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Letter to Support the Adoption of Nationwide Lower On-Road Heavy-Duty Engine Exhaust Emission Standards for NOx submitted by Erik C. White, Air Pollution Control Officer, Placer County Air Pollution Control District (June 1, 2016)	1
SCAQMD, Final 2012 Air Quality Management Plan (Feb. 2013), ES-1, Chapter 2, Appendix I at I-4 – I-7	2
EPA, Integrated Science Assessment for Ozone and Related Photochemical Oxidants (EPA Ozone ISA) (Feb. 2013) at lxxvi, 1-5, 1-7, 6-221, 6-222	3
CARB, Mobile Source Strategy (2016 Mobile Source Strategy) (May 2016) at 16, 20, 21, 22, 34, 50, 55, 56, 79-85, 98	4
EPA, Janet G. McCabe, Implementing the 2015 Ozone National Ambient Air Quality Standards, Memorandum, (McCabe Memorandum) (Oct. 2015) at 7, 8	5
SCAQMD, Blueprint for Clean Air: 2016 AQMP White Paper (Blueprint for Clean Air White Paper) (October 2015) at 1, 2	6
SCAQMD, Goods Movement: 2016 AQMP White Paper (Goods Movement White Paper) (October 2015) at 2, 3, 7, Appendix A at A-1	7
California Department of Transportation, et al., California Sustainable Freight Action Plan, Draft Discussion Document (Freight Action Plan) (May 2016) at 1, 6, 12	8
Presentation by Mr. Henry Hogo, SCAQMD, at the West Coast Collaborative Partners Meeting, Tacoma, WA (April 5, 2016)	9
EPA, Integrated Science Assessment for Oxides of Nitrogen – Health Criteria (EPA NOx ISA) (Jan. 2016) at 1-7	10
SCAQMD Governing Board Presentation (May 7, 2015), Further Emission Reduction from Mobile Sources Needed to Attain Federal Air Quality Standards, Agenda Item 2 at Slide 16	11
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Congressional Research Service, Ozone Air Quality Standards: EPA's 2015 Revisions (Jan. 25, 2016), Figures 2 and 3 at 4, 14	13
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NACAA Letter to Administrators McCarthy and Rosekind (Sept. 29, 2015)	16
Paul Carpenter, Lehigh Valley Morning Call, Nov. 2, 2008	17
SCAQMD, Socioeconomic Report for 2007 AQMP (June 2007), Benefits and Costs, Table 3-5 (Quantifiable Health Benefits) at 3-10	18
EPA, Regulatory Impact Analysis of the Final Revisions to the National Ambient Air Quality Standards for Ground-Level Ozone (2015 Ozone NAAQS RIA) (Sept. 2015) at ES-14, 16, 18	19

INDEX OF EXHIBITS

TAB 1

Placer County
AIR POLLUTION CONTROL DISTRICT
110 Maple Street, Auburn, CA 95603 • (530) 745-2330 • Fax (530) 745-2373 • www.placer.ca.gov/apcd
Erik C. White, Air Pollution Control Officer

June 1, 2016

The Honorable Gina McCarthy, Administrator
United States Environmental Protection Agency
William Jefferson Clinton Federal Building
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

RE: Letter to Support the Adoption of Nationwide Lower On-Road Heavy-Duty Engine Exhaust Emission Standards for NOx

Dear Ms. McCarthy:

The Placer County Air Pollution Control District (District) supports the South Coast Air Quality Management District's (SCAQMD) petition to the United States Environmental Protection Agency (U.S. EPA) to revise the current nationwide on-road heavy-duty engine exhaust emission standards for oxides of nitrogen (NOx) from 0.2 grams per brake horsepower (g/bhp-hr) to 0.02 g/bhp-hr. This action will greatly assist nonattainment areas not just within California, but throughout the country, in meeting health based federal ozone air quality standards.

With high density urban populations and unique terrain features, many areas in California are classified as nonattainment for the national ambient air quality standards for ozone. This means that many Californians suffer from the unhealthful impacts caused by ozone pollution. The County of Placer is located within the Sacramento federal ozone nonattainment area which is required to meet the 2008 federal 8-hour ozone standards in 2026. Our emission inventory shows that almost 50% of NOx emissions in the nonattainment area are from on-road heavy-duty vehicles, with interstate heavy-duty trucks traversing the Interstate 80 corridor contributing significantly to overall emissions in this sector. Given that NOx is an ozone precursor, reducing NOx emissions will significantly reduce ozone concentrations and is critical for the region to meet clean air standards. The adoption of lower on-road heavy-duty engine emission standards for NOx nationwide will greatly accelerate NOx reductions from interstate heavy-duty trucks and assist all California nonattainment areas, including the Sacramento federal ozone nonattainment area, in meeting federal ozone standards.

While the Federal Clean Air Act provides California the authority to establish its own new engine standards for heavy-duty trucks and engines, the District believes that nationwide standards would be much more effective than a California-only standard. Current technologies such as the Cummins Westport 8.9 liter compressed natural gas engine, which has already been California-certified below 0.02 g/bhp-hr, demonstrate that the technology already exists for these engines; and work currently underway by the California Air Resources Board and the Southwest Research Institute is showing that similar types of reductions are also feasible on diesel platforms as well. The District believes that nationwide standards will encourage manufacturers to invest in the advanced technologies needed to meet a 0.02 g/bhp-hr standard and will decrease compliance costs over time for fleet owners, which will better ensure that the benefits of these technologies are realized across the country.

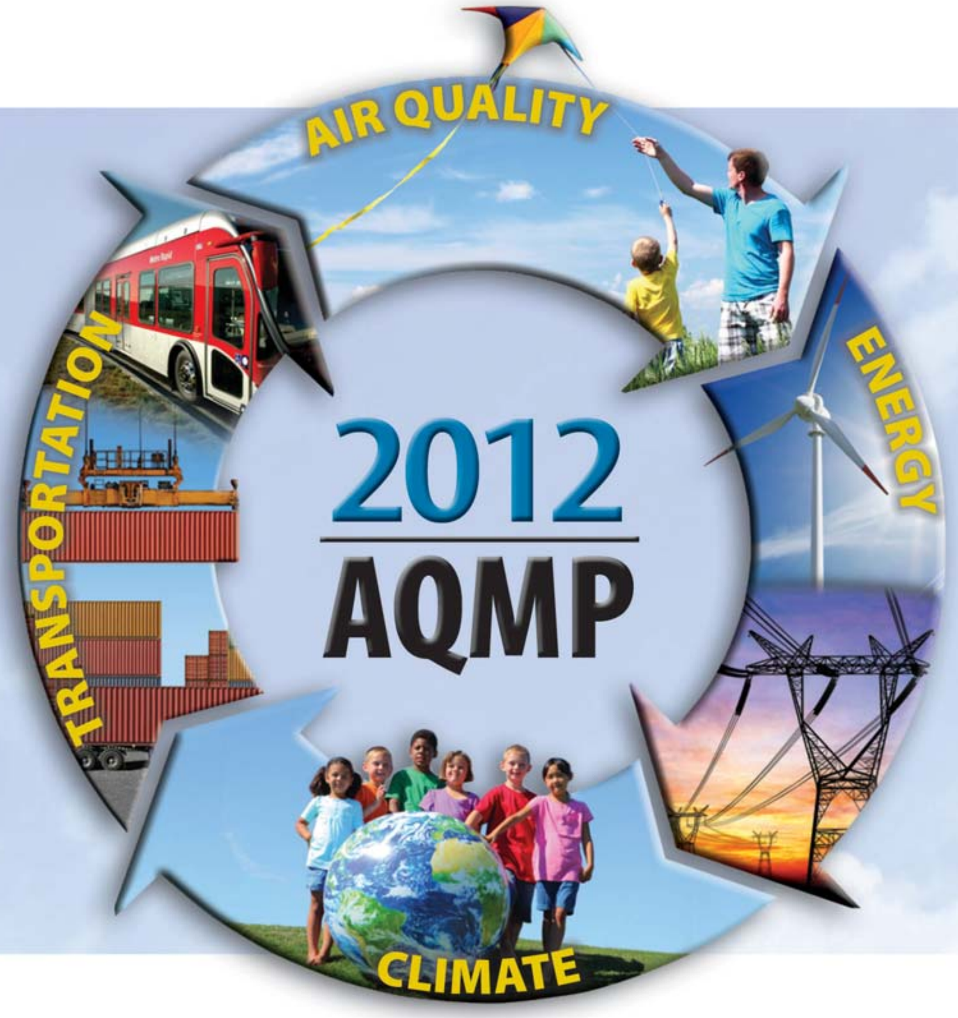
Thank you the opportunity for the District to offer its support of this petition. If you have any questions about this letter or would like to discuss it further, please contact me at 530-745-2330 or ecwhite@placer.ca.gov.

Sincerely,

Erik C. White
Air Pollution Control Officer
Placer County Air Pollution Control District

TAB 2

FINAL 2012
Air Quality Management Plan



February 2013

South Coast Air Quality Management District
Cleaning the air that we breathe...™

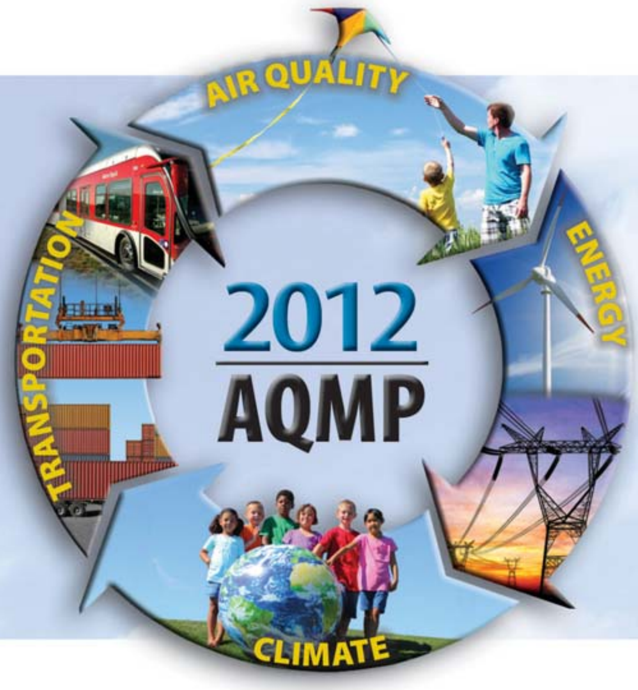
INTRODUCTION

The long-term trend of the quality of air we Southern Californians breathe shows continuous improvement, although the slowing rate of improvement in ozone levels causes concern. The remarkable historical improvement in air quality since the 1970's is the direct result of Southern California's comprehensive, multiyear strategy of reducing air pollution from all sources as outlined in its Air Quality Management Plans (AQMPs). Yet the air in Southern California is far from meeting all federal and state air quality standards and, in fact, is among the worst in the nation. Stemming from the preponderance of latest health evidence, new federal fine particulate (PM2.5) and 8-hour surface-level ozone standards are more stringent than the previous standards. To reach federal Clean Air Act (CAA) deadlines over the next two decades, Southern California must significantly accelerate its pollution reduction efforts.

Continuing the Basin's progress toward clean air is a challenging task, not only to recognize and understand complex interactions between emissions and resulting air quality, but also to pursue the most effective possible set of strategies to improve air quality, maintain a healthy economy, and coordinate efforts with other key public and private partners to meet a larger set of transportation, energy and climate objectives. To ensure continued progress toward clean air and comply with state and federal requirements, the South Coast Air Quality Management District (SCAQMD or District) in conjunction with the California Air Resources Board (CARB), the Southern California Association of Governments (SCAG) and the U.S. Environmental Protection Agency (U.S. EPA) have prepared the Final 2012 AQMP (Plan). The Plan employs the most up-to-date science and analytical tools and incorporates a comprehensive strategy aimed at controlling pollution from all sources, including stationary sources, on-road and off-road mobile sources and area sources.

The Final Plan demonstrates attainment of the federal 24-hour PM2.5 standard by 2014 in the South Coast Air Basin (Basin) through adoption of all feasible measures. The Final Plan also updates the U.S. EPA approved 8-hour ozone control plan with new measures designed to reduce reliance on the CAA Section 182 (e)(5) long-term measures for NOx and VOC reductions.

The Final 2012 AQMP also addresses several state and federal planning requirements, incorporating new scientific information, primarily in the form of updated emissions inventories, ambient measurements, and new meteorological air quality models. This Plan builds upon the approaches taken in the 2007 AQMP for the South Coast Air Basin for the attainment of federal PM and ozone standards, and highlights the significant



Chapter 2

Air Quality and Health Effects

South Coast Air Quality Management District

Cleaning the air that we breathe...™

South Coast AQMD

CHAPTER 2

AIR QUALITY AND HEALTH EFFECTS

INTRODUCTION

In this chapter, air quality is summarized for the year 2011, along with prior year trends, in both the South Coast Air Basin (Basin) and the Riverside County portion of the Salton Sea Air Basin (SSAB), primarily the Coachella Valley, as monitored by the South Coast Air Quality Management District (District). The District's 2011 air quality is compared to national ambient air quality standards (NAAQS). Nationwide air quality data for 2011 is also briefly summarized in this chapter, comparing air quality in the Basin to that of other U.S. and California urban areas. Health effects of the criteria air pollutants, that is, those that have NAAQS, are also discussed. More detailed information on the health effects of air pollution can be found in Appendix I: Health Effects.

Statistics presented in this chapter indicate the current attainment or non-attainment status of the various NAAQS for the criteria pollutants to assist the District in planning for future attainment. For ozone (O_3) and fine particulate matter (PM2.5, particles less that 2.5 microns in diameter), the main pollutants for which the U.S. EPA has declared the Basin to be a nonattainment area, maps are included to spatially compare the air quality throughout the Basin in 2011. The Los Angeles County portion of the Basin is also currently a nonattainment area for the federal lead (Pb) standard due to source-specific monitoring, but Pb air quality data and attainment has been addressed separately in greater detail in the 2012 Lead SIP for Los Angeles County. The Basin is a nonattainment area for the federal PM10 (particules less than 10 microns in diameter) standard, although a request to U.S. EPA to redesignate to attainment is pending. The Coachella Valley is currently declared a nonattainment area for both ozone and PM10 by U.S. EPA, although a request to redesignate to attainment for PM10 is pending. Appendix II: Current Air Quality provides additional information on current air quality and air quality trends, changes in the NAAQS, the impact on the District's attainment status for different pollutants, and air quality compared to state standards, as well as more information on specific monitoring station data.

There were some minor changes to the AQMD monitoring network since the 2007 AQMP, which included air quality data through 2005. New stations were added at South Long Beach, close to the Ports of Los Angeles and Long Beach, and at Temecula in southern Riverside County. In addition, the extent and frequency of PM2.5 monitoring has been increased throughout the District.

AMBIENT AIR QUALITY STANDARDS

Federal and State Standards

Ambient air quality standards for ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter (PM10 and PM2.5), and lead (Pb) have been set by both the State of California and the federal government. The state has also set standards for sulfates (SO_4^{2-}) and visibility. The state and federal ambient air quality standards for each of the criteria pollutants and their effects on health are summarized in Table 2-1.

Several changes to the NAAQS have occurred since the last AQMP update in 2007. The federal 1-hour ozone standard was revoked by the U.S. EPA and replaced by the 8-hour average ozone standard, effective June 15, 2005. However, the Basin and the former Southeast Desert Modified Air Quality Management Area (which included the Coachella Valley) had not attained the 1-hour federal ozone NAAQS by the attainment date and have some continuing obligations under the former standard. The 8-hour ozone NAAQS was subsequently lowered from 0.08 to 0.075 ppm, effective May 27, 2008. However, the SIP submittal for this standard is not due until 2015. In 2010, U.S. EPA proposed to lower the 8-hour ozone NAAQS again and solicited comments on a proposed standard between 0.060 and 0.070 ppm. To date, U.S. EPA has not taken final action on a lower ozone standard and the NAAQS currently remains at 0.075 ppm, as established in 2008. Statistics presented in this chapter refer to the most current 2008 8-hour ozone standard (0.075 ppm) and the former 1979 1-hour ozone standard for purposes of historical comparison.

U.S. EPA revoked the annual PM10 NAAQS (50 $\mu g/m^3$) and lowered the 24-hour PM2.5 NAAQS from 65 $\mu g/m^3$ to 35 $\mu g/m^3$, effective December 17, 2006. On June 14, 2012, U.S. EPA proposed to strengthen the annual PM2.5 federal standard from 15 $\mu g/m^3$ to a proposed range between 12 and 13 $\mu g/m^3$. U.S. EPA also proposed to require near-roadway PM2.5 monitoring. Final action on the proposed PM2.5 standards is expected by December 14, 2012.

The national standard for Pb was revised on October 15, 2008 to a rolling 3-month average of 0.15 $\mu g/m^3$, from a quarterly average of 1.5 $\mu g/m^3$. Most recently, U.S. EPA established a new 1-hour NO_2 federal standard of 0.100 ppm, effective April 7, 2010, and revised the SO_2 federal standard by establishing a new 1-hour standard of 0.075 ppm and revoking the annual (0.03 ppm) and 24-hour (0.14 ppm) standards, effective August 2, 2010.

TABLE 2-1

Current Ambient Air Quality Standards and Health Effects

AIR POLLUTANT	STATE STANDARD	FEDERAL STANDARD (NAAQS)	RELEVANT HEALTH EFFECTS#
	Concentration, Averaging Time	**Concentration, Averaging Time**	
Ozone (O_3)	0.09 ppm, 1-Hour 0.070 ppm, 8-Hour	0.075 ppm, 8-Hour (2008) 0.08 ppm, 8-Hour (1997)	(a) Pulmonary function decrements and localized lung edema in humans and animals; (b) Risk to public health implied by alterations in pulmonary morphology and host defense in animals; (c) Increased mortality risk; (d) Risk to public health implied by altered connective tissue metabolism and altered pulmonary morphology in animals after long-term exposures and pulmonary function decrements in chronically exposed humans; (e) Vegetation damage; (f) Property damage
Carbon Monoxide (CO)	20 ppm, 1-Hour 9.0 ppm, 8-Hour	35 ppm, 1-Hour 9 ppm, 8-Hour	(a) Aggravation of angina pectoris and other aspects of coronary heart disease; (b) Decreased exercise tolerance in persons with peripheral vascular disease and lung disease; (c) Impairment of central nervous system functions; (d) Possible increased risk to fetuses
Nitrogen Dioxide (NO_2)	0.18 ppm, 1-Hour 0.030 ppm, Annual	100 ppb, 1-Hour 0.053 ppm, Annual	(a) Potential to aggravate chronic respiratory disease and respiratory symptoms in sensitive groups; (b) Risk to public health implied by pulmonary and extra-pulmonary biochemical and cellular changes and pulmonary structural changes; (c) Contribution to atmospheric discoloration
Sulfur Dioxide (SO_2)	0.25 ppm, 1-Hour 0.04 ppm, 24-Hour	75 ppb, 1-Hour	Bronchoconstriction accompanied by symptoms which may include wheezing, shortness of breath, and chest tightness during exercise or physical activity in persons with asthma
Suspended Particulate Matter (PM10)	50 µg/m^3, 24-Hour 20 µg/m^3, Annual	150 µg/m^3, 24-Hour	(a) Exacerbation of symptoms in sensitive patients with respiratory or cardiovascular disease; (b) Decline in pulmonary function or growth in children; (c) Increased risk of premature death
Suspended Particulate Matter (PM2.5)	12.0 µg/m^3, Annual	35 µg/m^3, 24-Hour 15.0 µg/m^3, Annual	
Sulfates-PM10 (SO_4^{2-})	25 µg/m^3, 24-Hour	N/A	(a) Decrease in lung function; (b) Aggravation of asthmatic symptoms; (c) Aggravation of cardio-pulmonary disease; (d) Vegetation damage; (e) Degradation of visibility; (f) Property damage
Lead (Pb)	1.5 µg/m^3, 30-day	0.15 µg/m^3, 3-month rolling	(a) Learning disabilities; (b) Impairment of blood formation and nerve conduction
Visibility-Reducing Particles	In sufficient amount such that the extinction coefficient is greater than 0.23 inverse kilometers at relative humidity less than 70 percent, 8-hour average (10am - 6pm)	N/A	Visibility impairment on days when relative humidity is less than 70 percent

ppm – parts per million by volume ppb – parts per billion by volume
State standards are "not-to-exceed" values; Federal standards follow the design value form of the NAAQS
\# More detailed health effect information can be found in the 2012 AQMP Appendix I or the U.S. EPA NAAQS documentation at http://www.epa.gov/ttn/naaqs/

U.S. EPA allows certain air quality data to be flagged in the U.S. EPA Air Quality System (AQS) database and not considered for NAAQS attainment status when that data is influenced by exceptional events, such as high winds, wildfires, volcanoes, or some cultural events (Independence Day fireworks) that meet strict requirements. For a few PM measurements in the Basin in 2007 and 2008, the District applied the U.S. EPA Exceptional Events Rule to flag PM10 and PM2.5 data due to high wind natural events, wildfires and Independence Day fireworks (the District has submitted the required documentation and U.S EPA concurrence with these flags is pending). In the Coachella Valley, PM10 data has been flagged for high wind natural events, under the current Exceptional Events Rule and the previous U.S. EPA Natural Events Policy[1]. All of the exceptional event flags through 2011 have been submitted by the District to U.S. EPA's AQS along with the data. The most recent of these are pending submittal of the District's final documentation for each event and all are pending U.S. EPA concurrence. The pending PM10 redesignation request for the Coachella Valley may hinge on U.S EPA's concurrence with the exceptional event flags and the appropriate treatment of these uncontrollable natural events.

In this chapter and in Appendix II, air quality statistics are presented for the maximum concentrations measured at stations or in air basins, as well as for the number of days exceeding state or federal standards. These statistics are instructive in regards to trends and control effectiveness. However, it should be noted that an exceedance of the concentration level of a federal standard does not necessarily mean that the NAAQS was violated or that it would cause a nonattainment designation. The form of the standard must also be considered. For example, for 24-hour PM2.5, the form of the standard is the 98^{th} percentile measurement of all of the 24-hour PM2.5 samples at each station. For 8-hour ozone, the form of the standard is the 4^{th} highest measured 8-hour average concentration at each station. For NAAQS attainment/nonattainment decisions, the most recent 3 years of data are considered (1 year for CO and 24-hour SO_2), along with the form of the standard, and are typically averaged to calculate a *design value*[2] for each station. The overall design value for an air basin is the highest

[1] The U.S. EPA Exceptional Events Rule, *Treatment of Data Influence by Exceptional Events*, became effective May 21, 2007. The previous U.S. EPA *Natural Events Policy* for Particulate Matter was issued May 30, 1996. On July 6, 2012, U.S. EPA released the *Draft Guidance To Implement Requirements for the Treatment of Air Quality Monitoring Data Influenced by Exceptional Events* for public comment.

[2] A design value is a statistic that describes the air quality status of a given area relative to the level and form of the National Ambient Air Quality Standards (NAAQS). For most criteria pollutants, the design value is a 3-year average and takes into account the form of the short-term standard (e.g., 98^{th} percentile, fourth high value, etc.) Design values are especially helpful when the standard is exceedance-based (e.g. 1-hour ozone, 24-hour PM10, etc.) because they are expressed as a concentration instead of an exceedance count, thereby allowing a direct comparison to the level of the standard.

design value of all the stations in that basin. Table 2-2 shows the NAAQS, along with the design value and form of each federal standard.

TABLE 2-2

National Ambient Air Quality Standards (NAAQS) and Design Value Requirements

POLLUTANT	AVERAGING TIME	STANDARD LEVEL	DESIGN VALUES AND FORM OF STANDARDS*
Ozone (O_3)	1-Hour** (1979)	0.12 ppm	Not to be exceeded more than once per year averaged over 3 years
	8-Hour** (1997)	0.08 ppm	Annual fourth highest 8-hour average concentration, averaged over 3 years
	8-Hour (2008)	0.075 ppm	Annual fourth highest 8-hour average concentration, averaged over 3 years
Carbon Monoxide (CO)	1-Hour	35 ppm	Not to be exceeded more than once a year
	8-Hour	9 ppm	
Nitrogen Dioxide (NO_2)	1-Hour	100 ppb	3-year avg. of the annual 98th percentile of the daily maximum 1-hour average concentrations (rounded)
	Annual	0.053 ppm	Annual avg. concentration, averaged over 3 years
Sulfur Dioxide (SO_2)	1-Hour	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	24-Hour#	0.14 ppm	Not to be exceeded more than once per year
	Annual#	0.03 ppm	Annual arithmetic average
Particulate Matter (PM10)	24-Hour	150 $\mu g/m^3$	Not to be exceeded more than once per year averaged over 3 years
	Annual**	50 $\mu g/m^3$	Annual average concentration, averaged over 3 years
Particulate Matter (PM2.5)	24-Hour	35 $\mu g/m^3$	3-year average of the annual 98th percentile of daily 24-hour concentration
	Annual	15.0 $\mu g/m^3$	Annual avg. concentration, averaged over 3 years
Lead (Pb)	3-Month Rolling##	0.15 $\mu g/m^3$	Highest rolling 3-month average of the 3 years

* Standard is attained when the design value (form of concentration listed) is equal to or less than the NAAQS; for pollutants with the design values based on "exceedances" (1-hour O_3, 24-hour PM10, CO, and 24-hour SO_2), the NAAQS is attained when the concentration associated with the design value is less than or equal to the standard:

- For 1-hour O_3 and 24-hour PM10, the standard is attained when the 4th highest daily concentrations of the 3-year period is less than or equal to the standard
- For CO and 24-hour SO_2, the standard is attained when the 2nd highest daily concentration of the most recent year is equal to or less than the standard

** Standard is revoked or revised. For 1-hour O_3, nonattainment areas have some continuing obligations under the former 1979 standard. For 8-hour O_3, standard is lowered from (0.08 ppm to 0.075 ppm), but the 1997 O_3 standard and most related implementation rules remain in place until the 1997 standard is revoked by U.S. EPA

\# Annual and 24-hour SO_2 NAAQS will be revoked one year from attainment designations for the new (2010) 1-hour SO_2 standard

\## 3-month rolling averages of the first year (of the three year period) include November and December monthly averages of the prior year. The 3-month average is based on the average of "monthly" averages

NAAQS Attainment Status

Figure 2-1 shows the South Coast and Coachella Valley 3-year design values (2009-2011) for ozone and PM2.5, as a percentage of the corresponding federal standards. The current status of NAAQS attainment for the criteria pollutants is presented in Table 2-3 for the Basin and in Table 2-4 for the Riverside County portion of the SSAB (Coachella Valley).

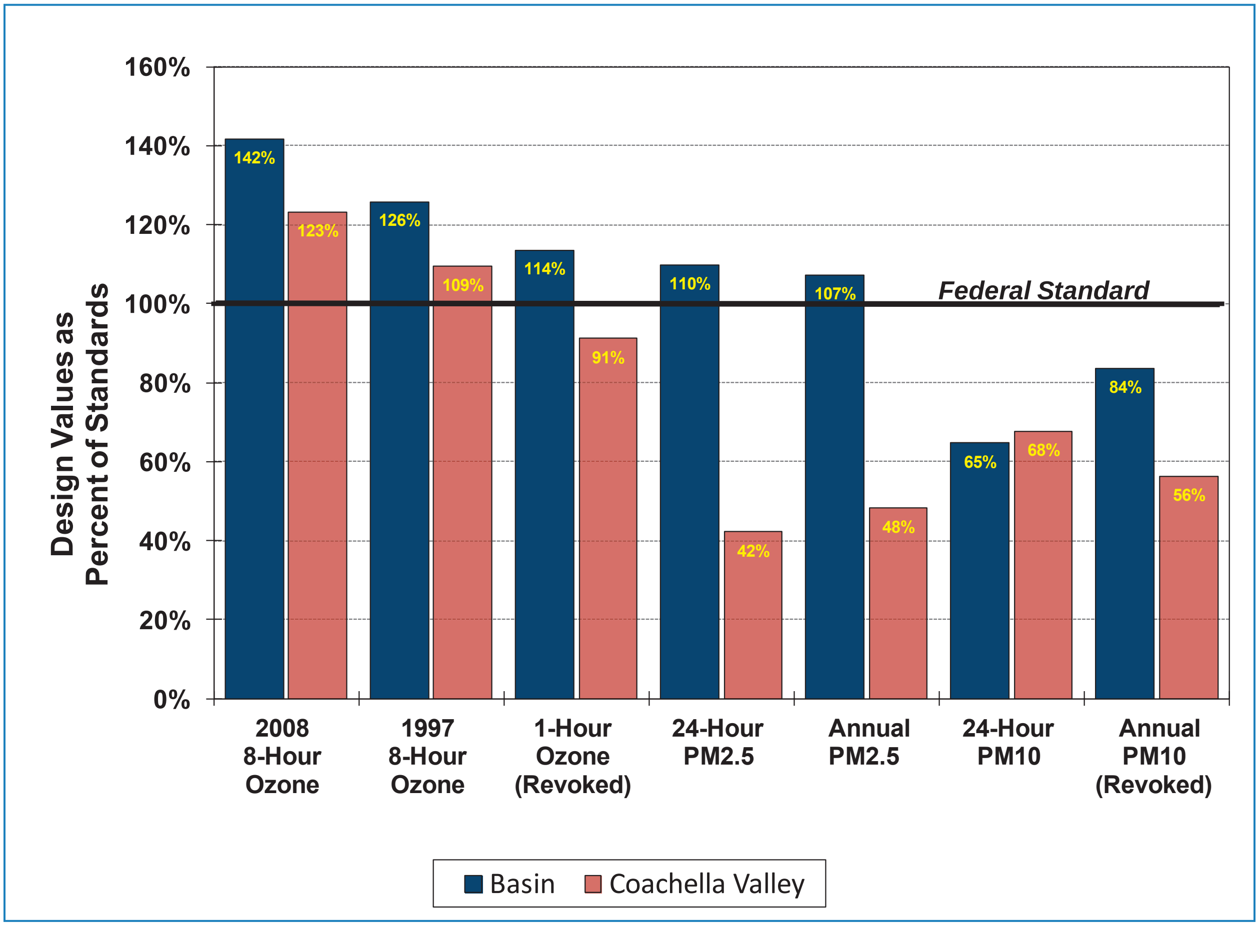


FIGURE 2-1

South Coast Air Basin and Coachella Valley 3-Year (2009-2011) Design Values (Percentage of Federal Standards, by Criteria Pollutant)

TABLE 2-3

National Ambient Air Quality Standards (NAAQS) Attainment Status
South Coast Air Basin

CRITERIA POLLUTANT	AVERAGING TIME	DESIGNATION [a)]	ATTAINMENT DATE [b)]
1979 **1-Hour Ozone**[c)]	1-Hour (0.12 ppm)	Nonattainment (Extreme)	11/15/2010 (not attained)[c)]
1997 **8-Hour Ozone**[d)]	8-Hour (0.08 ppm)	Nonattainment (Extreme)	6/15/2024
2008 **8-Hour Ozone**	8-Hour (0.075 ppm)	Nonattainment (Extreme)	12/31/2032
CO	1-Hour (35 ppm) 8-Hour (9 ppm)	Attainment (Maintenance)	6/11/2007 (attained)
NO_2[e)]	1-Hour (100 ppb)	Unclassifiable/Attainment	Attained
	Annual (0.053 ppm)	Attainment (Maintenance)	9/22/1998
SO_2[f)]	1-Hour (75 ppb)	Designations Pending	Pending
	24-Hour (0.14 ppm) Annual (0.03 ppm)	Unclassifiable/Attainment	3/19/1979 (attained)
PM10	24-hour (150 $\mu g/m^3$)	Nonattainment (Serious)[g)]	12/31/2006 (redesignation request submitted)[g)]
PM2.5	24-Hour (35 $\mu g/m^3$)	Nonattainment	12/14/2014[h)]
	Annual (15.0 $\mu g/m^3$)	Nonattainment	4/5/2015
Lead	3-Months Rolling (0.15 $\mu g/m^3$)	Nonattainment (Partial)[i)]	12/31/2015

a) U.S. EPA often only declares Nonattainment areas; everywhere else is listed as Unclassifiable/Attainment or Unclassifiable

b) A design value below the NAAQS for data through the full year or smog season prior to the attainment date is typically required for attainment demonstration

c) 1-hour O_3 standard (0.12 ppm) was revoked, effective June 15, 2005; however, the Basin has not attained this standard based on 2008-2010 data and has some continuing obligations under the former standard

d) 1997 8-hour O_3 standard (0.08 ppm) was reduced (0.075 ppm), effective May 27, 2008; the 1997 O_3 standard and most related implementation rules remain in place until the 1997 standard is revoked by U.S. EPA

e) New NO_2 1-hour standard, effective August 2, 2010; attainment designations January 20, 2012; annual NO_2 standard retained

f) The 1971 annual and 24-hour SO_2 standards were revoked, effective August 23, 2010; however, these 1971 standards will remain in effect until one year after U.S. EPA promulgates area designations for the 2010 SO_2 1-hour standard. Area designations are expected in 2012, with Basin designated Unclassifiable /Attainment

g) Annual PM10 standard was revoked, effective December 18, 2006; redesignation request to Attainment of the 24-hour PM10 standard is pending with U.S. EPA

h) Attainment deadline for the 2006 24-Hour PM2.5 NAAQS is December 14, 2014

i) Partial Nonattainment designation – Los Angeles County portion of Basin only

TABLE 2-4

National Ambient Air Quality Standards (NAAQS) Attainment Status
Coachella Valley Portion of the Salton Sea Air Basin

CRITERIA POLLUTANT	AVERAGING TIME	DESIGNATION [a]	ATTAINMENT DATE [b]
1979 **1-Hour Ozone**[c]	1-Hour (0.12 ppm)	Nonattainment (Severe-17)	11/15/2007 (not timely attained[c])
1997 **8-Hour Ozone**[d]	8-Hour (0.08 ppm)	Nonattainment (Severe-15)	6/15/2019
2008 **8-Hour Ozone**	8-Hour (0.075 ppm)	Nonattainment (Severe-15)	12/31/2027
CO	1-Hour (35 ppm) 8-Hour (9 ppm)	Unclassifiable/Attainment	Attained
NO_2[e]	1-Hour (100 ppb)	Unclassifiable/Attainment	Attained
	Annual (0.053 ppm)	Unclassifiable/Attainment	Attained
SO_2[f]	1-Hour (75 ppb)	Designations Pending	Pending
	24-Hour (0.14 ppm) Annual (0.03 ppm)	Unclassifiable/Attainment	Attained
PM10	24-hour (150 $\mu g/m^3$)	Nonattainment (Serious)[g]	12/31/2006 (redesignation request submitted)[g]
PM2.5	24-Hour (35 $\mu g/m^3$) Annual (15.0 $\mu g/m^3$)	Unclassifiable/Attainment	Attained
Lead	3-Months Rolling (0.15 $\mu g/m^3$)	Unclassifiable/Attainment	Attained

a) U.S. EPA often only declares Nonattainment areas; everywhere else is listed as Unclassifiable/Attainment or Unclassifiable
b) A design value below the NAAQS for data through the full year or smog season prior to the attainment date is typically required for attainment demonstration
c) 1-hour O_3 standard (0.13 ppm) was revoked, effective June 15, 2005; the Southeast Desert Modified Air Quality Management Area, including the Coachella Valley, has not attained this standard based on 2005-2007 data and has some continuing obligations under the former standard (latest 2009-2011 data shows attainment)
d) 1997 8-hour O_3 standard (0.08 ppm) was reduced (0.075 ppm), effective May 27, 2008; the 1997 O_3 standard and most related implementation rules remain in place until the 1997 standard is revoked by U.S. EPA
e) New NO_2 1-hour standard, effective August 2, 2010; attainment designations January 20, 2012; annual NO_2 standard retained
f) The 1971 Annual and 24-hour SO_2 standards were revoked, effective August 23, 2010; however, these 1971 standards will remain in effect until one year after U.S. EPA promulgates area designations for the 2010 SO_2 1-hour standard. Area designations expected in 2012 with SSAB designated Unclassifiable /Attainment
g) Annual PM10 standard was revoked, effective December 18, 2006; redesignation request to Attainment of the 24-hour PM10 standard is pending with U.S. EPA

In 2011, the Basin exceeded federal standards for either ozone or PM2.5 at one or more locations on a total of 124 days, based on the current federal standards for 8-hour ozone and 24-hour PM2.5. Despite substantial improvement in air quality over the past few decades, some air monitoring stations in the Basin still exceed the NAAQS for ozone more frequently than any other stations in the U.S. In 2011, three of the top five stations in the nation most frequently exceeding the 8-hour federal ozone NAAQS were located within the Basin (i.e., Central San Bernardino Mountains, East San Bernardino Valley and Metropolitan Riverside County). In the year 2011, the former 1-hour[3] and current 8-hour average federal standard levels for ozone were exceeded at one or more Basin locations on 16 and 106 days, respectively.

PM2.5 in the Basin has improved significantly in recent years, with 2010 and 2011 being the cleanest years on record. In 2011, only one station in the Basin (Metropolitan Riverside County at Mira Loma) exceeded the annual PM2.5 NAAQS and the 98th percentile form of the 24-hour PM2.5 NAAQS, as well as the 3-year design values for these standards. (Although other stations had 24-hour averages exceeding the federal 24-hour PM2.5 standard concentration level in 2011, the 98th percentile concentration did not exceed.) Basin-wide, the federal PM2.5 24-hour standard level was exceeded in 2011 on 17 sampling days[4].

The Basin and the Coachella Valley have technically met the PM10 NAAQS and redesignation for attainment for the federal PM10 standard has been requested for both. These requests are still pending with U.S. EPA at this time[5].

The District is currently in attainment for the federal standards for SO_2, CO, and NO_2. While the concentration level of the new 1-hour NO_2 federal standard (100 ppb) was exceeded in the Basin at two stations (Central Los Angeles and Long Beach, on the same day) in 2011, the NAAQS NO_2 design value has not been exceeded (the 3-year average of the annual 98th percentile of the daily 1-hour maximums). Therefore, the Basin remains in attainment of the NO_2 NAAQS. U.S. EPA requirements for future

[3] The federal 1-hour O_3 NAAQS has been revoked by U.S. EPA, although certain nonattainment areas, including the Basin, may be still required to demonstrate attainment of that standard based on recent court decisions.

[4] The number of PM exceedances may have been higher at some locations, since PM2.5 samples are collected every 3 days at most sites. However, seven sites sample every day, including the Basin maximum concentration stations. PM10 filter samples are collected every 6 days, except at the design value maximum sites in the Basin and the Coachella Valley at which samples are collected every 3 days. Daily PM10 data for the Basin maximum stations is provided by supplementing the filter measurements with Federal Equivalent Method (FEM) continuous monitors. The gaseous pollutants, including O_3, NO_2, SO_2, and CO, are sampled continuously.

[5] U.S. EPA has requested additional PM10 monitoring in the southeastern Coachella Valley for a 1-year period to further assess windblown dust in that area. This project is currently ongoing.

near-road NO_2 measurements are not a part of the current ambient NO_2 NAAQS determinations.

U.S. EPA designated the Los Angeles County portion of the Basin (excluding the high desert areas, and San Clemente and Santa Catalina Islands) as nonattainment for the recently revised (2008) federal lead standard (0.15 $\mu g/m^3$, rolling 3-month average), due to the addition of source- specific monitoring under the new federal regulation. This designation was based on two source-specific monitors in Vernon and in the City of Industry exceeding the new standard in the 2007-2009 period of data used. For the most recent 2009-2011 data period, only one of these stations (Vernon) still exceeded the lead standard, with a maximum 3-month rolling average of 0.67 $\mu g/m^3$ occurring in 2009. In 2011, the rolling 3-month average at that site was 0.46 $\mu g/m^3$.

The remainder of the Basin, outside the Los Angeles County nonattainment area, and the Coachella Valley remain in attainment of the 2008 lead standard and no ambient monitors exceed that are not source-oriented. For areas in attainment of the old 1978 lead standard (1.5 $\mu g/m^3$, as a quarterly average), the old standard remained in effect until one year after an area was designated for the 2008 standard. While the entire Basin and the Coachella Valley have remained in attainment of the 1978 lead standard, U.S. EPA's current lead designations for the new standard became effective on December 31, 2010; thus, the old standard is now superseded by the 2008 revised NAAQS. A separate SIP revision addressing the 2008 lead standard has been submitted to U.S. EPA.

CURRENT AIR QUALITY

In 2011, O_3, PM2.5, NO_2 and Pb exceeded federal standard concentration levels at one or more of the routine monitoring stations in the Basin. An exceedance of the concentration level does not necessarily mean a violation of the NAAQS, given that the form of the standard must be considered. For example, the Basin did not violate the federal NO_2 standard, based on the form of the standard. Ozone and PM10 concentrations exceeded the federal standard concentration levels in the Coachella Valley.

The PM2.5 2011 maximum 24-hour average (94.6 $\mu g/m^3$, measured in the East San Gabriel Valley area) and annual average (15.3 $\mu g/m^3$, measured in the Metropolitan Riverside County area) concentrations were 266 and 101 percent of the federal 24-hour and annual average standard concentration levels, respectively. The highest 24-

hour PM2.5 concentration in the Basin, mentioned above, was recorded on July 5, 2011, associated with Independence Day firework activities and has been flagged in the U.S. EPA Air Quality System (AQS) database for exclusion for NAAQS compliance consideration according to the U.S. EPA Exceptional Event Rule. The next highest 24-hour average PM2.5 concentration was 65 $\mu g/m^3$ recorded in Central San Bernardino Valley. The PM2.5 federal standard was nearly exceeded on one day in the Coachella Valley, during an exceptional event in which dust was entrained by outflow from a large summertime thunderstorm complex over Arizona and Mexico, transporting high concentrations of PM10 and PM2.5 into the Coachella Valley. None of these three stations with the highest 24-hour average PM2.5 concentrations had 98th percentile concentrations exceeding the standard. Only the Metropolitan Riverside County (Mira Loma) station had a 98th percentile concentration over the 24-hour federal standard.

The 2011 maximum PM10 24-hour average concentration measured in the South Coast Air Basin was 152 $\mu g/m^3$ in the Metropolitan Riverside County area, nearly 100% of the federal standard (but not exceeding it, since a concentration of 155 $\mu g/m^3$ is needed to exceed the PM10 standard). This maximum 24-hour average concentration was measured with a Federal Equivalent Method (FEM) continuous monitor. The highest 24-hour PM10 concentration in the Basin measured with the Federal Reference Method (FRM) filter sampler was 84 $\mu g/m^3$ recorded in Central San Bernardino Valley, 56 percent of the standard. The maximum annual average PM10 concentration (42.3 $\mu g/m^3$ in the Metropolitan Riverside County area) is 85 percent of the former (now revoked) federal annual average standard level. The two routine AQMD monitoring stations in the Coachella Valley exceeded the 24-hour PM10 federal standard on two days, both related to windblown dust generated by thunderstorm activity. These two days have been flagged by the District in the U.S. EPA AQS database for consideration under the Exceptional Event Rule.

The 2011 maximum ozone concentrations continued to exceed federal standards by wide margins. Maximum 1-hour and 8-hour average ozone concentrations (0.160 ppm and 0.136 ppm, both recorded in the Central San Bernardino Mountains area) were 128 and 181 percent of the former 1-hour and current 8-hour federal standards, respectively. The Coachella Valley did not exceed the former 1-hour federal standard in 2011, but the maximum 8-hour concentration (0.098 ppm) was 130 percent of the current federal standard.

The maximum 1-hour average NO_2 concentration in 2011 (110 ppb, measured in Central Los Angeles) was 109 percent of the federal standard, exceeding the concentration level, but not the 98th percentile form of the NAAQS. Lead concentrations in 2011 were well below the recently (2008) revised federal standard at all ambient monitoring sites not located near lead sources. However, the source-specific monitoring site immediately downwind of a stationary lead source in the City of Vernon recorded a maximum 3-month rolling average of 0.46 µg/m^3, or 297 percent of the standard. Concentrations of other criteria pollutants (SO_2 and CO) remained well below the federal standards.

Figure 2-2 shows the trend of maximum pollutant concentrations in the Basin for the past two decades, as percentages of the corresponding federal standards. Most pollutants show significant improvement over the years, with PM2.5 showing the most dramatic decrease. Again, these are maximum concentrations and actual attainment of the standards is based on the design value.

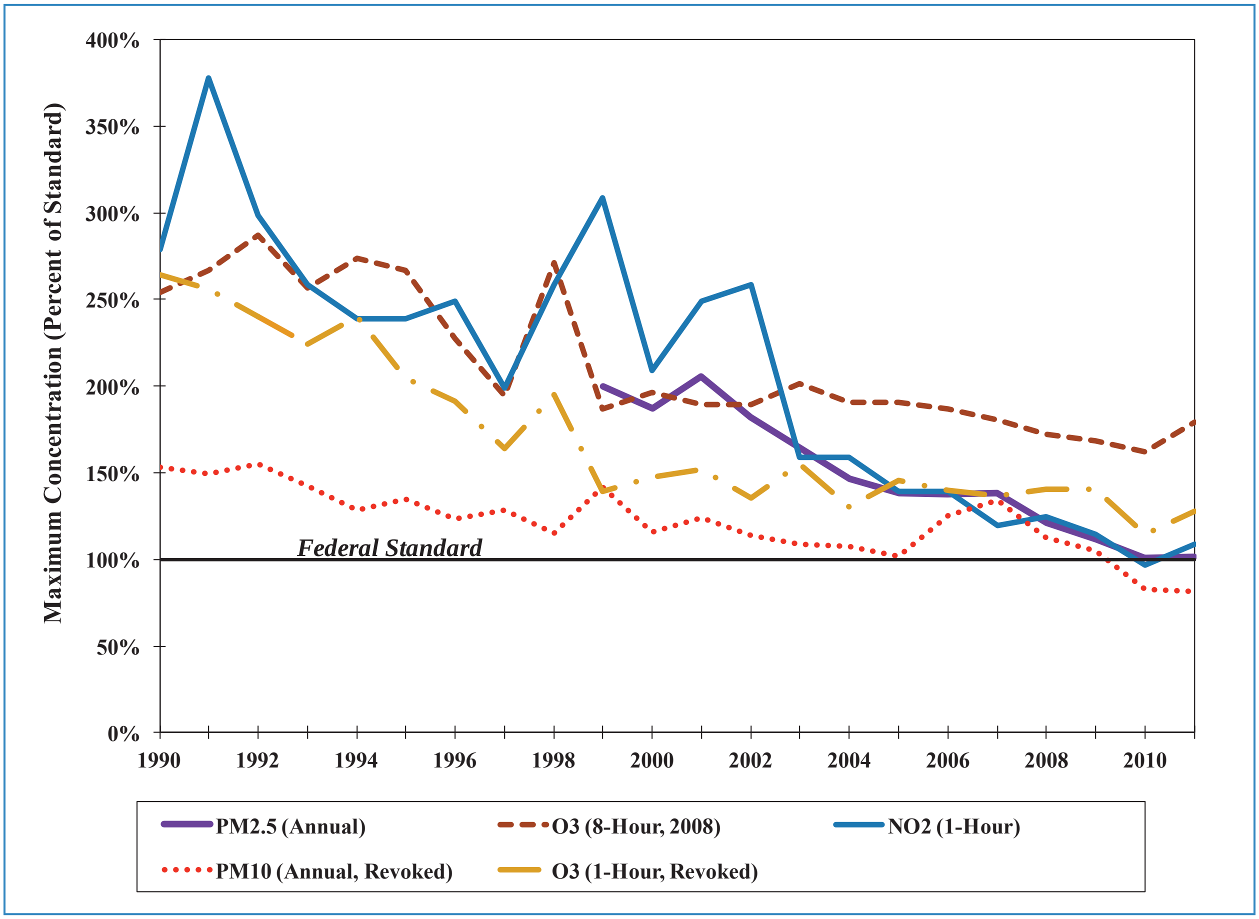


FIGURE 2-2

Trends of South Coast Air Basin Maximum Pollutant Concentrations
(Percentages of Federal Standards)

Particulate Matter (PM2.5 and PM10) Specific Information

Health Effects, Particulate Matter

A significant body of peer-reviewed scientific research, including studies conducted in Southern California, points to adverse impacts of particulate matter air pollution on both increased illness (morbidity) and increased death rates (mortality). The 2009 U.S. EPA *Integrated Science Assessment for Particulate Matter*[6] describes these health effects and discusses the state of the scientific knowledge. A summary of health effects information and additional references can also be found in the 2012 AQMP, Appendix I.

There was considerable controversy and debate surrounding the review of particulate matter health effects and the consideration of ambient air quality standards when U.S. EPA promulgated the initial PM2.5 standards in 1997[7]. Since that time, numerous additional studies have been published[8]. In addition, some of the key studies supporting the 1997 standards were closely scrutinized and the analyses repeated and extended. These reanalyses confirmed the initial findings associating adverse health effects with PM exposures.

Several studies have found correlations between elevated ambient particulate matter levels and an increase in mortality rates, respiratory infections, number and severity of asthma attacks, and the number of hospital admissions in different parts of the United States and in various areas around the world. In recent years, studies have reported an association between long-term exposure to PM2.5 and increased mortality, reduction in life-span, and an increased mortality from lung cancer.

Daily fluctuations in PM2.5 concentration levels have also been related to increased mortality due to cardiovascular or respiratory diseases, hospital admissions for acute respiratory conditions, school and kindergarten absences, a decrease in respiratory function in normal children, and increased medication use in children and adults with asthma. Long-term exposure to PM has been found to be associated with reduced lung function growth in children. The elderly, people with pre-existing respiratory

[6] U.S. EPA. (2009). Integrated Science Assessment for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F.
[7] Vedal, S. (1997). Critical Review. Ambient Particles and Health: Lines that Divide. JAMA, 47(5):551-581.
[8] Kaiser, J. (2005). Mounting Evidence Indicts Fine-Particle Pollution. Science, 307:1858-1861.
Enstrom, J.E. (2005), "Fine particulate air pollution and total mortality among elderly Californians, 1973–2002," *Inhalation Toxicology* 17:803–16

and/or cardiovascular disease, and children appear to be more susceptible to the effects of PM10 and PM2.5.

The U.S. EPA, in its most recent review, has concluded that long term exposure to PM2.5 is causally related to increases in mortality rates. Despite this, skepticism remains among some quarters whether exposures to PM2.5 in California are responsible for increases in mortality.[9] An expanded discussion of studies relating to PM exposures and mortality is contained in Appendix I of this document.

Air Quality, PM2.5

The District began regular monitoring of PM2.5 in 1999 following the U.S. EPA's adoption of the national PM2.5 standards in 1997. In 2011, PM2.5 concentrations were monitored at 21 locations throughout the District, 20 of which had filter-based FRM monitoring sites while one had only continuous monitoring. Six sites had collocated, continuous monitoring in addition to the FRM samplers. The maximum 24-hour and annual average PM2.5 concentrations in 2011 are shown in Tables 2-5 and 2-6.

Figure 2-3 maps the distribution of annual average PM2.5 concentrations in different areas of the Basin. Similar to PM10 concentrations, PM2.5 concentrations were higher in the inland valley areas of metropolitan Riverside County (highest at the Mira Loma Station). PM2.5 concentrations were also elevated in the metropolitan area of Los Angeles County, but did not exceed the level of the annual federal standard in 2011. Although maximum 24-hour concentrations exceed the standard, the 98th percentile form of the 2009-2011 design value only exceeded the standard at one station in Metropolitan Riverside County (Mira Loma).

The higher PM2.5 concentrations in the Basin are mainly due to the secondary formation of smaller particulates resulting from mobile, stationary and area source emissions of precursor gases (i.e., NOx, SOx, NH_4, and VOC) that are converted to PM in the atmosphere. In contrast to PM10, PM2.5 concentrations were low in the Coachella Valley area of SSAB. PM10 concentrations are normally higher in the desert areas due to windblown and fugitive dust emissions; PM2.5 is relatively low in the desert area due to fewer combustion-related emissions sources.

[9] CARB Symposium: Estimating Premature Deaths from Long-term Exposure to PM2.5, February 26, 2010, [http://www.arb.ca.gov/research/health/pm-mort/pm-mort-ws_02-26-10.htm].

TABLE 2-5

2011 Maximum 24-hour Average PM2.5 Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 24-HR AVERAGE[#] (μG/M^3)	PERCENT OF FEDERAL STANDARD* (35 μG/M^3)	AREA
South Coast Air Basin			
Los Angeles**	49.5	139	East San Gabriel Valley
Orange	39.2	110	Central Orange County
Riverside	60.8	171	Metropolitan Riverside County
San Bernardino	65.0	183	Central San Bernardino Valley
Salton Sea Air Basin			
Riverside***	35.4	99.7	Coachella Valley

\# Based on FRM data

* Although maximum 24-hour concentrations exceed the standard, the 98th percentile form of the 2009-2011 design value only exceeded the standard at one station in Metropolitan Riverside County (Mira Loma)

** One higher concentration that was recorded due to "Independence Day" firework activities has been flagged for exclusion from NAAQS comparison in accordance with the U.S. EPA Exceptional Events Rule; with this data included, the 2009-2011 design value for East San Gabriel Valley would also exceed the federal standard

*** While this concentration of 35.4 μg/m^3 is near the level of the standard, it is technically not exceeding the standard (35.5 μg/m^3 exceeds); this concentration was associated with a high wind exceptional event

TABLE 2-6

2011 Maximum Annual Average PM2.5 Concentrations by Basin and County

BASIN/COUNTY	ANNUAL AVERAGE* (μG/M^3)	PERCENT OF FEDERAL STANDARD (15 μG/M^3)	AREA
South Coast Air Basin			
Los Angeles	13.3	89	Central Los Angeles
Orange	11.0	73	Central Orange County
Riverside	15.3	101	Metropolitan Riverside County
San Bernardino	13.3	89	Southwest San Bernardino Valley
Salton Sea Air Basin			
Riverside	7.1	47	Coachella Valley

* Based on FRM data

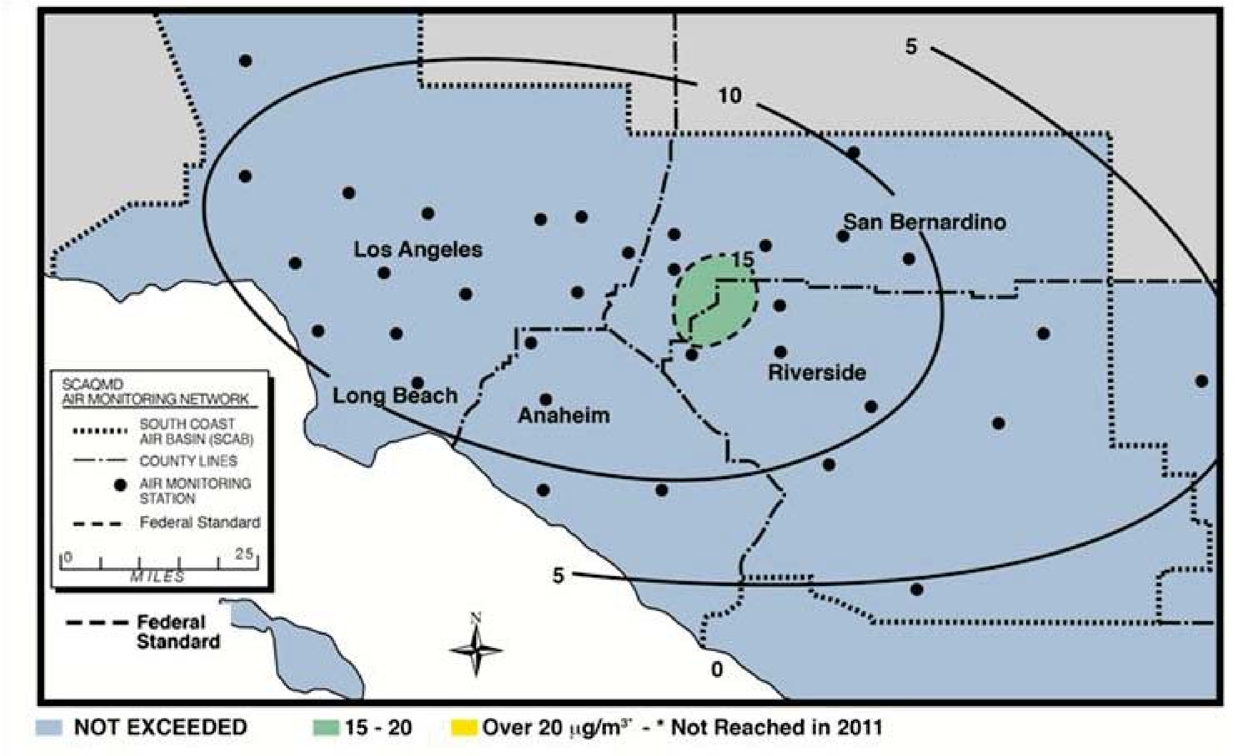


FIGURE 2-3

2011 PM2.5: Annual Average Concentration Compared to the Federal Standard
(Federal standard = 15 µg/m^3, annual arithmetic mean)

<u>Air Quality, PM10</u>

In 2011, the District monitored PM10 concentrations at 25 routine sampling locations, 22 with Federal Reference Method (FRM) filter samplers and 3 with Federal Equivalent Method (FEM) continuous monitors. Five sites had collocated FRM and FEM samplers. Maximum 24-hour and annual average PM10 concentrations in 2011 are shown in Tables 2-7 and 2-8.

The highest annual PM10 concentrations were recorded in Riverside and San Bernardino Counties, in and around the metropolitan Riverside County area and further inland in the San Bernardino valley areas. The federal 24-hour standard was not exceeded at any of the locations monitored in 2011, although Riverside County came close with a 24-hour average concentration of 152 µg/m^3 (155 µg/m^3 is needed to exceed). The revoked annual average PM10 federal standard (50 µg/m^3) was not exceeded in either the Basin or the Coachella Valley in 2011. The much more stringent state standards were exceeded in most areas of the Basin and in the Coachella Valley.

TABLE 2-7

2011 Maximum 24-hour Average PM10 Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 24-HR AVERAGE* (μG/M^3)	PERCENT OF FEDERAL STANDARD (150 μG/M^3)$^\#$	AREA
South Coast Air Basin			
Los Angeles	119	77	Central Los Angeles
Orange	79	51	Central Orange County
Riverside	152	98	Metropolitan Riverside County
San Bernardino	127	82	Central San Bernardino Valley
Salton Sea Air Basin**			
Riverside	120	77	Coachella Valley

* Based on the FRM and FEM data
** Higher concentrations were recorded for high wind events in the Coachella Valley which have been flagged for exclusion from NAAQS comparison in accordance with the U.S. EPA Exceptional Events Rule
# 155 μg/m^3 is needed to exceed the PM10 standard

TABLE 2-8

2011 Maximum Annual Average PM10 Concentrations by Basin and County

BASIN/COUNTY	ANNUAL AVERAGE* (μG/M^3)	PERCENT OF FEDERAL STANDARD** (50 μG/M^3)	AREA
South Coast Air Basin			
Los Angeles	32.7	64	East San Gabriel Valley
Orange	24.9	49	Central Orange County
Riverside	41.4	81	Metropolitan Riverside County
San Bernardino	31.8	62	Central San Bernardino Valley
Salton Sea Air Basin			
Riverside	32.6	64	Coachella Valley

* Based on the FRM and FEM data
** The federal annual PM10 standard was revoked in 2006

Ozone (O_3) Specific Information

Health Effects, O_3

The adverse effects of ozone air pollution exposure on health have been studied for many years, as is documented by a significant body of peer-reviewed scientific research, including studies conducted in southern California. The 2006 U.S. EPA document, *Air Quality Criteria for Ozone and Related Photochemical Oxidants*[10], describes these health effects and discusses the state of the scientific knowledge and research. A summary of health effects information and additional references can also be found in the 2012 AQMP, Appendix I.

Individuals exercising outdoors, children, and people with preexisting lung disease, such as asthma and chronic pulmonary lung disease, are considered to be the most susceptible sub-groups to ozone effects. Short-term exposures (lasting for a few hours) to ozone at levels typically observed in Southern California can result in breathing pattern changes, reduction of breathing capacity, increased susceptibility to infections, inflammation of the lung tissue, and some immunological changes. Elevated ozone levels are associated with increased school absences and daily hospital admission rates. An increased risk for asthma has been found in children who participate in multiple sports and live in high ozone communities.

Ozone exposure under exercising conditions is known to increase the severity of the above-mentioned observed responses. Animal studies suggest that exposures to a combination of pollutants which include ozone may be more toxic than exposure to ozone alone. Although lung volume and resistance changes observed after a single exposure diminish with repeated exposures, biochemical and cellular changes appear to persist, which can lead to subsequent lung structural changes.

Air Quality, O_3

In 2011, the District regularly monitored ozone concentrations at 29 locations in the Basin and the Coachella Valley portion of the SSAB. All areas monitored measured 1-hour average ozone levels well below the Stage 1 episode level (0.20 ppm), but the maximum concentrations measured in the Basin exceeded the health advisory level (0.15 ppm, 1-hour) in San Bernardino County. The maximum ozone concentrations in Los Angeles, Riverside and San Bernardino Counties all exceeded the former

[10] U.S. EPA. (2006). Air Quality Criteria for Ozone and Related Photochemical Oxidants (2006 Final). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/004aF-cF.

1-hour federal standard in 2011; Orange County and the Coachella Valley did not exceed that standard. Maximum ozone concentrations in the SSAB areas monitored by the District were lower than in the Basin and were below the health advisory level. All counties of the Basin and the Coachella Valley exceeded the current 8-hour ozone standard in 2011. Tables 2-9 and 2-10 show maximum 1-hour and 8-hour ozone concentrations by air basin and county.

TABLE 2-9

2011 Maximum 1-Hour Average Ozone Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 1-HR AVERAGE (PPM)	PERCENT OF FEDERAL STANDARD (0.12 PPM)	AREA
South Coast Air Basin			
Los Angeles	0.144	115	Santa Clarita Valley
Orange	0.095	76	North Orange County
Riverside	0.133	106	Lake Elsinore
San Bernardino	0.160	128	Central San Bernardino Mountains
Salton Sea Air Basin			
Riverside	0.124	99	Coachella Valley

TABLE 2-10

2011 Maximum 8-Hour Average Ozone Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 8-HR AVERAGE (PPM)	PERCENT OF FEDERAL STANDARD (0.075 PPM)	AREA
South Coast Air Basin			
Los Angeles	0.122	162	Santa Clarita Valley
Orange	0.083	110	Saddleback Valley
Riverside	0.115	152	Metropolitan Riverside County
San Bernardino	0.136	180	Central San Bernardino Mountains
Salton Sea Air Basin			
Riverside	0.098	130	Coachella Valley

The number of days exceeding federal standards for ozone in the Basin varies widely by area. Figures 2-4 and 2-5 map the number of days in 2011 exceeding the current 8-hour and former 1-hour ozone federal standards in different areas of the Basin in 2011. The former 1-hour federal standard was not exceeded in areas along or near the coast in the Counties of Los Angeles and Orange, due in large part to the prevailing sea breeze which transports emissions inland before high ozone concentrations are reached. The standard was exceeded most frequently in the Central San Bernardino Mountains. Ozone exceedances also extended through San Bernardino and Riverside County valleys in the eastern Basin, as well as the northeast and northwest portions of Los Angeles County in the foothill and valley areas. The number of exceedances of the 8-hour federal ozone standard was also lowest at the coastal areas, increasing towards the Riverside and San Bernardino valleys and the adjacent mountain areas. The Central San Bernardino Mountains area recorded the greatest number of exceedances of the 1-hour and 8-hour federal standards (8 days and 84 days, respectively) and 8-hour state standard (103 days). While the Coachella Valley did not exceed the former 1-hour ozone standard in 2011, the 2008 8-hour federal standard was exceeded on 54 days.

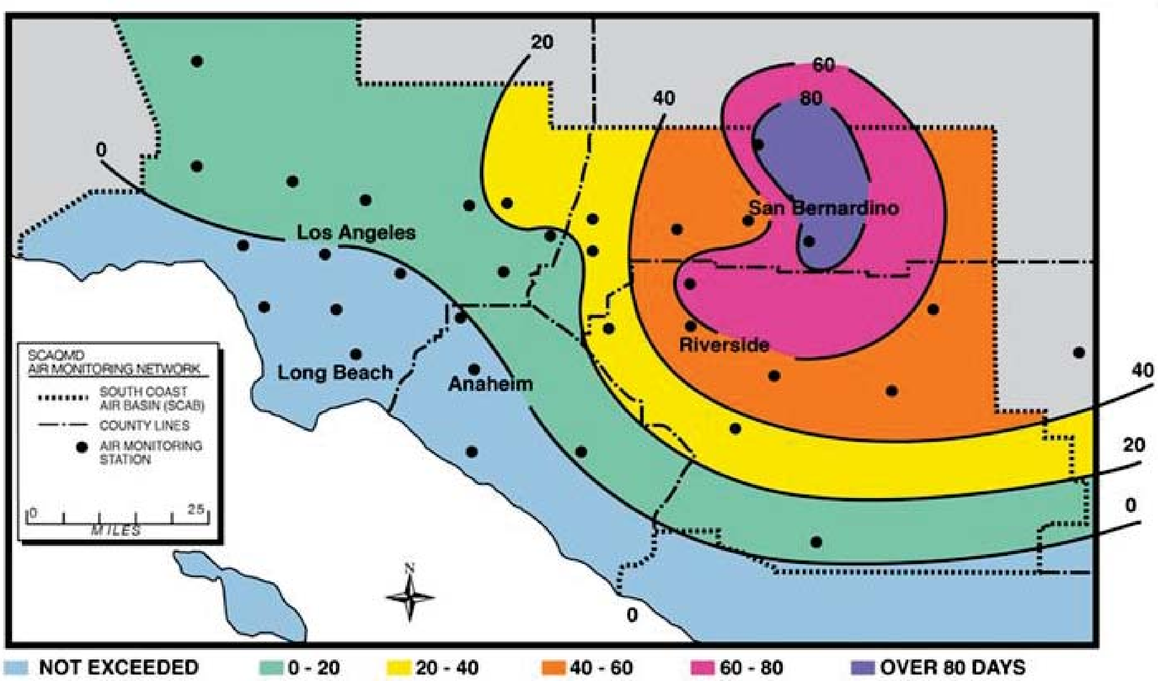


FIGURE 2-4

Number of Days in 2011 Exceeding the 2008 8-Hour Ozone Federal Standard
(8-hour average O_3 > 0.075 ppm)

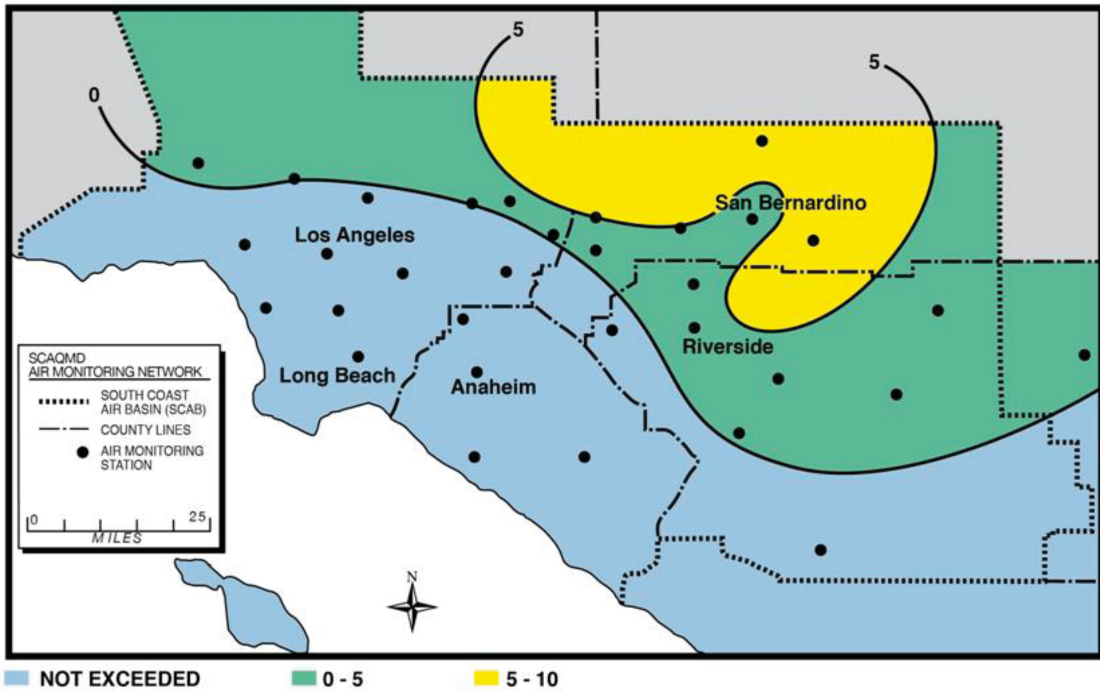


FIGURE 2-5

Number of Days in 2011 Exceeding the 1979 1-Hour Federal Ozone Standard
(1-hour average O_3 > 0.12 ppm)

Other Criteria Air Pollutants

<u>Carbon Monoxide (CO) Specific Information</u>

Health Effects, CO

The adverse effects of ambient carbon monoxide air pollution exposure on health have been recently reviewed in the 2006 U.S. EPA *Integrated Science Assessment for Carbon Monoxide.*[11] This document presents a detailed review of the available scientific studies and conclusions on the causal determination of the health effects of CO. A summary of health effects information and additional references can also be found in the 2012 AQMP, Appendix I.

Individuals with a deficient blood supply to the heart are the most susceptible to the adverse effects of CO exposure. The effects observed include earlier onset of chest

[11] U.S. EPA. (2010). Integrated Science Assessment for Carbon Monoxide (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/019F.

pain with exercise, and electrocardiograph changes indicative of worsening oxygen supply delivery to the heart.

Inhaled CO has no known direct toxic effect on the lungs, but exerts its effect on tissues by interfering with oxygen transport, by competing with oxygen to combine with hemoglobin present in the blood to form carboxyhemoglobin (COHb). Hence, people with conditions requiring an increased oxygen supply can be adversely affected by exposure to CO. Individuals most at risk include patients with diseases involving heart and blood vessels, fetuses, and patients with chronic hypoxemia (oxygen deficiency) as seen at high altitudes.

Reductions in birth weight and impaired neurobehavioral development have been observed in animals chronically exposed to CO resulting in COHb levels similar to those observed in smokers. Recent studies have found increased risks for adverse birth outcomes with exposure to elevated CO levels. These include pre-term births and heart abnormalities.

Air Quality, CO

Carbon monoxide concentrations were measured at 25 locations in the Basin and neighboring SSAB areas in 2011. Table 2-11 shows the 2011 maximum 8-hour and 1-hour average concentrations of CO by air basin and county.

In 2011, no areas exceeded the CO air quality standards. The highest concentrations of CO continued to be recorded in the areas of Los Angeles County where vehicular traffic is most dense, with the maximum 8-hour and 1-hour concentration (4.7 ppm and 6.0 ppm, respectively) recorded in the South Central Los Angeles County area. All areas of the Basin have continued to remain below the federal standard level since 2003.

TABLE 2-11

2011 Maximum 8-Hour and 1-Hour CO Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 8-HR AVERAGE (PPM)	PERCENT OF FEDERAL STANDARD (9 PPM)	MAXIMU M 1-HR AVERAGE (PPM)	PERCENT OF FEDERAL STANDARD (35 PPM)	AREA
South Coast Air Basin					
Los Angeles	4.7	49	6.0	17	South Central L.A. County
Orange	2.2	23	3.4	10	North Coastal Orange County
Riverside	1.9	20	2.7	8	Metropolitan Riverside County
San Bernardino	1.7	18	1.8	5	Central San Bernardino Valley
Salton Sea Air Basin					
Riverside	0.6	6	3.0	8	Coachella Valley

Nitrogen Dioxide (NO_2) Specific Information

Health Effects, NO_2

The adverse effects of ambient nitrogen dioxide air pollution exposure on health have been recently reviewed in the 2008 U.S. EPA *Integrated Science Assessment for Oxides of Nitrogen – Health Criteria*[12]. This document presents a detailed review of the available scientific studies and conclusions on the causal determination of the health effects of NO_2, including evidence supporting the recently adopted short-term NO_2 standard (1-hour, 100 ppb). A summary of health effects information and additional references can also be found in the 2012 AQMP, Appendix I.

Population-based studies suggest that an increase in acute respiratory illness, including infections and respiratory symptoms in children (not infants), is associated with long-term exposures to NO_2 at levels found in homes with gas stoves, which are higher than ambient concentrations found in Southern California. Increase in resistance to air flow and airway contraction is observed after short-term exposure to NO_2 in healthy subjects. Larger decreases in lung functions are observed in

[12] U.S. EPA. (2008). Integrated Science Assessment for Oxides of Nitrogen – Health Criteria (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/071.

individuals with asthma and/or chronic obstructive pulmonary disease (e.g., chronic bronchitis, emphysema) than in healthy individuals, indicating a greater susceptibility of these sub-groups. More recent studies have found associations between NO_2 exposures and cardiopulmonary mortality, decreased lung function, respiratory symptoms, and emergency room asthma visits.

In animals, exposure to levels of NO_2 that are considerably higher than ambient concentrations results in increased susceptibility to infections, possibly due to the observed changes in cells involved in maintaining immune functions. The severity of lung tissue damage associated with high levels of ozone exposure increases when animals are exposed to a combination of ozone and NO_2.

Based on the review of the NO_2 standards, U.S. EPA has established the 1-hour NO_2 standard to protect the public health against short-term exposure. The standard is set at 100 ppb 1-hour average, effective April 7, 2010.

Air Quality, NO_2

In 2011, NO_2 concentrations were monitored at 25 locations, including one in the Coachella Valley. The Basin has not exceeded the federal annual standard for NO_2 (0.0534 ppm) since 1991, when the Los Angeles County portion of the Basin recorded the last exceedance of the standard in any U.S. county. The recently established 1-hour average NO_2 standard (100 ppb), however, was exceeded on one day in 2011 (but the 98^{th} percentile form of the standard was not exceeded). The higher relative concentrations in the Los Angeles area are indicative of the concentrated emission sources, especially motor vehicles. The maximum 1-hour and annual average concentrations for 2011 are shown in Table 2-12, by basin and county.

TABLE 2-12

2011 Maximum 1-Hour and Annual Average NO_2 Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 1-HOUR AVERAGE (PPB)	PERCENT OF FEDERAL STANDARD (100 PPB)	MAXIMUM ANNUAL AVERAGE (PPB)	PERCENT OF FEDERAL STANDARD (53 PPB)	AREA
South Coast Air Basin					
Los Angeles	109.6*	109	24.6	46	Central Los Angeles County; Pomona/Walnut Valley
Orange	73.8	73	17.7	33	Central Orange County
Riverside	63.3	63	16.9	32	Metropolitan Riverside County
San Bernardino	76.4	76	21.1	39	Central San Bernardino Valley
Salton Sea Air Basin					
Riverside	44.7	44	8.0	15	Coachella Valley

* Although the maximum 1-hour concentrations exceeded the standard, the 98th percentile form of the design value did not exceed the NAAQS

Sulfur Dioxide (SO_2) Specific Information

Health Effects, SO_2

The adverse effects of SO_2 air pollution exposure on health have been recently reviewed in the 2008 U.S. EPA *Integrated Science Assessment (ISA) for Sulfur Oxides – Health Criteria*.[13] This document presents a detailed review of the available scientific studies and conclusions on the causal determination of the health effects of SO_2, including the justification to rescind the 24-hour standard and replace it with the new (2010) 1-hour standard (75 ppb). A summary of health effects information and additional references can also be found in the 2012 AQMP, Appendix I.

Individuals affected by asthma are especially sensitive to the effects of SO_2. Exposure to low levels (0.2 to 0.6 ppm) of SO_2 for a few (5-10) minutes can result in airway constriction in some exercising asthmatics. In asthmatics, increase in

[13] U.S. EPA. (2008). Integrated Science Assessment (ISA) for Sulfur Oxides – Health Criteria (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/047F.

resistance to air flow, as well as reduction in breathing capacity leading to severe breathing difficulties, are observed after acute high exposure to SO_2. In contrast, healthy individuals do not exhibit similar acute responses even after exposure to higher concentrations of SO_2.

Animal studies suggest that even though SO_2 is a respiratory irritant, it does not cause substantial lung injury at ambient concentrations. However, very high levels of exposure can cause lung edema (fluid accumulation), lung tissue damage, and sloughing off of cells lining the respiratory tract.

Some population-based studies indicate that the mortality and morbidity effects associated with fine particles show a similar association with ambient SO_2 levels. In these studies, efforts to separate the effects of SO_2 from those of fine particles have not been successful. It is not clear whether the two pollutants act synergistically or one pollutant alone is the predominant factor.

Based on the review of the SO_2 standards, U.S. EPA has established the 1-hour SO_2 standard to protect the public health against short term exposure. The 1-hour average standard is set at 75 ppb, revoking the existing annual (0.03 ppm) and 24-hour (0.14 ppm) standards, effective August 2, 2010.

Air Quality, SO_2

No exceedances of federal or state standards for sulfur dioxide occurred in 2011 at any of the seven District locations monitored. Though sulfur dioxide concentrations remain well below the standards, sulfur dioxide is a precursor to sulfate, which is a component of fine particulate matter. Maximum concentrations of sulfur dioxide for 2011 are shown in Table 2-13. Sulfur dioxide was not measured at the Coachella Valley sites in 2011. Historical measurements showed concentrations in the Coachella Valley to be well below state and federal standards and monitoring has been discontinued.

TABLE 2-13

2011 Maximum 1-Hour Average SO_2 Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 1-HR AVERAGE (PPB)	PERCENT OF FEDERAL STANDARD (75 PPB)	AREA
South Coast Air Basin			
Los Angeles	43.4	57	South Coastal LA County
Orange	7.8	10	North Coastal Orange County
Riverside	51.2	68	Metropolitan Riverside County
San Bernardino	12.4	16	Central San Bernardino Valley
Salton Sea Air Basin			
Riverside	N.D.		Coachella Valley

N.D. = No Data. Historical measurements and lack of emissions sources indicate concentrations are well below standards

Sulfates (SO_4^{2-}) Specific Information

Health Effects, SO_4^{2-}

In 2002, CARB reviewed and retained the state standard for sulfates, retaining the concentration level (25 µg/m^3) but changing the basis of the standard from a Total Suspended Particulate (TSP) measurement to a PM10 measurement. In their 2002 staff report,[14] CARB reviewed the health studies related to exposure to ambient sulfates, along with particulate matter, and found an association with mortality and the same range of morbidity effects as PM10 and PM2.5, although the associations were not as consistent as with PM10 and PM2.5. The 2009 U.S. EPA *Integrated Science Assessment for Particulate Matter*[15] also contains a review of sulfate studies. A summary of health effects information can also be found in the 2012 AQMP, Appendix I.

Most of the health effects associated with fine particles and SO_2 at ambient levels are also associated with sulfates. Thus, both mortality and morbidity effects have been observed with an increase in ambient sulfate concentrations. However, efforts to

[14] CARB. (2002). Staff Report: Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates. California Air Resources Board, Sacramento, CA. http://www.arb.ca.gov/regact/aaqspm/isor.pdf

[15] U.S. EPA. (2009). Integrated Science Assessment for Particulate Matter (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/139F.

separate the effects of sulfates from the effects of other pollutants have generally not been successful.

Clinical studies of asthmatics exposed to sulfuric acid suggest that adolescent asthmatics are possibly a subgroup susceptible to acid aerosol exposure. Animal studies suggest that acidic particles such as sulfuric acid aerosol and ammonium bisulfate are more toxic than non-acidic particles like ammonium sulfate. Whether the effects are attributable to acidity or to particles remains unresolved.

Air Quality, SO_4^{2-}

Sulfate from PM10 was measured at 22 stations in 2011, including one in the Coachella Valley. In 2011, the state PM10-sulfate standard was not exceeded anywhere in the Basin or the Coachella Valley. Maximum concentrations by air basin and county are shown in Table 2-14.

TABLE 2-14

2011 Maximum 24-Hour Average Sulfate (PM10) Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 24-HR AVERAGE (µG/M^3)	PERCENT OF STATE STANDARD (25 µG/M^3)	AREA
South Coast Air Basin			
Los Angeles	8.0	32	Central Los Angeles County
Orange	6.5	26	Central Orange County
Riverside	5.4	22	Metropolitan Riverside County
San Bernardino	6.0	24	Central San Bernardino Valley
Salton Sea Air Basin			
Riverside	5.7	23	Coachella Valley

Lead (Pb) Specific Information

Health Effects, Pb

The adverse effects of ambient lead exposures on health have been reviewed in the 2006 U.S. EPA document, *Air Quality Criteria for Lead (2006) Final Report*.[16] This document presents a detailed assessment of the available scientific studies and presents conclusions on the causal determination of the health effects of lead, including the justification to lower the federal lead standard.

Fetuses, infants, and children are more sensitive than others to the adverse effects of lead exposure. Exposure to low levels of lead can adversely affect the development and function of the central nervous system, leading to learning disorders, distractibility, inability to follow simple commands, and lower intelligence quotient. In adults, increased lead levels are associated with increased blood pressure.

Lead poisoning can cause anemia, lethargy, seizures, and death. It appears that there are no direct effects of lead on the respiratory system. Lead can be stored in the bone from early-age environmental exposure, and elevated blood lead levels can occur due to breakdown of bone tissue during pregnancy, hyperthyroidism (increased secretion of hormones from the thyroid gland), and osteoporosis (breakdown of bony tissue). Fetuses and breast-fed babies can be exposed to higher levels of lead because of previous environmental lead exposure of their mothers.

Air Quality, Pb

Based on the review of the NAAQS for lead, U.S. EPA has established a new standard of 0.15 $\mu g/m^3$ for a rolling 3-month average, effective October 15, 2008 (measured from total suspended particulates, TSP). Except for the source-specific monitoring that is now required under the new standard, there have been no violations of the lead standards at the District's regular air monitoring stations since 1982, as a result of removal of lead from gasoline. However, monitoring at two stations immediately adjacent to stationary sources of lead have recorded exceedances of the standards in localized areas of the Basin in more recent years. Table 2-15 shows the maximum 3-month rolling average concentrations recorded in 2011. In 2011, lead concentrations in the Basin exceeded the new 3-month rolling average standard (0.15 $\mu g/m^3$) at one source-specific monitoring site in Los Angeles County, located immediately downwind of a stationary lead source. The federal rolling 3-month and

[16] U.S. EPA. (2006). Air Quality Criteria for Lead (2006) Final Report. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/144aF-bF, 2006.

state 30-day standards for lead were not exceeded in any other area of the District in 2011.

TABLE 2-15

2011 Maximum 3-Month Rolling Average Lead Concentrations by Basin and County

BASIN/COUNTY	MAXIMUM 3-MONTH ROLLING AVERAGE (μG/M³)	PERCENT OF FEDERAL STANDARD (0.15 μG/M³)	AREA
South Coast Air Basin			
Los Angeles*	0.46	297	Central Los Angeles
Orange	N.D.		
Riverside	0.01	6	Metropolitan Riverside County
San Bernardino	0.01	6	Northwest San Bernardino Valley, Central San Bernardino Valley
Salton Sea Air Basin			
Riverside	N.D.		Coachella Valley

* This high lead concentration was measured at a site immediately downwind of a lead source.
N.D. = No Data. Historical measurements indicate concentrations are well below standards.

COMPARISON TO OTHER U.S. AREAS

The Basin's severe air pollution problem is a consequence of the combination of emissions from the nation's second largest urban area, mountainous terrain surrounding the Basin that traps pollutants as they are pushed inland with the sea breeze, and meteorological conditions which are adverse to the dispersion of those emissions. The average wind speed for Los Angeles is the lowest of the nation's ten largest urban areas. In addition, the summertime daily maximum mixing heights (an index of how well pollutants can be dispersed vertically in the atmosphere) in Southern California are the lowest, on average, in the U.S., due to strong temperature inversions in the lower atmosphere that effectively trap pollutants near the surface. The Southern California area is also an area with abundant sunshine, which drives the photochemical reactions which form pollutants such as ozone and a significant portion of PM2.5.

In the Basin, high concentrations of ozone are normally recorded during the late spring and summer months, when more intense sunlight drives enhanced photochemical reactions. In contrast, higher concentrations of carbon monoxide are generally recorded in late fall and winter, when nighttime radiation inversions trap the emissions at the surface. High PM10 and PM2.5 concentrations can occur throughout the year, but occur most frequently in fall and winter in the Basin. Although there are changes in emissions by season, the observed variations in pollutant concentrations are largely a result of seasonal differences in weather conditions.

Figures 2-6 and 2-7 show maximum pollutant concentrations in 2011 for the South Coast Air Basin compared to other urban areas in the U.S. and California, respectively. Maximum concentrations in all of these areas exceeded the federal 8-hour ozone standard. The annual PM2.5 standard was exceeded in the Basin and in one other California air basin (San Joaquin Valley). The 24-hour PM2.5 standard, however, was exceeded in a few of the other large U.S. urban areas and in many California air basins. The 24-hour PM10 standard was exceeded in one of the U.S. urban areas shown (Phoenix), although potential flagging of exceptional events may affect the treatment of that data. It is important to note that maximum pollutant concentrations do not necessarily indicate potential nonattainment designations, as the design values that are used for attainment status are based on the form of the standard.

Nitrogen dioxide concentrations exceeded the recently established 1-hour standard in the Basin and Phoenix (on one day each). Denver, Colorado (not shown in Figure 2-7), was the only other U.S. urban area exceeding the NO_2 standard in 2011. Sulfur dioxide concentrations were below the recently established 1-hour federal standard in the Basin and all of the urban areas shown in Figures 2-6 and 2-7. However, the SO_2 standard was exceeded in other U.S. areas, with the highest concentrations recorded in Hawaii, due to volcano emissions. The CO standards were not exceeded in the U.S. in 2011.

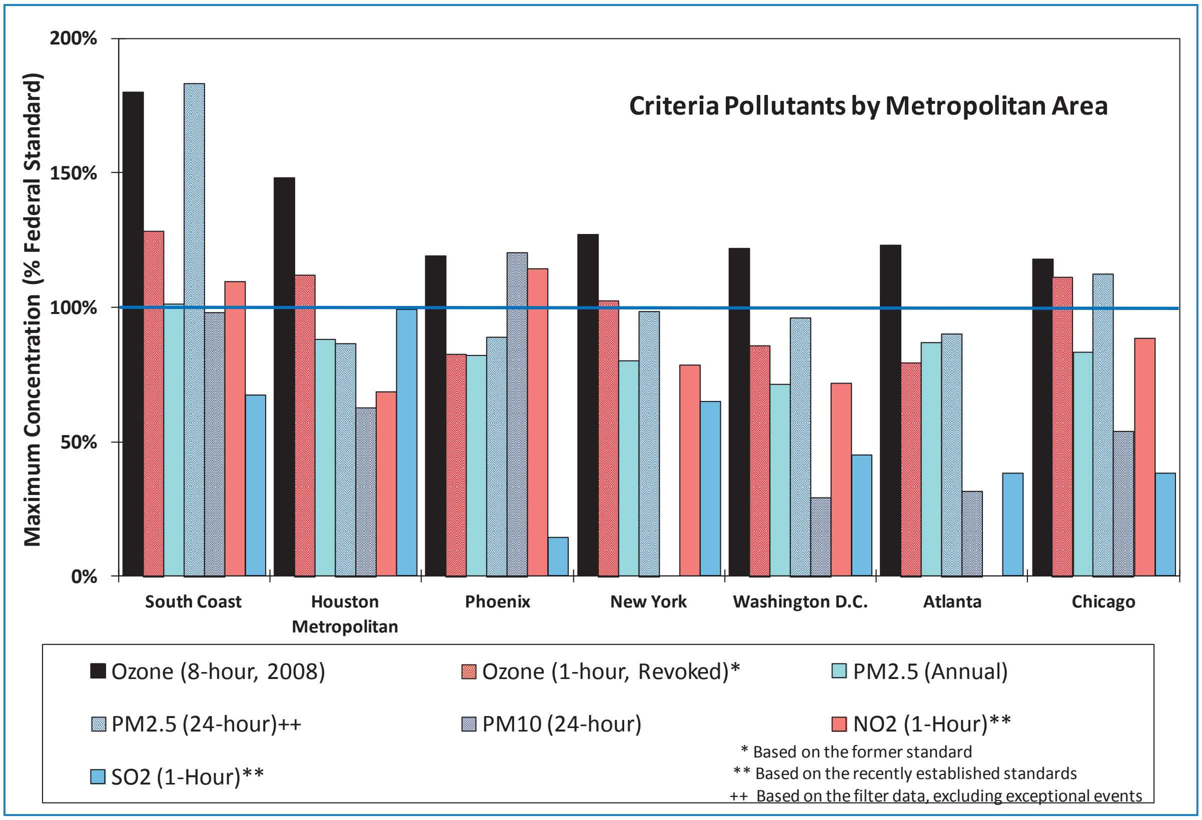


FIGURE 2-6

2011 South Coast Air Basin Air Quality Compared to Other U.S. Metropolitan Areas (Maximum Pollutant Concentrations as Percentages of Corresponding Federal Standards)

In 2011, the Central San Bernardino Mountains area in the Basin recorded the highest maximum 1-hour and 8-hour average ozone concentrations in the nation (0.160 and 0.136 ppm, respectively). The highest 8-hour average concentration was more than one and a half times the federal standard level. In 2011, seven out of ten stations with the highest maximum 8-hour average ozone concentrations in the nation were located in the Basin[17]. The South Coast Air Basin also exceeded the 8-hour ozone standard on more days (106) than most other urban areas in the country in 2011, with only California's San Joaquin Valley exceeding on more days (109).

[17] The 10 highest measured ozone concentrations in 2011 included 7 Basin stations: Central San Bernardino Mountains (Crestline), East San Bernardino Valley (Redlands), Central San Bernardino Valley (Fontana and San Bernardino), Santa Clarita Valley (Santa Clarita), Northwest San Bernardino Valley (Upland), and Metropolitan Riverside (Rubidoux).

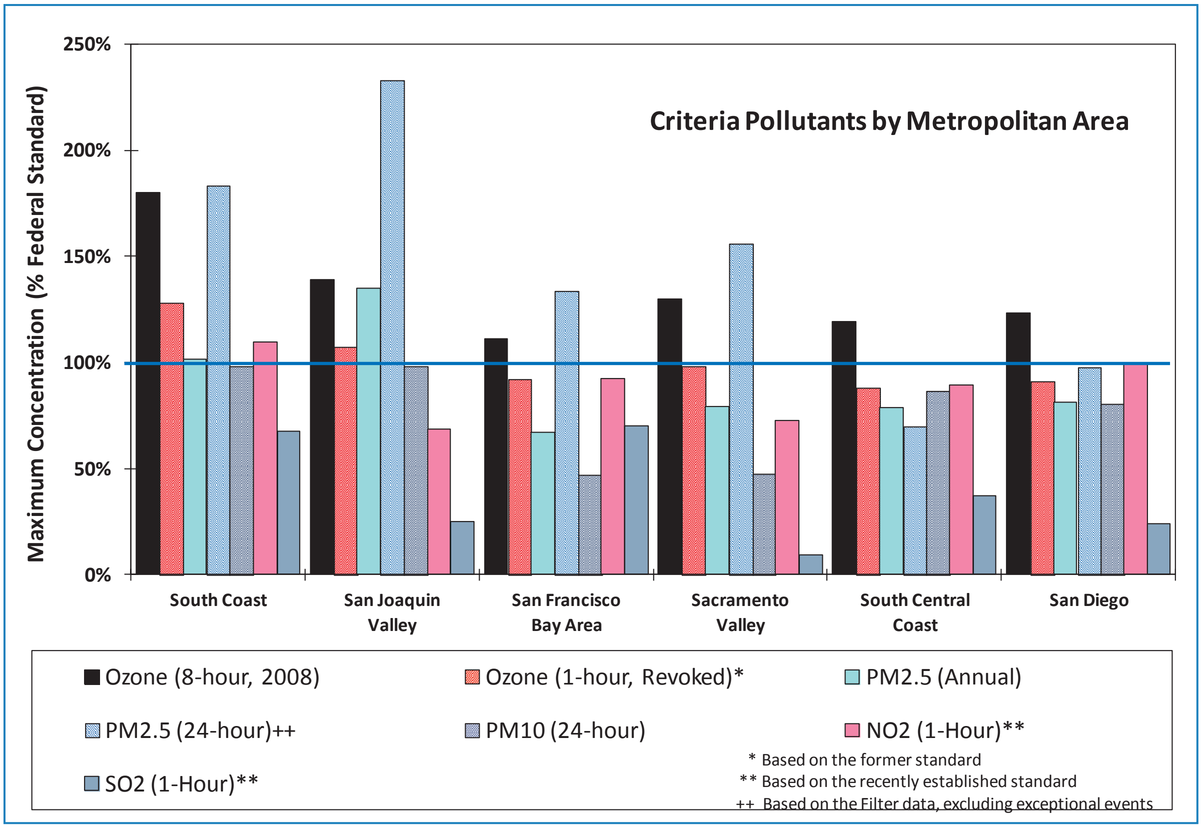


FIGURE 2-7

2011 South Coast Air Basin Air Quality Compared to Other California Air Basins (Maximum Pollutant Concentrations as Percentages of Corresponding Federal Standards)

SUMMARY

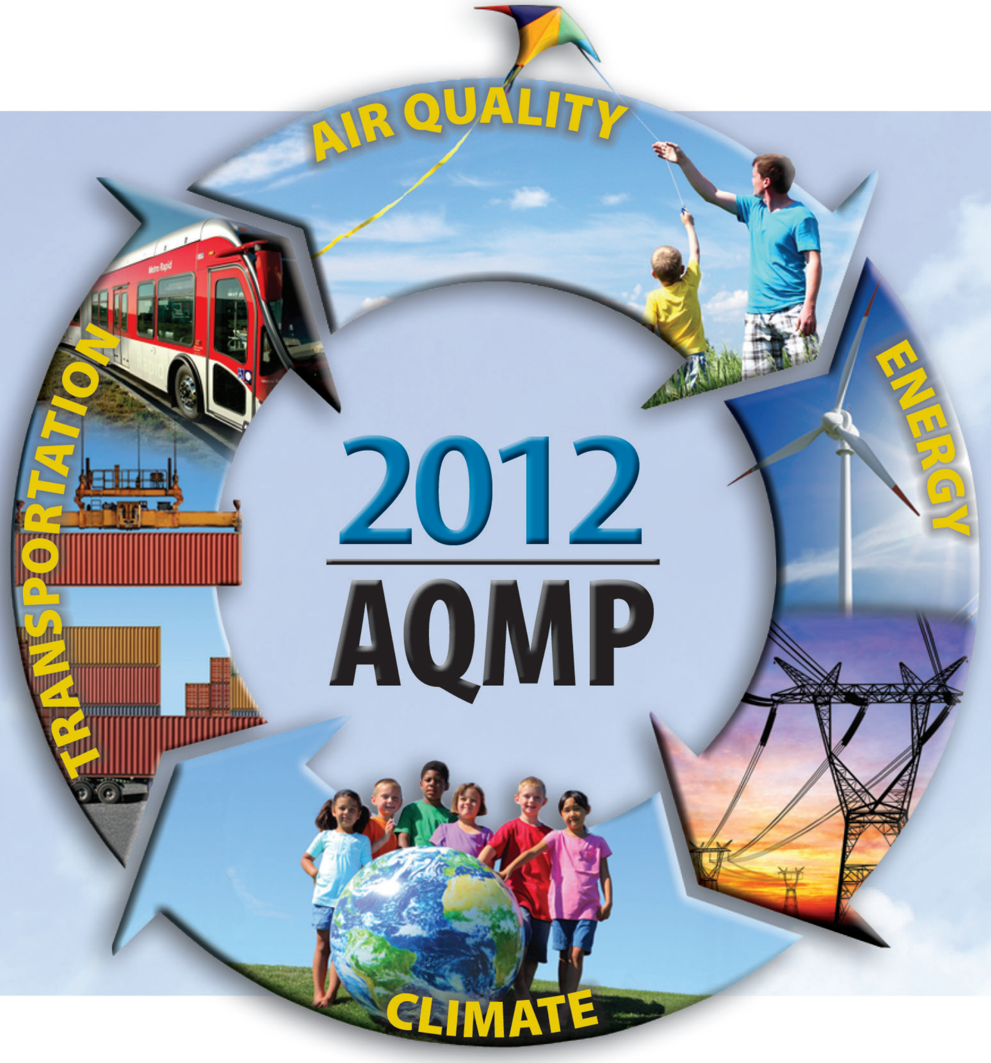
In 2011, the Basin continued to exceed federal and state standards for ozone and PM2.5. The maximum measured concentrations for these pollutants were among the highest in the country, although significant improvement has been seen in recent years for both 24-hour and annual PM2.5 concentrations and only one location in the Basin is currently exceeding the 24-hour and annual design value form of the PM2.5 federal standards. The Basin's federal 3-year design values for ozone and PM2.5 have continued to exhibit downward trends through 2011.

The Coachella Valley area in the Riverside County portion of the Salton Sea Air Basin exceeded federal and state standards for ozone and PM10. However, the high PM10 concentrations exceeding the federal 24-hour PM10 standard occurred on days influenced by high-wind natural events, which the District has flagged in the U.S. EPA AQS database so that U.S. EPA will consider excluding such data when determining the NAAQS attainment status in accordance with U.S. EPA's Exceptional Events Rule. For the stations in the Coachella Valley, the federal 3-year design values for 8-hour ozone have continued to exhibit downward trends through 2011.

The NO_2 concentrations in Los Angeles County exceeded the recently established short-term federal standard on one day at two locations, but did not exceed the standards anywhere on any other day in the Basin. The 98^{th} percentile form of the federal NO_2 standard was not exceeded and the Basin's attainment status remains intact. The Los Angeles County portion of the Basin also exceeded the 3-month rolling average Pb federal standard at one source-specific monitor adjacent to a Pb source. A separate SIP revision has been submitted to address Pb violations. Maximum concentrations for SO_2, CO, and sulfate (measured from PM10) continued to remain below the state and federal standards.

Appendix I

Air Quality Management Plan



Health Effects

February 2013

South Coast Air Quality Management District
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South Coast AQMD

TABLE I -2 (Concluded)

Weight of Evidence Descriptions for Causal Determination

DETERMINATION	WEIGHT OF EVIDENCE
Likely To Be A Causal Relationship	Evidence is sufficient to conclude that a causal relationship is likely to exist with relevant pollutant exposures, but important uncertainties remain. That is, the pollutant has been shown to result in health effects in studies in which chance and bias can be ruled out with reasonable confidence but potential issues remain. For example: a) observational studies show an association, but copollutant exposures are difficult to address and/or other lines of evidence (controlled human exposure, animal, or mode of action information) are limited or inconsistent; or b) animal toxicological evidence from multiple studies from different laboratories that demonstrate effects, but limited or no human data are available. Evidence generally includes replicated and high-quality studies by multiple investigators.
Suggestive Of A Causal Relationship	Evidence is suggestive of a causal relationship with relevant pollutant exposures, but is limited because chance, bias and confounding cannot be ruled out. For example, at least one high-quality epidemiologic study shows an association with a given health outcome but the results of other studies are inconsistent.
Inadequate To Infer A Causal Relationship	Evidence is inadequate to determine that a causal relationship exists with relevant pollutant exposures. The available studies are of insufficient quantity, quality, consistency or statistical power to permit a conclusion regarding the presence or absence of an effect.
Not Likely To Be A Causal Relationship	Evidence is suggestive of no causal relationship with relevant pollutant exposures. Several adequate studies, covering the full range of levels of exposure that human beings are known to encounter and considering susceptible populations, are mutually consistent in not showing an effect at any level of exposure.

Adapted from U.S. EPA, 2009

OZONE

Ozone is a highly reactive compound, and is a strong oxidizing agent. When ozone comes into contact with the respiratory tract, it can react with tissues and cause damage in the airways. Since it is a gas, it can penetrate into the gas exchange region of the deep lung.

The U.S. EPA primary standard for ozone, adopted in 2008, is 0.075 ppm averaged over eight hours. The California Air Resources Board (CARB) has established standards of 0.09 ppm averaged over one hour and at 0.070 ppm averaged over eight hours.

A number of population groups are potentially at increased risk for ozone exposure effects. In the ongoing review of ozone, the U.S. EPA has identified populations as having adequate evidence for increased risk from ozone exposures include individuals with asthma, younger and older age groups, individuals with reduced intake of certain nutrients such as Vitamins C and E, and outdoor workers. There is suggestive evidence for other potential factors, such as variations in genes related to oxidative metabolism or inflammation, gender, socioeconomic status, and obesity. However further evidence is needed.

The adverse effects reported with short-term ozone exposure are greater with increased activity because activity increases the breathing rate and the volume of air reaching the lungs, resulting in an increased amount of ozone reaching the lungs. Children may be a particularly vulnerable population to air pollution effects because they spend more time outdoors, are generally more active, and have a higher specific ventilation rate than adults (i.e. after normalization for body mass).

A number of adverse health effects associated with ambient ozone levels have been identified from laboratory and epidemiological studies (U.S. EPA, 1996; 2006, 2011; ATS, 1996). These include increased respiratory symptoms, damage to cells of the respiratory tract, decrease in lung function, increased susceptibility to respiratory infection, an increased risk of hospitalization, and increased risk of mortality.

Increases in ozone levels are associated with increased numbers of absences from school. The Children's Health Study, conducted by researchers at the University of Southern California, followed a cohort of children that live in 12 communities in Southern California with differing levels of air pollution for several years. A publication from this study reported that school absences in fourth graders for respiratory illnesses were positively associated with ambient ozone levels. An increase of 20 ppb ozone was associated with an 83% increase in illness-related absence rates (Gilliland, 2001).

The number of hospital admissions and emergency room visits for all respiratory causes (infections, respiratory failure, chronic bronchitis, etc.) including asthma shows a consistent increase as ambient ozone levels increase in a community. These excess hospital admissions and emergency room visits are observed when hourly ozone concentrations are as low as 0.06 to 0.10 ppm.

Numerous recent studies have found positive associations between increases in ozone levels and excess risk of mortality. These associations are strongest during warmer months but overall persist even when other variables including season and levels of particulate matter are accounted for. This indicates that ozone mortality effects may be independent of other pollutants (Bell, 2004).

Multicity studies of short-term ozone exposures (days) and mortality have also examined regional differences. Evidence was provided that there were generally higher ozone-mortality risk estimates in northeastern U.S. cities, with the southwest and urban mid-west cities showing lower or no associations (Smith, 2009; Bell, 2008). Another long-term study of a national cohort found that long-term exposures to ozone were associated with respiratory-related causes of mortality, but not cardiovascular-related causes, when PM2.5 exposure was also included in the analysis.

In the ongoing U.S. EPA review, it was concluded that there is adequate evidence for asthmatics to be a potentially at risk population (U.S. EPA, 2012c). Several population-based studies suggest that asthmatics are at risk from ambient ozone levels, as evidenced by changes in lung function, increased hospitalizations and emergency room visits.

Laboratory studies have also compared the degree of lung function change seen in age and gender-matched healthy individuals versus asthmatics and those with chronic obstructive pulmonary disease. In studies of individuals with chronic obstructive pulmonary decease, the degree of change evidenced did not differ significantly. That finding, however, may not accurately reflect the true impact of exposure on these respiration-compromised individuals. Since the respiration-compromised group may have lower lung function to begin with, the same total change may represent a substantially greater relative adverse effect overall. Other studies have found that subjects with asthma are more sensitive to the short-term effects of ozone in terms of lung function and inflammatory response.

Another publication from the Children's Health Study focused on children and outdoor exercise. In Southern California communities with high ozone concentrations, the relative risk of developing asthma in children playing three or more sports was found to be over three times higher than in children playing no sports (McConnell, 2002). These findings indicate that new cases of asthma in children may be associated with performance of heavy exercise in communities with high levels of ozone. While it has long been known that air pollution can exacerbate symptoms in individuals with preexisting respiratory disease, this is among the first studies that indicate ozone exposure may be causally linked to asthma onset.

In addition, human and animal studies involving both short-term (few hours) and long-term (months to years) exposures indicate a wide range of effects induced or associated with ambient ozone exposure. These are summarized in Table I-2.

Some lung function responses (volume and airway resistance changes) observed after a single exposure to ozone exhibit attenuation or a reduction in magnitude with repeated exposures. Although it has been argued that the observed shift in response is evidence of a probable adaptation phenomenon, it appears that while functional changes may exhibit attenuation, biochemical and cellular changes which may be associated with episodic and chronic exposure effects may not exhibit similar adaptation. That is, internal damage to the respiratory system may continue with repeated ozone exposures, even if externally observable effects (chest symptoms and reduced lung function) disappear. Additional argument against adaptation is that after several days or weeks without ozone exposures, the responsiveness in terms of lung function as well as symptoms returns.

In a laboratory, exposure of human subjects to low levels of ozone causes reversible decrease in lung function as assessed by various measures such as respiratory volumes, airway resistance and reactivity, irritative cough and chest discomfort. Lung function changes have been observed with ozone exposure as low as 0.06 to 0.12 ppm for 6-8 hours under moderate exercising conditions. Similar lung volume changes have also been observed in adults and children under ambient exposure conditions (0.10 - 0.15 ppm 1-hour average). The responses reported are indicative of decreased breathing capacity and are reversible.

TAB 3

United States
Environmental Protection
Agency

EPA 600/R-10/076F | February 2013 | www.epa.gov/ord

Integrated Science Assessment for Ozone and Related Photochemical Oxidants

Office of Research and Development
National Center for Environmental Assessment-RTP Division

U.S. Environmental Protection Agency
Research Triangle Park, NC

pose an unacceptable risk of harm, even if the risk is not precisely identified as to nature or degree. The CAA does not require the Administrator to establish a primary NAAQS at a zero-risk level or at background concentration levels, see Lead Industries v. EPA, 647 F.2d at 1156 n.51, but rather at a level that reduces risk sufficiently so as to protect public health with an adequate margin of safety.

In addressing the requirement for a margin of safety, EPA considers such factors as the nature and severity of the health effects involved, the size of the sensitive population(s) at risk, and the kind and degree of the uncertainties that must be addressed. The selection of any particular approach to providing an adequate margin of safety is a policy choice left specifically to the Administrator's judgment. See Lead Industries Association v. EPA, supra, 647 F.2d at 1161-1162; Whitman v. American Trucking Associations, 531 U.S. 457, 495 (2001).

In setting standards that are "requisite" to protect public health and welfare, as provided in Section 109(b), EPA's task is to establish standards that are neither more nor less stringent than necessary for these purposes. In so doing, EPA may not consider the costs of implementing the standards. [See generally, Whitman v. American Trucking Associations, 531 U.S. 457, 465-472, 475-76. (2001)]. Likewise, "[a]ttainability and technological feasibility are not relevant considerations in the promulgation of national ambient air quality standards." American Petroleum Institute v. Costle, 665 F. 2d at 1185.

Section 109(d)(1) requires that "not later than December 31, 1980, and at 5-year intervals thereafter, the Administrator shall complete a thorough review of the criteria published under section 108 and the national ambient air quality standards … and shall make such revisions in such criteria and standards and promulgate such new standards as may be appropriate…" Section 109(d)(2) requires that an independent scientific review committee "shall complete a review of the criteria … and the national primary and secondary ambient air quality standards … and shall recommend to the Administrator any new … standards and revisions of existing criteria and standards as may be appropriate …" Since the early 1980s, this independent review function has been performed by CASAC.

History of the NAAQS for Ozone

Tropospheric (ground-level) O_3 is the indicator for the mix of photochemical oxidants (e.g., peroxyacetyl nitrate, hydrogen peroxide) formed from biogenic and anthropogenic precursor emissions. Naturally occurring O_3 in the troposphere can result from biogenic organic precursors reacting with naturally occurring nitrogen oxides (NO_X) and by stratospheric O_3 intrusion into the troposphere. Anthropogenic precursors of O_3, especially NO_X, and volatile organic compounds (VOCs), originate from a wide variety of stationary and mobile sources. Ambient O_3 concentrations produced by these emissions are directly affected by temperature, solar radiation, wind speed, and other meteorological factors.

Table 1-1 Summary of O_3 causal determinations by exposure duration and health outcome.

Health Outcome[a]	Conclusions from 2006 O_3 AQCD	Conclusions from this ISA
Short-term Exposure to O_3		
Respiratory effects	The overall evidence supports a causal relationship between acute ambient O_3 exposures and increased respiratory morbidity outcomes.	Causal Relationship
Cardiovascular effects	The limited evidence is highly suggestive that O_3 directly and/or indirectly contributes to cardiovascular-related morbidity, but much remains to be done to more fully substantiate the association.	Likely to be a Causal Relationship
Central nervous system effects	Toxicological studies report that acute exposures to O_3 are associated with alterations in neurotransmitters, motor activity, short and long term memory, sleep patterns, and histological signs of neurodegeneration.	Suggestive of a Causal Relationship
Total Mortality	The evidence is highly suggestive that O_3 directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality.	Likely to be a Causal Relationship
Long-term Exposure to O_3		
Respiratory effects	The current evidence is suggestive but inconclusive for respiratory health effects from long-term O_3 exposure.	Likely to be a Causal Relationship
Cardiovascular effects	No conclusions in the 2006 O_3 AQCD.	Suggestive of a Causal Relationship
Reproductive and developmental effects	Limited evidence for a relationship between air pollution and birth-related health outcomes, including mortality, premature births, low birth weights, and birth defects, with little evidence being found for O_3 effects.	Suggestive of a Causal Relationship
Central nervous system effects	Evidence regarding chronic exposure and neurobehavioral effects was not available.	Suggestive of a Causal Relationship
Cancer	Little evidence for a relationship between chronic O_3 exposure and increased risk of lung cancer.	Inadequate to Infer a Causal Relationship
Total Mortality	There is little evidence to suggest a causal relationship between chronic O_3 exposure and increased risk for mortality in humans.	Suggestive of a Causal Relationship

[a]Health effects (e.g., respiratory effects, cardiovascular effects) include a spectrum of outcomes, from measureable subclinical effects (e.g., blood pressure), to more obvious effects (e.g., medication use, hospital admissions), and cause-specific mortality. Total mortality includes all-cause (non-accidental) mortality, as well as cause-specific mortality (e.g., deaths due to heart attacks).

respiratory health effects (including symptoms, new-onset asthma and mortality) combined with toxicological studies in rodents and nonhuman primates, provide biologically plausible evidence that there **is likely to be a causal relationship between long-term exposure to O_3 and respiratory effects.**

Mortality Effects

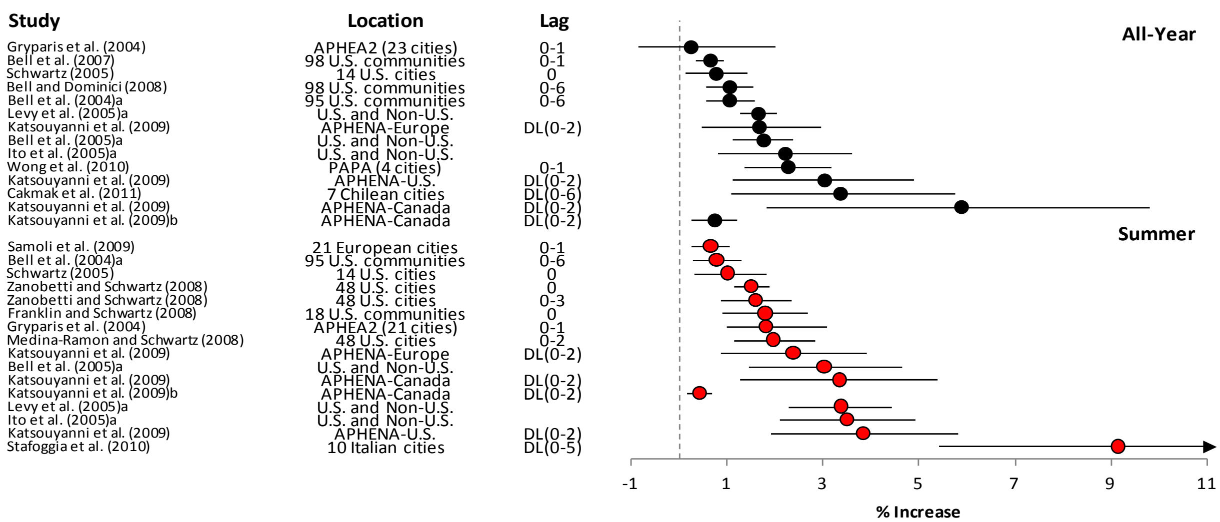
The last review concluded that the overall body of evidence was highly suggestive that short-term exposure to O_3 directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality, but that additional research was needed to more fully establish the underlying mechanisms by which such effects occur. Recent multicity studies and a multicontinent study have reported associations between short-term O_3 exposure and mortality, expanding upon evidence available in the last review (see Section 6.6). These recent studies reported consistent positive associations between short-term O_3 exposure and total (nonaccidental) mortality, with associations being stronger during the warm season, when O_3 concentrations were higher. They also observed associations between O_3 exposure and cardiovascular and respiratory mortality. These recent studies also examined previously identified areas of uncertainty in the O_3-mortality relationship, and provided additional evidence supporting an association between short-term O_3 exposure and mortality. As a result, the current body of evidence indicates that there **is likely to be a causal relationship between short-term exposures to O_3 and total mortality.**

Cardiovascular Effects

In previous O_3 reviews, very few studies were available which examined the effect of short-term O_3 exposure on the cardiovascular system. New toxicological studies, although limited in number, have provided evidence of O_3-induced cardiovascular effects. These effects may, in part, correspond to changes in the autonomic nervous system or to the development and maintenance of oxidative stress and inflammation throughout the body that resulted from inflammation in the lungs. Controlled human exposure studies also suggest cardiovascular effects in response to short-term O_3 exposure, including changes in heart rate variability and blood markers of systemic inflammation and oxidative stress, which provide some coherence with the effects observed in animal toxicology studies. Collectively, the experimental studies provide initial biological plausibility for the consistently positive associations observed in epidemiologic studies of short-term O_3 exposure and cardiovascular mortality. However, studies in the epidemiologic literature generally have not observed a relationship between short-term exposure to O_3 and cardiovascular morbidity including studies that examined the association between short-term O_3 exposure and cardiovascular-related hospital admissions and ED visits and other various cardiovascular effects. The lack of coherence between the results from studies that examined associations between short-term O_3 exposure and cardiovascular morbidity and cardiovascular mortality complicate the interpretation of the overall evidence for the O_3-mortality C-R function and whether a threshold exists; and the identification of populations at-risk to O_3-related health effects. Collectively, the 2006 O_3 AQCD concluded that “the overall body of evidence is highly suggestive that O_3 directly or indirectly contributes to non-accidental and cardiopulmonary-related mortality.”

6.6.2 Associations of Mortality and Short-Term O_3 Exposure

Recent studies that examined the association between short-term O_3 exposure and mortality further confirmed the associations reported in the 2006 O_3 AQCD. New multicontinent and multicity studies reported consistent positive associations between short-term O_3 exposure and all-cause mortality in all-year analyses, with additional evidence for larger mortality risk estimates during the warm or summer months (Figure 6-27 [and Table 6-42]). These associations were reported across a range of ambient O_3 concentrations that were in some cases quite low (Table 6-43).



Note: Effect estimates are for a 40 ppb increase in 1-h max, 30 ppb increase in 8-h max, and 20 ppb increase in 24-h avg O_3 concentrations. An “a” represent multicity studies and meta-analyses from the 2006 O_3 AQCD. Bell et al. (2005), Ito et al. (2005), and Levy et al. (2005) used a range of lag days in the meta-analysis: Lag 0, 1, 2, or average 0-1 or 1-2; single-day lags from 0 to 3; and lag 0 and 1-2; respectively. A “b” represents risk estimates from APHENA-Canada standardized to an approximate IQR of 5.1 ppb for a 1-h max increase in O_3 concentrations (see explanation in Section 6.2.7.2).

Figure 6-27 Summary of mortality risk estimates for short-term O_3 exposure and all-cause (nonaccidental) mortality from all-year and summer season analyses.

Table 6-42 Corresponding effect estimates for Figure 6-27.

Study*	Location	Lag	Avg Time	% Increase (95% CI)
All-year				
Gryparis et al. (2004)	APHEA2 (23 cities)	0-1	1-h max	0.24 (-0.86, 1.98)
Bell et al. (2007)	98 U.S. communities	0-1	24-h avg	0.64 (0.34, 0.92)
Schwartz (2005a)	14 U.S. cities	0	1-h max	0.76 (0.13, 1.40)
Bell and Dominici (2008)	98 U.S. communities	0-6	24-h avg	1.04 (0.56, 1.55)
Bell et al. (2004)[a]	95 U.S. communities	0-6	24-h avg	1.04 (0.54, 1.55)
Levy et al. (2005)[a]	U.S. and Non-U.S.	---	24-h avg	1.64 (1.25, 2.03)
Katsouyanni et al. (2009)	APHENA-europe	DL(0-2)	1-h max	1.66 (0.47, 2.94)
Bell et al. (2005)[a]	U.S. and Non-U.S.	---	24-h avg	1.75 (1.10, 2.37)
Ito et al. (2005)[a]	U.S. and Non-U.S.	---	24-h avg	2.20 (0.80, 3.60)
Wong et al. (2010)	PAPA (4 cities)	0-1	8-h avg	2.26 (1.36, 3.16)
Katsouyanni et al. (2009)	APHENA-U.S.	DL(0-2)	1-h max	3.02 (1.10, 4.89)
Cakmak et al. (2011)	7 Chilean cities	DL(0-6)	8-h max	3.35 (1.07, 5.75)
Katsouyanni et al. (2009)	APHENA-Canada	DL(0-2)	1-h max	5.87 (1.82, 9.81)
Katsouyanni et al. (2009)[b]	APHENA-Canada	DL(0-2)	1-h max	0.73 (0.23, 1.20)
Summer				
Samoli et al. (2009)	21 European cities	0-1	8-h max	0.66 (0.24, 1.05)
Bell et al. (2004)[a]	95 U.S. communities	0-6	24-h avg	0.78 (0.26, 1.30)
Schwartz (2005a)	14 U.S. cities	0	1-h max	1.00 (0.30, 1.80)
Zanobetti and Schwartz (2008a)	48 U.S. cities	0	8-h max	1.51 (1.14, 1.87)
Zanobetti and Schwartz (2008b)	48 U.S. cities	0-3	8-h max	1.60 (0.84, 2.33)
Franklin and Schwartz (2008)	18 U.S. communities	0	24-h avg	1.79 (0.90, 2.68)
Gryparis et al. (2004)	APHEA2 (21 cities)	0-1	8-h max	1.80 (0.99, 3.06)
Medina-Ramón and Schwartz (2008)	48 U.S. cities	0-2	8-h max	1.96 (1.14, 2.82)
Katsouyanni et al. (2009)	APHENA-europe	DL(0-2)	1-h max	2.38 (0.87, 3.91)
Bell et al. (2005)[a]	U.S. and Non-U.S.	---	24-h avg	3.02 (1.45, 4.63)
Katsouyanni et al. (2009)	APHENA-Canada	DL(0-2)	1-h max	3.34 (1.26, 5.38)
Katsouyanni et al. (2009)	APHENA-Canada	DL(0-2)	1-h max	0.42 (0.16, 0.67)
Levy et al. (2005)[a]	U.S. and Non-U.S.	---	24-h avg	3.38 (2.27, 4.42)
Ito et al. (2005)[a]	U.S. and Non-U.S.	---	24-h avg	3.50 (2.10, 4.90)
Katsouyanni et al. (2009)	APHENA-U.S.	DL(0-2)	1-h max	3.83 (1.90, 5.79)
Stafoggia et al. (2010)	10 Italian cities	DL(0-5)	8-h max	9.15 (5.41, 13.0)

*Studies included from Figure 6-27.

[a]Multicity studies and meta-analyses from the 2006 O_3 AQCD. Bell et al. (2005)[a], Ito et al. (2005)[a], and Levy et al. (2005)[a] used a range of lag days in the meta-analysis: Lag 0, 1, 2, or average 0-1 or 1-2; Single-day lags from 0-3; and Lag 0 and 1-2; respectively.

[b]Risk estimates from APHENA-Canada standardized to an approximate IQR of 5.1 ppb for a 1-h max increase in O_3 concentrations (see explanation in Section 6.2.7.2).

TAB 4

May 2016

Mobile Source Strategy

California Environmental Protection Agency
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process. These efforts will be predicated on early and sustained action. Regulatory approaches will help drive the introduction of cleaner technologies, fuels, and fueling infrastructure. Due to the magnitude of emission reductions needed to meet our air quality and climate goals, the natural fleet turnover rate and the current pace of market development for zero and near-zero technologies will not be sufficient to meet California's needs. Therefore, additional funding mechanisms, partnerships, research and demonstration projects, and other innovative strategies will be needed to incentivize accelerated deployment.

Successful approaches and strategies must consider the economics of individual sectors and begin to build an environmental and business case that encourages and supports adoption of these technologies and mechanisms. It will also require partnerships with the private sector and across all levels of government to secure the needed funding and resources, put enabling policies in place, and continue to spur technology innovation as ARB continues to build on California's successful legacy of innovative environmental and public health policies.

Advanced Transportation Technologies and Efficiency Improvements

Beyond the approaches described above, other technology innovations and policies provide opportunities for further transformation. Additional gains in passenger transportation efficiencies can be achieved by developing sustainable communities that feature a range of mobility choices, including easy and equitable access to public transit, active transportation, and improved public transit and rail service utilizing zero and near-zero emission technologies. SB 375[8], the Sustainable Communities and Climate Protection Act, is one key mechanism to move toward more efficient land use and to promote alternative modes of transportation. Local actions and leadership in planning and building more sustainable and livable communities will be critical.

Autonomous and connected vehicles and new approaches to personal mobility also represent an opportunity to fundamentally transform the transportation system and, if done correctly, substantially reduce emissions. Many new vehicles are now equipped with automated features for certain driving conditions, such as parking assist, adaptive cruise control, and automatic braking technology. The technology is maturing rapidly and several automakers are planning on the capability of a fully autonomous vehicle for sale by 2020. Part of this effort includes development of "vehicle-to-vehicle" or "connected vehicle" technology and software systems to communicate vehicle data and conditions of the surrounding driving environment. The potential for improvements in both speed and efficiency, from fewer stop-start cycles to more free-flowing traffic, as well as incorporating zero and near-zero emission technologies could be significant, and the heavy-duty truck and freight facility applications for these technologies also show great promise. Automated vehicles are a natural platform for zero-emission technologies. ARB has initiated efforts to understand what policies and programs are

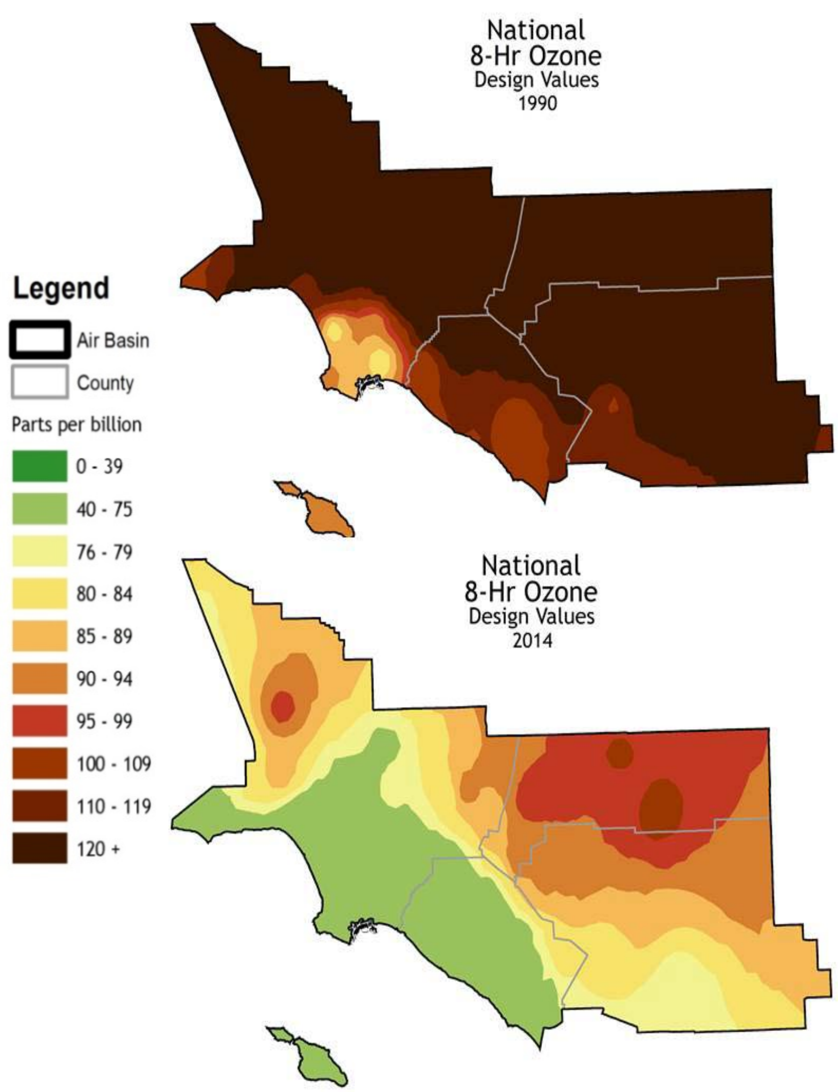
[8] Sustainable Communities http://www.arb.ca.gov/cc/sb375/sb375.htm

exacerbation of chronic heart and lung diseases, and other serious health impacts. Governor Brown has also set ambitious climate change goals that include GHG emission reduction targets of 40 percent below 1990 levels by 2030 and reducing petroleum use up to 50 percent by 2030. At the same time, we must continue efforts to minimize near-source risk and exposure to toxic air contaminants. As illustrated in Figure 2, mobile sources and the fuels that power them contribute over 80 percent of smog forming NOx emissions, over 90 percent of the diesel PM emissions, and nearly 50 percent of Statewide GHG emissions. Efforts to reduce pollution and fossil fuel use in mobile sources will therefore be essential in creating a future transportation system that provides the foundation for meeting California's goals.

Air Quality Standards

California has made significant progress in improving air quality through existing State and local air district control programs. Figure 3 illustrates the progress that has occurred since 1990 in the South Coast, the region with the highest ozone levels in the State. Twenty-five years ago the entire South Coast region violated the current 8-hour ozone standard of 75 ppb. Today, concentrations have declined 45 percent, and 40 percent of the population lives in communities that meet the standard. Nonetheless, the South Coast still has the highest ozone levels in the nation while the San Joaquin Valley has the greatest PM2.5 challenge.

Figure 3: South Coast Ozone Progress since 1990



Statewide, about 12 million Californians live in communities that exceed the federal ozone and PM2.5 standards. The health and economic impacts of exposure to elevated levels of ozone and PM2.5 in California are considerable; meeting air quality standards will pay substantial dividends in terms of reducing costs associated with emergency room visits and hospitalization, lost work and school days, and most critically, premature mortality.

Statewide Air Quality Needs

Sixteen areas in California are designated as nonattainment for the 75 ppb 8-hour ozone standard. Six areas that were originally designated nonattainment now meet the standard, with several additional areas poised to reach the standard within the next several years. Ozone nonattainment areas are classified according to the severity of their air pollution problem, and areas with higher pollution levels are given more time to meet the standard (attainment date). The South Coast and San Joaquin Valley are the only two extreme areas in the nation, with an attainment deadline of 2031. SIPs for meeting the 75 ppb ozone standard are due to U.S. EPA in 2016.

Four areas in California are designated as nonattainment for the 12 $\mu g/m^3$ annual PM2.5 standard. These areas include the South Coast and the San Joaquin Valley, as well as the border region of Imperial County and the City of Portola in Plumas County. While the PM2.5 challenges in the South Coast and the San Joaquin Valley are regional in nature, the Imperial County and Portola nonattainment areas reflect unique local conditions related to cross-border transport and wood smoke impacts, respectively. Separate, tailored control programs will be necessary for these two areas. SIPs for the 12 $\mu g/m^3$ annual PM2.5 standard are due in October 2016, and attainment dates range from 2021 to 2025.

Additionally, the South Coast and San Joaquin Valley must also continue to address progress towards attainment of earlier standards that they have not yet achieved, including the 8-hour ozone standard of 80 ppb, and the 24-hour PM2.5 standard of 35 $\mu g/m^3$.

Most recently, U.S. EPA finalized a more stringent 70 ppb ozone standard in October 2015. This more protective ozone standard will result in a number of additional nonattainment areas in the more rural regions of California, as well as require further emission reductions in California's existing nonattainment areas. SIPs for this standard will be due in 2021, with attainment dates through 2037. The progression of greater health protection in federal standards underscores the ongoing need for continuing transformation in the transportation sector.

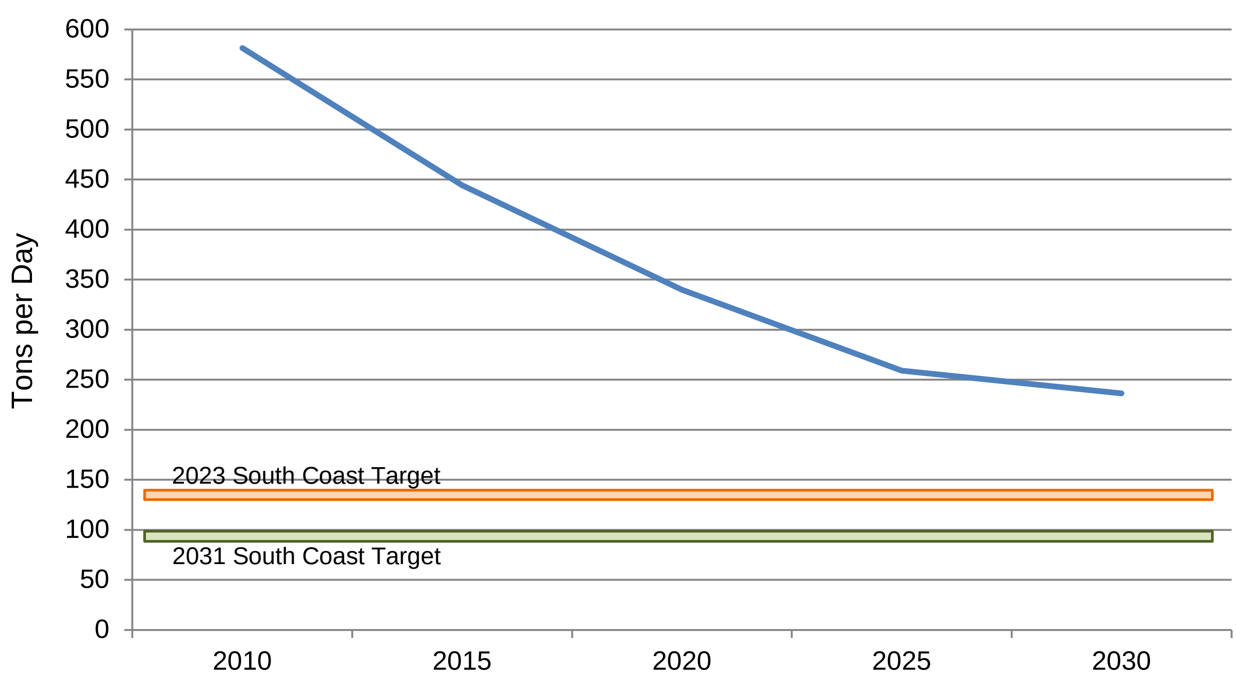
Air quality modeling is used to define the extent of emission reductions required to meet a standard by the attainment deadline. Based on this modeling, the existing control program will provide the reductions needed to bring almost all areas of the State into attainment of the ozone and PM2.5 standards. The key remaining challenges are meeting ozone standards in the South Coast, and PM2.5 standards in the San Joaquin Valley. The scope and timing of emission reductions required to meet air quality standards in these two regions are therefore key drivers for the development of the mobile source strategy.

South Coast Attainment Needs

Figure 4 illustrates the NOx emission levels in the South Coast over time, and shows that existing ARB and district control programs are projected to reduce NOx emissions by over 50 percent between 2015 and 2031. These programs will also result in significant reductions in PM2.5, as well as diesel particulate matter (diesel PM). ARB and the South Coast have been collaborating on modeling to provide estimates of the reductions necessary to meet the ozone and PM2.5 standards. Similar to ozone, PM2.5 air quality has been showing steady improvement. Annual average concentrations have been cut in half since 2001, and the region met the prior annual standard of 15 ug/m3 in 2013. Ongoing NOx reductions to reduce regional PM2.5 concentrations, coupled with targeted controls focused on the remaining area of nonattainment in Riverside are expected to bring the entire South Coast region into attainment by 2025.

Meeting the ozone standards will therefore drive overall emission reduction needs, and substantial reductions beyond those being achieved with the current control program will be needed to meet standards in 2023 and 2031. Current modeling indicates NOx emissions will need to decline to approximately 130 tons per day (tpd) in 2023, and 90 tpd in 2031 to provide for attainment in the remaining portions of the South Coast Air Basin that do not yet meet the standards. Reaching these levels will require an approximate 70 percent reduction from today's levels by 2023, and an overall 80 percent reduction by 2031. Achieving this magnitude of reductions will require

Figure 4: South Coast NOx Emission Trends



programs provide a trajectory that would meet the in-use NOx targets over time.

For heavy-duty trucks, current programs reduce in-use NOx emission rates by nearly 70 percent by 2031. The significant drop in emission rates through 2023 reflects new engine standards, implementation of the Truck and Bus Regulation, and incentive funding to further accelerate turnover. However, the pace of emission reductions from existing control programs in the heavy-duty sector flattens after 2023, and is never projected to reach the 2031 target. This demonstrates that although current programs achieve substantial reductions, in-use fleet emissions must continue to decrease and at a more rapid pace in order to meet ozone attainment needs. To achieve the incremental reduction between in-use emissions and the target requires a substantially cleaner technology introduced early enough to have sufficient time to penetrate the fleet. Analysis shows that a path to achieving these reductions will require establishing a low-NOx performance level that is 90 percent cleaner than today's technology.

While not pictured, NOx emissions from off-road sources such as construction and industrial equipment are projected to decrease approximately 45 percent by 2031 as a result of ARB programs to establish more stringent engine standards, in-use fleet rules, idling limits, and increasing electrification of smaller equipment. However, although engine standards have become more stringent over time, overall NOx emissions from sources that are primarily regulated by the federal government, such as ocean going vessels, aircraft, and locomotives, have not kept pace with reductions in other sectors, and are only projected to decrease by approximately 20 percent. Thus significant further progress is needed to reach similar emission reduction targets as those for on-road sources.

As shown in Figure 9, diesel PM emissions also continue to decrease significantly as a result of regulations associated with implementation of ARB's Diesel Risk Reduction Program. These efforts are reducing both regional and near-source risk. However, additional reductions are needed to reach the target established in the risk reduction plan.

The existing suite of clean vehicle, fuel and transportation policies that comprise current control programs are also anticipated to put California on track to meet the 2020 GHG target, with a further 20 percent reduction in on-road mobile source GHG emissions between 2020 and 2030, as illustrated in Figure 10. However, further reductions are needed to meet the 2030 GHG reduction target. In addition, beyond 2035, on-road GHG emissions begin to increase without adoption of additional policies as growth in VMT outpaces vehicle fuel efficiency improvements

Measures in each sector reflect the maturity of current control programs as well as the nature of further technology deployment needed. For light-duty vehicles, the need to significantly increase the penetration of current ZEV technology and encourage advancements in battery range, hydrogen technology and fueling infrastructure will be implemented through the Advanced Clean Cars 2 measure, along with an ongoing in-use performance assessment and incentive funding to expand the deployment of cleaner vehicles.

In the heavy-duty sector, while ARB's current Truck and Bus Regulation is ensuring that the fleet consists of the cleanest engines currently available, the scenario analysis demonstrated that combined ARB and federal action to develop a more stringent low-NOx engine standard will be necessary to move towards even cleaner combustion technologies. Parallel measures will require deployment of zero-emission and cleaner combustion technologies in initial applications such as last mile delivery and urban transit buses. Finally, given the long lifetime of heavy-duty trucks, further incentive funding will be critical to achieve greater fleet turnover, especially within the 2023 time frame.

Similar actions will be necessary in the off-road sector, with a focus on further federal and international actions to reduce emissions from these sources which, without further action, become an increasing portion of the emission inventory. Measures include a petition for new national Tier 5 emissions standards and cleaner remanufacture requirements for locomotives, as well as advocacy for international Tier 4 vessel standards. The remaining off-road equipment categories provide an opportunity to introduce zero and near-zero advanced emission technologies, with measures to initially deploy zero-emission technologies for sources such as forklifts, transport refrigeration units, and airport ground support equipment, with continued evaluation of technology transfer of cleaner on-road technologies to heavier off-road categories.

Coupled with these efforts is a measure to adopt a low-emission diesel requirement to ensure further reductions from vehicles and equipment still using combustion technologies.

Due to the severity of the South Coast's ozone challenge, each source sector also includes a measure that reflects the further deployment of cleaner technologies described in Chapter 3 needed for ozone attainment. The specific combination of approaches to achieve reductions under the further deployment measures will vary by source sector and the timing of needed reductions. ARB and South Coast staff have collaborated on developing an illustrative pathway for each sector, outlining the scope of cleaner technology required as well as a suite of implementation tools and recommended actions to be implemented by ARB, the South Coast, and U.S. EPA. These pathways are described as part of the measure write-ups contained in Chapters 6 through 10. These measures will also facilitate the broader transformation to cleaner technologies throughout the State.

Table 3 summarizes the core set of measures that will drive technology development and deployment, as well as provide the reductions necessary for ozone attainment in the South Coast. The table includes the implementing agency, the date by which

Regional Emission Reductions from Proposed Measures

In addition to providing significant benefits Statewide, Tables 5 and 6 show the regional reductions of criteria pollutants that will be incorporated into local attainment plans for the South Coast and the San Joaquin Valley. The emission reduction commitments for these two areas are further described in the State SIP Strategy.

South Coast Emission Reductions

The measures included for the South Coast, in conjunction with the existing control program, identify all of the reductions needed to achieve a 70 percent reduction in NOx emissions from mobile sources by 2023, and an 80 percent reduction by 2031. Approximately 80 percent of the reductions needed to meet the ozone standard in 2031 will come from regulatory actions associated with ongoing implementation of the existing control program and incentive programs, combined with new regulatory measures identified in the mobile source strategy. The remaining 20 percent will come from additional actions to enhance the deployment of these cleaner technologies through new incentive funding, efficiency improvements in moving people and freight, and support for the use of advanced transportation technologies such as intelligent transportation systems and autonomous vehicles. Together with the existing program, the actions called for in the strategy are designed to achieve 305 tons per day of NOx reductions by 2031. These measures also provide PM2.5 and ROG reductions. The anticipated emission reductions in the South Coast from the proposed strategy measures are summarized in Table 5.

San Joaquin Valley Emission Reductions

Air quality modeling has demonstrated that the substantial reductions from implementation of the existing mobile source control program will provide for attainment of both the 80 ppb ozone standard in 2023, and the 75 ppb ozone standard in 2031. These programs will reduce NOx emissions in the Valley by 134 tpd between 2015 and 2031. The new measures identified in this document will provide additional NOx reductions to enhance air quality progress. The anticipated NOx emission reductions in the Valley from the proposed strategy measures are summarized in Table 6.

Table 5: South Coast Expected Emission Reductions
Emission reductions in tons per day (tpd) from current levels

Proposed Measure	2031			2023
	NOx	ROG	PM2.5	NOx
On-Road Light-Duty				
Reductions from Current Control Program	62	65	0.3	48
Advanced Clean Cars 2	0.6	0.3	<0.1	--
Lower In-Use Emission Performance Assessment	NYQ	NYQ	NYQ	NYQ
Further Deployment of Cleaner Technologies	5	16	0.1	7
Total Category Reductions	**68**	**81**	**0.4**	**55**
On-Road Heavy-Duty				
Reductions from Current Control Program	94	8	1	86
Lower In-Use Emission Performance Level	NYQ	NYQ	NYQ	NYQ
Low-NOx Engine Standard – California Action	5	--	--	--
Low-NOx Engine Standard – Federal Action	7	--	--	--
Medium and Heavy-Duty GHG Phase 2	NYQ	NYQ	NYQ	NYQ
Advanced Clean Transit	0.1	<0.1	<0.1	<0.1
Last Mile Delivery	0.4	<0.1	<0.1	<0.1
Innovative Technology Certification Flexibility	NYQ	NYQ	NYQ	NYQ
Zero-Emission Airport Shuttle Buses	NYQ	NYQ	NYQ	NYQ
Incentive Funding to Achieve Further Emission Reductions from On-Road Heavy-Duty Vehicles	3	0.4	--	3
Further Deployment of Cleaner Technologies	11	1	--	34
Total Category Reductions	**121**	**10**	**1**	**123**
Off-Road Federal and International Sources*				
Reductions from Current Control Program	12	-3	-0.6	7
More Stringent National Locomotive Emission Standards	8	0.3	0.1	0.7
Tier 4 Vessel Standards	4	--	--	--
Incentivize Low-Emission Efficient Ship Visits	NYQ	NYQ	NYQ	NYQ
At-Berth Regulation Amendments	1	<0.1	<0.1	0.3
Further Deployment of Cleaner Technologies	30	0.4	NYQ	40
Total Category Reductions	**56**	**-3**	**-0.5**	**48**
Off-Road Equipment				
Reductions from Current Control Program	40	24	2	27
Zero-Emission Off-Road Forklift Regulation Phase 1	1	0.1	<0.1	--
Zero-Emission Off-Road Emission Reduction Assessment	NYQ	NYQ	NYQ	NYQ
Zero-Emission Off-Road Worksite Emission Reduction Assessment	NYQ	NYQ	NYQ	NYQ
Zero-Emission Airport Ground Support Equipment	<0.1	<0.1	<0.1	<0.1
Small Off-Road Engines	2	16	<0.1	0.7
Transport Refrigeration Units Used for Cold Storage	NYQ	NYQ	NYQ	NYQ
Low-Emission Diesel Requirement	2	NYQ	0.2	0.6
Further Deployment of Cleaner Technologies	17	20	NYQ	21
Total Category Reductions	**61**	**60**	**3**	**50**
Total Expected Emission Reductions	**305**	**148**	**4**	**275**

* Quantification of emission reductions are based on current growth forecasts, which are undergoing review.
"NYQ" denotes emission reductions are Not Yet Quantified
"—" denotes no anticipated reductions

on-road heavy-duty sector on multiple fronts: cleaner internal combustion engines, renewable fuels, and advanced technology. A low-NOx natural gas engine, the Cummins 8.9 liter natural gas engine, has already been certified to the optional 0.02 g/bhp-hr standard which is 90 percent below the current NOx standard. In addition, the Cummins 6.7 liter natural gas engine has been certified to the optional 0.10 g/bhp-hr NOx standard, which is 50 percent below the current standard. Both engines are expected to be commercially available in 2016. Cummins was able to achieve high levels of NOx emission reductions while simultaneously meeting the 2017 heavy-duty GHG standards with improved catalysts, improved air/fuel ratio controls, and closed crankcase ventilation system, demonstrating the technological ability of the industry to simultaneously achieve significant reductions in both NOx and GHG emissions. Other engine sizes meeting the optional NOx standards are expected within the next several years.

The optional NOx standard is paving the way for future mandatory requirements for California and federal trucks that have 90-percent lower NOx emissions in-use than today's required engines. Assuming the Low-NOx Engine Standard measure begins phase-in in 2024, 45 percent of the annual heavy-duty truck population in 2031 would be trucks meeting the new low-NOx engine standard, equating to approximately one million trucks statewide. A low-NOx pathway will provide broad health benefits at both the regional and community level. Exposure to PM2.5 and ozone are associated with premature death, increased hospitalizations and emergency room visits for exacerbation of chronic heart and lung diseases, and other serious health impacts. The available evidence indicates that PM2.5 is responsible for the largest share of the air pollution-related health burden and that all PM2.5 sources—both those that directly emit PM and those that lead to the formation of secondary constituents such as nitrates, sulfates, and organics—have similar potency on a mass basis. Nitrates formed from NOx emissions are the largest constituent of PM2.5, representing about half of the total particle mass. Therefore, large-scale deployment over the next 15 years of low-NOx heavy-duty engines for ozone and PM2.5 attainment, combined with particulate filters to reduce direct particle emissions, will provide the largest health benefit of any single new strategy.

To meet the 2030 GHG emissions and petroleum reductions targets statewide, low-NOx trucks will need to use renewable fuels. Low Carbon Fuel Standard (LCFS) credits, together with federal Renewable Fuels Standard RIN credits, are helping incentivize the use of renewable natural gas and renewable diesel. At the same time, near-term focused electrification and progress toward zero emission is critical to address the remaining localized risks of cancer and other adverse effects near major freight hubs, and must also play a growing role in reducing GHG emissions and petroleum use.

The Last Mile Delivery and Advanced Clean Transit measures included in the Mobile Source Strategy provide the foundation for initial deployment of zero emission vehicles in the heavy-duty truck sector. ARB is optimistic that the potential for zero emission technologies can continue to expand in the long term, especially in certain vocational classes and fleets that are under California regulatory authority. Continued growth in heavy-duty zero emission vehicles can also provide greater flexibility for use of renewable fuels in other applications. ARB therefore examined an additional scenario with zero emission sales assumptions for heavy-duty trucks that went beyond those included in the *Cleaner Technologies and Fuels* scenario described in Chapter 3. This scenario reflected expansion of zero emission technologies to light heavy-duty trucks, use of zero emission technologies in drayage trucks, as well as continued growth in last mile delivery sales post-2030. While continued technology development is needed for the largest class 7 and 8 trucks, and infrastructure requirements will limit applicability for interstate fleets, the scenario also assumed a small amount of zero emission vehicle deployment for in-state class 7 and 8 trucks beginning in 2030.

The sales assumptions for California fleets in the expanded zero emission scenario are shown in Tables 7 through 9. For last mile delivery and other light truck applications the scenario assumes zero emission vehicles would comprise 12 to 15 percent of sales by 2030, and reach approximately one third of all sales by 2050. Introduction of zero emission technology in the heavier class 7 and 8 vehicles would begin first with transit buses and port trucks. Today's zero emission port truck demonstration fleet would grow to approximately 3,000 vehicles by 2033, with continued growth through 2050. From 2030 on, sales of zero emission vehicles in other class 7 and 8 applications would begin, growing to 10 percent of sales by 2050.

California efforts to establish requirements for these key vocational applications would result in a growing population of zero emission trucks in the State. As shown in Figures 16 and 17, by 2030, approximately 38,000 lighter duty class 2B and last mile delivery zero emission trucks would be on the road, increasing to 260,000 by 2050. This would represent approximately 20 percent of the in-state light truck fleet in 2050. While the population of larger class 7 and 8 zero-emission trucks would remain small, their population would reach over 20,000 by 2050. These efforts would provide strong market signals for further development, and establish a framework for other jurisdictions to follow.

Achieving expanded deployment of zero emission vehicles fueled with renewable electricity or renewable hydrogen will require continued investments in technology development and demonstration. ARB is working with federal, State and local partners to foster these efforts. The development of heavy-duty zero emission technologies also yields dividends in improved performance at lower costs. Today, battery electric and fuel cell buses are in the early commercialization phase, with transit agencies deploying a growing number of buses. Currently there are 80 zero-emission buses in service in California, with more than 100 additional zero-emission buses on order. Commercial deployment and demonstrations are in progress across the State in an array of additional heavy-duty applications, including drayage trucks, delivery trucks, and school buses. Over 300 light-heavy-duty battery electric trucks are currently in service in California (with gross vehicle weight between 8,501 and 14,000 pounds). State incentives are in place that are encouraging the development and adoption of these technologies, increasing production volumes, fostering innovation, and reducing costs. For example, ARB recently provided a $24 million grant to the South Coast Air Quality Management District for a statewide demonstration project for zero-emission drayage trucks.

Figure 16: Population of In-State Class 2B and Last Mile Delivery Trucks

Under *Expanded Zero-Emission* Scenario

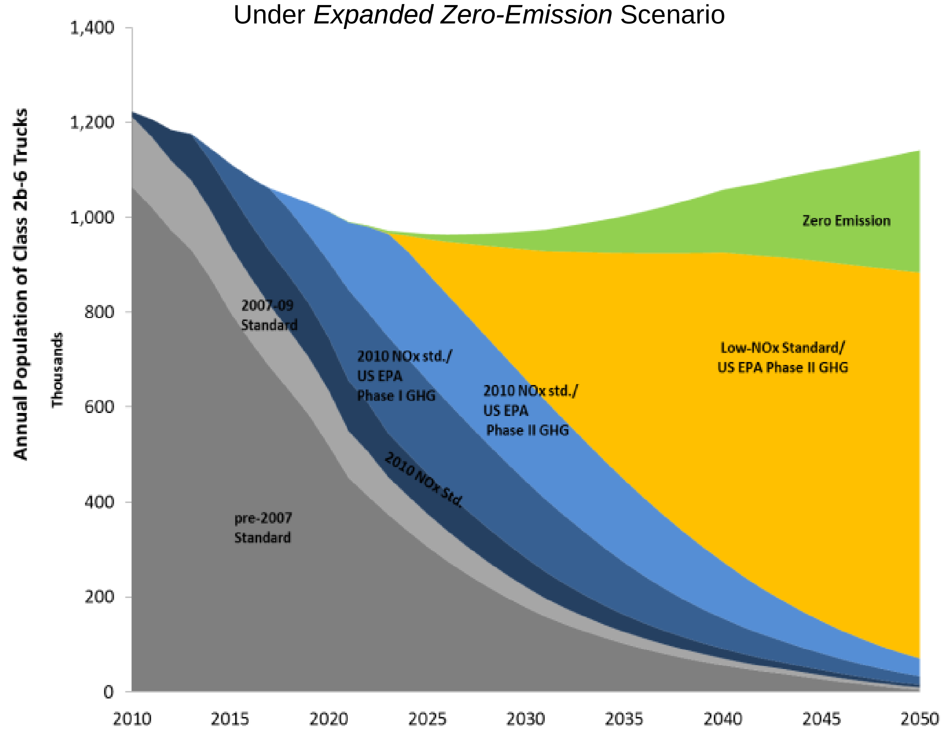


Figure 17: Population of In-State Class 7 and 8 Heavy-Duty Trucks

Under *Expanded Zero-Emission* Scenario

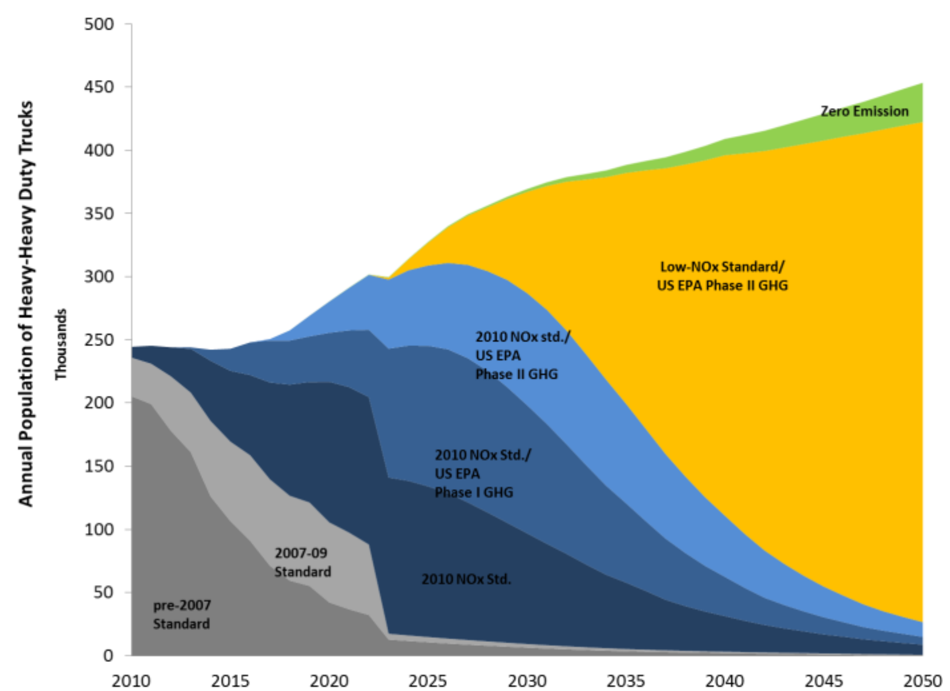


Table 7: Sales Assumptions for Last Mile Delivery Trucks
Under *Expanded Zero-Emission* Scenario

Model Year	Percent ZEV	FCEV/BEV
2020&21	2.5%	10/90
2022	7%	10/90
2023	8.5%	10/90
2024	9%	10/90
2025	10%	10/90
2030	15%	10/90
2035	20%	20/80
2040	25%	30/70
2045	30%	40/60
2050	35%	50/50

Table 8: Sales Assumptions for In-State Class 2B Light Trucks
Under *Expanded Zero-Emission* Scenario

Model Year	Percent ZEV	FCEV/BEV
2023&24	2.5%	10/90
2025	7%	10/90
2026	8.5%	10/90
2027	9%	10/90
2028	10%	10/90
2030	12%	10/90
2035	17%	20/80
2040	22%	30/70
2045	27%	40/60
2050	32%	50/50

Table 9: Sales Assumptions for In-state Class 7 and 8 Trucks
Under *Expanded Zero-Emission* Scenario

Model Year	Percent ZEV
2030	2.5%
2040	5%
2050	10%

The Importance of the Federal Low-NOx Standard

Because out-of-state heavy-duty vehicles operating in South Coast are not covered by California new engine emission standards, timely federal action to implement a national low-NOx performance standard is necessary to achieve an in-use fleet average that provides the emission reductions from heavy-duty trucks needed for ozone attainment. If U.S. EPA does not act at all, a California-only new engine emission standard would reduce NOx emissions, but not sufficiently enough to attain federal air quality standards.

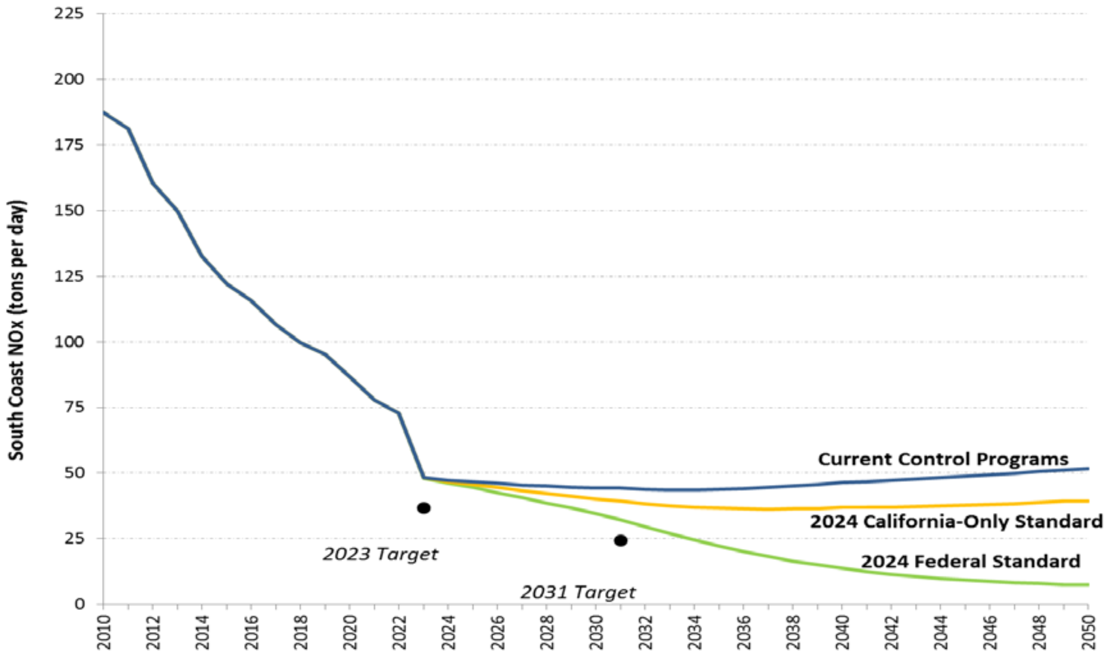
ARB's Truck and Bus Regulation will ensure that nearly every heavy-duty vehicle operated in California by 2023 will meet 2010 heavy-duty engine emission standards, but even a highly aggressive full-fleet penetration of 2010-compliant engines would not provide sufficient NOx reductions to attain the federal ozone standard in the timeframe required. This drives the need for progressively more stringent heavy-duty engine NOx emission standards. The measures outlined in this document call for U.S. EPA to develop a national low-NOx standard. Due to the preponderance of interstate trucking's contribution to in-state VMT, federal action would be far more effective at reducing in-state emissions than a California-only standard. However, California is prepared to develop a California-only standard, if needed, to meet federal attainment targets. Timely action is also important. While the *Cleaner Technology and Fuels* scenario discussed in Chapter 3 assumed U.S. EPA action by 2024, delaying implementation until 2027 would result in a significant loss in overall emission benefits.

U.S. EPA has also promulgated a lower 8-hour ozone standard of 70 ppb in October of 2015. Non-attainment areas will continue to need strategies that reduce NOx emissions in order to meet attainment deadlines for this more health protective standard. California has the authority to set emission standards as long as the standards meet or exceed any federal emissions regulations and U.S. EPA grants a waiver for California to implement the standards. In addition, Section 177 of the Clean Air Act allows other states to adopt California's standards in lieu of federal standards without U.S. EPA approval. This would allow other states to adopt a lower California NOx standard ahead of federal implementation if U.S. EPA does not act in a timely manner, or in lieu of the current standards if U.S. EPA fails to act, in order to meet attainment deadlines.

There have been past successes with other states adopting California emission standards in order to meet their specific air quality needs. During ARB's California Phase 2 Symposium held on April 22, 2015, Paul Miller, from the Northeast States for Coordinated Air Use Management (NESCAUM), presented on other states' positive experience adopting California's mobile source programs[24]. According to NESCAUM, it is evident that there is a continued need for cleaner heavy-duty vehicles in other states in order for GHG and NOx standards to be met. NESCAUM believes that some states

[24] Miller, Paul J. "States' Experience and Perspectives with CA Mobile Source Programs". Northeast States for Coordinated Air Use Management (NESCAUM). South Coast Air Quality Management District Headquarters, Diamond Bar, CA. 22 April 2015. Symposium Presentation.

Figure 18: The Importance of Federal Standards for Heavy-Duty Vehicles*



*The scenarios illustrated in this figure reflect natural turnover rates.

may consider adopting California's optional low-NOx engine standards if future federal action is insufficient to meet their air quality needs. Given past trends and successes, there is a strong possibility that other states would follow California's lead and adopt lower heavy-duty engine emission standards. This could result in emission reductions from a portion of out-of-state vehicles operating in California if new lower national NOx standards are not in place.

Figure 18 demonstrates the need for federal action and shows the benefits associated with federal action in 2024, as assumed in the *Cleaner Technology and Fuels* case in green, versus the benefits of a California only measure, shown in yellow.

Proposed Measures: On-Road Heavy-Duty Vehicles

Heavy-duty trucks over 8,500 pounds are currently the fastest growing transportation sector in the United States, responsible for about 33 percent of total statewide NOx emissions, approximately 26 percent of total statewide diesel PM emissions, and a significant source of GHG emissions. Most of the NOx emissions from heavy-duty engines come from diesel-cycle engines, especially in the higher weight classes. Gasoline and natural gas Otto-cycle spark-ignited engines are also used in heavy-duty trucks, to a lesser extent, and primarily in the lower weight classification vehicles.

Measures presented in the mobile source strategy will build on past successes to further reduce combustion emissions from engines and vehicles, and to quickly deploy currently available near-zero emission technologies, including low-NOx engines powered with renewable fuels. As vehicles purchased out-of-state account for a majority of the heavy-duty vehicle miles travelled in the South Coast on any given day, ARB will develop new heavy-duty diesel engine emission standards and, if necessary, petition U.S. EPA to establish a national standard, in order to achieve emission reductions from vehicles operating in California that were purchased in a different state. A lower NOx standard that reduces emissions from all trucks operating in California is critical to meeting 2031 air quality goals. Substantial future emission reductions can also be achieved through system and operational efficiency improvements to conventional technologies through measures supporting advanced combustion, aerodynamics, hybridization, and connected vehicle technologies.

To keep pace with achieving long-term, zero emission goals, measures will focus on expanding the use of ZEV technologies in lighter heavy-duty trucks and in applications where commercial products are feasible and commercially available, such as last mile delivery. Transit buses are one of the first heavy-duty applications where zero emission technologies have been demonstrated and are commercially available. Zero emission transit buses are primed to be one of the first heavy-duty vehicle types to achieve significant zero-emission vehicle sales volumes, leading and supporting technology development in the heavy-duty sector as a whole. While the development of heavy-duty zero emission technologies is well underway, it lags ZEV development in the light-duty sector; thus the heavy-duty sector has further to go to increase the penetration of zero-emission technologies. Nonetheless, ZEV technologies in heavier applications will benefit from technology migration and cost reductions achieved through economies of scale, technological innovation, and learning gained along the path to commercialization.

Early investments and incentives that accelerate deployment of zero and near-zero technologies in the heavy-duty sector are essential. Incentive programs have played a vital role in transitioning on-road heavy-duty vehicles and equipment to cleaner technology and they will continue to play a critical role in the success of transitioning the heavy-duty sector to cleaner technology. Incentives will not only encourage increased development and deployment of zero and near-zero emission technologies in heavy-duty applications, they will also help encourage acceptance of new technology with consumers. The vehicles and equipment in heavy-duty sectors have long lifetimes, and many of the engines sold today may still be operating in 2030. Investments that bring the cleanest technologies to market as quickly as possible are essential for achieving near-term criteria pollutant reductions to our air quality and climate goals.

Innovative Technology Certification Flexibility

Overview:

The goal of this proposed measure is to encourage early deployment of the next generation of truck and bus technologies through defined, near-term ARB certification and OBD compliance flexibility for medium- and heavy-duty vehicles. This regulation is intended to balance the need to provide key, promising technologies with a predictable, and practical ARB-certification pathway, while preserving ARB's overarching objective to ensure expected emission benefits of advanced truck and bus technologies are achieved in-use. This regulation would provide the greatest flexibility for potentially transformational engine and vehicle technologies, such as robust hybrids and heavy-duty engines meeting the current optional low-NOx standard.

The deployment of robust hybrids (including those with zero-emission capability) is expected to both yield near-term emission benefits and facilitate the battery innovation needed to expand the application of zero-emission technology. By enabling early deployment of electric drivelines, low-NOx engines, and other key truck and bus technologies, this regulation would also help lay the foundation for the future technology-advancing regulation(s) needed to meet air quality and climate goals.

Background / Regulatory History:

In December 2013, ARB adopted Optional Reduced Emission Standards for Heavy-Duty Engine to further reduce emissions from the heavy-duty vehicle sector. These optional low-NOx emission standards set targets of 0.10, 0.05, and 0.02 g/bhp-hr NOx, which are 50 percent, 75 percent, and 90 percent, respectively, below the current 2010 emission standard. As of November 1, 2015, only one heavy-duty engine has been certified to an optional low-NOx standard – a Cummins ISL 8.9 liter alternative-fueled engine meeting the 0.02 g/bhp-hr NOx standard.

California law requires new motor vehicles and engines to be certified by ARB for emission compliance before they are legal for sale, use, or registration in California. Light- and medium- duty vehicle emissions are typically evaluated on a *chassis dynamometer* as part of the vehicle certification process. Heavy-duty vehicles (greater than 14,000 lbs.) are not required to be ARB-certified as a complete vehicle; instead, an engine must be ARB-certified for use in a heavy-duty vehicle.[26] Heavy-duty engine emissions are certified using an engine dynamometer, in part due to challenges in chassis testing heavier vehicles, and the impracticality of chassis certifying the diversity of potential truck and bus configurations in which a heavy-duty engine could be installed. However, dynamometer testing of heavy-duty engines does not quantify the potential emission impact of innovative non-engine technologies, such as hybrid drivelines.

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[26] Hybrid heavy-duty vehicles have the option for complete full vehicle certification, utilizing ARB's Heavy-Duty Hybrid-Electric Vehicles Certification Procedures (December, 2013)

TAB 5

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OCT 1 2015

OFFICE OF
AIR AND RADIATION

MEMORANDUM

SUBJECT: Implementing the 2015 Ozone National Ambient Air Quality Standards

FROM: Janet G. McCabe, Acting Assistant Administrator
Office of Air and Radiation

TO: Regional Administrators, Regions 1-10

Following the directives of the Clean Air Act (CAA), on October 1, 2015, Administrator McCarthy signed a rulemaking action that revises the current national ambient air quality standards (NAAQS) for ozone to a new, more protective level of 0.070 parts per million (70 parts per billion). These revised standards will improve the health and well-being of millions of Americans in the coming years. They are built on a foundation of sound health and ecosystem science.

I am writing to you today to let you know about the process going forward for delivering the protections afforded by the revised standards. In doing so, I want to emphasize that we will work with our state, local, federal and tribal partners to carry out the duties of ozone air quality management in a manner that maximizes common sense, flexibility and cost-effectiveness while achieving improved public health expeditiously and abiding by the legal requirements of the CAA. The goal is achieving cleaner air, while recognizing the many other activities underway and the resource constraints that we and our co-regulators face. This has proved a successful partnership in the past, and I am confident it will continue to be so in the future. In particular, I note that a number of the other clean air programs currently underway will work to lower ozone levels nationally, such as Tier 3 vehicle standards, Mercury and Air Toxics Standards, measures to address the 2010 sulfur dioxide NAAQS, the Clean Power Plan and others.

The attached document highlights many of the issues related to implementing the revised national ozone standards, including policy and technical aspects of implementation that we anticipate facing in the coming years. It outlines actions that the EPA will take and our expectations of our air agency partners. Please share this memo with our state, local and tribal partners within your regions.

Attachment

(FIPs) that eliminate the emissions that significantly contribute to nonattainment and interfere with maintenance of the standards in downwind states.

We believe that the Good Neighbor provision for the 2015 NAAQS can be addressed in a timely fashion using the framework of the Cross-State Air Pollution Rule (CSAPR), especially given the recent court decisions upholding the rule. The CSAPR framework involves a 4-step process to address the requirements of the good neighbor provision: (1) identifying downwind receptors that are expected to have problems attaining or maintaining clean air standards (i.e., NAAQS); (2) determining which upwind states contribute to these problems in amounts sufficient to "link" them to the downwind air quality problems; (3) for states linked to downwind air quality problems, identifying upwind emissions that significantly contribute to nonattainment or interfere with maintenance by quantifying upwind reductions in ozone precursor emissions and apportioning upwind responsibility; and (4) for states that are found to have emissions that significantly contribute to nonattainment or interfere with maintenance of the NAAQS downwind, adopting SIPs or FIPs that eliminate such emissions.

As a first step in facilitating the implementation of the Good Neighbor provision for the 2015 NAAQS, the EPA intends to provide timely information regarding steps 1 and 2 of the CSAPR framework. We expect to conduct modeling necessary to identify projected nonattainment and maintenance receptors and identify the upwind states that contribute significantly to these receptors. We would make such information available in fall 2016 through a NODA process (similar to the one the EPA recently used in developing the transport modeling for the 2008 ozone NAAQS) so that air agencies and others can help assure that the EPA is using the best available information.

Finally, in light of our shared responsibility to address interstate transport, we intend to continue on-going discussions with eastern states and to undertake discussions with western states. These discussions are necessary to make sure we have a common understanding of the nature of inter-state ozone transport in each part of the country and that we are working together on appropriate solutions.

F. Addressing the Challenges in California

California has unique challenges among the states in addressing ozone pollution. Air basins surrounded by mountains and a generally warm climate combine to make many areas of the state conducive to ozone formation. In particular, the South Coast air basin in the Los Angeles area and the San Joaquin Valley in the central part of the state are the only two areas in the U.S. classified as "Extreme" nonattainment areas for the 1979, 1997 and 2008 ozone standards. Although ozone levels have decreased by 30 percent in South Coast and nearly 20 percent in the San Joaquin Valley since 2000, South Coast still has the highest 2012-2014 8-hour ozone design value in the nation at 102 ppb, and San Joaquin has the second highest at 95 ppb. Through September 29, 2015, South Coast had exceeded the 2008 ozone standards on 81 days this year, the San Joaquin Valley on 73 days. More than 25 million people in California breathe air that does not meet the 2008 ozone standards.

Air pollution from mobile sources dominates the ozone precursor emissions in California. With ports that bring in forty percent of the nation's goods and agricultural areas that produce nearly half of the nation's produce, as well as a population of over 38 million, the state is challenged by high levels of NOx emissions from freight movement and from transportation generally. Under section 209 of the CAA, California has the authority to regulate mobile sources. Beginning in the 1970s, the state has used this authority to set stringent emissions standards. In 2008, California began regulating in-use trucks and buses to reduce emissions from the legacy fleet, the only such mandatory program in the country. More recently, it adopted a voluntary low-NOx emissions standards for heavy-duty engines to help engine technology move toward even cleaner levels. In addition, the state has funded incentive programs to further reduce emissions from the legacy fleet and has pursued numerous advanced mobile source technologies. Since 2008, California has spent nearly $3 billion in funding the demonstration and deployment of innovative technologies such as zero-emission trucks and buses, hybrid-electric medium- and heavy-duty vehicles, and zero-emission freight equipment. The federal government has provided more than $200 million, largely through Diesel Emissions Reduction Act grants and the Department of Agriculture's Environmental Quality Incentives Program funds.

Even with these aggressive regulatory and non-regulatory programs to control mobile-source emissions, and with the most stringent stationary source emission standards in the U.S., most of central and southern California is likely to be designated nonattainment for the 2015 ozone standards. The South Coast Air Quality Management District estimates that it will need a reduction of at least 85 percent in NOx emissions from 2012 levels to attain a standard of 70 ppb by 2037.[10]

With the implementation of all the measures currently adopted and planned by 2032[11], the sources contributing the most NOx emissions in California's nonattainment areas will be heavy-duty diesel trucks, ships and commercial boats, off-road equipment, locomotives, aircraft, agricultural engines, and passenger cars. For California's ozone nonattainment areas to attain the 2015 ozone standards, the state and the EPA have recognized that transformational change is likely needed. For example, recent discussions have focused on a transition to largely zero and near-zero emissions vehicle technologies as well as significant turnover of the legacy fleet of vehicles. Additionally, California is undertaking a comprehensive review of its goods movement system with the goal to release a sustainable freight plan in July 2016. The state is also developing attainment plans for the 2008 ozone NAAQS, to be submitted to the EPA in 2016. For these and other related efforts, the EPA will work closely with California, local air quality officials, nongovernmental organizations, other federal agencies, and interested commercial representatives to identify both regulatory and non-regulatory emission control solutions best designed to achieve reductions in the transportation sector.

G. Managing Ozone Monitoring Networks

A sound ambient pollution monitoring program is one of the foundations of delivering environmental protection. The public counts on states and other air agencies to establish and operate air quality monitoring networks, and provide reliable, high quality air quality measurement data. We encourage air agencies to ensure their ozone networks are efficient and effective at determining public exposure to ozone, and in full compliance with existing air monitoring regulations. In rules accompanying the 2015 revision to the ozone NAAQS, we took three actions related to air monitoring. First, the monitoring season period for ozone monitors was extended in 32 states and the District of Columbia starting in 2017. All previously approved ozone monitoring site waivers are now revoked, however we encourage air management agencies to work with their respective EPA regional office in cases where they believe new waivers should be granted. We have not changed the process or reasons for granting seasonal exemptions for collecting monitoring data in cases where access or operations of the monitor are affected by inclement weather conditions. As a reminder, we expect that the CASTNET monitors will

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[10] South Coast Air Quality Management District documents:
http://www4.aqmd.gov/enewsletterpro/uploadedimages/000001/Celia/FactSheet-2016%20AQMP-v9.pdf;
http://www.aqmd.gov/docs/default-source/Agendas/aqmp/advisory4-item3.pdf?sfvrsn=2.

[11] The year 2032 is the attainment deadline under the 2008 ozone NAAQS for California nonattainment areas that are classified Extreme for that standard.

TAB 6

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

Blueprint for Clean Air

2016 AQMP WHITE PAPER

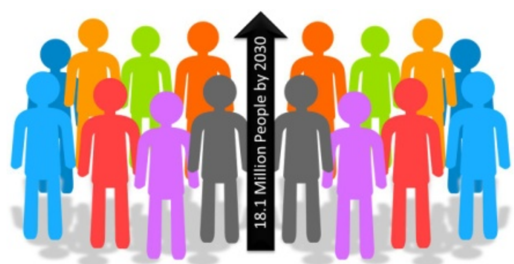
OCTOBER 2015

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 the federal and state 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]

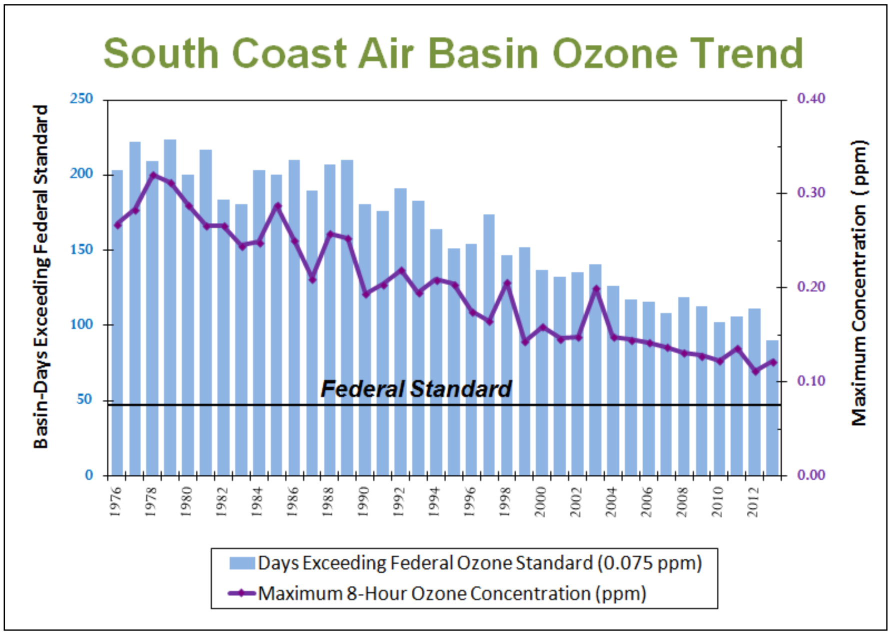
> The San Pedro Bay Ports anticipate cargo volumes to grow to 43 million containers annually by 2035: more than tripling from today's levels[1].

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 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]

[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.

[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.

TAB 7

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

Goods Movement

2016 AQMP WHITE PAPER

OCTOBER 2015

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.

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.

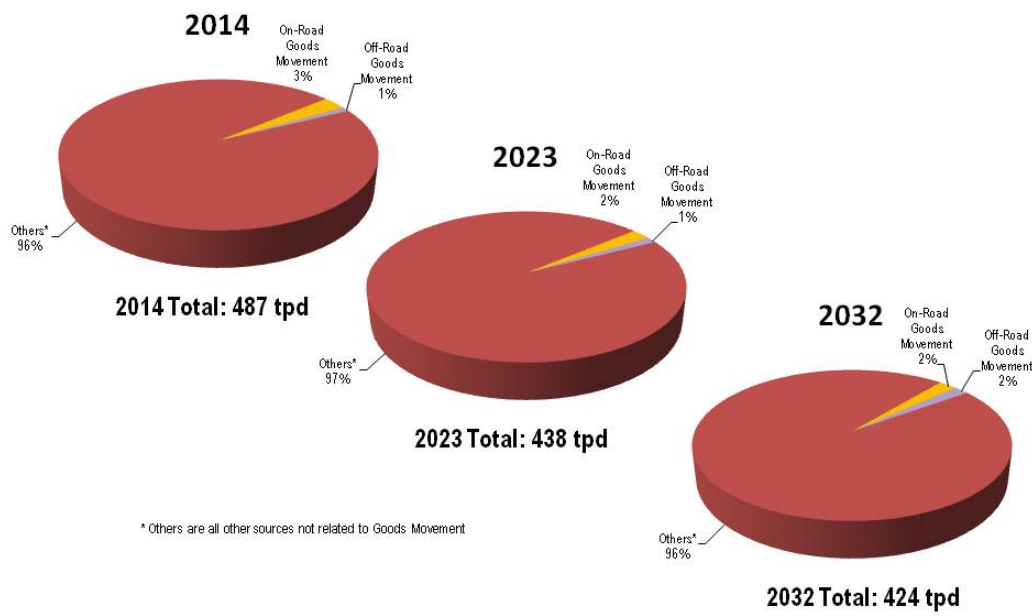


FIGURE 2

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

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.

TAB 8

CALIFORNIA SUSTAINABLE FREIGHT ACTION PLAN

DRAFT

DRAFT

Discussion Document

MAY 2016

Executive Summary

In July 2015, Governor Brown issued Executive Order B-32-15 (see Appendix A), which prioritizes California's transition to a more efficient and less polluting freight transport system. This transition of California's freight transport system is essential to supporting the State's economic competitiveness in coming decades while reducing harmful pollution affecting many California communities.

Improving the efficiency of California's freight transport system is vital to our State economy. Traditional routes of moving freight face increasing competition from across the globe, and California's system must anticipate and stay ahead of these changes. Currently, California is the nation's largest gateway for international trade and domestic commerce, with an interconnected system of ports, railroads, highways, and roads that allow freight from around the world to move throughout the State and nation. This system is responsible for one-third of the State's economic product and jobs, with freight-dependent industries accounting for over $740 billion in gross domestic product and over 5 million jobs in 2014. However, California's freight transport system is under pressure to serve our growing population and satisfy dynamic market demands, while other locations in the United States and across the world are fiercely competing for this economic activity.

At the same time, modernizing California's freight transport system in a manner that improves safety and reduces pollution is essential to improve public health and meet our environmental imperatives. Freight transportation in California generates a high portion of local pollution in parts of the State with poor air quality. Reducing these harmful pollutants is an important local, regional, and State priority, as well as a matter of compliance with the federal Clean Air Act. California has also recently set new, aggressive targets for reducing greenhouse gas emissions 40 percent below 1990 levels by 2030 in order to combat climate change. Reducing emissions in the freight sector is critical to meeting these 2030 targets.

The objectives laid out in the Governor's Executive Order to improve efficiency and reduce pollution of the freight transport system are not new. California's freight transport system has already successfully undergone major improvements toward shared efficiency and environmental objectives. Proposition 1B, passed by voters in 2006, provided almost $20 billion in funding for California's transportation infrastructure, with over $2 billion dedicated to the improvement of the State's freight network and $1 billion in funding for cleaner freight vehicles and equipment. Local and regional groups such as port commissions and metropolitan planning organizations are also taking action to improve freight operations. Large ports have adopted Clean Air Action Plans and many regional planning organizations have adopted regional freight plans that prioritize infrastructure improvements and improve land use to better operationalize logistics activities in their region.

- Improving safety and security: Reducing freight-related injuries and fatalities remains of utmost importance requiring continuous improvement to accommodate current and anticipated future vehicles and technology. It is necessary to increase awareness, prevention, and protection while allowing commerce to flow.

- Reducing exposure to air toxics: Despite substantial progress over the last decade, the diesel equipment operating in and around freight hubs continues to be a significant source of air toxics that can cause localized risks of cancer and other adverse health effects. New health science tells us that infants and children are 1.5 to 3 times more sensitive to the harmful effects of exposure to air toxics than we previously understood, which heightens the need for further risk reduction.

- More protective air quality standards: The federal Clean Air Act requires the State and local air districts to prepare State Implementation Plans demonstrating how the State will attain the national 8-hour ozone and fine particulate matter standards, with plans due in 2016. Attaining the current standards for the 2023 to 2032 timeframes will require broad deployment of zero and near-zero emission technologies in the South Coast and San Joaquin Valley air basins. Currently, freight equipment accounts for about half of the statewide diesel particulate matter emissions, and approximately 45 percent of the statewide nitrogen oxides emissions. Emission reductions from the freight transport system need to be part of the solution.

- Climate change goals: In April 2015, Governor Brown signed Executive Order B-30-15 establishing a 2030 greenhouse gas emissions reduction target of 40 percent below 1990 levels, addressing the need for climate adaptation, and directing State government to:

    - Incorporate climate change impacts into the State's Five-Year Infrastructure Plan.
    - Update the State's comprehensive strategy for safeguarding against climate impacts.
    - Factor climate change from a lifecycle perspective into State agency planning and investment decisions.
    - Implement measures under existing agency and departmental authority to reduce greenhouse gas emissions.

  Governor Brown further identified five key climate change strategy pillars for California to help achieve the 2030 emissions reduction target:

1. Fixing America's Surface Transportation Act

On December 4, 2015, President Obama signed into law a new five year, $305 billion surface transportation bill, the "Fixing America's Surface Transportation (FAST) Act," which authorizes funding for existing core highway and transit programs and created two new freight programs funded by the Highway Trust Fund. These include the National Highway Freight Program, from which California will receive an annual average of approximately $117 million per year by formula, and the Nationally Significant Freight and Highway Projects Program that is funded at approximately $900 million per year nationwide and subject to discretionary competitive awards. Prior to the Fixing America's Surface Transportation Act, the U.S. did not have a coordinated freight investment program. By establishing a dedicated, committed funding source, significant advances in public policy created an underlying message to all of the importance of freight movement and freight supporting infrastructure to the California and U.S. economies.[1]

2. Governor Brown's Fiscal Year 2016-2017 Budget Proposal

On January 7, 2016, the Governor released his proposed 10-year funding plan that will provide a total of $36 billion for transportation, with an emphasis on repairing and maintaining the existing transportation infrastructure. The Governor's proposal also includes a significant commitment to improving infrastructure on the State's trade corridors, with approximately $2 billion slated for freight infrastructure investments. The package includes a combination of new revenues, additional investments of Cap-and-Trade auction proceeds, accelerated loan repayments, Caltrans efficiencies and streamlined project delivery, accountability measures, and constitutional protections for the new revenues. [2]

The Governor's Proposed Budget also includes a one-year appropriation of funding for cleaner vehicles, equipment, and fuels used to transport passengers and freight, as well as off-road equipment used in agriculture and other applications.

As discussed in ARB's *Mobile Source Strategy Discussion Draft*, additional funding and additional options for long-term transformative funding mechanisms will be critical to achieve our air quality and climate goals, including the specific zero emission technology targets in this Action Plan.[3] ARB is also working with its local partners to identify funding needs and mechanisms to support the scale of zero and near-zero emission mobile sources that is essential for attainment of federal air quality standards. The freight industry will continue to need incentives for early

[1] See https://www.fhwa.dot.gov/fastact/legislation.cfm.
[2] See Governor's Budget Summary 2016-2017, http://www.ebudget.ca.gov/FullBudgetSummary.pdf.
[3] See ARB Mobile Source Strategy Discussion Draft, October 2015, http://www.arb.ca.gov/planning/sip/2016sip/2016mobsrc_dd.pdf.

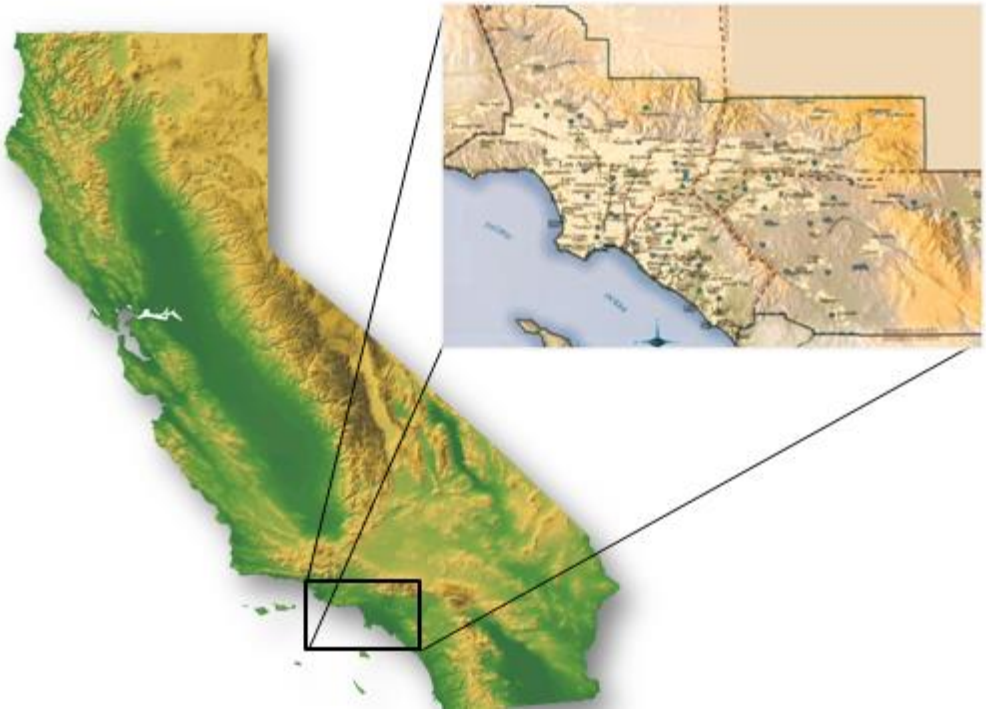
TAB 9

The Need to Further Reduce Emissions from Mobile Sources: A Local Perspective

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

WCC Plenary Session
Tacoma Green Transportation Summit/Expo and
West Coast Collaborative Partners Meeting
Tacoma, WA
April 5, 2016

California's South Coast Air Basin



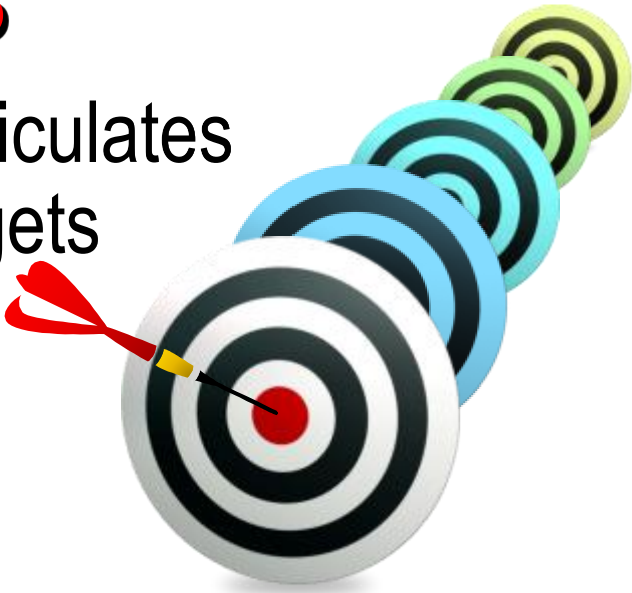
- Substantial Air Quality Progress, But Still Serious Health Impacts
- Nation's Largest Containerized Freight Gateway (~40% Containerized Goods to Nation)

4-county Region
16+ Million People

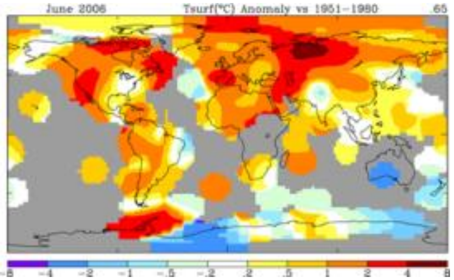
261,000+ Diesel Vehicles
11+ Million Gasoline Vehicles

Key Air Quality Challenges and Drivers

Ozone, Fine Particulates
Multiple Targets



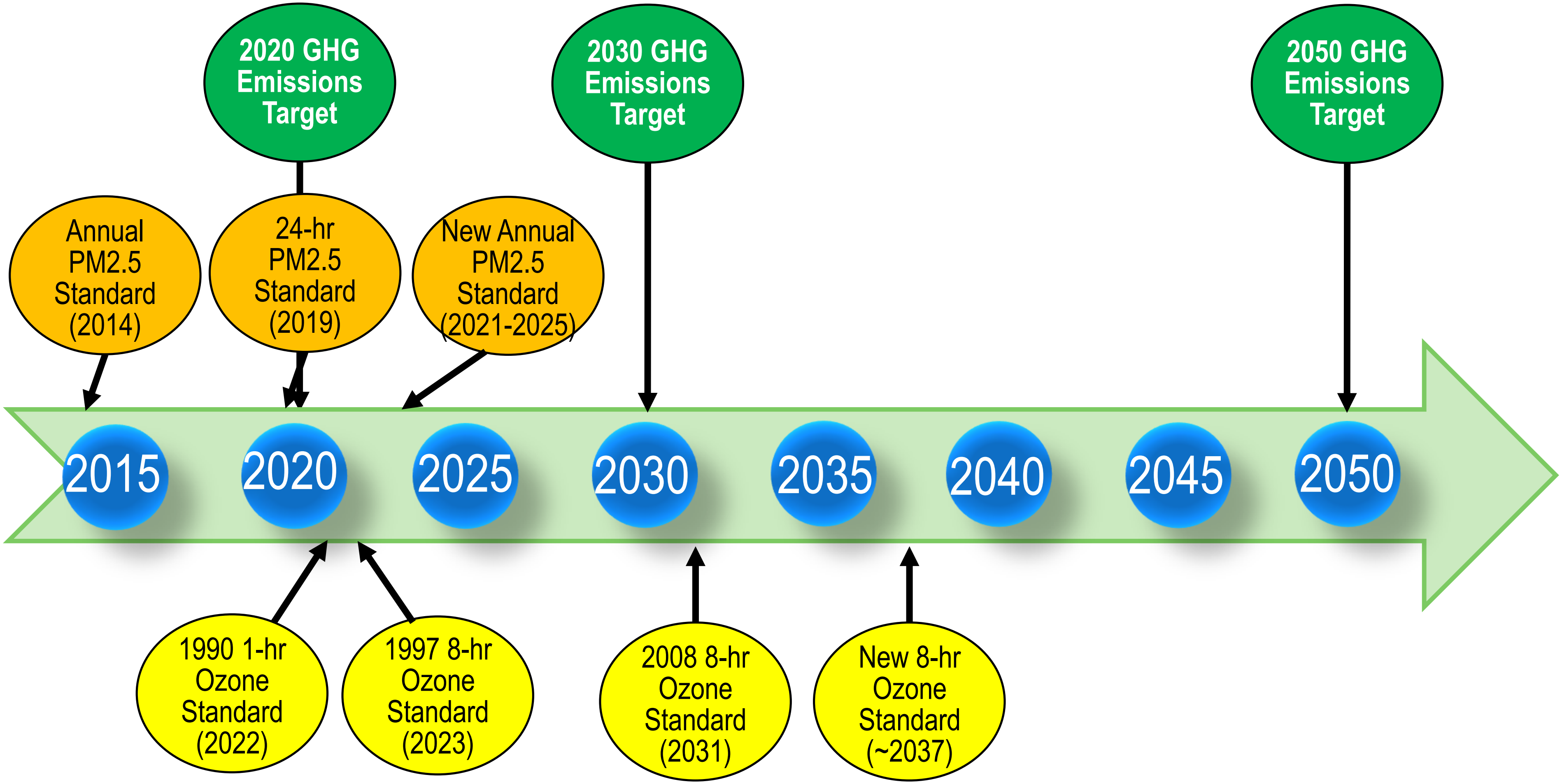
Air Toxic Exposure



Climate Change

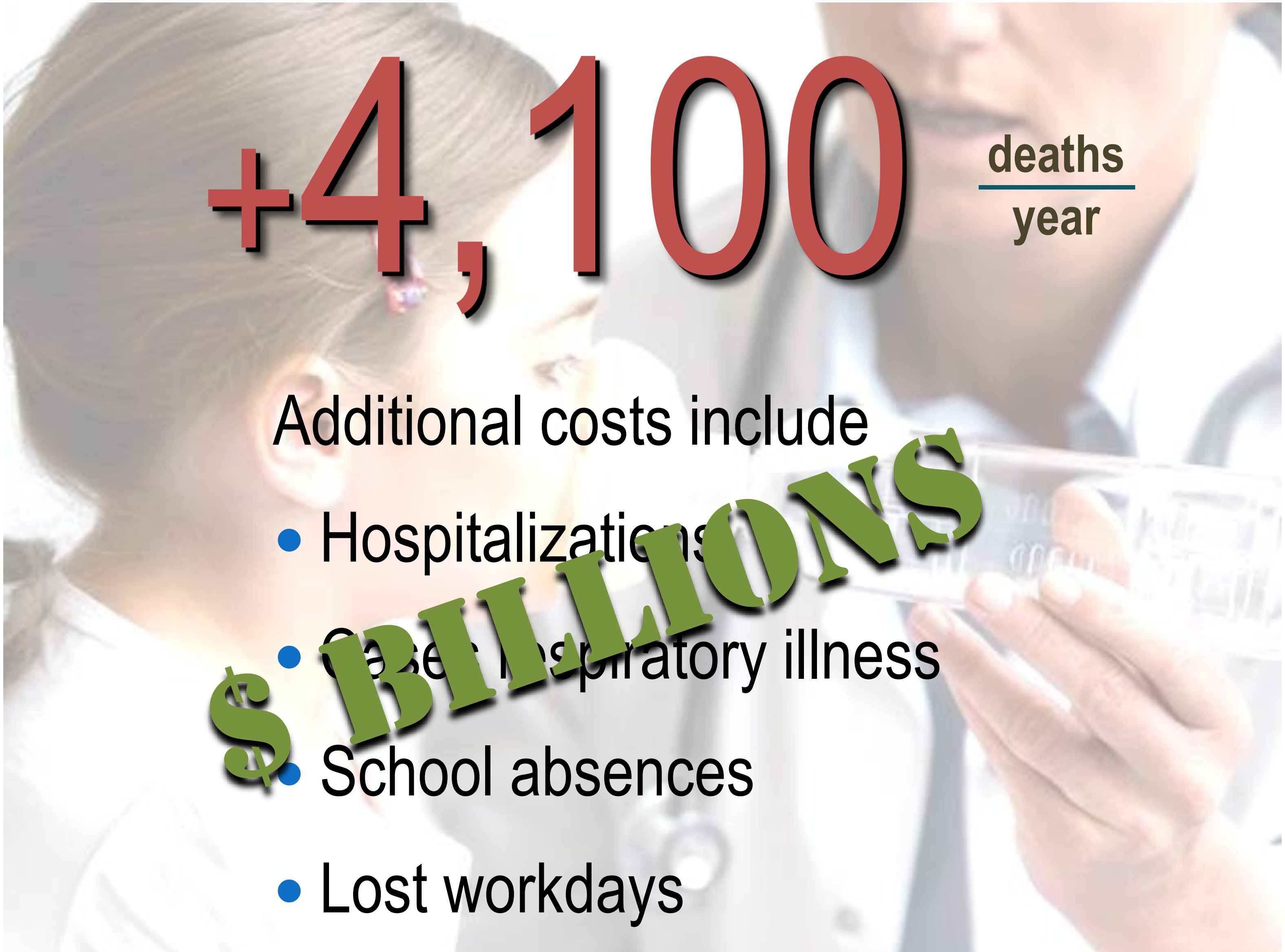
New Health Studies

National Ambient Air Quality Standards/ Climate Goals



Public Health Issues

- Respiratory Disease
  - Ozone and Fine Particulates ($PM_{2.5}$)
- Cancer Risk, Mainly from Diesel Exhaust
- Children's Health – High Asthma Incidents
- Environmental Justice
  - Disproportionate Community Impacts



+4,100 deaths / year

$ BILLIONS

Additional costs include

- Hospitalizations
- Cause respiratory illness
- School absences
- Lost workdays

Source: SCAB cardiopulmonary mortality estimate: CARB 2015

TECH & SCIENCE

Drivers Ex… Air Pollu… Lights, …

BY ZOË SCHLAN…

Your Car Could Be Driving Autism Rates

Harvard study links exposure to air pollution during pregnancy to autism risk.

December 19, 2014

Los Angeles Times

ON THE GROUND IN BEIJING

WITH JULIE MAKINEN

Weight gain? Blame smog

A study suggests air pollution plays a behavioral and biological role

LATIMES.COM

February 22, 2016

A Link Between Air Pollution … Adolescent ADHD

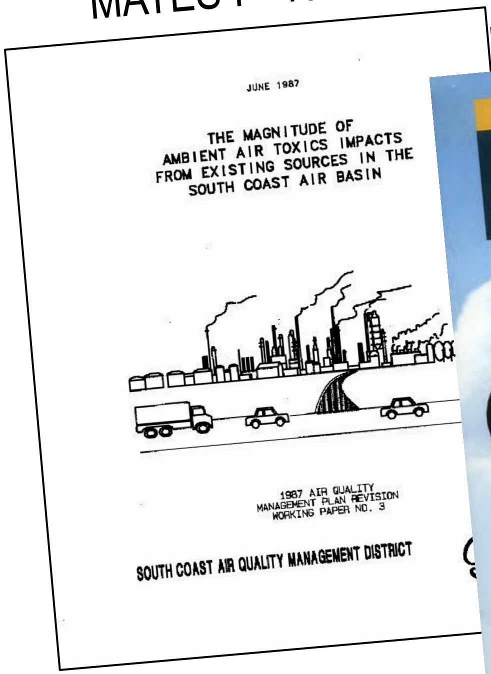
Certain pollutants common to urban areas could be harming the brains of unborn children, according to new research.

SAM STURGIS | @sampsturgis | Nov 5, 2014 | Comments

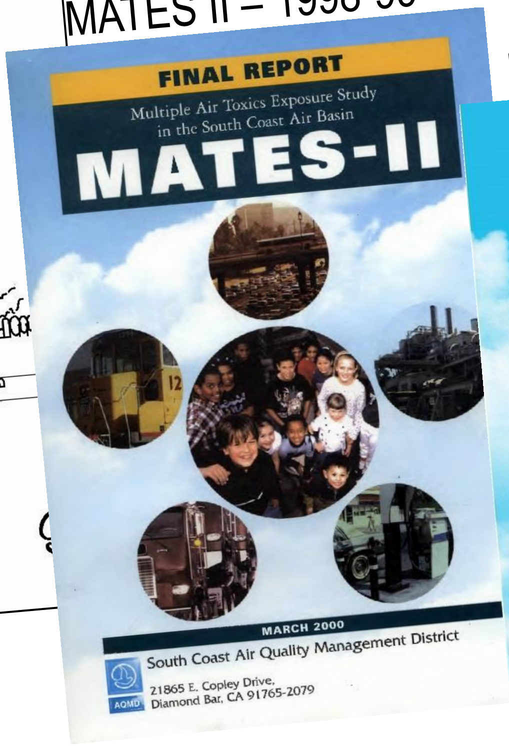
…ong … groups. … research … covered … nitrogen …e linked with an increased risk for suicide.

Multiple Air Toxics Studies

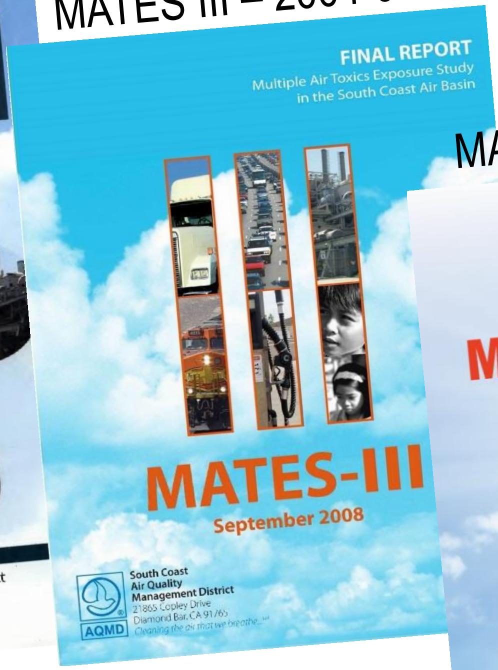
MATES I - 1987



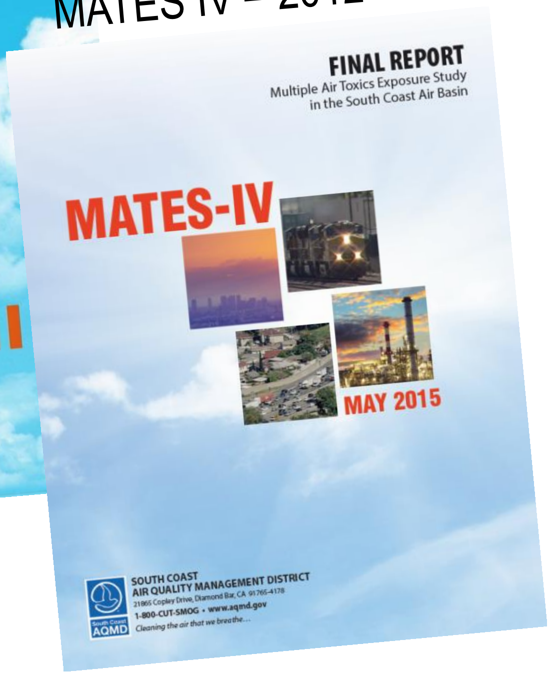
MATES II – 1998-99



MATES III – 2004-06



MATES IV – 2012-13



MATES-III and MATES-IV Monitoring

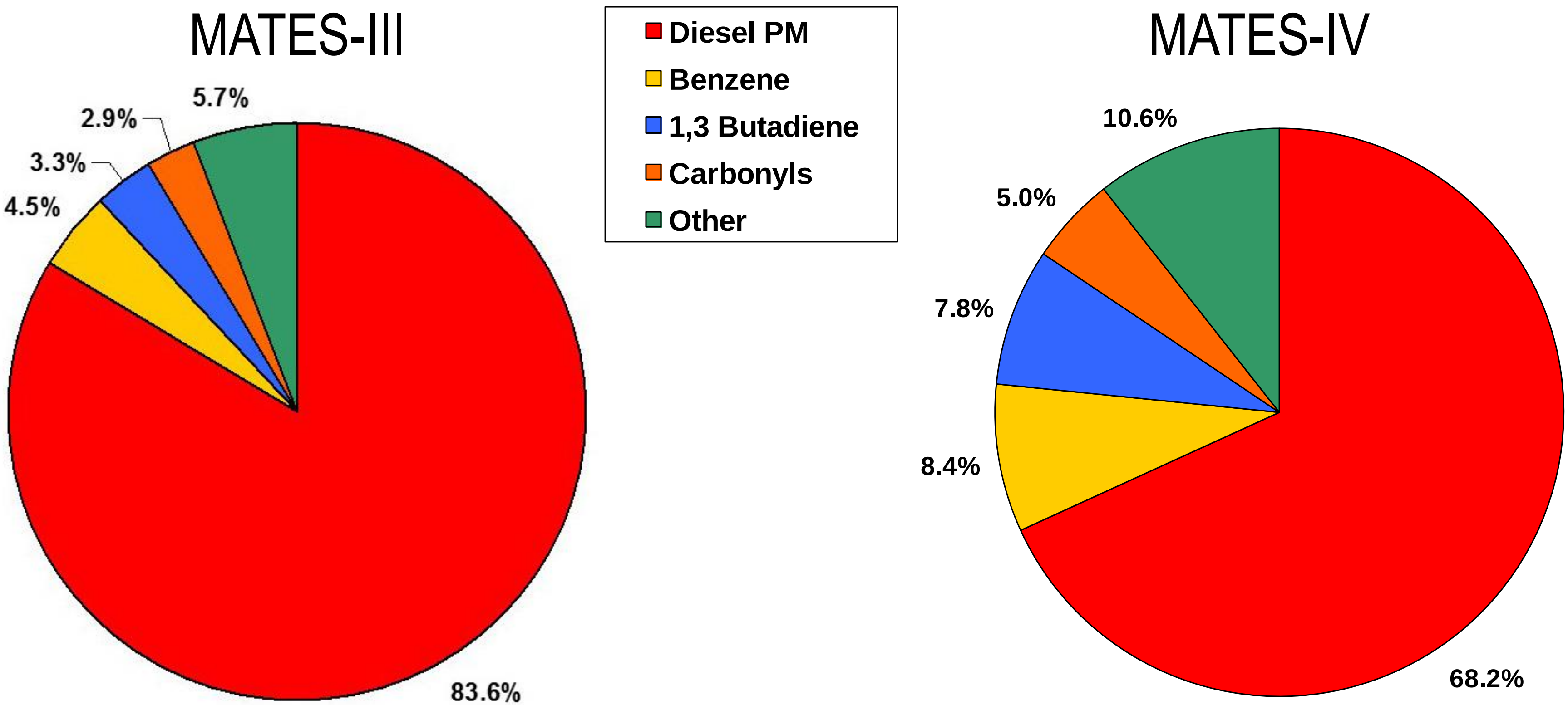
- One Year Toxics Monitoring at 10 Sites
  - MATES-III (2004 – 2005)
  - MATES-IV (2012 – 2013)
- Complementary Short-Term Sampling
- Over 30 Toxic Pollutants Measured
  - Gaseous
  - Particulates

Fixed Sites Temporary Sites

Summary of Major Findings

- Cancer Risk Decreased Around 65% on Average Since MATES III Study (2005)
- Diesel PM Exposure Dominates Overall Cancer Risk
- Highest Risk Areas Near Ports and Transportation Corridors
- Risk from All Air Toxics Continue to Decline, with Limited Exceptions
- Ultrafine Particle Measurements Show Higher Levels in Areas with Higher Population and Traffic Density

Monitored Air Toxics Risk – MATES-III Compared to MATES-IV

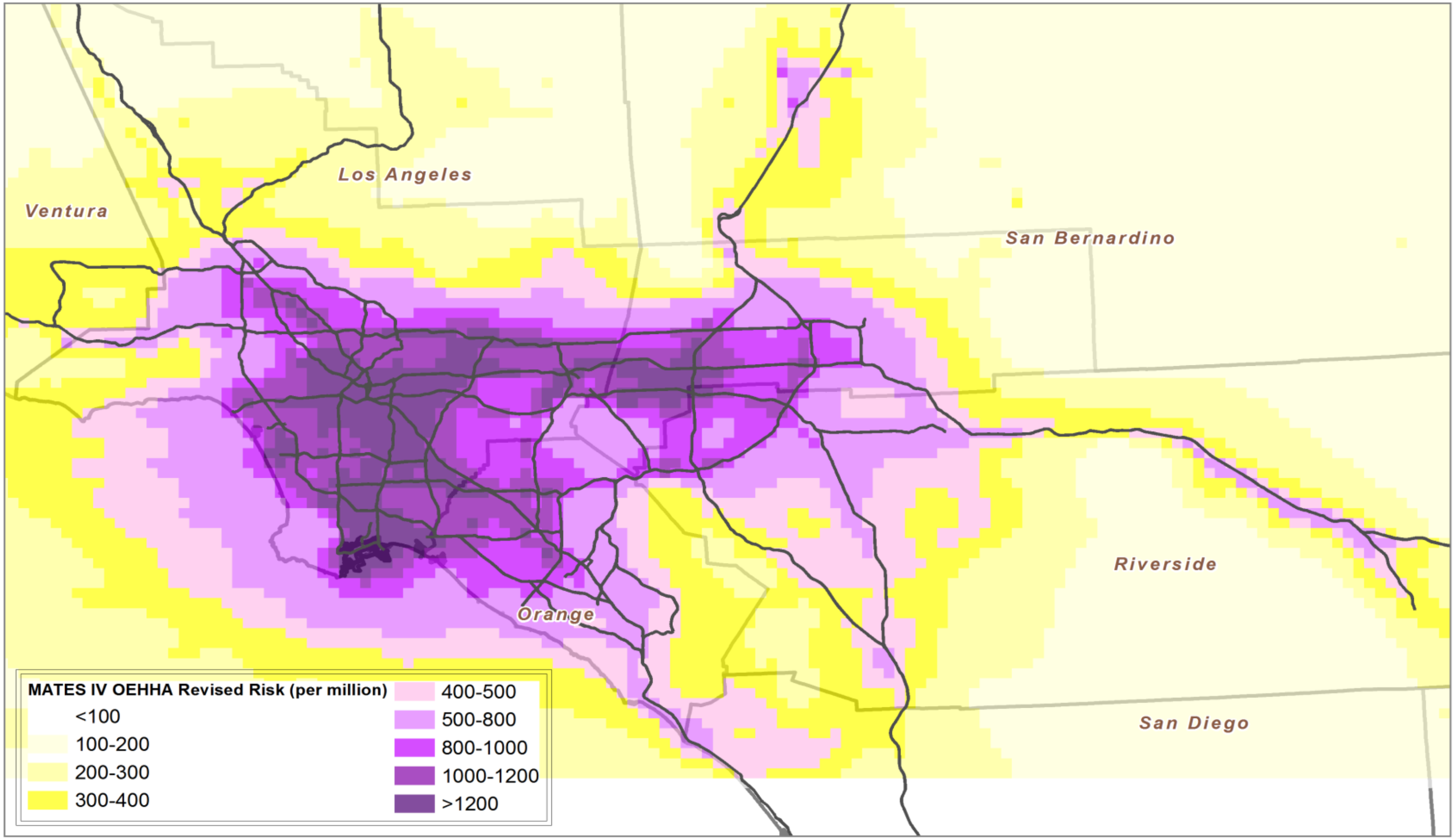


Basinwide Risk – 1194 per Million*

Basinwide Risk – 418 per Million*

* Average Risk Based on Previous Risk Factors Provided by OEHHA;
Latest Risk Factors are on Average 2.45 Times Higher

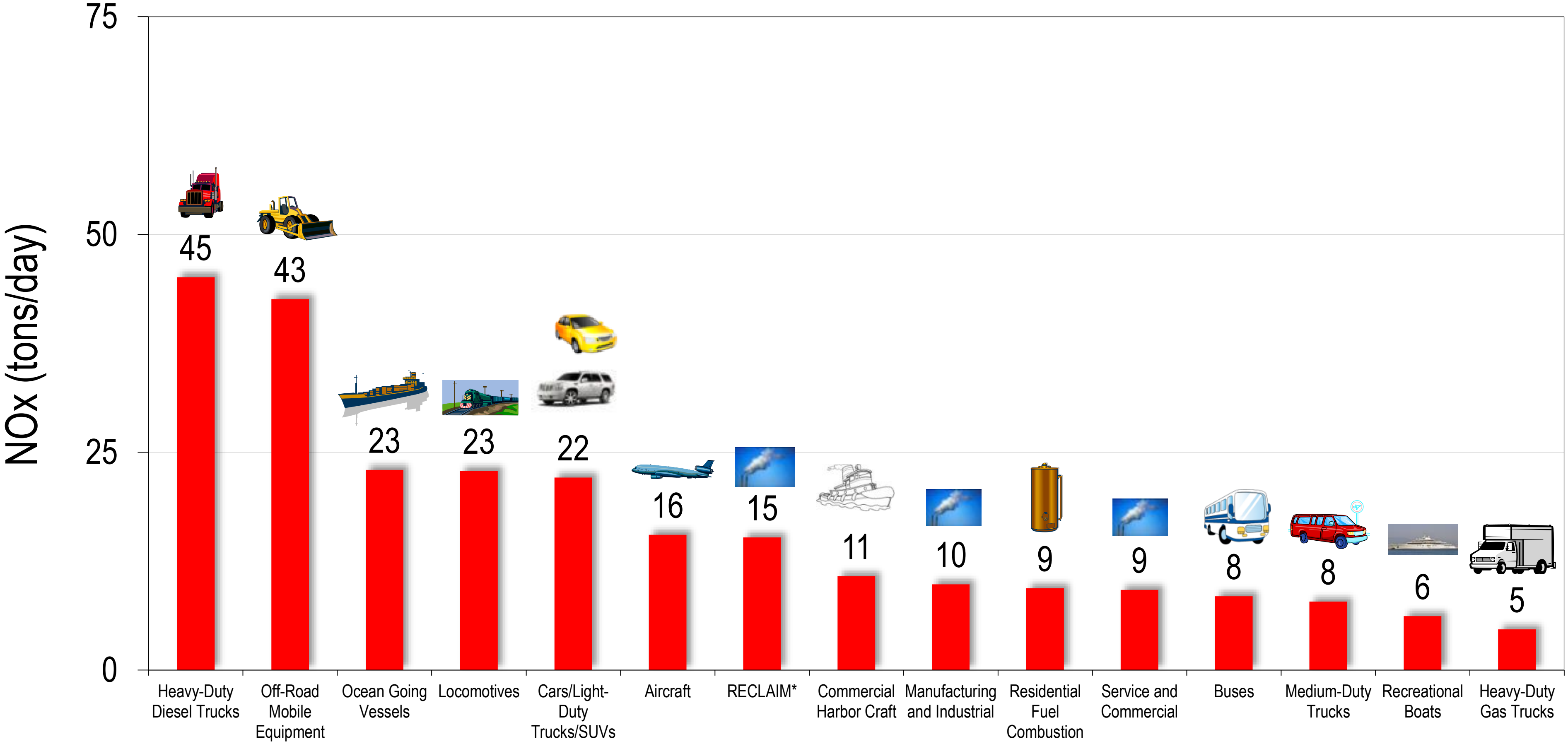
MATES IV Modeled Risk Based on Latest OEHHA Methodology



Inhalation Risks up by factor of about 2.7

Meeting Federal Air Quality Standards

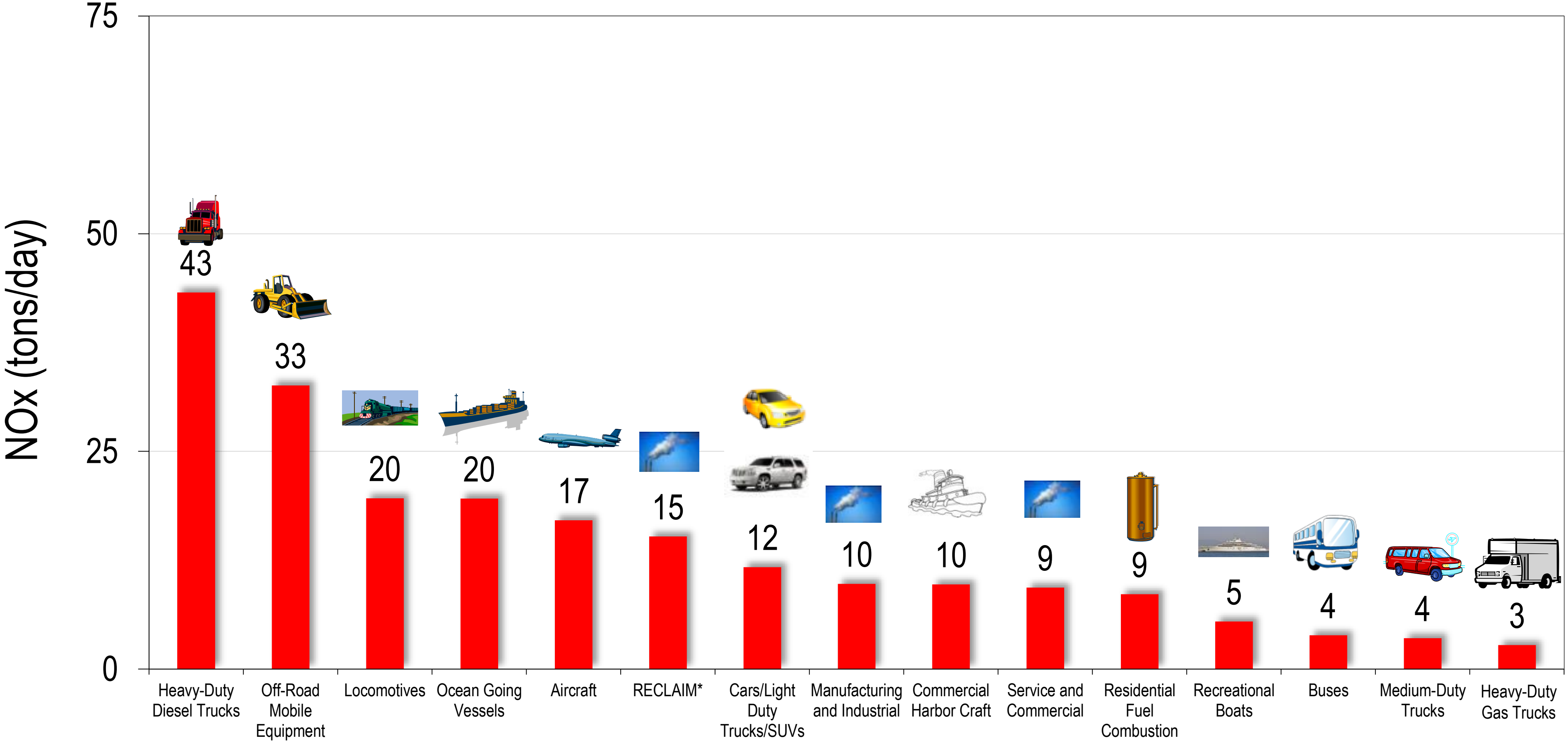
Top NOx Emissions Sources in 2023



*RECLAIM: 320 largest stationary sources, including all refineries and power plants

Source: Preliminary Draft 2016 AQMP Emissions Inventory – January 2016

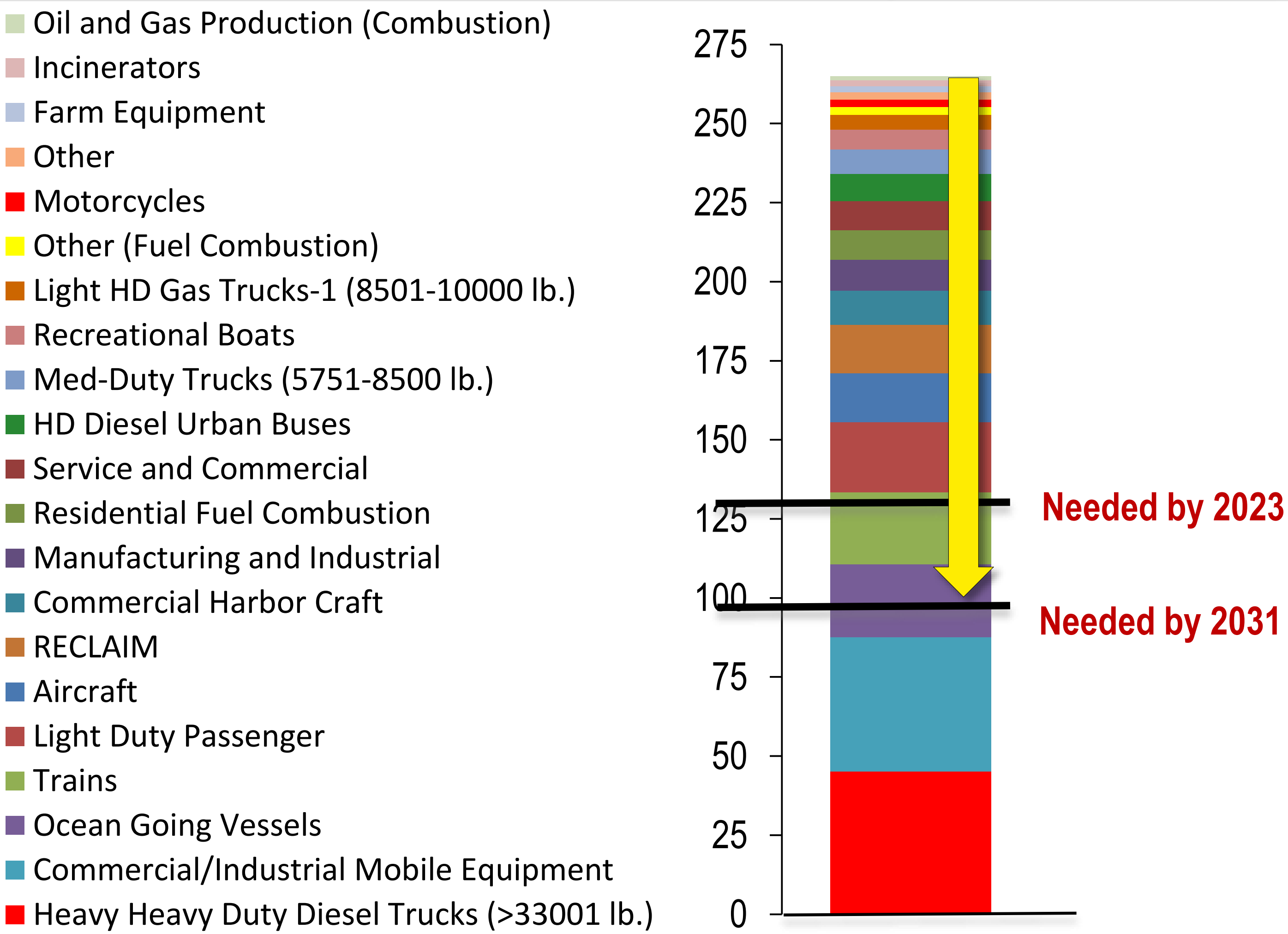
Top NOx Emissions Sources in 2031



*RECLAIM: 320 largest stationary sources, including all refineries and power plants

Source: Preliminary Draft 2016 AQMP Emissions Inventory – January 2016

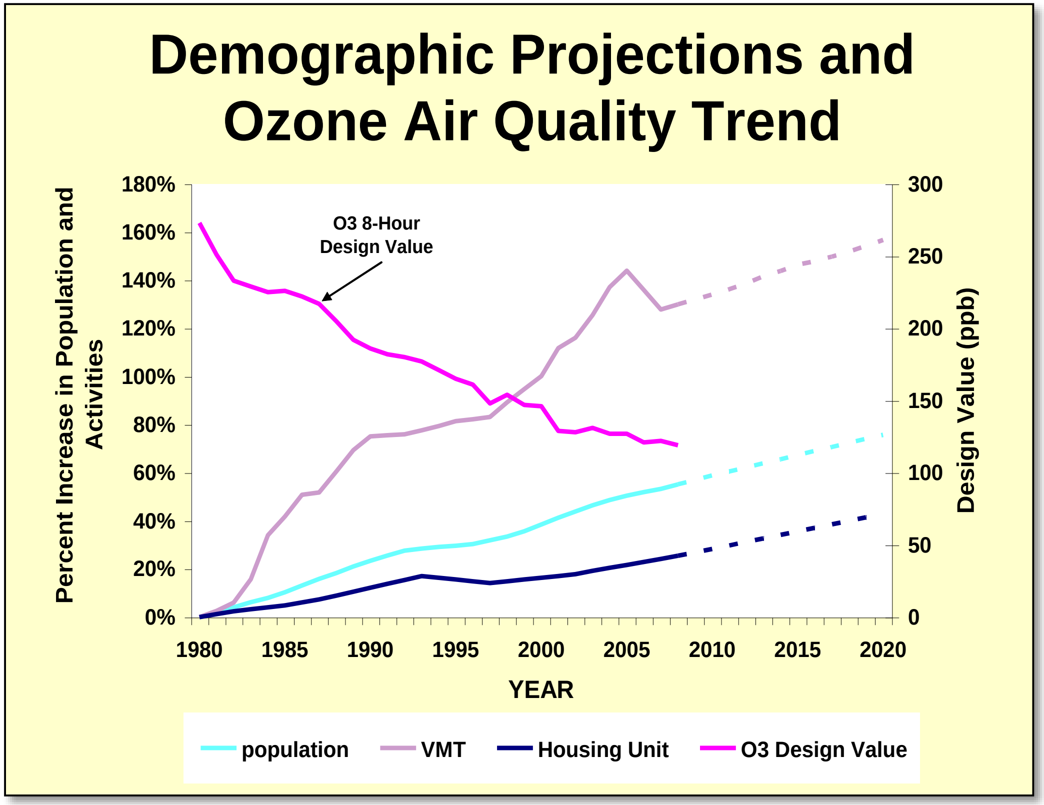
Needed Pollution Reduction to Meet Ozone Air Quality Standards



Key Challenges Moving Forward

- Significant Number of Conventional On-Road Vehicles
- Incentive to Purchase Zero- and Near-Zero Emission Technology
- Need for More Commercial Products (Especially, for Heavier Vehicle Applications)
- Enhancing the Electric, Alternative Fuel, and Hydrogen Fueling Infrastructure

Historically Air Quality Progress With Growth
Key Reason: *Technology*



- South Coast AQMD Policy Generally *Growth Accommodating*
- Sources Generally Controlled over 90%
- Technical Challenges Increasing
- Increasing Marginal Control Costs . . . Diminishing Marginal Returns

Commercially Available Battery Electric and Plug-in Electric Vehicles

Going Beyond Current Technologies

- Battery Electric
- Fuel Cell/Hybrid
- Natural Gas/Hybrid
- Extended Range Catenary/Wayside
- Alternative Fuels/ Going Beyond 2010 On-Road Emission Standards







Opportunities

- Research and Demonstration Programs
  - Heavy-Duty Truck Program Underway
  - Need to Develop Market Signals for Commercialization
- Funding Programs
  - Successful in Accelerating Vehicle/ Truck Turnover
  - Need for Additional Funding

Cleaner On-Road Heavy-Duty Combustion Engines

- Volvo Engines Certification Level at
0.06 g/bhp-hr for 0.8, 12.8, and 16.1 Liter Engines

- Smaller 6.8 Liter Natural Gas Engines
(242 hp to 362 hp)Between 0.05 to 0.01 g/bhp-hr

Heavy-Duty Natural Gas Engines

0.02 g NOx

90% ↓ Existing Standard

Near-Zero

8.9L

South Coast AQMD

State of California Energy Commission

Southern California Gas Company

Cummins

Westport

Clean Energy

12L

Source: www.blogcdn.com/www.autoblog.com/media/
2013/03/international-transtar-lpg.jpg

SCAQMD Zero-Emission Truck Projects

- Dedicated Battery-Electric Truck
  - Transpower (4 Trucks)
  - U.S. Hybrid (2 Trucks)

- Fuel Cell Hybrid Electric Truck
  - BAE Systems (Battery-Electric Truck with H2 Fuel Cell Range Extender)
  - Transpower (2 Battery-Electric Truck with H2 Fuel Cell Range Extender)
  - U.S. Hybrid (2 Battery-Electric Trucks with Onboard H2 Generator)

- Hybrid Electric Trucks with All Electric Range
  - Transpower (2 CNG Plug-In Hybrid Trucks)
  - U.S. Hybrid (3 LNG Plug-In Hybrid Trucks)
  - BAE Systems/Kenworth (Battery Electric with CNG Range Extender)
  - International Rectifier (Plug-In Hybrid Electric and Ultra-fast Chargers)
- Overhead Catenary System
  - Vovlo, Transpower, and BAE/Kenworth

Successful Partnership Model

TAB 10

EPA/600/R-15/068 | January 2016 | www.epa.gov/isa

United States
Environmental Protection
Agency

Integrated Science Assessment for Oxides of Nitrogen – Health Criteria

Office of Research and Development
National Center for Environmental Assessment, Research Triangle Park, NC

emissions is available for NO_X, which is emitted primarily as NO. NO rapidly reacts with radicals and ozone (O_3) to form NO_2 in the air. Based on the 2011 National Emissions Inventory, the largest single source of NO_X emissions in the U.S. overall and in major population centers (city and surrounding communities) is highway vehicles (40−67%; Section 2.3, Table 2-1). Sources such as electric utilities, commercial and residential boilers, and industrial facilities are more variable across locations but can be important contributors to ambient NO_2 concentrations for the U.S. as a whole and in certain populated areas. Some of these smaller sources can affect local air quality with large, transient emissions of NO_X. Natural sources such as microbial processes in soil and wildfires contribute 2% of emissions in U.S. population centers, and emissions from natural and anthropogenic sources from continents other than North America (i.e., North American Background) account for less than 1% (typically 0.3 ppb) of ambient concentrations (Section 2.5.6). Although highway vehicles are a large, ubiquitous source of NO_X, the varying presence and mix of specific emissions sources across locations can contribute to heterogeneity in ambient NO_2 concentrations regionally and locally, which has implications for variation in exposure to ambient NO_2 within the population.

In addition to emissions sources, factors that influence NO_2 ambient concentrations include chemical transformations, transport to other locations, meteorology, and deposition to surfaces (Figure 1-1 and in more detail, Figure 2-1). NO and NO_2 react with gas phase radicals and O_3 to form other oxides of nitrogen such as peroxyacetyl nitrate (PAN) and nitric acid (HNO_3; Section 2.2). NO and NO_2 also are involved in reaction cycles with radicals produced from volatile organic compounds (VOCs) to form O_3. The reactions of NO and NO_2 into other oxides of nitrogen typically occur more slowly than the interconversion between NO_2 and NO does, and NO and NO_2 are the most prevalent oxides of nitrogen in populated areas. HNO_3 and PAN can make up a large fraction of ambient oxides of nitrogen downwind of major emission sources.

Sources, atmospheric transformations, and meteorology contribute to the temporal trends observed in ambient NO_2 concentrations. As a result of pollution control technologies on vehicles and electric utilities (Section 2.3.2), NO_X emissions from highway vehicles and fuel combustion decreased by 49% in the U.S. from 1990 to 2013 (Figure 2-2). During that time (1990−2012), U.S.-wide annual average NO_2 concentrations decreased by 48% (Figure 2-22). In addition to long-term trends, ambient NO_2 concentrations show seasonal trends, with higher concentrations measured in the winter than summer. Reflecting trends in traffic, ambient concentrations at most urban sites are higher on weekdays than weekends, and within a day, concentrations peak in early mornings, decrease until late afternoon, then increase again in early evening corresponding with morning and evening commutes. Diurnal trends in ambient NO_2 also are affected by meteorology, with

TAB 11

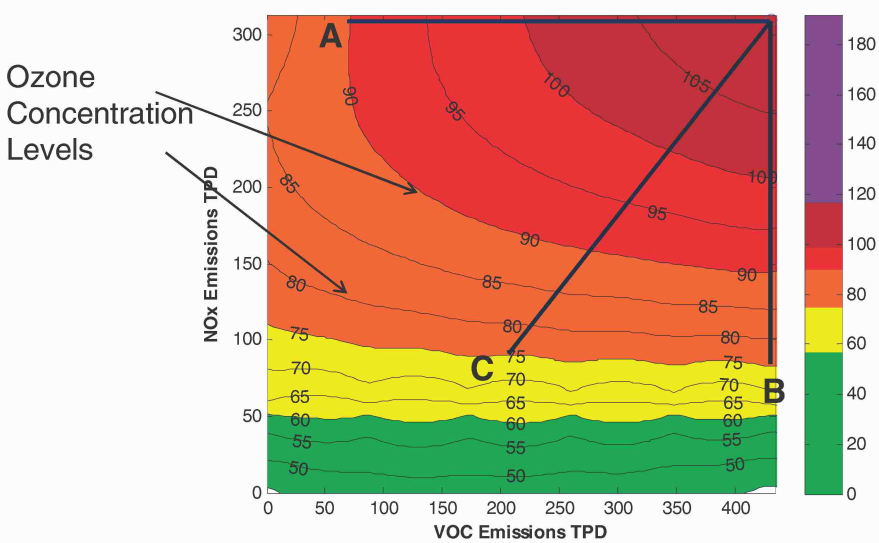
Agenda No. 2

Further Emission Reduction from Mobile Sources Needed to Attain Federal Air Quality Standards

Governing Board Retreat
May 7, 2015

Cleaning the Air That We Breathe…

Ozone Carrying Capacity Based on Attaining at Crestline

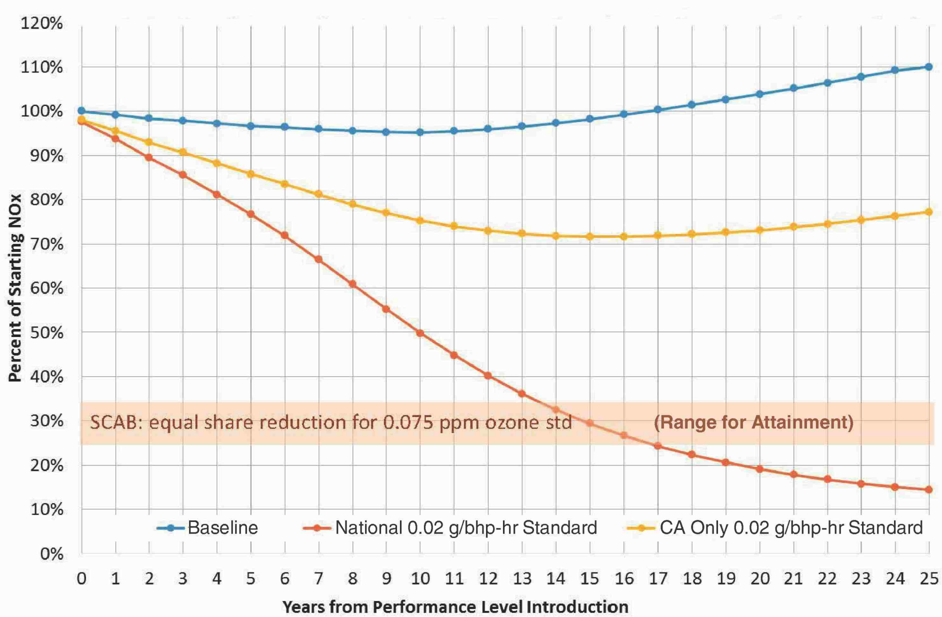


A – VOC Focused Strategy B – NOx Focused Strategy C – Combined Strategy

Staff Recommended Actions to U.S. EPA and CARB

- **On-Road Heavy-Duty Engines/Trucks**
  - 0.02 g/bhp-hr NOx Emission Standard for New On-Road HD Engines
  - Funding Incentives for Acquisition of 0.02 g HD Trucks
  - In-Use Regulations Requiring Deployment of HD Trucks
  - Zero-Emission Drayage Trucks to Near-Dock Railyards
- **Ocean-Going Vessels**
  - Accelerate Deployment of Tier 3 Marine Vessels through Incentives, Project Conditions, and/or Regulation
- **Locomotives**
  - Tier 4 or Cleaner Locomotives in CA by 2023

Emissions Analysis of a Statewide vs National Introduction of a New Technology*



Source: Presentation by Mr. Cory Palmer, ARB at the Symposium on California's Development of its Phase 2 Greenhouse Gas Emission Standards for On-Road Heavy-Duty Vehicles (April 22, 2015)

TAB 12

NESCAUM
www.nescaum.org
Northeast States for Coordinated Air Use Management
89 South Street, Suite 602 Boston, MA 02111
Phone 617-259-2000 Fax 617-742-9162
Arthur N. Marin, Executive Director

October 1, 2015

Christopher Grundler
Director, Office of Transportation and Air Quality
U.S. Environmental Protection Agency
Air and Radiation Docket and Information Center
Mail Code 28221T
1200 Pennsylvania Avenue NW
Washington, DC 20460
Attention: Docket I.D. #EPA-HQ-OAR-2014-0827

Mark R. Rosekind
Administrator
National Highway Transportation Safety Administration
U.S. Department of Transportation
Docket Management Facility M-30, West Building, Ground Floor, Rm. W12-140
1200 New Jersey Avenue SE
Washington, DC 20590
Attention: Docket I.D. #NHTSA- 2014-0132

Re: *Proposed Rules for Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2*

Dear Docket Administrator:

The Northeast States for Coordinated Air Use Management (NESCAUM) offers the following comments on the joint EPA/NHTSA proposal, published on July 13, 2015 in the Federal Register, entitled *Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2* (80 Fed. Reg. 40138-40765). NESCAUM is the regional association of air pollution control agencies in Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. The comments below reflect the majority views of NESCAUM as a state membership organization. Individual NESCAUM member states may hold views different from the NESCAUM states' majority consensus.

Our states commend EPA and NHTSA for proposing rules that will lead to substantial reductions in greenhouse gas (GHG) emissions from the heavy-duty sector. The rule as proposed, however, does not take full advantage of available and proven technologies and should be made stronger in several areas. In addition, our states remain concerned about emissions of nitrogen oxides (NOx) from this sector, and urge EPA to begin rulemaking to require further reductions in NOx from heavy-duty trucks at the earliest possible date. Below we discuss several specific areas in which the rule can and should be strengthened.

The agencies should adopt the timeline proposed in Alternative #4.
Given that the proposed technologies are already mature or have been successfully demonstrated, and given our states' need for significant GHG reductions in the near term, the timeline proposed in Alternative #4 is both reasonable and appropriate. Based on the assessments of the California Air Resources Board (CARB) and the International Council on Clean Transportation (ICCT), a full phase-in of the rules by 2024 is technologically feasible. Given the scope of needed GHG reductions, and the compelling benefits to freight industries and their consumers from reduced fuel expenditures, 2027 is too long to wait to realize the full potential of this rule.

As ICCT[1] and CARB[2] have noted, existing technologies are already available to provide the proposed reductions in the 2024 timeframe. Moreover, manufacturers have expressed their intentions to further increase the deployment of these technologies in the near term. These technologies are cost-effective and have been shown to provide strong return on investment for operators.

The engine standard should be stronger.
The proposal would reduce fuel consumption from engines by 4.2 percent, which is far short of what is achievable over the coming decade. We note that at least one engine manufacturer has indicated potential engine efficiency improvements of 15 percent or more even with advanced NOx controls. Moreover, EPA's estimates for both the effectiveness and likely market penetration of engine efficiency technology improvements are far too conservative, according to analyses performed by CARB[3] and ICCT.[4]

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[1] International Council on Clean Transportation, *Advanced Tractor-Trailer Efficiency Technology Potential in the 2020-2030 Timeframe* (April 2015). Available at: http://www.theicct.org/sites/default/files/publications/ICCT_ATTEST_20150420.pdf.

[2] California Air Resources Board, *Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency* (June 2015). Available at: http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf.

[3] California Air Resources Board, *Engine/Powerplant and Drivetrain Optimization: Vehicle/Trailer Efficiency Technology Assessment*, presented at the Air Resources Board Symposium on California's Development of its Phase 2 Greenhouse Gas Emission Standards for On-Road Heavy-Duty Vehicles (April 22, 2015). Available at: http://www.arb.ca.gov/msprog/onroad/caphase2ghg/presentations/2_1_alex_s_arb.pdf.

[4] International Council on Clean Transportation, *United States Efficiency and Greenhouse Gas Emission Regulations for Model Year 2018-2027 Heavy-Duty Vehicles, Engines, and Trailers* (July 2015). Available at: http://www.theicct.org/sites/default/files/publications/ICCT-update_US-HDV-Ph2-NPRM_jun2015_v2.pdf.

The full-vehicle standard should be stronger.
Commensurate with increased engine stringency, the tractor standards should be strengthened to ensure that manufacturers utilize the full suite of appropriate complementary technologies, in addition to engine improvements.

There should be no backsliding on fine particulate matter (PM2.5) and NOx from increased use of auxiliary power units (APUs).
We also urge the agencies to ensure that there are no increases in emissions of either PM2.5 or NOx as a result of the proposed rule. We note that the agencies project an increase in PM2.5 as a result of increased APU use. While idle reduction represents an important opportunity for fuel savings, any increase in this harmful pollutant is unacceptable, particularly given that appropriate PM control technology for APUs is already in the marketplace and currently required by CARB. EPA should adopt similar requirements to CARB's for PM control on APUs, and should do so concurrently with this proposed Phase 2 rulemaking. Similarly the agencies should ensure there is no backsliding on NOx emissions as a result of increased use of APUs.

The agencies should close the "Glider Kit" loophole.
We strongly support the proposed measure to ensure that glider kits are subject to the same applicable regulations as other new trucks. This common sense measure will prevent gaming and will avoid significant amounts of unnecessary emissions of GHGs, NOx, and PM2.5. The agencies request comment on the appropriate magnitude of the exemption. While we agree that some minimal exemption opportunity is probably appropriate in limited cases, we urge the agencies to set this number as low as is practical without impeding small businesses with legitimate claims.

EPA should address the potential for further NOx reductions at the earliest possible date.
Heavy-duty trucks represent the second largest source of NOx emissions in the NESCAUM region, and our states remain very concerned about the need to further control NOx emissions from this sector. We thank the agencies for acknowledging the challenge that states continue to face in this regard, and we urge EPA to begin a rulemaking without delay to ensure that the next generation of trucks is not only more fuel efficient but also much less of a contributor to states' air quality and public health problems.

The NESCAUM region, home to over 42 million people, is subject to episodes of poor air quality resulting from ground-level ozone and fine particle pollution. During severe events, the scale of the problem can extend beyond NESCAUM's borders and include over 200,000 square miles across the eastern United States. Local and regional sources as well as air pollution transported hundreds of miles from distant sources outside the region contribute to elevated ozone and fine particle concentrations in the region.

NOx emissions contribute to a number of adverse public health and environmental outcomes. NOx is the most important contributor to nitrogen dioxide and ground-level ozone pollution, and an important precursor to fine particulate matter formation. These pollutants are responsible for tens of thousands of premature deaths, hospital admissions, and lost work and school days in the U.S. annually. NOx is also a key factor in a number of environmental problems that affect the Northeast. Table 1 summarizes the major adverse impacts of NOx emissions in the NESCAUM region.

Table 1. Adverse Public Health and Environmental Impacts of NOx in the Northeast

Ozone and Fine Particulate Matter	Reduces lung function, aggravates asthma and other chronic lung diseases Can cause permanent lung damage from repeated exposures Contributes to premature death
Nitrogen Dioxide	Increases airway reactivity Worsens control of asthma Increases incidences of respiratory illnesses and symptoms
Acid Deposition	Damages forests Damages aquatic ecosystems, e.g., Adirondacks and Great Northern Woods Erodes manmade structures
Coastal Marine Eutrophication	Depletes oxygen in the water, which suffocates fish and other aquatic life in bays and estuaries, e.g., Chesapeake Bay and Long Island Sound
Visibility Impairment	Contributes to regional haze that mars vistas and views in urban and wilderness areas

Additional NOx reductions would benefit air quality and public health in the Northeast by: (1) lowering the "ozone reservoir" that forms in the eastern U.S., and (2) reducing the amount of low-level NOx emissions and pollutants derived from NOx that are transported into the Northeast/Mid-Atlantic region.

Ozone

Ozone remains a persistent pollution problem in parts of the NESCAUM region during warm weather months. The evolution of severe ozone episodes often begins with the passage of a large high pressure area from the Midwest to the middle or southern Atlantic states. Three primary pollution transport pathways affect air quality in the region: long-range, mid-level, and near-surface. During severe ozone episodes associated with high-pressure systems, these pathways converge on the Mid-Atlantic area, where sea and bay breezes act as a barrier and funnel ozone and other air pollutants up the Northeast Corridor.

Collectively, NOx emissions and ambient ozone concentrations in the region have dropped significantly since 1997, along with the frequency and magnitude of exceedances of the health-based ozone national ambient air quality standard (NAAQS).[5] Despite this demonstrated progress, some of the most populous areas of the region continue to violate the 2008 0.075 ppm ozone NAAQS. Attaining the standard in these areas will require significant additional NOx reductions within the Northeast and in upwind areas. Looking toward the future, additional NOx reductions will be critical to ozone attainment in order to meet the recently revised 0.070 ppm ozone NAAQS, which EPA projects will continue to be exceeded in our region in 2025.

Particulate Matter

Scientific evidence has established a solid link between cardiac and respiratory health risks and transient exposure to ambient fine particle pollution that is capable of penetrating deep into the lungs.[6] Exceedances of the fine particle NAAQS can occur at any time of the year, with some of the highest levels often reached in the winter. There are important differences in the chemical species responsible for high fine particle levels during summer and winter in the Northeast. Regional fine particle formation in the eastern United States is primarily due to SO_2, but NOx is also important because of its influence on the chemical equilibrium between sulfate and nitrate particles during winter when nitrates can be a relatively greater contributor to urban PM2.5 levels.

Acid Deposition

Atmospheric sources of nitrogen are a primary contributor to acidification of forest soils and fresh water ecosystems in the Northeast. Nitrogen saturation results in a number of important changes in forest ecosystem functions, including: (1) increased acidification of soils and surface waters; (2) depletion of soil nutrients and the development of plant nutrient imbalances; and (3) forest decline and changes in species composition. More than 30 percent of the lakes in the Adirondacks and at least 10 percent of the lakes in New England are susceptible to the effects of acidic episodes that include long-term increases in mortality, emigration, and reproductive

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[5] NESCAUM. 2010. *The Nature of the Ozone Air Quality Problem in the Ozone Transport Region: A Conceptual Description*, prepared for the Ozone Transport Commission by NESCAUM, Boston, MA (August 2010). Available at: http://www.nescaum.org/documents/2010_o3_conceptual_model_final_revised_20100810.pdf.

[6] U.S. EPA. 2005. *Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information*, USEPA OAQPS Staff Paper, EPA-452/R-05-005a (December 2005).

failure of fish, as well as short-term acute effects. Acidic episodes can occur at any time of the year but typically are most severe during spring snowmelt, when biological demand for nitrogen is low and saturated soils exhibit lower nitrogen retention.[7]

Marine Eutrophication

Airborne nitrogen is an important contributor to eutrophication, the process by which a body of water acquires a high concentration of nutrients that promote excessive growth of algae. As the algae die and decompose, high levels of organic matter and decomposing organisms deplete the water of available oxygen, causing the death of other organisms, such as fish. Atmospheric nitrogen is a major contributor to eutrophication of key coastal resources in the Northeast, including Barnegat Bay in New Jersey and Long Island Sound.[8] The Chesapeake Bay is the largest estuary in the U.S. and its watershed stretches across more than 64,000 square miles, encompassing parts of six states, including New York. Since the 1950s, the bay has experienced a decline in water quality due to over-enrichment of unwanted nutrients such as phosphorus and nitrogen. The major contributors to nutrient discharge in the bay are wastewater effluent, urban and agricultural runoff, and air deposition.[9]

Visibility Impairment

Regional haze is a form of air pollution that obscures the views of city skylines as well as "pristine" scenic vistas. It is caused by fine particle air pollution and can cover hundreds of square miles in the East. Natural visibility conditions in the East are estimated at 60 to 80 miles in most locations. Under current polluted conditions, average visibility ranges from 20 to 40 miles. On the worst days, regional haze can reduce visibility to just a few miles. Outdoor recreation is a multi-billion dollar industry in the U.S. and is of particular economic importance to communities near protected federal lands. Surveys indicate visitors have rated "clean, clear air" as among the most important features of national parks and have overwhelmingly ranked scenic views and clean air as "extremely" or "very" important. Studies have yielded estimates in the billions of dollars for the visibility benefits associated with substantial national pollution

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[7] Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. *Acidic deposition in the northeastern United States: Sources and inputs, ecosystem effects, and management strategies*, BioScience 51, 180–198.

[8] Bricker, S.B., C.G. Clement, D.E. Pirhalla, S.P. Orlando, and D.R.G. Farrow. 1999. *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*, NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science. Silver Spring, MD: 71 pp.

[9] Maryland Department of the Environment, *Chesapeake Bay Restoration*, http://www.mde.state.md.us/programs/Water/Pages/water/bayrestoration.aspx (accessed September 1, 2011).

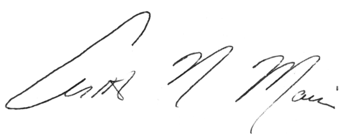
reductions.[10] While sulfate, formed from SO_2 emissions, is currently the most important particle constituent of regional haze in the East, reductions in other local and distant pollutant emissions, including NOx, will be necessary to achieve the nation's long-term goal of restoring pristine visibility conditions year-round in national parks and wilderness areas.[11]

Conclusion

In conclusion, we thank and commend the agencies for a diligent and thorough analysis, and for proposing a rule that is appropriate in structure and scope. The agencies, however, should strengthen certain provisions to maximize the benefits from this important program. In addition, EPA should ensure that emissions of other pollutants do not increase as a result of the rule, and should commence rulemaking to reduce NOx from heavy-duty vehicles at the earliest possible date.

If you have any questions regarding the issues raised in these comments, please contact Matt Solomon at NESCAUM (ph: 617-259-2029).

Sincerely,



Arthur N. Marin
Executive Director

[10] NESCAUM. 2001. *Regional Haze and Visibility in the Northeast and Mid-Atlantic States*, NESCAUM, Boston, MA (January 31, 2001). Available at: http://www.nescaum.org/documents/regional-haze-and-visibility-in-the-northeast-and-mid-atlantic-states/.

[11] In 1999, EPA promulgated the Regional Haze Rule in pursuit of the national visibility goal created by Congress in the Clean Air Act to ultimately restore natural visibility conditions in 156 national parks and wilderness areas across the country (called "Class I" areas).

TAB 13

Ozone Air Quality Standards: EPA's 2015 Revision

James E. McCarthy
Specialist in Environmental Policy

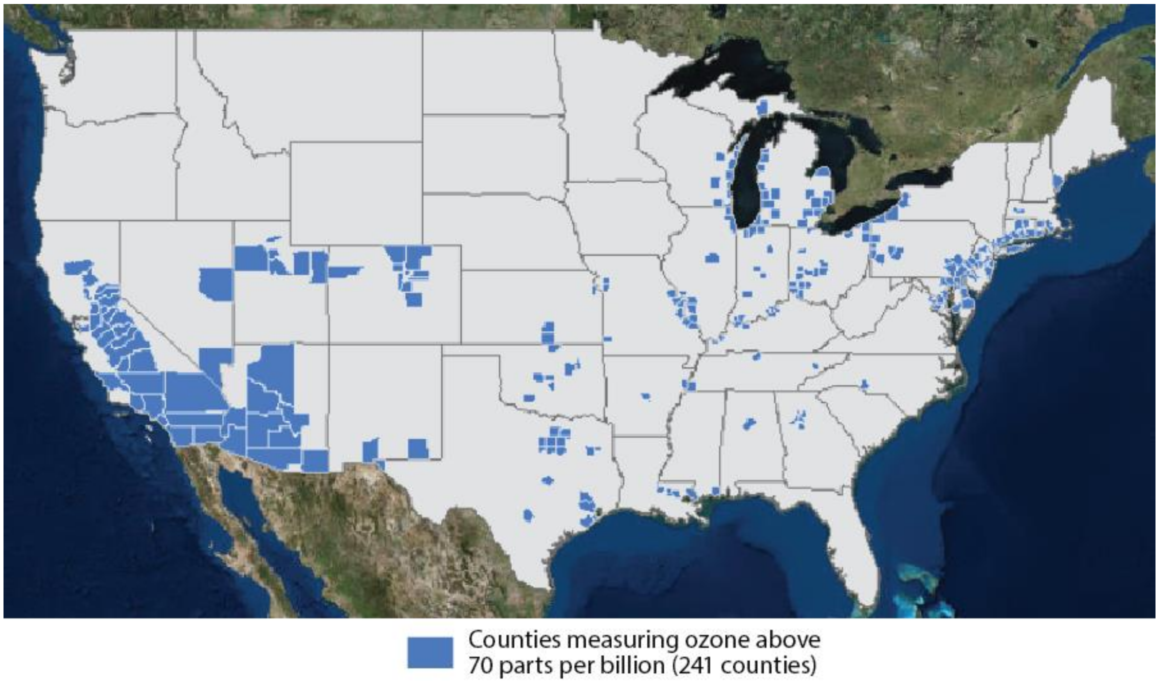
Richard K. Lattanzio
Analyst in Environmental Policy

January 25, 2016

Congressional Research Service
7-5700
www.crs.gov
R43092

CRS REPORT
Prepared for Members and
Committees of Congress

Figure 2. Counties Where Measured Ozone Is Above the Final Standard of 0.070 ppm, Based on 2012-2014 Monitoring Data



Source: U.S. Environmental Protection Agency, "Ozone Maps," http://www3.epa.gov/ozonepollution/maps.html.

Notes: Actual nonattainment area designations will be made in 2017 or later based on 2014-2016 or later monitoring data. No areas in Alaska and Hawaii exceeded the 70 ppb standard, based on 2012-2014 monitoring data.

What Are NAAQS?

NAAQS are federal standards that apply to ambient (outdoor) air. Section 109 of the Clean Air Act directs EPA to set both primary NAAQS, which are standards, "the attainment and maintenance of which in the judgment of the [EPA] Administrator ... are requisite to protect the public health," with "an adequate margin of safety," and secondary NAAQS, which are standards necessary to protect public welfare, a broad term that includes damage to crops, vegetation, property, building materials, climate, etc.[15]

The pollutants for which NAAQS have been set are generally referred to as "criteria" pollutants. The act defines them as pollutants that "endanger public health or welfare," and whose presence in ambient air "results from numerous or diverse mobile or stationary sources."[16] Six pollutants are currently identified as criteria pollutants: ozone, particulates, carbon monoxide, sulfur dioxide, nitrogen oxides, and lead. The EPA Administrator can add to this list if she determines

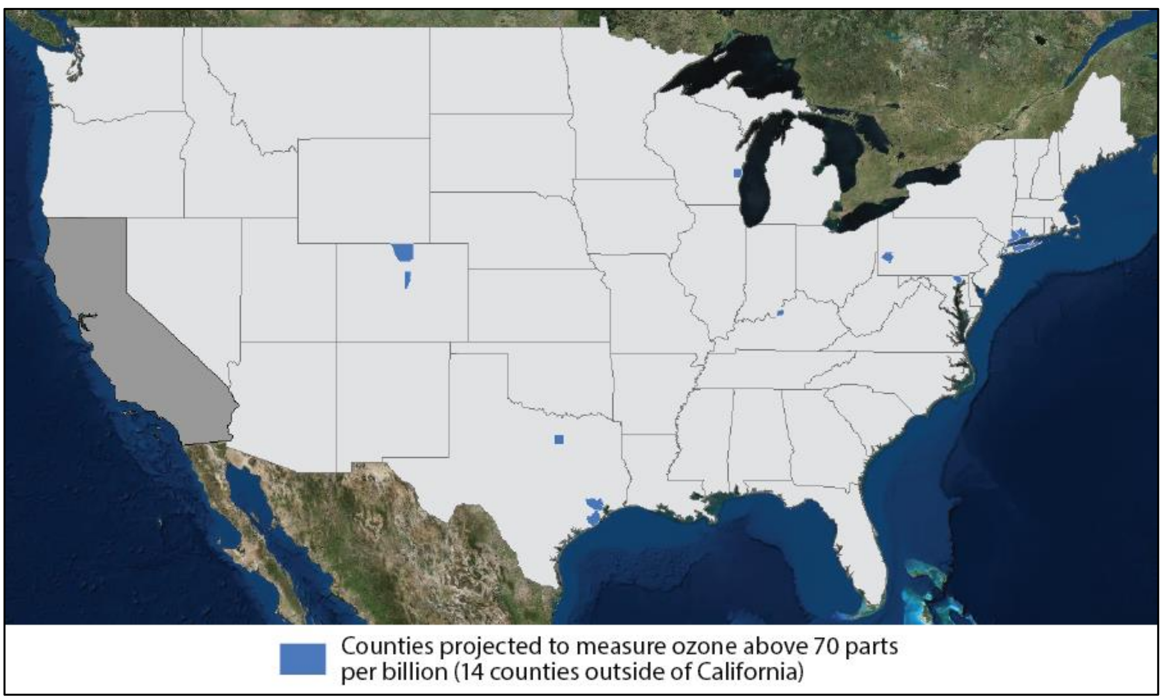
[15] The CAA's definition of welfare is found in Section 302(h) of the act (42 U.S.C. 7602(h)).

[16] Authority to establish NAAQS comes from both Sections 108 and 109 of the act; this definition of criteria pollutants is found in Section 108. The authority and procedures for controlling the sources of criteria pollutants are found throughout Titles I, II, and IV of the act. Many pollutants that are less widely emitted are classified as "hazardous air pollutants" and are regulated under a different section of the act (Section 112). That section lists 187 pollutants or groups of pollutants as hazardous and establishes different authorities and requirements for controlling their emissions.

The estimated annual nationwide costs (excluding the cost in California) is $1.4 billion in 2025 for a 70 ppb standard.[45] Although this is a large sum, it is substantially less than the cost estimates EPA provided for the same range of standards in 2008 and 2011. At that time, EPA projected costs of $19 billion to $25 billion to attain a 70 ppb standard. Two factors account for the reduction in cost:

1. The baseline from which additional costs are projected is now set at 75 ppb (the 2008 standard). In 2011, EPA projected $7.6 billion to $8.8 billion in costs to reach what is now that baseline.
2. Other rules promulgated since 2011 (notably the Tier 3 auto emission and gasoline standards and two rules affecting power plants) are expected to reduce ozone precursors whether or not EPA revises the NAAQS. As shown in **Figure 3**, the 2015 RIA projects that, by 2025, these other (already promulgated) rules will bring monitored ozone levels to 70 ppb or below in all but 14 counties (excluding California) of the 241 counties currently showing nonattainment with the 70 ppb level.[46]

Figure 3. EPA Projection of Counties That Will Not Meet the Revised Ozone Standards in 2025 Without Promulgation of Additional Emission Controls



Source: U.S. Environmental Protection Agency, "Ozone Maps" accompanying the October 2015 release of the final ozone NAAQS rule, http://www3.epa.gov/ozonepollution/maps.html.

Notes: EPA did not include areas in California. Because of more severe pollution, the Clean Air Act will give many areas in California until the 2030s to reach attainment. No areas in Alaska and Hawaii are projected to measure ozone above 70 ppb.

[45] EPA, 2015 RIA, p. ES-15.

[46] See EPA, "Ozone Maps," http://www3.epa.gov/ozonepollution/maps.html.

TAB 14

NACAA
national association of clean air agencies

Testimony of the
National Association of Clean Air Agencies
before the
U.S. Environmental Protection Agency
and the
National Highway Traffic Safety Administration
on the
Proposed Greenhouse Gas and Fuel Efficiency Standards for
Medium- and Heavy-Duty Engines and Vehicles – Phase 2
Docket ID No. EPA-HQ-OAR-2014-0827

August 6, 2015
Chicago, Illinois

The National Association of Clean Air Agencies (NACAA) appreciates this opportunity to provide testimony on the U.S. Environmental Protection Agency's (EPA) and the U.S. Department of Transportation National Highway Traffic Safety Administration's (NHTSA) Proposed Phase 2 Greenhouse Gas and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, as published in the *Federal Register* on July 13, 2015 (80 Fed. Reg. 40,137). NACAA is a national, non-partisan, non-profit association of air pollution control agencies in 41 states, the District of Columbia, four territories and 116 metropolitan areas. The air quality professionals in our member agencies have vast experience dedicated to improving air quality in the U.S. This testimony is based upon that experience. The views expressed in this testimony do not represent the positions of every state and local air pollution control agency in the country.

According to EPA, although heavy-duty trucks account for less than 5 percent of vehicles on U.S. roads, they are responsible for about 20 percent of the U.S. transportation sector's energy use and GHG emissions and are the second largest source of GHG emissions in the transportation sector after passenger cars and light trucks. These vehicles consume about 2.5 million barrels of oil a day and produce almost a half billion tons of carbon a year.

NACAA supported EPA's and NHTSA's efforts to adopt the first phase of GHG and fuel efficiency standards for heavy-duty vehicles and engines, which took effect with Model Year (MY) 2014 and is being phased in through MY 2018. Now, we are pleased to support your agencies' efforts to advance this program by establishing Phase 2 standards. We believe your proposal holds great promise for achieving further GHG reductions and better fuel efficiency from heavy-duty combination tractors, trailers, vocational vehicles and heavy-duty pickups and vans. Fulfilling that promise, however, will require some key improvements to the proposal.

But before addressing those, NACAA would like to commend EPA and NHTSA on several of the various aspects of the proposed rule that our association strongly supports. First, we fully endorse the continued inclusion of separate but complementary standards for engines and full vehicles – this is a fundamental aspect of the rule. Second, the inclusion of standards for trailers, particularly box trailers, is critical given their significant contribution to fuel consumption by long-haul trucks. Third, we are very much in favor of EPA's proposal to close the existing loophole for glider kits, under which used pre-2013 engines – with no limit on age – may be installed into new glider kits without meeting applicable standards. We agree with EPA that its regulations should be revised to require that only engines that have been certified to meet the prevailing standards be eligible for installation into new glider kits.

Now NACAA would like to highlight aspects of the rule our association believes should be improved.

In a March 18, 2015 letter to your respective agencies,[1] NACAA provided our recommendations for essential components of a Phase 2 rule. In those recommendations, we urged for a rule that would reduce GHG emissions and fuel consumption across the entire fleet by at least 40 percent, on average, compared to 2010. Unfortunately, we find the overall effectiveness of the Phase 2 proposal to fall short of our recommendation and, more importantly, significantly short of what can and should be achieved. Accordingly, we believe the overall stringency of the proposal should be enhanced to take advantage of missed opportunities that, if incorporated into the final rule, would drive technology and ensure that maximum benefits are gained.

Toward this end, we believe the proposed engine standard must be strengthened. Others – including the California Air Resources Board (CARB),[2] engine makers[3] and independent non-governmental organizations[4] – have suggested engine efficiency can be improved by 15 percent or more, compared to the 4.2 percent proposed by EPA. Further, their analyses, as well as those of EPA, indicate that technologies to achieve this degree of improvement are currently available and highly cost effective. We believe it is imperative that EPA strengthen the engine standard in the final rule to reflect this.

With respect to timing, NACAA strongly supports EPA's proposed Alternative 4, under which the standards would be fully implemented by 2024. This implementation deadline is entirely feasible and vitally important to spur much-needed near-term emissions reductions and technological innovation. NACAA urges EPA to finalize Alternative 4 rather than Alternative 3, which would unnecessarily extend full implementation by three years to 2027.

Our March 18, 2015 letter also included a recommendation that EPA articulate in the proposal the need for significantly lower national heavy-duty nitrogen oxide (NO_x) standards beyond the current 2010 onroad heavy-duty NO_x exhaust emission standards and nonroad heavy-duty engine exhaust emission standards. We are very disappointed that EPA has not included such a discussion in this proposal.

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[1] NACAA Letter to EPA and NHTSA providing recommendations on a Phase 2 regulatory proposal (March 18, 2015), http://www.4cleanair.org/sites/default/files/Documents/NACAA-Letter_to_EPA_DOT-Ph2_HD_Fuel_EffGHG_Stds-031815.pdf.
[2] California Air Resources Board, *Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency* (June 2015), http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf.
[3] Cummins, *Engine Technologies for GHG and Low NO_x* (April 2015), http://www.arb.ca.gov/msprog/onroad/caphase2ghg/presentations/2_7_wayne_e_cummins.pdf.
[4] International Council on Clean Transportation, *Advanced Tractor-Trailer Efficiency Technology Potential in the 2020-2030 Timeframe* (April 2015), http://www.theicct.org/sites/default/files/publications/ICCT_ATTEST_20150420.pdf.

Although there is the potential for ancillary NO_x reductions from the Phase 2 rule, the achievement of these reductions is not certain (we note that predicted ancillary benefits of Phase 1 did not occur). Moreover, even if ancillary NO_x benefits do accrue under the Phase 2 rule, they will not be nearly sufficient given the challenges state and local agencies face in attaining and maintaining current and upcoming ozone and fine particulate matter (PM) standards and protecting against visibility impairment and eutrophication of water bodies. We urge that EPA include in the final Phase 2 rule a clear and comprehensive discussion of the need for very substantial additional NO_x reductions from heavy-duty vehicles and engines and, even more critically, an explicit commitment to begin immediately a separate rulemaking initiative to capture those reductions.

Finally, EPA projects an increase in the use of auxiliary power units (APUs) in Phase 2 and an associated 10-percent increase in PM emissions. The agency seeks comment on this, but proposes nothing to address the unacceptable and unnecessary expected rise in PM pollution. NACAA recommends that EPA include in the final rule a requirement, similar to CARB's, that APUs be equipped with diesel particulate filters to capture the PM.

In conclusion, NACAA believes EPA and NHTSA have a tremendous opportunity to finalize a rule that will effectively address heavy-duty vehicle and engine GHG emissions and fuel consumption and set the stage for a separate rule to achieve meaningful additional NO_x reductions. We urge you to make the most of this opportunity. Further, in doing so, we encourage that your agencies collaborate with experts at CARB, given California's unique ability to regulate these same source categories, its decades of experience in doing so and the past success that has been achieved when EPA, and more recently NHTSA, have collaborated with CARB.

In the coming weeks, we will continue to study issues related to the Phase 2 proposal and will offer additional comments in writing by the September 17, 2015 deadline. In the meantime, we appreciate the chance to provide the comments we have offered today and look forward to continuing to work with EPA and NHTSA on this important initiative.

TAB 15

NACAA
national association of clean air agencies

Testimony of
Henry Hogo
on behalf of the
National Association of Clean Air Agencies
before the
U.S. Environmental Protection Agency
and the
National Highway Traffic Safety Administration
on the
Proposed Greenhouse Gas and Fuel Efficiency Standards for
Medium- and Heavy-Duty Engines and Vehicles – Phase 2
Docket ID No. EPA-HQ-OAR-2014-0827

August 18, 2015
Long Beach, California

Good morning. I am Henry Hogo, Assistant Deputy Executive Officer for the Mobile Source Division in the Office of Science and Technology Advancement of the South Coast Air Quality Management District. I appear here this morning on behalf of NACAA – the National Association of Clean Air Agencies. I appreciate this opportunity to provide the association's testimony on the U.S. Environmental Protection Agency's (EPA) and the U.S. Department of Transportation National Highway Traffic Safety Administration's (NHTSA) Proposed Phase 2 Greenhouse Gas and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, as published in the *Federal Register* on July 13, 2015 (80 Fed. Reg. 40,137). NACAA is a national, non-partisan, non-profit association of air pollution control agencies in 41 states, the District of Columbia, four territories and 116 metropolitan areas. The air quality professionals in our member agencies have vast experience dedicated to improving air quality in the U.S. This testimony is based upon that experience. The views expressed in this testimony do not represent the positions of every state and local air pollution control agency in the country.

According to EPA, although heavy-duty trucks account for less than 5 percent of vehicles on U.S. roads, they are responsible for about 20 percent of the U.S. transportation sector's energy use and GHG emissions and are the second largest source of GHG emissions in the transportation sector after passenger cars and light trucks. These vehicles consume about 2.5 million barrels of oil a day and produce almost a half billion tons of carbon a year.

NACAA supported EPA's and NHTSA's efforts to adopt the first phase of GHG and fuel efficiency standards for heavy-duty vehicles and engines, which took effect with

Model Year (MY) 2014 and is being phased in through MY 2018. Now, we are pleased to support your agencies' efforts to advance this program by establishing Phase 2 standards. We believe your proposal holds great promise for achieving further GHG reductions and better fuel efficiency from heavy-duty combination tractors, trailers, vocational vehicles and heavy-duty pickups and vans. Fulfilling that promise, however, will require some key improvements to the proposal.

But before addressing those, NACAA would like to commend EPA and NHTSA on several of the various aspects of the proposed rule that our association strongly supports. First, we fully endorse the continued inclusion of separate but complementary standards for engines and full vehicles – this is a fundamental aspect of the rule. Second, the inclusion of standards for trailers, particularly box trailers, is critical given their significant contribution to fuel consumption by long-haul trucks. Third, we are very much in favor of EPA's proposal to close the existing loophole for glider kits, under which used pre-2013 engines – with no limit on age – may be installed into new glider kits without meeting applicable standards. We agree with EPA that its regulations should be revised to require that only engines that have been certified to meet the prevailing standards be eligible for installation into new glider kits.

Now I would like to highlight aspects of the rule NACAA believes should be improved.

In a March 18, 2015 letter to your respective agencies,[1] NACAA provided recommendations for essential components of a Phase 2 rule. In those recommendations, we urged for a rule that would reduce GHG emissions and fuel consumption across the entire fleet by at least 40 percent, on average, compared to 2010. Unfortunately, we find the overall effectiveness of the Phase 2 proposal to fall short of our recommendation and, more importantly, significantly short of what can and should be achieved. Accordingly, we believe the overall stringency of the proposal should be enhanced to take advantage of missed opportunities that, if incorporated into the final rule, would drive technology and ensure that maximum benefits are gained.

Toward this end, we believe the proposed engine standard must be strengthened. Others – including the California Air Resources Board (CARB),[2] engine makers[3] and independent non-governmental organizations[4] – have suggested engine efficiency can be improved by 15 percent or more, compared to the 4.2 percent proposed by EPA. Further, their analyses, as well as those of EPA, indicate that technologies to achieve this degree of improvement are currently available and highly cost effective. We believe it is imperative that EPA strengthen the engine standard in the final rule to reflect this.

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---

[1] NACAA Letter to EPA and NHTSA providing recommendations on a Phase 2 regulatory proposal (March 18, 2015), http://www.4cleanair.org/sites/default/files/Documents/NACAA-Letter_to_EPA_DOT-Ph2_HD_Fuel_EffGHG_Stds-031815.pdf.

[2] California Air Resources Board, *Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency* (June 2015), http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf.

[3] Cummins, *Engine Technologies for GHG and Low* NO_x (April 2015), http://www.arb.ca.gov/msprog/onroad/caphase2ghg/presentations/2_7_wayne_e_cummins.pdf.

[4] International Council on Clean Transportation, *Advanced Tractor-Trailer Efficiency Technology Potential in the 2020-2030 Timeframe* (April 2015), http://www.theicct.org/sites/default/files/publications/ICCT_ATTEST_20150420.pdf.

Our March 18, 2015 letter also included a recommendation that EPA articulate in the proposal the need for significantly lower national heavy-duty nitrogen oxide (NO_x) standards beyond the current 2010 onroad heavy-duty NO_x exhaust emission standards and nonroad heavy-duty engine exhaust emission standards. We are very disappointed that EPA has not included such a discussion in this proposal. Although there is the potential for ancillary NO_x reductions from the Phase 2 rule, the achievement of these reductions is not certain (we note that predicted ancillary benefits of Phase 1 did not occur). Moreover, even if ancillary NO_x benefits do accrue under the Phase 2 rule, they will not be nearly sufficient given the challenges state and local agencies face in attaining and maintaining current and upcoming ozone and fine particulate matter (PM) standards and protecting against visibility impairment and eutrophication of water bodies. We urge that EPA include in the final Phase 2 rule a clear and comprehensive discussion of the need for very substantial additional NO_x reductions from heavy-duty vehicles and engines and, even more critically, an explicit commitment to begin immediately a separate rulemaking initiative to capture those reductions.

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In conclusion, NACAA believes EPA and NHTSA have a tremendous opportunity to finalize a rule that will effectively address heavy-duty vehicle and engine GHG emissions and fuel consumption and set the stage for a separate rule to achieve meaningful additional NO_x reductions. We urge you to make the most of this opportunity. Further, in doing so, we encourage that your agencies collaborate with experts at CARB, given California's unique ability to regulate these same source categories, its decades of experience in doing so and the past success that has been achieved when EPA, and more recently NHTSA, have collaborated with CARB.

In the coming weeks, NACAA will continue to study issues related to the Phase 2 proposal and will offer additional comments in writing by the September 17, 2015 deadline. In the meantime, we appreciate the chance to provide the comments today and look forward to continuing to work with EPA and NHTSA on this important initiative.

TAB 16

NACAA
national association of clean air agencies

September 29, 2015

Administrator Gina McCarthy
U.S. Environmental Protection Agency
Air and Radiation Docket and Information Center
Docket ID No. EPA-HQ-OAR-2014-0827
Mail Code: 28221T
1200 Pennsylvania Avenue, NW
Washington, DC 20460

Administrator Mark R. Rosekind
U.S. Department of Transportation
National Highway Traffic Safety Administration
Docket ID No. NHTSA-2014-0132
Docket Management Facility, M-30
1200 New Jersey Avenue, SE
Washington, DC 20590

Dear Administrators McCarthy and Rosekind:

The National Association of Clean Air Agencies (NACAA) appreciates this opportunity to comment on the U.S. Environmental Protection Agency's (EPA) and the National Highway Traffic Safety Administration's (NHTSA) joint proposal, entitled *Greenhouse Gas and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2*, as published in the *Federal Register* on July 13, 2015 (80 Fed. Reg. 40,137). NACAA is a national, non-partisan, non-profit association of air pollution control agencies in 41 states, the District of Columbia, four territories and 116 metropolitan areas. The air quality professionals in our member agencies have vast experience dedicated to improving air quality in the U.S. This testimony is based upon that experience. The views expressed in this testimony do not represent the positions of every state and local air pollution control agency in the country.

According to EPA, although heavy-duty trucks account for less than 5 percent of vehicles on U.S. roads, they are responsible for about 20 percent of the U.S. transportation sector's energy use and greenhouse gas (GHG) emissions, and are the second largest source of GHG emissions in the transportation sector after passenger cars and light trucks. These vehicles consume about 2.5 million barrels of oil a day and produce almost a half billion tons of carbon a year.

NACAA supported EPA's and NHTSA's efforts to adopt the first phase of GHG and fuel efficiency standards for heavy-duty vehicles and engines, which took effect with Model Year (MY) 2014 and are being phased in through MY 2018. Now, we are pleased to support your agencies' efforts to advance this program by establishing Phase 2 standards. We believe your proposal holds great promise for achieving further GHG

444 North Capitol Street, NW • Suite 307 • Washington, DC 20001 • phone 202.624.7864 • fax 202.624.7863 • www.4cleanair.org

reductions and better fuel efficiency from heavy-duty combination tractors, trailers, vocational vehicles and heavy-duty pickups and vans. Fulfilling that promise, however, will require some key improvements to the proposal.

But before addressing those, NACAA would like to commend EPA and NHTSA on several aspects of the proposed rule that our association strongly supports.

We strongly endorse the continued inclusion of separate but complementary standards for engines and whole vehicles – this is a fundamental aspect of the rule. Separate engine standards are critical for the Phase 2 program because they directly address the source of GHG emissions and ensure that engine manufacturers will incorporate some level of engine efficiency improvements that will reduce GHG emissions over the useful life of the vehicle. Engine test procedures and methods have been refined over decades of implementation and provide high certainty that verifiable emission reductions will occur when engines are in use. Separate engine standards are also important because engine GHG emission levels can be directly verified through the existing engine certification test protocols: the Supplemental Emission Test (SET) and Federal Test Procedure (FTP). The SET and FTP used to certify engines to GHG and criteria pollutant emission standards, such as for oxides of nitrogen (NO_x), provide a direct link between GHG and NO_x emission measurement methods. Further, separate engine standards prompt development of advanced engine technologies that, in turn, can offer a substantial improvement in a vehicle's fuel efficiency. In the absence of separate engine standards, some vehicle manufacturers may rely more heavily on vehicle improvements, such as aerodynamic technologies, that are less effective at reducing fuel consumption and emissions, particularly as vehicles change vocations, or functions, over time.

We are also very much in favor of EPA's proposal to close the existing loophole for glider kits and glider vehicles, under which used pre-2013 engines – with no limit on age – may be installed into new glider kits without meeting applicable standards. We agree with EPA that its regulations should be revised to require that only engines that have been certified to meet the prevailing standards be eligible for installation into new glider kits. The sale of glider kits has increased 10-fold[1] since the implementation of federal 2007/2010 particulate matter (PM) and NO_x emission standards. The proposed changes will stem the unrestricted sale of glider vehicles with older, higher-emitting engines. With respect to implementation of EPA's proposed glider requirements, we believe this should occur as soon as possible but no later than January 2018.

With respect to aspects of the proposal NACAA believes should be improved, we offer the following comments.

In a March 18, 2015 letter to your respective agencies,[2] NACAA provided our recommendations for essential components of a Phase 2 rule. In those recommendations, we urged for a rule that would reduce GHG emissions and fuel consumption across the entire fleet by at least 40 percent, on average, compared to 2010. Unfortunately, we find the overall effectiveness of the Phase 2 proposal to fall short of our recommendation and, more importantly, significantly short of what can and should be achieved. Accordingly, we believe the overall stringency of the proposal should be enhanced to take advantage of

[1] U.S. EPA, *Frequently Asked Questions about Heavy-Duty "Glider Vehicles" and "Glider Kits"* (2015), http://www.epa.gov/OMS/climate/documents/420f15904.pdf.
[2] NACAA Letter to EPA and NHTSA providing recommendations on a Phase 2 regulatory proposal (March 18, 2015), http://www.4cleanair.org/sites/default/files/Documents/NACAA-Letter_to_EPA_DOT-Ph2_HD_Fuel_EffGHG_Stds-031815.pdf.

missed opportunities that, if incorporated into the final rule, would drive technology and ensure that maximum emission reductions and reduced fuel consumption are achieved.

Toward this end, we believe the proposed engine standards must be strengthened. Others – including the California Air Resources Board (CARB),[3] engine makers[4] and independent non-governmental organizations[5] – have suggested engine efficiency can be improved significantly more than the modest 4.2 percent proposed by EPA. Recent work by the Southwest Research Institute, West Virginia University, the U.S. Department of Energy's SuperTruck teams and Cummins, the largest manufacturer of heavy-duty truck engines, all indicates the feasibility of engine GHG reductions in the Phase 2 timeframe at levels more than twice that included in the proposal. Further, these analyses, as well as those of EPA, indicate that technologies to achieve this degree of improvement are currently available and highly cost effective. In conjunction with increasing engine standards, we also recommend that EPA increase the corresponding whole-vehicle standards to capitalize on the full emission reduction potential of efficiency-improving technologies. We believe it is imperative that EPA strengthen the engine and vehicle standards in the final rule to reflect this.

With respect to timing, NACAA strongly supports EPA's proposed Alternative 4, under which the standards would be fully implemented by 2024. This implementation deadline is entirely feasible and vitally important to spur much-needed near-term emissions reductions and technological innovation. Further, Alternative 4 would provide manufacturers of heavy-duty engines and vehicles nearly eight years of lead time to develop and apply technologies needed to comply with the most stringent GHG emissions standards and is consistent with the lead-time requirements of section 202(a)(2) of the Clean Air Act. NACAA urges EPA to finalize Alternative 4 rather than Alternative 3, which would unnecessarily extend full implementation by three years to 2027, particularly when all of the technologies/approaches required already exist, with many already deployed on today's trucks.

We believe, in general, that the Phase 2 proposal is overly pessimistic regarding the implementation outlook for advanced technologies nationwide. The proposal also underestimates the ability of engine and truck manufacturers to incorporate longer-term technical solutions now for meeting global climate goals. As such, we recommend that EPA take a more assertive stance in challenging industry to accelerate technology innovation by adopting Alternative 4. EPA includes the projected compliance costs for the proposed emission standards under Alternatives 3 and 4 in the proposal. Even the projected higher compliance costs for Alternative 4 – which constitute only a fraction of the base costs of new engines and vehicles – are more than offset by the cost savings from reduced fuel consumption within two to six years. With respect to fuel efficiency and emission reductions, the proposal indicates that, on a nationwide basis, Alternative 4 overall would save 10 billion more gallons of fuel and provide about 130 more million metric tons of GHG reductions by 2030 than Alternative 3. These are important improvements that can and should be realized.

Additionally, EPA assumes in the proposal only a modest level of hybrid technology and no use of other advanced technologies, such as electric or fuel cell. Further, the proposal lacks sufficient stringency

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[3] California Air Resources Board, *Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency* (June 2015), http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf.

[4] Cummins, *Engine Technologies for GHG and Low NO_x* (April 2015), http://www.arb.ca.gov/msprog/onroad/caphase2ghg/presentations/2_7_wayne_e_cummins.pdf.

[5] International Council on Clean Transportation, *Advanced Tractor-Trailer Efficiency Technology Potential in the 2020-2030 Timeframe* (April 2015), http://www.theicct.org/sites/default/files/publications/ICCT_ATTEST_20150420.pdf.

to drive market development of these technologies and eliminates the Advanced Technology Credits included in the Phase 1 program intended to encourage development of these technologies. Therefore, we also recommend that EPA reinstate Advanced Technology Credits to help advance zero- and near-zero-emission technologies and to make Alternative 4 more attractive and attainable.

NACAA commends EPA for including requirements to regulate GHG emissions associated with trailers for the first time at the national level. While we support the proposal as a first step by requiring nearly all trailer types designed for on-highway use to use low rolling resistance (LRR) tires and automatic tire inflation systems, we believe the proposed trailer provisions miss several opportunities to maximize fuel efficiency technologies in the heavy-duty trailer sector.

Based on manufacturers' and fleets' experiences with EPA's SmartWay program and CARB's experience in implementing its Tractor Trailer Greenhouse Gas Regulation, we urge EPA to 1) consider expanding the proposed requirements for aerodynamic technologies on box type trailers to include other trailer types, such as tanker and flatbed trailers; 2) increase the proposed penetration rate for Level 1 LRR tires to at least 95 percent for short and long box type trailers; 3) adopt Alternative 4 augmented with revisions to include a nominal adoption rate in Bin VIII technologies (which represent as yet undeveloped technology) in order to further advance aerodynamic technology development; and 4) increase the final Alternative 4 stringency (applicable to MY 2024) for long box refrigerated van trailers so that the combined adoption of Bins VI and VII match or exceed that of long box dry van trailers.

Our March 18, 2015 letter also included a recommendation that EPA articulate in the proposal the need for significantly lower national heavy-duty NO_x standards beyond the current 2010 onroad heavy-duty NO_x exhaust emission standards and nonroad heavy-duty engine exhaust emission standards. We are very disappointed that EPA has not included such a discussion in this proposal. Although there is the potential for ancillary NO_x reductions from the Phase 2 rule, the achievement of these reductions is not certain (we note that predicted ancillary benefits of Phase 1 did not occur). Moreover, even if ancillary NO_x benefits do accrue under the Phase 2 rule, they will not be nearly sufficient given the challenges state and local agencies face in attaining and maintaining current and upcoming ozone and fine PM standards and protecting against visibility impairment and eutrophication of water bodies.

In addition to early climate benefits, federal action on our recommendation to adopt Alternative 4 (full implementation by 2024) would also provide manufacturers the ability to incorporate technologies to significantly reduce NO_x emissions from heavy-duty vehicles in a more timely manner. While already crucial for a number of areas, NO_x reductions from the heavy-duty sector will become increasingly important to additional areas under strengthened National Ambient Air Quality Standards for ozone, which are expected imminently. We urge that EPA include in the final Phase 2 rule a clear and comprehensive discussion of the need for very substantial additional NO_x reductions from heavy-duty vehicles and engines and, even more critically, an explicit commitment to begin immediately a separate rulemaking initiative to capture those reductions.

Next, EPA projects an increase in the use of auxiliary power units (APUs) under the Phase 2 proposal and an associated 10-percent increase in PM emissions. The agency seeks comment on this, but proposes nothing to address the unacceptable and unnecessary expected rise in PM pollution. Exposure to diesel PM is one of the greatest public health challenges of our time. In California, for example, diesel PM was identified as a toxic air contaminant in 1998. However, even after implementation by the state of extensive control programs, diesel PM remains responsible for 60 percent of the known risk from toxic air contaminants. Therefore, NACAA recommends that, concurrent with the final Phase 2 rule, EPA adopt national requirements to equip APUs with diesel particulate filters, similar to CARB's requirements.

Additionally, while MOVES modeling points to other air quality benefits of APU usage, there remains a significant difference between the emission standards for Tier 4 smaller nonroad diesel engines typically used in APUs when compared to the emission rates of a modern long-haul truck at idle. To prevent any potential backsliding from air quality benefits appreciated from the newest onroad engine standards, we recommend adding provisions to ensure that there are no increases in emissions of NO_x or PM as a result of increased use of APUs on all affected vehicles. We also encourage EPA to ensure against overestimation of the potential NO_x benefits associated with APU use.

Finally, NACAA urges that EPA do everything feasible to implement in-use compliance verification. We support EPA's testing regime for engines and the requirement for manufacturers to submit data from chassis testing – these are good first steps. However, we believe the current whole-vehicle provisions should be complemented with some type of whole-vehicle validation to ensure long-term compliance by vehicles in-use. For example, tracking vehicle weight and speed with engine carbon dioxide and nitrous oxide emissions could be used as a tool to determine overall vehicle performance for corrections/correlations to EPA's Greenhouse Gas Emissions Model moving forward.

In conclusion, NACAA believes EPA and NHTSA have a tremendous opportunity to finalize a rule that will effectively address heavy-duty vehicle and engine GHG emissions and fuel consumption and set the stage for a separate rule to achieve meaningful additional NO_x reductions. We urge you to make the most of this opportunity. Further, in doing so, we encourage your agencies to continue collaborating with experts at CARB, given California's unique ability to regulate these same source categories, its decades of experience in doing so and the past success that has been achieved when EPA, and more recently NHTSA, have collaborated with CARB.

Once again, NACAA appreciates the opportunity to provide comments on this important proposal. If you have any questions, please contact either of us or Nancy Kruger, Deputy Director of NACAA, at (202) 624-7864.

Sincerely,

Nancy L. Seidman
Massachusetts
Co-Chair
NACAA Mobile Sources and Fuels Committee

Barry R. Wallerstein
Los Angeles, CA
Co-Chair
NACAA Mobile Sources and Fuels Committee

TAB 17

Carpenter

There's a reason Valley trucks have Oklahoma plates

November 02, 2008 | By Paul Carpenter Of The Morning Call

The explosion of Lehigh Valley trucking distribution terminals in recent years, especially around Fogelsville, has been accompanied by an explosion in traffic jams, highway damage and other problems.

As I have argued previously, studies say one large truck does 9,600 times as much roadway damage as one car, but truckers never pay their fair share. They pay about the same fuel tax percentage as that for a car. I have said the state should require them to pay more.

At least one person with insights into the situation agrees. He works at a distribution center in the Fogelsville area, but asked me to withhold his name. "If you said who I was, I'd be gone the next day," he said. So let's call him Chuck.

An unfair fuel tax, however, was not the main reason he contacted me. Chuck said many of the biggest trucks operate exclusively within this region.

"The trucks are registered to Oklahoma," he said. "These are trucks that have never seen Oklahoma. ... Same goes for trailers."

He said there are thousands of such trucks. "The trucking companies look for low registration states and list all their trucks there," he said. "And these trucks, at 80,000 pounds, are tearing up the highways."

Pennsylvania's basic registration fee for a truck that size is $1,687.50. Until recently, the fee in Oklahoma was $200, but was raised to $948 in the wake of a big fuss involving lawsuits by other states (notably Illinois and Missouri) that resulted in multi-million-dollar awards. Also, some Oklahoma officials went to prison for ripping off the system designed to compensate various states and Canadian provinces for trucks registered elsewhere.

That system is called the International Registration Plan Inc., based in Virginia. The IRP was established to avoid the need for truckers to register in every state. (Years ago, you'd see a truck with a dozen license plates. Now, there's one.)

I asked Nathan Maddox, an attorney for the Illinois Secretary of State, about the fuss over truckers dodging "pro-rated" IRP fees.

"Oklahoma was not enforcing that" for trucks operating in Illinois, he said. "They let companies all over the country use Oklahoma as a front." With the Illinois fee at $2,000 and Oklahoma's at $200, he said, Illinois might wind up with a $20 pro-rated share.

Maddox said Illinois won a $7.1 million award, and Oklahoma also had to pay awards to 11 other states.

I contacted the Pennsylvania Department of Transportation about the IRP system, and was put in touch with Andy Cleaver, director of customer services, and Craig Johnson, registration section manager.

"Vehicles are allowed to be registered within [another] jurisdiction," Johnson said. "Oklahoma [is] responsible for collecting registration fees for any apportioned vehicle that is operating [in Pennsylvania]. ...

"Everyone has a different fee," he said, so each state gets a percentage of its registration fees based on the number of

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miles a truck operates in that state. "If 90 percent of travel is in Pennsylvania, they would pay 90 percent of Pennsylvania's fee of $1,687.50."

Why, I asked, would a trucking company register all its trucks in Oklahoma when they operate exclusively in Pennsylvania?

"Because they chose that as their base of operations," Cleaver said. "Pennsylvania is still getting a share of those registration fees."

Based on our $1,687.50?

"Yes," said Cleaver.

Nope, said Matt Skinner, a spokesman for the Oklahoma Corporations Commission, which handles that state's pro-rated IRP fees.

"We have lower tag fees. It's ... $948 for an 80,000-pound truck," Skinner said. So I asked if Oklahoma compensates Pennsylvania on the basis of this state's $1,687.50 fee.

"No. It's based on the IRP formula," he said. "It is cheaper to tag trucks here."

And what does that formula provide? The people at IRP who knew were out. If they return my calls, I'll tell you what they said.

In the meantime, as you bounce along roads ruined at a 9,600-to-1 rate, think of trucking companies that pay no more in fuel taxes than you do -- and may not even pay the state their fair share in registration fees.

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Paul Carpenter's commentary appears Sundays, Wednesdays and Fridays.

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TAB 18

CHAPTER 3

BENEFITS AND COSTS

The avoided premature deaths for $PM_{2.5}$ in Table 3-4 include a pooled estimate from three $PM_{2.5}$ adult mortality functions. The baseline deaths represent the total number of expected deaths among the population 30 and above. The STMPRAG (Scientific, Technical and Modeling Peer Review Advisory Group) members did not reach consensus on how to weigh the three different studies related to $PM_{2.5}$ mortality. Some members wanted to give more weight to the Jerrett el al. study (2005) because it was performed using the Los Angeles monitoring data. Table 3-4 shows the range of avoided premature deaths from the three mortality functions for 2020 relative to the baseline number of deaths in the four-county area. A sensitivity analysis indicates that if the Jerrett et al. study was used, the number of avoided premature deaths would be 2,985. The Jerret et al. study would increase the health benefit for $PM_{2.5}$ by approximately 40 percent. However, other STMPRAG members recommended not using the Jerrett et al. study until it is replicated and corroborated by other researchers.

TABLE 3-4

$PM_{2.5}$ Premature Deaths by Adult Mortality Function in 2020

	Pooled Estimates	Pope et al.	Jerrett et al.	Laden et al.
No. of Avoided Deaths	2,017	1,128	2,985	2,826
% of Baseline Deaths	0.67%	0.37%	0.99%	0.93%

Table 3-5 shows the quantifiable health benefit of improved air quality associated with the 2007 AQMP for ozone and $PM_{2.5}$ morbidity and mortality relative to air quality without the Plan. The total health benefit is projected to reach $16 billion in 2023. On average, the annual benefit from 2007 to 2025 is approximately $9.8 billion. The $PM_{2.5}$ health benefit significantly outweighs the ozone benefit.

TABLE 3-5

Quantifiable Health Benefits
(millions of 2000 dollars)

Category	2014	2020	2023	Average Annual (2007-2025)
Ozone Morbidity	-$46	-$20	$143	$16
Ozone Mortality	-236	-21	1,291	237
$PM_{2.5}$ Morbidity	587	827	947	618
$PM_{2.5}$ Mortality	8,470	11,910	13,631	8,902
Total	$8,775	$12,696	$16,011	$9,773

Ozone benchmark years are 2009, 2012, 2020, and 2023. $PM_{2.5}$ benchmark years are 2014 and 2020. Benefits for non-benchmark years are linearly interpolated based on benchmark year estimates.

Agricultural Benefit

Ozone has been recognized to damage vegetation and many crops more than all other pollutants combined. Since the early 1970s, numerous studies have shown that ozone inhibits crop productivity and results in potential reductions in crop yield.

Based on published ozone damage functions (Olszyk and Thompson, 1989; Randall and Soret, 1998) for many crops (i.e., grapes, oranges, lemons, tangerines, beans, field corn, sweet corn,

TAB 19

Regulatory Impact Analysis of the Final Revisions to the National Ambient Air Quality Standards for Ground-Level Ozone

ES.2 Results of Benefit-Cost Analysis

Below in Table ES-5, we present the primary costs and benefits estimates for 2025 for all areas except California. We anticipate that benefits and costs will likely begin occurring earlier than 2025, as states begin implementing control measures to show progress towards attainment. In these tables, ranges within the total benefits rows reflect multiple studies upon which the estimates associated with premature mortality were derived. $PM_{2.5}$ co-benefits account for approximately 60 to 70 percent of the estimated benefits, depending on the standard analyzed and on the choice of ozone and PM mortality functions used. Assuming a 7 percent discount rate, for a standard of 70 ppb the total health benefits are comprised of between 29 and 34 percent ozone benefits and between 66 and 71 percent $PM_{2.5}$ co-benefits. Assuming a 7 percent discount rate, for a standard of 65 ppb the total health benefits are comprised of between 29 and 35 percent ozone benefits and between 62 and 70 percent $PM_{2.5}$ co-benefits. In addition for 2025, Table ES-6 presents the numbers of premature deaths avoided for the revised and alternative standard levels analyzed, as well as the other health effects avoided. Table ES-7 provides information on the costs by geographic region for the U.S., except California in 2025, and Table ES-8 provides a regional breakdown of benefits for 2025. See the tables in Chapter 6 for additional characterizations of the monetized benefits.

In the RIA we provide estimates of the costs of emissions reductions to attain the revised and alternative standard levels in three regions -- California, the rest of the western U.S., and the eastern U.S. In addition, we provide estimates of the benefits that accrue to each of these three regions resulting from both control strategies applied within the region and reductions in transport of ozone associated with emissions reductions in other regions.

The net benefits of emissions reductions strategies in a specific region reflect the benefits of the emissions reductions occurring both within and outside of the region minus the costs of the emissions reductions. Because the air quality modeling was conducted at the national level, we do not estimate separately the nationwide benefits associated with the emissions reductions occurring in any specific region.[7] As a result, we are only able to provide net benefits estimates at the national level. The difference between the costs for a specific region and the benefits

[7] For California, we provide separate estimates of the costs and nationwide estimates of benefits, so it is appropriate to calculate net benefits. As such, we provide net benefits for the post-2025 analysis for California.

Table ES-6. Summary of Total Number of Annual Ozone and PM-Related Premature Mortalities and Premature Morbidity: 2025 National Benefits [a]

	Revised and Alternative Standard Levels	
	70 ppb	**65 ppb**
Ozone-related premature deaths avoided (all ages)	96 to 160	490 to 820
$PM_{2.5}$-related premature deaths avoided (age 30+)	220 to 500	1,100 to 2,500
Other health effects avoided		
Non-fatal heart attacks (age 18-99) (5 studies) [PM]	28 to 260	140 to 1,300
Respiratory hospital admissions (age 0-99) [O3, PM]	250	1,200
Cardiovascular hospital admissions (age 18-99) [PM]	80	400
Asthma emergency department visits (age 0-99) [O3, PM]	630	3,300
Acute bronchitis (age 8-12) [PM]	340	1,700
Asthma exacerbation (age 6-18) [O3, PM]	230,000	1,100,000
Lost work days (age 18-65) [PM]	28,000	140,000
Minor restricted activity days (age 18-65) [O3, PM]	620,000	3,100,000
Upper & lower respiratory symptoms (children 7-14) [PM]	11,000	53,000
School loss days (age 5-17) [O3]	160,000	790,000

[a] Nationwide benefits of attainment everywhere except California. All values are rounded to two significant figures. Additional information on confidence intervals are available in the tables in Chapter 6.

Table ES-7. Summary of Total Control Costs (Identified + Unidentified Control Strategies) by Revised and Alternative Standard Levels for 2025 - U.S., except California (billions of 2011$, 7% Discount Rate)[a]

Revised and Alternative Standards Levels	Geographic Area	Total Control Costs (Identified and Unidentified)
70 ppb	East	1.4
	West	<0.05
	Total	**$1.4**
65 ppb	East	15
	West	<0.75
	Total	**$16**

[a] All values are rounded to two significant figures. Costs are annualized at a 7 percent discount rate to the extent possible. Costs associated with unidentified controls are based on an average cost-per-ton methodology (see Chapter 4, Section 4.3 for more discussion on the average-cost methodology).

Table ES-9. Total Annual Costs and Benefits[a] of the Identified + Unidentified Control Strategies Applied in California, Post-2025 (billions of 2011$, 7% Discount Rate)[b]

	Revised and Alternative Standard Levels	
	70 ppb	**65 ppb**
Total Costs[c]	$0.80	$1.5
Total Health Benefits	$1.2 to $2.1[d]	$2.3 to $4.2[d]
Net Benefits	**$0.4 to $1.3**	**$0.8 to $2.7**

[a] Benefits are nationwide benefits of attainment in California.
[b] The guidelines of OMB Circular A-4 require providing comparisons of social costs and social benefits at discount rates of 3 and 7 percent. The tables in Chapter 6 provide additional characterizations of the monetized benefits, including benefits estimated at a 3 percent discount rate. Estimating multiple years of costs and benefits is not possible for this RIA due to data and resource limitations. As a result, we provide a snapshot of costs and benefits in 2025, using the best available information to approximate social costs and social benefits recognizing uncertainties and limitations in those estimates.
[c] The engineering costs in this table are annualized at a 7 percent discount rate to the extent possible. See Chapter 4 for more discussions.
[d] Excludes additional health and welfare benefits that could not be quantified (see Chapter 6, Section 6.6.3.8).

Table ES-10. Summary of Total Number of Annual Ozone and PM-Related Premature Mortalities and Premature Morbidity: Post-2025[a]

	Revised and Alternative Standard Levels	
	70 ppb	**65 ppb**
Ozone-related premature deaths avoided (all ages)	72 to 120	150 to 240
$PM_{2.5}$-related premature deaths avoided (age 30+)	43 to 98	84 to 190
Other health effects avoided		
Non-fatal heart attacks (age 18-99) (5 studies) [PM]	6 to 51	11 to 100
Respiratory hospital admissions (age 0-99)[O3, PM]	150	300
Cardiovascular hospital admissions (age 18-99) [PM]	16	31
Asthma emergency department visits (age 0-99) [O3, PM]	380	760
Acute bronchitis (age 8-12) [PM]	64	130
Asthma exacerbation (age 6-18) [O3, PM]	160,000	330,000
Lost work days (age 18-65) [PM]	5,300	10,000
Minor restricted activity days (age 18-65) [O3, PM]	360,000	720,000
Upper & lower respiratory symptoms (children 7-14) [PM]	2,000	3,900
School loss days (age 5-17) [O3]	120,000	240,000

[a] Nationwide benefits of attainment in California. All values are rounded to two significant figures. Additional information on confidence intervals are available in the tables in Chapter 6.

TAB 20

State of California
AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS FOR PROPOSED RULEMAKING

PROPOSED GREENHOUSE GAS (GHG) REGULATIONS FOR MEDIUM- AND HEAVY-DUTY ENGINES AND VEHICLES, OPTIONAL REDUCED EMISSION STANDARDS FOR HEAVY-DUTY ENGINES, AND AMENDMENTS TO THE TRACTOR-TRAILER GHG REGULATION, THE DIESEL-FUELED COMMERCIAL MOTOR VEHICLE IDLING RULE, AND THE HEAVY-DUTY HYBRID-ELECTRIC VEHICLES CERTIFICATION PROCEDURES



Date of Release: October 23, 2013
Scheduled for Consideration: **December 12, 2013**

No significant impacts to the competitive advantages or disadvantages for businesses currently doing business within the state are anticipated because the amendments would not result in any additional costs to affected regulated entities.

c. Potential Costs to Local and State Agencies

The proposed amendments are not anticipated to have any cost impacts to local or state agencies since they would not result in any additional costs to affected regulated entities.

5. Technical Feasibility

The proposed amendments to the Tractor-Trailer GHG regulation all consist of clarifying or deleting existing requirements. Because the existing Tractor-Trailer GHG regulation is technically feasible, the proposed amendments are therefore also technically feasible.

6. Regulatory Alternatives

No alternative considered by the agency would be more effective in carrying out the purpose for which the regulation is proposed or would be as effective as or less burdensome to the affected private persons than the proposed Tractor-Trailer GHG regulation amendments.

The primary alternative considered by staff was not to amend the Tractor-Trailer GHG regulation, but this alternative was rejected in part because it would result in duplicative California-only requirements for owners of Phase 1 GHG certified tractors that would also be subject to the regulation. Also, making no changes to the regulation would require 2011 and subsequent MY day-cab tractors that are later retrofitted with sleeper-cab compartments to be SmartWay designated models. Day-cab tractors cannot readily be retrofitted to meet the SmartWay designation requirements since many of the required components are major design elements incorporated at the time of manufacture. It was never staff's intention to require day-cab tractors retrofitted with sleeper-cab compartments to meet SmartWay designation requirements.

C. Optional Low NOx Emission Standards (New Proposal)

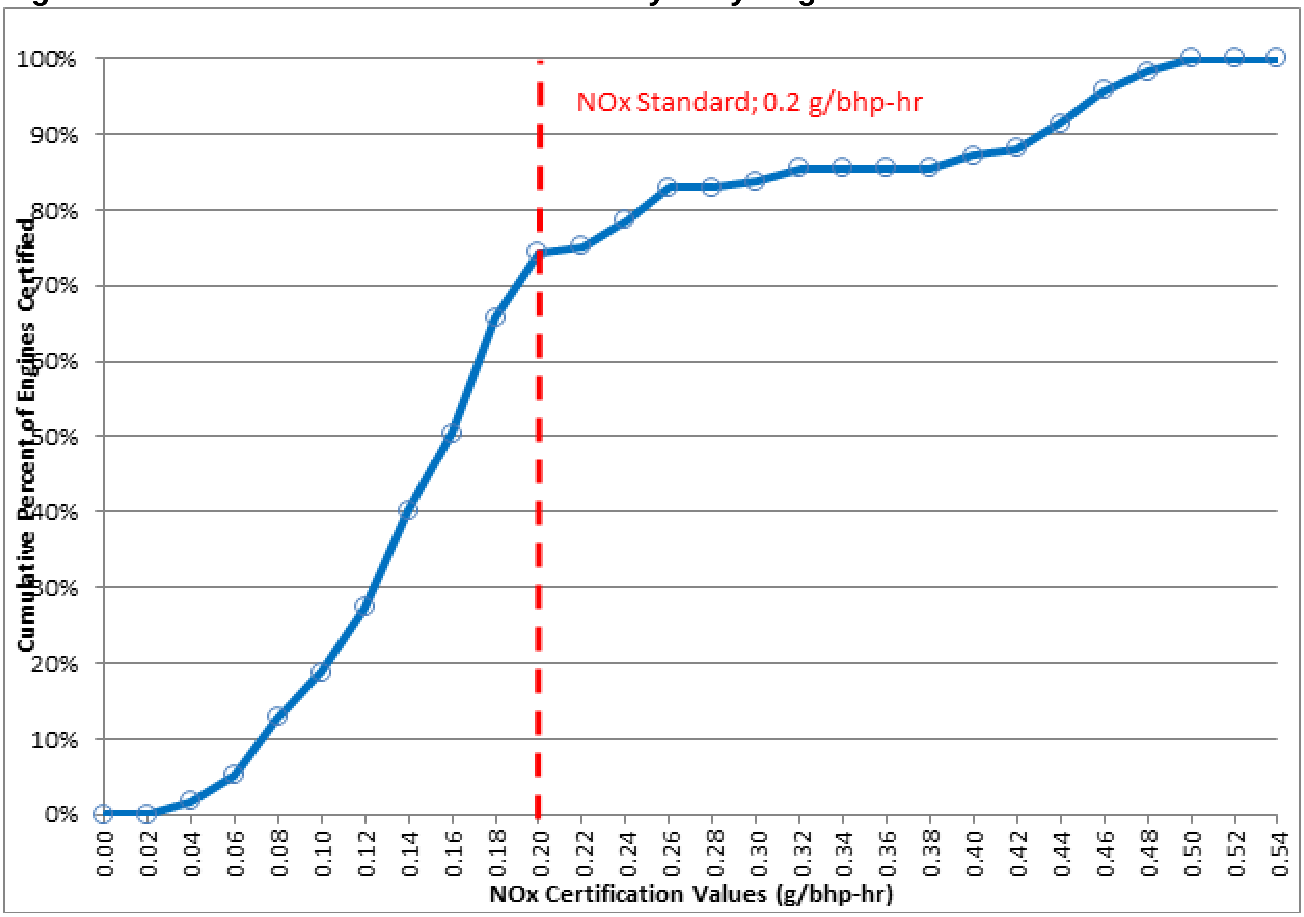
The proposed new regulation would establish the next generation of optional NOx standards for heavy-duty engines, and consists of three optional NOx emission standards of 0.1 g/bhp-hr, 0.05 g/bhp-hr, and 0.02 g/bhp-hr (i.e., 50 percent, 75 percent, and 90 percent lower than the current mandatory NOx emission standard of 0.2 g/bhp-hr). The text of the proposed Optional Low NOx engine emission standards is contained in Appendix I.C.

1. Background

a. Certification Levels

A number of existing certified heavy-duty engines have certification levels, (i.e., the emission level at the end of the required testing period for certification) that are at or below the proposed optional levels. While this is in itself noteworthy, manufacturers typically certify to levels below the standard (with a "compliance margin") to provide them assurance that the engine will comply with the standard for its useful life. Compliance margins vary by manufacturer and engine, but a compliance margin of 50 percent below the standard is common.

Figure 6 - California Model Year 2012 Heavy-Duty Engine NOx Certification Values



As shown in Figure 6, over 70 percent of MY 2012 engines are certifying below the current 0.2 g/bhp-hr standard. About 8 percent of the MY 2012 engines are already certifying at levels 30 percent or more below the optional 0.1 g/bhp-hr standard, at 0.03 to 0.07 g/bhp-hr. See Appendix IV for a summary of certification data for engines with certification levels below the current 0.2 g/bhp-hr NOx standard.

b. Advances in Heavy-Duty Engine Technology

There have been major advances in heavy-duty engine technology to meet the current 0.2 g/bhp-hr standard, and staff believes it likely that

TAB 21

California Environmental Protection Agency
AIR RESOURCES BOARD

DRAFT
TECHNOLOGY ASSESSMENT: LOWER NO_X HEAVY-DUTY DIESEL ENGINES

September 2015

State of California
AIR RESOURCES BOARD

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Executive Summary

This report is part of a series of technology and fuels assessment reports that evaluate the state of technology to further reduce emissions from the transportation sector including trucks, locomotives, off-road equipment, ships, commercial harborcraft, aircraft, and transportation fuels. The purpose of the assessments is to support the Air Resources Board's (ARB) planning and regulatory efforts, including the development of California's Sustainable Freight Strategy, the State Implementation Plan, funding plans, the Governor's Zero Emission Vehicle Action Plan, and Governor's petroleum reduction goals. The reports focus not only on zero and near-zero emission technologies that will ultimately be necessary to meet long-term air quality and climate goals, but also on improvements to conventional technologies that could provide near-term emissions reductions and help facilitate the transition to zero and near-zero emission technologies.

Specifically, this technology assessment report is intended to provide a comprehensive evaluation of the current state and projected development over the next 5 to 10 years of lower oxides of nitrogen (NO_X) heavy-duty diesel engines. For each technology, the assessment will include a description of the technology, its suitability in different applications, current and anticipated costs at widespread deployment (where available), and emission levels.

Overall, the assessment finds that emissions from heavy-duty diesel engines can be significantly reduced utilizing a systems approach combining advanced aftertreatment systems with engine management strategies. Reducing NO_X emissions to the 0.02 grams per brake horsepower-hour (g/bhp-hr) level will require reducing emissions significantly during cold start and during low load, low speed operations and also maintaining high selective catalytic reduction (SCR) conversion efficiency at high speed-high temperature operation. A variety of strategies can be used to achieve these reductions. However, the final solution will depend on ensuring no adverse impacts on greenhouse gas (GHG) emissions.

Presented below is an overview which briefly describes technologies to further reduce NO_X emissions from on-road heavy-duty diesel engines and staff's proposed next steps. For simplicity, the discussion is presented in question-and-answer format using commonly asked questions about the technology assessment. It should be noted that this summary provides only brief discussion on these topics. The reader should refer to subsequent chapters in the main body of the report for more detailed information.

Q. What are the current emission certification standards of on-road heavy-duty diesel engines?

A. Currently, on-road heavy-duty diesel engines are required to meet the 2010 emission limits of 0.20 g/bhp-hr NO_X emissions and 0.01 g/bhp-hr particulate matter (PM) emissions, on the heavy-duty transient federal test procedure and on the ramped modal cycle supplemental emission test. To further reduce NO_X emission emissions, ARB also adopted optional low NO_X standards that are 50 percent, 75 percent, and 90 percent lower than the current NO_X standard of 0.20 g/bhp-hr. The optional low NO_X standards were developed to encourage engine manufacturers to develop new technologies and also to provide them with a mechanism to optionally certify engines to lower NO_X standards. Certification to lower optional standards would also enable certified low-NO_X engines to become eligible for incentive funding.

Depending on vehicle weight class, heavy-duty diesel engines are also required to reduce GHG emissions by 5 to 9 percent relative to 2010 GHG emission levels by 2017.

Q. What are the market characteristics of heavy-duty trucks and engines?

A. The majority of the heavier trucks are diesel engine powered, while the lighter trucks are predominantly gasoline engine powered. There are approximately 10 manufacturers of Class 4 to 8 trucks in the U.S. Two of these manufacturers only produce Class 4 to 6 trucks.

Sales of Classes 4 to 8 heavy-duty trucks increased by 17.6 percent, from a total of 345,876 in 2013 to 406,747units in 2014 (See Figures ES-1 and ES-2). For these truck classes, in 2014, Freightliner had the biggest market share with 31 percent, while International had 14 percent. For Class 8 trucks, in 2014, Freightliner had the biggest market share, with 36 percent market share, while International had 14 percent market share (Davis et. al, 2015).[1]

Although many of the heavy-duty truck manufacturers produce the engines used in their trucks, they also purchase and install engines made by other manufacturers such as Cummins, Inc. As shown in Figure ES-3, Cummins leads the heavy-duty diesel engine market with 47 percent followed by Detroit Diesel with 11.1 percent and Volvo with 10.9 percent of the market share in 2013 (Davis et. al, 2015).[2] A detailed description of the truck market analysis is provided in a companion report, Technology Assessment: Truck Sector Overview.

[1] *Annual Financial Profile of America's Franchised New-Car Dealerships*, NADA Data, 2014 <https://www.nada.org/nadadata/>.

[2] Davis, Stacy C., S. W. Diegel, R. G. Boundy, and S. Moore, *2014 Vehicle Technologies Market Report*, Oak Ridge National Laboratory, U.S. DOE. ORNL/TM-2015/85 <http://cta.ornl.gov/vtmarketreport/index.shtml>.

Figure ES-1: Class 4 to 7 Truck Sales, 2013 and 2014

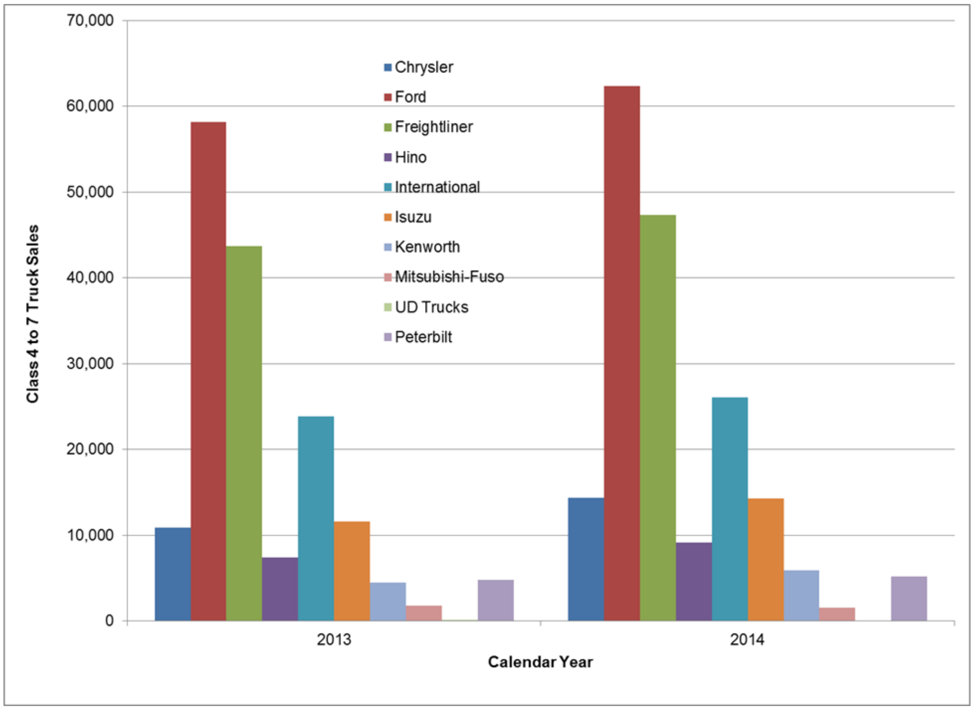


Figure ES-2: Class 8 Truck Sales, 2013 and 2014

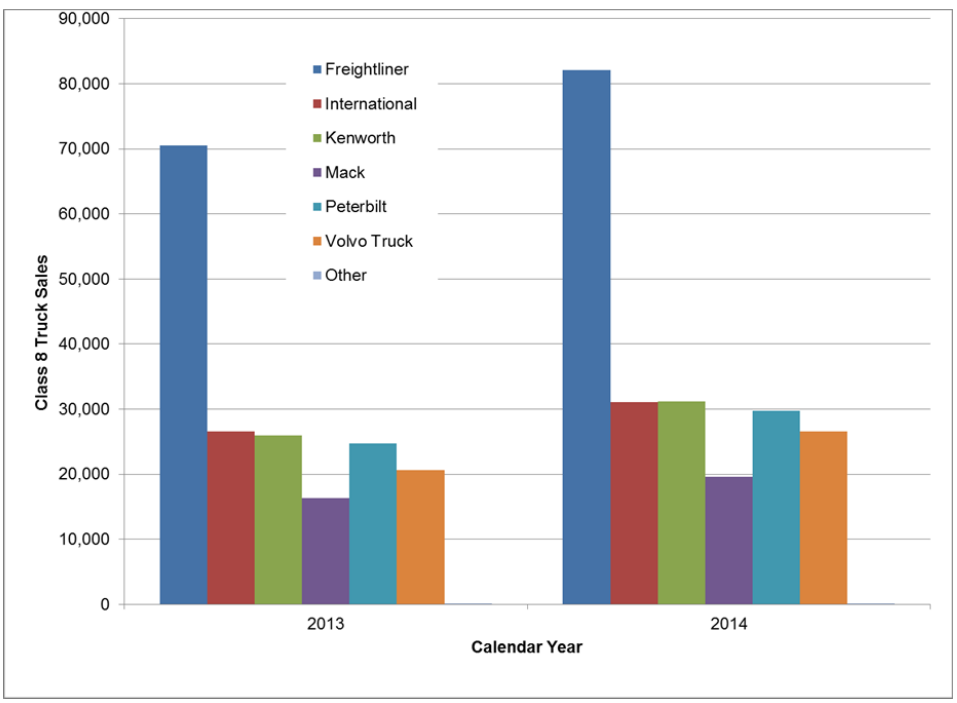
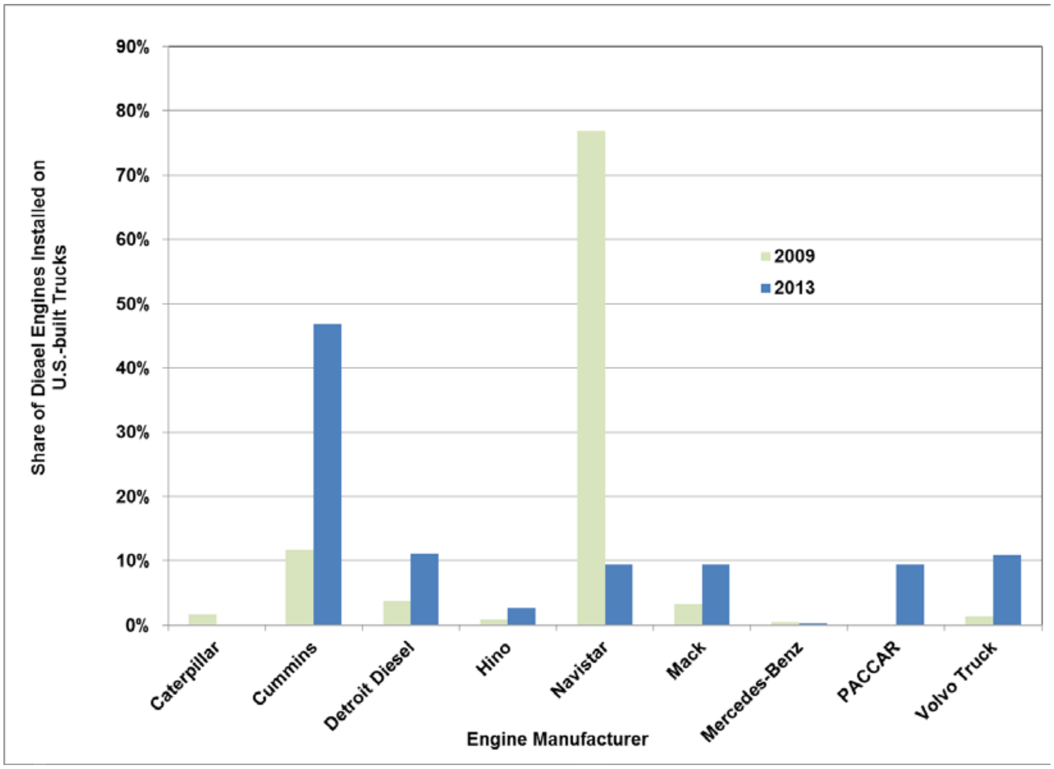


Figure ES-3: Diesel Engine Manufacturers Market Share, 2009 and 2013



Q. How do current diesel vehicles compare to current natural gas vehicles?

A. Heavy-duty diesel-fueled engines are based on lean combustion, compression ignition (CI) engine technology and use SCR to control NO_X and a diesel particulate filter (DPF) to control PM. Heavy-duty natural gas engines, on the other hand, can either use spark-ignited (SI) stoichiometric combustion engine technology or CI dual fuel high pressure direct injection (HPDI) engine technology. SI natural gas engines are similar to gasoline engines and use a similar aftertreatment system, the three-way catalyst, to control NO_X, carbon monoxide, and hydrocarbons, without the need of a DPF to meet PM standards. HPDI natural gas engines are based on the conventional CI diesel engine, but use a small amount of diesel fuel injected at the end of the compression stroke to initiate ignition. As with diesel engines, HPDI natural gas engines require SCR to control NO_X and a DPF to control particulate matter emissions. SI natural gas engines are currently the only original-equipment manufacturer natural gas heavy-duty engines produced for on-road applications.

In general, heavy-duty SI natural gas engines are expected to be certified to today's optional low-NO_X emission standards (0.02, 0.05, and 0.1 g/bhp-hr) sooner than will diesel engines since recent in-use emissions test data show that natural gas engines do not appear to suffer the control challenges experienced by diesel engines in low temperature, low speed operations. Recently, a Cummins Westport Inc., 8.9 liter (L) SI natural gas engine was certified by ARB to the 0.02 g/bhp-hr optional NOx standard and the 2017 heavy-duty GHG standards for urban bus, vocational truck, and tractor applications.[3]

Besides the different engine technologies used in diesel and natural gas vehicles, other characteristics also distinguish these vehicles and their uses. Unlike diesel vehicles, current use of natural gas vehicles has largely been limited to urban vocational applications rather than line-haul applications. This difference is primarily driven by the lower energy density of natural gas, which requires larger and heavier on-board fuel storage systems. Other factors driving differences in the adoption of diesel and natural gas vehicles include the differences in the extent of development of the refueling infrastructure and current engine offerings. In addition, purchasing prices of heavy-duty diesel vehicles are currently lower than those of comparable heavy-duty natural gas vehicles; however, owners of natural gas vehicles can realize a return on investment due to the lower cost of natural gas fuel compared to diesel fuel. For more details about the differences between diesel vehicles and natural gas vehicles, please refer to a companion report: "Draft Technology Assessment: Low Emission Natural Gas and Other Alternative Fuel Heavy-Duty Engines."

Q. How are emissions from on-road heavy-duty diesel engines currently controlled to meet the 2010 standards?

A. In order to meet the 0.20 g/bhp-hr NO_X and 0.01 g/bhp-hr PM standards, engine manufacturers are using engine controls such as cooled exhaust gas recirculation (EGR), variable geometry turbochargers, high pressure fuel injection, and other associated electronic controls, as well as aftertreatment controls such as diesel oxidation catalysts, DPF, urea-SCR, and ammonia slip catalysts. In addition to reducing NO_X emissions, the introduction of SCR technology enabled engine manufacturers to overcome the NO_X/PM and NO_X/GHG trade-off design issues that existed prior to the introduction of 2010-compliant SCR-equipped engines. The inclusion of the highly effective SCR aftertreatment system enables the optimization of engine performance for lower PM emissions and improved fuel efficiency; in other words, low PM and GHG emissions can be achieved at the expense of high engine-out NO_X, but lower tailpipe NO_X can also be realized with an effective SCR aftertreatment system.

Q. Can NO_X emissions be lowered further from current levels?

A. Yes. Reducing cold start emissions and emissions during low speed, low load operations can significantly lower NO_X emissions from current levels since the current urea-SCR system is ineffective at the low exhaust temperatures that

[3] ARB Executive Orders, September 15, 2015.
http://www.arb.ca.gov/msprog/onroad/cert/mdehdehdv/2016/2016.php

occur during cold start, extended idling, and low speed operations. This will require the employment of strategies that raise exhaust gas temperatures and advanced catalysts with much higher NO_X control at low temperatures such as NO_X storage catalysts and advanced SCR catalysts. Further NOx reductions can also be achieved during high-speed/high-load driving via advanced SCR catalysts with high cell density and high porosity substrates and better urea injection control.

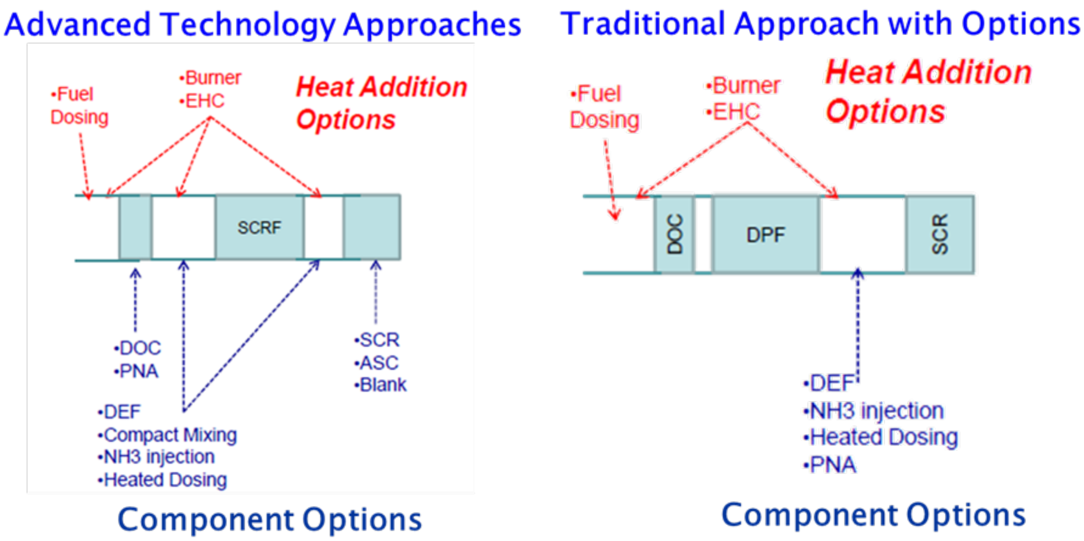
Q. What technology development and demonstration programs are currently in progress to demonstrate the feasibility of low NO_X?

A. In 2013, ARB initiated a project with Southwest Research Institute (SwRI) to demonstrate maximum NO_X reductions possible from heavy-duty engines through a combination of engine tuning practices, exhaust gas thermal management strategies, and aftertreatment strategies[4]. The target NO_X emission rate for this project is 0.02 g/bhp-hr while continuing to meet all applicable standards for hydrocarbons, carbon monoxide, and PM and not incur a GHG penalty.

Figure ES-4 shows some of the technology options that SwRI is investigating. The approach includes screening of a wide range of aftertreatment components and exhaust gas thermal management strategies using a low cost diesel-based burner test rig capable of simulating test cycles and exhaust conditions from a diesel engine. The screening will identify technology packages with the greatest potential to provide maximum NO_X and GHG benefits. The final technology packages selected will then be evaluated on an engine dynamometer over the heavy-duty engine certification cycles and three other low-temperature/low-load vocational cycles. The project is expected to be completed by the end of 2016.

[4] ARB funded SwRI Low NOx Program: *Evaluating Technologies and Methods to Lower Nitrogen Oxide Emissions from Heavy-Duty Vehicles* (http://www.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm)

Figure ES-4: Advanced Technology Approaches and Options (SwRI)



Q. What technologies seem most promising for further reducing NO_X emissions from heavy-duty diesel engines?

A. This technology assessment evaluated technologies and strategies that when packaged may have the greatest potential to significantly reduce NOx emissions without impacting GHG emissions. These technologies include advanced aftertreatment technologies that improve NO_X conversion efficiency at both low and high exhaust temperature operation and strategies designed to raise the exhaust gas temperature during low temperature operations. Advanced aftertreatment technologies evaluated include advanced SCR catalysts, NO_X storage catalysts, alternative ammonia sources, urea delivery and injection control, and ammonia slip catalysts. Exhaust gas thermal management strategies evaluated include exhaust system thermal insulation, EGR, and turbocharger, idle speed, and injection timing control. Other supplemental heating strategies were also evaluated such as fuel burners and electrically heated catalysts.

It is not expected that a single strategy or technology will reduce NO_X significantly on its own. Maximum NO_X reductions can be realized from integrating engine control strategies with advanced catalysts and aftertreatment system control. Many of the engine control strategies and fuel burners designed to add heat to the exhaust may require additional fuel consumption during cold starts or low temperature operations. However, it is imperative that the technology package must have minimal or no impact on fuel consumption and GHG emissions over the vehicle's entire duty cycle.

Although the package that provides maximum benefits of both NO_X and GHG emissions is currently not yet determined, technology development is progressing and showing promising signs that these objectives will be realized. In fact, some of the technologies evaluated in this document are currently being commercialized for light-duty applications. For heavy-duty applications, currently ongoing development and demonstration programs such as the ARB-sponsored SwRI Low NO_X program are expected to identify technology packages that will provide significant further reductions of both NO_X and GHG emissions by the end of 2016.

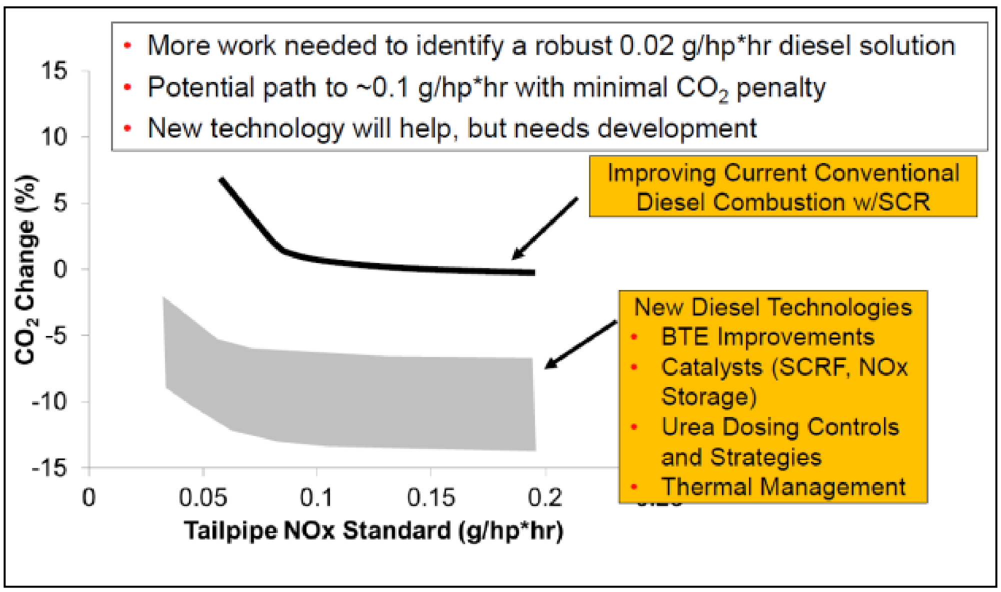
Q. Can NO_X and GHG be reduced simultaneously at lower NOx levels?

A. Yes. To comply with the pre-2010 model year NO_X standards, engines were designed to reduce in-cylinder NO_X at the expense of in-cylinder PM emissions and fuel consumption or GHG emissions (NO_X/GHG trade-off). However, continued developments in combustion systems, fuel injection systems, turbochargers, and electronic controls allowed engine manufacturers to partially mitigate the excess PM and fuel consumption. The introduction of the SCR and DPF aftertreatment systems to meet the 2010 NO_X standards further enabled engine manufacturers to optimize engine fuel economy, while minimizing both PM and NO_X emissions, thus overcoming the NO_X/GHG trade-off. The same engine optimization strategy will be used with future advanced SCR technologies, providing greater NO_X and GHG reductions, especially at high speed and high load operations.

Reducing NO_X emissions to the 0.02 g/bhp-hr levels will require significant emissions reductions during cold start and during low load, low speed operations. There are a variety of strategies which may be used to achieve these reductions. One approach is to provide greater exhaust gas thermal management. Close coupled SCR on DPF formulations and low thermal mass catalyst substrates can efficiently utilize existing heat in the exhaust gas, allowing better thermal management under a broader range of low speed, low load operations. Start-stop technology allows the engine to shut off rather than idling, which conserves heat in the catalyst and allows for higher catalyst control efficiencies. Another approach would be to use NO_X storage catalysts. These catalysts temporarily capture NO_X emissions at low temperatures and release NO_X at higher temperatures when they can be effectively controlled by the SCR system. A third approach involves advanced catalyst formulations and ammonia injection techniques that provide increased control efficiencies under a wide range of engine operating conditions. All of these strategies can provide additional NO_X reductions while allowing for optimal fuel economy. Finally, some strategies may involve providing supplemental heat to the exhaust gas which requires the use of external heat source. Such a strategy may impact fuel economy, but the impact will be minor. For further discussion on the NO_X/GHG trade-off, the reader is referred to the companion report: Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency.

Figure ES-5 shows an assessment of the feasibility of achieving lower NOx emissions and the impacts on GHG emissions by Cummins Inc., the largest manufacturer of heavy-duty diesel engines in the U.S. (Eckerle, 2015). The solid black line in the figure represents current diesel technology. The chart shows that Cummins believes a 0.1 g/bhp-hr NO_X level is feasible with some improvements to the current SCR technology and the conventional diesel combustion process while still allowing for fuel economy optimization. According to Cummins, reducing NO_X further to the 0.02 to 0.05 g/bhp-hr levels and simultaneously reducing GHG emissions (shaded grey curve) would require more improvements in engine combustion efficiency, thermal management strategies, and advanced aftertreatment technologies such as NO_X storage catalysts, SCR coated on DPFs, and urea dosing control strategies. These strategies and technologies are discussed in chapter III of this document.

Figure ES-5: Cummins' Assessment of GHG and NOx Reduction Opportunities with New Engine Technologies



(Eckerle, 2015)

Manufacturers normally certify their engines with a compliance margin at levels below the numerical standard to protect themselves against non-compliance due to minor increases in emissions in use. The certification levels also include deterioration factors to account for any increase in emissions over the useful life of an engine. An analysis of NO_X certification levels indicates that the compliance margins for the latest diesel engines are 10 percent to 60 percent below the 2010 NO_X certification standard, depending on engine size. Hence, based on the above assessment and the current certification levels, staff believes diesel engines are likely to be certified to the optional NO_X emission standard of 0.1 g/bhp-hr by 2016, while engines meeting 0.05 g/bhp-hr or below are likely to be certified later.

Q. How much will these technology packages cost?

A. Engine manufacturers are using the urea-SCR aftertreatment system to comply with the current 0.20 g/bhp-hr NO_X standard. Depending on engine size, the added cost for the current urea-SCR system is estimated to be approximately $3,000 to $4,500 relative to the 2007 model year engine.[5] ARB staff believes further NO_X reductions to lower levels of approximately 90 percent below current standards will be possible through a combination of newer diesel engine designs, advanced diesel aftertreatment technologies, improved SCR catalysts with advanced substrates, and improved controls. It is expected that there will be costs associated with the development of these technologies. The Manufacturers of Emission Control Association estimates that the incremental cost of future advanced technologies needed to achieve NO_X levels of 0.02 g/bhp-hr to be approximately $500 per vehicle averaged over the medium and heavy-duty fleet.[6] Such an increase in cost is small compared to the initial introduction of SCR systems in 2010. Staff expects the cost-effectiveness of these technologies to fall within the cost-effectiveness range of previous NO_X reduction requirements from new engines.

Q. What next steps does staff recommend?

A.
- ARB should continue to support incentive funding for low-NOx heavy-duty engines to encourage engine manufacturers to develop and certify engines that meet the optional NO_X standards.
- Given California's criteria pollutant, GHG, and petroleum reduction needs, staff recommends that ARB implement statewide strategies that employ lower NO_X combustion engines coupled with the use of renewable fuels in order to attain near-term air quality and climate goals.
- In order to achieve air quality goals, ARB intends to begin the development of lower mandatory NO_X standards applicable to all California-certified heavy-duty vehicles. Since out-of-state registered heavy-duty vehicles that operate in California contribute significantly to the emissions inventory, it is also critical that ARB petition the United States Environmental Protection Agency to require lower NO_X standards applicable to all heavy-duty vehicles nationally.

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[5] Blumberg, K., F. Posada, and J. Miller. *Revising Mexico's NOM 044 standards: Considerations for decision-making* International Council on Clean Transportation, Working Paper 2014-5. May 2014. <http://www.theicct.org/series/heavy-duty-vehicle-policies-for-mexico>.

[6] *MECA's Written Statement on the U.S. EPA's Proposal to Revise the NAAQS for Ozone.* Manufacturers of Emission Control Association. March 16, 2015. <http://www.meca.org/attachments/2560/MECA_EPA_ozone_NAAQS_testimony_031715.pdf>.

I. Introduction and Purpose of Assessment

This report is part of a series of technology and fuels assessment reports that evaluate the state of technology to further reduce emissions from the transportation sector including trucks, locomotives, off-road equipment, ships, commercial harborcraft, aircraft, and transportation fuels.

Air Resources Board's (ARB) objective is to transform the on- and-off-road mobile source fleet into one utilizing zero and near-zero emission technologies to meet air quality and climate change goals. This assessment is intended to provide a comprehensive evaluation of the current state and projected development over the next 5 to 10 years of lower oxides of nitrogen (NO_X) heavy-duty diesel engines. For each technology, the assessment will include a description of the technology, its suitability in different applications, current and anticipated costs at widespread deployment (where available), and emissions levels.

This technology assessment will support ARB planning and regulatory efforts, including:

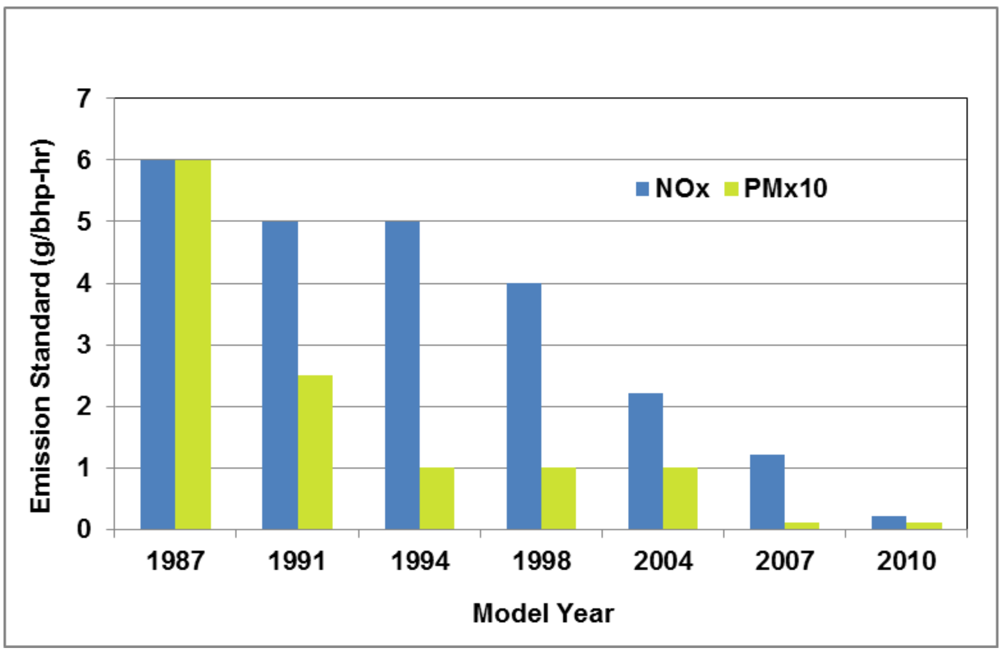
- California's integrated freight planning
- State Implementation Plan (SIP) development
- Funding Plans
- Governor's Zero Emission Vehicle Action Plan
- California's coordinated goals for greenhouse gas (GHG) and petroleum use reduction

Chapter II discusses the history and current status of emission control for heavy-duty diesel engines. Chapter III discusses advanced aftertreatment technologies and the diesel engine control strategies that have the potential to reduce NO_X emissions. Chapter IV discusses system suitability and infrastructure needs. Chapter V discusses currently ongoing technology development and demonstration programs. Chapter VI and VII discuss the cost of the new technologies and the level of emissions reduced by these technologies, respectively. Chapter VIII discusses the impacts of NO_X control on GHG emissions and vice versa (NO_X/GHG trade-off). Finally, Chapter IX and X discuss staff's recommended next steps and conclusions.

II. History of Emission Control for Heavy-Duty Diesel Engines

Regulations to control pollutant emissions from on-road heavy-duty diesel engines (HDDE) have been getting more and more stringent since the 1970s, beginning with smoke controls, and continuing in the 1990s through 2010, with increasingly stringent standards for NO_X and particulate matter (PM) emissions. Figure II-1 illustrates the evolution of California NO_X and PM standards for on-road HDDEs. Most of the NO_X and PM standards that were implemented in the early years prior to the 2007 and 2010 standards were met using in-cylinder emission controls that reduced engine-out NO_X emissions. For example, during the late 1980s and early 1990s, the main strategies used for NO_X control were injection timing retard together with charge air cooling to reduce intake manifold temperatures. These strategies reduce NO_X by lowering peak combustion temperatures. However, reducing NO_X using injection timing control also tends to increase fuel consumption and PM emissions. Thus, other strategies such as increased injection pressures and increased intake manifold pressures had to be used to offset the increased fuel consumption and PM.

Figure II-1: California – On-Road HDDE NO_X and PM Standards



The 1998 NO_X standard of 4 grams per brake horsepower-hour (g/bhp-hr) was met with continued improvement of the previous control strategies and advances in electronic controls which allowed a more flexible and accurate control of engine operating parameters including fuel injection timing, fuel injection pressures, fuel metering, and turbocharger control.

Compliance with the 2004 NO_X standards required the use of exhaust gas recirculation (EGR) coupled with higher fuel injection pressures to mitigate potential increases in PM and fuel consumption and the use of variable geometry (VG) turbochargers to control and ensure the required EGR flow.

Beginning in 2007, heavy-duty engine manufacturers were required to meet a PM standard of 0.01 g/bhp-hr, a NO_X standard of 0.20 g/bhp-hr, and a non-methane hydrocarbon (NMHC) standard of 0.14 g/bhp-hr. Specifically, the PM standard took full effect beginning in 2007, while the NO_X and NMHC standards were phased-in on a percent of sales bases; 50 percent from 2007 to 2009 and 100 percent in 2010. To comply with the phase-in NOx standards, engine manufacturers opted to certify engines to a fleet average NOx standard of approximately 1.2 g/bhp-hr, rather than certifying engines to two different standards (50 percent at 0.2 g/bhp-hr NOx and 50 percent at 2.4 g/bhp-hr NOx+NMHC standard).

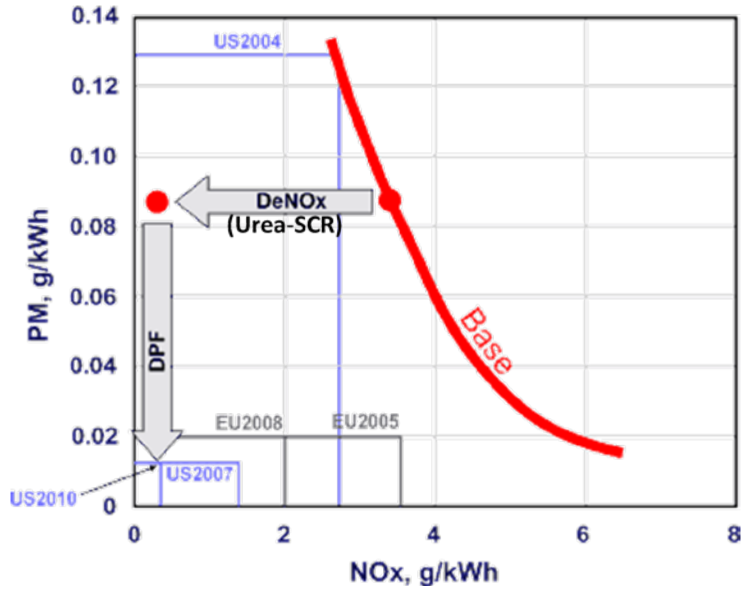
The 2007 PM standard was met using diesel particulate filters (DPF). Higher rates of cooled-EGR, VG turbochargers, high pressure fuel injection and electronic controls were used to comply with the 2007 through 2009 fleet average NOx standard of 1.2 g/bhp-hr, and diesel oxidation catalysts (DOC) were used to meet the NMHC standard.

Moreover, in addition to the continued use of existing technologies, NOx aftertreatment control technologies were used to comply with the 2010 NO_X standard of 0.20 g/bhp-hr. For most engine manufacturers, the NOx aftertreatment control system of choice was the urea-selective catalytic reduction (SCR) including ammonia slip catalysts to control ammonia slip at the tailpipe.

Since sulfur can poison and degrade the performance of aftertreatment catalysts, ultra-low sulfur diesel fuel (ULSD) with sulfur content less than 15 parts per million (ppm) was introduced prior to the implementation of the 2007 and 2010 heavy-duty engine NO_X and PM standards. The introduction of ultra-low sulfur diesel fuel also had the additional effect of reducing PM from the entire in-use heavy-duty fleet.

It is well known that simultaneous NO_X and PM control using only engine design changes is very complex and can have offsetting effects (i.e., the so-called NO_X/PM trade-off). Nevertheless, advances in engine development such as electronic controls, combustion chamber design, fuel injection systems, turbocharging, and associated controls have enabled and continue to enable manufacturers to overcome the NO_X/PM trade-off and achieve lower tailpipe levels of both NO_X and PM. Furthermore, the use of aftertreatment systems to control NO_X and PM has also enabled engine developers to overcome the NO_X/PM trade-off. For example, the high NO_X reduction capability of the SCR system enables the engine to be calibrated for high engine-out NO_X emissions, low fuel consumption, and low PM emissions (Figure II-2). An additional benefit of this strategy is that since less PM is collected in the filter, less filter maintenance is required. Also, the presence of higher concentrations of nitrogen dioxide (NO_2) that results from the introduction of DOCs in the exhaust system facilitates passive filter regeneration at lower exhaust gas temperatures.

Figure II-2: Emission Strategy for SCR and DPF Systems

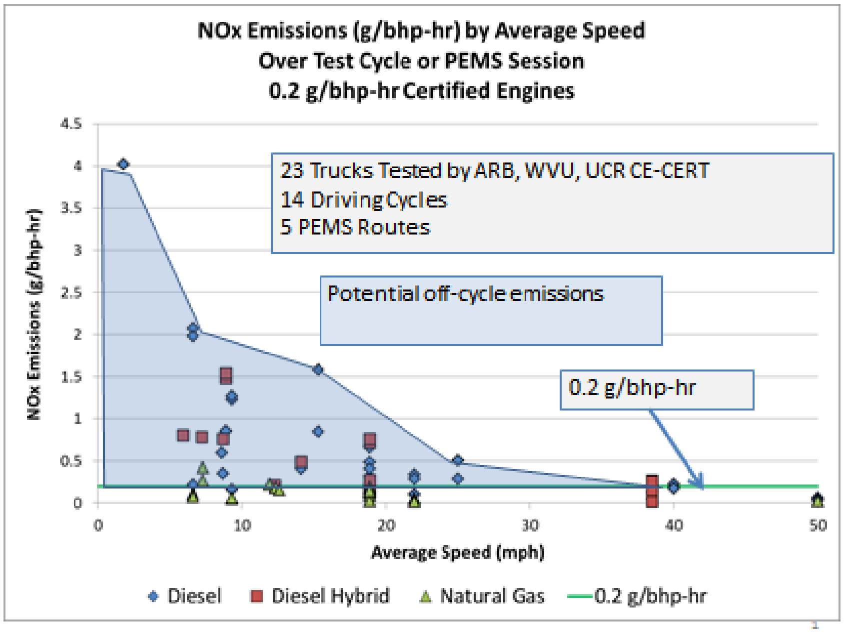


(www.dieselnet.com)

Current SCR systems are providing high NO_X conversion efficiencies during steady-state and high-speed operations. Despite meeting the current standards during certification test cycles, they have poor NO_X conversion efficiency when exhaust gas temperatures are low, such as during cold start, low-speed city driving and during extended idling. This is because SCR performance is limited by urea decomposition and hydrolysis issues at exhaust gas temperatures below 200°C. If urea is injected at exhaust gas temperatures below 200°C, solid deposits, such as ammonium nitrate and/or ammonium sulfate, are formed over the catalyst and exhaust system. The solid deposits degrade the NO_X conversion efficiency of the system.

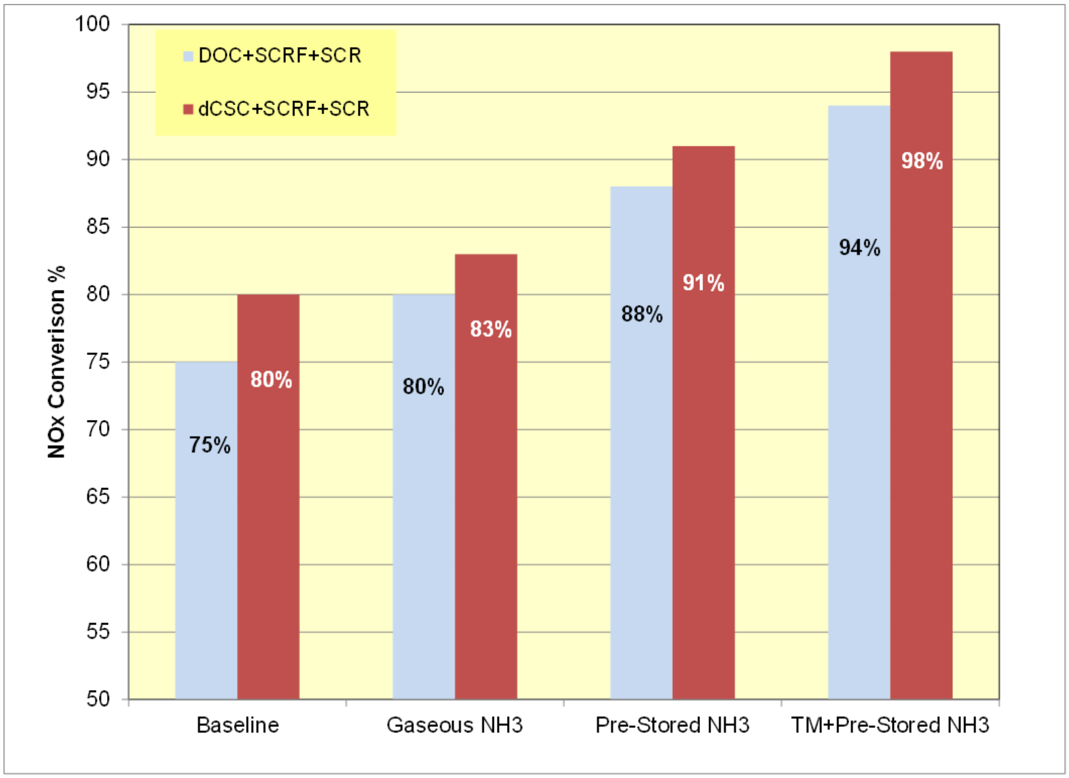
Furthermore, as shown in Figure II-3, recent in-use emissions test data from natural gas, diesel, and diesel hybrid engines certified to the 2010 NO_X emission standard show that diesel engines appear to suffer the control challenge experienced in low temperature, low speed, and low load operations. However, at high speed engine operating temperature, as are seen during cruise and high-load operations, diesel engines appear to emit below the NO_X certification standard.

Figure II-3: In-Use Running Exhaust NOx Emissions Diesel, Diesel Hybrid, and Natural Gas Trucks



Thus, a significant challenge to achieving further emission reductions involves reducing cold start emissions to the lowest possible levels and controlling emissions at light load and low-speed operations. This can be achieved by improving the low temperature performance of the SCR system, which would involve controlling NO_X during cold start and accelerating the catalyst light-off temperatures; controlling emissions at light load and low-speed operations; and once warmed-up, maintaining high conversion efficiency. To meet certification standards lower than 0.20 g/bhp-hr NOx, such as ARB's optional NO_X standards of 0.1, 0.05, and 0.02 g/bhp-hr (ARB, 2013), it may also be necessary to further reduce NO_X emissions at high speed and high load operations. Reducing NO_X at cold start, light load, low-speed, high load and high speed operations may require a combination of strategies including exhaust thermal management methods, advanced catalyst formulations, better control systems, and more effective alternative sources for ammonia. As shown in Figure II-4, Naseri et al. recently demonstrated significant NO_X conversion efficiency improvements of greater than 95 percent during the cold federal test procedure (FTP) transient test using an advanced aftertreatment system that included low temperature NO_X storage catalyst (dCSC), SCR coated on DPF (SCRF) with a downstream high porosity SCR catalyst, ammonia slip catalyst in combination with thermal management (TM) strategies (electrical heater), and early availability of pre-stored ammonia in the system (Naseri et al., 2015). The strategies are discussed in detail in Chapter III.

Figure II-4: Cold-Start Technologies Being Demonstrated



(Naseri et al., 2015)

III. Technologies Evaluated

This chapter discusses a number of measures and technologies currently being explored to reduce cold start and low temperature emissions and improve the NO_X conversion efficiency of SCR aftertreatment systems at all engine operating conditions, including low-speed and high-speed operations. Section A discusses improvements to the aftertreatment system, which may improve NO_X conversion without incurring a fuel consumption penalty. Section B discusses engine-based exhaust gas thermal management and exhaust system thermal management strategies. Strategies that have the potential for reducing NO_X further without a fuel penalty are presented first, followed by strategies that may incur a fuel penalty.

It is not expected that a single emission control strategy will reduce emissions significantly on its own. Maximum NO_X and GHG benefits can result from proper systems integration and optimization of engine management control strategies with advanced aftertreatment systems and their control strategies. For example, one integrated system could include accelerating the catalyst light-off by raising the exhaust gas temperature using engine-based strategies and improving aftertreatment conversion efficiency using advanced catalyst formulations and a urea-SCR control system. Furthermore, as discussed at further length in the ARB's companion report Technology Assessment: In-Use Emissions Truck Technology Assessment, improving the certification and in-use compliance programs would help ensure emission reductions are achieved in the real world and durable.

A. Advanced Aftertreatment Systems

1. Advanced SCR catalysts

Table III-1 shows urea-SCR catalysts in commercial use today. Vanadia based catalysts are not currently used for on-road applications in North America due to the possibility of emissions of vanadium compounds being produced at elevated exhaust gas temperatures that may occur during active DPF regeneration.

SCR catalyst formulations and designs have been undergoing continuous development to improve the durability and the overall NO_X conversion performance of the SCR system. To improve the temperature operating window, catalysts with high cell density and thinner durable substrate walls are being developed. The high cell density and increased porosity provide increased surface area to allow sufficient contact area between the exhaust gas and the active catalytic materials. The thin substrate walls also reduce the catalyst thermal mass allowing rapid warm-up. Other catalyst formulations such as chemical mixtures of copper and iron zeolites have also been shown to improve the low temperature performance versus copper-zeolite alone (Yang & Narula, 2011). High cell density substrates are also being evaluated and are showing faster reactions than current substrates (Johnson, 2014a). Furthermore, low temperature performance of new generation copper zeolites has also been improving relative to earlier generation copper zeolites (15 percent improvement at temperatures of 175° and 200°C) (Walker, 2012). Moreover, as discussed below in paragraph 3, combined SCR-DPF systems are being developed to improve SCR catalyst light-off, reduce system size, packaging, and cost.

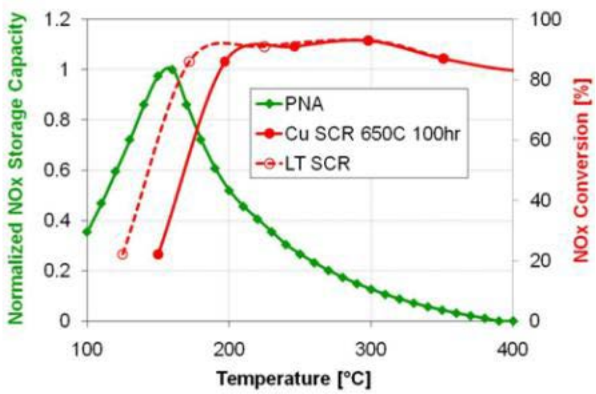
Table III-1: Urea-SCR catalysts in commercial use today

Copper-zeolite	- High performance at low temperatures - Temperature window 150°C to 450°C - High efficiency at high space velocity - Little sensitivity to NO_2 concentration - Susceptible to sulfur poisoning /requires occasional desulfation - Does not create dioxins
Iron-zeolite	- High performance at high temperature - Temperature window 350°C to 600°C - NO_2 management of the inlet gas needed for improved low temperature performance - No sulfur poisoning but susceptible to moderate HC poisoning
Vanadia	- Cheapest of the catalysts - Temperature window: 300°C to 450°C - Poor high temperature durability (deteriorates at 550°–600°C) - Not utilized in systems with DPFs that require active regeneration - Low temperature performance strongly depends on NO_2 availability

2. Passive NO_X adsorber

A passive NO_X adsorber (PNA) is a NO_X storage device that is placed upstream of an SCR to store NO_X during cold start and during low temperature operations and then release the NO_X at higher temperatures when the downstream SCR catalyst becomes active. Figure III-1 illustrates the NO_X storage capacity of the PNA and the NO_X conversion efficiency of a urea-SCR system during the cold start segment of the light-duty FTP-75 (Henry et al., 2011). In this illustration, the PNA stores approximately 65 percent of the NO_X at temperatures less than 150°C. The majority of the stored NO_X is released at temperatures of around 150°C to 200°C when the SCR activity is still very low. Thus, a low temperature SCR catalyst (e.g., close-coupled SCR coated on DPF) and/or ammonia gas injection or using pre-stored ammonia in the catalyst can be used to bridge the gap and improve NO_X conversion at the lower temperatures. The technology is currently under research and development and more work is needed to optimize the PNA to improve the NO_X storage efficiency (≥ 90 percent) and to increase the NO_X release temperature (> 150°C).

Figure III-1: PNA Strategy to Improve Low Temperature Performance

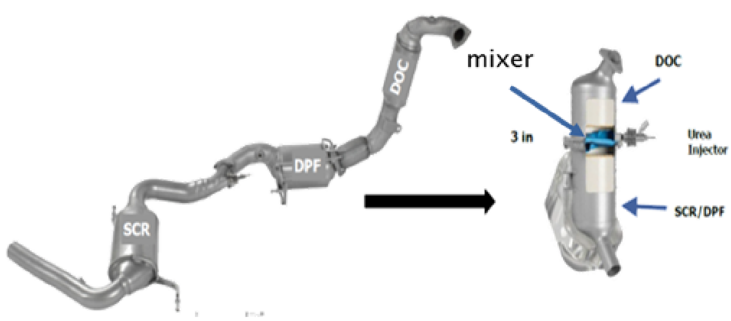


(Henry et al., 2011)

3. Combined SCR-DPF systems

A technology that is receiving considerable attention is the combined SCR-DPF system (also referred to, by different manufacturers, as SCRF, SDPF, or SCRoF), in which the porous walls of the DPF substrate are impregnated with SCR catalytic material. As shown in Figure III-2, it combines the functionalities of two systems, the SCR and the DPF, into one aftertreatment system, reducing system size, weight, complexity, and cost. With the addition of a compact urea mixer, the system can be close-coupled to the DOC for faster light-off and improved cold start emissions. To maximize NO_X conversion, the system may also require an additional SCR system downstream of the combined system. Copper and iron-based catalysts are more appropriate for use as SCR catalysts on the DPF due to their higher thermal stability (Karamitros et al., 2014).

Figure III-2: Close-coupled combined SCR-DPF System



There are competing requirements that need to be considered in the development of combined SCR-DPF systems. These include the impacts of competitive NO_2 consumption by the SCR and the DPF, the effect of soot loading on NO_X conversion, and the effect of NO_X conversion activity on filter regeneration. For improved NO_X conversion, it is desirable to have the highest possible amount of active SCR sites on the pores of the filter, so a high porosity filter substrate would be required. Furthermore, filter performance such as pressure drop, filtration efficiency, and thermal durability may also limit the amount of catalyst washcoat loading.

The technology is still under research and development for heavy-duty applications. Catalyst manufacturers are currently investigating the performance of the technology on HDDEs and have reported some promising results, although more work needs to be done to optimize the performance of the system at low temperatures (Naseri et al., 2014; Naseri et al., 2015).

4. Close-coupled SCR catalyst

Placing the SCR catalyst upstream of the DPF and closer to the DOC exposes the SCR to higher exhaust gas temperatures compared to a conventional DPF-SCR system (see Figure III-3). This enables faster SCR light-off and therefore better cold start NO_X conversion efficiency. However, the exhaust gas reaching the DPF will be cooler and will have relatively lower concentration of NO_2, thus minimizing the passive regeneration potential and increasing the potential for needed active regeneration. As a result, the filter may require supplemental heat to improve filter regeneration during extended low exhaust gas temperature events, resulting in a potentially higher fuel consumption penalty.

Figure III-3: SCR Upstream of DPF

5. Alternative Sources for Ammonia

In a traditional SCR system, the ammonia gas is generated by injecting urea into the hot exhaust stream upstream of the SCR catalyst. However, current SCR performance is limited by urea decomposition and hydrolysis issues at exhaust gas temperatures below 200°C. If urea is injected at exhaust gas temperatures below 200°C, solid deposits, such as ammonium nitrate and/or ammonium sulfate, are formed over the catalyst and exhaust system. The solid deposits degrade the NO_X conversion efficiency of the system. Furthermore, aqueous urea freezes at an ambient temperature of -11°C, so a heating system may be required to heat the urea tank for low ambient temperatures. Two alternative sources of ammonia that could enable SCR conversion at temperatures below 200°C are discussed below.

a. Solid Ammonia Precursors

The issues with urea may be resolved to a certain extent using solid ammonia precursor compounds, which when heated can deliver ammonia gas. Candidate ammonia storage materials should have high ammonia storage capacity, low decomposition/desorption temperature, and should be safe and easy to handle. Two groups of ammonia storage materials that show a desirable combination of properties are ammonium salts and metal ammines.

Since the density of ammonia is higher in ammonium salts than in urea, ammonium salts require smaller storage containers than urea. Ammonium carbamate and ammonium carbonate are two types of ammonium salts that decompose completely into gases without leaving solid deposits. Both materials release ammonia and carbon dioxide when heated, though ammonium carbonate also generates water upon decomposition. Both compounds generate ammonia at temperatures below 100°C (Fulks et al., 2009).

Solid ammonia storage systems in conjunction with low temperature SCR catalysts can reduce NO_X at temperatures significantly below 200°C. However, continuous ammonia dosing during prolonged low temperature operations may result in the formation of deposits such as ammonium nitrate. As a result, advanced control algorithms are needed to calculate the amount of deposits formed as a function of the ammonia injected and the operating temperature, and then stop ammonia dosing once the maximum allowed deposit mass is reached.

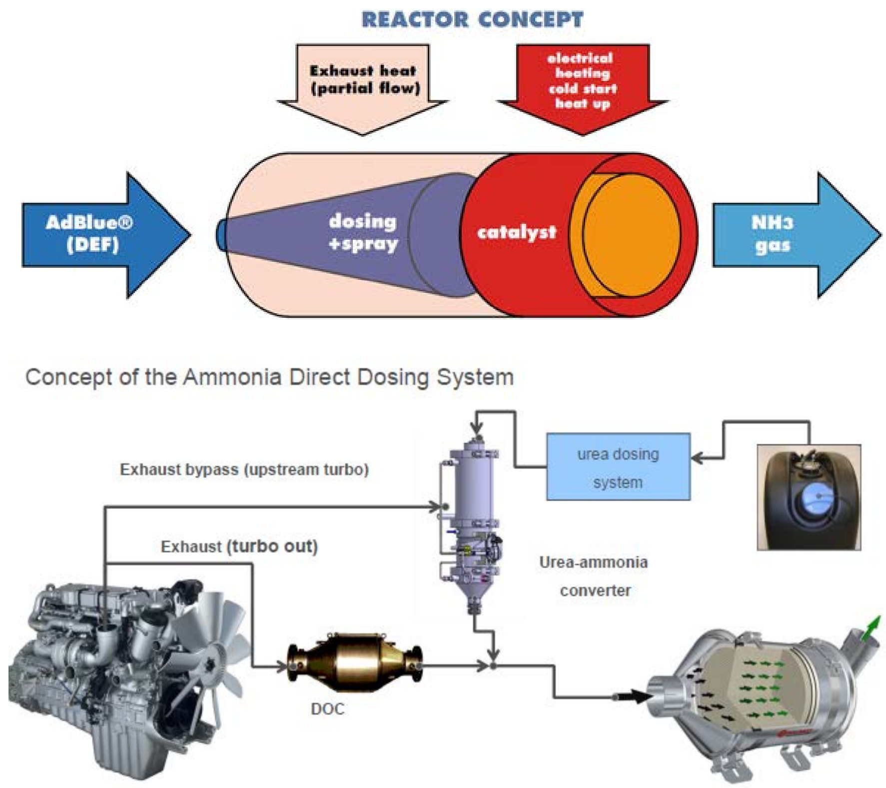
A solid storage system that uses strontium amine chloride has been developed for light- and heavy-duty vehicles. The system starts releasing ammonia at exhaust temperatures of about 100°C. The version for heavy-duty engines consists of two replaceable/refillable dosing systems: an engine coolant heated main cartridge and an electrically heated start-up cartridge for cold start. The technology is currently in pilot demonstration phase.

To become widely used, solid ammonia storage systems would require development of infrastructure for the replacement and recharging of used cartridges.

b. Heated Ammonia Generation from Aqueous Urea

An alternative solution that is gaining commercial acceptance is to convert the urea solution on-board the vehicle to ammonia gas. In this system, shown in Figure III-4, ammonia gas generation occurs in a separate module outside of the main exhaust line (Doelling et al., 2014). Urea solution is injected into the module via a urea dosing system and the heat needed to convert the urea solution is provided via two sources: (1) a partial exhaust flow taken off from the main exhaust upstream of the turbocharger, and (2) an electrically heated catalyst (cold start heat up). The two heat sources can be used either one at a time or together. The ammonia gas generated is then injected into the main exhaust line upstream of the SCR catalyst. This improves the SCR performance at lower exhaust gas temperatures when urea injection into the main exhaust gas is not possible. The drawbacks of this system are it requires a separate device which requires additional space, mounting parts, pipes, connectors, cables, and electrical energy. The system is commercially available and can be used on new engines as well as in retrofit applications.

Figure III-4: The B-NOx System (Ammonia Generator)



6. Urea Delivery System

The urea delivery system comprises of the urea storage tank, heated delivery line, pump, dosing module which includes the injector and mixer, and the control system and associated sensors. The main functions of the urea dosing and injection system include dosing of the precise amount of urea necessary for NO_X conversion and mixing urea and ammonia thoroughly with the exhaust gas. Potential improvements to the urea delivery system are discussed below.

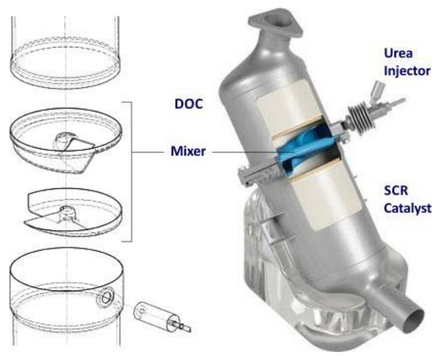
a. Urea Dosing and Injection System

New generations of urea dosing systems are being developed and introduced to enable high SCR conversion efficiencies. Air assisted injectors, which need separate air pumps specific for urea injection are being replaced by airless injectors where the energy for atomization is supplied by the urea pressure. Urea pumps, dosing modules and injectors are moving from separate component designs into integrated designs. For example, Delphi has developed an integrated pump and airless injector system that delivers a peak injection pressure of 50 bar and a highly optimized injection spray. The system is designed to perform well with close coupled catalysts where the mixing length is very short and uniform ammonia distribution at the catalyst inlet is required (Needham et al., 2012).

b. Urea Mixer

Currently, low temperature SCR activity is limited by urea decomposition and hydrolysis issues at exhaust gas temperatures below 200°C. Improved mixers enable urea injections at temperatures as low as 180°C (Alano et al., 2011). For example, compact swirl mixers with very short mixing paths have been developed to enable the SCR catalyst to be placed closer to the engine for faster heat-up (Figure III-5). The technology is in the research and development stage for heavy-duty vehicles.

Figure III-5: SCR BlueBox Compact Mixer



(Faurecia, 2014)

c. Urea Hydrolysis Catalyst

Urea hydrolysis catalysts that use base metal oxide formulations such as titania can be placed between the urea injection point and the SCR catalyst to ensure more complete urea decomposition and to accelerate the formation of ammonia, potentially improving cold start and overall SCR performance.

d. Urea Injection Control

The objective of the urea injection control system is to simultaneously minimize the tailpipe NO_X and ammonia emissions by enabling the urea dosing system to inject the precise amount of urea necessary for NO_X conversion. Closed-loop control SCR systems are used in applications such as 2010 heavy-duty diesel engines, where high NO_X conversion efficiency (>90 percent) is needed (Majewski, 2014). For a closed-loop SCR control system, a NO_X sensor upstream of the SCR and downstream NO_X and ammonia sensors are needed to adjust the amount of urea injected.

Ammonia sensors which recently became commercially available are enabling direct measurements of ammonia slip at the SCR outlet (Majewski, 2014). Thus, the combination of NO_X and ammonia sensors and model-based closed-loop control has significantly improved the precision in urea injection of the SCR system (Wang et al., 2008). The use of ammonia sensors can also provide the flexibility to eliminate or reduce the size of the ammonia slip catalyst.

e. Ammonia Slip Catalysts

Ammonia slip catalysts are precious metal-based oxidation catalysts that are needed to oxidize excess unreacted ammonia that may have slipped through the SCR catalyst and would otherwise be exhausted to the environment. Ammonia slip catalysts are designed to have high selectivity for ammonia, oxidizing ammonia to form nitrogen. However, if the nitric oxide to ammonia ratio coming out of the SCR catalyst is very high, the catalyst may also catalyze undesirable reactions that produce nitrous oxide, a potent greenhouse gas. The latest generations of ammonia slip catalysts with reduced precious metal content are showing much better selectivity for ammonia, while forming less undesirable products at the tailpipe. This technology is commercially available for heavy-duty applications.

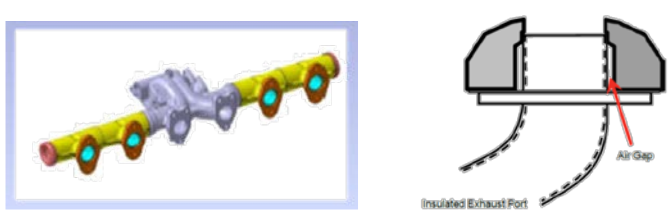
B. Exhaust Gas Thermal Management

This strategy involves increasing and maintaining the exhaust gas temperature through thermal insulation of the exhaust system, direct heat addition to the exhaust using fuel burners or electrically heated catalysts, and increasing the exhaust gas temperature through engine control strategies. Except for the exhaust system heat retention strategy, all of the other strategies discussed in this section involve heat addition and therefore may have negative impacts on fuel consumption.

1. Exhaust system heat retention

The use of exhaust thermal management strategies to reduce cold start emissions has also led to improvements of the exhaust system components upstream of the SCR in order to retain as much heat as possible in the exhaust gases. Reducing the mass of the exhaust system and insulating it from the outlet of the turbocharger to the inlet of the SCR system would reduce the amount of heat lost to the walls. Double walled manifolds and pipes with a very thin inner wall and an air gap separating the inner and outer wall may be used to insulate the exhaust system and reduce the thermal mass, minimizing the amount of heat lost to the walls (Figure III-6). This technology is prevalent in gasoline-fueled engine applications and is in the demonstration phase for diesel engine applications. There is no fuel penalty with this strategy.

Figure III-6: Insulated Exhaust System



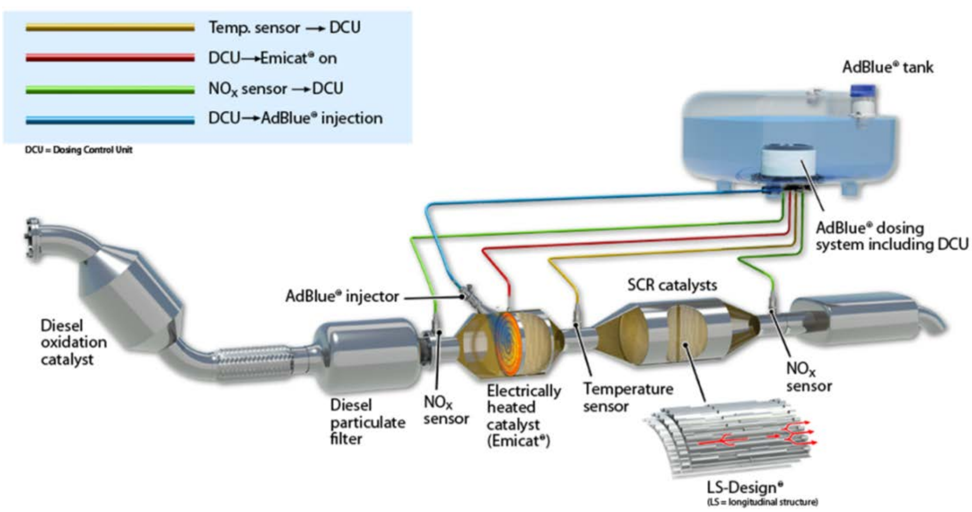
2. Supplemental heat to the exhaust gas

Another approach to raising the exhaust gas temperature to improve SCR conversion efficiency at low temperatures is to directly add heat to the exhaust using electrically heated catalysts or fuel burners.

a. Electrically heated catalyst

Electrically heated catalysts (EHC) use a small catalyst ahead of the main catalyst to deliver heat directly to the exhaust gases. The system can be programmed to activate only when it is needed during cold starts or during light-load operations when the exhaust gas temperature drops below the catalyst light-off temperature. Since EHCs use electricity generated by the engine's alternator, the exhaust gas heating is a parasitic load on the engine and therefore consumes fuel. However, the fuel consumption penalty may become less significant when used in combination with electric hybrid vehicles where the electrical energy used is recovered via braking energy. Heated metal catalysts, with a power rating between 1 and 3 kW, can raise the exhaust gas temperature by 20 to 30°C in commercial vehicles (Emitec, 2013). The technology is widely commercially available in light-duty vehicles and is in the demonstration phase for commercial heavy-duty vehicle applications. Shown in Figure III-7 is Emitec's electrically heated catalyst.

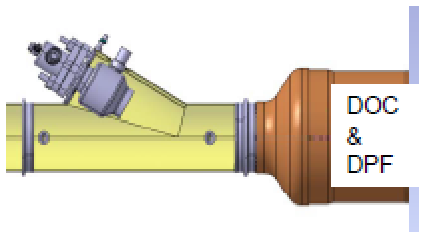
Figure III-7: Electrically Heated Catalyst



b. Exhaust fuel dosing / fuel burners

In this approach, the exhaust gas temperature is increased either by combusting the fuel in the fuel burner with the flame entering the exhaust system or injecting fuel into the exhaust gas and oxidizing it over an oxidation catalyst, or a combination of the two. Similar to the EHC, the fuel burner (Figure III-8) may be operated only when needed during cold start or when the exhaust gas temperature drops below the light-off temperature. The strategy can increase fuel consumption. The technology is widely available commercially to add heat to the exhaust to facilitate diesel particulate filter regeneration.

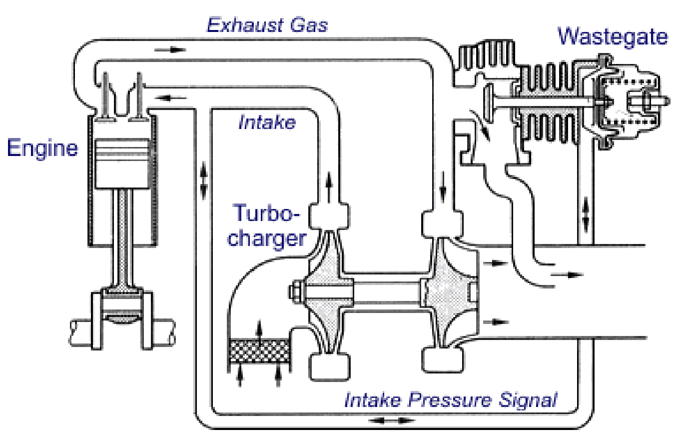
Figure III-8: Fuel Burner



3. Turbocharger bypass (Wastegate)

Turbocharger bypass is simply a valve in the turbine housing that allows some portion of the exhaust gas to bypass the turbocharger and divert it directly to the exhaust system (Figure III-9). Having the exhaust gas bypass around the turbocharger limits the turbine speed and the amount of power delivered by the turbine. This reduces the amount of inlet boost pressure that the compressor provides, resulting in a fuel rich mixture condition. Since there is insufficient oxygen in the mixture, combustion of the fuel rich mixture results in reduced NO_X emissions. In addition to reducing in-cylinder NO_X, this strategy also avoids heat loss across the turbine housing, accelerating catalyst warm-up during cold starts. The bypass valve may be closed during transient operations to minimize effects on drivability and emissions. Using this strategy to increase exhaust gas temperature can increase fuel consumption. The technology is widely available commercially.

Figure III-9: Turbocharger with External Wastegate



(www.dieselnet.com)

4. VG turbocharge control

Electronically controlled VG turbochargers may also be used to increase the exhaust gas temperature by partially closing the VG turbine vane to increase the exhaust manifold pressure. The high exhaust manifold pressure makes the engine work harder thereby increasing the exhaust gas temperature. Since the engine is made to work harder, there could be a fuel consumption penalty with this strategy. The technology is widely available commercially.

5. Increasing idle speed

Increasing idle speed increases the amount of fuel injected during idle, thereby producing a rich exhaust. The unburned hydrocarbons in the exhaust are oxidized in the DOC, providing a moderate increase of exhaust gas temperature. However, this strategy can impact fuel consumption negatively. The technology is widely available commercially.

6. In-cylinder post injection

Injecting fuel late in the combustion process allows some of the unburned hydrocarbons in the exhaust to create an exothermic reaction downstream at the DOC. This increases the exhaust gas temperature, which improves aftertreatment performance during cold start or low temperature operation. This strategy can increase fuel consumption. The technology is widely available commercially.

7. Intake air throttling

A commonly used method of increasing the exhaust gas temperature is intake air throttling. The method involves partially reducing the amount of air entering the cylinder, which in turn reduces the power output of the engine. In a diesel engine, load control is generally accomplished by varying the amount of fuel injected to the engine. Therefore, to maintain the required engine load, fuel consumption increases resulting in fuel rich mixture combustion. This supplies unburned fuel to the DOC creating an exothermic reaction and as a result increases the exhaust gas temperature. This strategy can increase fuel consumption. The technology is widely available commercially.

8. EGR

EGR is used as a NO_X reduction strategy in modern commercial heavy-duty diesel engines. EGR involves routing some portion of the exhaust gas back into the cylinder. The exhaust gas dilutes the oxygen fraction of the inlet charge entering the combustion chamber and reduces the peak combustion temperatures, thereby reducing the formation of NO_X emissions. The use of EGR to reduce NOx emissions can increase fuel consumption and PM emissions. However, as discussed in Chapter II, manufacturers have been mitigating these negative impacts through advances in engine development such as electronic controls, increased fuel injection pressure, and increased intake manifold boost pressure. As discussed in paragraphs (a) and (b) below, in addition to reducing NOx emissions, EGR can also be used to increase the exhaust gas temperature during certain engine operating conditions.

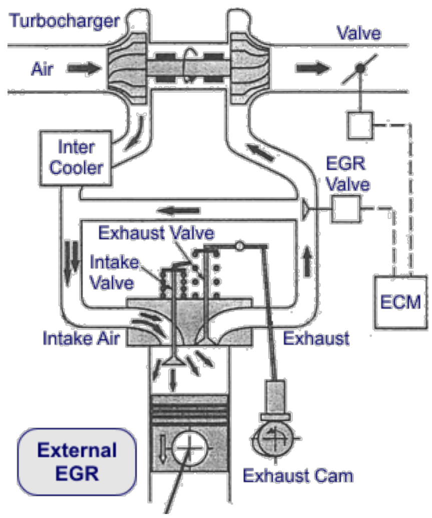
a. External EGR

This method involves routing some portion of the hot exhaust gas from the exhaust manifolds back into the cylinder (Figure III-10). Introducing hot EGR into the intake manifold increases the mixture temperature and reduces the inlet charge mass, or air to fuel ratio. The higher inlet charge temperature due to EGR improves fuel evaporation and air-fuel mixing during the ignition delay period and during combustion, increasing exhaust gas temperature. However, cooled EGR provides better in-cylinder NO_X reduction and lower PM emissions than hot EGR and therefore HDDE applications often use cooled EGR. As a result, the use of hot EGR as a strategy to increase exhaust gas temperature may be limited only to certain engine operating conditions such as cold start, extended idle, and light load operations. An EGR cooler bypass or dual loop systems may be used to allow uncooled EGR into the intake manifold. This strategy can result in additional fuel consumption. The technology is widely available commercially.

b. Internal EGR

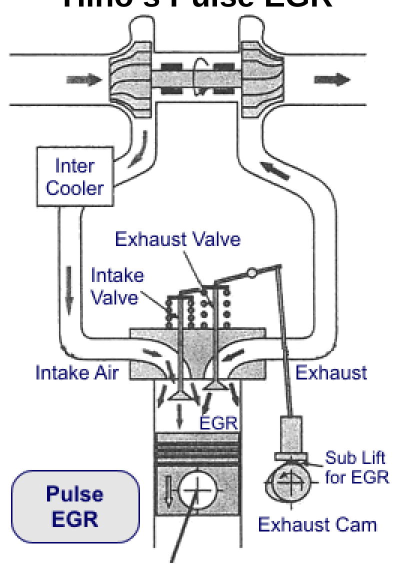
Exhaust temperature can also be increased during cold start and extended idle with internal EGR (Figure III-11). Internal EGR can be achieved with variable valve actuation (VVA) by opening the exhaust valve slightly during the intake stroke and drawing exhaust gas into the cylinder; or by opening the intake valve slightly during the exhaust stroke and pushing some of the exhaust into the intake manifold. The exhaust gas that is left in the cylinder heats up the intake charge and reduces the air-fuel ratio, providing higher combustion temperatures. This strategy can result in additional fuel consumption. The technology is widely available commercially.

Figure III-10: External EGR



(www.dieselnet.com)

Figure III-11: Internal EGR
Hino's Pulse EGR



(www.dieselnet.com)

IV. System/Network Suitability and Operational/Infrastructure Needs

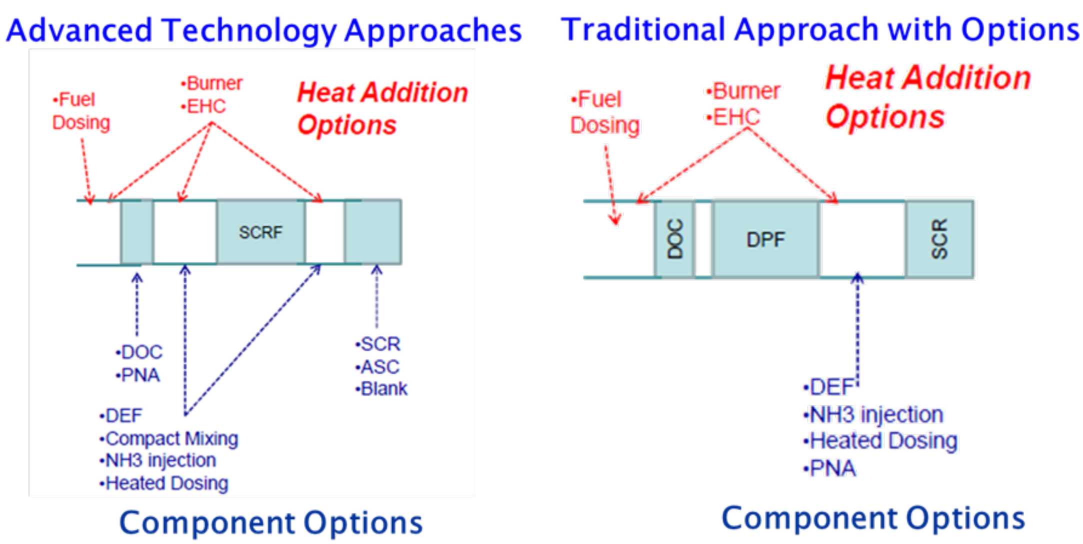
HDDEs require ULSD to enable the use of DPF and SCR control technologies to meet the 2007-2010 standards. Since 2007, almost all diesel fuel sold in the U.S. at facilities where trucks are fueled is ULSD. In addition, these vehicles are equipped with SCR aftertreatment systems and require periodic replenishment of urea for the SCR and the vehicle to function properly. Since 2010, infrastructure for urea (Diesel Exhaust Fluid) distribution has been developed, making it available at truck stops, dealerships, fueling stations, and repair and service operations. Thus, there is no specific infrastructure issue that needs to be addressed that otherwise would be an impediment to enable the lower-NO_X technology options evaluated in this assessment.

V. Demonstration Status / Technology Readiness

In 2013, ARB initiated a project with Southwest Research Institute (SwRI) to demonstrate maximum NO_X reductions from two heavy-duty engines: a stoichiometric natural gas engine and a diesel engine. SwRI will evaluate the feasibility of achieving lower NO_X emissions through a combination of engine tuning practices, exhaust thermal management strategies, and aftertreatment strategies. The engine technology must also continue to meet all applicable standards for hydrocarbons, carbon monoxide, and PM; not incur a GHG penalty; and be consistent with a technological path to meeting the upcoming U.S. Environmental Protection Agency (EPA) GHG standards for heavy duty vehicles. The target NO_X emission rate for this project is 0.02 g/bhp-hr.

The technology strategies for diesel engines are more complex and varied. Figure V-1 shows some of technology options that SwRI is investigating to demonstrate maximum feasible NO_X reductions from the HDDE. SwRI's research plan includes identification and screening of candidate aftertreatment options and engine management strategies using a low-cost diesel-based burner test rig capable of simulating test cycles and exhaust conditions from a diesel engine. The screening will identify optimum technology packages for final on-engine demonstration testing. The demonstration testing will include some but not all of the strategies listed in Figure V-1. SwRI will then perform engine dynamometer tests for the selected strategies in accordance with title 40, Code of Federal Regulations, section 1065. The tests will measure performance over the heavy-duty transient FTP, Ramped Modal Cycle (RMC), World Harmonized Transient Cycle (WHTC), extended idle, and three other low-load, low-temperature vocational cycles. The projected is expected to be completed by 2016.

Figure V-1: Options for Advanced SCR Configurations (SwRI)



VI. Cost

Almost all engine manufacturers are complying with the current 0.20 g/bhp-hr NO_X standard using the urea-SCR aftertreatment system. The incremental cost of the SCR system is estimated to add approximately $3,000 to $4,500 to the cost of the 2007 model year engine (ICCT, 2014).

It is expected that further reductions in NO_X emissions will be achieved through a combination of engine control strategies and the continued development and enhancement of new and existing aftertreatment systems, as were discussed at length in Chapters III through V. As shown in Figure VIII-1, according to Cummins, achieving a 0.1 g/bhp-hr NO_X standard is feasible (with minimal GHG penalty) with improvements to current conventional engine combustion and SCR system. Therefore, staff believes that the additional technology development cost to achieve 0.1 g/bhp-hr NO_X levels to be minimal or zero. However, it is expected that there will be costs associated with the development of technologies and strategies to reduce NO_X to lower levels of about 0.02 g/bhp-hr while at the same time also reducing GHG emissions. The Manufacturers of Emission Control Association estimates that the incremental cost of future advanced technologies needed to achieve NO_X levels of 0.02 g/bhp-hr to be approximately $500 per vehicle averaged over the medium and heavy-duty fleet (MECA, 2015). Staff expects the cost-effectiveness of these technologies to fall within the cost-effectiveness range of previous NO_X reduction requirements from new engines.

VII. Emission Levels

Currently, HDDEs are required to meet NO_X standards of 0.20 g/bhp-hr and PM standards of 0.01 g/bhp-hr on the heavy-duty transient FTP and on the RMS. Although manufacturers are certifying HDDEs to these standards, ARB in-use testing of SCR equipped HDDEs show that these engines may be emitting higher NO_X emissions during sustained real world city driving, which are conditions not covered by the heavy-duty transient FTP (Misra et al., 2013). HDDEs are also required to meet the Phase 1 GHG emission standards that will reduce GHG emissions by 5 to 9 percent by 2017, depending on vehicle weight class. In addition, ARB, U.S. EPA and the National Highway Traffic Safety Administration are currently jointly developing the Phase 2 GHG regulations that will further reduce GHGs from on-road HDDEs.

The technologies evaluated in this assessment report are expected to provide significant NO_X reductions during cold start, low load and low speed operation, and during high speed or high load operations. However, emissions data are currently not available since the current ARB-SwRI Low NO_X Program is still in the early stages of engine and aftertreatment development and no emissions test results have been reported yet.

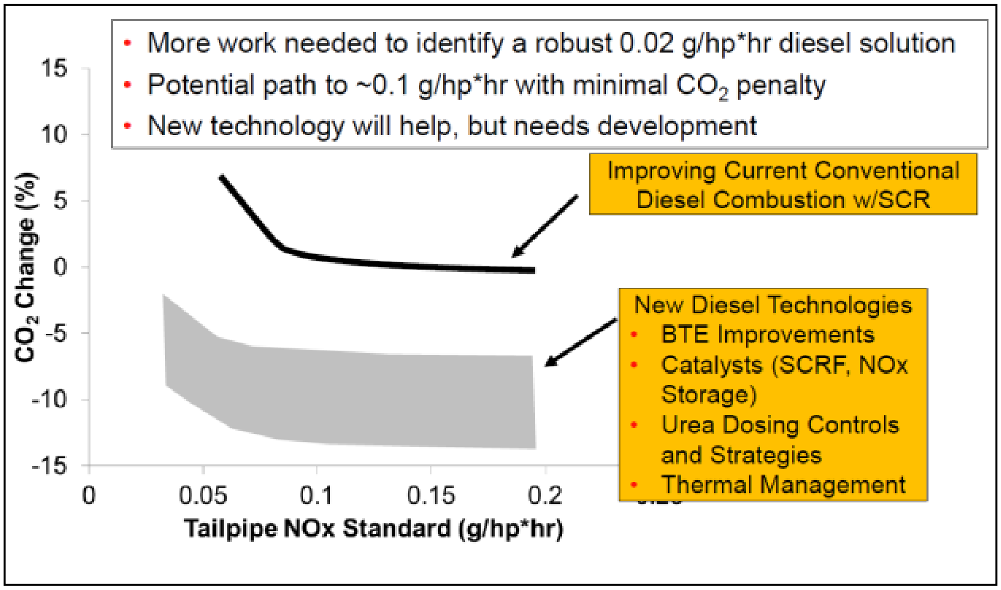
VIII. Potential for Reducing Both NO_X and GHG Emissions

As discussed in Chapter II, to comply with the pre-2010 model year NO_X standards, engines were designed to reduce in-cylinder NO_X at the expense of in-cylinder PM emissions and fuel consumption or GHG emissions (NO_X/GHG trade-off). However, continued developments in combustion systems, fuel injection systems, turbochargers, and electronic controls allowed engine manufacturers to partially mitigate the excess PM and fuel consumption. The introduction of the SCR aftertreatment systems to meet the 2010 NO_X standards further enabled engine manufacturers to optimize engine fuel economy, while minimizing both PM and NO_X emissions, thus overcoming the NO_X/GHG trade-off. The same engine optimization strategy will be used with future advanced SCR technologies, providing greater NO_X and GHG reductions, especially at high speed and high load operations.

Reducing NO_X emissions to the 0.02 g/bhp-hr levels will require significant emissions reductions during cold start and during low load, low speed operations. There are a variety of strategies which may be used to achieve these reductions. One approach is to improve exhaust gas thermal management. Close coupled SCR on DPF formulations and low thermal mass catalyst substrates can efficiently utilize existing heat in the exhaust gas, providing improved NO_X control during cold start conditions and during low speed and low load operations. In addition, start-stop technology shuts the engine off rather than idling, which allows the latent heat in the aftertreatment system to be retained, improving NO_X emission control when the engine is restarted for operation. Another approach would be to use NO_X storage catalysts during cold starts. These catalysts temporarily capture NO_X emissions at low temperatures and release NO_X at higher temperatures when they can be effectively controlled by the SCR system. Also, advanced catalyst formulations and ammonia injection techniques rather than only relying on urea injection, would provide increased NO_X control efficiencies under a wide range of engine operating conditions. All of these strategies can provide additional NO_X reductions while allowing for optimal fuel economy. Finally, strategies that use external heat source may be used to provide supplemental heat to the exhaust gas. These strategies can impact fuel economy, but the impact should be minor.

Figure VIII-1 shows an assessment of the feasibility of achieving lower NO_X emissions and the impacts on GHG emissions by Cummins Inc., one of the largest manufacturer of heavy-duty diesel engines in the U.S. (Eckerle, 2015). The solid black line in the figure represents current diesel technology. The chart shows that a 0.1 g/bhp-hr NO_X level is feasible with some improvements to the current SCR technology and the conventional diesel combustion process while still allowing for fuel economy optimization. According to Cummins, reducing NO_X further to the 0.02-0.05 g/bhp-hr levels and simultaneously reducing GHG emissions (shaded grey curve) would require more improvements in engine combustion efficiency, thermal management strategies, and advanced aftertreatment technologies such as NO_X storage catalysts, SCR coated on DPFs, and urea dosing control strategies. Most of these strategies and technologies are discussed in Chapter III of this document.

Figure VIII-1: Cummins' Assessment of GHG and NOx Reduction Opportunities with New Engine Technologies



(Eckerle, 2015)

Manufacturers normally certify their engines with a compliance margin at levels below the numerical standard to protect themselves against non-compliance due to minor increases in emissions in use. The certification levels also include deterioration factors to account for any increase in emissions over the useful life of an engine. An analysis of NO_X certification levels indicates that the compliance margins for the latest diesel engines are 10 percent to 60 percent below the 2010 NO_X certification standard, depending on engine size. Hence, based on the above assessment and the current certification levels, staff believes diesel engines are likely to be certified to the optional NO_X emission standard of 0.1 g/bhp-hr by 2016, while engines meeting 0.05 g/bhp-hr or below are likely to be certified later.

IX. Next Steps

- ARB should continue to provide incentive funding for low-NO_X heavy-duty engines to encourage engine manufacturers to develop and certify engines that meet the optional NO_X standards.

- Given California's criteria pollutant, GHG, and petroleum reduction needs, staff recommends that ARB implement statewide strategies that employ lower NO_X combustion engines coupled with the use of renewable fuels in order to attain near-term air quality and climate goals.

- In order to achieve air quality goals, ARB intends to begin development of lower mandatory NO_X standards applicable to all heavy-duty vehicles that operate in California. Since out-of-state registered heavy-duty vehicles that operate in California contribute significantly to the emissions inventory, it is also critical that ARB petition the U.S. EPA to require lower NO_X standards applicable to all heavy-duty vehicles nationally.

X. Conclusion

Even with advanced technologies (hybrid, battery, fuel cell vehicles), heavy-duty diesel internal combustion engines will continue to play a major role in the passenger and freight transportation industry of the nation. Even though HDDEs are significantly cleaner than they were in the past decade, additional reductions are needed to meet air quality and GHG goals. To this end, ARB is contracting with SwRI to demonstrate the feasibility of low-NO_X emissions without incurring a GHG penalty. Aftertreatment system manufacturers are also conducting research to develop technologies that would significantly improve the performance of the aftertreatment system to reduce emissions during cold start, light load, and high-speed steady-state operations, and the developments are showing promising signs that NO_X can be reduced significantly below current standards. To achieve maximum NO_X and GHG reductions, engine management and aftertreatment control integration is necessary. Based on ARB staff's technology assessment, staff is optimistic that with the technologies and strategies discussed in this report, manufacturers will within the next decade be able to certify heavy-duty diesel engines that can be certified to significantly lower than the current 0.20 g/bhp-hr NOx new engine standard. The strategies to be employed and the extent of further NOx reductions remain to be determined, but progress is certainly possible.

XI. References

(Alano et al., 2011) Alano, E., Jean, E., Perrot, Y., Brunel, J. et al. *Compact SCR for Passenger Cars;* SAE Technical Paper 2011-01-1318, 2011, doi:10.4271/2011-01-1318.

(ARB, 2013) Air Resources Board. *Optional Reduced Emission Standards for Heavy-Duty Engines.* Staff Report: Initial Statement of Reasons. Sacramento. October 22, 2013. <http://www.arb.ca.gov/regact/2013/hdghg2013/hdghg2013.htm> (accessed on May 5, 2015).

(Doelling et al., 2015) Doelling, W.S., Y. Zhang, S. Wang, J. Li, J. Margraf, T. Haake, C. Luecking, W. Frank, M. Mrosek, *NH3 Generator for Enhanced Low-Temperature SCR Performance; An Option also for Retrofit.* Proceedings of SAE-China Congress 2014: Selected Papers, Lecture Notes in Electrical Engineering 328, DOI 10.1007/978-3-662-45043-7_21

(Eckerlie, 2015) Eckerle, Wayne. *Engine Technologies for GHG and Low NOx* Presentation at ARB Symposium on Phase 2 GHG. Los Angeles. April 22, 2015. <http://www.arb.ca.gov/msprog/onroad/caphase2ghg/presentations/caphase2ghg_symposium_presentations.htm> (accessed on May 5, 2015).

(Emitec, 2013) EMITEC; Press Release 65th IAA Cars; September 2013. <http://www.emitec.com/fileadmin/user_upload/Presse/Presseinformationen/IAA_2013/Heated_catalyst.pdf> (accessed on September 23, 2014).

(Faurecia, 2014) SCR Bluebox. <http://www.faurecia.com/en/innovations/our-areas-innovation> (accessed on September 25, 2014).

(Fulks et al., 2009) Fulks, G., Fisher, G., Rahmoeller, K., Wu, M. et al. *A Review of Solid Materials as Alternative Ammonia Sources for Lean NO_X Reduction with SCR*; SAE Technical Paper 2009-01-0907, 2009, doi:10.4271/2009-01-0907.

(Henry et al., 2011) Henry, C., D. Langenderfer, A. Yezerets, M. Ruth, H. Chen, H. Hess, M. Naseri. *Passive Catalytic Approach to Low Temperature NO_X Emission Abatement*; Presented at the 2011 DEER Conference, Detroit, MI.

(ICCT, 2014) Blumberg, K., F. Posada, and J. Miller. *Revising Mexico's NOM 044 standards: Considerations for decision-making* International Council on Clean Transportation, Working Paper 2014-5. May 2014. <http://www.theicct.org/series/heavy-duty-vehicle-policies-for-mexico> (accessed on March 5, 2015).

(Johnson, 2014a) Johnson, T. *Review of Selective Catalytic Reduction (SCR) and Related Technologies for Mobile Applications*; In I. Nova and E. Tronconi (eds.), Urea-SCR Technology for deNOx After Treatment of Diesel Exhausts, Fundamental and Applied Catalysis, DOI: 10.1007/978-1-4899-8071-7_1,_ Springer Science+Business Media New York; 2014.

(Karamitros et al., 2014) Karamitros, D., S. Skarlis, and G. Koltsakis. *Exhaust Gas Aftertreatment Technologies and Model Based Optimization*; In: Automotive Exhaust Emissions and Energy Recovery; Editor: Apostolos Pesiridis © 2014 Nova Science Publishers, Inc.

(MECA, 2015) *MECA's Written Statement on the U.S. EPA's Proposal to Revise the NAAQS for Ozone.* Manufacturers of Emission Control Association. March 16, 2015. <http://www.meca.org/attachments/2560/MECA_EPA_ozone_NAAQS_testimony_031715.pdf> (accessed on May 21, 2015).

(Majewski, 2014) Majewski, A. *Urea Dosing and Injection Systems*; Revision 2014.08a. <www.DieselNet.com> (accessed on October 1, 2014).

(Misra et al., 2013) Misra, C., J. Collins, J. Herner, T. Sax, M. Krishnamurthy, W. Sobieralski, M. Burntizki, and D. Chernich. *In-Use NO_X Emissions from Model Year 2010 and 2011 Heavy-Duty Diesel Engines Equipped with Aftertreatment Devices*; Environmental Science and technology; Volume 47, pages 7892-7898.

(NADA, 2015). NADA Data. Annual Financial Profile of America's Franchised New-Car Dealerships. 2014 <https://www.nada.org/nadadata/> (accessed on September 4, 2015).

(Naseri et al., 2014) Naseri, M., Conway, R., Hess, H., Aydin, C. et al. *Development of Emission Control Systems to Enable High NO_X Conversion on Heavy Duty Diesel Engines*; SAE Technical Paper 2014-01-1525, 2014, doi:10.4271/2014-01-1525.

(Naseri et al., 2015) Naseri, M., Aydin, C., Mulla, S., Conway, R. et al., *Development of Emission Control Systems to Enable High NO_X Conversion on Heavy Duty Diesel Engines*, SAE Int. J. Engines 8(3):2015, doi:10.4271/2015-01-0992.

(Needham et al., 2012). Needham, D., P. Spadafora, and H. Schiffgens. *Delphi SCR Dosing System – An alternative approach for close-coupled SCR catalyst systems*; SIA Diesel International Conference, Rouen; June 2012. <http://delphi.com/images/news/2012/Delphi-SCR-Dosing-System-SIA Diesel-Rouen-2012.pdf> (accessed on October 15, 2014).

(Walker, 2012) Walker, A. (2012) as cited in Johnson, T.; *Vehicular Emissions in Review*; SAE Int. J. Engines 6(2):699-715, 2013, doi:10.4271/2013-01-0538.

(Wang et al., 2008) Wang, D., Yao, S., Shost, M., Yoo, J. et al. *Ammonia Sensor for Closed-Loop SCR Control*; SAE Int. J. Passeng. Cars - Electron. Electr. Syst. 1(1):323-333, 2009, doi:10.4271/2008-01-0919. <www.delphi.com/pdf/techpapers/2008-01-0919.pdf>.

(Yang & Narula, 2011) Yang, X., Narula, C. *Simple Approach to Tuning Catalytic Activity of MFI-Zeolites for Low Temperature SCR of* NO_X; poster at U.S. Department of Energy. <http://energy.gov/sites/prod/files/2014/03/f8/p-18_yang.pdf> (accessed on October 15, 2014).

TAB 22

BOARD MEETING DATE: November 6, 2015 AGENDA NO. 4

PROPOSAL: Recognize Revenue and Execute Contract for Development, Integration and Demonstration of Ultra-Low-Emission Natural Gas Engine for On-Road Heavy-Duty Vehicles

SYNOPSIS: The Board previously awarded contracts to Cummins Westport Inc. (CWI) and Cummins Inc. to develop next generation ultra-low-emission heavy-duty natural gas engines that are 90% cleaner than the current NOx emission standard. As a follow-on to this development project and given market demand for natural gas engines in the 11- to 13-liter range, the CEC, Southern California Gas Company and Clean Energy have expressed interest in cofunding the advancement of the current 11.9-liter natural gas engine to achieve ultra-low NOx emissions. These actions are to recognize revenues up to $2.5 million and execute a contract with CWI for development, integration and demonstration of an 11.9-liter ultra-low-emission natural gas engine in an amount not to exceed $4.25 million from the Clean Fuels Fund (31).

COMMITTEE: Technology, October 16, 2015; Recommended for Approval

RECOMMENDED ACTIONS:

1. Recognize, upon receipt, up to $500,000 from Clean Energy and up to $1 million each from the CEC and Southern California Gas Company into the Clean Fuels Fund (31) for the development, integration and demonstration of ultra-low-emission natural gas engines for on-road heavy-duty vehicles and appropriate these monies into the Clean Fuels Fund; and
2. Authorize the Chairman to execute a contract with CWI for the development, integration and demonstration of an 11.9-liter ultra-low-emission natural gas engine for on-road heavy-duty vehicles in an amount not to exceed $4.25 million from the Clean Fuels Fund (31), of which SCAQMD’s share is not to exceed $1,750,000.

Barry R. Wallerstein, D.Env.
Executive Officer

MMM:HH:RP:AAO:RC

Background
On-road heavy-duty diesel vehicles are currently one of the largest sources of NOx emissions, which are precursors to ozone formation, in the South Coast Air Basin. This source category is projected to be one of the largest contributors to NOx emissions even as the legacy fleet of older and higher polluting vehicles are retired and replaced with vehicles meeting the 2010 heavy-duty exhaust emissions standards. However, research is being conducted for the next generation natural gas engines to achieve a 90% cleaner NOx emissions level compared to the current emission standard. The SCAQMD is sponsoring projects with Cummins Westport Inc. (CWI) and Cummins Inc. to develop and demonstrate 8.9- and 15-liter natural gas engines. In fact, CWI recently received CARB certification for its 8.9-liter engine at 0.02 g/bhp-hr NOx.

As a follow-on to the engine development and demonstration projects and given market demand for natural gas engines in the 11- to 13-liter range, the CEC, Southern California Gas Company (SoCalGas) and Clean Energy have expressed interest in cofunding advancement of the current 11.9-liter natural gas engine to achieve ultra-low-NOx emissions.

Proposal
This action is to recognize, upon receipt, up to $500,000 from Clean Energy and up to $1 million each from the CEC and Southern California Gas Company for a total of up to $2.5 million and appropriate these monies into the Clean Fuels Fund (31). This action is to also execute a contract with CWI for the development, integration and demonstration of an 11.9-liter ultra-low-emission natural gas engines for use in on-road heavy-duty vehicle applications in an amount not to exceed $4,250,000, of which SCAQMD's share is not to exceed $1,750,000.

The project is intended to advance engine and aftertreatment technologies in the current 11.9-liter natural gas engine to achieve NOx emission levels that are at least 90% lower than 2010 engine emission certification standards. CWI will be required to conduct engine and aftertreatment development activities to achieve the ultra-low-emissions target and perform substantial validation and durability testing to confirm the robustness of their design. Once developed, the engine will be tested using both the Federal Test Procedure for emissions certification and non-certification test cycles representative of the real-world use in different vocations that are prevalent in the air basin. The use of vocational specific test cycles will provide additional insight towards the engine's real-life emission reduction potential. The program will ultimately conclude with the engine being integrated into on-road heavy-duty chassis and placed in commercial service to fully validate its performance and viability.

Benefits to SCAQMD
The Board previously awarded a contract to CWI to develop, integrate and demonstrate 8.9-liter ultra-low-emission heavy-duty natural gas engines that are capable of achieving 0.02g/bhp-hr or lower NOx emissions. CWI recently received CARB certification for

the 8.9-liter natural gas engine at 0.02 g/bhp-hr NOx emissions. Because of market demand for natural gas engines in the 11- to 13-liter range, the proposed project is a follow-on phase of natural gas engine development project to transfer the technology and use lessons learned from the successful development of the 8.9-liter engine to advance the current 11.9-liter natural gas engine to achieve ultra-low NOx emissions. The development and use of ultra-low-emission engines in on-road heavy-duty truck applications will assist the SCAQMD in attaining federal ambient air quality standards. This proposed project is included in the *Technology Advancement Office Clean Fuels Program 2015 Plan Update* under "Engine Systems."

Sole Source Justification

Section VII.B.2 of the Procurement Policy and Procedure identifies provisions by which sole source awards may be justified. This request for a sole source award is made under provision B.2.d: Other circumstances exist which in the determination of the Executive Officer requires such waiver in the best interest of the SCAQMD. This request for sole source award is made under provision B.2.d(1): Projects involving cost sharing by multiple sponsors, and provision B.2.d(3): Projects involving commitment to multiple project phases. The proposed project will be cost-shared by CEC, SoCalGas, Clean Energy and CWI.

Resource Impacts

The proposed project budget is approximately $5.25 million, with funding anticipated from the CEC, SoCalGas and Clean Energy to be recognized, upon receipt, into the Clean Fuels Fund (31). Of this $5.25 million, SCAQMD's cost-share shall not exceed $1.75 million from the Clean Fuels Fund (31). The total cost-share for the proposed project is summarized below:

Proposed Project Cost-Share

Funding Source	Funding Amount	% of Project
Clean Energy	$ 500,000	10%
CEC	$1,000,000	19%
SoCalGas	$1,000,000	19%
CWI (in-kind)	$1,000,000	19%
SCAQMD *(requested)*	$1,750,000	33%
Total	**$5,250,000**	**100%**

Sufficient funds are available from the Clean Fuels Fund (31), established as a special revenue fund resulting from the state-mandated Clean Fuels Program. The Clean Fuels Program, under Health and Safety Code Sections 40448.5 and 40512 and Vehicle Code Section 9250.11, establishes mechanisms to collect revenues from mobile sources to support projects to increase the utilization of clean fuels, including the development of the necessary advanced enabling technologies. Funds collected from motor vehicles are restricted, by statute, to be used for projects and program activities related to mobile sources that support the objectives of the Clean Fuels Program.

TAB 23

California Environmental Protection Agency

AIR RESOURCES BOARD

DRAFT
TECHNOLOGY ASSESSMENT: LOW EMISSION NATURAL GAS AND OTHER ALTERNATIVE FUEL HEAVY-DUTY ENGINES

September 2015

Cummins, Inc., in partnership with the CEC, is developing an SI engine that runs on E85 (a blend of 85 percent ethanol and 15 percent gasoline by volume). The use of E85 allows for greater use of renewable energy, with the potential of up to 80 percent reduction in CO_2 emissions compared to a baseline gasoline vehicle, depending on the drive cycle and source of the ethanol in E85.

Q. What is the expected timeframe of lower-NOx natural gas engines coming to market?

A. As indicated above, CWI has certified an 8.9 L natural gas engine as a 2016 model year engine that meets a 0.02 g/bhp-hr NO_X and will begin field testing the engine this year in California on transit buses. Although CWI did not announce the commercial availability date of this engine, it has indicated that it plans to make the new engine available on new transit and refuse trucks and as an engine replacement for existing ISL G equipped vehicles.

Also, as discussed above, ARB and SCAQMD are independently funding research projects to demonstrate the feasibility of a 0.02 g/bhp-hr NO_X emission level on larger capacity, 11.9 L and 15 L heavy-duty natural gas engines. These projects are expected to be finalized between mid-2016 to end of 2017. Thus, staff expects some lower-NO_X natural gas engines to become commercially available by 2016, with additional engine sizes becoming available as time goes on.

Q. What next steps does staff recommend?

A.

- ARB should continue to support incentive funding for low-NOx heavy-duty engines to encourage engine manufacturers to develop and certify engines that meet the optional NO_X standards. Natural gas engines certified to 0.02 g/bhp-hr, capable of Class 7-8 long-haul use (12 to 15 L), and powered with renewable natural gas should be a particular focus.

- Given California's criteria pollutant, GHG, and petroleum reduction needs, staff recommends that ARB implement statewide strategies that employ lower NO_X combustion engines coupled with the use of renewable fuels in order to attain near-term air quality and climate goals.

- In order to achieve air quality goals, ARB intends to begin the development of lower mandatory NO_X standards applicable to all California-certified heavy-duty vehicles. Since out-of-state registered heavy-duty vehicles that operate in California contribute significantly to the emissions inventory, it is also critical that ARB petition the United States Environmental Protection Agency to require lower NO_X standards applicable to all heavy-duty vehicles nationally.

II. Demonstration Status

ARB and other agencies such as the South Coast Air Quality Management District (SCAQMD) in Southern California and the California Energy Commission (CEC) are currently independently funding projects to develop or demonstrate lower-NO_X natural gas engines for various engine sizes. Some of these projects are briefly discussed below.

In 2013, ARB initiated a project with Southwest Research Institute (SwRI) for demonstrating maximum NO_X reductions possible from a 12 L CWI heavy-duty natural gas engine for use in Classes 6 to 8 vehicle applications such as refuse trucks, transit buses, general purpose trucks, and short haul and long haul trucks (ARB, 2014a). SwRI will demonstrate feasibility of lower NO_X emissions through a combination of engine tuning practices, thermal management strategies, and aftertreatment strategies. The engine technology must also continue to meet all applicable standards for hydrocarbons, non-methane hydrocarbons, carbon monoxide, and PM; not incur a GHG penalty; and be consistent with a technological path to meeting the upcoming U.S. Environmental Protection Agency (U.S. EPA) GHG standards for heavy-duty vehicles. The target NO_X emission rate from this project is 0.02 g/bhp-hr, a 90 percent reduction from the current standard. SwRI will conduct on-engine dynamometer screening of advanced TWCs, electrically heated catalysts, close-coupled light-off catalysts, and exhaust thermal management strategies, and determine the technology package(s) that provides maximum NO_X and GHG emission benefits. The project is expected to be completed by mid-2016.

In 2014, SCAQMD, in partnership with CEC and the Southern California Gas Company (SoCalGas), initiated projects for developing 8.9 L and 15 L natural gas engines with CWI and Cummins Inc., respectively (SCAQMD, 2013). The 8.9 L engine is designed for use in the Class 6 to 8 vehicle weight rating in on-road applications such as shuttle buses, transit buses, refuse trucks, Class 7 tractors, and the lighter end of Class 8 tractors, while the 15 L engine is designed for use in the Class 7 to 8 vehicle weight rating in on-road applications where there is a demand for high power/high torque natural gas engines. The target emission level for the new engines is 0.02 g/bhp-hr NOx or lower, a 90 percent reduction from the current standard, through stoichiometric combustion with high rates of cooled EGR and a TWC. In addition to achieving the NO_X emission reduction target, the projects' objectives also include system durability demonstration through on-road tests after the engines are integrated onto vehicle chasses. The road tests will be performed for a year, and their performance will be fully evaluated. CWI recently announced that it demonstrated a 0.02 g/bhp-hr NO_X emission level on the 8.9 L ISL G SI natural gas engine and will begin field testing the engine this year in California on transit buses (CWI, 2015). According to CWI, in addition to lowering NO_X emissions by 90 percent from current engines, the engine also meets the 2017 heavy-duty GHG standards. However, CWI did not disclose the technologies used to reduce NO_X emissions nor the cost of the low NO_X technology. The completion of these projects is expected by the end of 2017.

V. Cost

A. Current Technology

Current costs of heavy-duty natural gas vehicles are higher than those of heavy-duty diesel vehicles. The incremental cost of a heavy-duty natural gas vehicle over that of a comparable heavy-duty diesel vehicle ranges between $30,000 to $80,000, depending on vehicle weight, power, etc. (see Table V-1), with the cost of the fuel tank system accounting for the majority of the added cost (TIAX, 2012, JB Hunt, 2014). In addition, maintenance costs of natural gas vehicles are about one to two cents per mile greater than for diesel vehicles due to more frequent oil changes and inspections, high replacement costs for spark plugs, and injectors (Malloy, 2013). Natural gas vehicles, however, have a lower overall operating cost primarily due to the lower fuel cost of natural gas compared to diesel (see Figure V-1). Thus, the lower fuel costs would allow the vehicle owner to recover the added vehicle and maintenance costs associated with heavy-duty natural gas vehicles within several years, depending on the purchase price of the vehicle, the mileage driven per year, and the price differential between diesel fuel and natural gas fuel (see Figure V-1). Note that the recent decline in diesel fuel prices is closing the gap between diesel and natural gas fuel prices, and this may have a negative impact on the payback period for natural gas vehicles. However, diesel fuel prices fluctuate more than natural gas prices and it is not known how diesel fuel prices will behave in the future. The payback period for liquefied natural gas (LNG) fueled vehicle would be higher since LNG fuel is normally more expensive than compressed natural gas (CNG) fuel due to the cost to convert and transport the natural gas in a liquid form. Figure V-2, which shows the payback period for a short haul CNG truck as a function of diesel fuel cost and mileage driven in a year, illustrates how payback can range from less than 3 years to more than 15 years, depending on the differential in diesel versus CNG cost and the annual mileage.

Table V-1: Current Incremental Cost of Heavy-Duty Natural Gas Vehicles by Application

Application	Incremental Cost
School Bus	$30,000 - $40,000
Transit Bus	$40,000 - $50,000
HD Vocational Truck	$50,000 - $60,000
Regional Haul Tractor	$65,000 - $80,000
Short Haul Tractor	$45,000 - $60,000
Refuse Truck	$30,000 - $40,000

(TIAX, 2012)

TAB 24

BOARD MEETING DATE: October 4, 2013 AGENDA NO. 9

PROPOSAL: Recognize Revenue and Execute Contracts for Development, Integration, and Demonstration of Ultra-Low Emission Natural Gas Engines for On-Road Heavy-Duty Vehicles

SYNOPSIS: In May 2013, the Board released an RFP for the development, integration and demonstration of ultra-low emission natural gas engines for heavy-duty vehicles. Six proposals were received in response to the RFP. This action is to recognize up to $5,000,000 in revenue from the CEC and Southern California Gas Company, and to execute contracts with Cummins Westport Inc. and Cummins Inc. to conduct engine development and demonstration activities at a total cost not to exceed $7,000,000 from the Clean Fuels Fund (31).

COMMITTEE: Technology, September 20, 2013. Less than a quorum was present; the Committee Members concurred that this item be forwarded to the Board for consideration.

RECOMMENDED ACTIONS:
Authorize the Chairman to:

1. Recognize upon receipt up to $4,000,000 from the CEC into the Clean Fuels Fund (31);
2. Recognize upon receipt up to $1,000,000 from the Southern California Gas Company into the Clean Fuels Fund (31); and
3. Execute contracts from the Clean Fuels Fund (31) with:
   a. Cummins Westport Inc. (CWI) to develop and demonstrate an ultra-low emission natural gas engine in an amount not to exceed $3,500,000; and
   b. Cummins Inc. to develop and demonstrate an ultra-low emission natural gas engine in an amount not to exceed $3,500,000.

Barry R. Wallerstein, D.Env.
Executive Officer

MMM:DS:JC

Background
Heavy-duty on-road diesel vehicles are currently one of the largest sources of NOx emissions in the South Coast Air Basin. This source category is still projected to be one of the largest contributors to NOx emissions, even as the legacy fleet of older and higher polluting vehicles are retired from operation and replaced by the cleanest vehicles meeting the most stringent emission levels required by 2010 emissions standards. The 2012 AQMP showed that NOx reductions in excess of 60% will be needed from all source categories to meet future federal ambient air quality standards for ozone. The development of ultra-low emission natural gas engines would significantly reduce emissions from this on-road heavy-duty source category and assist the region in meeting federal ambient air quality standards in the future. To achieve this goal, staff worked closely with the CEC, So Cal Gas Company and the DOE to craft an RFP for the development of an ultra-low NOx emissions engine.

The objective of the RFP was to develop natural gas engines for on-road heavy-duty applications that would achieve NOx emission levels 90% lower than 2010 engine emission certification standards. The RFP required applicants to conduct development activities to achieve the emissions target, as well as durability testing to validate the robustness of their design. Once developed, these engines shall be emissions tested on both the Federal Test Procedure for emissions certification, as well as non-certification test cycles. The non-certification cycles will be representative of the real-world use in different vocations that are prevalent in the air basin. The use of vocational specific test cycles will provide additional insight towards the engine's real-life emission reduction potential. The program will ultimately conclude with the engines being integrated into on-road heavy-duty chassis and placed in commercial service to fully validate the performance and viability of the engines developed as part of this program.

Outreach
In accordance with SCAQMD's Procurement Policy and Procedure, a public notice advertising the RFP/RFQ and inviting bids was published in the Los Angeles Times, the Orange County Register, the San Bernardino Sun, and Riverside County Press Enterprise newspapers to leverage the most cost-effective method of outreach to the South Coast Basin.

Additionally, potential bidders may have been notified utilizing SCAQMD's own electronic listing of certified minority vendors. Notice of the RFP/RFQ has been emailed to the Black and Latino Legislative Caucuses and various minority chambers of commerce and business associations, and placed on the Internet at SCAQMD's website (http://www.aqmd.gov). Information is also available on SCAQMD's bidder's 24-hour telephone message line (909) 396-2724.

Proposal Evaluations
Six proposals were received in response to RFP #P2013-22 by the deadline of July 24, 2013. The proposals were reviewed and evaluated by an eight-member panel in accordance with established SCAQMD guidelines, using technical and cost criteria outlined in the RFP. The eight-member evaluation panel consisted of two SCAQMD Air Quality Specialists with experience in private industry engine development and exhaust aftertreatment, a Technology Development Manager and Senior Technology Development Advisor from the Southern California Gas Company, two engineering advisors from the CEC, a Senior Combustion and Fuels Engineer from the DOE's National Renewable Energy Lab and a representative from CARB; two Asian, six Caucasian; eight male.

The proposals receiving a score of at least 56 out of 70 points were considered technically qualified and eligible for contract awards. Bidders were awarded additional evaluation points associated with the amount of requested funding and cost-share provided up to a maximum of 30 points. Upon evaluation, Cummins Westport Inc. and Cummins Inc. proposals received 87 and 82 points, respectively, while the remaining proposals scored less than the minimum 56 points required to be deemed technically acceptable by all panel members. The Cummins Westport Inc. and Cummins Inc. technical and cost scores are shown below.

	Proposal		
	Technical	**Cost**	**Total**
Cummins Westport Inc.	65	22	87
Cummins Inc.	62	20	82

Proposed Awards

Cummins Westport Inc. (CWI)
CWI is a joint venture company with 50/50 ownership by Cummins Inc. and Westport Innovations Inc. Established in 2001, CWI's objectives are to develop, commercialize and support alternative fueled engines for commercial vehicle applications. The CWI Product Engineering team has brought multiple natural gas engines to market dating back to the early 1990's, prior to the inception of CWI. The most recent product offerings include the 8.9L ISL G and 11.9L ISX G natural gas engines, which are currently being broadly used in our air basin in applications that include transit buses, refuse trucks and other class 8 vehicles. The organization follows the Cummins product development and commercialization process, which is focused on delivering robust products that meet critical customer requirements including emissions, performance, cost and quality. In addition, CWI has strong industry partners and end-users for this program. The proposed partners include Peterbilt, Autocar, New Flyer, Waste

Management, LA MTA, and Advanced Transit Vehicle Consortium. SCAQMD staff believes these attributes and partnerships will allow CWI to successfully meet the objectives of the program.

Staff proposes to execute a contract with CWI to develop and demonstrate an ultra-low emission 8.9L natural gas engine.

Cummins Inc.

Cummins Inc. is a Fortune 500 corporation and original equipment engine manufacturer that sells in 190 countries, with engines that span the displacement range between 5.9L to 95L. The Cummins Technical Center in Columbus, IN, consists of a multi-building complex with 378,000 sq. ft. of laboratory space. The Center has 88 test cells that cover all aspects of diesel engine and alternative fuel engine applications. These engine testing capabilities also include the ability to dynamically model the vehicle and test vehicle emissions and performance prior to installing the engine in a chassis. Additionally, Cummins Inc. has assembled a strong project team that includes both industry leaders in their respective fields and relevant end-users operating in the SCAQMD air basin. The proposed partners include Peterbilt for chassis integration, Johnson Matthey for aftertreatment, UCR for in-use emissions testing, and California Cartage Company for the end-use demonstration. SCAQMD staff believes these strong partnerships, along with Cummins' demonstrated capabilities, will result in a project that meets the goals identified in the RFP.

Staff proposes to execute a contract with Cummins Inc. to develop and demonstrate a 15L natural gas engine.

Benefits to SCAQMD

The proposed projects support the implementation of advanced alternative fuel technology that could potentially be used to further reduce NOx emissions from on-road heavy-duty vehicles. The proposed projects are included in the *Technology Advancement Office 2013 Plan Update* under "Engine Systems."

Resource Impacts

The total cost for these two projects is estimated to be $13,645,000, of which SCAQMD's cost-share shall not exceed $2,000,000. The contract with Cummins Westport Inc. shall not exceed $3,500,000 and Cummins Westport will provide up to $4,837,000 in cost-share. The Cummins Inc. contract shall not exceed $3,500,000 and Cummins will provide up to $1,808,000 in cost-share. The total estimated cost-share for these projects is shown in the table below:

Project Partners	Funding Amount	Funding %
CEC	$4,000,000	29.3%
So Cal Gas Co.	$1,000,000	7.3%
Cummins Westport Inc.	$4,837,000	35.4%
Cummins Inc.	$1,808,000	13.3%
SCAQMD Requested	$2,000,000	14.7%
Total	$13,645,000	100%

Sufficient funds for these two proposed projects are available from the Clean Fuels Fund (31), established as a special revenue fund resulting from the state-mandated Clean Fuels Program. The Clean Fuels Program, under Health and Safety Code Sections 40448.5 and 40512 and Vehicle Code Section 9250.11, establishes mechanisms to collect revenues from mobile sources to support projects to increase the utilization of clean fuels, including the development of the necessary advanced enabling technologies. Funds collected from motor vehicles are restricted, by statute, to be used for projects and program activities related to mobile sources that support the objectives of the Clean Fuels Program.

TAB 25

WRITTEN STATEMENT
OF THE
MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION
ON THE U.S. ENVIRONMENTAL PROTECTION AGENCY'S PROPOSAL TO REVISE THE NATIONAL AMBIENT AIR QUALITY STANDARDS FOR OZONE
DOCKET ID NO. EPA-HQ-OAR-2008-0699

March 16, 2015

The Manufacturers of Emission Controls Association (MECA) is pleased to provide testimony in response to the U.S. EPA's request for public comment on the Proposal to Revise the National Ambient Air Quality Standards for Ozone (Docket ID No. EPA-HQ-OAR-2008-0699). MECA firmly believes that the emission control technologies for mobile sources that will be needed to help meet the most stringent standards for ozone are cost effective and readily available. Many of these nitrogen oxides (NOx) emission control technologies for mobile sources are being used today on on-road and non-road applications in the U.S. and other major marketplaces in the world.

MECA is a non-profit association of the world's leading manufacturers of emission control technology for motor vehicles. Our members have over 40 years of experience and a proven track record in developing and manufacturing emission control technology for a wide variety of on-road and non-road vehicles and equipment. A number of our members have extensive experience in the development, manufacture, and application of hydrocarbon, PM and NOx emission control technologies for both new and existing engines. These companies have commercialized control technologies for gasoline, diesel, and alternative-fueled engines.

MECA will defer to the health experts to determine the appropriate ozone levels for the ambient standards given that they are not within our area of expertise. The Clean Air Act requires that these standards be set to protect the public health with an adequate safety margin.

While beyond the scope of the health-based decision before the agency, MECA offers comments here to demonstrate there are technologically feasible and cost effective emission control technologies for mobile source engines that are available to meet the most stringent ozone standards under consideration by EPA. MECA commends EPA for proposing to update the ozone standards to ensure that the standards are as protective as recommended by EPA's Clean Air Scientific Advisory Committee (CASAC).

The U.S. EPA has already put in place important regulatory programs for reducing PM and NOx emissions from new on-road and non-road diesel engines beginning with the 2007-2010 heavy-duty highway engine emission program, followed by the Tier 4 non-road diesel emission regulations that have been phased in over the 2008-2015 timeframe. Both of these regulatory programs rely on a systems approach that combines advanced diesel engine technology, the use of ultra-low sulfur diesel fuel, and advanced diesel exhaust emission control technologies to achieve significant reductions in both PM and NOx emissions compared to older technology diesel engines.

Diesel exhaust emission control technologies, that will play a major role in complying with EPA's emission standards for new diesel engines, include diesel oxidation catalysts (DOCs), diesel particulate filters (DPFs), closed crankcase filters (CCFs), selective catalytic reduction catalysts (SCR), and NOx adsorber catalysts. High efficiency diesel particulate filters are already standard equipment on all new light-duty diesel vehicles and on-road heavy-duty diesel trucks sold in the U.S. and Canada. These filters provide more than 95% reduction in particulate mass over a very broad range of particle sizes and have proven durability over hundreds of thousands of miles of service. Similar diesel particulate filter systems are being used by some manufacturers to comply with EPA's Tier IV final emission standards for nonroad engines. The significant reductions in diesel particulate emissions that result from the use of filters not only provides significant health-related benefits but also significant climate change impacts due to the large reduction in black carbon emissions associated with filter operation on diesel engines. Particulate filter technology could also be used in the future as a strategy to reduce the mass and number of particulate emissions from direct injection gasoline vehicles to ensure that these future powertrain technologies' PM emissions are equivalent to those associated with filtered diesel exhaust.

The emergence of "clean diesel" light-duty vehicles in the U.S. that employ DPFs, SCR catalysts, and/or NOx adsorber catalysts, and the significant number of ultra-low tailpipe and evaporative emission light-duty gasoline vehicle models that have been certified to California's partial-zero emission vehicle (PZEV) or super ultra-low emission vehicle (SULEV) standards provides strong evidence that new light-duty vehicles sold in the U.S. are capable of achieving hydrocarbon and NOx exhaust emissions to comply with a more stringent ozone standard. California's LEV III and EPA's Tier 3 light-duty vehicle programs will deploy proven advanced emission control technologies for both exhaust and evaporative emissions to achieve further reductions in hydrocarbon and NOx emissions in new passenger cars and light-duty trucks. These LEV III/Tier 3 regulations also require gasoline light-duty vehicles to meet tougher evaporative emission requirements. Technologies including advanced carbon canister designs, the use of advanced materials with ultra-low fuel permeation characteristics for fuel tanks and fuel lines, and air intake hydrocarbon adsorbers are available today to meet the stringent evaporative emission requirements required by these light-duty regulations. NOx adsorber technology is another available NOx control strategy that can reduce NOx emissions from light-duty diesel and lean gasoline engines. NOx adsorber catalysts have been used commercially in some light-duty gasoline direct injection (GDI) engines sold in Europe and Japan and on several light-duty and medium-duty diesel vehicles in the U.S. to comply with either the ARB LEV II/EPA Tier 2 light-duty vehicle emission limits or EPA 2010 heavy-duty engine emission standards. Manufacturers are demonstrating novel application of NOx adsorber technologies on lean-burn GDI engines in combination with a downstream SCR. In such applications, the primary role of the NOx adsorber is to generate the ammonia reductant during periodic rich operation that is stored on the downstream SCR catalyst and consumed to reduce NOx during lean operation. A similar approach utilizes a three-way catalyst to generate ammonia during rich operations that can be stored on an underfloor SCR catalyst for NOx control under lean engine operations. These approaches may be used by vehicle manufacturers to meet future LEV III/Tier 3 regulations on future lean GDI engines that offer attractive improvements in fuel consumption for achieving future EPA light-duty vehicle greenhouse gas standards. The types of technologies being developed for light-duty passenger cars to meet these future ultra-low emission levels from passenger cars will find their way to applications on medium and heavy-duty on-road vehicles and engines and ultimately the nonroad sector as well to achieve NOx levels below those required by today's Tier 4 final standards.

In their Regulatory Impact Analysis (RIA, Table 3-1), EPA reported 2025 baseline NOx emissions of 9,530 ktons, including 1,492 ktons from on-road and 796 ktons from nonroad heavy-duty vehicles and equipment. Although the California NOx inventory was not included in the RIA, the Northeast and Mid-Atlantic states represented by the Ozone Transport Commission (OTC) share many of the ozone concerns with California. In addition to ozone transported from the west, the Northeast and Mid-Atlantic states are impacted by significant NOx emissions from mobile sources along the I-95 corridor. Approximately 46% of the NOx emissions in this region are attributed to mobile sources with 60% of these coming from on-road sources. Table 4-10 of the RIA summarizes the emission reductions from known and unknown controls for regions in the eastern and western United States impacted by the 60, 65, and 70 ppb alternate standards. By far, the majority of these reductions occur in the eastern half of the United States. The unknown NOx reductions in the east represent 150, 750 and 1,900 ktons respectively for the 70, 65 and 60 ppb alternative standards. In the RIA baseline and alternate standard analyses, EPA applied only a single known mobile control measure, nonroad diesel retrofits and engine rebuilds, to reduce NOx by 5 ktons at a cost of $4,600/ton. The remaining known NOx controls were derived from stationary sources such as electricity generating units (EGUs), non-EGU point and nonpoint sources at an average cost of $12,000/ton, $3,000/ton and $1,100/ ton, respectively. The weighted cost of these stationary controls necessary to achieve the 65 ppb alternative standard is $3,732/ton of NOx. We believe that the majority of the unknown NOx reductions can be achieved cost effectively from mobile sources if the types of NOx reduction measures under discussion in California were to be adopted across the remaining 49 states by EPA.

MECA believes that further reductions in NOx emissions from new heavy-duty on-road and off-road diesel engines beyond the 2010 on-road and Tier 4 off-road requirements will be possible through the combinations of more advanced diesel engines with advanced diesel exhaust emission control technologies including advanced substrates, improved SCR catalysts and/or NOx adsorber catalysts. The California Air Resources Board (ARB), recognizing these opportunities, adopted voluntary on-road low NOx standards and incentives to encourage manufacturers to develop state-of-the-art engines and emission controls to achieve NOx levels as low as 0.02 g/bhp-hr which is equivalent to a 90% reduction from EPA's 2010 highway, heavy-duty engine standards. Additional tightening of NOx standards for both heavy-duty on-road and off-road new diesel engines beyond the 2010 on-road requirements and the Tier 4 final off-road requirements should be considered by EPA as a cost effective strategy that would further reduce ozone levels across the country.

To demonstrate the feasibility of achieving these low NOx levels from heavy-duty engines, ARB and MECA are funding a test program at Southwest Research Institute on a state-of-the-art 13 L Euro VI certified engine as well as a 12 L stoichiometric natural gas engine. The program focuses on reducing NOx emissions from the low temperature portions of the test cycle including cold-start and low speed operation. MECA is providing several exhaust system solutions for both engines that will deploy the most advanced substrate and catalyst combinations into novel system architectures focused on low temperature NOx reduction.

Beyond catalyst advances, the next generation NOx reduction strategies will require careful attention to both active and passive thermal management strategies to retain the exhaust heat provided by the engine for activating catalytic controls, as well as, offering innovative approaches to actively heat the exhaust during low speed and low load operation of the engine when exhaust temperature is at a premium. An example of the types of thermal management strategies being considered under this program include dual wall and insulated exhaust pipes, dual wall stamped exhaust manifolds, active exhaust heating systems and thermally insulating substrate mounting materials along with other low thermal mass exhaust components. To achieve these very low NOx levels will require advanced reductant delivery systems and close attention to reductant dosing control strategies. To complete the system approach, SwRI engineers will optimize the engine calibration strategies to deliver the lowest possible engine-out emission levels in the exhaust. The goal of the program is to demonstrate the capabilities of next generation advanced NOx reduction technologies with no impact on the fuel efficiency of the diesel and natural gas engines. MECA is extremely confident that its members will deliver a successful result. ARB anticipates releasing preliminary results in early 2016 with final results later on in 2016.

To estimate the achievable level of NOx inventory reduction through the deployment of technologies being demonstrated by the low NOx test program, MECA funded an independent emission inventory forecast study, at ENVIRON, to better understand the full benefit of future potential NOx tightening for both on-road and nonroad heavy-duty diesel engines. This analysis relied on EPA's current official models, including MOVES2014 for on-road vehicle emissions and the NONROAD2008 (within the National Mobile Inventory Model, or NMIM, framework) model for off-road emissions. These models account for all "on-the-books" regulations, including the recently finalized Tier 3 light-duty vehicle requirement, and are consistent, but not exactly the same, with the Base Case (i.e. with current emission controls) used in EPA's ozone NAAQS proposal. In the RIA, EPA used a modified version of the MOVES2010 that was adjusted to include Tier 3 (MOVESTier3FRM). Because of slight differences in the model input parameters between the EPA version of MOVES, used in the RIA, and MOVES2014 used in this study, the results were put on the same basis by multiplying the ratio of the models' forecasted emission totals for each calendar year by the 2025 Base EPA RIA inventory estimates. To estimate the future NOx reduction potential of new controls, by-model-year emissions were determined for on-road vehicles, and modified input databases for the NONROAD model for the off-road equipment to develop emissions estimates with and without new potential future emissions standards. The models were run to generate emissions inventories of NOx, VOC, CO and PM for on-road and off-road sources for calendar years 2025, 2030, 2040, and 2050 for the Base Case and the control scenarios discussed below.

For the heavy-duty sector controls scenarios, we selected NOx reduction and implementation timeline inputs for these sectors based on California ARB's June 28, 2012 Vision Document. The model inputs included a 90% NOx reduction from heavy-duty diesel, on-road engines below 2010 levels phased-in over the 2021-2024 timeframe. For the heavy-duty nonroad fleet, we assumed a nominal 70% NOx reduction from Tier 4 final levels for engine power ranges from 75-750 hp and an 80% NOx reduction from the small diesel nonroad power category from 25-75 hp. The NOx reductions from the nonroad engines were phased in from 2025-2027 and staggered by power ranges analogous to those used to phase-in Tier 4 final nonroad engine standards. To be consistent with EPA's ozone NAAQS Regulatory Impact

Analysis, we selected a 2012 baseline emissions inventory using the MOVES2014 and NONROAD2008 models and projected regional benefits consistent with the ozone impacted regions used in the RIA for the 70, 65 and 60 ppb alternate ozone standard scenarios. Because the regions impacted by a potential 60 and 65 ppb standard are similar, we combined these into a single scenario (65/60 ppb).

Because of the implementation timing that these heavy-duty highway and nonroad engine regulations could take affect extends beyond the 2025 model year used in the RIA, their impact on reducing NOx emission in the near term is limited. Our modeling work estimates that the on-road, heavy-duty diesel sector could deliver 14.4 ktons and 35.8 ktons of NOx reduction under the 70 ppb and 65/60 ppb alternative standards within the impacted regions in 2025. Similarly, the nonroad sector could achieve 3.8 ktons and 7.4 ktons of NOx reduction for the two study regions in that year because of the implementation timeline selected in this study. Because ozone will continue to pose health impacts far beyond 2025 we estimated the NOx reduction potential of the fully implemented and phased-in regulations out to 2050. The reductions from the on-road sector are estimated to be 74.9 and 190.8 ktons for the 70 and 65/60 ppb alternate standards, whereas the non-road sector could achieve 72.6 and 145.4 ktons respectively, for the impacted regions in 2050. When fully implemented under the 65 ppb alternate standard scenario, these two heavy-duty mobile control measures deliver over 335 ktons/year of NOx reductions and are in the range of the single largest stationary NOx control measure listed in the RIA (Table 4A-9). The NOx emission benefit of potential federal heavy-duty standards will extend beyond the county regions analyzed in the RIA as the operation of these vehicles will not be limited to nonattainment areas. We therefore extended our analysis to the 47 contiguous states including the District of Columbia but excluding California. The modeling results show that these two heavy-duty mobile control measures have the potential of delivering over 481 ktons/year of NOx reductions across the 47 lower United States plus D.C. We believe that these two heavy-duty control measures combined represent the largest opportunity for achieving NOx reductions from the mobile sector.

To derive a cost effectiveness value, we estimated the incremental cost of the types of additional emission controls, discussed above, that would be necessary to achieve the target reductions from heavy-duty trucks, beyond the exhaust controls being used to meet current 2010 heavy-duty on-road standards and from nonroad equipment relative to Tier 4 final standards for the 25-750 hp power ranges. The next generation of exhaust reductions can be achieved through incremental improvements to the major emission control devices that are already on vehicles and equipment to meet today's standards. Our incremental cost estimate for future advanced on-road emission control systems is approximately $500 per vehicle averaged over the medium and heavy-duty highway fleet. For nonroad equipment, the incremental cost varies more widely due to the broad power range and equipment configurations that make up this sector. An average incremental cost of exhaust controls, beyond Tier 4 final, over the 25-750 hp power range is approximately $350 per engine.

Based on the results of our analysis, we estimate that on-road trucks can deliver NOx reductions at a cost of $3,000-$4,000 per ton. Because there are greater opportunities to reduce NOx from the nonroad sector, we estimate that these reductions can be achieved within a range of costs from $1,000 - $1,500 per ton of NOx. Both of these control measures are well below

EPA's threshold of $15,000 per ton used for consideration in the RIA. The NOx weighted average cost benefit of these potential heavy-duty regulations combined is approximately $2,500/ton which is 33% lower than the NOx weighted cost of $3,700/ton estimated for the stationary cost of controls discussed in the ozone RIA.

Our assumptions for the types of controls that will be used to reduce NOx from mobile sources in the calculations above is based on continued use of Selective Catalytic Reduction (SCR) technology. We believe that SCR catalysts will continue to be the predominant NOx reduction strategy deployed on next generation heavy-duty trucks and nonroad equipment. The use of SCR to reduce NOx has a long history. SCR has been used to control NOx emissions from stationary sources for over 20 years. More recently, it has been applied to select mobile sources including trucks, marine vessels, and locomotives. In 2005, SCR using a urea-based reductant was introduced on a large number of on-road diesel heavy-duty engines to help meet the Euro V heavy-duty NOx emission standards. Hundreds of thousands of new heavy-duty truck engines are operating in Europe equipped with SCR systems that use urea as the reductant for reducing NOx emissions. SCR is being used by most engine manufacturers for complying with on-road heavy-duty diesel engine emission standards in both the U.S. for 2010 compliance, and Japan for 2009 compliance. In addition to delivering reductions in criteria pollutants, application of SCR on heavy-duty trucks allows engine manufacturers to further optimize and reduce fuel consumption of these engines, providing important reductions in greenhouse gas emissions. Achieving improvements in low temperature NOx reduction through thermal management strategies, passive NOx adsorbers and improved low temperature catalyst activity will provide engine manufacturers a broader operating window for optimizing their engine calibration for fuel efficiency while taking advantage of advanced low temperature catalysts to remediate any increases in NOx resulting from the calibration change.

Specifically to address NOx emitted at low exhaust temperatures, manufacturers are developing passive NOx adsorber (PNA) catalyst technology which is used upstream in combination with the DOC to trap and store NOx at temperatures below 200^{o}C before the SCR catalyst becomes active. Once the exhaust temperature is sufficient for SCR catalyst activity and to allow the urea dosing system to be activated, the NOx stored on the PNA begins to desorb and can be converted by the ammonia reductant over the SCR catalyst. This new technology will likely be one of the strategies available to engine and vehicle manufacturers to achieve lower tailpipe NOx levels.

Since the mid-1990s, SCR technology using a urea-based reductant has been installed on a variety of marine applications in Europe including ferries, cargo vessels, and tugboats with over 200 systems installed on engines ranging from approximately 450 to over 10,000 kW. These marine SCR applications include the design and integration of systems on a vessel's main propulsion and auxiliary engines. SCR systems have been successfully installed on one of New York City's Staten Island ferries and ferries operating in the San Francisco area. A smaller number of SCR systems have been installed on diesel locomotives in Europe and the U.S. to validate the performance of SCR catalysts in another off-road application area. EPA cited SCR catalysts as the most feasible technical approach for complying with its Tier 4 locomotive and commercial marine diesel engine emission standards that began in 2014. SCR technology is being applied on some ocean-going vessels to reduce NOx emissions consistent with the

International Maritime Organization's Tier 3 NOx requirements that will be required in designated Emission Control Areas near many coastlines around the world (including the ECA designations for the coastlines of the U.S. and Canada).

Similarly, MECA believes that further reductions of hydrocarbon and NOx emissions from the in-use fleet of passenger vehicles can be achieved cost effectively by adopting tighter aftermarket converter requirements for light-duty, gasoline vehicles that set higher performance and durability standards consistent with performance standards required by California for aftermarket gasoline converters since 2009. ARB's regulation eliminates the sale of older aftermarket converter products that have modest performance standards and a limited 25,000 mile warranty, and require that higher performance and more durable OBD-compliant aftermarket converter products be used on both non-OBD and OBD-equipped vehicles since January 2009. New York adopted California's aftermarket converter requirements in January 2014. These ARB-approved OBD-compliant aftermarket converters are warranted for five years or 50,000 miles based on the use of a more aggressive, high temperature accelerated engine-aging protocol compared to the vehicle durability demonstration currently required by EPA for approved aftermarket converter products. EPA has not updated its aftermarket converter requirements since 1986 and with more than three million aftermarket converters sold per year across the U.S. (based on surveys completed by MECA with aftermarket converter manufacturers), significant additional reductions of hydrocarbon emissions, including toxic hydrocarbon emissions, and NOx emissions could be achieved with a national aftermarket converter policy that made use of the same higher performance OBD-compliant aftermarket converters available in California and New York. For example, ARB estimated that requiring these advanced aftermarket converters in California would result in the reduction of over 36 tons/day of HC + NOx, at a cost effectiveness of $3,760/ton in 2012, once the new technology was fully implemented. Similarly, the Ozone Transport Commission estimated a reduction of 12,000 tons/year of NOx and HC (36 tpd) from the in-use light-duty fleet in the Northeast and Mid-Atlantic states through adoption of stricter aftermarket converter standards under a revised federal program.

A recent test program conducted and published by MECA (SAE technical paper 2013-01-1298) compared the tailpipe emissions of 6 passenger cars and light-duty trucks certified to LEV I emission standards. The vehicles were equipped with fully aged federal and California aftermarket technology converters and tested over the FTP-75 emission test cycle. After 25,000 miles of equivalent aging, the California converter technology emitted 85% less NOx and 65% fewer hydrocarbons and carbon monoxide than the EPA converter. MECA contracted with ENVIRON to run the MOVES2014 model and calculate the emission inventory reduction in tons per year of ozone precursors as a result of just upgrading the federal requirements to match the California 2009 standards. We believe this change could be fully implemented before 2025 because the technology is available and already being sold in California since 2009 and New York State since 2014. Based on state inspection and maintenance program statistics and MECA's annual aftermarket converter sales surveys, approximately 1% of light-duty vehicles experience an OBD catalyst error code, or fail their IM-240 emissions test, as a result of a damaged converter. We assumed a 2018 implementation date in our modeling work and a five year life for an aftermarket converter based on the duration of a California warranty. It was assumed that after 5 years the aftermarket converter would be replaced with another aftermarket converter resulting in full implementation of the advanced technology after five years. The maximum reduction benefit would be achieved over 5% of the total light-duty car and truck fleet. The MOVES2014 model predicts that 8,800 tons/year of NOx + HC would be reduced for the 70 ppb alternate standard and 20,600 tons/year for the 65/60 ppb alternate standard in 2025. Extended to the 47 contiguous states plus D.C. the reduction potential grows to 31,500 tons/year of ozone precursors. These NOx and HC reductions can be achieved by an average incremental cost of only $150 above the cost of today's federal aftermarket converter.

In reality the NOx emissions impact could be much worse now that most states are relying on OBD-based inspection and maintenance programs. When a typical EPA certified Tier 2 Bin 5 vehicle triggers an engine light (MIL) it could be emitting only slightly above its certified emission limit. By replacing the deteriorated OEM converter with a brand new EPA aftermarket converter, that is required to achieve only a 30% reduction in NOx, the vehicle may end up emitting far more NOx, as much as 14 times more, than it was emitting before the deteriorated OE converter was just replaced. On the other hand, a new California aftermarket converter must match the emission limit that the vehicle met when new and is equivalent to the OEM converter.

Another strategy that can achieve additional NOx emission reduction to meet the most stringent ozone standards would be for EPA to adopt California's 0.6 g/bhp-hr HC + NOx, 2010 emission standard for off-road spark-ignited engines with power ratings greater than 25 horsepower. The technology to reduce emissions from these SI engines is based on automotive-type closed-loop, three-way catalyst technology. This technology has been used on well over 300,000,000 automobiles with outstanding results. These same catalyst technologies have been adapted to spark-ignited engines used in off-road mobile sources such as forklift trucks, airport ground support equipment, and portable generators. Closed-loop, three-way catalyst-based systems are already being used on these large, spark-ignited, off-road engines to meet ARB's and EPA's 2004 3.0 g/bhp-hr HC + NOx standard. Closed-loop, three-way catalyst systems are also the primary technology pathway for meeting the EPA and ARB 2007 exhaust emission standard of 2.0 g/bhp-hr HC + NOx. Retrofit kits that include air/fuel control systems along with three-way catalysts have been sold into the LPG-fueled fork lift industry for installation on uncontrolled engines (an LSI application) for nearly 10 years. In both new engine and retrofit applications, these closed-loop three-way catalyst systems have shown durable performance in LSI applications, consistent with the excellent durability record of closed-loop three-way catalyst systems used in automotive applications for more than thirty-five years. MECA believes that advanced three-way catalyst technology based on automotive applications can provide a cost-effective, durable, high performance solution for controlling NOx and HC emissions from new and existing large spark-ignited engines used in stationary applications.

In July 2006, EPA finalized its regulation for new stationary compression ignition internal combustion engines to reduce diesel air pollution emissions. In February 2010, EPA issued its final regulation for existing stationary reciprocating internal combustion engines that would reduce toxic pollution emissions. The technologies discussed in this document for gasoline and diesel engines on vehicles are available and have been proven effective for stationary internal combustion engines. These include DOCs and SCR catalysts as well as DPFs to reduce PM emissions from stationary diesel engines. Three-way catalysts, also known as nonselective catalytic reduction catalysts (NSCR), have been used effectively on thousands of large, natural gas-fueled, reciprocating engines (so-called rich burn or stoichiometric natural gas engines) used for power production or pumping applications. Additional tightening of standards for both existing and new stationary internal combustion engines should be considered in the future to further reduce the HC, NOx and PM emissions that contribute to ozone levels across the country from these stationary engines.

MECA believes that additional NOx emissions reduction can be achieved by adopting more stringent HC + NOx emission standards for Class II off-road, spark-ignited engines with horsepower ratings less than 25 horsepower. Further reductions of HC + NOx emissions than what is required by the current Phase III EPA standards for these nonroad gasoline engines is technologically feasible through the use of catalyst technology that is fully optimized as part of a complete engine/emission control/exhaust system. Small engine manufacturers have been able to meet these standards through the redesign of existing Class II engines or through the use of emission credits, without the application of three-way catalysts. Both EPA and ARB have shown that the application of catalysts to nonroad equipment with Class II spark-ignited engines can be accomplished using available engineering exhaust system design principles in a manner that does not increase the safety risk relative to today's uncontrolled equipment. In particular, the EPA safety study on non-handheld equipment outfitted with catalyzed mufflers represents the most thorough safety study completed to date on this class of spark-ignited engines. The results of this EPA study showed that properly designed catalyzed mufflers pose no incremental increase in safety risk (and in many cases even lower muffler surface temperatures) relative to currently available non-handheld equipment sold without catalysts. An opportunity for further reductions in Class II HC + NOx emissions through the application of three-way catalysts should be considered by EPA as a way to achieve reductions of ozone precursors from this sector of engines. Furthermore, small engines pose significant health exposure hazards to end users due to the close proximity to the exhaust during normal operation. These health exposures to toxics and criteria pollutants should be considered as part of future justification to further tighten emission standards for small spark-ignited engines.

Other off-road spark-ignited engines including those used on ATVs, off-road motorcycles, outboard marine engines, and snowmobiles are contributors to mobile-source hydrocarbon and NOx emissions. MECA believes that hydrocarbon and NOx emissions from these recreational engines can be significantly reduced by adopting tighter regulations that employ the use of advanced three-way catalysts for these mobile sources. All classes of off-road, spark-ignited engines can also benefit from advanced materials and systems developed for controlling evaporative emissions from PZEV or SULEV light-duty, gasoline vehicles. Recognizing the significant source of VOC emissions from recreational spark ignited engines, California has recently tightened evaporative emission requirements for gasoline marine engines over 30 kW. These more stringent marine evaporative emission standards for larger engines will be introduced starting in 2018 and include new fuel hose, tank, venting, and fuel injection requirements. Additional, more stringent fuel hose permeation limits will start in 2020. In 2013, ARB adopted more stringent evaporative standards for recreational motorcycles that will require low permeability tanks and hoses, as well as carbon canisters to achieve the new 1 g/day total organic gas emission limit starting in 2018. EPA should review their evaporative emission requirements for all classes of off-road, gasoline engines and revise them to ensure that best available evaporative emission technologies are used in these applications.

On-road motorcycles are relying on three-way catalysts in the U.S. to comply with ARB's 2008 and EPA's 2010 exhaust emission standards. However, the exhaust and evaporative emissions of these catalyst-equipped on-road motorcycles will still be at levels considerably higher than late model, light-duty gasoline cars and trucks. Additional HC + NOx reductions can be obtained from on-road motorcycles through the use of engine, exhaust, and evaporative emission control strategies employed on today's best-in-class light-duty gasoline vehicles. In late 2012, the European Council adopted more stringent Euro 5 standards for two and three-wheeled vehicles to go into effect in 2020. These future standards will include much tighter NOx emissions (60 mg/km) as well as PM emissions (4.5 mg/km) and will bring motorcycle emissions limits on par with modern passenger cars.

Conclusion

In closing, we believe that there are numerous proven strategies available to further reduce hydrocarbon and NOx emissions from mobile source engines to meet the most stringent ozone ambient standards under consideration by EPA. The emission inventory modeling contracted by MECA, using the MOVES and NONROAD models forecasted the NOx reduction benefits in 2025 and 2050 of three potential NOx reduction strategies applied to heavy-duty and light-duty vehicles and equipment. Our analysis concludes that reduction of ozone precursors, such as HC and NOx, from the mobile sector, under the three control scenarios that were modeled (heavy-duty low NOx standards and California gasoline aftermarket catalysts), can deliver over 345,000 tons/year of NOx reductions in 2050 for the 65/60 ppm alternate standard region. When extended to the 47 contiguous states plus the District of Columbia and excluding California, the opportunity to reduce ozone precursors using the three control scenarios grows to nearly 500,000 tons per year in 2050 and represents the largest opportunity to reduce NOx from mobile sources. These reductions can be achieved extremely cost effectively at approximately $2,900/ton (NOx weighted average), relative to EPA's cost effectiveness threshold of $15,000 per ton of NOx used in the ozone NAAQS RIA. These mobile control strategies are cost competitive compared to the cost benefits of stationary control options included in the ozone NAAQS RIA with a NOx weighted average of approximately $3,700/ton for the 65/60 ppm scenario. Once appropriate health-based standards and corresponding NOx regulations are in place, our industry is prepared to do its part and deliver these cost-effective, advanced emission control technologies to the market.

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TAB 26

STATEMENT OF THE
MANUFACTURERS OF EMISSION CONTROLS ASSOCIATION
ON THE
U.S. ENVIRONMENTAL PROTECTION AGENCY'S
PROPOSED RULEMAKING ON GREENHOUSE GAS EMISSIONS STANDARDS AND FUEL EFFICIENCY STANDARDS FOR MEDIUM- AND HEAVY-DUTY ENGINES AND VEHICLES – PHASE 2

DOCKET ID NO. EPA-HQ-OAR-2014-0827

September 25, 2015

The Manufacturers of Emission Controls Association (MECA) is pleased to provide comments in support of the U.S. EPA's proposed rulemaking to establish medium- and heavy-duty greenhouse gas emission standards and corporate average fuel economy standards for model years 2018 and beyond. We believe an important opportunity exists to continue to reduce greenhouse gas emissions and improve fuel economy from medium- and heavy-duty engines and vehicles by applying the fundamental regulatory structure that has been effective under the first phase of the medium and heavy-duty standards.

MECA is a non-profit association of the world's leading manufacturers of emission control technology for mobile sources. Our members have over 40 years of experience and a proven track record in developing and manufacturing emission control and efficiency technology for a wide variety of on-road and off-road gasoline and diesel fueled vehicles and equipment in all world markets. Now that regulated pollutants have been expanded to include CO_2, the portfolio of products offered by our members has expanded to technologies that impact combustion efficiency and improve the overall CO_2 emissions of the powertrain. These technologies include waste heat recovery, turbochargers, turbo-compounding, EGR coolers, EGR valves and other air management technologies, thermal management strategies including insulated dual wall manifolds and exhaust systems, active thermal management approaches, advanced fuel injection and ignition systems. Our industry has played an important role in the emissions success story associated with light and heavy-duty vehicles in the United States, and has continually supported efforts to develop innovative, technology-forcing, emissions programs to deal with air quality problems.

INTRODUCTION

Anthropogenic activities, particularly the burning of fossil fuels, have changed the composition of the atmosphere in ways that threaten dramatic changes to the global climate. Signs of climate change are evident worldwide and additional changes will have serious impacts on our nation's future. Although transportation is a vital part of the economy and is crucial for everyday activities, it is also a significant source of greenhouse gas (GHG) emissions. Some of the important greenhouse gas emissions from fossil fuel combustion from mobile sources include: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and black carbon. Climate change is also impacted negatively by higher ground-level ozone emissions. Ozone levels are in turn linked to hydrocarbon and NOx emissions from mobile and stationary sources. The adverse health effects of ozone is compounded by rising temperatures caused by climate change. These complex relationships support the need to continue to reduce emissions of criteria pollutants and climate forcing compounds and we commend the agency for making further progress in this effort. Medium and heavy-duty vehicles contribute about 20% of the transportation-related GHG emissions in the U.S. The proposed regulations will have a global impact as the same technologies are deployed to meet future GHG and efficiency standards in other major world economies.

Proposed Regulatory Structure and Stringency to Incentivize Efficiency Technologies

MECA supports the EPA proposed reductions in greenhouse gas emissions for the heavy-duty truck segment, and believes that the proposed reductions are technically feasible using technologies that are ready for deployment on trucks today. Numerous analyses have estimated greater potential reductions of CO_2 than will be achieved by this proposal suggesting that EPA's Alternative 4 may be the more realistic scenario. EPA's own analysis shows that the faster Alternative 4 implementation timeline provides nearly the same payback periods as the longer Alternative 3 implementation timeline. The Department of Energy's SuperTruck program has demonstrated the magnitude of reductions that engine and vehicle technologies can deliver. A 2024 final implementation date, under Alternative 4, would allow developmental technologies to be optimized and ready for deployment under future, Phase 3 heavy-duty GHG standards to achieve the full potential reductions that exist from this transportation sector. We urge EPA to finalize a set of stringent Phase 2 standards that would incentivize the deployment of the full spectrum of cost effective technologies developed for engines and vehicles to guide industry investment and maximize environmental benefits. At a minimum, MECA is supportive of a final rule with a 2024 final phase-in date.

Technology development has a 15-20 year cycle from the lab to commercialization. This is why stringent standards are a critical signal to industry to make investments today for technologies that will be needed in the future. MECA members are engaged in developing a large portfolio of efficiency technologies that will directly or indirectly impact CO_2 emissions. These technologies include advanced SCR catalysts, passive NOx adsorbers (PNA) and substrates, waste heat recovery, turbochargers, turbo-compounding, EGR coolers, EGR valves and other air management technologies, thermal management strategies including insulated dual wall manifolds and exhaust systems, active thermal management approaches, advanced fuel injection and ignition systems. Technologies, like turbo-compounding and advanced air management strategies are already being commercialized in Europe whereas others such as Rankine cycle systems and advanced high pressure injection, are under demonstration and technologies with still longer term horizons, such as thermoelectric generators are still in the laboratory. MECA members estimate that using the proposed Alternative 3, 2027 engine efficiency standards, some of these technologies, such as waste heat recovery, will fall significantly short of the penetration rates forecasted in the proposal. Furthermore, without incentives or credits, manufacturers will be forced to halt further development and optimization of emerging technologies to achieve the type of return on investment the trucking industry demands.

In the absence of sufficiently stringent standards innovative technologies depend on incentives to achieve initial market penetration. Some of these technologies are not yet optimized to deliver the return on investment that truck owners require in today's low cost fuel environment. We urge EPA to include the advanced technology credits, which were part of the first phase of these regulations, in the final Phase 2 regulation. These credits would help to support continued development, optimization and testing of efficiency technologies to deliver cost-effective CO_2 reductions in the out years of the Phase 2 regulation and to meet future heavy-duty GHG requirements.

MECA strongly supports EPA's decision to retain the Phase 2 regulatory structure based on separate engine and vehicle standards that has been proven effective under the Phase 1 heavy-duty GHG standards. Our industry and the regulatory agencies have invested significant resources to insure that the current structure delivers cost-effective and durable emission reductions. Manufacturers have made significant investments in developing engine-based technologies under the first phase of heavy-duty GHG standards that will continue to deliver environmental benefits under this second set of GHG regulations. Engine and powertrain CO_2 reductions are verifiable and future OBD systems can be used to insure reductions over the life of the vehicle. The proposal includes a number of engine and vehicle technologies that demonstrate significant reductions but may not remain on the vehicle over its lifetime. These include, low friction lubricants, aerodynamic fairings, low rolling resistance tires among others. To achieve the goals of this regulation, we urge EPA to develop methodologies and policies that insure that the real emission reduction benefits from all technologies remain through the end of life and multiple owners of the vehicle.

There is a large set of technologies that can significantly reduce, either directly or indirectly, mobile source emissions of CO_2, N_2O (as well as other NOx emissions), CH_4, and black carbon. A range of powertrain technologies can be applied to both heavy-duty gasoline and diesel powertrains to help improve overall vehicle efficiencies, reduce fuel consumption, both of which can result in lower CO_2 exhaust emissions. In many cases, the application and optimization of advanced emission control technologies on advanced heavy-duty powertrains can be achieved in a manner that lowers overall fuel consumption while reducing criteria emissions. Our comments focus on available engine efficiency and exhaust emission control technologies and the impacts these technologies can have on greenhouse gas and criteria emissions.

The link between Ground Level Ozone and Climate Change

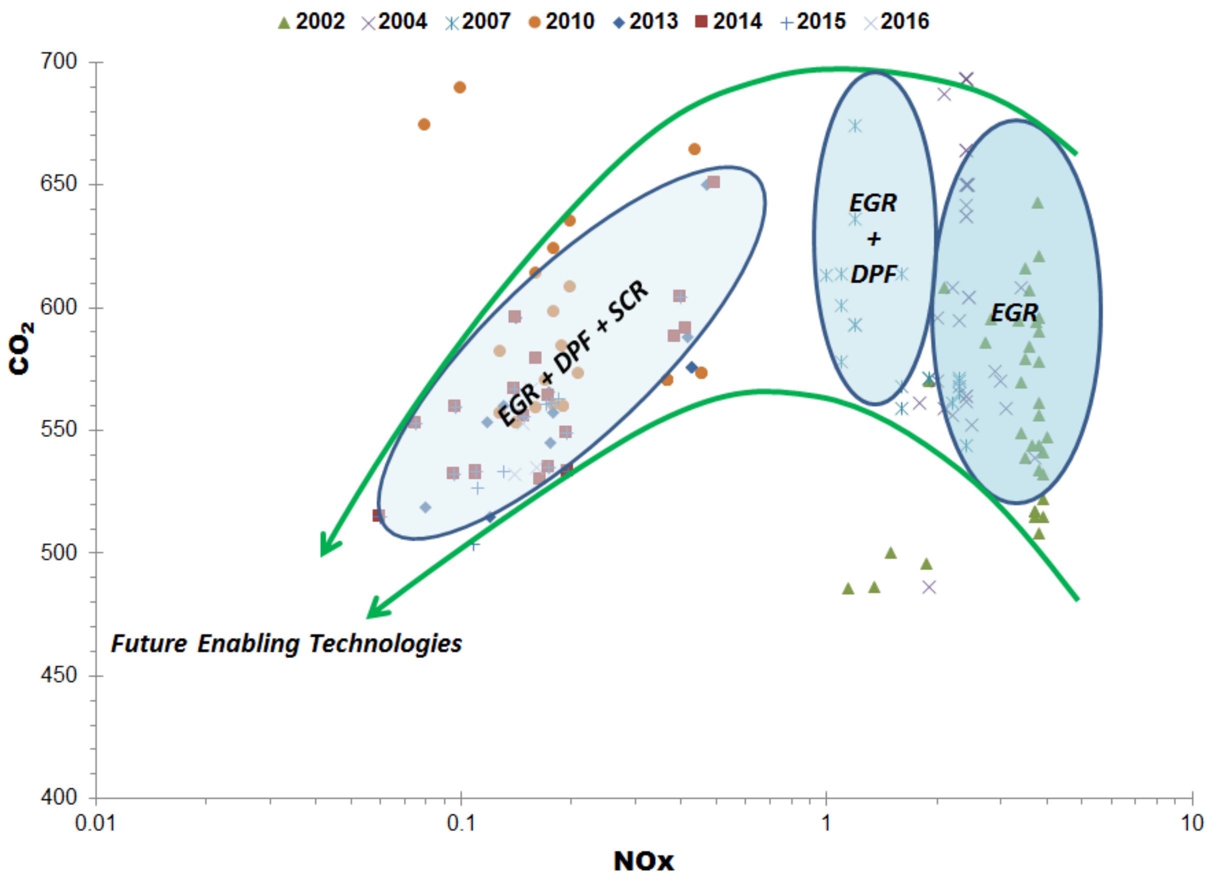
There is a significant linkage between ground level ozone concentrations and climate change impacts. One example was detailed by a group of researchers from the United Kingdom in a 2007 *Nature* publication. In this work, ground-level ozone was shown to damage plant photosynthesis resulting in lower carbon dioxide uptake from plants that have been exposed to higher levels of ozone. Other studies have shown that increasing average annual temperatures, resulting from climate change, are likely to result in even higher levels of ozone in the environment. Emission reductions aimed at lowering emissions of the primary precursors of ozone such as volatile organic compounds (VOCs) and NOx, will have a positive impact on lower ambient ozone levels, climate change, as well as human health. Policies that aim to reduce ambient ozone levels may also become more necessary and important to either mitigate the climate change impacts of ground level ozone or to mitigate higher ozone levels that result from climate change. The health-based National Ambient Air Quality Standards require that states focus on reducing their ambient levels of criteria pollutants. California and the Northeast states are struggling to achieve existing federal ozone ambient standards, and are already preparing to meet tighter ozone NAAQS limits in the future. These states are concerned about GHG emissions as well as NOx from mobile sources such as heavy-duty engines since the mobile sector represent 50-80% of their NOx inventory. Implicit in federal and state greenhouse gas emission analyses is the ability of these advanced powertrain options to meet the applicable criteria pollutant emission standards, such as CO, NOx, and non-methane organic gases (NMOG). All of these advanced, heavy-duty powertrain options combined with the appropriately designed and optimized emission control and efficiency technologies can meet all current and future federal and state criteria emission requirements. In this manner, advanced emission controls for criteria pollutants enable advanced powertrains to also be viable options for reducing greenhouse gas emissions.

The Relationship between NOx and CO_2 Emissions from the Engine

The calibration of internal combustion engines is a delicate balance that has to deal with trade-offs to optimize performance and emissions. For example, there is an inverse relationship between PM and NOx emissions that engine manufacturers applied to meet emission standards up through the 2006 heavy-duty highway regulations. In 2007, the requirement to reduce both PM and NOx emissions caused OEMs to install particulate filters on diesel vehicles which allowed engine calibrators to optimize the combustion in the engine to meet lower NOx emissions while relying on the DPF to remediate the resulting higher PM emissions. This example of effective emission regulations provided a technology solution to overcome the traditional barriers of engine calibration. In 2010, another game changing technology was installed on most trucks in response to a further tightening of NOx limits. Selective catalytic reduction or SCR allowed calibrators to not only reduce the soot load on filters and soot regeneration as a way of improving fuel efficiency but also to take advantage of another well-known trade-off in combustion thermodynamics between fuel consumption, CO_2 and NOx emissions out of the engine.

Since 2010 the predominant technology to reduce NOx from diesel engines has been SCR and every generation of SCR systems has led to improvements in catalyst conversion efficiency (a detailed discussion of SCR technology is provided below). The SCR system is just one technology option that has allowed engine and vehicle manufacturers to meet the first phase of heavy-duty GHG standards while still achieving NOx reduction targets from the engine. The portfolio of technology options that are available to reduce greenhouse gas emissions from heavy-duty trucks and engines is continually growing in response to tighter regulations set by U.S. EPA and the California Air Resources Board. In fact, a review of heavy-duty engine certifications from 2002 to 2015 shows that once emission and efficiency technologies were required on engines, the relationship between CO_2 and NOx emissions at the tailpipe went from a trade-off to a benefit (see Figure 1 below). By setting stringent emission targets for both CO_2 and NOx through realistic regulations and expanding the calibrator's tool box from the engine to the powertrain allowed engineers to achieve both reduced NOx levels and engine efficiency improvements simultaneously. Figure 1 plots the certification level for NOx and CO_2 from heavy-duty engines over the last 14 years and several generations of emissions technology.

<u>Figure 1: Heavy-Duty Engine Certification Levels for NOx and CO_2</u>



Selective Catalytic Reduction (SCR) Catalysts for Diesel Engines

Selective catalytic reduction (SCR), catalysts have been used to significantly reduce NOx emissions from lean combustion engines for decades. The SCR system uses a chemical reductant, usually a urea/water solution, or other ammonia sources (e.g., solid urea or metal chloride amines), to convert nitrogen oxides to molecular nitrogen and oxygen-rich exhaust streams across a suitable catalyst. Upon thermal hydrolysis and decomposition in the exhaust, urea forms CO_2, water and ammonia which serves as the reductant for NOx over the catalyst. As exhaust and reductant pass over the SCR catalyst, chemical reactions occur that reduce NOx emissions to nitrogen and water.

SCR catalyst can achieve over 98% NOx conversion in hot operation and over 70% during the cold-start portion of the heavy-duty transient test cycle. SCR catalysts are used on medium and heavy-duty engines around the world to achieve low NOx emission regulations. Applying SCR to diesel-powered engines provides simultaneous reductions of NOx, PM, and HC emissions. In addition to reductions in criteria pollutants, SCR applications on heavy-duty trucks allow engine manufacturers to further optimize and reduce fuel consumption of these engines through calibration optimization, in-turn providing important reductions in greenhouse gas emissions.

SCR applications on new highway, heavy-duty trucks in both Europe and the U.S. have already been shown to allow engine manufacturers the possibilities of calibrating engines for lower fuel consumption (and lower greenhouse gas emissions), while still meeting applicable NOx emission standards. Engine manufacturers that employed SCR technologies on 2010-compliant heavy-duty, highway engines in the U.S. claimed up to 5% improvements in fuel efficiency vs. engines that did not employ SCR technology. These fuel efficiency improvements are most evident at highway speeds, however in the future, employing thermal management strategies can shorten the warm-up portion of the cold start and facilitate urea injection earlier in the test cycle and thus expand the calibration optimization window to further reduce CO_2 emissions. The high NOx conversion efficiencies associated with SCR catalysts enable engines to be operated at conditions that yield lower fuel consumption. Engine manufacturers are expected to continue to further optimize engine fuel consumption characteristics and SCR system designs to assist in achieving the reductions proposed by EPA under this regulation. One example of future improvements in SCR catalyst system designs on heavy-duty engines is the direct application of SCR catalysts to diesel particulate filter substrates to provide a single catalyst module that provides reductions to all four criteria pollutants: hydrocarbons, CO, NOx, and PM. By deploying the SCR catalyst onto the filter moves the catalyst closer to the engine for faster warm-up, thus allowing earlier urea dosing. These SCR coated filters are already commercialized on several light-duty diesel passenger car models and are expected on heavy-duty highway and off-road engines in the near future. Beyond SCR, a number of other technology advances will facilitate significant criteria emission reductions, efficiency gains and reductions of short lived climate pollutants.

One such technology that has evolved specifically to address NOx emitted at low exhaust temperatures, includes a family of new materials referred to as passive NOx adsorbers (PNA). This catalyst technology is used upstream of the traditional exhaust control system, in combination with the DOC, to trap and store NOx at temperatures below 200^{o}C before urea can be dosed into the hot exhaust. Once the exhaust temperature is sufficient for SCR catalysts to convert NOx to nitrogen, and to allow the urea dosing system to be activated, the NOx stored on the PNA begins to desorb so it can be converted by the ammonia reductant over the SCR catalyst. This emerging technology will be one of the strategies available to engine and vehicle manufacturers to achieve lower cold-start tailpipe NOx levels.

The Advanced Collaborative Emissions Study (ACES) Phase 2 report published in 2012 showed that modern heavy-duty engines are achieving PM and NOx levels well below the federal standards. Recognizing the capability of technologies to deliver complimentary reductions of NOx and GHGs, California has adopted voluntary low NOx standards to incentivize development of state-of-the-art engines and emission controls to achieve NOx levels as low as 0.02 g/bhp-hr which is equivalent to a 90% reduction from EPA's 2010 highway, heavy-duty engine standards. Certification of cleaner engines ahead of proposing mandatory standards opens up opportunities for the state to direct incentive funds toward the development of cleaner engines. To support their regulatory efforts, ARB is funding a technology demonstration test program at Southwest Research Institute to demonstrate the feasibility to further reduce NOx emissions from heavy-duty engines. Advanced emission technologies like SCR coated filters and passive NOx adsorbers are included in this demonstration test program. EPA is monitoring this important test program as a member of the program's advisory committee.

To estimate the achievable level of NOx inventory reduction through the deployment of technologies capable of achieving a 90% NOx reduction below 2010 levels in the lower 47 states (excluding California), MECA funded an independent emission inventory forecast study, at ENVIRON. This analysis relied on EPA's MOVES2014 emissions inventory model for on-road vehicle emissions to estimate the future NOx reduction potential of a 0.02 g/bhp-hr heavy-duty NOx standard under a federal program. By-model-year emissions were determined for on-road vehicles to develop emissions estimates with and without new potential future emission standards. The model was run to generate emission inventories of NOx, VOC, CO and PM for on-road heavy-duty sources for calendar years 2025, 2030, 2040, and 2050.

When fully implemented, the achievable reductions from tighter NOx regulations on the heavy-duty on-road sector are estimated to be 266,000 tons per year or 730 tons per day in 2050 across the 47 contiguous United States and D.C., excluding California. We believe that these heavy-duty control measures represent the largest opportunity for achieving NOx reductions from the mobile sector going forward. We estimated the incremental cost of the types of additional emission controls that would be necessary to achieve the target reductions from heavy-duty trucks, beyond the exhaust controls already being used to meet current 2010 heavy-duty on-road standards at approximately $500 per vehicle averaged over the medium and heavy-duty highway fleet. Based on the results of our analysis, we estimate that heavy-duty trucks can deliver NOx reductions at a cost of approximately $3,000-$4,000 per ton. The very cost-effective NOx reductions available from the heavy-duty highway sector reflect the continued evolution of diesel exhaust emission controls. It has been more than 15 years since EPA closely examined diesel emission technologies as part of finalizing their 2007-2010 heavy-duty highway engine standards. Manufacturers of these technologies have and continue to improve the base technologies used to control NOx and PM from diesel engines. Significant experience has been provided by commercial roll-out of heavy-duty engines equipped with DPFs and SCR catalyst systems in this sector since 2007. These evolutionary improvements provide the pathway to achieving additional significant, cost-effective NOx reductions from this sector.

MECA believes that further reductions in NOx emissions from new heavy-duty on-road and off-road diesel engines beyond the 2010 on-road and Tier 4 off-road requirements will be possible through the combinations of more advanced diesel engines with advanced diesel exhaust emission control technologies. Much of the system development necessary to meet lower NOx emissions will be focused on the initial cold-start portion of the heavy-duty transient FTP test cycle representing approximately 70% of the total NOx emissions over the entire cycle. The types of future evolutionary technologies deployed, to achieve a future lower NOx standard, will likely include advanced substrates, improved SCR catalysts, more efficient SCR reductant delivery technologies and algorithms, and/or passive NOx adsorber catalysts. Substrate mounting matt materials have also evolved through newer technology generations including innovative, insulating intumescent canning materials that retain heat in the catalyst during periods of engine shutdown. The emission reduction benefits achieved through the deployment of cold start technologies such as advanced thermal management strategies, close-coupled catalysts, low thermal mass materials, improved ammonia dosing strategies among others will extend to increased conversion during low temperature duty-cycle operations. Already in several commercial light-duty diesel applications, higher porosity within the ceramic filter walls has allowed SCR catalyst to be deposited directly onto the DPF and thereby effectively moving the SCR closer to the turbocharger outlet in a more close-coupled position. Faster heat-up of the SCR catalyst has allowed earlier ammonia injection and NOx reduction. The sooner the SCR catalyst is activated in the test cycle, engine calibrators can optimize combustion for reduced CO_2 emissions. Furthermore, these cold-start technologies will allow vehicle manufacturers to deploy hybrid systems, stop-start technologies and waste heat recovery to improve vehicle efficiency while still meeting tighter NOx limits.

MECA believes the time is right for EPA to begin a rulemaking effort aimed at further significant reductions in NOx emissions from heavy-duty highway engines. Improved NOx reduction technologies are available today to deliver ultra-low NOx emissions from these engines. Existing and future ozone non-attainment regions will need these cost-effective NOx reductions to support attainment plans. Engine manufacturers can combine these advanced NOx emission controls with other efficiency technologies to optimize future truck performance to deliver both lower NOx emissions and improved fuel efficiency.

Nitrous Oxide (N_2O)

While total N_2O emissions are much lower than CO_2 emissions, N_2O is approximately 298 times more powerful than CO_2 at trapping heat in the atmosphere. One of the anthropogenic activities producing N_2O in the U.S. is fuel combustion in motor vehicles. In 2006, N_2O emissions from mobile source combustion were approximately 9% of total U.S. N_2O emissions. N_2O is emitted directly from motor vehicles and its formation is highly dependent on temperature, NO_2 to NOx ratio entering the SCR catalyst, ammonia to NOx ratio, the SCR catalyst formulation and the temperature of the catalyst over the test cycle. Temperatures favorable for N_2O formation (approximately 250º C) are achieved inside catalytic converter systems, especially during cold-start conditions when engine exhaust temperatures are lower.

EPA is proposing to tighten the N_2O cap and deterioration factor by 50% from 100 mg/bhp-hr to 50 mg/bhp-hr and 20 mg/bhp-hr to 10 mg/bhp-hr, respectively. This is to ensure that climate change impacts of this potent greenhouse gas are minimized on future medium- and heavy-duty vehicles. Furthermore because 75% of engine families certified in 2014 already meet a 50 mg/bhp-hr N_2O level, the agency is concerned that engine manufacturers may emit higher levels in the future as they optimize the overall CO_2 emissions of engines. EPA estimates that a 40 mg/bhp-hr N_2O emission reduction has the CO_2 equivalent climate impact of a 2.6% improvement in engine efficiency. Although MECA members believe that meeting the proposed N_2O levels will be achievable, it will be challenging given the types of engine developments that we expect to see in the future. In particular we expect that future engines will have higher engine-out NOx levels in the exhaust as a way of achieving lower CO_2 levels. Furthermore, overall cooler exhaust temperatures may be expected as a result of efficiency technologies such as turbo-compounding being deployed upstream of the exhaust emission control system. Furthermore, it is important to consider N_2O emissions in-light of future regulations such as the 0.02 g/bhp-hr heavy-duty NOx standard under consideration by California. Below, we discuss the primary formation mechanisms for N_2O and some approaches that may be used in the future to achieve lower levels of N_2O emissions on future diesel engines.

At low temperatures, around 250^{o} C, the predominant mechanism for N_2O formation is by the decomposition of ammonium nitrate, whereas at high temperatures, above 500^{0} C, the primary mechanism is ammonia oxidation. Nitrous oxide can form at intermediate temperatures ($300\text{-}350^{0}$ C) if the NO_2 to NOx ratio exceeds 50%. Excess ammonia injection across the SCR catalyst can also lead to an increase in N_2O formation if the ammonia to NOx ratio exceeds 1.0. A recent study published by the Society of Automotive Engineers (SAE Technical Paper 2013-01-2463) concluded that the test cycle, cycle exhaust temperature, system design and urea injection calibration all play a role in the formation of N_2O on the SCR catalyst. The authors observed that the inlet conditions of the SCR catalyst had the greatest effect on the formation of nitrous oxide.

Another SAE technical paper (2015-01-0997) studied the effect of SCR catalyst type on the formation of N_2O. The authors observed that the lowest N_2O emissions were observed from a vanadia/titania SCR and Cu-zeolite SCR systems. Furthermore the Cu-zeolite SCR exhibited little deactivation after aging. The authors found that the system design, linear versus muffler, can impact the overall NOx performance and N_2O emissions as a result of the average temperature of the SCR catalyst in each configuration relative to the optimal temperature for N_2O formation. Upstream components such as the DOC and DPF can also impact the N_2O levels based on their relative activity to form higher NO_2/NOx ratio feedgas to the SCR. The authors of this paper discuss ways to formulate the precious metal composition and loading on the DOC and DPF to minimize their contribution to N_2O formation while still maintaining high NOx conversion efficiency. For all SCR systems, the N_2O emissions could be reduced by tighter urea dosing control to limit excess ammonia, by targeting an optimal amount of ammonia storage in the SCR catalyst and reducing engine-out NOx.

In another recent paper published at the 2015 SAE Congress (SAE paper Number 2015-01-1030), the authors looked at ways to design the SCR catalyst architecture to target lower N_2O emissions from the system. Because the front part of the SCR catalyst is more prone to form N_2O, the authors looked at coating the front of the SCR substrate with a vanadia-SCR formulation and the rear of the substrate with a standard Cu-zeolite SCR. Further optimization may be possible through the use of modeling tools to identify the SCR formulation and coating volume combinations that minimize N_2O emissions and maximize NOx conversion.

Advanced gasoline and diesel powertrains for medium- and heavy-duty vehicles in conjunction with advanced emission control technologies can be optimized to minimize N_2O emissions. Catalyst manufactures can utilize a number of approaches to reduce N_2O emissions from the exhaust emission control components and therefore MECA believes that the proposed N_2O emission cap is achievable with the use of appropriately designed emission controls on today's medium- and heavy-duty powertrain options. The proposal further provides manufacturers with the flexibility of meeting emission caps or factoring in emissions of N_2O or

CH_4 into the CO_2-equivalent emissions calculation of the overall vehicle. MECA supports continuing this proposed flexibility introduced under Phase 1 of this regulation.

Control of Black Carbon with Particulate Filters

Black carbon is a major component of particulate matter emissions from mobile sources and is believed to have a significant net atmospheric warming effect by enhancing the absorption of sunlight. Black carbon is a mix of elemental and organic carbon, in the form of soot, emitted by fossil fuel combustion, bio-mass burning, and bio-fuel cooking. Black carbon is a dominant absorber of visible solar radiation in the atmosphere. Anthropogenic sources of black carbon are transported over long distances and are most concentrated in the tropics where solar irradiance is highest. Because of the combination of high absorption, a regional distribution roughly aligned with solar irradiance, and the capacity to form widespread atmospheric brown clouds in a mixture with other aerosols, emissions of black carbon are thought to be the second strongest contribution to current climate change, after CO_2 emissions. The glacier retreat has accelerated since the 1970s and several scientists have speculated that solar heating by soot in atmospheric brown clouds and deposition of dark soot over bright snow surfaces may be an important contributing factor for the acceleration of glacier retreat. A study published in a 2009 issue of *Nature Geoscience* (vol. 2, 2009) by researchers from the NASA Goddard Institute and Columbia University found that black carbon is responsible for 50% of the total Arctic warming observed from 1890 to 2007 (most of the observed Arctic warming over this timeframe occurred from 1976 to 2007).

It is estimated that 70% of the black carbon emissions from mobile sources are from diesel-fueled vehicles, with the assumption that 40% of gasoline PM is black carbon and 60% of diesel PM is black carbon. The black carbon concentration and its global heating will decrease almost immediately after reduction of its emission. Black carbon from diesel vehicles can be significantly reduced through emission control technology that has been required on every U.S. heavy-duty diesel truck manufactured since 2007. The basis for the design of wall-flow particulate filters is a ceramic honeycomb structure with alternate channels plugged at opposite ends. As the gases pass into the open end of a channel, the plug at the opposite end forces the gases through the porous wall of the honeycomb channel and out through the neighboring channel. The porous wall and the filter cake of particulate matter that forms within and on the surface of the wall serve as the filter media for particulates. Since the filter can fill up over time by developing a layer of retained particles on the inside surface of the porous wall, the accumulated particles must be burned off or removed to regenerate the filter. This regeneration process can be accomplished with a variety of methods including both active strategies that rely on generating external sources of heat (e.g., fuel burners, fuel dosing strategies that utilize fuel combustion over a catalyst, electrical elements, intake air throttling) and passive strategies that utilize catalysts that are displayed directly on the filter element or upstream of the filter. During the regeneration of DPFs, captured carbon is oxidized to CO_2 but this filter regeneration still results in a net climate change benefit since the global warming potential of black carbon has been estimated to be as high as 2,200 times higher than that of CO_2 on a per gram of emission basis. It is estimated that the installation of DPFs has reduced PM emissions from U.S. heavy-duty diesel vehicles by 110,000 tons per year. The ACES Phase 2 study that evaluated the PM emissions from 2010 technology heavy-duty engines showed that DPF equipped engines emit PM at one to two orders of magnitude below the current standard of 0.01 g/bhp-hr and deliver over 99% PM capture efficiency over their lifetime. MECA encourages EPA to develop policies and/or incentives that reward vehicle and engine manufacturers for employing technologies such as particulate filters that provide significant reductions in mobile source black carbon emissions.

Control of PM from Auxiliary Power Units

Auxiliary power units or APUs are used on heavy-duty trucks during "hoteling" at truck stops or other suitable rest areas. During long periods of idling, the APU provides power to auxiliary systems such as cabin electricity and air conditioning so that the main truck engine can be turned off. Because APUs have diesel engines less than 10 horsepower, they burn less fuel than the main engine and thus reduce CO_2 emissions. Under Tier 4 standards, the small displacement of these engines allows them to operate without exhaust emission controls such as diesel particulate filters and as a result they emit 5-10 times more PM emissions than the much larger displacement but filter-equipped main truck engine idling for the same amount of time. The California Air Resources Board recognized this fact and in 2008, included as part of their anti-idling regulations for heavy-duty trucks, a requirement that APUs must be retrofit with a particulate filter capable of achieving at least an 85% reduction in PM or have the APU exhaust diverted through the main DPF in the exhaust system of the truck. To achieve an 85% PM reduction, the particulate filter must be a wall flow device, or similar. ARB has verified four of these retrofit devices, made by third-party manufactures, for installation on existing APU engines. Due to the relatively cold exhaust temperatures of these small engines, the DPF filters installed on APUs must use either all active or a combination of passive and active regeneration to periodically clean the soot from the filter. Active regeneration can be accomplished through the use of a fuel burner or electrical heater upstream of the filter element that can be activated if the back pressure is too high.

California's APU Air Toxics Control Measure (ATCM) regulation demonstrates that it is feasible to control PM from small APU engines and several companies are supporting this market. The technology is commercially available and has been implemented on APUs since 2008 as part of the state's Diesel Risk Reduction Plan (DRRP). In the Phase 2 proposal, EPA estimates the potential PM reduction impacts from installing DPFs on APUs as approximately 3,000 tons in 2035. Because these engines operate for many hours in a single location, the health impact from PM exposure to people that work, stop or live near rest areas and truck stops may be of greater concern than might be indicated by a simple mass-based inventory. Groups of trucks operating their APUs at a truck stop are similar to a stationary point source. California based their requirements for using PM controls on stationary sources on the health-based cancer risk of PM exposure around a point source exceeding one in a million. To better quantify the emissions impacts of installing emission controls on small diesel engines, such as APUs, TRUs and other small off-road engines, CARB is funding a demonstration program at UC-Riverside. MECA is supporting this effort with technology and expertise and we encourage EPA to seriously consider requiring DPF technology on APU engines as part of this regulation. We agree with EPA's cost estimates for a DPF retrofit on an existing APU, that cost includes the expense of verifying the device and the need for a separate control unit to monitor and regenerate the filter. We believe that the cost would be significantly lower if the filter could be integrated onto the APU engine at the time of manufacture or the APU exhaust is routed into the truck exhaust, upstream of the DPF, at the time of vehicle manufacture and incorporates economies of scale that an OEM can achieve with larger numbers of engines.

Heavy-Duty Glider Kits and Glider Vehicles

MECA strongly supports the agency's proposal to require that the engines installed in glider vehicles meet the same criteria and GHG emission requirements as new engines certified in the same model year. The recent rapid growth in the number of glider vehicles sold since 2007 to over 5,000 vehicles a year shows the large emissions impact that this category of high emitters has on the overall contribution of PM and NOx from heavy-duty engines. As new engines become cleaner in the future the contribution from glider vehicles will continue to grow. Glider vehicles are classified as "new motor vehicles" because they use a new chassis, although they can continue to use engines that are 10-15 years old and emit 20-40 times more pollution than vehicles equipped with a new engine. The existing exemption of glider vehicles from the latest pollution requirements represents a huge loophole in the regulation. Using this "new motor vehicle" designation under the clean air act, glider vehicles could potentially qualify for clean air incentive funding under some state in-use fleet programs while not meeting the intent or emission reduction goals of those programs. Glider vehicles, equipped with old diesel engines, or converted to alternative fuels could potentially compete for funding with newly manufactured trucks, replacement engines or retrofit emission control devices. The proposed glider kit and glider vehicle provision in this proposal takes an important step towards closing this loophole and MECA supports inclusion of this provision in the final regulation and moving the implementation date ahead of the proposed 2018 start date. There should be no "dirty diesel" loophole left in EPA's regulatory programs.

MECA is concerned that the present proposed limited grandfathering of glider vehicle production for existing small businesses would still allow the continued production of up to 300 assembled gliders a year, per company. This exemption poses a significant threat to air quality as 300 trucks could emit the same amount of NOx as 7500 new heavy duty trucks. EPA should include a phase-out of this glider loophole completely that reduces the 300 glider kit limit per small existing business over a course of three years after which full compliance is required. This should provide sufficient time for small businesses to adapt their business models to produce and maintain clean diesels. Retaining a 300 per year limit indefinitely could result in a disproportionate number of dirty vehicles to continue to be produced and remain in the fleet for decades to come. To minimize the opportunity to abuse this exemption, EPA might consider limiting the conditions under which a glider vehicle may be purchased to legitimate situations such as when a vehicle is damaged in an accident and the engine can be salvaged. Requirements should include record keeping guidelines to support legitimate transactions to purchase glider vehicles.

Methane and PM Emissions from Stoichiometric Natural Gas Engines

Because methane is a potent climate forcing agent with Global Warming Potential (GWP) that is 25 times greater than CO_2 over a period of 100 years, we applaud the agencies consideration of both upstream and downstream methane emissions from the growing fleet of natural gas trucks. EPA's Greenhouse Gas Reporting Program (GHGRP) is an important source for updating the upstream GHG inventories from the production and transportation of this alternate fuel. As the interest in natural gas as a domestic energy source and transportation fuel grows, it leads to expansion of the fuel production and transportation infrastructure. We are encouraged with EPA's intentions to further regulate methane emissions from natural gas production facilities. The upstream production, distribution and transportation of methane may be a significant contributor to the overall GHG contribution from this fuel sector.

MECA is a long supporter of technology and fuel neutral standards and we believe that the proposed provisions to control fugitive methane emissions from natural gas vehicles and engines represent a fair and balanced approach to addressing the CO_2-equivalent emissions from the growing natural gas vehicle sector. Because of the low vapor pressure of this alternate fuel, the potential source of emissions goes beyond just the tailpipe. Similar to the case of evaporative emissions from gasoline vehicles, it is important to control the non-combustion related emissions from natural gas engines and fuel systems. We support the EPA's inclusion of boil-off requirements for LNG vehicles in the Phase 2 proposal and to require closed crankcases on all natural gas vehicles. MECA supports the reclassification, starting in 2021 under Phase 2, of natural gas engines according to their primary intended service classes, similar to compression ignition engines. Although MECA lacks the expertise in suggesting the life cycle climate impacts, a number of ongoing studies by California, EPA and others may provide additional insight into how this may be done in the near future. California's Low Carbon Fuel Standard provides methodology that producers may employ to revise climate impacts of newly developed production pathways and this may serve as a model of how that may be done for upstream methane emissions. If natural gas truck applications continue to grow, as some market analysts predict, EPA should consider developing a separate set of engine efficiency standards that better reflect the full life cycle emissions of natural gas vehicles including leakage and upstream emissions.

It is worth noting that stoichiometric, heavy-duty natural gas engines have been shown to emit large numbers of ultrafine particulates that are largely the result of the consumption of lubricant oil during the engine combustion process (see ARB's funded work published by West Virginia University on particle emissions from stoichiometric natural gas bus engines published in *Environmental Science & Technology* in June 2014). These stoichiometric heavy-duty engines are currently certified without filters due to their low particulate mass emissions. The mass of metal oxide ash particles from these natural gas engines were an order of magnitude greater than the mass of metal oxide ash emitted from a 2010 technology diesel engine equipped with a DPF and SCR system. The oxidative stress potential (OS) of the PM was also characterized in-vitro through DTT and ROS assays. High correlation coefficients were observed between the mass of lube oil-derived elemental species and both DTT and macrophage ROS, suggesting that the chemical species forcing oxidative stress are metallic in nature. The authors further suggest that, although the PM mass emissions from natural gas vehicles are low, the presence of nucleation mode solid metal particles could pose significant health risks in the alveolar regions of the respiratory system due to the higher surface area of these nanoparticles. Filters on these stoichiometric natural gas engines would significantly reduce the ultrafine particle emissions from these engines and provide additional climate and public health benefits. MECA encourages EPA to investigate the health and climate benefits of applying filters to these engines and enact appropriate policies that force the use of high efficiency filters on these engines to reduce ultrafine metal oxide exposure.

SUMMARY

Looking ahead, transportation greenhouse gas emissions are forecast to continue increasing rapidly, reflecting the anticipated impact of factors such as economic growth, increased movement of freight by trucks, ships, and rail, and continued growth in personal travel. The transportation sector is the largest source of domestic CO_2 emissions, representing 33% of the nation's total in 2006. There are significant opportunities to reduce greenhouse gas emissions from the transportation sector through the design of fuel efficient powertrains that include advanced exhaust emission controls for meeting even the most stringent criteria pollutant standards being discussed today in California. These emission control technologies allow all high efficiency powertrains to compete in the marketplace by enabling these powertrains to meet current and future criteria pollutant standards. Similarly experimental or developmental engine efficiency technologies rely on a stringent set of CO_2 standards and incentives or advanced technology credits to penetrate the market. Credit opportunities offered under the Phase 1 program should be extended in the final Phase 2 rule.

The engine certification levels for criteria pollutants and CO_2 since 2010 demonstrate that these fuel-efficient powertrain designs, combined with appropriate emission controls and efficiency technologies, can be optimized to improve overall CO_2 emissions of the vehicle while also achieving ultra-low NOx and other criteria pollutant emissions. This optimization extends beyond carbon dioxide emissions to include other significant greenhouse gases such as methane and nitrous oxide.

Diesel particulate filters are extremely effective at removing black carbon emissions from diesel engines. Effective climate change policies should include programs and incentives aimed at reducing black carbon emissions from unfiltered new off-road engines and existing diesel engines through effective retrofit programs that implement filters on the full range of in-use diesel engines operating in the U.S.

Ground level ozone also has a strong linkage to climate change. EPA needs to continue its efforts to review and adjust criteria pollutant programs for all mobile sources going forward to not only provide needed health benefits from technology-forcing emission standards but also the co-benefits these emission standards have on climate change. In particular for heavy-duty highway engines, MECA urges EPA to begin a rulemaking effort as soon as possible aimed at further NOx reductions from heavy-duty engines.

In conclusion, MECA commends EPA for taking important steps to continue to reduce greenhouse gas emissions and improve fuel economy from medium- and heavy-duty vehicles. MECA believes that a variety of advanced powertrain options are available for reducing carbon dioxide emissions from these vehicles and engines. MECA believes that the proposed reductions for greenhouse gas emissions from heavy-duty vehicles proposed by EPA are technically and economically feasible under a 2024 implementation timeframe. Our industry is prepared to do its part and deliver cost-effective advanced emission control and efficiency technologies to the heavy-duty sector to assist in achieving lower greenhouse gas emissions, while also meeting future reductions in NOx and other criteria pollutants.

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TAB 27

SOUTH COAST
AIR QUALITY
MANAGEMENT DISTRICT

VOC Controls

2016 AQMP WHITE PAPER

OCTOBER 2015

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.