQMP)

(a) On-Road Passenger Transportation Vehicles

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
LDA	6.83	3.07	5.33	5.33	4.00	2.66	1.33
LDT1	1.91	1.09	1.08	1.08	0.81	0.54	0.27
LDT2	4.48	1.93	3.13	3.13	2.35	1.57	0.78
MDV	6.82	3.00	3.09	3.09	2.32	1.54	0.77
UBUS-DSL	7.85	2.59	0.54	0.05	0.04	0.03	0.01
UBUS-GAS	0.54	0.15	0.10	0.01	0.01	0.01	0.00
SBUS-GAS	0.05	0.02	0.01	0.00	0.00	0.00	0.00
SBUS-DSL	1.07	0.43	0.30	0.03	0.02	0.02	0.01
OBUS-GAS	0.37	0.12	0.22	0.02	0.02	0.01	0.01
OBUS-DSL	1.15	0.23	1.15	0.11	0.09	0.06	0.03
MH	0.92	0.92	0.75	0.08	0.06	0.04	0.02
MCY	2.07	0.52	2.07	2.07	2.07	2.07	2.07
Total	**34.06**	**14.07**	**17.77**	**15.00**	**11.77**	**8.54**	**5.30**

(b) Off-Road Passenger Transportation

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	1.79	0.50	1.76	1.36	1.36	1.36	1.36
Passenger Locomotives	4.91	1.38	2.12	0.21	0.16	0.11	0.05
Harbor Craft	3.30	0.76	0.92	0.6	0.60	0.60	0.60
Aircraft	15.06	3.46	7.53	7.53	7.53	7.53	7.53
Total	**25.06**	**6.10**	**12.32**	**10.00**	**9.95**	**9.90**	**9.85**

(c) Total On-Road and Off-Road Passenger Transportation

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	**59.12**	**20.17**	**30.09**	**25.00**	**21.72**	**18.44**	**15.15**

Equal Share Reduction in NOx Scenario

For the 2023 attainment year, an overall 65% NOx reduction for all source categories in the South Coast Air Basin was determined 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 passenger transportation source categories, resulting in an overall decrease of NOx emissions from 53.53 tons/day to 18.74 tons/day for on-road passenger transportation vehicles, and NOx emissions decrease from 24.92 to 8.72 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 27.46 tons/day [Table 9(c)].

For the 2032 attainment year, an overall 75% NOx reduction in all source categories based on 2023 baseline emission inventories was determined to be needed for attainment of the 75 ppb Federal 8-hour ozone standard. This is reflected in a straight 75% reduction across all passenger transportation sources as applied to 2023 baseline emission inventories, with remaining inventories applied to the 2032 attainment year. This 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 passenger transportation emission sources, the on-road NOx emissions are reduced from 34.0 tons/day to 14.1 tons/day in 2032 [Table 10(a)]. Off-road NOx emissions are reduced from 25.06 tons/day to 6.1 tons/day [Table 10(b)]. The total remaining NOx emissions combining on-road and off-road emissions are 20.17 tons/day [Table 10(c)].

100 Percent Existing Standards Scenario

This scenario assumes full implementation of existing adopted emission standards and complete fleet turnover to vehicles that meet these emission standards. For vehicles weighing up to 14,000 lbs. GVWR, the applicable emission standards are based on full implementation of CARB's Accelerated Clean Car Program in 2023 and 2032 (i.e., the vehicle emission standard component of this program (LEV III regulation) is fully phased–in by 2023). The in-use fleet average emission level for NOx was developed for the 2025 to 2032 calendar year timeframe, reflecting an in-use vehicle fleet that meets the most stringent LEV III emission standards while incorporating emissions deterioration.

A similar methodology was utilized for passenger transportation vehicle sources with gross vehicle weight ratings greater than 14,000 lbs. It was assumed that all vehicles 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. Reflecting all passenger transportation emission sources (on-road and off-road sources), the NOx inventory was reduced from 78.45 tons/day to 23.03 tons/day in 2023, and 59.12 tons/day to 30.09 tons/day in 2032 [Table 9(c) and 10(c)].

90 Percent Cleaner Combustion Technologies Scenario

For this scenario, light- and medium-duty vehicles (up to 14,000 lbs GVWR) are assumed to meet the cleanest combustion levels provided in the Advanced Clean Car Program (LEV III element). For vehicles weighing more than 14,000 lbs. GVWR, the 90% cleaner combustion technology reflects the entire on-road fleet meeting a 0.02 g/bhp-hr NOx emissions standard. For off-road passenger transportation 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 ferry vessels emissions would be further reduced through deployment of cleaner engines and hybrid systems. The resulting remaining emissions shown in Tables 9(c) and 10(c), are 19.17 tons/day (from 78.45 tons/day) in 2023 and 25.0 tons/day (from 59.12 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% 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 16.13 tons/day, 13.08 tons/day, and 10.03 tons/day, respectively, from a baseline inventory of 78.45 tons/day. In 2032, the remaining NOx inventories are reduced to 21.72 tons/ day, 18.44 tons/day, and 15.15 tons/day, respectively, from a baseline inventory of 59.12 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 passenger transportation 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.

- 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 for turning over older vehicles to meet air quality standards.

- If all vehicles and 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 passenger transportation sector would not achieve the 75 percent "equal share" NOx emissions reductions needed to attain the federal ozone air quality standard in 2032.

- If all vehicle and equipment were turned over to meet the lowest emissions standards established in current exhaust emission standards, the passenger transportation sector would potentially achieve the 65 percent "equal share" NOx emissions reduction needed to attain the federal ozone air quality standard in 2023. However, given the significant number of vehicles and equipment in this sector, the likelihood of complete turnover will be challenging.

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

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

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

- While significant emission reductions have occurred in this sector, new exhaust emission standards need to be established as early as possible. For the light- and medium-duty vehicle sectors, new criteria pollutant tailpipe emissions standards are needed beginning in 2025 and beyond to increase deployment of zero- and near-zero emission vehicles. In addition, 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.

- Given the sheer number of registered vehicles in the South Coast Air Basin and their NOx contribution to the total emissions in this sector, the most effective set of strategies will consist of a combination of accelerated advanced technology deployment, incentive programs to accelerate older vehicle retirement, alternative mobility options, infrastructure enhancements, and transformative urban forms.

- Operational efficiency enhancements can be made relative to congestion relief, greater use of intelligent transportation systems, and connected vehicle technologies (i.e., equipped for wireless communication).

- There is a nexus with the goods movement 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 Goods Movement White Paper for more information on the freight rail sector.

Advanced Technologies

The following are observations on the availability of zero- and near-zero emission technologies for the transportation 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. A discussion of existing emission control technologies and advanced technologies is provided in Appendix B.

- There is an increasing number of commercially-available battery-electric and plug-in hybrid electric light-duty vehicle models and increasing numbers of models sold each year. Current sales of zero-emission and plug-in hybrid electric vehicles have exceeded projections provided in CARB's Advanced Clean Car Program.

- Battery storage capacity is expected to increase significantly over the next few years and is expected to interest more consumers in acquiring a zero-emission or plug-in hybrid electric vehicle.

- There is a need to expand zero-emission technologies into categories of larger vehicles.

- Zero-emission buses are commercially available either in dedicated battery electric configurations or fuel cell configurations.

- The region's passenger rail locomotives are being replaced with Tier 4 locomotives. In the longer term, cleaner locomotives will need to be developed and demonstrated in the passenger transportation sector. Metrolink, the region's primary commuter rail service, has committed to testing cleaner locomotive technologies, such as alternative fuels, hybrid system, and wayside/external power, that provide emission benefits beyond current Tier 4 emission standards.

- Hybridization will have a significant role in reducing emissions from cruise ships and ferries.

- 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 and Active Transportation

While greater penetration of zero- and near-zero emission technologies are needed to attain air quality standards, operational efficiencies in the roadway network and implementation of SB 375 sustainable community strategies will play an important role to help meet air quality standards. Some initial observations are:

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

- Operational efficiencies in goods movement will help reduce road congestion and reduce emissions.

- Implementation of SB 375 (including increased transit and commuter rail ridership) and active transportation programs will help reduce emissions and congestion.

RECOMMENDATIONS

The emission reduction scenario analysis for the passenger transportation sector shows a need for greater penetration of zero- and near-zero emission technologies in order to attain air quality standards. Given the large number of passenger cars registered in the South Coast Air Basin, existing programs such as older vehicle scrapping and incentives for zero-emission and alternative fueled vehicles are integral in the overall effort to reduce emissions from this sector. 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, the numbers of on-road zero-emission and plug-in hybrid electric vehicles offered commercially are growing every year. However, the sale percentage of advanced technology vehicles is relatively small compared to annual sales of conventionally-fueled vehicles, and the vehicle choices are generally smaller sized vehicles. Implementing the following recommendations would help accelerate deployment of cleaner vehicles.

- Current programs to accelerate early retirement of light- and medium-duty vehicles are important given the significant number of older vehicles operating in the South Coast Air Basin. Accelerated vehicle retirement combined with incentives to purchase cleaner, fuel efficient vehicles and advanced technology vehicles can help accelerate penetration of advanced technology vehicles for the foreseeable future.

- Increased public funding assistance will be beneficial for all categories of emissions in the passenger transportation sector.

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

- Establish a new NOx emissions standard for urban buses and school buses that is 90 percent cleaner than the current bus exhaust emissions standard. As part of this effort, develop new certification test procedures for urban buses that take into account integration of hybrid systems that provide for zero-emission miles operation.

- Given the limited financial resources of public transit agencies and public school districts, seek additional funding opportunities for near-zero and zero-emission bus deployment.

- Seek funding opportunities to assist Metrolink in demonstrating alternative fuel and hybrid locomotives that are potentially significantly cleaner than the current Tier 4 locomotive NOx emissions standards.

- As deployment of near-zero and zero-emission technologies occur, additional public funding assistance will help in training technicians who are not familiar with the new technologies to maintain and operate advanced-model buses and vehicles.

- Encourage greater deployment of "emissions capture systems" at marine ports and at passenger rail maintenance facilities to reduce emissions from cruise ships and ferries while at berth and passenger rail locomotives during maintenance.

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

- 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.]

Vehicle Miles Traveled (VMT) and Operational Efficiency Recommendations

Meeting SB 375 targets and improving operational efficiency in existing transportation infrastructure can have potential criteria pollutant co-benefits. The following recommendations can potentially help to further reduce criteria pollutant emissions and greenhouse gas emissions.

- Work with SCAG and the county transportation commissions to aggressively pursue and effectively implement SB 375 to reduce vehicle miles travelled (VMT).

- Work with the county transportation commissions to promote alternative forms of transportation to the single occupant vehicle. Such alternative forms include greater utilization of public transit and commuter rail, and active transportation.

- Encourage municipalities to consider "last mile" (e.g., distance from nearest public transportation node to the passenger's home or workplace) travel options in future land use planning efforts.
- Support studies to assess intelligent transportation systems' (ITS) potential to reduce congestion and criteria pollutant emissions.
- Support efforts to deploy ITS in key congestion areas and best practices in transit, commuter rail, and aviation to help further reduce emissions and reduce congestion.
- Urge Caltrans and the county transportation commission to incentivize zero- and near-zero trucks on proposed dedicated truck lanes as part of freeway expansion projects that can help reduce commuter traffic congestion where appropriate. However, there is a general recognition that an expanded freeway may eventually become congested due to economic and population growth.

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 – April 2012.

APPENDIX A

CURRENT EMISSION CONTROL PROGRAMS

CURRENT EMISSION CONTROL PROGRAMS

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

PASSENGER TRANSPORTATION SECTOR

Commute Vehicles – Automobile, Light-Duty Trucks, SUVs, Passenger Vans

Commute vehicles are a subset of the on-road vehicle emission inventory, which is developed from activity data and emission rate data. For these categories of vehicles, activity data includes vehicle miles travelled and number of trips, and are generally estimated from vehicle owner surveys and vehicle count data. Emission rates are primarily based on actual measurements of tailpipe emissions (exhaust emissions) during engine operation and measurements of fuel that escapes from the vehicle's fuel system (evaporative emissions) both during engine operation and non-operation. Exhaust emissions result from incomplete fuel combustion and combustion byproducts, and consist of hydrocarbons, oxides of nitrogen, and particulate matter. Evaporative emissions consist solely of hydrocarbon emissions. The control of exhaust and evaporative emissions for a particular vehicle fundamentally depends on the technology used by the vehicle manufacturer to meet the applicable exhaust and evaporative emission standards, which are adopted and implemented by CARB, as well as control programs targeting the maintenance and repair of in-use vehicle emission control systems, implemented by CARB and the Bureau of Automotive Repair (BAR).

The specific processes generating exhaust emissions occur during running, idling, and starting conditions. Evaporative emission processes include diurnal, resting, hot soak, and running-loss. Diurnal and resting emissions result from heating and vaporization of the vehicle's fuel as the ambient temperature rises or declines during the day. Hot soak emissions are generated from residual engine heat vaporizing vehicle fuel subsequent to engine shut-down. Finally, running losses are generated by engine heat vaporizing vehicle fuel during engine operation. It should be noted that fuel evaporative emissions can also occur from vehicle refueling, where liquid fuel displaces vapor in the fuel tank during the refueling process.

SCAQMD Rule 2202 – On-Road Motor Vehicle Mitigation Options directly impacts mobile source emissions generated from employee commutes. Rule 2202 applies to employer worksites[3] with 250 or more employees, affecting home-to-work commute trips occurring between 6:00 AM and 10:00 AM from Monday through Friday. Rule 2202 provides a methodology to quantify commute emissions, an emission reduction target by employer depending on a number of factors such as employer location and number of commute vehicles, as well as a menu of options that can be implemented by employers to generate emission reductions for rule compliance. Rule 2202 was adopted in December 1995, with the first full year of implementation in 1996, replacing earlier trip reduction rules.

In Calendar Year 2013, Rule 2202 affected around 1,400 worksites, encompassing approximately 685,000 employees and 440,000 vehicles. During this calendar year, Rule 2202 targeted emission reductions were 1.68 tons/day VOC, 1.68 tons/day NOx, and 16.54 tons/day CO. Actual emission reductions exceeded these targets: 2.09 tons/day VOC, 1.70 tons/day NOx, and 17.41 tons/day CO.

Work-Related/Non-Goods Movement – Automobile, Light-Duty Trucks, and Cargo Vans

A small subset of the overall population of automobiles, light-duty trucks and vans are considered work related vehicles that carry workers from their residents to a jobsite and are considered as part of the passenger transportation sector. During the 1998 Low-Emission Vehicle (LEV) II rulemaking, CARB determined that work related vehicles up to 8,500 lbs. GVWR should be controlled to passenger car emission standards since available evidence indicated that these vehicles are primarily used for passenger transportation purposes, not as work vehicles. Cargo vans clearly are work vehicles; and models can weigh above or below 8,500 lbs. GVWR. It should be noted that the 8,500 lbs. to 10,000 lbs. GVWR category corresponds to the CARB Light-Heavy-Duty I category, and is included within the scope of the Goods Movement White Paper. In terms of how emissions are generated from these vehicles and controlled through regulation, see the preceding discussion on commute vehicles.

3 In Rule 2202, worksite means "a structure, building, portion of a building, or grouping of buildings that are in actual physical contact or are separated solely by a private or public roadway or other private or public right-of-way, and that are occupied by the same employer. Employers may opt to treat more than one structure, building or grouping of buildings as a single worksite, even if they do not have the above characteristics, if they are located within a 2 mile radius and are in the same Performance Zone. "

Transit System (Buses/Shuttles)

Transit system and shuttle bus vehicle emissions are regulated by a combination of rules, including the CARB heavy-duty vehicle emission standard regulations, Fleet Rule for Transit Agencies, and Truck and Bus Rule. In addition, transit agency emissions are regulated by SCAQMD Rule 1192 – Clean On-Road Transit Buses. CARB's emission standard regulation applies to engine manufacturers, while the remaining CARB and SCAQMD rules apply to vehicle fleets. In general, the CARB fleet rules require faster turnover to cleaner vehicles than would otherwise occur in the absence of the rules, or installation of retrofit emission control hardware. The SCAQMD rule requires the purchase of clean-fueled vehicles (e.g., CNG, LNG, electric) when a fleet decides on its own to either replace or add a vehicle to its fleet. Finally, CARB has adopted a zero-emission bus purchase requirement. CARB staff is conducting a technical assessment and is planning amendments to the transit fleet rule in an effort to further reduce criteria pollutant and greenhouse gas emissions, as well as promote zero-emission technologies in this sector.

Student Transportation

School buses come in a variety of sizes and configurations, powered by gasoline, diesel, CNG, propane, or electricity, and are generally assigned to one of four types: A, B, C, or D. Type A is considered a medium-duty vehicle with a weight rating of more than 10,000 lbs GVWR (Type A-I) or less than 10,000 lbs GVWR (Type A-II). Type A school buses are capable of transporting 10 to 24 passengers. The Type B school bus model is considered a step-van configuration, weighing more than 10,000 lbs. GVWR, with similar passenger capacities as Type A school buses. Type C school buses are considered heavy-duty vehicles weighing more than 14,000 lbs GVWR, with a front-mounted engine, capable of transporting between 42 and 72 passengers. Finally, the Type D school bus model is considered a "transit style bus" with a flat frontal area, and engine located either at the front or rear of the bus. These school buses can accommodate up to 90 passengers.

School buses are covered by a various regulations that impact engine and vehicle manufacturers as well as fleet owners. Specifically, CARB's Low-Emission Vehicle Regulation applies to school bus engines/vehicles weighing 14,000 lbs GVWR or less, and heavier school buses are covered by CARB's on-road heavy-duty engine emission standards. In addition, CARB's Truck and Bus Regulation affects school bus fleet owners, requiring them to install particulate filters on diesel-powered school buses weighing more than 14,000 lbs GVWR in accordance with a phase-in schedule. In addition, school bus fleets can obtain Truck and Bus Regulation compliance credit through the use of alternative-fuel vehicles (CNG, LNG, or electric).

Locally, SCAQMD's Rule 1195 affects school bus fleet operators by requiring the purchase of alternative-fuel school buses when a fleet owner decides on its own to replace or add to its vehicle fleet. To-date, a large number of the school buses operated by public school districts have been replaced with natural gas-powered buses. There have been various incentive programs to promote the use of low-emissions technology for the school bus sector – the largest program is the Lower Emission School Bus Incentive Program. Using state, federal and local matching funds, a total of 1,021 pre-1987 diesel school buses have been retired and replaced with 935 new CNG-powered school buses and 86 low-emitting diesel buses in the South Coast Air Basin. In addition, this incentive program has funded the installation of particulate filters in 3,425 school buses (1994 model-year and newer).

Passenger Locomotives

The four-county region of the Basin is serviced by a network of intercity (Amtrak) and commuter (Metrolink) heavy rail networks. Emissions are produced 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. Passenger locomotives also have auxiliary engines that provide power for lighting, utility power, heat and air conditioning the passenger cars. Passenger locomotives are forecast to contribute approximately 4.5 tons per day or 1.5% of NOx emissions in the South Coast Air Basin in 2023. In 2015, U.S. EPA Tier 4 standards take effect for new locomotive engines which are 90% lower in NOx and PM emissions than pre-control engines. Due to the long life of locomotives (>30 years), however, it will take many years to fully benefit from Tier 4 engines. In addition, Tier 4 locomotive NOx standards are substantially less stringent than Tier 4 off-road NOx standards, providing an opportunity to further strengthen locomotive emission standards in the future and to introduce alternative near-zero or zero-emission technology.

Commercial Aircraft

Commercial aircraft emission inventories combine passenger aircraft and dedicated cargo aircraft. CARB estimates that 87% of commercial aircraft emissions are attributable to passenger transport by commercial airlines. In addition, general aviation aircraft, primarily piston engine powered, contribute about 2% (0.3 tons per day) of aircraft emissions. Based on the South Coast Air Basin aircraft NOx emission forecast for 2023, 13.6 tons per day or 4% of NOx emissions in 2023 are attributed to aircraft emissions. 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 provided approximately 50% cleaner NOx emissions than engines manufactured before 2005.

Commercial Harbor Craft

Approximately 65 ferries and excursion vessels transport passengers within the District. They are forecast to emit 3.3 tons per day NOx in 2023. These vessels generally have multiple propulsion and auxiliary engines with total power between several hundred and several thousand horsepower. Essentially all of these vessels are currently diesel powered. Activities include scheduled trips to Catalina Island, whale watching, dinner cruises, and sightseeing trips. These harbor craft are subject to new engine regulations that now require Tier 3 standards for engines less than 800 hp and Tier 4 standards, the most stringent currently adopted, for engines greater than 800 hp. In addition, excursion vessels and ferries are subject to the CARB Commercial Harbor Craft regulation which specifies turnover of older marine engines for new engines on a schedule that essentially will leave all regulated harbor craft with Tier 2 or cleaner engines by 2023.

Ocean-Going Vessels

Ocean-going vessels transporting passengers, i.e., cruise ships, which primarily run on diesel fuel, contribute a significant portion of NO_x, 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 3.5 tons per day 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 introduced low sulfur fuel standards which reduced PM and SOx emissions but not NOx emissions. Lower NOx emission propulsion and auxiliary engines are being introduced in compliance with the International Maritime Organization (IMO) standards but due to the long useful life of ocean-going vessels, these standards will have limited beneficial effect by 2023. Additional retrofit control technologies are being explored by the San Pedro Bay Ports Technology Advancement Program (TAP) Advisory Group, which is comprised of CARB, U.S. EPA, SCAQMD, and the ports of Los Angeles and Long Beach. The ports are also exploring the use of dock-side or barge-mounted capture and treatment systems for auxiliary engine emissions which represent a significant fraction of the marine vessel NOx emissions, particularly near the ports.

OTHER PLANNING EFFORTS AFFECTING THE PASSENGER TRANSPORTATION SECTOR

SB 375 Sustainable Communities and Climate Protection Act of 2008

The Sustainable Communities and Climate Protection Act of 2008 supports California's climate action goals to reduce greenhouse gas (GHG) emissions through coordinated transportation and land use planning with the goal of more sustainable communities.

Under the Sustainable Communities Act, CARB sets regional targets for GHG emissions reductions from passenger vehicle use. In 2010, CARB established these targets for 2020 and 2035 for each region covered by one of the State's metropolitan planning organizations (MPO), and CARB will periodically review and update the targets as needed.

Each MPO must prepare a Sustainable Communities Strategies (SCS) as an integral part of its Regional Transportation Plans (RTP). The SCS contains land use, housing, and transportation strategies that, if implemented, would allow the region to meet its GHG emission reduction targets. Once adopted by the MPO, the RTP/SCS guides the transportation policies and investments for the region. CARB must review the adopted SCS to confirm and accept the MPO's determination that the SCS, if implemented, would meet the regional GHG targets. If the combination of measures in the SCS does not meet the regional targets, the MPO must prepare a separate "alternative planning strategy" (APS) to meet the targets.

SCAG Regional Transportation Plan

The Southern California Association of Governments (SCAG) prepares the RTP, with the primary goal of increasing mobility in the region. An additional goal includes increasing the region's sustainability and reduction in greenhouse gas emissions, officially incorporated into the RTP as the SCS. The most recent RTP/SCS is the 2012 – 2035 RTP/SCS, and was adopted by SCAG on April 12, 2012. (http://www.scagrtp.net).

The 2012 RTP/SCS includes elements that would reduce emissions from transportation sources, improve public health, and help the region meet national ambient air quality standards. 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 energy security, cost certainty, increased public support for infrastructure, GHG reduction, and economic development.

Federal Surface Transportation Reauthorization

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 system, and related local infrastructure projects. The latest federal surface transportation legislation enacted by Congress is the "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 never 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.

Caltrans California Transportation Plan 2040

The California Transportation Plan (CTP) provides a long-range policy framework to meet California's future mobility needs and reduce greenhouse gas emissions. The CTP defines goals, performance-based policies, and strategies to achieve our collective vision for California's future statewide, integrated, multimodal transportation system. The plan envisions a sustainable system that improves mobility and enhances the quality of life. While the plan focuses on sustainable transportation, the plan identifies key mobility and technology strategies that can potentially lead to criteria pollutant emission reduction benefits. A draft CTP (CTP 204) was released in March 2015 for public comments. (http://www.dot.ca.gov/ hq/tpp/californiatransportationplan2040/)

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 passenger transportation 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 not only congestion, but also criteria pollutant and greenhouse gas emissions.

PASSENGER TRANSPORTATION SECTOR

Light- and Medium-Duty Vehicles

In January 2012, CARB adopted the Low-Emission Vehicle (LEV) III Program, commonly called the Advanced Clean Car (ACC) Regulation. This regulation incorporates a coordinated approach to meet criteria pollutant and climate air quality goals. Incorporated into this regulatory package are more stringent low-emission vehicle standards for vehicles weighing up to 14,000 lbs. GVWR, with a major objective to reduce the fleet average emissions of passenger cars, light-duty trucks, and medium-duty passenger vehicles to super ultra-low emissions levels by 2025. This program element will yield significant emission benefits for the transportation vehicle sector, and will lead to advanced gasoline and diesel technologies applied to almost all vehicle product lines for this sector, resulting in an overall 75% reduction from current average emission levels. It should be noted that this control program will also reduce GHG emissions by 34% in 2025 for this vehicle sector.

Another component of the ACC Program is the Zero-Emission Regulation. This regulation will require manufacturers to commercialize increasing numbers of plug-in hybrid electric vehicles and zero-emission vehicles for the 2018 to 2025 timeframe. CARB projects that by 2025, approximately 15% of new vehicles sales will consist of a mix of fuel cell vehicles, battery-electric vehicles, and plug-in hybrid vehicles. The Zero-Emission Regulation in combination with the LEV III Regulation puts California on a trajectory to generate the needed GHG reductions from this sector to contribute to the overall state attainment of an 80% reduction in GHG emissions from 1990 levels by 2050.

As part of the ACC Program, CARB developed market penetration forecasts of zero- and near-zero vehicle technologies. Figure B-1 illustrates one scenario depicting new vehicle sales statewide for zero- and new-zero technologies through 2025. In addition, Figure B-2 shows one possible zero- and near-zero vehicle penetration scenario through 2050 for GHG target attainment, which builds upon the 2025 new vehicle sales forecast shown in Figure B-1.

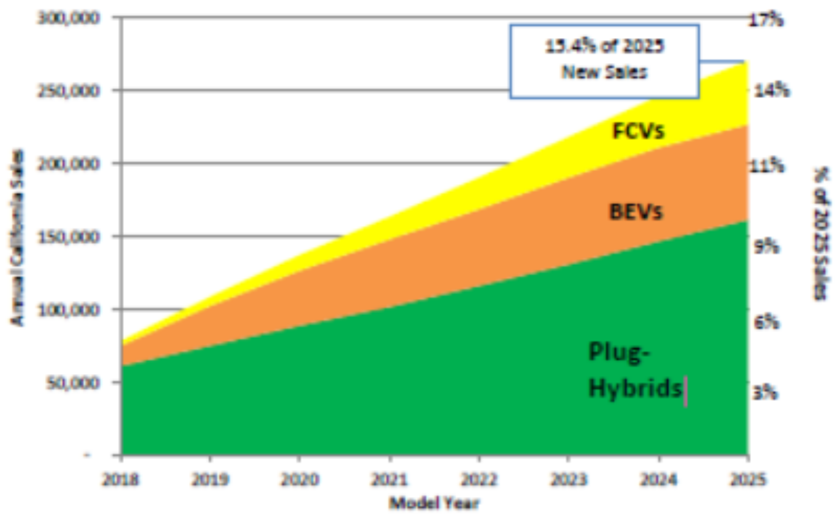


FIGURE B-1

Expected ZEV Regulation Compliance for 2018 to 2025 Model Years[4]

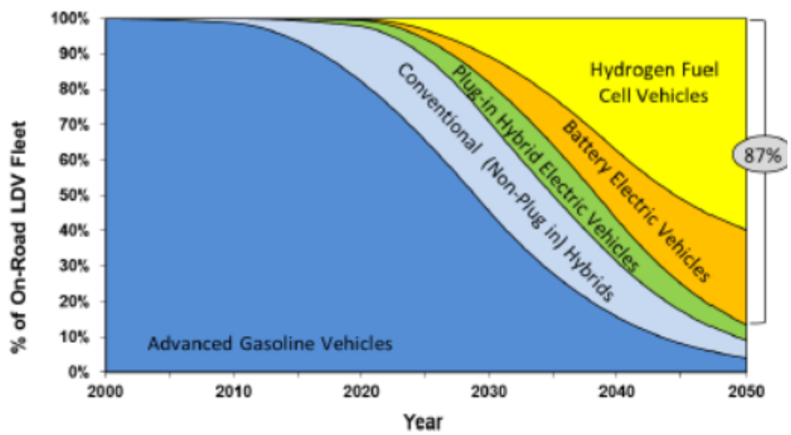


FIGURE B-2

On-Road Passenger Car Scenario to Meet 2050 Goal

[4] Advanced Clean Cars Summary, California Air Resources Board, January 2012

The final component of the ACC Program is the Clean Fuels Outlet Regulation. An amendment to this regulation was proposed as part of the ACC Program, which would have required construction and operation of alternative fuel outlets for a particular fuel, triggered when specific numbers of alternative fuel vehicles are commercially deployed. The Clean Fuels Outlet requirements have been placed on hold to allow for funding opportunities to expand the network of hydrogen refueling stations throughout California.

Current on-road vehicles powered by spark ignition engines (e.g., gasoline and natural gas engine) use a portfolio of on-board emission reduction technologies to meet emission standard requirements. To reduce exhaust emissions from internal combustion engines, three-way catalytic converters, on-board computer hardware, and sensors measuring engine operational parameters and inputting this information into the on-board computer hardware are used to simultaneously reduce tailpipe hydrocarbon, NOx, and carbon monoxide emissions. In addition, exhaust gas recirculation (EGR) valve and other engine-based technologies such as improved combustion-chamber and ignition system design are used to further reduce exhaust emissions.

To comply with CARB low-emission vehicle requirements, including the Advanced Clean Cars Program requirements, vehicle manufacturers have significantly improved these technologies resulting in exhaust emission reductions greater than 95% compared to uncontrolled levels (MECA, 2013). Examples of these improvements include dual oxygen sensors, adaptive fuel control systems, sequential multi-point fuel injections, close-coupled catalysts, increased catalyst loading in catalytic converters, electrically-heated catalysts, and full electronic EGR.

As mentioned previously, another major source of vehicle pollution is fuel evaporative emissions (gasoline vehicles). These emissions are addressed by on-board carbon canisters that adsorb evaporative emissions and subsequently release these emissions into the engine for combustion. Examples of improvements needed to meet the latest evaporative emission standards include low permeation polymer fuel tanks, multilayer co-extruded hoses, low permeation seals and gaskets, and high working capacity activated carbon canisters. These improvements have substantially reduced evaporative emissions from gasoline vehicles.

With regard to compression ignition engines (diesel engines), current exhaust aftertreatment control technologies include urea-based selective catalytic reduction (SCR) systems, catalyzed diesel particulate filters, diesel oxidation catalysts, ammonia slip catalysts, as well as engine based technologies such as cooled EGR, variable geometry turbochargers, and high pressure injection (CARB, 2014). Depending on system design SCR systems can reduce NOx emissions greater than 95% (MECA, 2014). These systems can also reduce hydrocarbon and PM emissions by up to 80%

and 20 to 30%, respectively. Catalyzed diesel particulate filters can additionally reduce PM emissions more than 90% (MECA, 2014).

Alternative-Fuel Vehicles, Biofuels, Hybrid, and Dedicated Zero-Emission Technologies

Alternative fuel vehicles and biofuels in the light- and medium-duty vehicle sector (up to 14,000 lbs. GVWR), follow CARB low-emission vehicle regulations, meeting the same corresponding emission standards as conventional fuels including gasoline and diesel. Because these emission standards are so stringent, requiring advanced engine-based emission control and exhaust aftertreatment technologies, emission reduction potential for both categories of fuels are similar. It should be noted that hybrid-electric, battery electric, and fuel cell vehicles will generate additional emission reductions depending on percent of operation in all-electric or zero-emission mode.

Fuel cell technology can be utilized in all types of vehicle models; however, according to vehicle manufacturer input received by CARB, fuel cell vehicles will most likely be used in mid-sized sedans and larger sized vehicles such as trucks and sport utility vehicles. Battery electric vehicles will most likely be used in small vehicle platforms, in urban locations where fewer batteries need to be used. Plug-in hybrid vehicles will most likely be used as a bridge from conventional hybrid electric vehicles to battery electric and fuel cell vehicles. Plug-in hybrid vehicles have the advantage of adequate vehicle range for all applications; however, there is currently a tradeoff between longer all-electric range and associated costs. CARB indicated that in order for plug-in hybrid vehicles to achieve needed GHG reductions, advanced low carbon biofuels need to be used to meet the 2050 goal. It is uncertain whether biofuel fuel use in plug-in hybrid applications will be utilized in significant quantities in the long term without additional incentives given that conventional gasoline fuel remains the dominant choice to power these vehicles when not operating in all-electric mode.

Transit and School Buses

The same general principles that apply to lighter vehicles also apply to heavy-duty passenger shuttles, transit buses, and school buses (14,000lbs. GVWR and greater), regarding the need to implement advanced engine based and exhaust aftertreatment technologies to meet emission standards for both alternative- and conventional-fuel vehicles. Similarly, the potential for additional emission reductions also exists for operation in zero-emissions mode for dedicated and hybrid technologies. However, there is the potential for significant additional NOx emission reductions for both diesel and natural gas heavy-duty engines.

Research is underway 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 CARB under a contract with Southwest Research Institute. Under funding from the SCAQMD, California Energy Commission, and Southern California Gas Company, several natural gas engine manufacturers are developing the next generation natural gas engines to meet a 0.02 g/bhp-hr exhaust emissions level in the next several years. CARB research efforts focus on the development of emission control technologies that could be used to further reduce NOx emissions from diesel and natural gas engines. The ultimate goal of the work being conducted under sponsorship from the SCAQMD, CEC, and Southern California Gas Company is to have commercialized natural gas engine products as early as possible. 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 diesel, biofuels, and renewable natural gas) to further address criteria pollutant and GHG emission reduction goals.

Battery electric and hybrid-electric technologies can also play an important role in generating needed emission reductions in heavy-duty passenger transportation applications (includes urban buses, school buses, other buses, and motor homes). Similar limitations associated with the use of these technologies in light- and medium-duty passenger transportation applications are also applicable for heavy-duty vehicle applications.

Passenger 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. These engine modifications include high rate cooled EGR, two stage turbochargers, and improved fuel injection systems. These technologies were previously adopted in automotive and truck diesel engines. Also due to the long service life of locomotives, modification of in-use engines should also be considered. These 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 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. These technologies may also be retrofitted to in-use engines where technically feasible. Diesel oxidation catalysts do not reduce NOx but can reduce hydrocarbons by 50% and particulates by 20-25%. Three-way catalysts for stoichiometric spark ignition natural gas engines can reduce hydrocarbon, carbon monoxide, and NOx by 90% but are not effective on particulates or for NOx reductions in lean burn gas or diesel engines. 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. 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. Aftertreatment systems do not reduce CO2 emissions.

Alternative power sources include electric hybrid, fuel cell, battery-electric with tender car, and catenary electric systems. Hybrid systems provide emission reductions of criteria and GHG emissions of 20-30% when used in applications with opportunities for energy recovery such as commuter service with multiple stops and/or hilly terrain. Alternative power sources have been commercialized for on-road vehicles, but have not been extensively adopted for passenger locomotives in the region; due in part, that the local commuter rail agencies, Metrolink and Amtrak, share their operations on freight rail tracks owned by the Class I railroads.

Alternative fuels include dedicated natural gas, dual fuel systems (diesel ignition with natural gas), propane, biodiesel, and hydrogen. The use of these fuels has the potential to further reduce NOx emissions with appropriate engine development similar to their on-road counterparts. The use of alternative fuels also reduces particulate and CO2 emissions compared to diesel or gasoline. For passenger locomotives, the most likely alternative fuel will be natural gas, either liquefied or compressed due to the lower fuel cost.

There are opportunities for combining technologies to gain greater emission reductions. For example, natural gas-hybrids with high-efficiency aftertreatment systems combine low carbon emissions of natural gas engines, energy savings of hybrids, and low NOx emissions from advanced aftertreatment.

Efficiency measures include improved route scheduling, addition of double tracks and sidings to reduce congestion at traffic choke points, and steps to reduce accidents and equipment downtime.

Ocean-Going Vessels (OGVs)

OGVs produce emissions from main (propulsion) engines as well as auxiliary engines (electrical generators). Passenger-carrying OGVs are cruise ships. Cruise ships have particularly large auxiliary engines to provide shipboard power while docked and at sea. New vessels built beginning in 2016 must have engines capable of meeting Marine Category 3 Tier 3 standards when operating in Emission Control Areas (ECAs) established by the International Maritime Organization (IMO). These areas include waters off the United States and Canada. Technologies required to meet these standards include engine modifications/improvements such as common rail injection, electronic engine monitoring/control, slide valve injectors, advanced injector orifice design, turbocharging, and cooled EGR. The controls individually, do not necessarily achieve Tier 3 standards, but enable use of aftertreatment seawater scrubber or SCR technology, which will. Tier 3 standards vary by engine horsepower and design but typically reduce NOx by approximately 80% compared to a fleet average of Tier 1.

Liquified natural gas (LNG) is being considered as a fuel for ocean-going vessels to reduce both fuel cost and emissions. LNG-powered vessels are currently deployed in several regions around the world. Some of the LNG-powered vessels are meeting Tier 3 NOx emissions levels. However, LNG-powered cruise vessels have not been deployed. Combined with aftertreatment, LNG-powered engines have the potential to achieve NOx levels lower than Tier 3 diesel engines. In addition to LNG fuel, emulsified fuels have been considered as an alternative or supplement to EGR for NOx reduction.

Cruise ships are also subject to the CARB At-Berth regulation to reduce fleet emissions from auxiliary engines when docked. This regulation is generally satisfied by using shore power instead of ship-board power although alternative capture and treatment systems can be used if shown to provide equivalent reductions to shore power. At-berth auxiliary emissions from cruise ships using shore power or capture and treatment systems are reduced about 90%. Capture and treatment systems can also be applied to boiler emissions which are not regulated by the At-Berth Regulation.

IMO standards require 30% improvement in vessel fuel efficiency by 2025 as a means of reducing GHG from ocean-going vessels. Reductions in fuel consumption will also lead to proportional reductions in NOx emissions. Several alternative technologies can contribute to that goal: fuel cells, wind power, hull coatings, hull design, propeller optimization, and engine heat recovery. Vessel trip optimization and vessel speed reduction also contribute to reduced fuel consumption and emissions.

Commercial Harbor Craft

Commercial harbor craft used in passenger transport include ferries and excursion vessels. The boats operate primarily in or from the Ports of Los Angeles and Long Beach. Commercial harbor craft have a long useful life and turnover to newer engines or vessels is slow. Most commercial harbor craft have engines less than 800 horsepower, for which the most stringent standard is Tier 3 (5.4 g/bhp-hr NOx) for Category 1 and 2 marine engines. Engines greater than 800 horsepower, used mainly on ferries, are subject to the Tier 4 standard (1.3 g/bhp-hr NOx) for Category 1 and 2 marine engines, which may need SCR and possibly diesel particulate filters. Marine emission standards are not as stringent as off-road standards of the same tier. As such, additional emission reductions could be obtained by introducing lower emission standards to force new engine designs or use of SCR aftertreatment. Promising alternative technologies include fuel cells and hybrid-diesel or hybrid-natural gas engines. Hybrid vessels have been shown to reduce overall emissions approximately 30%. Fuel cells and battery systems can be used for auxiliary power which would reduce emissions.

Improvements in vessel efficiency will also lead to proportional reductions in NOx emissions. Several alternative technologies can contribute to that goal: hull coatings, hull design, and propeller optimization.

Commercial Aircraft

Lower NOx emissions and fuel consumption will be obtained 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.

TRANSPORTATION SYSTEM EFFICIENCY MEASURES

While improvements in existing control technologies and increased deployment of near-zero and zero-emission vehicles will lead to reduced emissions, improvements and enhancements to the transportation system in terms of reduced roadway congestion can result in reduced idling emissions and vehicle miles traveled when considering alternative mode choices (i.e., ridesharing, public transit, commuter rail, and active transportation).

The state of technology for providing real-time information is continuing to grow and become available to commuters and regional traffic managers. Intelligent transportation systems (ITS) cover a broad range of information communications and control technologies that improve the safety, efficiency, and performance of the surface transportation system. ITS technologies provide the traveling public with accurate, real-time information, allowing them to make more informed and efficient travel decisions.[5] Such technologies will enhance current traffic control and

[5] Caltrans (2015). Draft California Transportation Plan 2040. March 2015.

management systems, incident management systems, and advance traveler information systems, which potentially can result in reducing emissions. In addition, greater use of sophisticated technologies such GPS (global positioning systems), wireless connected vehicles, and intelligent transportation systems can potentially lead to additional criteria pollutant reductions.

Land use decisions by local governments and SCAG can have a beneficial impact on the transportation system through coordinated planning with the county transportation commissions and SCAG. For more information, see SCAG's 2012 – 2035 RTP/SCS.

(http://www.dot.ca.gov/hq/tpp/californiatransportationplan2040/)

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

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

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

Goods Movement

2016 AQMP WHITE PAPER

OCTOBER 2015

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

Randall Pasek, Ph.D.
Planning and Rules Manager
Off-Road Strategies Section

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

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.

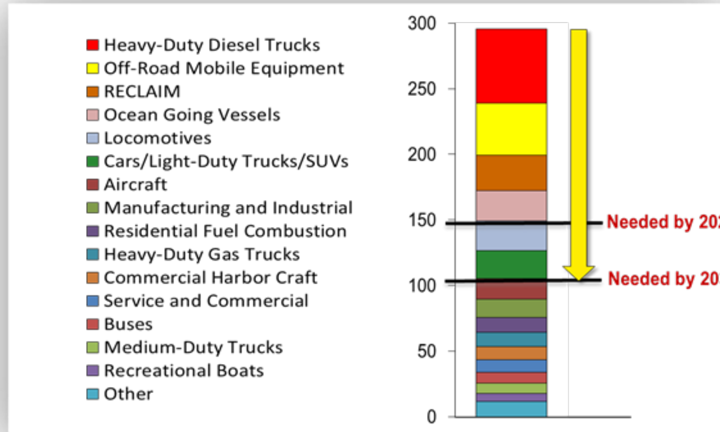
BACKGROUND

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

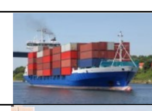
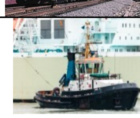
On-Road Goods Movement Vehicle Categories

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.

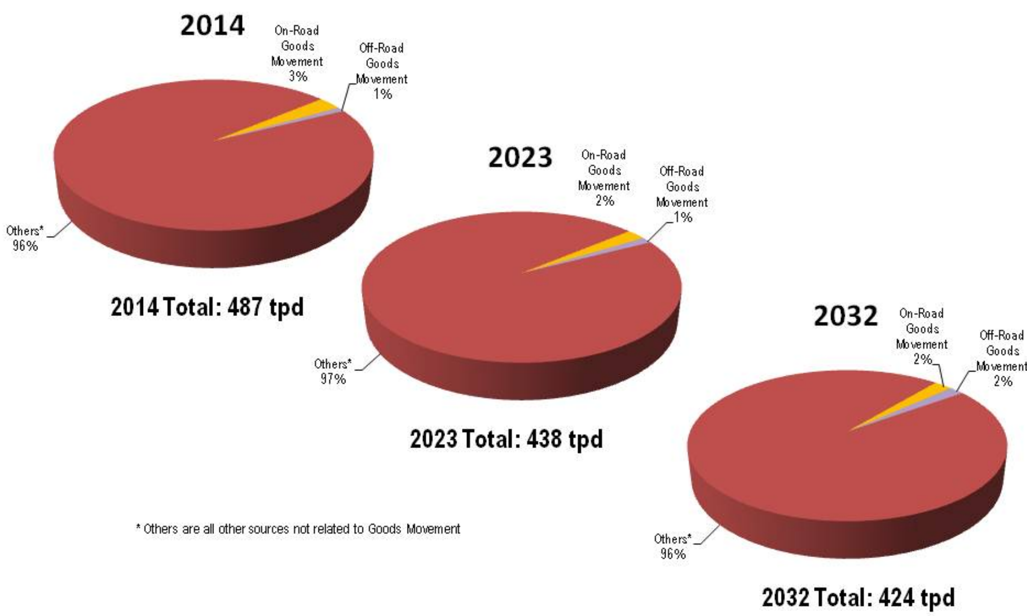


FIGURE 2

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

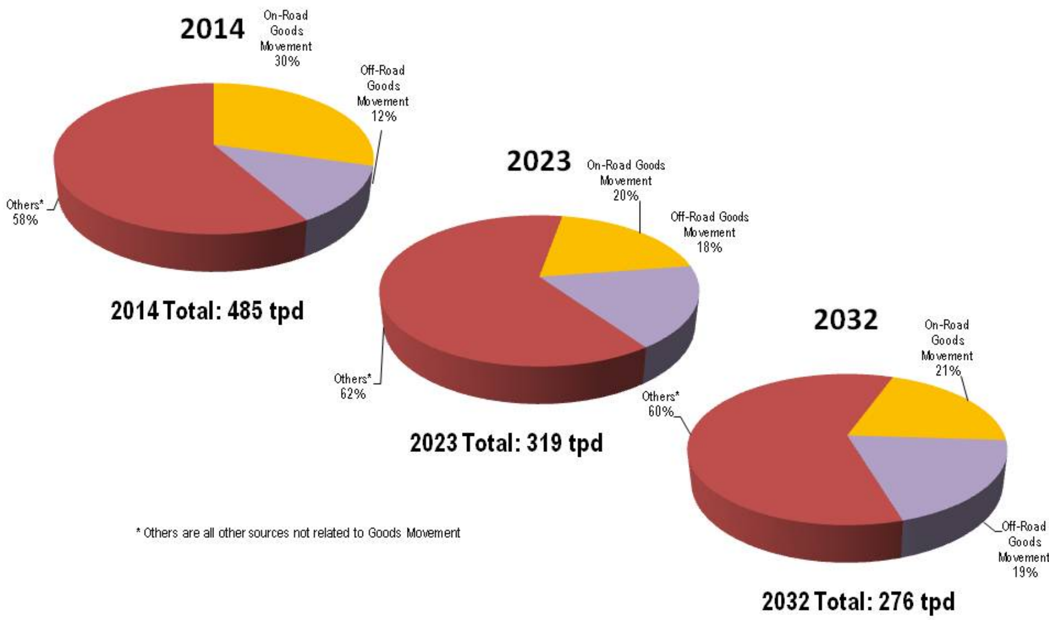


FIGURE 3

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.

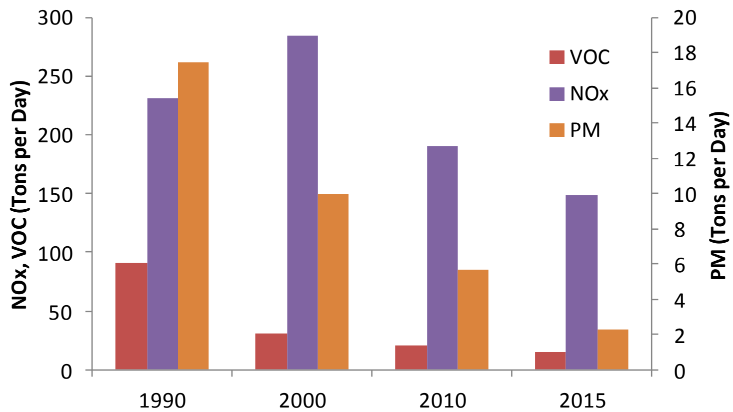


FIGURE 4

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).

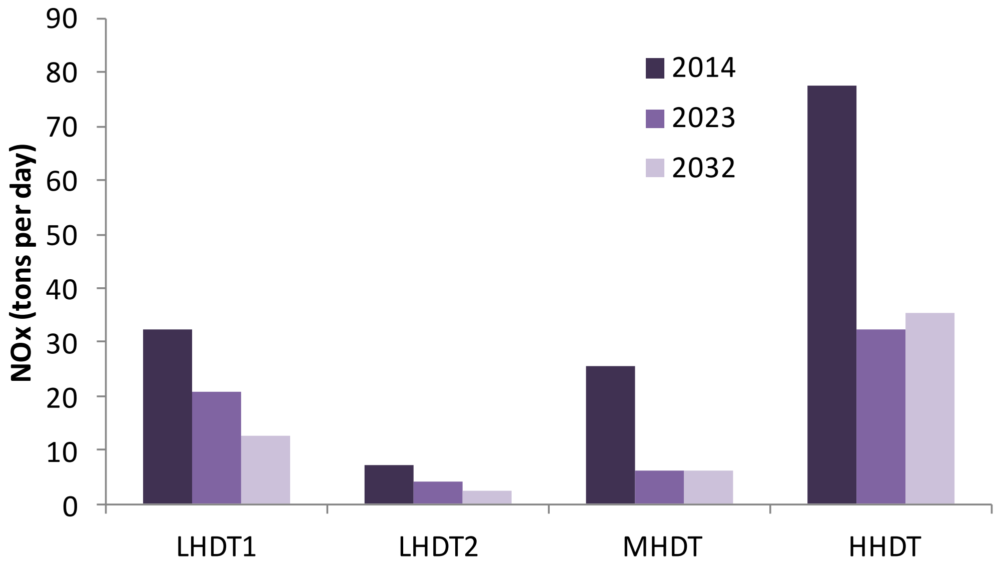


FIGURE 5

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)

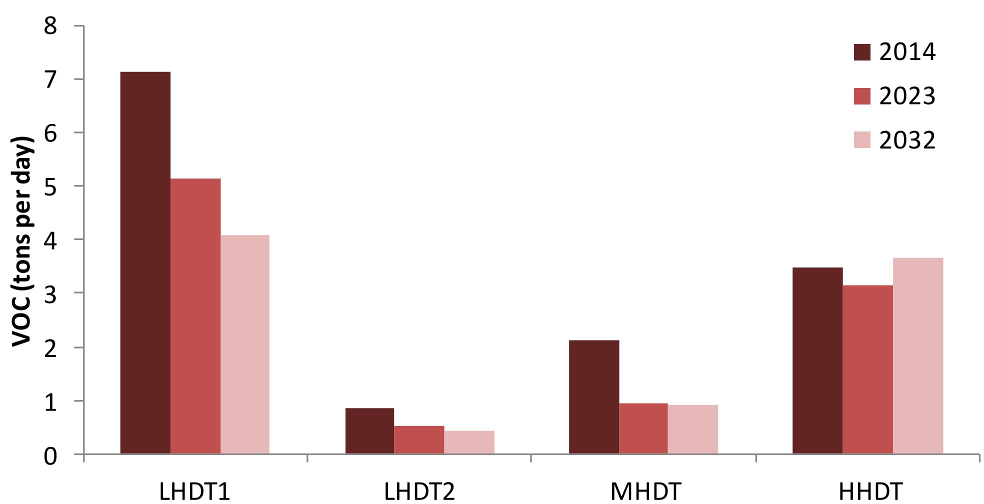


FIGURE 6

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

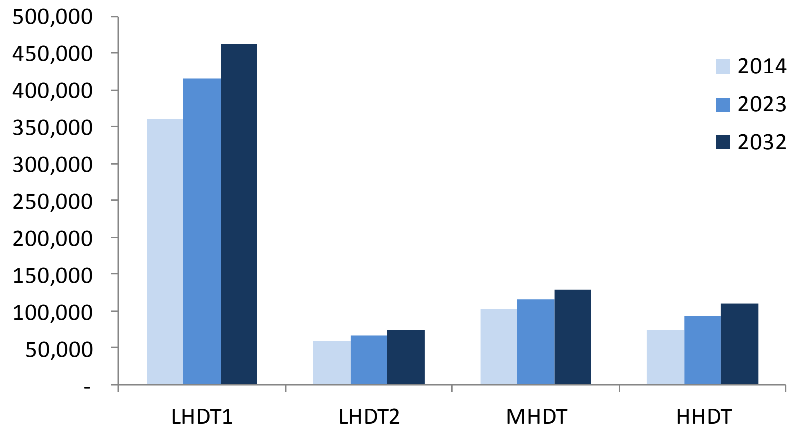


FIGURE 7

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.

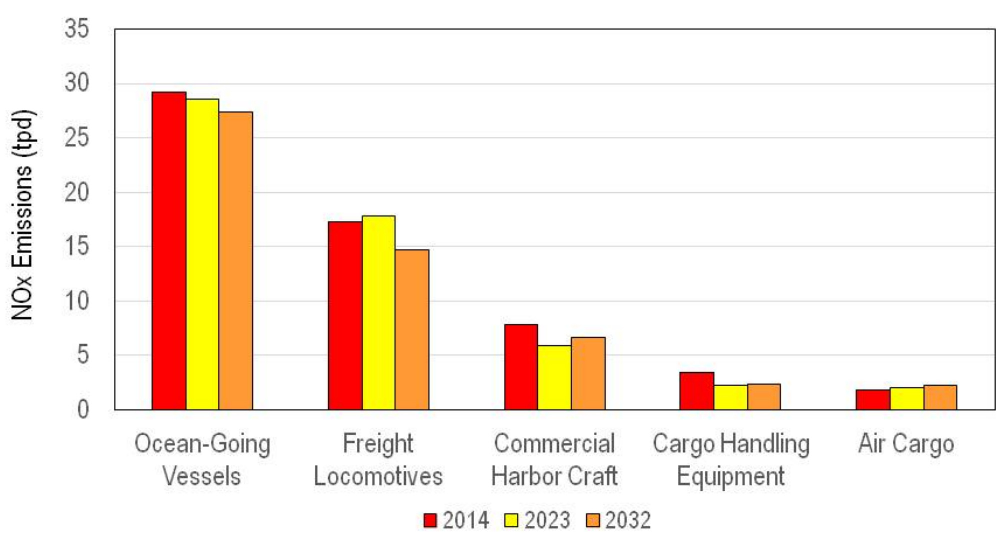


FIGURE 8

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

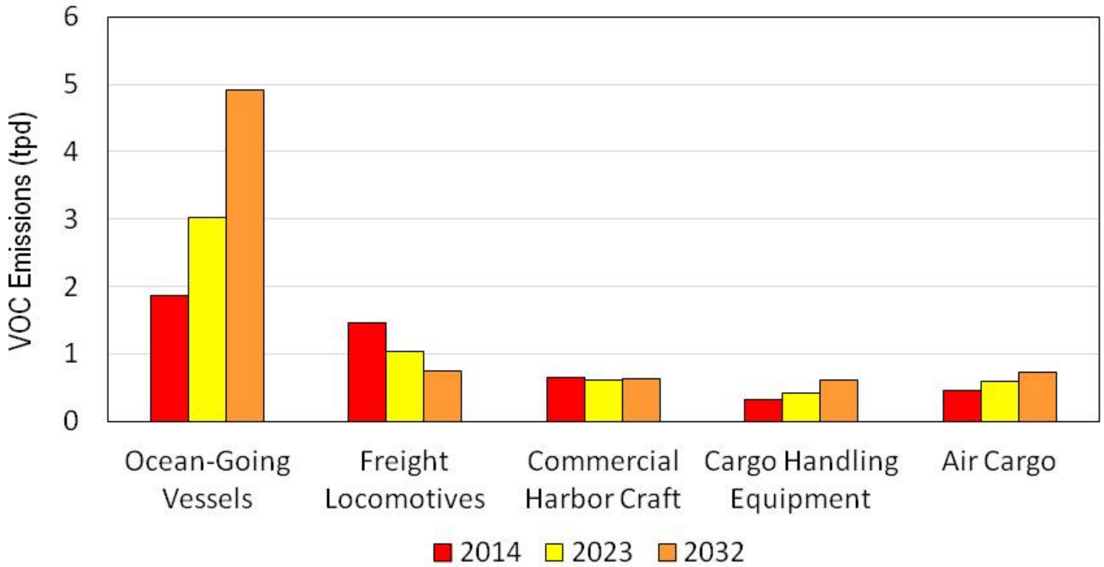


FIGURE 9

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 extensively that Class 1 railroad companies are currently evaluating the technical, economic and logistical feasibility of deploying LNG fueled locomotives rail system wide.[1] *A positive decision to move from diesel to natural gas fuel would likely result in deployment of LNG technology simultaneously and rapidly across all Class 1 railroad companies, with a complete switch from diesel to LNG occurring in the span of 20 years.*[2] *Furthermore, it is believed that LNG will be deployed trans-continentally on a line-by-line basis with LNG fueling infrastructure installed at appropriate intervals along the specific route. Conversion of a line would ensure the most modern locomotives will be operating on this route as they would be either a Tier 4 new build or an older locomotive repowered to meet a Tier 3+ NOx emission rate; all earlier Tier locomotives would be removed from service, defacto.*

If LNG fueling infrastructure and capacity was readily available at intermodal port facilities, such as OGV bunkering facilities, Class 1 railroad companies could be engaged to initiate their conversion with Southern California intercontinental 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

[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.

[2] This is based on the time it took the Class 1 railroad companies to switch from coal to diesel fuel.

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.

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[3] 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[4] and Caribbean[5] 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, [6] *State-owned shipyards in China are laying plans for the building of 20 LNG ready very large ore*

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

[4] 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.

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

[6] "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.

carriers (Valemax) for charter to Vale, Brazil[7] *and the Port of Singapore issued its first Request for Proposal for interested parties to apply for LNG bunker supplier license in July 2015.* [8] *Table B-1 describes the current state of Pacific Rim Ports that have the most advanced plans for installing LNG 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.* [9]

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.

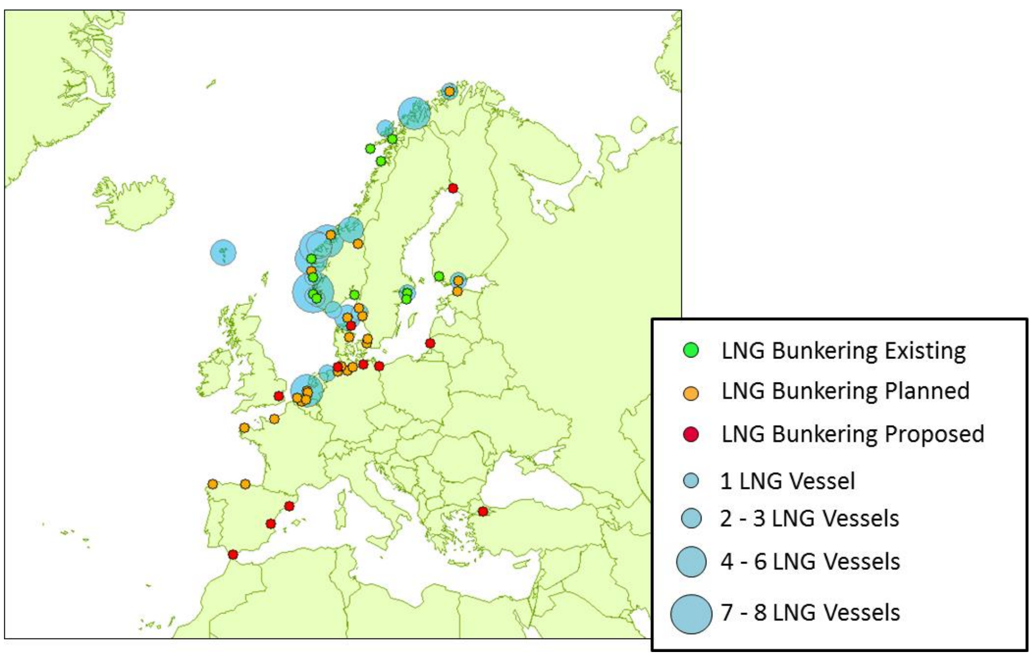


FIGURE B-1

European LNG ship deployment correlated with existing LNG bunkering

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

[8] "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.

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

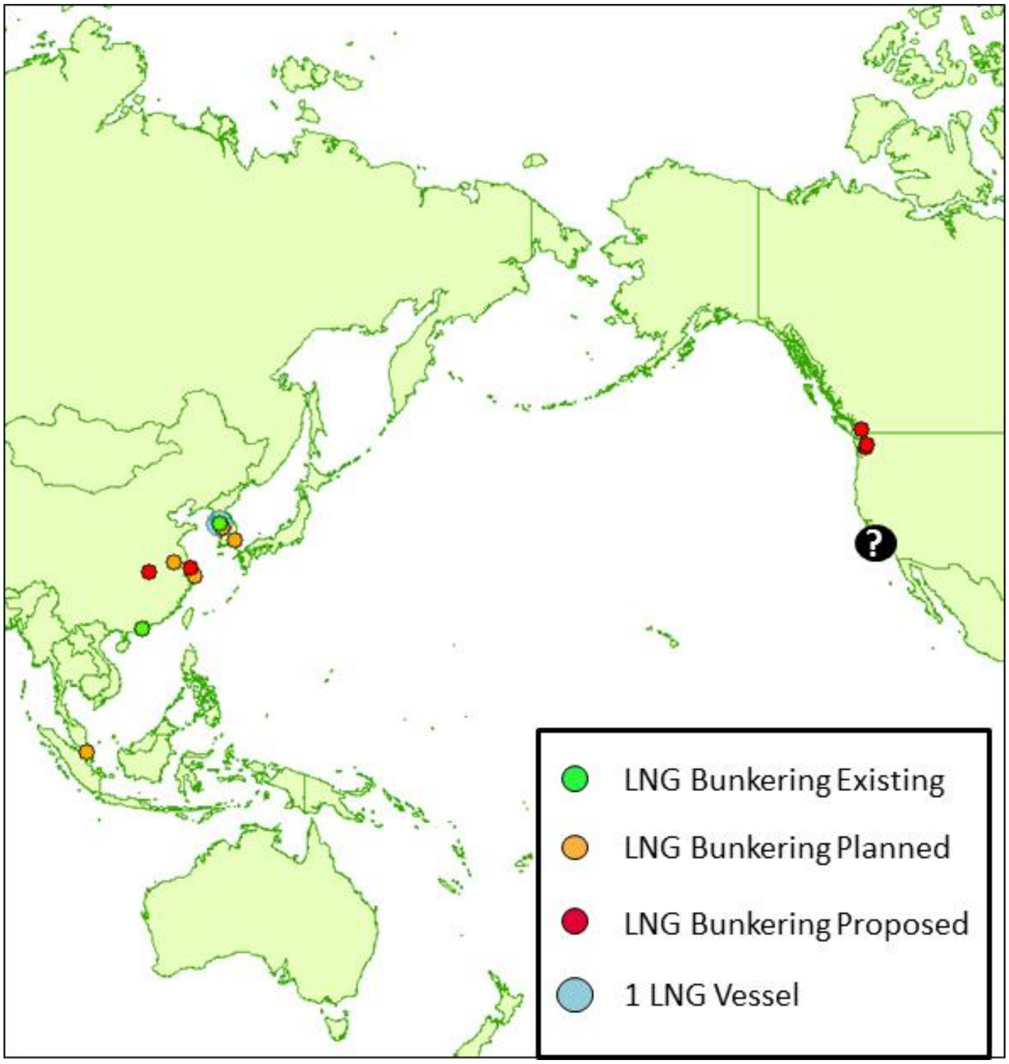


FIGURE B-2

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)

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

South Coast AQMD

Off-Road Equipment

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

Randall Pasek, Ph.D.
Planning and Rules Manager
Off-Road Strategies Section

Author

Richard Carlson – Air Quality Specialist

Reviewers

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

.

Table of Contents

INTRODUCTION

Purpose and Objective

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

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

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

Document Outline

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

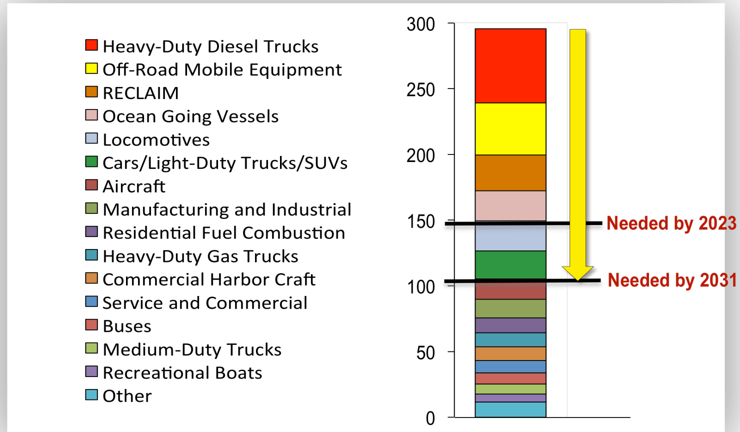
A discussion of current regulatory programs and other planning efforts is provided in Appendix A. Information on potential emission reduction technologies and efficiency measures is discussed in Appendix B.

BACKGROUND

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

Attainment Challenge

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



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

FIGURE 1

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

Climate Challenge

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

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

OFF-ROAD EQUIPMENT RELATED EMISSIONS SOURCE CATEGORIES

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

TABLE 1

Off-Road Equipment Emission Source Categories

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

TABLE 1 (concluded)

Off-Road Equipment Emission Source Categories

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

Air Quality Impacts of Off-Road Equipment Sources

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

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

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

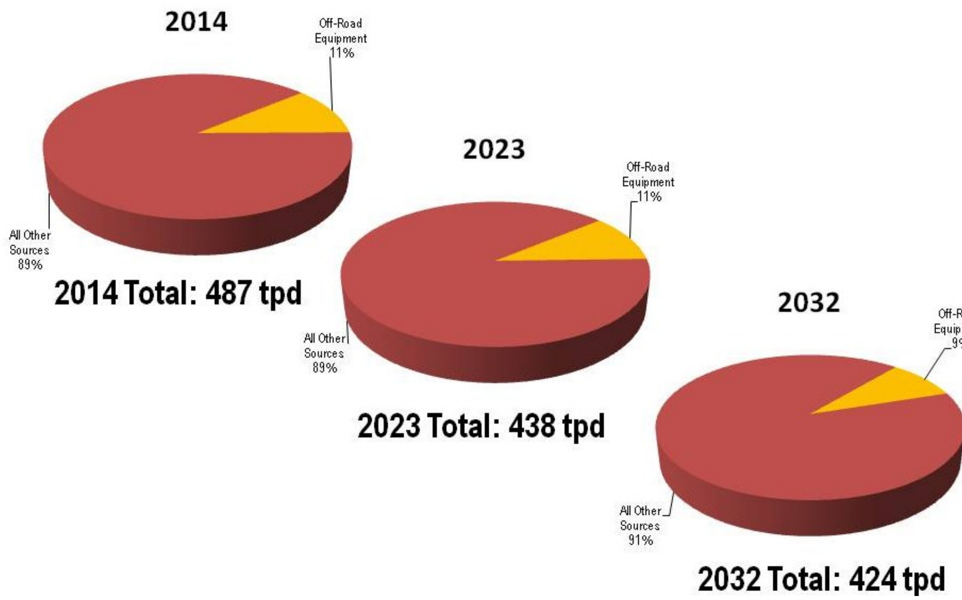


FIGURE 2

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

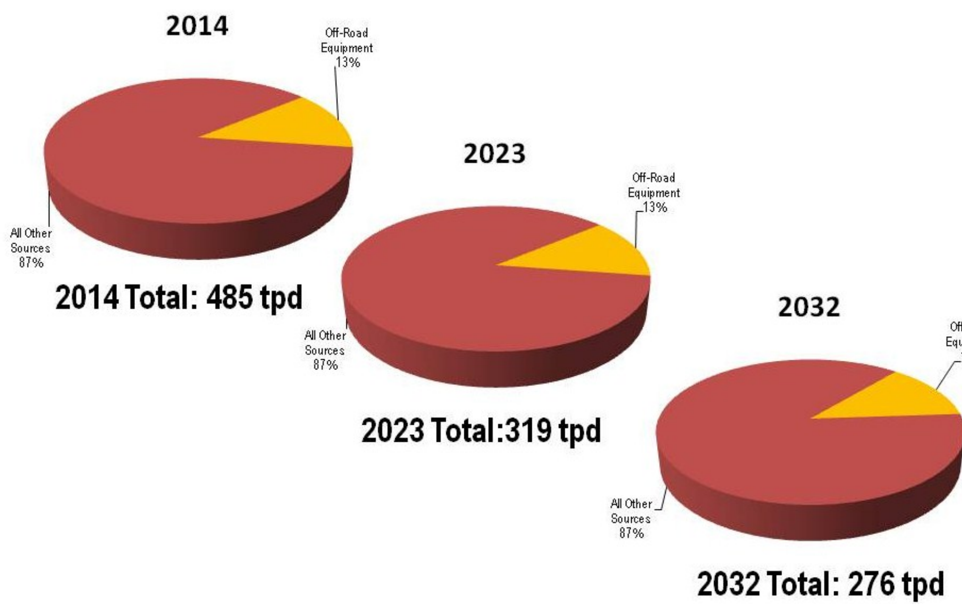


FIGURE 3

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

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

TABLE 2

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

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

TABLE 3

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

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

TABLE 4

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

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

Emissions Reduction Progress to Date

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

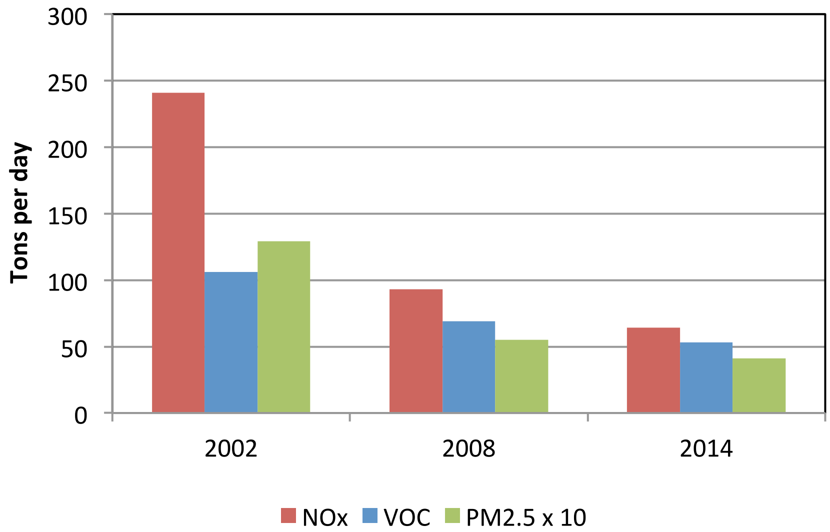


FIGURE 4

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

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

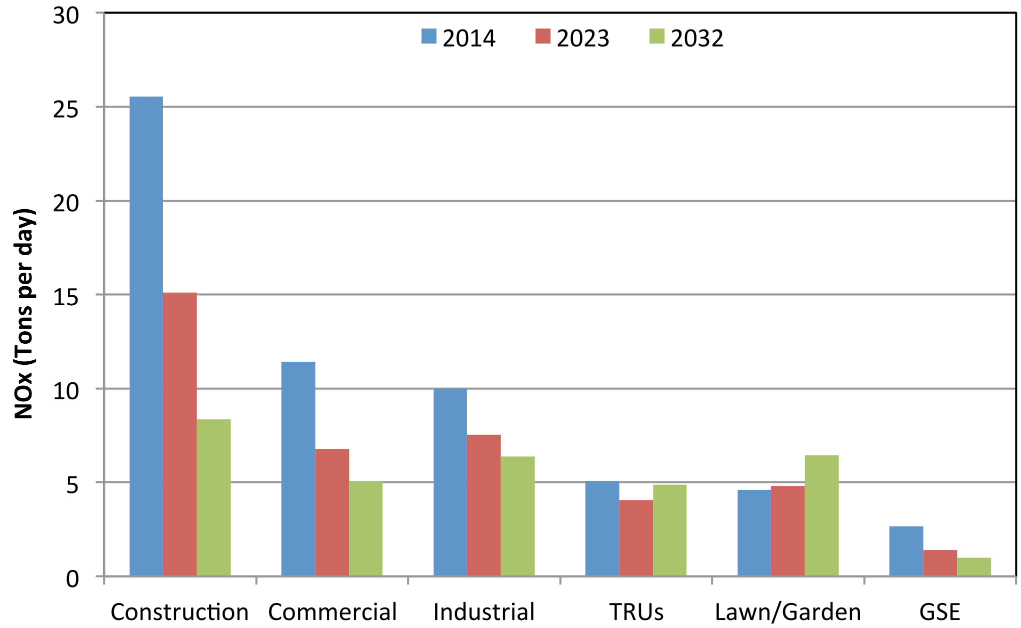


FIGURE 5

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

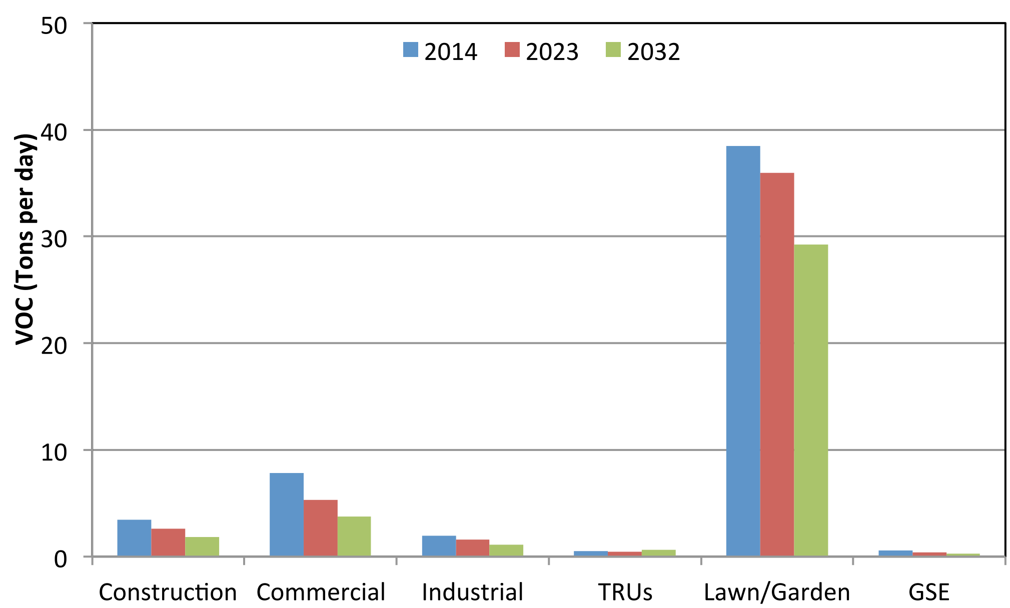


FIGURE 6

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

NOx EMISSION REDUCTION SCENARIOS

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

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

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

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

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

TABLE 5

Remaining NOx Emissions (tons/day) in 2023

(Baseline and Equal Share Emissions from the 2012 AQMP)

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

TABLE 6

Remaining NOx Emissions (tons/day) in 2032

(Baseline and Equal Share Emissions from the 2012 AQMP)

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

Equal Share Reduction in NOx Scenario

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

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

100 Percent Existing Standards

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

INITIAL OBSERVATIONS

Emission Reduction Scenarios

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

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

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

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

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

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

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

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

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

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

Advanced Technologies

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

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

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

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

Efficiency Measures

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

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

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

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

RECOMMENDATIONS

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

Technology-Related and Equipment Deployment Recommendations

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

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

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

- Sustained incentive programs (monetary and non-monetary) are needed for operators to deploy the cleanest equipment in the South Coast Air Basin. As part of this effort, research and demonstration projects should be initiated to develop new engines meeting the lower emission standards.

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

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

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

Operational Efficiency Recommendations

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

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

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

- Develop methodologies to quantify emission reductions from the implementation of best practices. Such quantification methodologies can be used in the 2016 AQMP and future AQMPs as well as CEQA for purposes of tracking and reporting criteria pollutant and greenhouse gas emission reduction benefits.

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

- As new incentive programs are developed, administration of the programs should be streamlined as much as possible in recognition that many fleets, especially smaller fleets, do not have sufficient resources to manage the projects.

- As new emissions inventories are being developed, there is a need to reflect the most up-to-date information regarding activity and future year projections.

- Given that there may be multiple compliance requirements from different regulations that may affect the same piece of equipment, there is a desire that the regulations be as consistent as possible.

- Similar to the desire for regulatory consistency, there is a desire that the various incentive programs have a consistent set of provisions.

- Quantifying the emission benefits from operational efficiency strategies will be challenging. There is a need to develop a process to evaluate strategies for each vocation.

APPENDIX A

CURRENT EMISSION CONTROL PROGRAMS

CURRENT EMISSION CONTROL PROGRAMS

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

OFF-ROAD EQUIPMENT SECTOR EMISSION SOURCES

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

Diesel Construction and Industrial Equipment

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

Large Spark Ignition Equipment

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

Transportation Refrigeration Units

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

Portable Equipment

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

Lawn and Garden Equipment

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

Ground Support Equipment

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

Incentive Programs

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

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

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

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

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

APPENDIX B

POTENTIAL EMISSION REDUCTION TECHNOLOGIES AND EFFICIENCY MEASURES

POTENTIAL EMISSION REDUCTION TECHNOLOGIES AND EFFICIENCY MEASURES

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

OVERVIEW - TYPES OF CONTROL TECHNOLOGIES AND EFFICIENCY MEASURES

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

Cleaner Combustion Engines

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

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

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

Aftertreatment Emissions Control Technologies

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

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

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

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

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

Exhaust Gas Recirculation

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

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

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

Engine Modifications

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

Alternative Fuels

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

Hybrid Systems

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

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

Plug-in Hybrid Systems

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

Fuel Cells

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

Battery Electric

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

Technology Combination

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

Efficiency Measures

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

CONTROL TECHNOLOGY APPLICATION BY EMISSIONS SOURCE CATEGORY

Construction/Mining and Commercial Equipment.

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

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

Industrial Equipment

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

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

Transportation Refrigeration Units

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

Lawn and Garden

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

Ground Support Equipment

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

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

EFFICIENCY MEASURES

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

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

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

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

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

Residential and Commercial Energy

2016 AQMP WHITE PAPER

OCTOBER 2015

South Coast Air Quality Management District

Barry R. Wallerstein, D.Env.
Executive Officer
Philip M. Fine, Ph.D.
Deputy Executive Officer
Planning, Rule Development & Area Sources
Jill Whynot
Assistant Deputy Executive Officer
Planning, Rule Development & Area Sources

Author

Aaron Katzenstein, Ph.D. – Program Supervisor

Reviewers

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

Contributors

Elaine Chang, DrPH – Deputy Executive Officer (retired)

Working Group

Crystal Adams – Western Riverside Council of Governments
Grieg Asher, Rongsheng Luo – SCAG
Carter Atkins, Tim DeMoss – Port of Los Angeles
Eugene Ayuyao, Tom Gross – SoCal Edison
Duane A. Baker – SANBAG
Leila Barker, David Jacot, P.E., Dat Quach, Mark J. Sedlacek – LADWP
Lou Bronstein – John Wayne Airport, Orange County
Joshua Cunningham, Holger Sdun – California Air Resources Board
Peter Herzog, Jennifer Johnson – NAIOP SoCal and Inland Empire
Christine Houston, Allyson Teramoto – Port of Long Beach
Joe Hower – ENVIRON
Rita Loof – RadTech
Ben Machol, Cara Gillen – U.S. EPA Region 9
Adrian Martinez – Earthjustice
Danielle K. Morone – Residential and Non-Residential Land Use Development
Noel Muyco, Lee Wallace – SoCal Gas
Hal Nelson – Claremont Grad University
Stephanie Pincetl – UCLA
Patty Senecal, Mike Wang, Ron Wilkniss – WSPA
Barbara Spoonhour – WRCOG
Carla Walecka – Realtors Committee on Air Quality

Table of Contents

RESIDENTIAL AND COMMERCIAL ENERGY WHITE PAPER

I. Introduction

Purpose and Objective

To attain the federal ozone and $PM_{2.5}$ standards, significant NOx reductions are needed within the Basin. California has a long history in implementing energy efficiency, conservation, and distributed generation programs, and these programs are an integral part in achieving AB 32 targets. Reducing, managing, and changing the way energy is used in the commercial and residential sectors provides needed emission reductions, and reduced energy costs. Governor Jerry Brown recently highlighted these benefits in his 2015 inaugural speech by establishing new targets to double energy efficiency within existing buildings, reduce petroleum use by 50%, and increase renewable power generation to 50% by 2030. Additionally, the U.S. EPA recognizes the emission reduction potential of efficiency and renewable energy programs and in 2012, released a roadmap to including them within state implementation plans for criteria pollutants[1]. The Residential and Commercial Energy workgroup has been assembled to assist SCAQMD staff in the development of this white paper that evaluates the existing and emerging energy programs in the residential and commercial sectors to determine how NOx reduction co-benefits can be better quantified and captured in the 2016 AQMP. Additionally, this review identifies actions the SCAQMD may pursue as part of the 2016 AQMP to encourage and incentivize renewable energy use and emission reduction efforts in these sectors.

II. Background

Overview of Residential and Commercial Sector in the Basin

The South Coast Basin (Basin) is home to approximately 17 million residents, 44% of the population in California, who reside in close to 6 million housing units and utilize commercial space for shopping, entertainment, and places of employment. Structures making up the residential and commercial spaces within the Basin differ widely in their periods of construction, size, purpose, and locations within different climate zones. These factors, along with income variations, regulations, ordinances, economic sectors, and tenant or owner occupancy result in differences in the amount of energy, water and other resources needed to support these structures. The consumption of energy within the residential and commercial sectors is a direct and indirect source of criteria pollutants and greenhouse gas emissions. These emissions can be reduced through energy savings measures that include efficiency, conservation, and distributed generation. California has policies in place that support agency and utility efforts that provide resources, technologies, and financial support to help minimize energy consumption in residential and commercial structures. Additional policies are being developed to reduce water consumption in the residential and commercial sectors. The energy/water nexus within Southern California has long been evident in the infrastructure of conveyance, treatment, distribution, and wastewater treatment[4]. Reduced water consumption is an immediate need within California which is in the midst of the worst unbroken drought interval in the past millennium[5].

Despite California's stringent building energy standards, high potential remains for improving energy efficiency within existing buildings. For instance, over 64% of the residential structures in Southern California were constructed before the 1979 California Title 24 building energy standards were enacted (Figure 1). Despite the many potential benefits from undertaking energy savings measures and the availability of multiple financial assistance programs, there remain many barriers to overcome. One of these barriers is increasing efficiencies within rental and leased properties where tenants are often responsible for utility costs (Figure 2). Some of these barriers have been reduced through regulations that require energy savings measures be employed within new construction, building retrofits, appliance energy standards, and incentive programs that help lower the capital cost barriers.

Undertaking energy efficiency and distributed generation projects provide numerous other economic benefits beyond reduced energy costs, such as providing local employment opportunities. Within California, the organization Next 10 estimates that 196,000 people were employed within California's Core Clean Economy in 2012[2]. These measures also provide economic benefits to residential and commercial property owners by increasing property values and improving community appearance through updated structural attributes such as energy efficient windows.

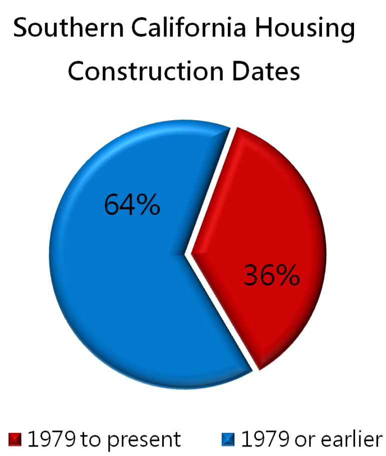


FIGURE 1

Housing units constructed in the Orange, Los Angeles, Riverside, and San Bernardino counties before and after California Title 24 building standards were implemented (U.S. Census Bureau/ AmericanFactfinder)

Smart energy measures have beneficial cascading effects when viewed holistically from the supply side to the end users. Efficiency measures in place in California have already reduced the need to build 12,000 MW of generating capacity and have been beneficial during peak electrical load periods[3].

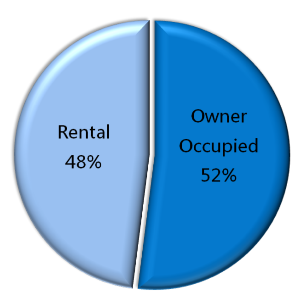


FIGURE 2

Among the four counties within the Basin almost half of the residential units are rental properties (U.S. Census Bureau/AmericanFactFinder)

III. Residential and Commercial Energy Usage

Residential and commercial energy needs are met primarily by utility-provided natural gas and electricity. Within Southern California energy consumption from the combined residential and commercial sectors resulted in 29% of the energy used within the Basin in 2008 (Figure 3). The milder climate, heavy reliance on transportation in Southern California, and existing California energy policies together result in the residential and commercial sectors accounting for less of the overall energy consumed in the Basin as compared to the rest of California and the nation.

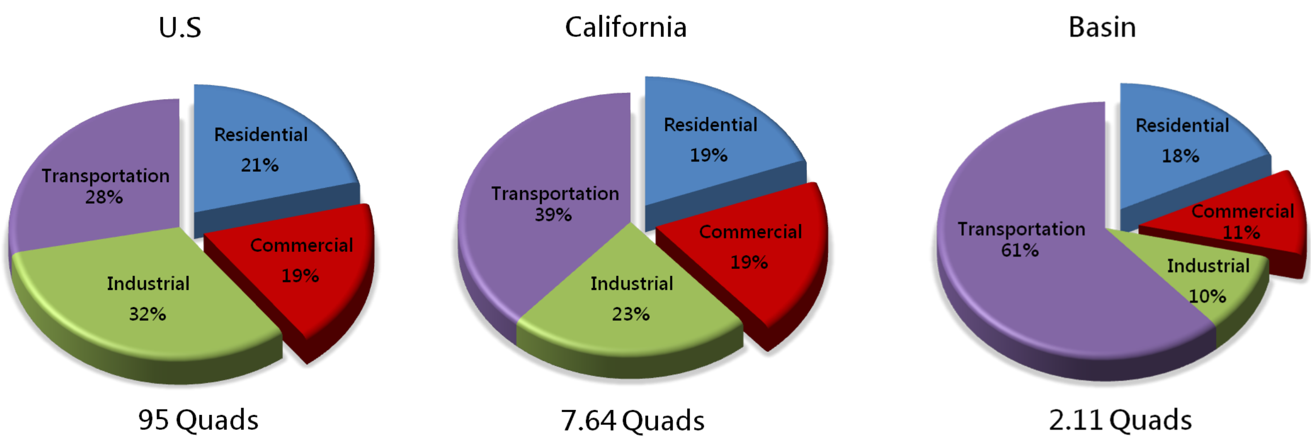


FIGURE 3

Relative energy consumption by sector, U.S and California data for year 2012; Basin data for year 2008 (2012 AQMP).
Note: Quad = one quadrillion British Thermal Units (BTUs)

Within the Basin the residential and commercial sectors account for over 71% of the electricity consumption and over 64% of the natural gas consumption (Figure 4).

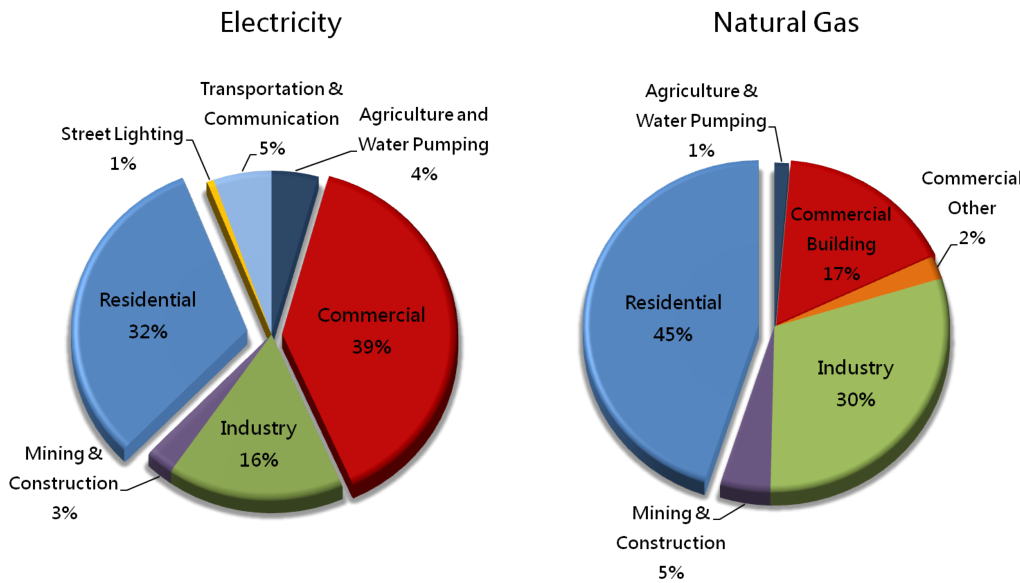


FIGURE 4

Southern California electricity and natural gas consumption by economic sector in 2013 (Electricity data for Basin utilities; natural gas covers SoCalGas territory; CEC Energy Almanac)

Commercial Sector:

The commercial sector is the largest electricity consumer within the Basin. Office spaces are the largest consumers of electricity in the commercial sector with electric vehicles currently consuming the least amount (Figure 5). In contrast, office spaces are among the lowest natural gas consumers, with restaurants having the highest usage.

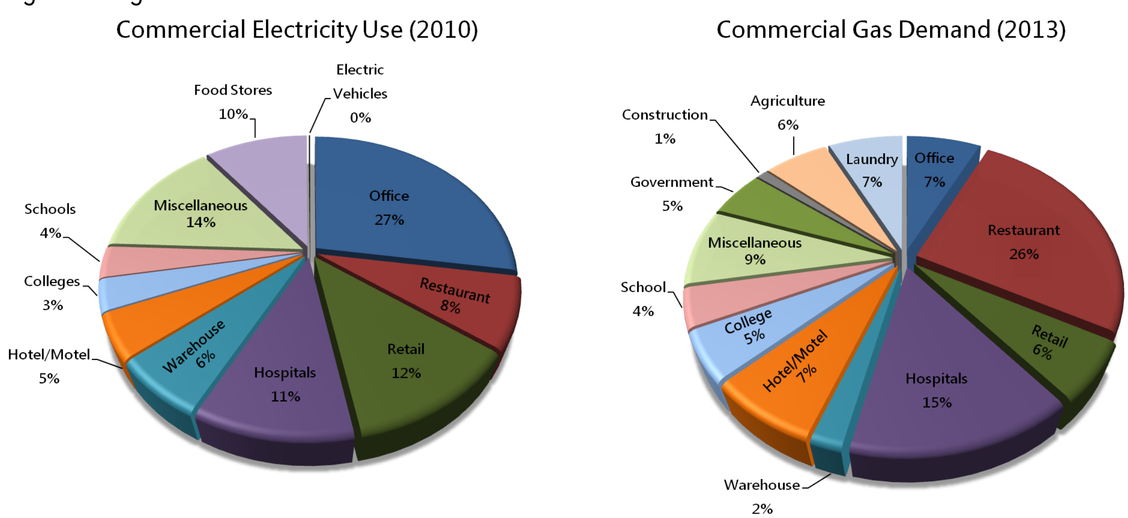


FIGURE 5

Distribution of electricity and natural gas demand by commercial business type for Southern California utilities in 2010 and 2013 (CEC California Energy Demand Forecast; NG Forecast Report).

As shown in Figure 6, electricity consumption in the commercial sector is predicted to increase by 16% by 2023, with natural gas consumption increasing by a minor 1.7% by 2025. The relatively small increase in natural gas consumption is a result of efficiency efforts in building and appliance standards in place within California. The largest predicted percent change within the commercial electricity sectors by 2023 is increased usage attributed to higher market penetration of electric vehicles (56 to 206 GWh by 2023)[24]. The large projected increase in electric vehicle energy usage within the commercial sector links the transportation sector with electricity demand, a new development since historically; transportation sector energy needs have not been reliant on the electrical sector. However, the trend will provide needed emission reductions from the transportation sectors.

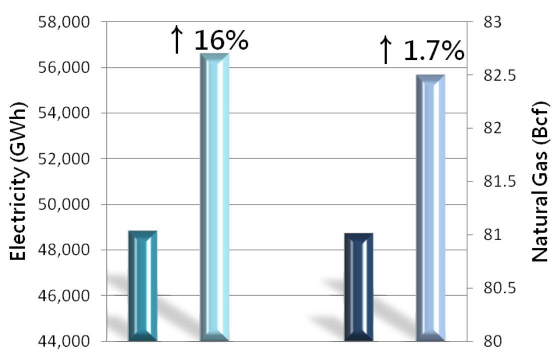
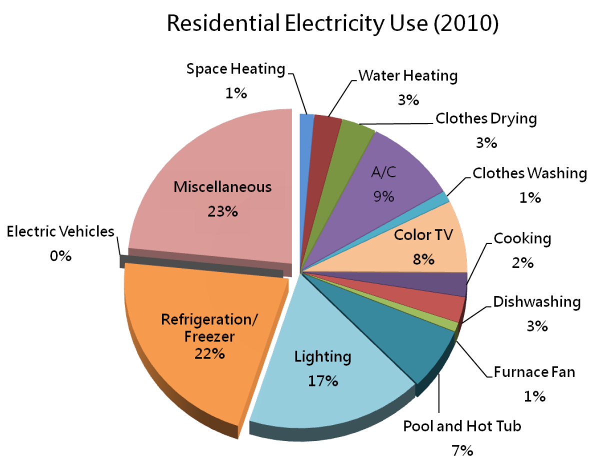


FIGURE 6

Predicted electricity and natural gas consumption increases within the Southern California commercial sector (California Energy Demand 2014-2023, NG Forecast Report).

Residential Sector:

The residential sector is the largest consumer of natural gas and second largest consumer of electricity within the Basin. In California, the average annual household electricity consumption is 6,300 kWh, and the average annual natural gas consumption is 350 therms. The largest uses of natural gas in the residential sector within California are for water heating and space heating. Appliances and lighting account for the most electricity consumption in residential settings.



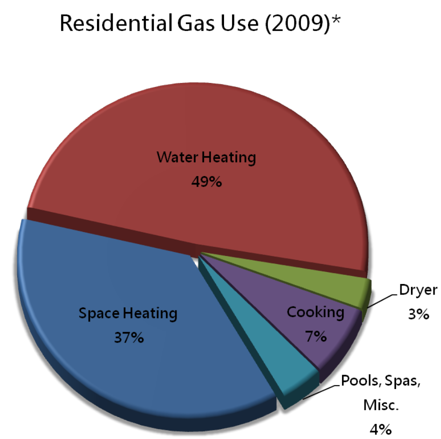


FIGURE 7

Electricity and natural gas consumption in the residential sector by end use; residential natural gas use is average for California. Residential electricity includes Basin electrical utilities. (CEC California Energy Demand 2014-2024; KEMA Appliance Saturation Survey).

It is estimated the residential demand for natural gas will decline 4.2% between 2013 and 2025 as a result of building and appliance efficiency programs currently in place (Figure 8). Electricity consumption is predicted to increase by 25% between 2010 and 2023. The largest electricity consumption will continue to be within the miscellaneous category. However, similar to the commercial sector the largest categorical percentage increase is predicted to be for residential electric vehicle charging (1.4 to 2,100 GWh by 2023)[24]. Overall, net decreases in electricity consumption by 2023 are estimated to occur within lighting, water heating, refrigeration, and televisions while all other categories are predicted to have electricity consumption increases.

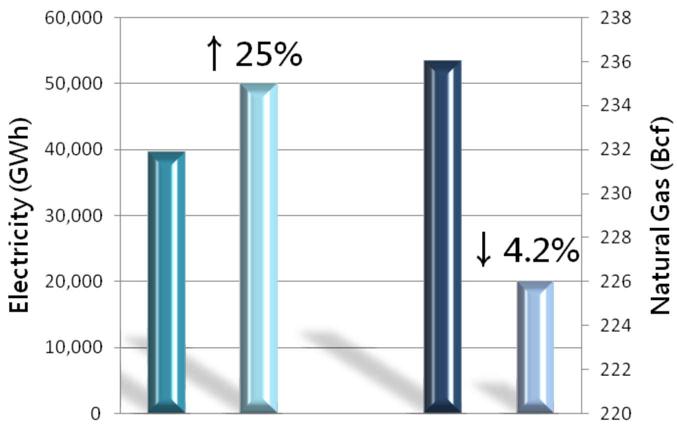


FIGURE 8

Estimated electricity consumption increase and natural gas consumption decrease within the southern California residential sector (CEC California Energy Demand 2014-2023, NG Forecast Report).

IV. Emissions

Based on 2012 AQMP emissions inventory projections, the residential and commercial sectors together directly emitted 29.3 tons per day of NOx and 8.5 tons per day of $PM_{2.5}$ in the Basin in 2014 (Table 1). The 2012 AQMP baseline inventory projections for emissions from the residential and commercial sector in 2023 and 2030 will become 8% of the overall NOx inventory as reductions are achieved in other sectors. The majority of NOx sources within the residential and commercial sectors are from water heating and space heating; the residential sector has higher PM2.5 direct emissions resulting from residential wood burning.

TABLE 1

2012 AQMP Emissions Inventory for Residential and Commercial Sectors

YEAR	2014	2023	2030	2014	2023	2030
	Residential (tons/day, % of total Inventory)			*Commercial (tons/day, % of Inventory)*		
NOx	19.79 (3.9%)	15.58 (4.7%)	13.45 (4.6%)	9.53 (1.9%)	9.17 (2.8%)	9.60 (3.3%)
VOC	8.61 (1.9%)	8.59 (2.1%)	8.57 (2.1%)	4.47 (1.0%)	4.42 (1.1%)	4.60 (1.1%)
PM2.5	7.15 (10.2%)	7.12 (10.1%)	7.09 (9.7%)	1.37 (2.0%)	1.39 (2%)	1.45 (2%)

Source: *2012 Air Quality Management Plan – Appendix III*

These emission estimates do not include non-combustion emissions resulting from residential or commercial cooking, upstream emissions occurring at power plants, or those resulting from support services such as water transport and treatment, waste hauling, construction, landscaping services, and material deliveries. Additionally, the 2012 AQMP inventory did not include projections for recent efficiency targets established by Governor Brown or the recent net zero energy targets under California's Title 24-Building Energy Efficiency Standards. In Section II, the residential and commercial sectors are shown to account for 71% of the electricity consumption. A rough estimate of the NOx emissions resulting from upstream power plants providing electricity to the residential and commercial sectors is an additional 1.4 tons of NOx per day. The total NOx emissions from in-Basin power plants are currently nearly 2 tons per day and are not expected to increase dramatically due to other emissions regulations and implementation of new renewable generation technologies.

V. Current Practices and Barriers to Implementation

Current Practices:

Generally, within the residential and commercial sectors, undertaking energy measures occurs through categorized efforts involving efficiency, conservation, onsite generation, and demand management.

Decisions made to implement one or more of the energy measures within those categories are often not arrived at through strategic assessments that implement the least costly measures to achieve the greatest energy savings. For instance, many homeowners have neighbors that installed solar, and there are door-to-door outreach efforts by solar companies promoting the benefits of adding generation. Many homeowners decide to add solar generation before considering less costly but potentially more beneficial efficiency efforts such as adding insulation. Undertaking strategic efficiency efforts prior to adding generation capacity can provide a more cost effective approach to energy savings. In reality, energy saving measure decisions are not often made through a thoughtful cost benefit analysis and may be influenced by the following:

- Immediate Needs: Energy savings decisions are often made on the immediate need for equipment or appliances.
- Perceptions: Common perceptions benefit certain individual activities, technologies, or measures that often result in them being popular choices.
- Outreach Efforts: Businesses selling products through retail chains, mailings, and door to door efforts influence behavior on implementing measures. Available incentive programs are often a highlight of business sales pitches.
- Competitive Efforts: Businesses may undertake energy savings measures to reduce energy costs, reduce exposure to energy volatility, highlight sustainability efforts, and increase property value.

Barriers to Implementing Energy Savings Measures and Renewable Generation:
The benefits that energy and water savings measures provide in addition to available incentives should result in rapid and widespread implementation. However, there are a multitude of barriers as to why owners of residential and commercial buildings do not implement water and energy savings measures. These barriers, in part, include[6,7,8]:

- Lack of Awareness: Residents and businesses are often occupied with other issues than reviewing energy consumption or the benefits energy-saving measures may provide.
- Lack of Information: Those that would like to reduce energy consumption often lack information on how to best initiate the effort. Is it better to undertake efficiency projects relative to adding generation? What measures are available and appropriate to implement first? What incentives and programs are available and are they aligned with my efficiency needs? How are benefits quantified? Who do I trust to provide correct information and reasonable costs?
- Difficulty in Measuring Success: Once energy savings measures are implemented it is often difficult to evaluate, measure, and verify the savings.
- Utility Rate Designs: Complex and changing rate designs make it difficult to quantify benefits of reduced energy usage.
- Lack of Responsibility: Building owners who lease or rent residential and commercial spaces often do not feel obligated to reduce energy usage since tenants typically do not pay the utility bills.
- Lack of Capital: The initial capital cost of undertaking energy saving measures is either not available or is competing with other priorities for limited funds.

VI. Existing Programs, Regulations, and Financing Mechanisms

The Warren-Alquist Act of 1974 established the California Energy Commission (CEC) and has moved energy consumption within the residential and commercial energy sectors from a business-as-usual path to an innovative approach, establishing a positive reinforcement cycle of increasingly strengthened energy standards that lead to new technologies, manufacturing processes, building materials and techniques[3,9]. California has led the nation and the world in aggressively developing and implementing energy conservation regulations, incentives, and market innovations. What is termed the "California Effect" or "Rosenfeld Curve", is the level of per-capita energy consumption in California since the early 1980's, whereas the rest of the nation has seen increases in per-capita consumption in energy as the use of electronic devices has increased significantly at residences and workplaces (Figure 9).

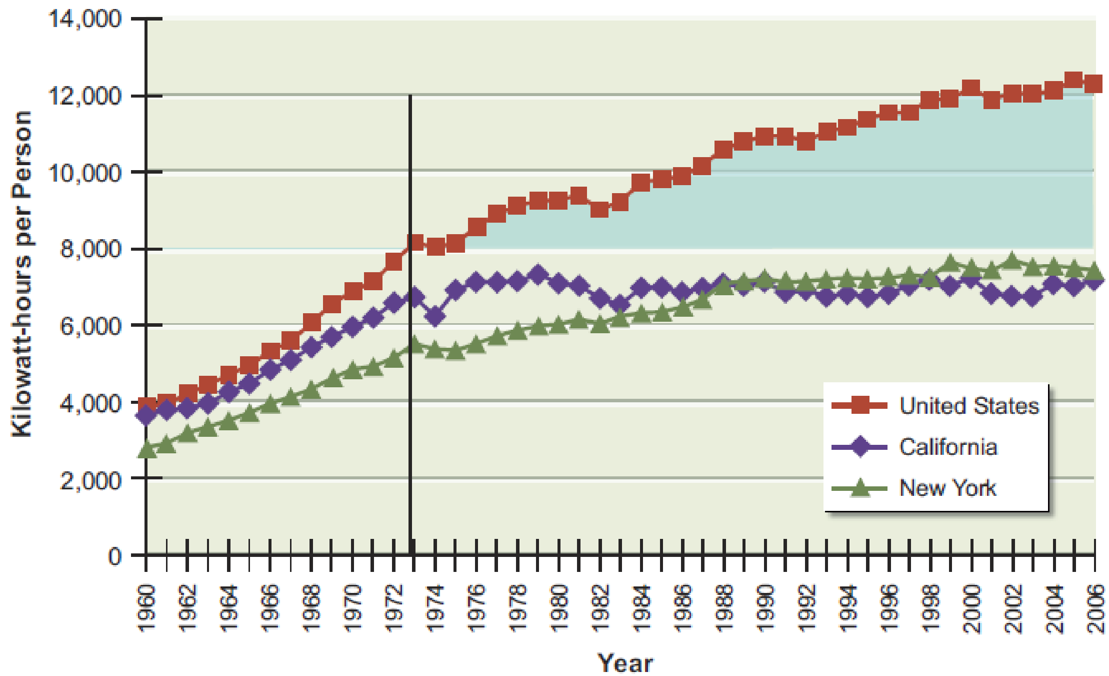


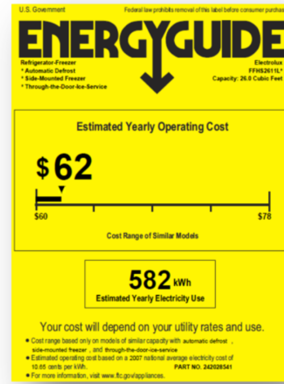
FIGURE 9

Per capita electricity consumption levels have remained relatively flat in California and New York, partially as a result of California energy policies in place[21].

Regulations and Policies:

In 1982 the California Public Utilities Commission removed a potential economic incentive for utilities to oppose efficiency efforts by decoupling electricity sales from revenues. This decoupling led to pathways for energy efficiency, distributed generation, combined heat and power applications, and demand-side management to be considered what are termed 'preferred resources' in managing energy needs within California[9]. Implementing 'preferred resources' (i.e. alternatives to fossil fuel fired generation) is an important component of the CEC's long-term energy procurement planning and has resulted in the establishment of many different types of incentives to promote these priority resources.

The earliest and most recognizable residential and commercial energy programs within California were the Title 20 appliance efficiency standards adopted in 1976, followed by the building efficiency standards in Title 24 adopted in 1978. The implementation of the Title 20 efficiency standards has saved consumers over $75 billion in electricity and natural gas costs. These two programs are still in effect within California and currently work in conjunction with federally established appliance and building efficiency programs, such as the EPA Energy STAR building and DOE appliance standards (EnergyGuide label). Generally the most stringent energy building codes and appliance standards have been first adopted in California. As the CEC further couples renewable power, efficiency, energy management, and new technologies into future Title 24 codes, the path has been set to achieve net zero energy use in new residential construction by 2020 and net zero energy use in commercial construction by 2030.



Incentive/Rebate Programs:

In 2014, over $1.4 billion in ratepayer funded programs were administered by the CPUC through utilities towards efforts that help develop preferred resources. These programs provide incentives and rebates for measures that include insulation, energy audits, shade trees, solar panels, low-flow showerheads, turf replacement, adding demand-response capabilities, and load shifting technologies. Additional incentives to promote energy savings measures include offering tax incentives. The Database of State Incentives for Renewables & Efficiency (DSIRE) developed and maintained by the North Carolina Clean Energy Technology Center provides a comprehensive list of available incentives by zip code (www.dsireusa.org).

Financing and Funding Mechanisms:

As identified earlier, the lack of funds for initial capital costs is often a reason many owners of residences and commercial buildings do not undertake energy saving measures, even though a project can later have partial cost recovery through available tax incentives and/or rebate programs. Currently there are multiple financing mechanisms and purchase agreements available for different types of projects. Some of these current mechanisms include:

- On-Bill Financing: Energy measures are financed through utilities and loans are added to customers' utility bills[10].
- California Clean Energy Jobs Act (Prop. 39): Provides roughly $550 million yearly to improve energy efficiency and expand clean energy generation in California Schools.
- Property Assessment Clean Energy (PACE) financing: Provides loans that get repaid through property tax assessments to fund approved energy savings measures or new generation.
- Power Purchase Agreement (PPA): Under PPAs, the solar installation company provides, installs, and retains ownership of the equipment that generates electricity, which the user purchases at a predetermined rate. Due to the declining costs of solar panel equipment and the incentives available to third parties that own and maintain the equipment, electricity costs through the PPA are generally less than the higher-tiered rates charged to residential users.
- Power Efficiency Agreements (PEA): This is a relatively new financing technique that allows a third party to install an energy saving project that is financed through expected future energy cost savings.

VII. Achieving Greater Penetration of Energy Efficiency

Existing buildings in the residential and commercial sector generally do not meet the current Title 24 building codes and thus offer significant opportunities for energy savings. This in part is being addressed under AB 758-Comprehensive Energy Efficiency in Existing Buildings, which requires the CEC to develop an action plan to achieve cost-effective energy savings within existing residential and nonresidential buildings[11]. Reducing energy consumption within existing buildings is particularly difficult with rental and leased properties[12]. It is usually not apparent that it is in the property owner's best interest to undertake energy savings measures when the tenants pay utility energy costs. Under AB#1103, tenants leasing commercial buildings will have a better understanding of the previous energy costs since these must be disclosed; nonresidential buildings must disclose their past energy use to a prospective buyer, a prospective lessee, or a lender financing the building. There currently is not a program in place requiring past energy disclosures from residential structures.

Energy usage within the residential sector shows a correlation with household income. Many of the rebates and financing programs require property ownership and upfront capital[13]. Income qualified programs are available such as the federally funded Weatherization Assistance Program (WAP) and ratepayer funded Energy Savings Assistance Program (ESAP). Both programs provide energy assistance measures at no or very low cost to lower income households. One of the drawbacks of these two programs has been the requirement to own the residence or have property owners consent for the programs to be implemented[14].

Incorporating non-energy benefits into energy savings programs may provide more of a motivating factor to utilize existing programs. A recent UCLA study showed a study group of Los Angeles residents were least motivated to undertake energy saving measures when they were linked to reduced energy costs; a more significant motivator was to link energy saving efforts with reduced emissions. Therefore coupling energy savings with the amounts of emissions reduced may provide additional motivation to implement energy savings measures. Emission benefits could also be included on appliance energy efficiency labels.

Turning energy savings into a competitive game or contest that uses existing incentives and resources provides a novel tool for achieving reduced energy usage[15]. Within the California Cool Communities Challenge, city governments and residents compete against each other in reducing energy usage. At the end of the competition the city with the highest points not only receives bragging rights for winning the competition, but also a portion of $100,000 in prize money. Currently the Cool Communities Challenge tracks energy savings and estimates the GHG reductions from energy-saving activities; benefits may further be extended to include criteria pollutant emission reductions along with water conservation[16]. Energy savings contests could be further extended to California schools with support from Prop 39 (California Clean Energy Jobs Act) funding.

Lastly, bringing together efficiency projects and/or renewable energy through aggregated procurements can provide reduced rates and help with the technical difficulties in implementing these projects. The costs can be reduced through larger purchases and customers working together by developers avoiding significant customer acquisition expenses, streamlining construction scheduling at multiple sites, bulk equipment purchases and enticing more competitive bids with a larger pool of customers. An example of aggregated purchases was undertaken with cities and counties in Silicon Valley joining together to purchase 31 MW of solar panel systems at 180 sites.

Net Zero Energy Home of the Near Future

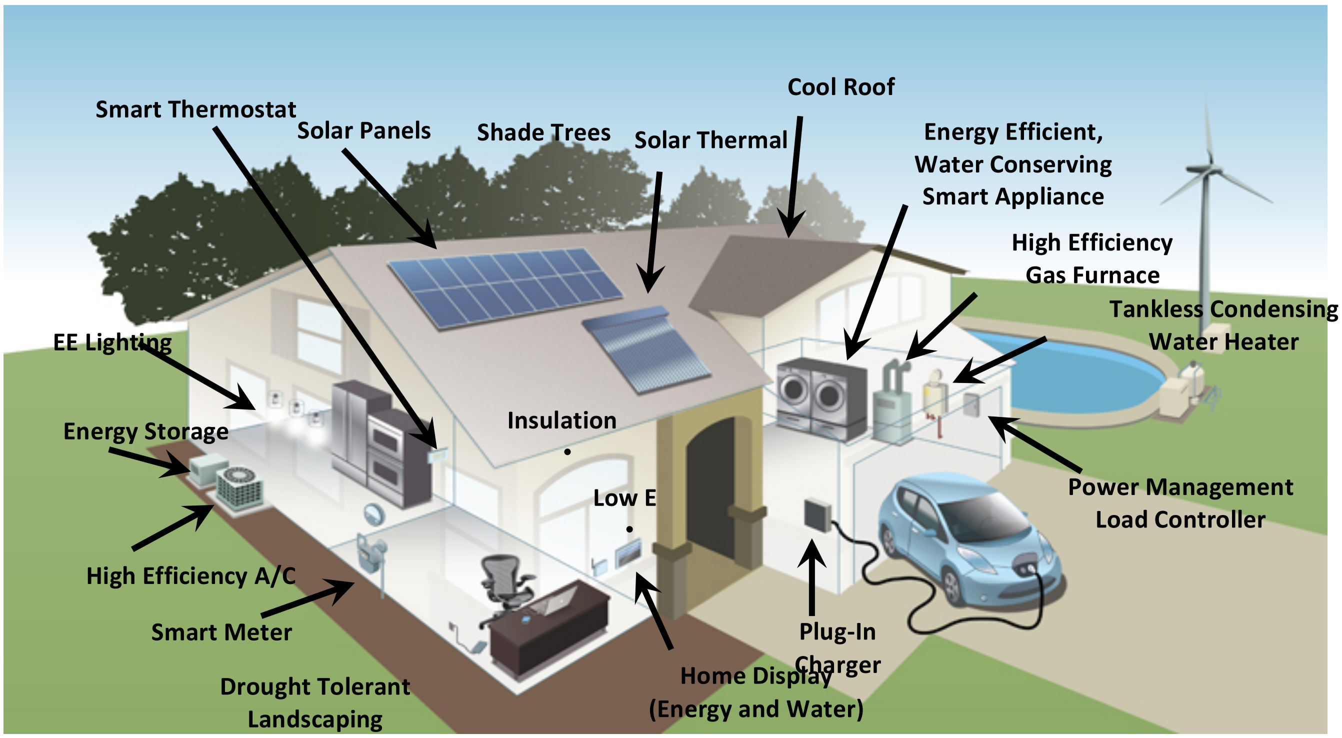


FIGURE 10

Building materials, grid connected distributed generation, power management, and low water use will help move residential construction toward the CEC goal that all new homes are net zero energy beginning in 2020 (adapted from San Diego Gas & Electric).

VIII. Technology Assessment

New technologies are helping California move forward in establishing net zero energy usage in new construction, implementing higher renewable portfolio standards, providing climate resilience, and reducing air emissions.

Distributed Generation

California is currently leading the nation in installed renewable generation capacity with over 4,000 MW of installed solar, over 6,000 MW of installed wind capacity, and 1,200 MW of biomass generating capacity accounting for 15% of the total generation capacity within the state as of 2013[17]. Policies and incentives helped initiate the market for renewable generation systems; more recently, rapidly declining costs, increased electrical utility rates, and innovative financing mechanisms have greatly increased installations.

Rooftop photovoltaic (PV) systems are currently the most popular generation technology being installed at residential and commercial buildings. Generating efficiencies for solar panels over the years have been increasing from around 10% solar energy conversion to over 40% with new panel technologies[18]. New solar panel designs are also being coupled with solar thermal systems to reduce rooftop space needed for both systems. Fuel cell energy systems are being implemented within residential and commercial settings that can provide power as well as waste heat for use in building hot water and/or space heating needs[19].

Energy Flexibility

Rooftop photovoltaic systems may no longer be considered an emerging technology due to the large number of installations occurring. The current primary motivation behind the decision to install these systems is to help avoid the highest tiers on electricity rate structures. The installation of PV systems within commercial buildings does not generally provide large utility savings for larger commercial buildings due to power demand charges that are in effect into the evening hours. Power demand charges on commercial users are typically based on the highest 15 minutes of power usage (kW) over a billing period. Utilities usually apply the highest demand charge rates during the summer months when electricity consumption is the highest. PV system generation is also intermittent and thus can be destabilizing to the electrical grid. Currently, these systems need to be coupled with other flexible generation capacity such as fossil peaking units, which has created some excess generation capacity.

To address generation intermittency, demand charges, and help provide capabilities to participate in demand-response events; new technologies and rate structures are being implemented. Among these technologies is energy storage at residential and commercial buildings which provides a flexible resource that can be coupled with generation, load management needs, and utility rates. Usage of battery storage systems can reduce the vulnerability from intermittency associated with onsite renewable generation, reduce demand charges through peak shaving, provide energy arbitrage capabilities (i.e. storing energy purchased at off-peak times and selling or using it on-peak), and provide utility grid services support.

There are different types of storage technologies, including batteries (chemical), thermal, and pumped water (hydro) (Figure 10). Some of the stationary battery systems utilize electric vehicle batteries as a second-life application. Battery systems coupled with solar PV help reduce utility power demand charges by filling in generation intermittency and help reducing utility demand charges (peak shaving). In large commercial applications, thermal storage is widely used to chill water or create ice during periods of off-peak electricity rates, that is later used to cool buildings during peak demand charge periods. Smaller applications are being developed for the residential sector that has ice storage capabilities next to air conditioning compressors. New storage technologies are being developed that utilize compressed air and flywheels.

In the residential and commercial sectors, new load management technologies will enable residents to optimize their energy consumption and cost relative to utility rate structures that include real-time pricing, time-of-use rates, and demand management needs. These technologies include using Home and Area Network (HAN) devices that utilize the Internet of Things, connecting smart appliances, thermostats, irrigation controllers with user habits, the weather, and utility prices[8]. Additionally, use of newer lower energy manufacturing processes such as using photochemical or electron beam curing processes other than traditional heated methods can provide significant paybacks in long term energy savings[25].

Building Materials and Lighting

New building materials and methods provide the greatest potential reduction in energy consumption within residential and commercial buildings, along with providing some of the fastest paybacks through cost savings. As shown in Figure 7, space heating and cooling are the largest sources of energy consumption. Adding insulation and ensuring ducting is properly sealed does not require emerging technologies and is often the least expensive measure to reduce building-energy consumption. Coupling insulation with energy efficient windows, envelope sealing and using building materials with high thermal mass helps reduce the need for larger heating and cooling systems. Additionally, as Southern California's warmer climate causes air conditioning to be a larger energy load, incorporating cool roofs, fenestration systems, and trees that shade buildings helps reduce the cooling demand of the buildings occupied spaces.

Cool roofs reduce the heat loads going into buildings through increasing the reflectance of the rooftop and/or incorporate roofing materials that have high thermal emittance. This not only helps reduce air conditioning needs of interior spaces, but also can reduce outside temperatures and lower the urban heat island effect. Lowering outside temperatures and using less energy to cool interior spaces reduces criteria and greenhouse gas pollutants[20].

One of the largest advances in efficiency technology has been in lighting. Lighting traditionally has been with incandescent filament bulbs with a total system efficiency of less than 2%, considering the chemical energy being converted to electricity at a power plant then being delivered to light an incandescent bulb[22]. Advances in high efficiency lighting technologies include fluorescent and light emitting diodes along with advances in luminaires that provide lighting in the right places and lighting controls[21,22]. Lower tech developments in daytime interior lighting have been solar light tubes, skylights, and daylight redirecting films on windows that allow for natural daytime lighting within interior spaces through insulated spaces[23].

Cross Sector Coupling

With new technologies and efficiency tools being rapidly adopted in the residential and commercial sectors, the traditional utility business model of adding power plant capacity to meet demand is rapidly changing. With buildings being capable of adding generation and providing energy flexibility, we can reduce the need for new generation capacity and allow for more efficiently utilizing existing energy infrastructure. This coupling and improved management of energy supply and demand will need to include new transportation technologies that use electric, natural gas, and fuel cell vehicle technologies. The interconnection of energy use between residential, commercial and transportation sectors is increasing rapidly as a result of the alternatively powered transportation technologies that are being rapidly developed and deployed.

IX. Scenario Analysis

Two scenarios are presented here that account for updates to energy savings targets since the 2012 AQMP inventory was developed. The emissions from the 2012 AQMP presented earlier in Table 1, on page 6, do not currently account for increased efficiency targets set in place under Title 24, within the CEC's Integrated Energy Planning Report (IEPR), and recent efficiency improvements in appliances. Using energy demand reductions estimated by the State from these efforts, an expected 25% decline in energy consumption within the residential and commercial sectors will occur as a result of current targets in place (Scenario 1); a 50% decline is expected, with current targets plus the Governor's new proposal (Scenario 2) (http://www.arb.ca.gov/html/fact_sheets/2030_energyefficiency.pdf). A linear implementation of these scenarios is assumed along with a linear and proportional reduction in criteria pollutants as a result of reduced energy usage.

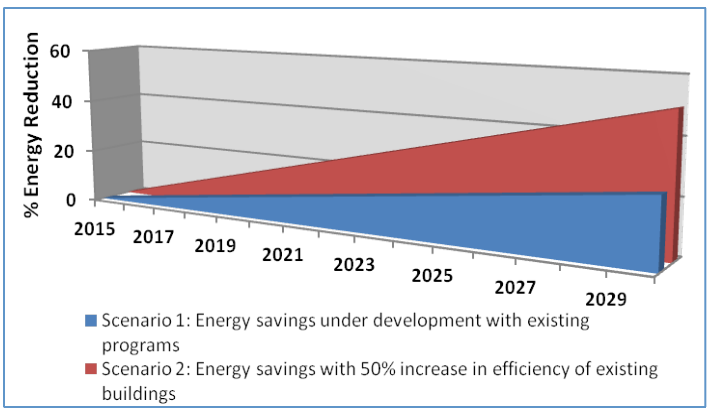


FIGURE 12

Two scenarios that account for updated energy savings targets

Using the existing efficiency and energy programs set in place, the NOx emissions within the residential and commercial sectors might be expected to decline by 3 to 5 tpd in 2023 and 2030 respectively as shown in Table 2. With the new targets set by the Governor a decline of 7 to 11 tpd of NOx might result by 2023 and 2030.

TABLE 2

NOx Reductions That May Result From Updated State Energy Targets as of 2015

YEAR	2014	2023	2030	2014	2023	2030
	Residential (tons/day)			*Commercial (tons/day)*		
2012 AQMP	19.79	15.58	13.45	9.53	9.17	9.60
Scenario 1 (25% by 2030)	-	13.6	10.1	-	8.0	7.2
Scenario 2 (50% by 2030)	-	11.4	6.7	-	6.7	4.8

X. Findings and Recommendations for the 2016 AQMP

Southern California is facing challenges in providing capacity and infrastructure for water, energy, and transportation. Traditional development patterns and policies may not be appropriate for the future. Fortunately, many policies, programs, and technologies have been and continue to be implemented in California and within the Basin to alleviate resource challenges and accommodate an increasing population. Additionally to increase resilience against persistent drought conditions, a changing climate, and to address looming air quality attainment deadlines, more needs to be done sooner.

As part of the 2016 AQMP development, staff is recommending the inclusion of the following actions:

- *General*
  - Develop a control measure in the 2016 AQMP to recognize emission reduction potentials from energy saving programs that are implemented locally, statewide, and nationally;
  - In consultation with state energy agencies and utilities, develop a tracking mechanism for timely quantification of SIP creditable emission reductions from energy efficiency and distributed generation programs within the residential and commercial sectors;
  - Work with appropriate agencies to augment the current appliance labeling programs to include air quality benefits of using higher efficiency models (e.g., Over one year energy savings from this appliance can power a certain amount of EVs or zero emission miles, or an equivalent emission reduction rating system);
  - Monitor implementation of AB#1103 and effectiveness of energy disclosures for prospective tenants leasing commercial buildings. Review the need and support for legislation requiring energy use disclosures for residential rental properties;
  - Identify ways to help incentivize and implement energy saving measures with building owners who lease or rent commercial and/or residential spaces;

- Provide technical assistance along with other agencies to compile methodologies and best practice guidelines to retrofit existing buildings towards net zero energy consumption;
- Sponsor energy savings competitions or campaigns at schools and promote student youth participation in energy saving practices (e.g., financial awards to winning schools);
- Include energy efficiency in the District's outreach and education materials to enhance awareness of energy saving opportunities; and
- Help expand Property-Assessed Clean Energy (PACE) programs into existing commercial buildings and multi-unit dwellings. Further review additional ways to incentivize additional energy saving measures, including but not limited to, tax credits or low-interest loan programs;

- *Electricity*:
  - Work with electrical utilities and state agencies to make rate structures transparent and easier to understand so consumers can make informed energy choices, including alternatively fueled vehicle choices; and
  - Work with stakeholders to develop incentive programs for solar installations and other renewable distributed generation systems that are zero or near-zero emitting for existing buildings.

- *Natural Gas*: While SCAQMD has adopted the most stringent NOx emission regulations for new residential and commercial natural gas-fired water heaters and space heaters in the nation, residential natural gas combustion related NOx emissions remain a significant source of emissions, ranked second highest among stationary NOx emission sources. Energy efficiency is an effective means to augment SCAQMD existing regulations to bring about further NOx reductions.
  - Where SCAQMD funding is available, provide financial incentives to promote energy efficient equipment/appliances beyond regulatory requirements or to accelerate equipment/appliance replacements that are targeted towards maximizing criteria and greenhouse gas emission reductions. These incentive programs can be in conjunction with or an augmentation to the existing utility programs; and
  - Consider and promote equipment energy efficiency in future SCAQMD regulatory or incentive programs.

REFERENCES:

1. EPA, Roadmap for Incorporating Energy Efficiency/Renewable Energy Policies and Programs into State and Tribal Implementation Plans, 2012; EPA-456/D-12-001a.
2. Next 10, *California Green Innovation Index*, 6th edition, 2014.
3. Rosenfeld and Poskanzer, *A Graph is Worth a Thousand Gigawatt-Hours: How California Came to Lead the United States in Energy Efficiency*, innovations, 2009.
4. CEC, *California's Water-Energy Relationship*, 2005.
5. Griffin and Anchukaitis, Geophys. Res. Lett. 10. 1002/2014.
6. EPA, *Discussion of Consumer Perspectives on Regulation of Energy Efficiency Investments - A Resource of the National Action Plan for Energy Efficiency*, Sept. 2009 (www.epa.gov/eeactionplan).
7. McKinsey & Co., *Unlocking Energy Efficiency in the U.S. Economy*, 2009.
8. IEA, *More Data, Less Energy: Making Network Standby More Efficient in Billions of Connected Devices*, 2014.
9. 2003 Energy Action Plan (http://www.energy.ca.gov/energy_action_plan/index.html).
10. Zhang, S., *On-Bill Financing: Encouraging Energy Efficiency*, C2ES, August, 2013.
11. CEC, *Draft - California Existing Buildings Energy Efficiency Action Plan,* March 2015 (http://www.energy.ca.gov/ab758/documents/)
12. Lucas, D.; *Evaluating the Slow Adoption of Energy Efficient Investments: Are Renters Less Likely to Have Energy Efficient Appliances?*, National Bureau of Economic Research, June 2010.
13. IEA, *Evaluating the Co-Benefits of Low-Income Energy Efficiency Programs*, June 2011
14. E2e, *Are the Non-Monetary Costs of Energy Efficiency Investments Large? Understanding Low Take-up of a Free Energy Efficiency Program*, January 2015.
15. ACEEE, *Gamified Energy Efficiency*, Feb. 2015.
16. Cool California City Challenge, https://coolclimate.berkeley.edu/challenge/index.php?type=login .
17. CEC Tracking Progress : http://www.energy.ca.gov/renewables/tracking_progress/
18. NREL; http://www.nrel.gov/news/press/2014/15436.html, (2014).
19. Bloomberg Businessweek, *Powering Your Home with a Box of Hydrogen*, January 19-25, 2015.
20. Levinson *et al., Inclusion of Cool Roofs in Nonresidential Title 24 Prescriptive Requirements*, Energy Policy 33 (2005) 151-170.
21. Distributed Generation, *Flipping the Switch*, March/April 2012
22. National Academy of Sciences, *Real Prospects for Energy Efficiency in the United States*, 2010.
23. Wall Street Journal, *Finally: Sunlight in the Office Cubicle*, March 3, 2015
24. CEC, California Energy Demand 2014-2024 Final Forecast: Volume 2; January 2014 (www.energyalmanac.ca.gov/electricity/electricity_stats/index.html)
25. SCAQMD Rule 1130, Appendix D "Sustainability Advantages of Ultraviolet and Electron Beam Curing".

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

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

South Coast AQMD

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

A Business Case for Clean Air Strategies

2016 AQMP WHITE PAPER

OCTOBER 2015

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT GOVERNING BOARD

South Coast Air Quality Management District

Barry R. Wallerstein, D.Env.
Executive Officer

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

Jill Whynot
Assistant Deputy Executive Officer
Planning, Rule Development & Area Sources

Joe Cassmassi
Planning and Rules Director
Planning, Rule Development & Area Sources

Authors

Elaine Shen, Ph.D. – Program Supervisor
Shah Dabirian, Ph.D. – Program Supervisor
Priscilla Hamilton – Air Quality Specialist

Contributors

Peter Greenwald – Senior Policy Advisor (retired)
Matt Miyasato, Ph.D. – Deputy Executive Officer, Science and Technology Advancement
Naveen Berry – Planning and Rules Manager, Science and Technology Advancement
Al Baez – Program Supervisor
Brian Choe – Air Quality Specialist
Michael Morris - Program Supervisor
John Andrews, Christy Elshof, Larry Vaupel – County of San Bernardino
Duane A. Baker - San Bernardino Association of Governments
Tim DeMoss, Teresa Pisano - Port of Los Angeles
David Englin, Paul Granillo, Kevin Maggay - BizFed
Sue Gornick, Patty Senecal, Mike Wang, Ron Wilkniss – WSPA
Peter Herzog - NAIOP SoCal and Inland Empire
Austin Hicks, Kurt Karperos - California Air Resources Board
Bill La Marr, Gary Stafford - California Small Business Alliance
Richard Lambros – Southern California Leadership Council
Scott Lavery – United Parcel Service
Melissa LinPerrela – National Resources Defense Council
Ken Marko – Pepsico
Thomas McHenry - LA Area Chamber of Commerce
Renee Moilanen, Allyson Teramoto - Port of Long Beach
Noel Muyco, David Raney, Lee Wallace - SoCal Gas
Jonathan Nadler – Southern California Association of Governments
Peter Okurowski, Darcy Wheeles - Association of American Railroads
Nancy Pfeffer - Gateway Cities COG
Bill Quinn – California Council on Environmental and Economic Balance
Steve Schuyler – BIASC
Chris Shimoda - California Trucking Association
Chuck Tobin – Burrtec Waste Industries, Inc.

Reviewers

Elaine Chang, DrPH – Deputy Executive Officer (retired)
Henry Hogo – Assistant Deputy Executive Officer, Science and Technology Advancement
Barbara Baird, J.D. – Chief Deputy Counsel
Patti Whiting – Staff Specialist

Table of Contents

1. Introduction

The South Coast Air Basin is one of only two "extreme" non-attainment areas in the nation that have not reached the federal eight-hour ozone standards. Ground-level ozone, or smog, forms when volatile organic compounds (VOC) photochemically react with nitrogen oxides (NOx) in the presence of sunlight. Encompassing a major swath of Southern California, the South Coast Air Basin is among the most densely populated areas nationwide, with about 13 million cars, trucks, and other vehicles operating on its extensive network of highways and roads.[1] The amount of pollutants produced by modern urban life and industrial activities, combined with Southern California's year-round sunny weather, all contribute to the high concentrations of ground-level ozone in the area. Ozone exposure can cause immediate, adverse effects on the respiratory system and result in various symptoms such as coughing, throat irritation, chest pain, and shortness of breath. It can also inflame the lining of the lungs, and for asthma patients, it may increase the number and severity of attacks. Long-term impacts of frequent exposure to ozone may lead to permanent lung damage and increase the risk of premature death.

Due to a myriad of factors, including advancements in transportation and pollution control technologies, it is expected that air pollutant emissions will continue to decline over the coming decades. However, SCAQMD staff projects that deeper reductions of NOx emissions are necessary in the South Coast Air Basin. To reach the 1997 standard of 80 parts per billion (ppb) by the attainment deadline, NOx emissions will have to be reduced by approximately 50 percent from the projected baseline level in 2023. To reach the more stringent 2008 standard of 75 ppb, an additional 15-percent reduction will be needed from the projected baseline level in 2032.[2]

According to SCAQMD staff's estimates, about 60 percent[3] of the region's NOx emissions in 2032 will come from the sectors of passenger transportation and goods movement, the latter of which includes emission-

---

[1] According to estimates provided by the California Department of Motor Vehicles, there were a total of 13.7 million registered vehicles in Los Angeles, Orange, Riverside, and San Bernardino counties for the period of January 1 to December 31, 2013. (https://www.dmv.ca.gov/portal/wcm/connect/add5eb07-c676-40b4-98b5-8011b059260a/est_fees_pd_by_county.pdf?MOD=AJPERES, accessed February 18, 2015.) The South Coast Air Basin covers all of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties; therefore, the total number of vehicles would have been somewhat smaller.

[2] Figures are based on preliminary analysis for the 2016 Air Quality Management Plan (AQMP). The baseline projection assumes a specific set of growth factors and that no additional clean air programs and regulations would be introduced.

[3] Based on emission projections in the 2012 AQMP.

producing sources such as heavy-duty trucks, marine vessels, commercial harbor craft, cargo handling equipment, and freight locomotives. Therefore, in order to attain upcoming federal air quality standards, significant investments will need to be made to develop and deploy advanced technologies, including those with zero and near zero emissions. At the same time, passenger transportation and goods movement sectors together offer over 260,000 jobs, or 4.3 percent of total private industry employment, in the SCAQMD region.[4] During the recent economic recession, the warehousing and storage industry—which belongs to the broader goods movement sector—was particularly resilient. Between 2007 and 2012, it experienced nearly 50 percent of job growth in the otherwise hard-hit counties of Riverside and San Bernardino.[5]

Given the importance of passenger transportation and goods movement sectors to the regional economy, SCAQMD staff is faced with the challenge of remaining sensitive to the business sector's needs while at the same time implementing control strategies and programs that will ensure the Basin reaches federal air quality standards. Anticipating the need for zero or near zero emission technologies, SCAQMD is exploring potential means to maximize emission control strategies that have a "business case" for implementation. A business case could exist where a technology, fuel, or other strategy reduces emissions and also improves energy efficiency, reduces fuel or maintenance costs, creates new job opportunities, or has other cost savings and economic benefits. To this end, this white paper seeks to develop planning concepts for control measures and related programs (e.g., incentive or financing programs) to be included in the 2016 Air Quality Management Plan (AQMP) that, to the extent possible, create a business case for deployment of needed technologies and efficiency measures. The working group discussions, and consequently this white paper, have placed particular emphasis on mobile source emission reductions. However, most of the proposed concepts for AQMP control strategies and related programs are also applicable to stationary sources, and a companion white paper regarding Industrial Facility Modernization further explores business cases for stationary sources.

To actively involve stakeholders from the early stages of AQMP development, SCAQMD staff organized ten working groups, one for each of the 2016 AQMP white papers that aim to provide a policy framework and guidance for the formulation of upcoming control measures and programs. Staff solicited volunteer participation among the 2016 AQMP Advisory Group members who were also asked to recommend technical experts in relevant fields. Moreover, all working group meetings are open to the public.

---

[4] Figures are based on the 2014 fourth quarter Quarterly Census of Employment and Wages (QCEW) data for industries classified under the North American Industry Classification System (NAICS): 48-49—transportation and warehousing, and 541614—process and logistics consulting services; and for Los Angeles, Orange, Riverside, and San Bernardino counties.

[5] Based on historical QCEW data. The warehousing and storage industry is classified under NAICS 493.

The "A Business Case for Clean Air Strategies" white paper working group conducted a total of five meetings between June 2014 and March 2015. At the very first meeting, the participating stakeholders shared two premises that are consistent with the SCAQMD staff's evaluation:

1) Within the constraint of given air quality attainment deadlines, it is unlikely that all affected industries would have a business case regardless of the design of AQMP control measures and related programs.
2) The upcoming AQMP will most likely produce the largest impact on the goods movement sector, which consists largely of transportation and logistics industries.

In addition to open discussions and exchanges through the working group process, this white paper benefited greatly from stakeholder presentations of industry-specific case studies. The presentations covered various topics, including future opportunities enabled by technology advancement, successes and failures, and lessons learned from past experiences, all of which are instructive as to how business cases may be achieved under different circumstances. Section 2 of this white paper will discuss potential means to create a business case, based on lessons learned from the five industry case studies. In Section 3, other lessons from additional stakeholder comments will be discussed and supplemented by a number of examples researched by SCAQMD staff. Section 4 focuses on how to leverage incentive programs to create a business case. Building on the findings and recommendations from the working group process and staff research, Section 5 then develops the principal planning concepts to support the creation of business cases within clean air planning and programs. Section 6 discusses the next steps for AQMP development.

2. Potential Means to Create a Business Case: Five Key Lessons from Industry Case Studies

This section summarizes five case studies that were presented by various stakeholders from the private sector. These case studies are all based on actual business experiences, which offer valuable lessons that will aid the SCAQMD in the development of the 2016 AQMP.

a. Understand Industry Structure and Small Business Needs for Technology Adoption

The California Trucking Association provided an overview of the state's trucking industry and recommended a list of important factors to be taken into account to craft clean air strategies that can potentially create a business case. Below is a summary:[6]

- *The majority of California trucking operators are small businesses:* Commercial truckers in California are extremely diversified in their fleet size and operation type. In 2006, more than half of California-registered trucks belonged to fleets with five or fewer trucks, including one third being solo operators. Certain niche markets, such as drayage trucks operating at the Ports of Los Angeles and Long Beach, have an even larger presence of small trucking operators.
- *Small, local truckers tend to use pre-owned equipment:* New trucks are typically purchased by large national fleets or other high-mileage operations;[7] once the odometer hits 500,000 miles, the used truck is then traded in for sale in the secondary market or shifted to a company's local operation. Some "niche" operators (e.g., drayage, construction, seasonal agriculture) may buy from the tertiary market.
- *Fuel-neutral policy designs are recommended to preserve fleet turnover model:* Two fuel-neutral policies were specifically recommended: first, enact a cap on fleet age/mileage to accelerate the retirement of older trucks with higher emissions while preserving the existing fleet turnover model;[8] second, incentivize early adoption of zero or near zero emissions transportation technologies that otherwise cannot be achieved through normal fleet turnover due to high prices. It was argued that such policy design can better provide businesses with certainty on equipment life and minimize stranded assets.
- *Rules need to be adequately enforced and amendments should be avoided shortly after a rule goes into effect:* Policymakers must avoid inadequate enforcement and making amendments, especially those that would loosen rule stringency, shortly after the original compliance deadline. Otherwise, businesses that adhere to the rule requirements and the original rule compliance schedule may suffer from unfair competition for having made substantial investments to come into rule compliance.

---

[6] Slides for this presentation are available at http://www.aqmd.gov/docs/default-source/Agendas/aqmp/white-paper-working-groups/business-case-ca-trucking-10312014.pdf?sfvrsn=2.

[7] High-mileage operations typically refer to those that accumulate more than 100,000 miles a year.

[8] According to SCAQMD staff estimates using the EMFAC 2011 model, the average age of heavy-duty trucks in the SCAB region is about 11 years, with many trucks, especially those in the light heavy-duty categories, being utilized well beyond the expected life of 12 years.

b. Targeted Incentives Can Cost-Effectively Accelerate Advanced Technology Adoption

The Southern California Gas Company provided a comprehensive overview of the development and prospect of low-emitting natural gas technologies. The presentation also reported the preliminary findings from an ongoing study that quantitatively analyzed the emission reduction potential of providing financial incentives for the purchase of natural gas vehicles. The lessons learned are summarized below:[9]

- *Conventional natural gas heavy-duty trucks are financially viable:* The price advantage of natural gas over conventional fuels can drive natural gas technology adoption by the heavy-duty trucking sector. The adoption can be further accelerated by near-term and consistent financial and other incentives that shorten the payback period. In the meantime, the infrastructure of natural gas fueling stations has also improved in design that is lowering costs.
- *Near zero emission natural gas heavy-duty trucks will soon be technologically feasible:* The SCAQMD and the Southern California Gas Company have supported natural gas technology developers and engine manufacturers with their research, development, and deployment (RD&D) programs. Technological advancements for on-road heavy-duty natural gas engines are expected to achieve a 0.02 grams/bhp-hr level of NOx emissions between 2015 and 2023. Moreover, the anticipated advancements in compressed natural gas (CNG) storage technologies can potentially have a large impact on design, and thus costs, for both heavy- and light-duty vehicles.
- *Increased financial incentives can encourage early adoption of near zero emission natural gas technologies:* The company's economic analysis indicated that additional financial incentives ($10,000 or less per vehicle) can shift conventional natural gas technology purchases to near zero emission natural gas technology purchases. Among all categories of heavy-duty trucks, financial incentives provided to the heavy-heavy-duty trucks will be the most cost-effective in terms of NOx emission reductions, due to their use in high mileage operations.

c. Stakeholder Involvement and Financial Assistance Are Necessary for Industry-Wide Technology Adoption

Burrtec Waste Industries, Inc. presented the waste management industry's conversion to natural gas vehicles, following the 2010 amendments to SCAQMD Rule 1193 – Clean On-Road Residential and Commercial Refuse

[9] Slides for the presentations are available at http://www.aqmd.gov/docs/default-source/Agendas/aqmp/white-paper-working-groups/business-case-socalgas-pres-final.pdf?sfvrsn=2.

Collection Vehicles. This rule requires public solid waste collection fleet operators with 15 or more solid waste collection vehicles, and private fleet operators that provide solid waste collection services to governmental agencies, to acquire alternative-fuel refuse collection heavy-duty vehicles when procuring or leasing these vehicles for use by or for governmental agencies in the SCAQMD region. The lessons learned from the industry's experience are summarized below:[10]

- *Both large and small businesses have to be involved in the rule-making process; moreover, the affordability for smaller fleets to finance capital costs needs to be carefully considered:* Today, almost all waste management trucks in the region, whether belonging to large or small fleets, are powered by natural gas.[11] The "phase-in" rule implementation schedule–which allowed more time for small fleets to come into compliance–and financial incentives (e.g., the Carl Moyer Program[12]) have made it possible for small- and medium-sized companies to finance the upfront capital costs.
- *A unique business model (i.e., exclusive franchise) provides greater certainty of returns to capital investment:* A typical contract between a private solid waste collection fleet operator and a governmental agency is an exclusive ten-year franchise. The nature of such contracts, in addition to the persistently lower price of natural gas relative to diesel, ensured that the capital costs of fleet conversion would be sufficiently paid back within the contract lifetime. Moreover, a solid waste collection fleet consists mostly of route trucks with long[13] expected equipment lifetimes, which also allows for a longer pay-back period than that of higher-mileage trucking operations.
- *Public funds are potentially needed to help build the infrastructure for an industry-wide adoption of needed transportation technologies:* The waste management industry's conversion to low-emission technologies also involved building fueling infrastructure, since there were few natural gas fueling stations in the initial stage of transition. Companies such as Burrtec had to obtain public funds to afford necessary installation of natural gas fueling stations. Government funds also promoted infrastructure at "network nodes," such as landfill and transfer stations that provide public access to natural gas fueling stations.

---

[10] Slides for this presentation are available at http://www.aqmd.gov/docs/default-source/Agendas/aqmp/white-paper-working-groups/burrtec-bus-case-31115.pdf?sfvrsn=2

[11] Electric vehicles were not considered as a technically viable option due to a list of battery-related limitations, including the pure weight of the battery pack.

[12] The Carl Moyer Memorial Air Quality Standards Attainment Program provides grant funding for cleaner-than-required engines and equipment. The grants are funded by the State of California and administered by local air districts including the SCAQMD.

[13] According to Chuck Tobin, Development Director of Burrtec Waste Industries, Inc., a solid waste collection truck is functional as long as its chassis remains in a good condition; other parts of the truck are replaceable.

- *Government support, such as facilitating information flow about the needed technologies, can help individual businesses choose the best fitting technology*: During the Rule 1193 process, many solid waste collection operators were faced with technical challenges, including the choice between different engine technologies. At the SCAQMD's request, engine manufacturers provided technology demonstrations so that the affected businesses could be better informed and choose the technology that would best fit their operational needs.

d. Learn From Early Adopters of Clean Air Technologies

Frito-Lay North America Inc. shared their successful experience of building a fuel-efficient fleet and identified the challenges and hurdles in their implementation process. Below is a summary:[14]

- *Corporate vision to build the most fuel-efficient fleet in America catalyzed the early voluntary adoption of alternative transportation technologies:* Senior management at Frito-Lay promoted the "Green Vision" to transform North America's seventh largest fleet. With 280 all-electric trucks and 333 CNG tractors, it has reduced the use of traditional fuel by 20 percent to date and is on track to reach their 50 percent target by 2020.
- *Alternative fuel vehicles are a viable fleet option:* The CNG tractor is financially viable on its own. It currently provides 40-50 percent fuel cost savings compared to diesel and has a payback period of 2-3 years, which is significantly shorter than the time the company keeps the equipment. For all-electric trucks with zero emissions, however, public grants were needed to shorten the payback time on the initial capital investment despite the significantly lower operating and maintenance (O&M) costs for the vehicles *per se*. In the near future, government incentives for electric vehicles are expected to continue to be needed.
- *Multi-dimensional approach helps manage operational challenges:* The key to success is to 1) ensure that new technologies are well integrated into business operations, which includes understanding equipment capabilities, improving fueling/charging capacity, and having reliable maintenance; 2) engaging drivers and technicians throughout the transition by offering training, site preparation, program leadership, and frequent communication via meetings, calls, and sign boards.

[14] Slides for this presentation are available at http://www.aqmd.gov/docs/default-source/Agendas/aqmp/white-paper-working-groups/agenda-no-2---frito-lay-march-11-2015---scaqmd.pdf?sfvrsn=2.

e. One Size Doesn't Fit All, and Infrastructure Is Needed to Expand Technology Adoption

United Parcel Service (UPS) Inc. is the world's largest package delivery company with a fleet of more than 100,000 ground vehicles worldwide. The company shared their experience experimenting with a wide array of alternative fuels and technologies in building up their "green fleet." Similar to Frito-Lay's experience, UPS also found it important to provide technology training for drivers and other personnel and to fully understand the key operational variables that can be very different from operating a conventional fleet. The additional lessons learned from the UPS experience are summarized below:[15]

- *Current alternative fuel technologies have attributes that are suitable for different business operations:* By the end of 2015, UPS will have about 7,800 vehicles in operation worldwide that are powered by alternative fuel technologies, including natural gas, hydraulic hybrid, propane, hybrid electric, plug-in electric, and fuel cells. Among them, about 1,200 will be operating in California alone, mostly in the package fleet. Since the attributes of current alternative fuel technologies are varied, only compressed and liquefied natural gas (CNG and LNG) technologies have been found sufficiently mature and suitable for tractor operations currently. Concerning electric vehicles, they are very sensitive to slope and weight of load, thus resulting in a very different energy use pattern that a fleet operator must be aware of and take into account.
- *Infrastructure can be a challenge in green fleet expansion:* UPS stated that the alternative fuel vehicles can have, at most, a five-year payback period to be financially feasible for its fleet operations; importantly, this pay-back period is calculated assuming that the necessary infrastructure is already in place. UPS has temporarily saturated the nation's LNG fueling infrastructure, which presents an important constraint on its LNG fleet expansion. Without suitable fueling infrastructure, natural gas vehicle fleets can also suffer from "range anxiety," an issue that is more often associated with limited battery capacity among electric vehicles. For plug-in electric vehicles (PEVs), the infrastructure issue can be more complicated. In addition to the number and condition of charging stations, the existing grid capacity in smaller towns may not be able to accommodate a large fleet of PEVs.
- *Partnership with other stakeholders is crucial to find a better way forward:* UPS works with manufacturers, government agencies, and nonprofit organizations to advance new fuel technologies and find less expensive, cleaner-burning domestic fuels that are better for the environment and more sustainable than conventional diesel. UPS emphasized that, to promote alternative fuel technologies,

[15] Slides for this presentation are available at http://www.aqmd.gov/docs/default-source/Agendas/aqmp/white-paper-working-groups/ups-bus-case-31115.pdf?sfvrsn=2.

more businesses and interested parties need to be involved to help increase the market demand for the vehicles. Financial incentives and other types of regulatory programs help with this process.

3. Potential Means to Create a Business Case: Other Lessons from Additional Stakeholder Comments and Examples

This section begins by summarizing the valuable comments and suggestions provided by other participating stakeholders on what is necessary to create a business case for clean air strategies.[16] Stakeholder comments are supplemented by additional examples researched by SCAQMD staff where applicable.

a. Provide Regulatory Certainty to Minimize Long-term Business Investment Risks

In addition to cost-effectiveness, regulatory certainty needs to be another important factor in the evaluation of AQMP control measures and related programs. Specifically, SCAQMD staff and stakeholders need to work together to carefully examine credible projections of zero and near zero emission technologies, evaluate and compare their technical applicability and financial viability for commercial adoption, while keeping in mind the global business environment and how it may impact the financial capacity of the affected industries.

Regulatory certainty is also affected by the ease of rule compliance and enforcement. The ability to adequately enforce air regulations should be an important consideration, as lack of enforcement could hurt business profits by creating competitive disadvantages for those who have made investments to comply with the regulation. It was additionally suggested that clean air strategies should involve minimal red tape, such as better streamlining the permitting process, which can also reduce staff time and other resources needed for rule enforcement. The SCAQMD has enacted and amended rules that reward low-emission sources with a streamlined permitting process or permit exemption (e.g., Rules 219 and 222) and will continue to evaluate the expansion of such programs to incentivize emission reductions.

[16] Many stakeholders also expressed concerns regarding the SCAQMD's socioeconomic analysis and the need to reform the California Environmental Quality Act. These issues are being or have been separately addressed by the SCAQMD and will not be repeated in this white paper. Additionally, following the 2014 recommendations from Abt Associates, an extensive socioeconomic analysis will be conducted in the upcoming AQMP to address regional macroeconomic impacts.

b. Maximize Compliance Flexibility within the Constraint of Air Quality Attainment

By allowing individual businesses to choose from a menu of permissible actions to come into compliance, flexible air regulations have a greater potential for improving air quality while minimizing overall compliance costs, and possibly create economic benefits for some businesses that can identify innovative solutions to cost-effectively lower pollutant emissions. It was also suggested that the SCAQMD look into a more flexible use of emission reduction credits and potentially allow for conversion of credits that are created from different sources so that, for example, a company that generates a large amount of stationary source credits can use or sell its credits for mobile source emission reductions and vice versa.[17]

c. Seek Support and Funding from Outside the Region

A case was made that, since mobile source emissions partly originate from outside the SCAB region, individuals and businesses within the region should not bear the sole responsibility for and incur all costs of emission reductions. It was suggested that outside funds (e.g., federal grants and the California Greenhouse Gas Reduction Fund) should be appropriately channeled to the SCAB region to assist the region and its businesses in achieving the emission reduction targets. These funds can come in the form of financial incentives, grants, and subsidies.

d. Offer Financial Incentives for Both Technology Development and Adoption

It was emphasized that financial incentives are necessary not only for technology adoption, but equally importantly, for research and development (R&D) activities to develop and enhance zero and near zero emission technologies. Moreover, the stakeholders cautioned that, in order to make incentive programs work, it is necessary to identify the best practices, learn from past successes and failures, and ensure that they do not attach unnecessary and/or impractical contingencies that work to discourage the use of these incentive programs.

---

[17] Currently, the application of emission reduction credits is generally restricted within the origin source category. The Rule 2202 program is an exception: those employers who are subject to the rule are allowed to use stationary source credits to reduce mobile source emissions produced by the daily commutes of their employees.

e. Make Public Grants Available for Necessary New Technology Adoption and Promote Voluntary Technology Adoption by Small Businesses

New technologies are not always costly if one takes a long-term view. Often, they have higher upfront capital costs, but offer a continuous stream of cost-savings when in operation. When new technologies are commercially available and deemed necessary for clean air objectives, public grants may be necessary for certain sectors or some segments of an industry (e.g., small businesses) which have limited financial capacity and resources to invest in the new technologies.

- *Transit agencies continue to leverage federal, state, and local funds to develop alternative fuel fleets:* Several major transit authorities in Southern California, including the Los Angeles County Metropolitan Transit Authority (LA Metro), utilized public funds from federal, state, and local sources to convert all buses from petroleum to CNG fuel over the past decade. Not only did grants help mitigate the upfront costs of adopting cleaner technologies, they also enabled the transit agency to cut operational costs, due to the lower fuel price, as well as participate in R&D activities that improved design and lowered costs even further. Today, the over 2,000 CNG buses run by LA Metro will continue to lead to cost savings and reduced emissions over the long term. Agencies are now following the same model for deploying Zero Emission Buses (ZEBs) by using funds from California's cap and trade program.
- *Public grants were provided for professional wet cleaning systems to phase out perchloroethylene (perc):* In addition to the initial capital costs involved in replacing perc machines, operation of a wet cleaning machine requires learning time and is more labor intensive. Therefore, since the 2002 amendments to Rule 1421, the SCAQMD has provided grants of up to $10,000 to each owner/operator of dry cleaners to install professional wet cleaning systems (and $20,000 is offered for the more costly carbon dioxide machines). The State of California offers an additional $10,000 to replace a perc machine with a wet cleaning machine or another non-toxic and non-smog forming alternative. Moreover, compared to perc machines, a professional wet cleaning system offers operational benefits, such as potential energy savings, and allows dry cleaners located in more affluent areas to charge higher prices for providing environmentally friendly services.[18]
- *Public grant programs can incentivize small businesses to voluntarily adopt clean technologies and/or practices to reduce stationary-source emissions:* With funds from the U.S. EPA's Targeted Air Shed Grant Program, the SCAQMD has successfully administered grant programs that are targeted to assist small

[18] Based on phone interviews conducted by SCAQMD staff in April 2015.

businesses within or close to environmental justice (EJ) communities to voluntarily reduce their stationary-source emissions. Specifically, grants were made available to auto repair shops and auto refinishing shops within certain EJ areas in the City of San Bernardino and Boyle Heights. The purpose of these grants was to shorten the payback period of purchasing clean, low-emission capital equipment (aqueous brake cleaning system for auto repair shops and laser paint targeting system for auto refinishing shops) and/or to assist employee training for applying emission-reducing techniques.

f. Promote Efficiency-Enhancing Low-Emission Technologies

Another potential means of supporting a business case is to promote technologies that can achieve emission reductions, and at the same time, are more efficient and can lead to cost-savings per unit of throughput.

- *High Volume Low Pressure (HVLP) spray guns reduce paint usage and VOC emissions at the same time:* HVLP spray guns were created to meet the spray equipment transfer efficiency requirements of a multitude of categories including automotive, metal, wood, and marine coatings. A conventional spray gun applies about 33 percent of the atomized coating to the substrate, with the rest released into atmosphere. In comparison, the HVLP technology has a transfer efficiency of 65 percent or higher, thus reducing the amount of paint needed while lowering VOC emissions. Importantly, the cost of an HVLP spray gun is comparable to purchasing conventional ones; moreover, the earlier drawback of a slower application rate has been largely mitigated by technology advancement, particularly the availability of hybrid spray guns.

4. Beyond Initial Equipment Purchase Subsidies: Other Ways to Incentivize Clean Air Actions in the Private Sector

In the case studies and examples summarized above, it is recognized that targeted financial incentives that offset initial capital costs of equipment purchases can accelerate and broaden the adoption of zero and near zero emission technologies. However, public assistance that directly subsidizes equipment purchases is not the only route. The following examples demonstrate how various types of incentives can be used to promote clean air actions in the business community.

a. Creative Incentive Programs Can Promote Technology Adoption Via Market Mechanisms

SCAQMD staff has identified two examples where smart uses of market mechanisms can reduce air pollutant emissions with minimal public funds. Albeit fiscally desirable, this approach may however have limited applications as both cases involve public authorities that manage crucial transportation infrastructure.

- *Cargo owners incentivized to work with "clean" truck operators:* As part of the Clean Air Action Plan (CAAP) at the Ports of Los Angeles and Long Beach, the Clean Air Trucks program exempts cargo owners from paying the Clean Truck Fee ($35 per container) when they use truckers operating with alternative fuel equipment or "clean" diesel trucks.[19] According to the progress report published at the end of 2012, all diesel trucks calling at the Ports had 2007 or newer model year engines, and 8 percent of the entire fleet was powered by natural gas. Moreover, the collected fees have enabled the Ports to offer financial assistance to truckers for the purchase of cleaner trucks.
- *'Privileged' use of infrastructure incentivizes clean technology adoption:* A freight corridor is currently being evaluated as a component of an alternative for the Interstate Highway 710 Corridor Project, which extends from the Ports of Long Beach and Los Angeles to the Pomona Freeway (SR-60), an 18-mile major trucking artery. The project alternative would expand I-710 to include four lanes designated exclusively for trucks with zero tailpipe emissions, which are expected to significantly reduce traffic congestion for these trucks, thus increasing their operational efficiency with less travel time. According to preliminary estimates made by the project team, the monetized time savings over a payback period of five years is projected to be large enough to substantially offset the price premium of zero emission trucks.

b. Small Operational Changes Can Be Incentivized to Reduce Emissions

In addition to adopting new technologies and purchasing new or retrofitting equipment, some of the emission reductions that are needed for the upcoming air quality standard deadlines can be achieved by small operational changes that have low marginal costs. Financial incentives can be targeted to offset these costs to induce emission-reducing changes.

---

[19] The "clean" diesel trucks need to meet or exceed the U.S. EPA's 2007 engine standard. However, cargo owners may not be exempted from the Clean Truck Fee if the "clean" trucks are purchased with Clean Truck Program funds. For details, see http://www.portoflosangeles.org/ctp/CTP_Clean_Truck_Fee.pdf (accessed June 16, 2015).

- *Ports of Los Angeles and Long Beach Incentivize Voluntary Speed Reduction to Reduce Emissions of Multiple Pollutants:* The Ports' Voluntary Speed Reduction program, a component of the Clean Air Action Plan, offers reduced dockage rates and environmental awards for ocean-going vessel operators who voluntarily reduce their speed to 12 knots within 20-40 nautical miles out from Port Fermin. More than 90 percent of all vessels calling at the Ports currently participate in the program, thus leading to substantial emission reductions of multiple pollutants.

c. Clean Technology R&D Incentives Reduce Investment Risks, Lower New Technology Cost Premiums, and Potentially Create Jobs

As already stated by many of the stakeholders, incentive programs will play a pivotal role in encouraging and promoting clean technology R&D efforts. These programs serve two major purposes. First, they have the potential to expedite technology advancement by reducing the upfront investment costs, and if the research efforts do not come to fruition, minimizing potential investment loss. Second, they can bring down the price premium needed for R&D cost recovery, thus potentially increasing the scale of early technology adoption.

- *Public grants can help demonstrate and eventually commercialize emerging electric truck technology:* The California Energy Commission and the SCAQMD co-funded a demonstration project of battery-electric heavy-duty trucks developed by Transportation Power, Inc. (TransPower). The funding enabled the technology developer and manufacturer to test its pilot truck in real-world conditions for nearly a year and use the experience to further enhance technology and incorporate more advanced components. By the end of 2015, the technologies and components will have been used in an expanded demonstration project of at least 20 medium- and heavy-duty electric trucks, and they are also being applied to other types of heavy-duty vehicles, including off-road yard tractors and school buses. Recent testing of these electric trucks, conducted by University of California, Riverside, projected that the combined fuel and maintenance savings can significantly outweigh the higher upfront equipment cost.
- *Public R&D incentives spur private investment in zero emission vehicle (ZEV) infrastructure:* Newport Beach based FirstElement Fuel Inc. received nearly $28 million from the California Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program to construct publicly available hydrogen refueling stations across the state. Encouraged by the state's commitment to developing a consumer market for ZEVs, Toyota and Honda supplied FirstElement Fuel with millions more in additional infrastructure funding. This example illustrates how R&D incentives can mitigate risk and send signals to private businesses and investors to enter the market.

Importantly, R&D grants and incentives have the potential to create jobs related to advanced technology manufacturing and also in businesses that will support infrastructure building and maintenance. According to TransPower's estimate, for example, commercial manufacturing of 2,500 electric Class 8 trucks per year is expected to create a total of 1,500 new jobs. Moreover, the example of TransPower also demonstrates how the SCAQMD may leverage outside funding to potentially reduce mobile source emissions from international trade passing through the Ports. The SCAQMD obtained the grant funding from U.S. EPA Region 9's Clean Air and Technology Innovation (CATI) Program.

5. 2016 AQMP Planning Concepts to Support a Business Case

This section lays out the principal planning concepts that will guide the development of the 2016 AQMP, based on the potential means that have been identified to help create a business case for clean air strategies. Many of the concepts proposed in this section are consistent with the set of criteria used for evaluating control measures used in the 2012 AQMP. These include cost-effectiveness, technological feasibility, and the potential for reduced emissions. It's also important that these concepts be legal and enforceable, acceptable to the public, and help the Basin reach future emissions goals.

a. Prioritize Business Case Strategies

To the extent possible, the 2016 AQMP will prioritize implementation of strategies that have the potential to create a business case. This is consistent with the existing approach of cost-effectiveness ranking of control measures, as the business case strategies will be designed to generate economic benefits, such as lower capital, fuel, or other operation and maintenance costs and improvements in energy efficiency. These benefits are anticipated to offset overall compliance costs for at least some of the affected industries.

b. Maximize Flexibility with Multiple Pathways to Compliance

The 2016 AQMP will, to the extent practicable, maximize compliance flexibility for businesses by allowing multiple pathways to achieve an emission reduction target. Given that each facility approaches cost decisions differently, more flexibility enables businesses to choose an approach that makes the most economic sense for compliance. Moreover, regulatory flexibility encourages voluntary actions that can result in implementation that goes above and beyond the policy target.

c. Maintain a Technology-Neutral Approach

Acknowledging that different fuel technologies may be more suitable for different types of business operations, the 2016 AQMP will maintain a technology-neutral approach in the design of control measures and related programs to the extent practicable. A technology-neutral approach, where practicable, will allow businesses to select and diversify their energy sources, thus allowing compliance flexibility to buffer the effect of energy price fluctuations. Diversity in fuel choices can spur innovation and trigger cost reductions as more technology developers compete. Moreover, given that businesses located in the Basin often compete with out-of-state firms not subject to the same regulations, the SCAQMD will advocate for national performance standards to level the playing field.

d. Ensure a Fair Share of Emission Reduction Obligations and Broad Stakeholder Involvement

The 2016 AQMP will identify ways to more fairly distribute emission reduction and funding obligations by, for example, seeking interstate collaboration, as well as federal and international support to reduce emissions from sources in interstate and international commerce. In addition, the 2016 AQMP will also make a good faith effort to fairly distribute emission reduction obligations among the sources of pollution within the region. This will require broad stakeholder involvement; therefore, the 2016 AQMP and the ensuing rule-making activities will further utilize the agency's public outreach and consensus building efforts to actively involve the broadest possible base of potential stakeholders.

e. Avoid Stranded Assets By Utilizing Strategies That Can Potentially Enhance Operational Efficiency While Reducing Emissions

Within the constraint of given air quality attainment deadlines, the 2016 AQMP will minimize the need to replace equipment that has a remaining useful life consistent with the industry standard. To the extent possible, the 2016 AQMP will make every effort to first explore the emission reduction potential of strategies that can possibly enhance operational efficiency on the existing equipment, while maintaining the current level of throughput. These strategies may include, for example, promotion of best management practices and full utilization of information and data acquisition technologies to monitor and optimize operations.

f. Propose Targeted Incentive, Financing, and Funding Programs for Business Operators

In cases where equipment replacement and procurement are needed, the 2016 AQMP will propose financing and funding programs with public grants, through private collaborators, or via public-private partnerships. These programs will be specifically designed to assist equipment operators with overcoming the economic "gaps" in achieving a business case (e.g., high up-front capital costs and long payback periods). The 2016 AQMP will also propose targeted incentive programs to accelerate voluntary early adoption of zero and near zero emission technologies as well as to speed up voluntary retirement of old equipment with high emission rates. The incentives will provide direct financial benefits or indirect, non-monetary benefits with economic values. For example, the SCAQMD may consider seeking public-private partnerships with truck manufacturers and other public agencies to establish a conditional incentive program that limits its participation to small truckers. The design of such a program could offer price discounts/financial assistance to purchase zero and near zero emissions vehicles on the condition that the previously used "dirty" truck is scrapped. The amount of financial incentives can be determined in a way that is proportional to a weighted index of the scrapped truck's emissions of air pollutants and its market value.

g. Propose Targeted Public Grants and Explore Innovative Financing Tools for Technology Developers and Infrastructure Providers

Due to their inherently high investment risks, early stage research, development, and deployment as well as long-term infrastructure planning usually have to rely heavily on public grants or angel investments. To potentially increase technological feasibility, the 2016 AQMP will propose to focus public RD&D funding and incentives on technologies and fuels with the potential to reduce capital or O&M costs, and/or the potential to address multiple needs (e.g., criteria pollutants, local toxics, energy security, greenhouse gas, etc.) with single investments. A similar proposal will also be made to spur infrastructure investment to support zero and near zero emission technologies, either by lowering investment risks or ensuring a financially sustainable level of market demand. Moreover, the 2016 AQMP will explore innovative financing tools, such as impact investment bonds, that have been used for projects where institutions and organizations traditionally have difficulties recruiting private investors and have shown success in promoting cross-sector collaboration to achieve socially or environmentally desirable outcomes. Cross-sector collaboration is now at a significant level, as noted in the White House's announcement in June that the private and nonprofit sectors have committed over $4 billion to the development of clean energy technologies. In addition, several Executive Actions were announced that would create an impact investing center at the U.S. Department of Energy, allow the U.S. Treasury Department to provide assistance to charitable foundations investing in clean energy technologies, and improving the U.S. Small Business Administration's financing options for early stage technology development. [20]

[20] https://www.whitehouse.gov/the-press-office/2015/06/16/fact-sheet-obama-administration-announces-more-4-billion-private-sector

h. Pay Close Attention to the Unique Needs of Small Businesses

SCAQMD staff is fully aware of the importance of small businesses in supporting the regional economy and creating jobs. Therefore, the 2016 AQMP and the ensuing rule making activities will continue, and enhance where needed, the ongoing practice of paying close attention to the unique needs of small businesses and establishing small business assistance programs as applicable. As small businesses tend to hold on to equipment for a longer-than-average amount of time (e.g., small truckers), the 2016 AQMP will carefully evaluate the industry structure of affected sectors and their equipment usage pattern to avoid stranded assets, within the constraint of attaining air quality standards by the given deadlines. When proposing incentives and other financing/funding programs, consideration will also be given to the relatively limited financial capacity of small business operators.

i. Minimize Resources Required for Compliance and Enforcement

In anticipation that the 2016 AQMP may propose that all or a portion of the goods movement sector begin or expand the adoption of zero or near zero emission technologies, the SCAQMD will make every effort to help ensure full information flow between businesses and the technology developers/equipment manufacturers to minimize the resources spent on trial and error. This can be potentially achieved by, for example, providing venues for technology demonstration and assisting with information dissemination. The 2016 AQMP and the ensuing rule-making activities will also, to the extent possible, minimize administrative burdens required for regulated facilities to come into compliance and for the SCAQMD to enforce regulations. This will work toward the goal of minimizing inadvertent costs to business due to possible competitive disadvantages created by inadequate enforcement.

j. Facilitate Job Training and Job Creation Associated with Low-Emission Technologies

One important lesson provided by the large fleets that have adopted low-emission transportation technologies is that driver and technician training is critical in successfully adopting new advanced technologies. Therefore, the 2016 AQMP will explore the possibility of multi-sector collaboration to support job training associated with zero and near zero emission technologies in order to facilitate and accelerate broader adoption of advanced technologies. In addition, the 2016 AQMP will also explore feasible ways to facilitate the placement of new/relocated businesses developing, manufacturing, or employing zero and near zero emission technologies, with the aim of creating well-paid advanced technology jobs in this region.

6. Next Steps

As mentioned at the beginning of this white paper, SCAQMD staff is committed to prioritizing, when possible, measures where a business case can be made for deployment of needed technologies and efficiency measures when developing the 2016 AQMP. The principal planning concepts will be used to guide the development of control measures and related programs. Moreover, SCAQMD staff will also develop an evaluation matrix, to be included in the 2016 AQMP, to monitor and assess whether and to what degree these concepts have been integrated into the proposed clean air strategies to support a business case for clean air strategies.

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

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

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

Energy Outlook

2016 AQMP WHITE PAPER

OCTOBER 2015

South Coast Air Quality Management District

Barry R. Wallerstein, D.Env.
Executive Officer

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

Jill Whynot
Assistant Deputy Executive Officer
Planning, Rule Development & Area Sources

Author

Aaron Katzenstein, Ph.D. – Program Supervisor

Reviewers

Barbara Baird, J.D. – Chief Deputy Counsel
Scott Epstein, Ph.D. – A.Q. Specialist
Jong Hoon Lee, Ph.D. – A.Q. Specialist
Mohsen Nazemi, P.E. – Deputy Executive Officer
Patti Whiting – Staff Specialist

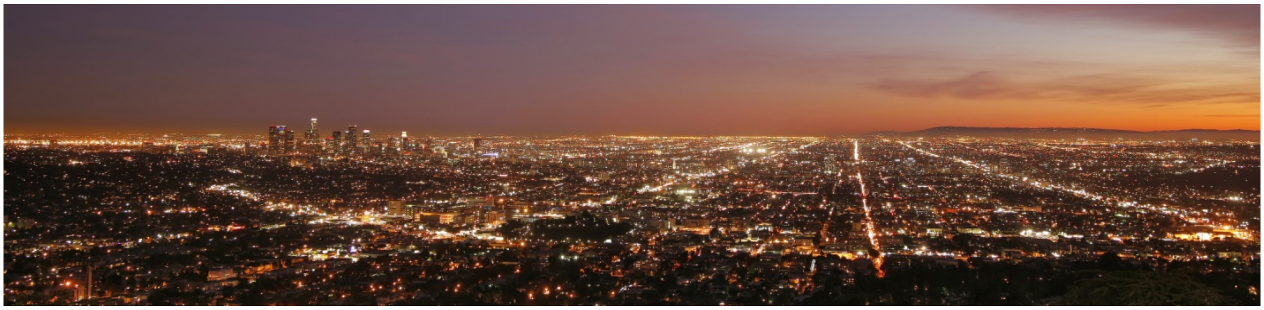
Contributor

Mia Camacho – Student Intern

Working Group

Carter Atkins, Teresa Pisano - Port of Los Angeles
Leila Barker, Mark J. Sedlacek, Dat Quach – LADWP
Frank Caponi. David Rothbart – SCAP
Evan Gillespie - Sierra Club
Maya Golden-Krasner, Julia May – Communities for a Better Environment
Sue Gornick, Bill Quinn – Council of Environmental and Economic Balance
Jeremy Herbert, Michael Tollstrup – California Air Resources Board
Christine Houston, Allyson Teramoto – Port of Long Beach
Joe Hower – ENVIRON
Richard Lambros – Southern California Leadership Council
Mike Lewis - Construction Industry Air Quality Coalition
Rita M. Loof – RadTech International
Rongsheng Luo – Southern California Association of Governments
Kevin Maggay – BNSF Railway
Thomas McHenry – LA Chamber of Commerce
Danielle K. Morone – Residential and Non-Residential Land Use Development
Noel Muyco, Lee Wallace – SoCal Gas
Rob Oglesby - California Energy Commission
Stephen O'Kane - AES
Peter Okurowski, Darcy Wheeles - Association of American Railroads
Stephanie Pincetl – UCLA
Alex Pugh – Southern California Edison
Patty Senecal, Mike Wang, Ron Wilkniss – Western States Petroleum Association
Chris Shimoda - California Trucking Association
Barbara Spoonhour - WRCOG

Table of Contents



I. Purpose

In order to attain federal ambient air quality standards for ozone and $PM_{2.5}$ in the South Coast Air Basin (Basin), and to achieve the state's GHG reduction targets, transformational changes regarding how we select and use energy resources are essential. The Energy Outlook White Paper Workgroup was assembled to assist staff in the development of a white paper that provides insight and analysis on a range of topics that impact the energy sector and air quality within the Basin. The range of topics and analysis, in part, cover:

- Review of the energy resource choices within the AQMP planning horizon;
- Identification of potential demand, supply, and infrastructure needs for energy sectors based on existing and proposed regulations, policies, and programs;
- Review of emerging technologies that impact efficiency and reliability;
- Scenario analysis based on input from other working groups for various energy sectors;
- Energy infrastructure; and
- Recommended actions for coordinated efforts among the public agencies, fuel providers, and consumers for the scenarios analyzed.

II. Background

The 2016 Air Quality Management plan will largely focus on a NOx heavy reduction strategy to achieve the 2023 and 2031 federal ozone standard deadlines in the Basin. Additional but limited reductions of VOCs are needed to help achieve the federal ozone standards, and reductions of both NOx and VOCs will reduce levels of fine particulate matter being formed within the atmosphere. In addition to reducing these criteria pollutants, significant reductions in greenhouse gas (GHG) emissions are needed to achieve the State GHG targets, and to develop pathways for others in the nation and the world to limit atmospheric levels of GHGs below thresholds that lessen the potential for catastrophic climate change impacts.

Within California, many different policies, regulations, market-based mechanisms and incentives are in place and/or are being implemented that impact the types of energy supplied and used, how energy is used, and the emissions associated with energy generation and use. Policies and regulations previously enacted for air quality improvement have had an impact on the types of energy supplied and used in the Basin. As an example, the amount of coal use for electricity production in California has declined from a peak of 1,363 tons in 1993 to 539 tons in 2012[1]. This partially is a result of the Emission Performance Standard established by SB 1368 in 2006, which does not allow an increase in generating capacity of a facility that exceeds 1,100 lbs. CO2 per MWh[2]. Similar GHG emissions limits are being implemented under the EPA's Clean Power Plan and will result in fuel switching of several coal power plants nationally. The sources of energy in California will continue to change as a result of the rapid development of new technologies and renewables, needs to protect public health from air pollution, and initiatives such as Governor Brown's new targets to reduce fossil fuel usage by 50%, increase renewable power generation to 50%, and increase efficiency within existing buildings 50% by 2030.

The energy supply and consumption pathways for California in 2008 are shown in Figure 1. These energy pathways show a clear split of energy supply vs. end use, with liquid petroleum fuels primarily used in transportation, whereas, stationary non-transportation end uses utilize gaseous, solid, nuclear, and renewable energy sources. These historical energy flows have relatively little energy crossover between the stationary and

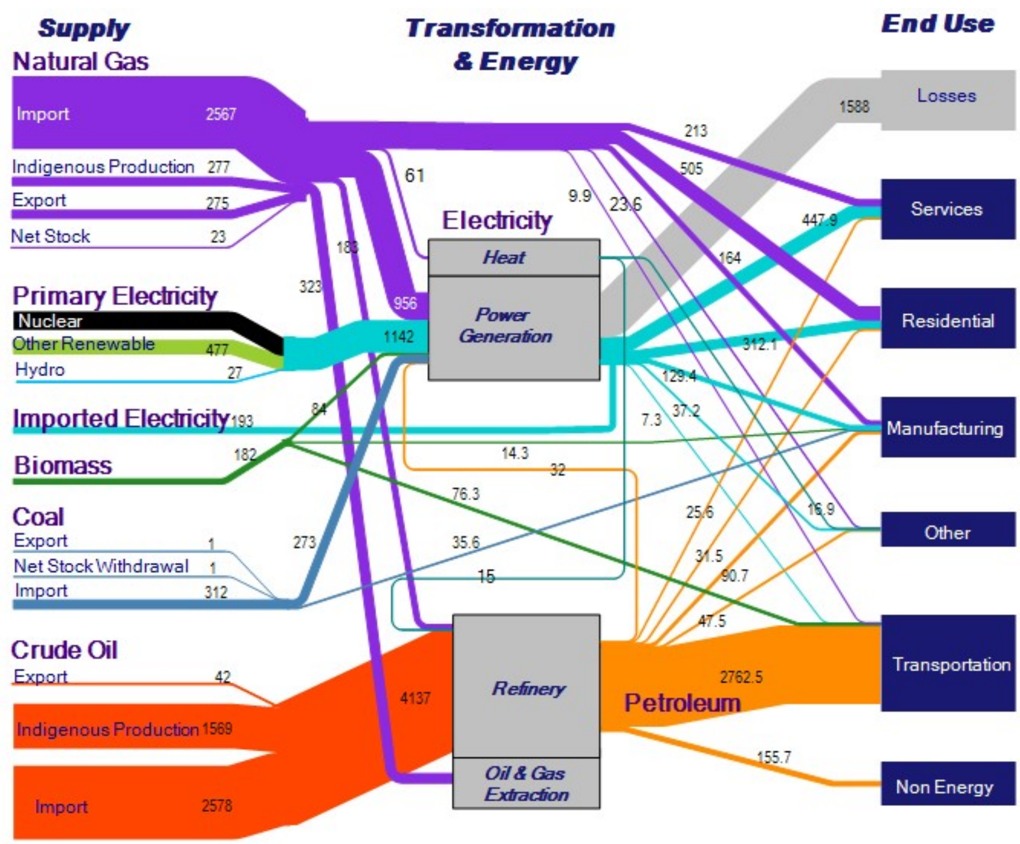


FIGURE 1

2008 California Energy Flow in Trillion BTUs[3].

transportation sectors. Newer technologies, declining renewable energy costs, changing and volatile fossil energy prices, along with newly implemented policies and regulations are resulting in the traditionally separated transportation and stationary energy sectors becoming more integrated and economically coupled. The changes in energy supply and the increase in cross sector energy demand will create benefits and potential costs for the use of each energy type along with potential impacts on criteria pollutant, toxic, and GHG emissions.

Additionally, the energy losses within the overall energy system are high. Energy losses relating to power generation are shown in Figure 1 to be 62% of the total primary energy used to generate electricity (not including losses associated with imported electricity generation). These losses are a result of inefficiencies within technologies to generate energy that result in waste heat. Also shown in Figure 1, the difference between energy inputs into the refinery sector and petroleum outputs result in 25% losses in energy also as a result of waste heat production. Not shown in Figure 1 are the significant energy losses that occur within the stationary and transportation end uses of electricity, natural gas, and petroleum. Within the transportation sector these losses are typically around 80% to the heat losses associated with the widespread use of internal combustion drive train technologies[4].

New renewable energy policies, implementation of new technologies and the enhanced energy efficiency efforts being undertaken in California are driven, in part, by the need for significant reductions in greenhouse gases and will also result in significant criteria pollutant reductions. Since NOx emissions largely do not have a naturally occurring source in the Basin, except for biomass burning sources, the entire inventory of NOx emissions is the direct result of combustion sources and the properties of the fuel and end use technologies. Additionally, a large majority of VOC and GHG emissions in the Basin also result from either fugitive or combustion emissions resulting from our energy choices. In 2011, the SCAQMD Governing Board adopted the SCAQMD Air Quality Related Energy Policy which guides the SCAQMD in integrating air quality and GHG reductions along with Basin energy issues in a coordinated manner[5]. The Energy Outlook white paper in part further implements the policies and actions within the SCAQMD Air Quality Related Energy Policy. To further reduce Basin emissions while providing clean reliable energy sources, transformations of the traditional energy infrastructure will be needed as new technologies that have zero and near zero emissions and renewable energy sources are increasingly implemented.

III. Emissions by Energy Type

Shown below in Figure 2 are the NOx emissions from the 2012 AQMP inventory resulting from different types of energy use. The diesel and gasoline fuels (consumed primarily for transportation) result in the highest NOx emissions. Even as fleet turnover to lower emission vehicles occurs in the transportation sector and further reductions are achieved for stationary sources, The 2016 AQMP baseline inventory projects that the Basin will not achieve NOx levels sufficient to achieve the 2023 and 2031 ozone standard, without significant further reductions of NOx.

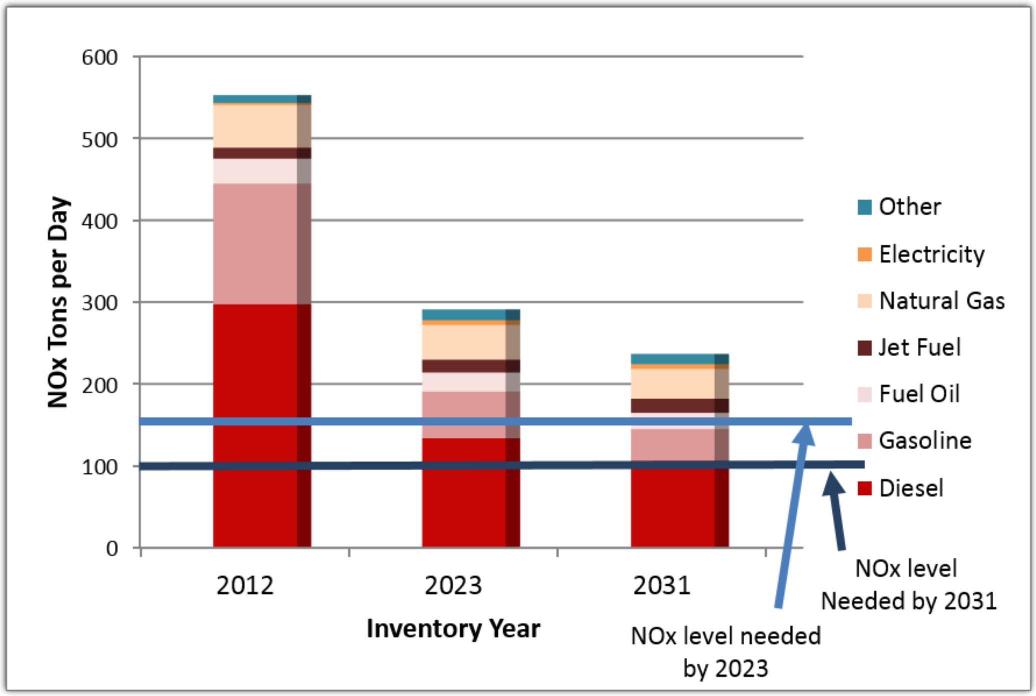


FIGURE 2

NOx Annual Average Emissions Inventory by Fuel Type (*2016 AQMP inventory*)

The carbon dioxide emissions in the Basin associated with fossil fuel combustion are directly linked to the carbon content in the fuels and the amount of fuels used. As shown in Figure 3 the 2008 Basin carbon dioxide emissions were over 134 million metric tons. This emission estimate does not include fuels used to generate power that is imported into the Basin or the impact of many of the GHG policies and regulations that have come into effect since the 2012 AQMP analysis.

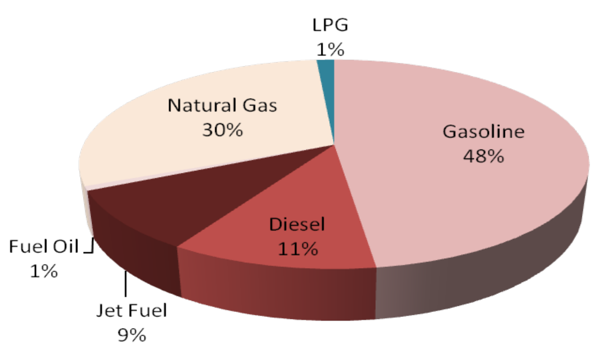


FIGURE 3

Greenhouse Gas (CO2) Emissions in 2008 by Fuel Type (Total 134 MMT CO2, *2012 AQMP*)

IV. Policies and Regulations Impacting Energy Use in California

There are several federal, state, and local regulations and policies that impact energy usage in California. Table 1 provides a partial list of policies and regulations, which have been recently enacted or proposed at the different levels of government.

TABLE 1

Policies and Regulations Impacting Energy Use in California

Policy Objective	Level of Government	Name	Goal
Air Quality	Federal	Clean Air Act	Achieve health based standard levels of criteria and toxic pollutants along with protecting public health from ozone depleting substances and greenhouse gases.
GHG Reduction	Federal	Clean Power Plan	Reduce GHG emissions from new, modified and existing power plants
Fuel Standard	Federal	Energy Independence and Security Act of 2007	36 billion gallons of renewable transportation fuel by 2022
Truck GHG Reductions	Federal	Phase 2	Increases fuel economy of trucks and trailers starting for model year 2021
Petroleum Reduction	State	California State Alternative Fuels Plan, Governors Target	Reduce petroleum use in to 15% below 2003 levels by 2020; 50% reduction in petroleum fuel use by 2030.
ZEV Mandate	State	California Executive order B-16-2012	1 million EVs by 2023 and 1.5 million by 2025
Vehicle Efficiency	State	Pavley Standards AB 1493	Increase vehicle efficiencies and reduce GHG emissions
GHG Reduction	State	AB32, California Global Warming Solutions Act Governor Targets	Reduce GHG emissions to 1990 levels by 2020, 40% below 1990 levels in 2030, and 80% below 1990 levels by 2050.
GHG Reduction	State	Cap and Trade	Reduce GHG emissions from stationary facilities and fuel providers.
Renewable Power Generation	State	Renewable Portfolio Standard Governors Target, SB 350	33% renewable electricity generation by 2020 and target of 50% renewable power generation by 2030.
Building Efficiency Standards	State	Title 24, Governors Target, SB 350	Net zero energy new residential construction by 2020, net zero energy commercial construction by 2030, increase in existing building efficiency 50% by 2030.
Emissions Performance Standard	State	SB 1368	Establish base load generation to not exceed 1,100 lbs CO2/MWh
Coastal water protection	State	Once Through Cooling	Eliminate use of once through ocean water cooling by coastal power plants. Protection of coastal waters and marine life.
Energy Storage Mandate	State	AB2514	1.3GW storage mandate by 2020
Large Stationary Emissions Reductions	Local	Regional Clean Air Incentives Market (RECLAIM)	Declining Allocations and Credit trading program within Basin for NOx and SOx reductions from large stationary sources.
Electrical system reliability	State/Local	AB 1318	Needs assessment report evaluates electrical system reliability needs of the South Coast Air Basin.

V. Energy Landscape

Over the past decade the energy landscape in the United States has changed dramatically. This is largely the result of an increase in domestic fossil fuel production from implementing unconventional recovery techniques such as fracking. As a result the United States is requiring less imported energy to match consumption and, by around 2028, is projected to recover as much fossil energy as consumed, Figure 4[6]. However, there are many potential environmental issues and concerns associated with unconventional recovery techniques and the transport of fuel from increased domestic energy production. These concerns, in-part, include the potential for groundwater contamination, wastewater disposal, and emissions associated with well production.

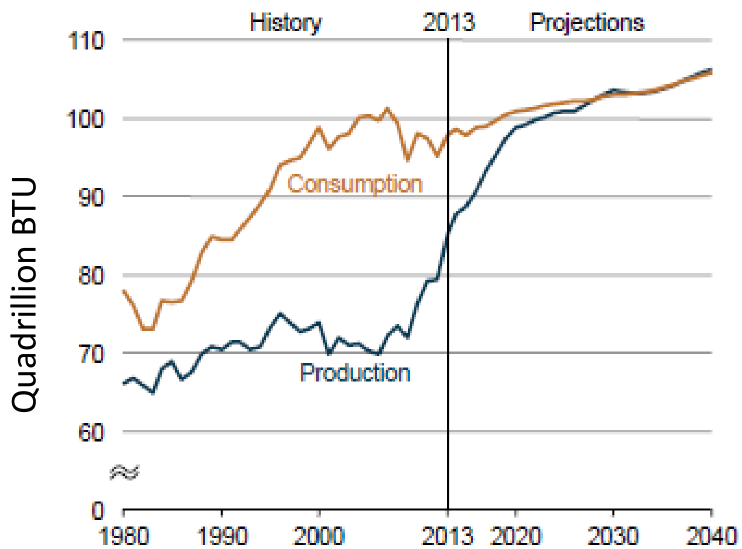


FIGURE 4

Historical and Projected United States Domestic Energy Production and Consumption[6]

At the same time, renewable energy is also being more widely implemented and integrated with new technologies in transportation, energy storage, distributed energy, and demand side management[7]. One of the most significant changes in the renewable landscape has been the dramatic drop in costs for solar power generation as shown in Figure 5. Under the California Solar
Initiative, the installed costs for rooftop photovoltaic (PV) systems have dropped 50% over the last 7 years to a recent average below $5 per watt.

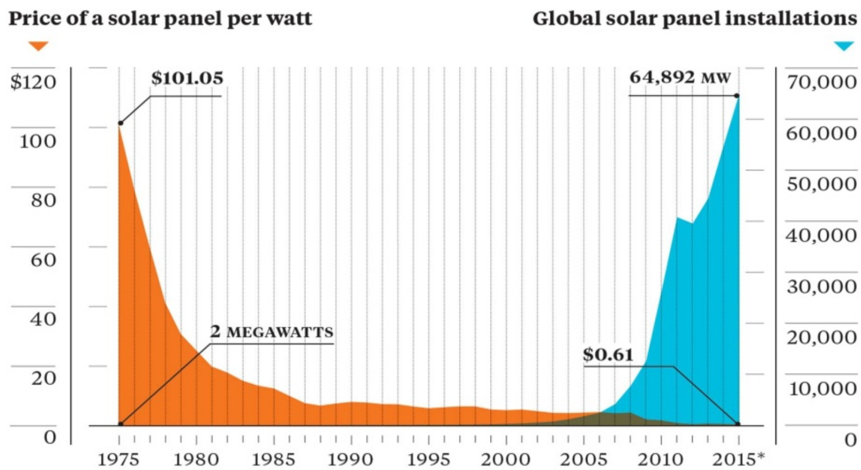


FIGURE 5

Solar Panel Prices and Installations over Time (*Source: Bloomberg Markets*[8])

The increase in production of oil and gas within the United States has also led to declining prices. These changes, new technologies, along with new policies and regulations are changing the energy landscape within the Basin. Current and upcoming issues and technologies for each energy sector that may result in emissions impacts are discussed below.

a. Electricity

Background

The electricity energy sector is reliant on many different types of fossil and renewable energy sources to meet electrical load demands in real time. A stable grid relies upon the delicate balancing of matching generation with demand, traditionally accomplished by using large central power plants connected to transmission grids operated by grid balancing agencies such as the California Independent System Operator (CAISO). These large transmission grids help supply localized distribution grids operated by utilities to supply end use customers. The traditional generation and distribution system meets electricity demand increases through large central power plants and peaking generation units. The need to balance generation capacity with peak demand periods, occurring during the daytime during the summer months, requires excess generating capacity that often sits idle. For instance, peaking generator units typically provide the excess generating capacity when needed, but have low capacity factors (utilization factors) around 5% and do not operate as efficiently as larger combined cycle base load power plants[9].

The traditional one way flow of electricity from large power plant to passive end use creates additional expenses for ratepayers based on the need for excess infrastructure and generating capacity. A version of the simplified traditional utility model with large plants supplying end users is still somewhat in place within California, but started changing with state demand side programs being implemented by the CEC and DOE in the 1970's. These programs started the process of adjusting end user demand to help minimize the amount of electrical infrastructure needed to maintain the electrical grid. The early demand side management regulations implemented by the CEC, include building energy standards under Title 24 and appliance efficiency standards. End use efficiency programs along with other demand side measures have helped lower and leveled the per capita electricity consumption in California while also reducing the amount of new power plants needed (see Residential and Commercial Energy White Paper).

Electricity pricing structures also reduce electricity demand during peak demand periods. Many large electricity consumers are billed largely based on time of use and for on-peak power demand. Under this pricing structure electricity rates vary substantially during the highest usage hours of the summer months. Time of use rate structures have recently become available to residential customers as utility smart meters have been implemented. To help shave energy during peak demand periods, many utilities have created demand response programs that provide financial benefits to customers that install equipment to shave energy use during high demand periods.

The electricity sector in Southern California is undergoing rapid changes with the unexpected shutdown of the San Onofre Nuclear Generating Station along with the repowering of coastal generating plants to meet the state's requirements of the Once-Through-Cooling (OTC) Policy. At the same time, other mandates requiring implementation of more renewable power generation and increasing the amount of electric cars in California are quickly creating additional demands on the electricity system.

POWER CONTENT LABEL

ENERGY RESOURCES	2013 SCE POWER MIX (Actual)	2012 CA POWER MIX**
Eligible Renewable	**22%**	**15%**
-- Biomass & waste	1%	2%
-- Geothermal	9%	4%
-- Small hydroelectric	1%	2%
-- Solar	1%	1%
-- Wind	10%	6%
Coal	6%	8%
Large Hydroelectric	4%	8%
Natural Gas	28%	43%
Nuclear	6%	9%
Other	0%	0%
Unspecified sources of power*	**34%**	**17%**
TOTAL	**100%**	**100%**

* "Unspecified sources of power" means electricity from transactions that are not traceable to specific generation sources.

** Percentages are estimated annually by the California Energy Commission based on the electricity sold to California consumers during the previous year.

For specific information about this electricity product, contact Southern California Edison. For general information about the Power Content Label, contact the California Energy Commission at 1-800-555-7794 or www.energy.ca.gov/consumer.

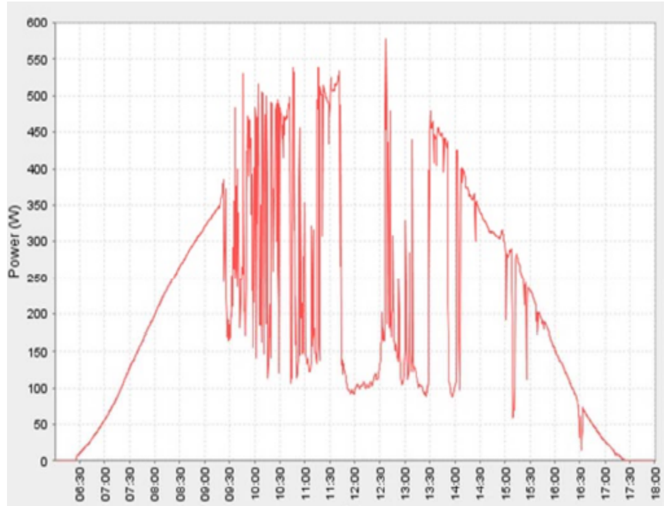
FIGURE 6

Power Content Label for Southern California Edison's Power Supply Mix in 2013

Under AB162, utilities are required to disclose the percentage of power from different generation sources that they supply to customers as they progress toward supplying at least 33% energy from renewable generation sources by 2020. As shown in Figure 6, SCE in 2013 supplied 22% from qualifying renewable resources and is currently on track to achieve the 33% target in 2020. In 2003, the Energy Action Plan implemented the states preferred resources for electrical loading order which places priority, respectively, on demand side management, renewable generation, and lastly, additional fossil fuel powered generation[10]. Other regulations such as California's GHG Cap and Trade Program provide market incentives that promote increased generation efficiencies and the use of renewable fuels.

FIGURE 7

Daily Power Output from Solar Panel Array showing Generation Intermittency from Passing Clouds (*Courtesy UC, Irvine*)



As higher percentages of variable and intermittent renewable resources are integrated into the electrical grid, matching generation with demand becomes increasingly difficult with traditional grid systems, and can make the electrical grid less reliable. The addition of large amounts of renewable generation often requires resources that can balance the short term intermittency. For photovoltaics and wind generation, this often results from intermittent cloud cover (Figure 7) and varying wind speeds, respectively. Additional resources must be implemented to balance large variable renewable power sources on the larger transmission and utility distribution electrical grids. Figure 8, shows the actual and projected net generation demand that is required from fossil generation as more wind and solar power are projected to be added to the CAISO transmission electrical grid. Referred to as the "Duck Curve", due to its shape, the primary impact of adding more solar generation requires the output from fossil generation units to significantly decline or idle during the peak daylight hours. The generation units, however, must be quickly dispatchable not only to help balance potential renewable generation intermittency, but also be capable and ready to provide the rapid generation ramp needed as the sun sets and system load increases into the evening.

Currently, peaking generation plants and synchronous condensers are being utilized to help provide the flexible and dispatchable resources that help integrate renewable resources into the electrical grid. The peaking generation units help support renewable resources by having fast ramp rates and response times, but negate some of the GHG emissions benefits of using renewables by maintaining reliance on fossil generation. Additionally, increasing the number of startup events along with ramping needs results in slightly higher criteria pollutant emissions from peaking generation units than have been observed from these generators in the past (refer to: UCI Professor Jack Brouwer April 15th Energy Outlook Workgroup Presentation[11]).

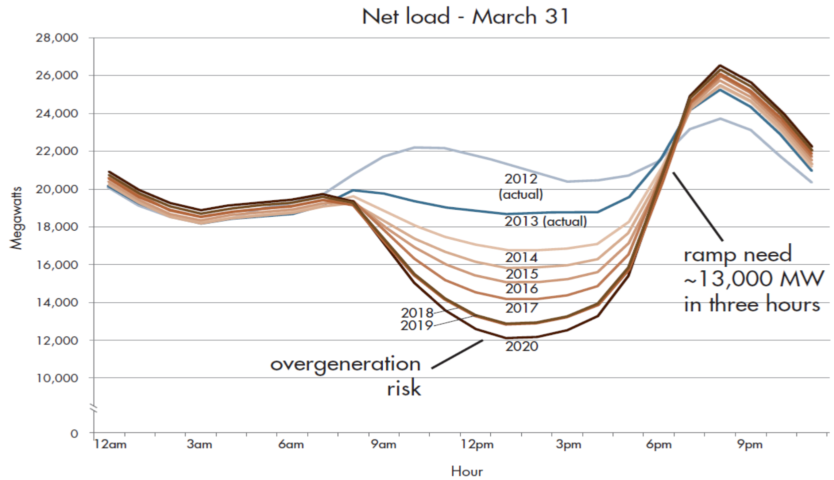


FIGURE 8

"Duck Curve" represents the Net Load which shows the variability in demand and supply that CAISO must balance with controllable flexible resources. The net load represents the load that must be met with flexible and dispatchable resources. The net load subtracts the variable renewable generation from the end user demand.

As a result of changes in power plants such as San Onofre closure, along with the planned closure and repowering of additional Southern California coastal power plants, there is a need for voltage support on the local distribution networks. Smaller generating plants and other distributed energy resources are being implemented in a newer grid structure that provides more resilience and less reliance on large traditional generation, and operates with less infrastructure redundancy. Additionally, a change under CPUC Rule 21 is being made to start allowing smart inverters attached to rooftop solar installations to provide grid support services such as voltage support. Allowing the large amounts of rooftop solar inverters to help provide other grid service needs other than energy helps provide cleaner more reliable grid power. In California most inverters installed with rooftop solar panel systems are smart inverters; however, the grid services capabilities, such as voltage support, has been disallowed under outdated grid interconnection requirements that are currently under review[12]. Allowing smart inverters to provide grid services has already been implemented in Europe.

New Technologies and Adapting to a Changing Grid Landscape

As mentioned earlier, the traditional electric grid management paradigm has been to add additional generation to match demand with end use customers being passive consumers. It has been shown that demand side management is much less costly than adding generation and provides greater utilization of existing resources[13,14,15]. Demand side management is increasingly becoming more important as higher amounts of power are derived from renewable generation making it more difficult to match generation with demand[16]. Southern California Edison is undertaking a preferred resources pilot program within Orange County that is studying which types of demand side management resources can help alleviate infrastructure needs, in part, due to the San Onofre shutdown[17]. Large amounts of renewable power

during low demand periods have recently resulted in periods of over-generation that led to negative wholesale market prices[18]. New technologies are rapidly being developed and implemented that provide flexible resources to help manage any excess power generated from renewable resources along with reduced load during times of peak demand or high net load ramping needs[16].

To help balance end user demand with generation, households and businesses are increasingly relying on energy management systems that help reduce peak demand charges, can participate in demand response events, and better manage energy loads with onsite generation and occupancy needs. One example of these technologies in the residential sector has been the implementation of Wi-Fi connected smart thermostats that help reduce heating and cooling energy use by using occupancy sensors along with weather forecasts. Other technologies are beginning to utilize utility smart meters with cellular phones to incentivize participation in demand response events (Ohmconnect.com). These systems also can be registered with utility demand response programs and are being developed to integrate with other electricity end uses.

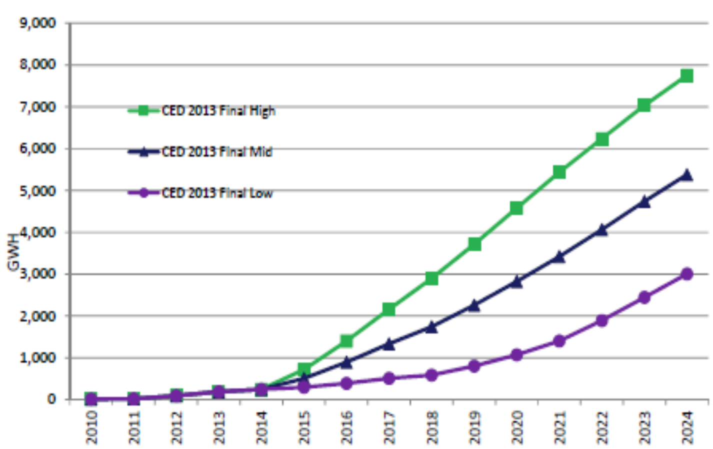


FIGURE 9

Projected Energy Needs by Electric Vehicles in California (*High, Mid, and Low Scenarios*)[19].

One of the largest challenges facing the electricity sector will be integrating increasingly large amounts of power and energy demands from an increasingly electrified transportation sector (Figure 9). Traditionally, as shown in Figure 1, the transportation sector primarily has relied on liquid fuels and has been separated from the electricity sector. Original implementation designs for the existing electrical infrastructure did not incorporate energy or power requirements for transportation. As increasing numbers of electric vehicles become reliant on the electrical grid for energy needs, incorporating electric vehicles into the grid can be done in a manner that actually helps provide needed grid resources. Demonstrations are being done with managed charging of electric vehicles that synchronize with grid resource needs during periods of over generation and peak usage. Existing utility rules are being reviewed to also allow electric vehicles to provide other ancillary grid services such as frequency regulation, voltage support and reactive power. Managing electric transportation charging in this manner may be done by the site host, local utility, and/or system integrator. Collectively, plugged in electric vehicles can provide significant grid resources when intelligently integrated with the grid. If unmanaged, the integration of transportation energy needs onto the electrical grid will create additional infrastructure needs without benefits to grid stability.

Incorporating large amounts of energy storage will help integrate increasing amounts of renewable generation, better manage demand charges and help reduce infrastructure costs for electric vehicle chargers. Energy storage systems can be deployed on the larger transmission grid, the local utility distribution grids, and behind the meter applications. Several different technologies are being utilized for energy storage systems which include: batteries, fuel production, flywheels, pumped hydro, and compressed air. Currently the most widely used storage systems utilize different battery chemistries along with using second life electric vehicle batteries. The costs for batteries for both vehicle and stationary storage applications have been shown to be steadily dropping, however, it is often difficult to reliably determine and compare recent prices without a standard methodology. Thus, there is a need to establish a battery price index or energy storage price index as these technologies become more widely used[20].

Grid scale energy storage systems are starting to be implemented that replace the need for peaking generation plants. These systems have several advantages over peaking generation units in that they have high utilization capacity factors, zero emissions, and are easier to site. As more renewable generation is integrated, and over generation becomes more prominent, the excess power may be used to electrolyze water to form hydrogen and oxygen. The hydrogen can then be stored nearby and used for transportation applications, power generation, integrated into the natural gas pipelines, and/or used to develop synthetic fuels. The application of hydrogen in natural gas pipelines is being demonstrated in Europe.


The World's Biggest Battery Is Being Built For Southern California's Grid

AES is building a 400 MW-hour lithium-ion battery for SCE as an alternative to gas peaker plants.

Eric Wesoff
November 12, 2014

The world's biggest battery is coming to California.

Last week, Southern California Edison (SCE) revealed the winners of a massive

Greentechgrid: Nov. 2014

Behind the meter storage systems are being used to help offset peak demand charges, provide backup power when needed, integrate vehicle chargers with existing infrastructure, and off grid applications. As many residences and businesses are under time of use utility rates, the storage systems can provide arbitrage opportunities for the residents and businesses to utilize low electricity costs during off peak hours and use the stored power during high priced periods "on-peak" [21]. Behind the meter applications also include backup power and in many applications may reduce or eliminate the need for backup generation units and, when coupled with renewable generation under high utility rates, may become a cost effective technology for off grid solutions[22].

b. Natural Gas

Within the United States the natural gas supply has gone from a possible need for imports to that of ample supply and declining prices. This is a result of technological developments in exploration, drilling, and well stimulation that have increased recoverable reserves within the United States (Figure 10). The increase in supply and resource base has driven natural gas prices down to a recent $3 per thousand cubic feet in May 2015, 60% lower than in May 2008 when reserves started to dramatically increase. In 2008, an estimated $3 billion worth of natural gas was consumed in the residential and commercial sectors Basin wide.

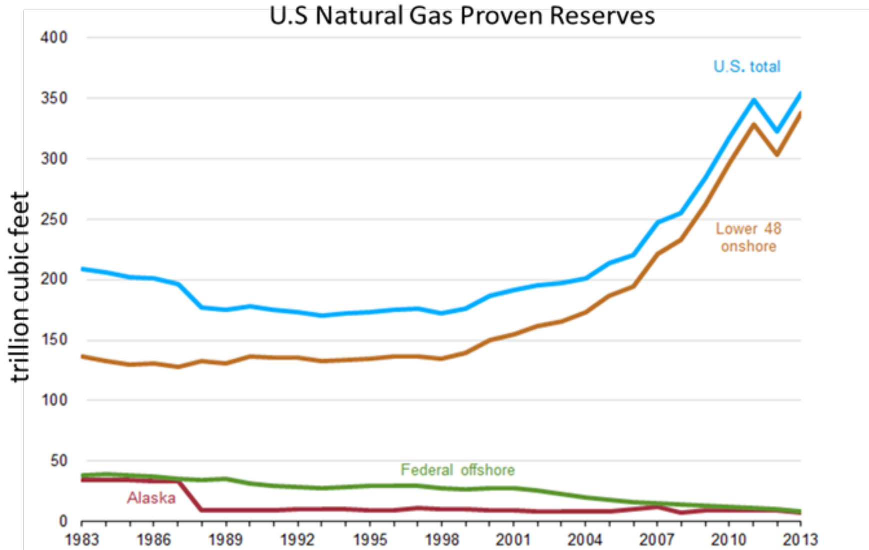


FIGURE 10

Increase in U.S. Natural Gas Proven Reserves over Time[6].

In the Basin, the natural gas distribution infrastructure provides the primary fuel used for electricity generation along with cooking and heating needs in the residential and commercial sectors and process heating in the industrial sector (Figure 11; also see Residential and Commercial White Paper). Within California, the majority of non-renewable power generation derives from natural gas powered generation. This is, in part, due the increased generating efficiency that natural gas combined cycle power plants provide over traditional steam boilers that helps provide overall emission benefits relative to other fuel choices[9]. Additionally, natural gas when combusted has lower particulate matter formation relative to other fuels with complex carbon molecules. This property allows for lower particulate matter emissions than other fuel choices and, when used in heavy duty transportation applications, does not have the associated toxicity of diesel fuel combustion.

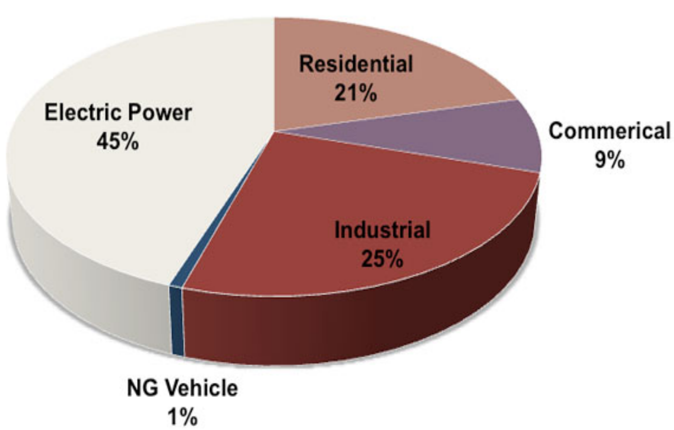


FIGURE 11

California Natural Gas Demand by Sector in 2012 (*CEC Energy Almanac*)

Natural gas has an existing pipeline infrastructure that makes it easily transportable, is often a lower energy cost option, and can often provide GHG and criteria emissions benefits over petroleum and coal. However, methane, the primary component in natural gas, has a long atmospheric lifetime of 10 to 14 years, whereas, other hydrocarbons have atmospheric lifetimes from hours to days. Therefore, the fugitive releases of methane within the Basin do not contribute to photochemical production of ozone or secondarily formed particulate matter as result of short residence times in the Basin and long atmospheric lifteimes. However, on a global scale, the atmospheric levels of methane do contribute to increased global background levels of ozone as well as being a potent GHG.

Using natural gas can provide reduced end use carbon dioxide emissions as a result of methane having a higher hydrogen to carbon molecular ratio than every other hydrocarbon. Combustion of methane therefore releases less CO2 on a weight per weight basis relative to other hydrocarbons[23]. However, the direct end use GHG emission benefits from natural gas can be negated or reversed from upstream fugitive releases of methane into the atmosphere. Further efforts and research are needed to minimize fugitive methane emissions along the entire natural gas production, distribution, and end use chain[24]. Due to the high climate forcing impacts from methane, the fugitive emissions of methane need to be better understood and further incorporated into the lifecycle analysis.

The greatest GHG benefits from methane use are realized from renewable sources. There are many different supply streams of renewable methane that include landfills, wastewater treatment plants, and food waste and manure digesters. Difficulties recovering renewable sources of methane include the implementation of clean and efficient systems that separate methane from other impurities in a cost effective manner. The SCAQMD Clean Fuels program along with other state agencies' programs have helped develop and demonstrate technologies to clean up renewable methane waste streams for power generation and transportation uses. Although these technologies are being implemented, it is currently unclear how much renewable methane might be cost-effectively recovered within the Basin from the many different waste streams.


NATURE'S SONG

THE PRESS-ENTERPRISE

LOCAL

TUESDAY

FOOD TO FUEL

Temecula and Calimesa are participating in a new recycling program that turns food waste into natural gas. Your town might be next.

Hemet shouldn't let neighborhood problems drive away truckers

Closing the food waste cycle

LOOKING FOR A CREATIVE CAREER CHANGE?

Press Enterprise; Aug 18, 2015

New Technologies and Uses

The natural gas distribution system in California is slightly constrained during the winter month periods when more natural gas is required for heating purposes[25]. During these months underground storage helps provide natural gas during peak demand periods. Much like electricity generation constraints during peak summer demand periods, the natural gas pipelines require a similar balancing technique during times of high usage in the winter months. Within Southern California, there is currently over 140 Billion cubic feet of underground storage using depleted reservoirs that help balance Basin natural gas needs between seasons of high use and high prices with seasons that have lower prices and lower natural gas demands.

As mentioned earlier, methane use in California will increasingly be derived from renewable sources. Several technologies will likely become more prominent; these include[11,26]:

- Technologies, such as pressure swing adsorption that help scrub the natural gas from different waste streams.
- Developing natural gas from excess renewable power generation (power to gas).
- Increasing use of natural gas for stationary and transportation fuel cells.
- Using oxy generation systems for combustion processes without pollutant emissions.
- Ultra low NOx heavy duty compressed natural gas (CNG) engines.

c. Liquid Fuels

In the Basin, the primary use of liquid petroleum fuels is for transportation purposes. In 2008 over 7.3 billion gallons of gasoline and 1.4 billion gallons of diesel were consumed within the Basin with a combined estimated cost of $32 billion dollars (2012 AQMP). Of all the different energy types, the gasoline and diesel fuels often have more significant price volatilities as a result of variations in global crude prices, refinery capacity issues, and overall supply for California blended fuels[4] as shown in Figures 12 and 13. Supply issues for California reformulated gasoline can result in prices for California gasoline being decoupled from crude oil market prices and gasoline prices in the rest of the nation, Figure 13.

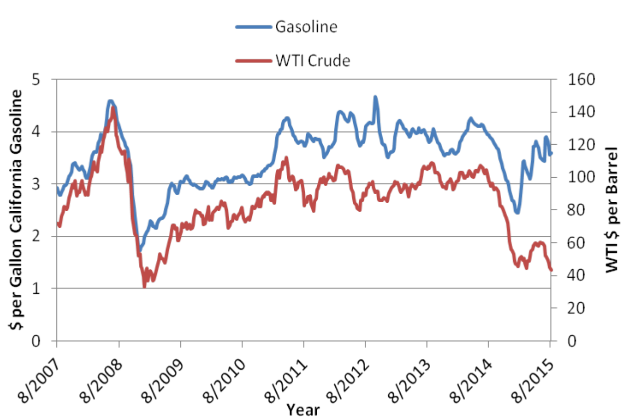


FIGURE 12

Average Weekly Market Price between a Gallon of California Gasoline and WTI Crude (*CEC Energy Almanac and EIA*)

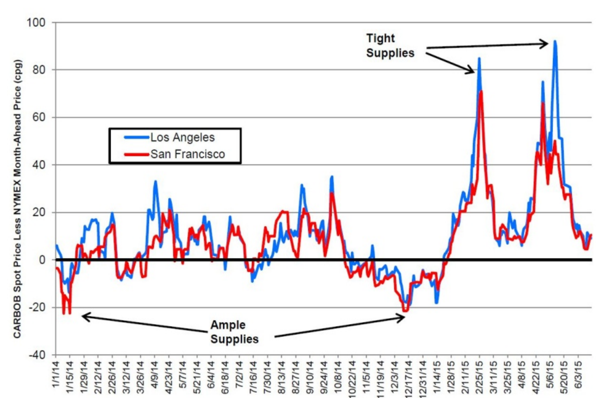


FIGURE 13

Recent High Market Premium (in cents) on California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) minus the NYMEX national price (*CEC Petroleum Watch July 15, 2015*)

As previously shown in Figure 2, the use of liquid fuels currently result in the highest emissions of NOx and is the largest contributor to GHG emissions within the Basin. A large transformation is needed within engine technologies to lower NOx emissions from transportation sources. As shown in Figure 2, diesel use results in significant NOx emissions, particularly within the heavy duty and off-road engine categories. As outlined within the Goods Movement, On-Road and Off-Road white papers, new technologies are needed to improve engine emissions and drive train efficiencies to reduce NOx along with GHG levels[27].

Continued use of liquid fuels will increasingly require climate friendly fuel use pathways that, in part, include more efficient end use technologies. Overall GHG emissions need to be considered, not only at the tailpipe but also by using a full well to wheels emissions analysis that accounts for fuel production and distribution. This is currently implemented within the Low Carbon Fuel Standard (LCFS) to determine the carbon intensities of different fuels by reviewing the lifecycle analysis of bio-fuels along with other low carbon intensity alternative fuels. A similar analysis can also consider the associated lifecycle emissions of criteria and toxic pollutant emissions but is currently not part of the LCFS program. Unfortunately, the majority of bio-fuels produced still have a positive GHG impact and the upstream emissions associated with traditional oil and gas recovery are still relatively uncertain[28]. The use of bio-fuels can provide a partial solution to GHG reductions, particularly in applications that don't have alternative technologies available such as aircraft. However, the limited availability of fuel feed stocks, land use considerations, weather variability, and potential negative impacts upon food prices are all issues that should be addressed as bio-fuels develop as part of the solution in reducing GHG emissions.

d. Other Energy Choices

As newer technologies such as fuel cells become more widely available for power generation and transportation, the supply of alternative energy sources will become more important. Partially discussed in earlier sections, these energy sources will include renewable fuels such as biodiesel, ethanol, and waste woody biomass. Some of these renewable fuels may be produced from algae that sequester CO2 from power plant emissions that are then converted back into fuels used again at the power plant (*See: SoCal Gas, Ron Kent's April 15th Energy Outlook Workgroup Presentation*[26]).

Other energy supply choices that will be produced from different feed stocks and energy sources are fuels that do not occur naturally in pure form such as hydrogen and dimethyl ether (DME). The production of these fuels will help provide emission benefits but may also be produced to help integrate increasingly larger percentages of renewables onto the electrical grid, provide renewable energy streams for transportation, and use existing infrastructure for transport and delivery.

In 2015 the first fuel cell vehicles for purchase were introduced in California from Toyota and Hyundai. As these vehicles are being introduced, supplies of hydrogen and fueling infrastructure is needed to support their operation. Using hydrogen as an energy source produces water as a byproduct in fuel cell applications.

Additionally, the fugitive release of hydrogen into the atmosphere does not have an impact on climate, criteria pollutants, or toxic risk.

Although the end uses of hydrogen are generally considered zero-emission, the sources of hydrogen fuel and the associated emissions to generate hydrogen can vary significantly. Currently, the largest supply of hydrogen within California comes from steam reformation of hydrocarbons. Methane currently is widely used as the hydrocarbon source for production of hydrogen; however, other compounds such as methanol have been utilized for onsite reformation and fuel cell systems. Unfortunately the reformation process emits CO2 as a byproduct which can be mitigated by using renewable sources, or possibly by future carbon capture technologies such as algae systems.

Production of hydrogen can also occur through the electrolysis of water. As mentioned within the Electricity section, the implementation of renewable generation will result in periods of overproduction relative to real time demand. Rather than curtail the production of power, the excess energy can also be stored by producing fuels. Hydrogen generated during periods of excess power through electrolysis of water, referred to as "power to gas", can be utilized by fuel cells during periods of high electrical demand or within the transportation sector. During the electrolysis process, hydrogen and oxygen are produced, and the oxygen might also be recovered and used at nearby peak generation units using zero-emission oxy combustion technologies (see natural gas emerging technologies section). Additionally, the hydrogen produced renewably through this process might eventually be blended with natural gas and added into the distribution pipelines. It is also possible to use the hydrogen produced with waste CO2 streams to produce synthetic natural gas along with other hydrocarbons.

While it is currently not possible to track the amount of hydrogen being produced from different sources within the Basin, the implementation of both stationary and transportation fuel cells along with implementing clean pathways to develop large quantities of hydrogen needs to be closely monitored and supported.

VI. Scenario Analysis

Studies have been conducted to show how new technologies can help achieve both air quality and climate goals. For example, there have been several studies conducting "back casts" on the state energy sectors to identify potential pathways to achieve the 2050 GHG targets [29,30,.31]. Achieving the GHG state targets will have the co-benefit of criteria pollutant reductions. The scenario case shown in Figure 14 uses the 2016 AQMP baseline inventory and applies two variations of the Governor's 2030 target reductions of 50% reduced petroleum use, a 50% increase in existing building energy efficiency, and a 50% renewable portfolio standard. Under SB 350, the 50% increase in building efficiency and 50% renewable energy production by 2030 are being set into law. The potential impact on NOx reductions from these targets is represented as Scenario #1 in Figure 14. Further implementing the 50% reduction in fossil fuels in addition to the other two targets, represented as Scenario #2 in Figure 14, results in the largest potential NOx reductions. In both scenarios, a linear implementation of the 50%

targets is assumed along with a linear and proportional reduction in criteria pollutants applied to the forecasted inventory years (2012, 2023, and 2031).

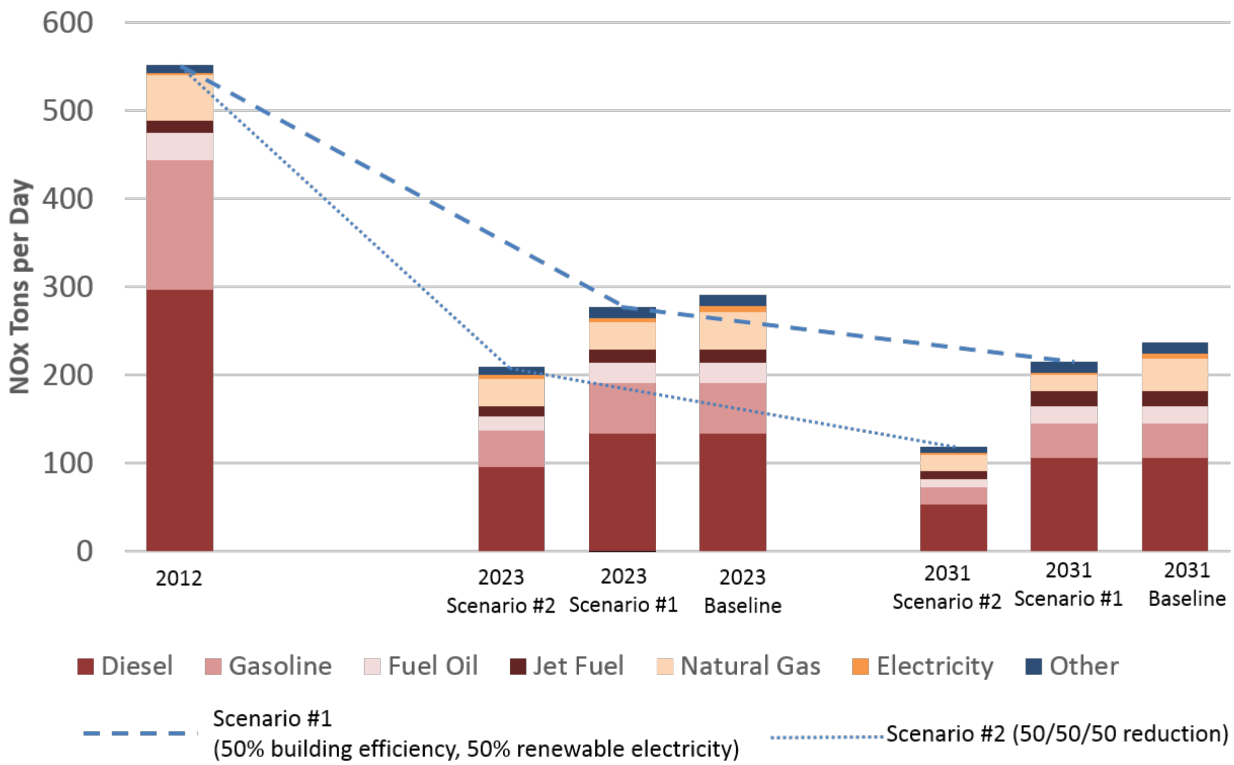


FIGURE 14

Potential Impact on 2016 AQMP Inventory from Scenarios Implementing 50% Reduction in Existing Building Energy Usage, 50% Renewable Power, and in Scenario #2, 50% Fossil Fuel Reduction by 2030. Dashed Lines show Reductions in NOx from Applied Scenarios over 2016 Baseline Inventory

In Figure 15, the two "50% reduction" scenarios are shown again in relation to the NOx levels needed for attainment and 2016 AQMP baseline inventory. The two scenarios shown in Figure 15 provide the potential for significant NOx reductions, but do not meet the projected NOx carrying capacities for ozone attainment in 2023 and 2031. Further NOx reductions will be needed above and beyond these scenarios designed primarily to make progress towards the state's 2030 GHG targets. However, the NOx reductions that might be achieved through the Governor's 50/50/50 targets provide significant progress towards the ozone standards.

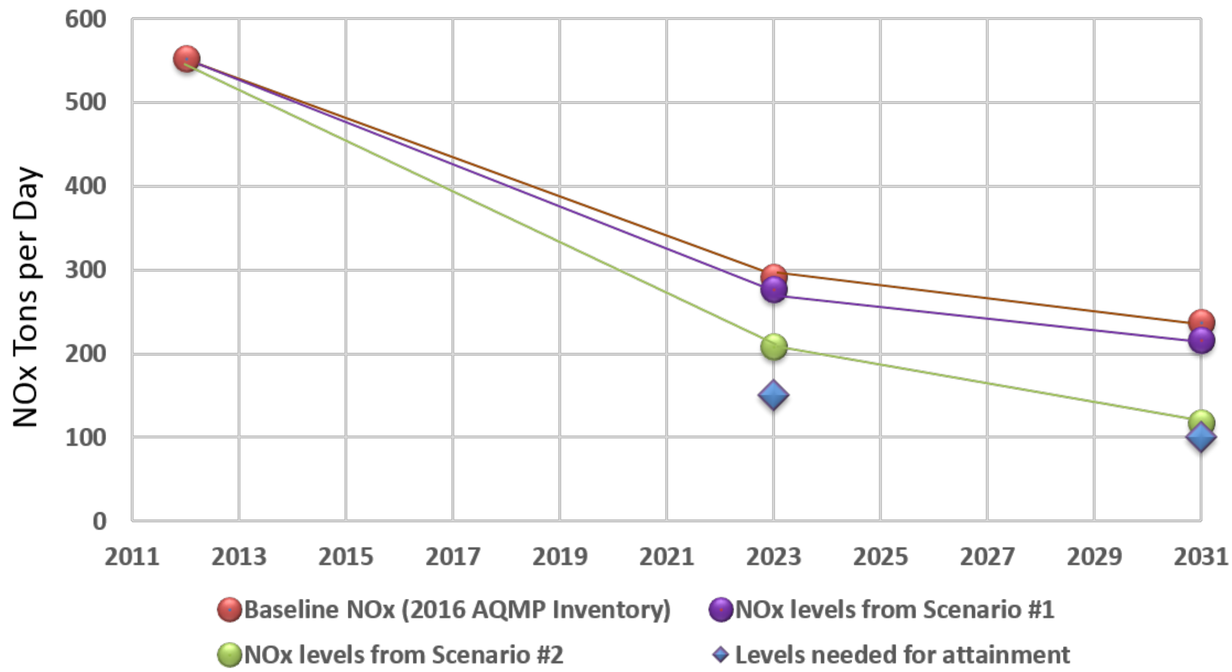


FIGURE 15

Basin NOx Levels showing Projections for Future Years from 2016 AQMP Inventory (red), Future NOx levels with Scenario #1 50% Increase in Building Efficiency and Renewable Power Generation by 2030 (purple), Scenario #2 showing Significant NOx Reduction when 50% Fossil Fuel Reduction is included. Diamonds (blue) show NOx Levels Needed for Attainment of Federal Ozone Standards.

VII. Findings and Recommendations for 2016 AQMP

Southern California is facing challenges in providing its residents with clean air, clean and sufficient supplies of water, affordable and reliable energy, and efficient transportation options. The traditional energy landscape is rapidly changing to incorporate new technologies that alleviate resource challenges, are adaptable to match changing demand profiles, and provide more efficient use of energy with fewer emissions. To increase resilience and provide leadership in reducing greenhouse gas emissions while addressing looming air quality deadlines, the changes occurring within the energy sector are providing opportunities and pathways to achieve these goals.

As part of the 2016 AQMP, staff is recommending consideration of the following actions:

Electricity:

- Monitor the implementation of increasingly large electrical energy demand from electric transportation. Promote the demonstration and development of technologies that minimize the emission impacts of adding electric transportation while reducing infrastructure needs.
- Support the development of a battery price index and/or energy storage index to provide clarity on recent storage prices.
- Support development and demonstrate energy storage applications and the benefits they can have on reducing the need for additional fossil generation units and/or increased start up/shutdown/ramping of existing peaking units.
- Review and develop programs for increased demand side management implementation and for technology development with an additional focus on emission benefits.

Natural Gas:

- Further study the potential supply of renewable natural gas from applicable waste streams, such as waste water treatment plants, in the Basin.
- Implement new technologies such as fuel cells that use reformation and can provide high efficiencies through combined heat and power applications. Use these technologies to help integrate the transportation sector, to provide grid services, and as a potential replacement for backup generation units.
- Work with utilities and other energy developers to review the integration of the natural gas system with power generation and the further implementation of renewables.
- Assess the development of oxy combustion power generation systems.

Liquid Fuels

- Consider criteria pollutants in the well to wheels lifecycle analysis of fuels. This analysis would include criteria and toxic emissions associated with flaring at well sites, processing, and delivery.
- Promote the development of renewable fuels that provide criteria pollutant emission reductions as well as GHG benefits.

<u>Other Fuels</u>

- Support the development of an index that monitors of the amounts of hydrogen used in transportation along with a price tracking monitor for costs associated with different hydrogen producing technologies.
- Continue to demonstrate and promote renewable energy sources that provide criteria pollutant reductions as well as GHG reductions.

VIII. References

1. EIA, California Electric Power Consumption Estimates, http://www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/eu/use_eu_CA.html&sid=California.
2. 2014 Total System Power, CEC; http://energyalmanac.ca.gov/electricity/total_system_power.html.
3. CEC, California Energy Balance Database, January 2012.
4. U.S. DOE, Where the energy goes: gasoline vehicles, http://www.fueleconomy.gov/feg/atv.shtml .
5. http://www.aqmd.gov/home/about/policies/aqmd-air-quality-related-energy-policy
6. EIA Annual Energy Outlook 2015, April 2015.
7. Jacobson *et al.* 100% clean and renewable wind, water, and sunlight all-sector energy roadmaps for the 50 United States, Energy Environment Sci., 2015, 8, 2093.
8. Bloomberg Markets, May 2015 page 40.
9. CEC, Thermal Efficiency of Gas-Fired Generation in California: 2014 Update, Sept. 2014, (CEC-200-2014-005).
10. 2003 Energy Action Plan (http://www.energy.ca.gov/energy_action_plan/index.html).
11. Brouwer, Jack; Air quality simulations – renewable energy and other technology implementation scenarios, Energy Outlook workgroup presentation, April 15, 2015 (http://www.aqmd.gov/home/about/groups-committees/aqmp-advisory-group/2016-aqmp-white-papers#energy).
12. California Public Utilities Commission, Rule 21 Smart Inverter Working Group, (http://www.energy.ca.gov/electricity_analysis/rule21/).
13. The Program Administrator Cost of Saved Energy for Utility Customer-Funded Energy Efficiency Programs, Lawrence Berkeley Laboratory, March 2014.
14. OPOWER, Without energy efficiency there'd be an extra Europe plugged into the grid, October 2014.
15. New Expectations for Electricity Consumers, The Wall Street Journal, Aug. 3, 2015.
16. Rocky Mountain Institute, The Economics of Demand Flexibility: How "Flexiwatts" Create Quantifiable Value for Customers and the Grid, 2015 (http://www.rmi.org/electricity_demand_flexibility).
17. Southern California Edison, Preferred Resources Pilot Program; http://www.edison.com/home/innovation/preferred-resources-pilot.html#.
18. Bloomberg Business, Solar Shines as Sellers Sometimes Pay Buyers to Use Power, May 26, 2015.
19. CEC, California Energy Demand 2014-2024 Final Forecast, January 2014.
20. Nature Climate Change, Rapidly Falling Costs of Battery Packs for Electric Vehicles, March 23, 2015.
21. Applied Energy, Economic viability of energy storage systems based on price arbitrage potential in real-time U.S. electricity markets, 114 (2014) 512-519.
22. Rocky Mountain Institute, The Economics of Grid Defection: When and Where Distributed Solar Generation Plus Storage Competes with Traditional Utility Service, 2014 (http://www.rmi.org/electricity_grid_defection#economics_of_grid_defection).
23. Leveraging Natural Gas to Reduce Greenhouse Gas Emissions, C2ES, June 2013.
24. Brandt et al., Methane Leaks from North American Natural Gas Systems, *Science*, 343(6172) 2014.
25. 2013 Natural Gas Issues, Trends, and Outlook, *CEC* July 2014. CEC-200-2014-001-SF.
26. Gas Co. Energy Outlook Workgroup presentation by Ron Kent on April, 15, 2015 (http://www.aqmd.gov/docs/default-source/GB-Committees/energy-outlook-white-paper-working-group/socal-gas.pdf?sfvrsn=2).
27. Goods Movement, Passenger Transportation, and Off-Road Commercial 2016 AQMP White Papers. (http://www.aqmd.gov/home/about/groups-committees/aqmp-advisory-group/2016-aqmp-white-papers).
28. Low Carbon Fuel Standard, Table 6. Carbon Intensity Lookup Table for Gasoline and Fuels that Substitute Gasoline (http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf).

29. Yang et al., Achieving California's 80% greenhouse gas reduction target in 2050: Technology, policy and scenario analysis using CA-TIMES energy economic systems model, Atmospheric Environment, February 2015 (118-130).
30. E3, Pathways to Deep decarbonization in the United States, November 2014 (http://unsdsn.org/what-we-do/deep-decarbonization-pathways/).
31. E3, Summary of the California State Agencies' PATHWAYS Project: Long-term Greenhouse Gas Reduction Scenarios, April 6, 2015 (http://www.arb.ca.gov/html/fact_sheets/e3_2030scenarios.pdf).

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

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