White Paper

Comparing the Emissions Reductions of the LEV II Program to the Tier 2 Program

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I. Executive Summary

All new vehicles sold in the U.S. are subject to emissions standards set by either the federal government or the State of California. California is the only state with the authority to set its own vehicle standards; other states may adopt either the California or the federal standards.[1] In the 1990s, several Northeast states (specifically, Maine, Massachusetts, New York and Vermont) adopted the California Low Emission Vehicle (LEV) program in lieu of federal standards. Other Northeast states (Connecticut, New Hampshire, New Jersey and Rhode Island) currently participate in the federal National Low Emission Vehicle Program (NLEV) but now have the opportunity to switch to California's second-generation "LEV II" program. If they choose to remain with the federal program, cars sold in these states will be subject to federal Tier 2 emissions standards beginning in 2004 (with full implementation of the Tier 2 program in 2007), at which time NLEV will be replaced by the Tier 2 program.

Under the NLEV program, auto manufacturers agreed to provide voluntary, nationwide emissions reductions beyond the federal Tier 1 program on the condition that states not switch to California's standards before model year 2006. Because states must provide manufacturers with at least two years of lead time before implementing new emissions standards and because new model year vehicles typically enter the marketplace a year early, any Northeast states that are interested in adopting California's LEV II standards at the earliest possible date (i.e. in time to affect model year 2007 vehicles) must act before 2004.

NESCAUM commissioned this study to assist states in quantifying the emissions reductions of the California LEV II program compared to the federal Tier 2 program. As such, it is a follow-up to an earlier NESCAUM report which evaluated the emissions reductions of adopting the California LEV program in 1991. The analysis itself was conducted by Cambridge Systematics, Inc., an independent consulting firm that, for more than 20 years, has conducted projects associated with the implementation of transportation and air quality planning initiatives.

An important feature of the California program is that it includes an advanced technology vehicle component. Originally designed to mandate the introduction of battery electric "zero-emission vehicles" (ZEVs), California's ZEV requirement has since been changed to allow credit for a variety of advanced automobile technologies besides battery electric vehicles, including hybrid-electric vehicles, super low-emitting gasoline vehicles and hydrogen fuel cell vehicles.[2] Because the emissions benefits of LEV II

[1] The authority of other states to adopt California standards in lieu of federal standards was granted under Section 177 of the Clean Air Act Amendments of 1990.

[2] Advanced automobile technologies include vehicles with zero tailpipe and evaporative emissions (ZEVs), vehicles that have some electric drivetrain components (called advanced technology partial ZEVs or AT PZEVs), and conventional gasoline vehicles that meet certain emissions, durability, and warranty requirements (called partial ZEVs or PZEVs). Recent changes to the ZEV mandate greatly reduce the number of pure ZEVs required to meet the mandate

depend in part on how the ZEV mandate is complied with and since automobile manufacturers have significant flexibility in complying with the program, Cambridge Systematics evaluated four variations on that component of the California program.[3] The assumptions and methodologies used to conduct this analysis are detailed in Section V of this report; the different scenarios evaluated with respect to ZEV implementation are summarized in Table 5 on page 21.

Findings

Both the federal Tier 2 program and the California LEV II program will provide substantial further reductions in new vehicle exhaust emissions (on the order of 90 percent or more) over the next two decades. *However, the analysis conducted by Cambridge Systematics for NESCAUM finds that California's standards provide additional emissions reduction benefits over and above what the federal program is expected to achieve.* Specifically, the analysis finds additional reductions in light duty vehicle hydrocarbon (HC) emissions of 4 percent in 2010 and 16 percent in 2020 under the LEV II program compared to the federal Tier 2 program. Moreover, pollution benefits are particularly significant with respect to those HC emissions that are also considered toxic (e.g., benzene, formaldehyde and 1,3-butadiene). Specifically, additional reductions in toxic vehicle emissions under LEV II are estimated at approximately 25 percent in 2020, compared to the federal program. Finally, the analysis also finds that LEV II yields modest carbon dioxide reduction benefits (on the order of 3 percent in 2020) compared to Tier 2, primarily as a result of the advanced technology vehicle component of the California program.

The emission reduction benefits calculated in this analysis are summarized in the table below. Note that while absolute daily emissions reductions were calculated for three of the four Northeast states that have already adopted LEV II (Massachusetts, New York and Vermont[4]), similar benefits – in percentage reduction terms – would be expected for any other state choosing to adopt this program in lieu of federal standards.[5]

[3] The analysis evaluated emissions from the fleet of light duty vehicles only, and not the two heavier classes of passenger cars that include heavier SUVs, pickup trucks, and minivans (LDT3 and 4). All four scenarios evaluated in this analysis included a minimum of 2 percent all-electric vehicles. California has revised its ZEV program since the analysis was conducted to largely eliminate the all-electric component. The impact of this change on the emissions results would however be minimal given that larger numbers of AT PZEVs will be used to replace the all-electric vehicles. An analysis prepared by California Air Resources Board staff and presented to the Air Resources Board in April concluded that "even though ZEVs are cleaner on a per vehicle basis, under our credit ratios over the long term one ZEV must be replaced by about six AT PZEVs. Therefore the greater numbers of AT PZEVs that are needed to replace ZEVs [as a result of the changes to the ZEV mandate] results in an air quality benefit. This analysis takes into account the change in implementation date for the ZEV mandate from 2003 to 2005."

[4] Maine, the fourth LEV state in the Northeast, was not included in the emissions analysis because Maine has chosen not to implement the ZEV component of the California program at this time. Since this feature is the source of much of the variation in emissions results between LEV II and Tier 2, emissions reduction benefits were not estimated for Maine.

[5] Note that the combined vehicle fleets of existing LEV II States – MA, ME, NY and VT – total approximately 16 million registered vehicles - approximately 62 percent of the Northeast light duty vehicle fleet.

Table ES-1: Annual Emissions Benefits of the LEV II Program in 2020

State	HC reduced (tons)	% HC Reduction Over Tier 2	Toxics[6] reduced (tons)	% Toxics Reduction Over Tier 2	CO_2 reduced (tons)	% CO_2 reduced
NY	10,020	15%	502	25% for each toxin	2,500,000	2.25%
MA	3,300	17%	185	25% for each toxin	900,000	2.25%
VT	510	14%	29	19% for each toxin	120,000	2.25%
Total	**13,830**	**Average Reduction 15.3%**	**716**	**Average Reduction 23%**	**3,520,000**	**Average Reduction 2.25%**

It is important to note, in connection with the findings summarized above, that calculated emissions benefits depend to a critical extent on assumptions made in the course of the analysis. The U.S. Environmental Protection Agency (EPA) has conducted its own comparative analysis of the California and federal programs and has reached different conclusions on different occasions. In a December 2001 draft guidance document, EPA recommended that states use the MOBILE6 model to compare LEV II and Tier 2 emissions. The approach EPA recommended at that time predicts LEV II will provide additional HC emissions reductions on the order of 21 percent compared to federal Tier 2. However, the approach recommended in a subsequent EPA guidance document – issued in June 2002 – predicts a substantially smaller HC benefit (on the order of 5 percent).[7] The latter result appears to have been driven largely by that fact that EPA assumed that vehicles that comply with the ZEV mandate will meet the same evaporative emissions standards as regular LEV II vehicles, even though California's evaporative standards are more stringent for ZEV-compliant vehicles. Further differences between EPA's most recent results and those found in this study arise from different assumptions about the compliance strategies used by manufacturers under the Tier 2 program. Specifically, the EPA June 2002 guidance assumed over-compliance with the emissions standards in lighter vehicles to make up for sales of heavier, more polluting vehicles. Based on NESCAUM's discussions with industry representatives, NESCAUM did not make that assumption for purposes of this analysis.[8] As a result, our findings are closer to those predicted in the earlier EPA assessment. It is important to

[6] Toxics include benzene, 1,3 butadiene, formaldehyde and acetaldehyde.

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note that NESCAUM assumed that Tier 2 vehicles will meet regular LEV II vehicle evaporative emission standards, even though the LEV II evaporative emission standards are more stringent than the federal standards. The reason NESCAUM assumed this "over compliance" with the evaporative emission standards is that manufacturers have said they will manufacture cars in all 50 states which meet the LEV II evaporative emission standards. Thus, the NESCAUM study could underestimate the emissions reductions achieved in states that adopt the LEV II program - if manufacturers do not comply with this voluntary approach.

Conclusions

The LEV II program provides significant toxic and CO_2 emission reductions over the Tier 2 program. Unlike the federal program which will remain the same for at least a decade (as is required by the Clean Air Act) the California program will probably continue to become more stringent. Thus emissions differences between the California and federal programs will likely become greater as California adopts more stringent phases of the LEV program. In particular, risks associated with exposure to toxics such as benzene, formaldehyde, and 1,3-butadiene will be significantly reduced by adoption of the California LEV II program.

II. Introduction

All new vehicles sold in the U.S. are subject to emissions standards set by either the federal government or the State of California. California is the only state with the authority to set its own vehicle standards; other states may adopt either the California or the federal standards.[9] In the 1990s, several Northeast states (specifically, Maine, Massachusetts, New York and Vermont) adopted the California Low Emission Vehicle (LEV) program in lieu of federal standards. Other Northeast states (Connecticut, New Hampshire, New Jersey and Rhode Island) currently participate in the federal National Low Emission Vehicle Program (NLEV) but now have the opportunity to switch to California's second-generation "LEV II" program. If they choose to remain with the federal program, cars sold in these states will be subject to federal Tier 2 emissions standards beginning in 2004 (with full implementation of the Tier 2 program in 2007), at which time NLEV will be replaced by the Tier 2 program.

Under the NLEV program, auto manufacturers agreed to provide voluntary, nationwide emissions reductions beyond the federal Tier 1 program on the condition that states not switch to California's standards before model year 2006. Because states must provide manufacturers with at least two years of lead time before implementing new emissions standards and because new model year vehicles typically enter the marketplace a year early, any Northeast states that are interested in adopting California's LEV II standards at the earliest possible date (i.e. in time to affect model year 2007 vehicles) must act before 2004.

NESCAUM commissioned this study to assist states in quantifying the emissions reductions of the California LEV II program compared to the federal Tier 2 program. As such, it is a follow-up to an earlier NESCAUM report which evaluated the emissions reductions of adopting the California LEV program in 1991. The analysis itself was conducted by Cambridge Systematics, Inc., an independent consulting firm that, for more than 20 years, has conducted projects associated with the implementation of transportation and air quality planning initiatives.

An important feature of the California program is that it includes an advanced technology vehicle component. Originally designed to mandate the introduction of battery electric "zero-emission vehicles" (ZEVs), California's ZEV requirement has since been changed to allow credit for a variety of advanced automobile technologies besides battery electric vehicles, including hybrid-electric vehicles, super low-emitting gasoline vehicles and hydrogen fuel cell vehicles.[10] Because the emissions benefits of LEV II depend in part on how the ZEV mandate is complied with and since automobile

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manufacturers have significant flexibility in complying with the program, Cambridge Systematics evaluated four variations on that component of the California program.[11] The assumptions and methodologies used to conduct this analysis are detailed in Section V of this report; the different scenarios evaluated with respect to ZEV implementation are summarized in Table 5 on page 15.

III. Findings

Both the federal Tier 2 program and the California LEV II program will provide substantial further reductions in new vehicle exhaust emissions (on the order of 90 percent or more) over the next two decades. *However, the analysis conducted by Cambridge Systematics for NESCAUM finds that California's standards provide additional emissions reduction benefits over and above what the federal program is expected to achieve.* Specifically, the analysis finds additional reductions in light duty vehicle hydrocarbon (HC) emissions of 4 percent in 2010 and 16 percent in 2020 under the LEV II program compared to the federal Tier 2 program. Moreover, pollution benefits are particularly significant with respect to those HC emissions that are also considered toxic (e.g., benzene, formaldehyde and 1,3-butadiene). Specifically, additional reductions in toxic vehicle emissions under LEV II are estimated at approximately 25 percent in 2020, compared to the federal program. Finally, the analysis also finds that LEV II yields modest carbon dioxide reduction benefits (on the order of 3 percent in 2020) compared to Tier 2, primarily as a result of the advanced technology vehicle component of the California program.

The emission reduction benefits calculated in this analysis are summarized in the table below. Note that while absolute daily emissions reductions were calculated for three of the four Northeast states that have already adopted LEV II (Massachusetts, New York and Vermont[12]), similar benefits – in percentage reduction terms – would be expected for any other state choosing to adopt this program in lieu of federal standards.[13]

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The results of this analysis clearly show that the LEV II program provides significant emissions reductions over and beyond what the federal Tier 2 program provides for HC, toxics, and for CO_2.

IV. Discussion

The additional emissions benefits associated with LEV II and summarized in the previous section stem from two chief differences between the California and federal programs. First, the ZEV mandate described in Section I results in the introduction of vehicles with even lower emissions than those required of new conventional gasoline vehicles under either program. (While California has introduced additional flexibility to this aspect of its program, any gasoline powered vehicles used to satisfy the mandate will have to meet more demanding tailpipe and evaporative standards, as well as stringent durability requirements.)[17] Second, California's LEV II standards for evaporative and tailpipe HC emissions are more stringent than those of the federal Tier 2 program.[18]

Overall, approximately 30 percent of the additional hydrocarbon benefit estimated for the California LEV program is a consequence of the ZEV mandate (with the remaining 70 percent coming from more stringent evaporative and tailpipe standards); the ZEV mandate also accounts – as previously noted – for nearly all of the carbon dioxide benefit.

The results of this analysis indicate that Northeast States would derive air quality and public health benefits from adopting the California program in at least three areas:

- reducing ambient levels of priority airborne toxic pollutants
- attaining health-based air quality standards for ozone and fine particles
- meeting state and regional climate change objectives

[17] Specifically, eligibility for ZEV credit is tied to California's Super Ultra Low Emission Vehicle (SULEV) certification (tailpipe emissions as low as 0.01 g/mile NMOG), as well as near-zero evaporative emissions and a 150,000 mile durability requirement.
[18] Because of differences in the way each program structures its compliance requirements, it is difficult to make a straightforward comparison of the stringency of the LEV II standards compared to the Tier 2 standards. For example California requires manufacturers to comply with a fleet average for non-methane organic gas (NMOG) but not NOx and EPA requires manufacturers to comply with a fleet average for NOx but not hydrocarbons. In spite of these differences it is possible to assess relative program benefits using certain assumptions which, according to this analysis, suggest that LEV II provides additional emissions benefits over Tier 2.

Additional context for each of these issues is provided below. First, however, it is worth noting a final, important difference between the California and federal programs. That is, that California has historically revised its standards more frequently than the federal government. The result has often been more stringent standards in California for a period of some years before the federal standards "catch up." True to form, California air regulators are already beginning to discuss the possible parameters of "LEV III" successor standards to the LEV II requirements, while EPA has no plans at present for another round of federal standards. In short, states that adopt LEV II are likely to benefit from the additional reduction benefits associated with a tightening of California's requirements in coming years, whereas states in the federal program are unlikely to see further reductions from any changes to the Tier 2 standards for at least another decade or possibly longer.

A. Air Toxics

Although airborne toxins have not been the focus of most past regulatory efforts related to motor vehicle emissions, these pollutants represent an important health concern in the Northeast states and, according to our analysis, account for perhaps the most significant air quality and public health benefits of the California LEV II program compared to the federal Tier 2 program. In general, mobile sources (including both highway and nonroad engines) have been estimated to account for 75-90 percent of the total emissions inventory for four important air toxins (benzene, formaldehyde, 1,3-butadiene and acetaldehyde) in the Northeast.[19] Of these compounds, benzene has been classified by EPA as a "known" human carcinogen,[20] while formaldehyde and 1,3-butadiene are classified as "probable" carcinogens.

Recent studies indicate that current levels of these toxins in ambient air are a concern in many areas of the Northeast. For example, data from EPA's National Air Toxics Assessment (NATA) indicate that of the ten U.S. counties where modeling predicted the greatest added cancer risk from air toxics, 8 were in the Northeast.[21] This finding is buttressed by current state monitoring data that show ambient levels of air toxics exceeding state health benchmarks in every county of the Northeast.

Toxic air pollution should decline in the future as a result of several new federal mobile source emissions control programs, including not only the Tier 2 program, but EPA's recently issued highway diesel rule and new federal standards for nonroad gasoline engines, among other regulations.[22] Nevertheless, toxics are likely to remain a

[19] http://www.epa.gov/ttn/atw/nata/

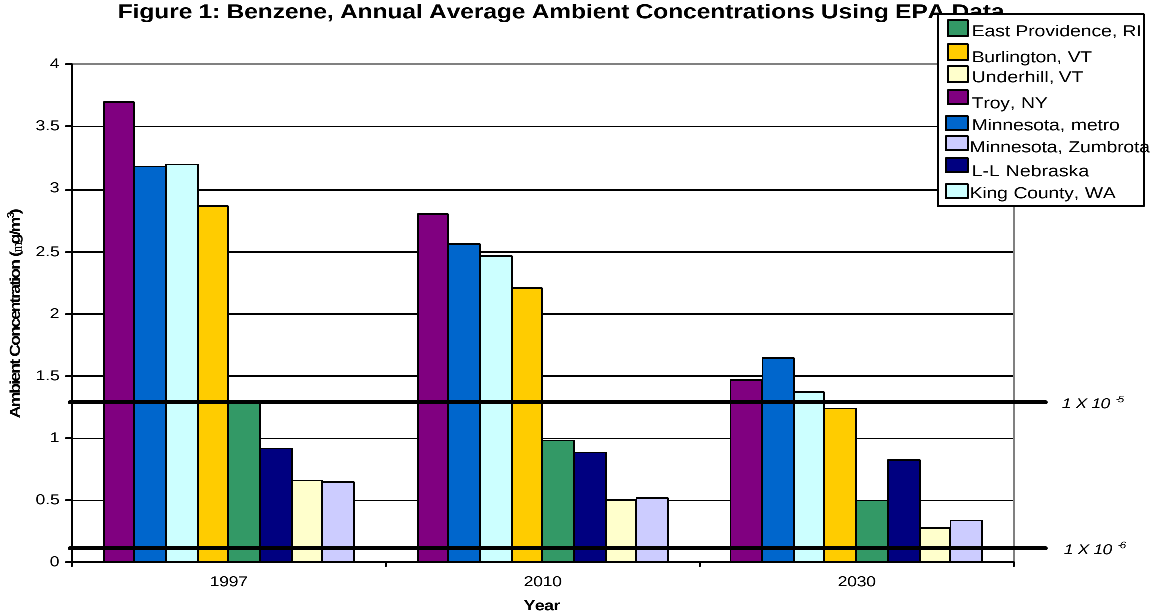
[20] Carcinogens are agents that cause cancer. EPA's classification of formaldehyde and 1,3 butadiene as "probable" carcinogens is based on epidemiological data and animal studies.

[21] In fact, the NATA study found that ambient levels of air toxics are likely to exceed the commonly used 1-in-100,000 added cancer risk threshold in all major American cities.

[22] "Control of Emissions of Air Pollution From Nonroad Diesel Engines and Fuel; Proposed Rule" May 23, 2003, 68 FR 28328, "Control of Emissions of Air Pollution from 2004 and Later Model Year Heavy-Duty Highway Engines and Vehicles; Revision of Light-Duty On-Board Diagnostics Requirements," October 6, 2000, 65 FR 59896, "Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur

significant concern for the foreseeable future. A recent NESCAUM analysis, for example, concluded that even taking into account new regulatory programs, ambient air toxics levels are likely to remain above the 1-in-100,000 cancer risk threshold in most U.S. urban areas and above the 1-in-1,000,000 risk threshold in all parts of the Northeast (rural and urban) through 2030. These results, in terms of predicted future benzene levels at sites in the Northeast and elsewhere, are graphically illustrated in Figure 1.

Figure 1: Benzene, Annual Average Ambient Concentrations Using EPA Data



In sum, given current and predicted levels of ambient air toxics – and given that light-duty vehicles represent an important part of the overall toxics inventory – the additional 25 percent reduction achieved by the California LEV program with respect to these pollutants is significant and is probably among the more compelling arguments for adopting LEV II in lieu of the federal Tier 2 program.

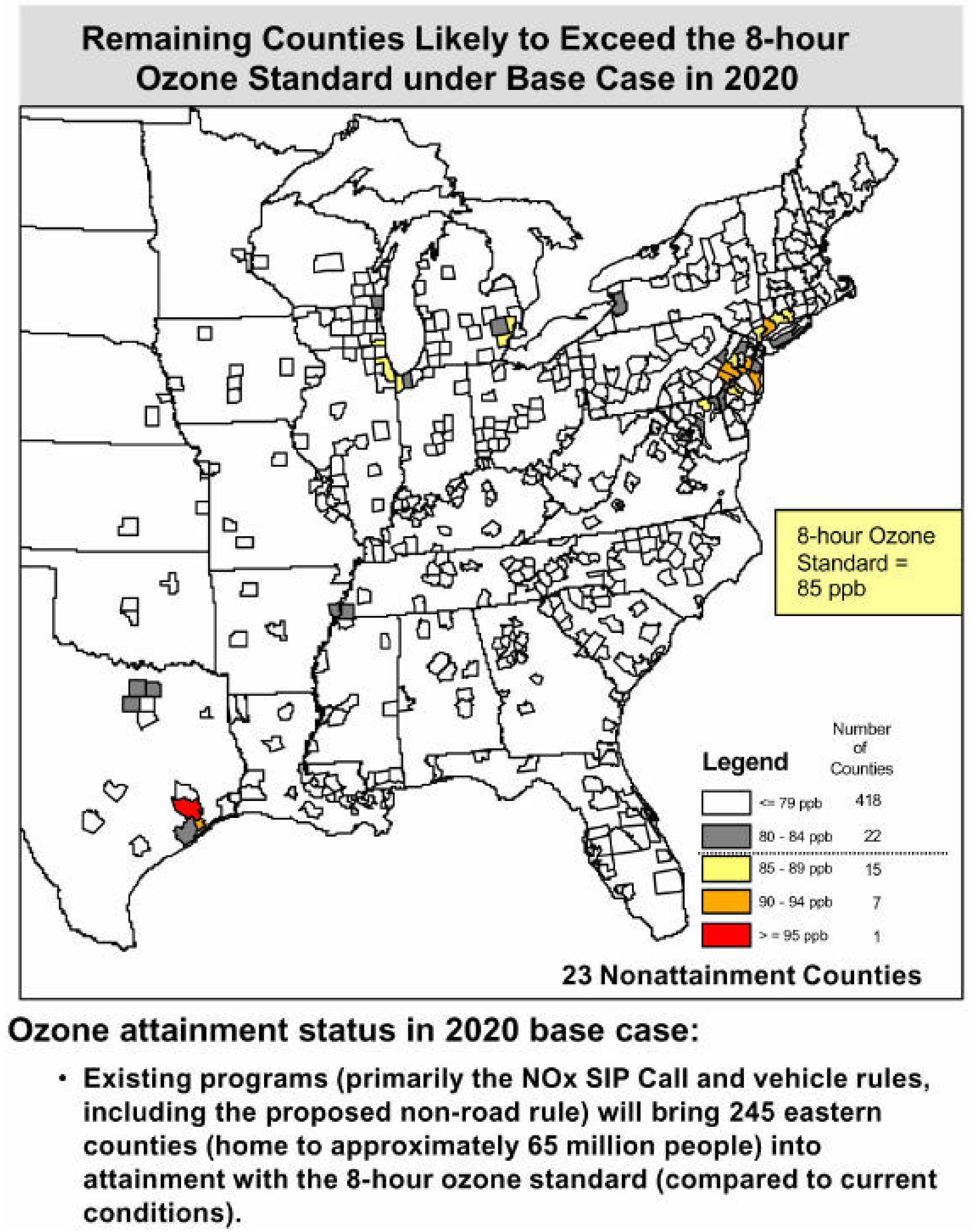
B. Ozone and Fine Particle Pollution

Attainment of health-based National Ambient Air Quality Standards (NAAQS) for ozone and fine particle pollution is likely to present significant policy challenges for Northeast states in the next decade and beyond. With the exception of Vermont, all of the states in the region have areas that violate the NAAQS for ozone. In addition, non-attainment problems are likely to become more widespread and difficult to rectify under

Control Requirements" January 18, 2001, 66 FR 5135, "Control of Emissions From Nonroad Large Spark-Ignition Engines, and Recreational Engines (Marine and Land-Based)" November 8, 2002, 67 FR 68241, "Phase 2 Emission Standards for New Nonroad Spark-Ignition Handheld Engines at or Below 19 Kilowatts and Minor Amendments to Emission Requirements Applicable to Small Spark-Ignition Engines and Marine Spark Ignition Engines," April 25, 2000, 65 FR 24268, "Control of Emissions From New Marine Compression-Ignition Engines at or Above 30 Liters Per Cylinder," February 28, 2003, 68 FR 9745, "Emissions Standards for Locomotives and Locomotive Engines; Final Rule," April 16, 1998, 63 FR 18978.

the new and more stringent ozone and fine particle NAAQS introduced by EPA in 1997. Figure 2 shows predicted non-attainment areas in the Northeast in 2020, taking into account all existing and currently anticipated regulatory programs. The map shows that non-attainment of the new 8-hour ozone standard is likely to remain widespread throughout the region. At the same time, non-attainment of the new fine particle ($PM_{2.5}$) standard is expected to be common in many urban areas.

Figure 2: 8-Hour Ozone nonattainment areas in 2020



Source: EPA

Both ozone and fine particle pollution are associated with serious health impacts. In the case of ozone, documented health risks include decreased lung function and increased respiratory problems, and – with repeated exposure – long-term and potentially irreversible lung damage. Meanwhile, large-scale epidemiological studies of the health risks associated with fine particle pollution have produced convincing evidence for a host of adverse effects, including premature mortality, aggravation of respiratory and cardiovascular disease and increased incidence of asthma attacks, chronic bronchitis and hospital visits. The substantial contribution of motor vehicles to ozone pollution is well established. Automobiles and other mobile sources emit hydrocarbons and nitrogen oxides (NOx), the two primary precursor pollutants that – when mixed in the atmosphere in the presence of sunlight – combine to form ozone. In fact, light-duty vehicles account for approximately one-third of all ozone precursor (NOx and HC) emissions in the Northeast. In the case of fine particles – which have emerged as a focus of air quality regulation and public health concern only in the last decade or so – the relative contribution of different source categories to ambient concentrations is less well understood. However, it is clear that organic aerosols constitute a significant fraction of overall fine particle mass in many urban locales. Together with other sources of organic compounds – notably highway and nonroad diesel-powered engines – light duty vehicles are therefore likely to play at least some role in the formation of fine particle pollution in most urban areas.

In this context, any additional hydrocarbon reductions[23] achieved through the California LEV program will help states address the formidable challenge of attaining (and maintaining) new ozone and fine particle ambient air quality standards despite continued growth in vehicle miles traveled and other pollution-generating activities. More importantly, resulting air quality improvements will translate to potentially significant public health benefits, especially for the millions of citizens who live in urban areas of the Northeast that frequently experience unhealthy concentrations of ozone and fine particle pollution.

C. Climate Benefits

In the Northeast, emissions from gasoline-powered vehicles account for approximately 30 percent of total GHG emissions, compared to a national average of approximately 22 percent. The transportation sector not only accounts for a large share of overall GHG emissions in the region, its contribution has increased more rapidly than that of other sectors in recent decades. That trend – spurred by ever-increasing vehicle miles traveled and flat or declining fleet fuel economy – looks set to continue, with the transportation sector projected to account for most of the growth in overall GHG emissions in the Northeast in coming years as well. At the same time, states face particular challenges in addressing emissions from this sector, given the difficulty of reducing transportation demand and the fact that federal pre-emption precludes direct state regulation of automobile fuel economy. In light of existing state and regional commitments to address climate concerns, the modest greenhouse gas emissions reductions associated with the advanced technology component of the California program therefore represent another benefit of LEV II compared to the federal program. These

[23] Note that while both LEV II and Tier 2 will achieve very substantial reductions in NOx emissions relative to current vehicles, there is only a minimal difference in stringency between the two programs with respect to this pollutant. Given that the difference in NOx requirements is so small, we did not seek to evaluate the NOx benefits of LEV II relative to Tier 2.

benefits could become more significant over time if advanced technology vehicle requirements lead to the mass commercialization of next-generation vehicle technologies that can achieve substantially reduced GHG as well as criteria pollutant emissions.

A brief summary of other state efforts related to climate change – in the Northeast and elsewhere – follows:

- In 2001, the Conference of New England Governors and Eastern Canadian Premiers (NEGC/ECP) adopted a climate action plan with specific regional GHG reduction targets. Specifically, the NEGC/ECP plan calls for returning regional emissions to 1990 levels by 2010 with further reductions (to 10% below 1990 levels by 2020 and to sustainable levels – i.e. 75-85% -- in the longer term) to follow.

- New Jersey adopted a target to reduce greenhouse gases 3.5 percent below 1990 levels by the year 2005 and 7 percent below 1990 levels by 2010.

- New York recently announced an energy plan with a goal of reducing GHG emissions 5 percent below 1990 levels by 2010 and 10 percent below 1990 levels by 2020. As part of the plan, renewable energy use will increase from the current level of 10 percent to 15 percent by 2020.

- Other states have proposed or adopted specific greenhouse gas reduction targets for other sectors, notably for the power sector. For example, Oregon, Massachusetts and New Hampshire have established specific GHG requirements for power plants; and Washington State is expected to follow suit in the near future. In addition, New York governor George Pataki has proposed a regional carbon cap for power plants from Maryland to Maine.

- Under legislation passed in 2002, the California Air Resources Board is required to adopt "regulations that achieve the maximum feasible reduction of GHG emissions" from passenger vehicles by January 2005. The regulations would affect new cars starting in model year 2009 and thereafter.

D. Conclusions

The LEV II program provides significant toxic and CO_2 emission reductions over the Tier 2 program. Unlike the federal program which will remain the same for at least a decade (as is required by the Clean Air Act) the California program will probably continue to become more stringent. Thus emissions differences between the California and federal programs will likely become greater as California adopts more stringent phases of the LEV program. In particular, risks associated with exposure to toxics such as benzene, formaldehyde, and 1,3-butadiene will be significantly reduced by adoption of the California LEV II program.

V. Overview of the LEV II and Tier 2 Programs

This section provides additional information on the differences between the Tier 2 and the LEV II programs. Both programs require manufacturers to certify passenger cars to individual vehicle tailpipe emissions and evaporative standards. In addition, automobile manufacturers must meet a fleet-wide emissions average in each year. Manufacturers are given the flexibility to produce vehicles meeting any set of standards so long as their sale-weighted average complies with declining emissions average requirements.

A. LEV II Program Summary

California's program establishes a declining fleet average for non-methane organic gas (NMOG) emissions. The fleet average NMOG requirement is reduced each year until 2010 when the requirement for passenger cars will be .035 grams per mile and .043 for heavier trucks. California has established four categories or "bins" of emissions standards that automobile manufacturers can certify vehicles to. These are LEV, ULEV, SULEV and ZEV. Standards corresponding to each bin are summarized in Table 2.

Table 2. LEV II Exhaust Mass Emission Standards for New 2004 and Subsequent Model Year Passenger Cars

Vehicle Type	**Durability Vehicle (miles)**	**Vehicle Emission Category**	**NMOG (g/mi)**	**Carbon Monoxide (g/mi)**	**Oxides of Nitrogen (g/mi)**
All passenger cars and light duty trucks 8,500 lbs. GVW or less	50,000	LEV	0.075	3.4	0.05
		LEV, option 1	0.075	3.4	0.07
		ULEV	0.040	3.4	0.05
	120,000	LEV	0.090	1.7	0.07
		LEV option 1	0.090	4.2	0.10
		ULEV	0.055	2.1	0.07
		SULEV	0.010	1.0	0.02
	150,000 (optional)	LEV	0.090	4.2	0.07
		LEV option 1	0.090	4.2	0.10
		ULEV	0.055	2.1	0.07
		SULEV	0.010	1.0	0.02

In addition to the emission standards outlined above, the California LEV program requires that, beginning in 2005, 10 percent of cars sold by large volume manufacturers must be "advanced technology vehicles." Advanced technology vehicles include vehicles with zero tailpipe and evaporative emissions (ZEVs), vehicles that have some electric drivetrain components (advanced technology partial ZEVs or AT PZEVs), and conventional gasoline vehicles that meet certain emissions, durability, and warranty requirements (called partial ZEVs or PZEVs).[24] Recent changes to the ZEV mandate greatly reduce the number of pure ZEVs required to meet the mandate.

The current ZEV program allows manufacturers to follow one of two compliance paths. The conventional path maintains the 2 percent ZEV, 2 percent AT PZEV and 6 percent PZEV requirement that was established in 2001. Manufacturers can use banked credits to satisfy the ZEV requirement. The second or "alternative compliance" path allows manufacturers to meet the entire 10 percent ZEV mandate with AT PZEVs (such as hybrid electric vehicles) and PZEVs. Manufacturers who choose the alternative compliance path must produce a small number of fuel cell or battery electric vehicles.[25]

B. Tier 2 Program Summary

Like California's LEV II program, the federal Tier 2 program requires manufacturers to certify individual vehicles to tailpipe and evaporative emissions standards and to meet a sales-weighted fleet-wide emissions average. However, the Tier 2 program differs from LEV II in that it requires manufacturers to meet a fleet wide average for NOx rather than NMOG. Emissions standards for individual vehicles are listed below in Table 3. The Tier 2 fleet-wide average NOx standard is .07 grams per mile. This corresponds to a bin 5 vehicle, although manufacturers can certify vehicles in any bin as long as they meet the fleet wide average.

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[24] All vehicles that qualify for ZEV credit must meet the SULEV tailpipe emissions standards at 150,000 miles, satisfy second-generation on-board diagnostics requirements (OBD II), have zero evaporative emissions and carry an emission warranty covering all malfunctions identified by the OBD II system for 15 years or 150,000 miles.

[25] The requirement is for all manufacturers combined to produce 250 ZEV vehicles (a combination of fuel cell and/or battery electric vehicles) between 2005 and 2008. The number of ZEV vehicles required increases in 2009 - this number has not been determined.

Table 3. Tier 2 Full Useful Life Exhaust Mass Emission Standards

Bin #	NOx	NMOG	CO	HCHO
11*	.9	.280	7.3	0.032
10*	.6	0.156/0.230	4.2/6.4	0.018/0.027
9*	.3	0.90/0.180	4.2	0.018
8	0.20	0.125/0.156	4.2	0.018
7	0.15	0.090	4.2	0.018
6	0.10	0.090	4.2	0.018
5 (LEV)	0.07	0.090	4.2	0.018
4	0.04	0.070	2.1	0.011
3	0.03	0.055	2.1	0.011
2 (SULEV)	0.02	0.010	2.1	0.004
1 (ZEV)	0.00	0.000	0.0	0.000

C. Evaporative Standards Under the LEV II and Tier 2 Programs

Table 4 details the 2-day and 3-day evaporative emissions standards required under the federal and California programs.

Table 4. Evaporative Emissions Standards for LEV II and Tier 2

Vehicle Class	2-day/3-day diurnal + hot soak test standard in grams/test	
	California	**Federal**
Passenger cars	.65/.5	1.2/.95
Light duty trucks <6,000 lbs GVW	.85/.65	1.2/.95
Light duty trucks 6,000-8,500 lbs GVW	1.15/.9	1.5/1.2
Medium duty vehicles under 10,000 lbs. GVW	1.25/1.0	1.75/1.4

Table 4 shows that the LEV II program evaporative standards are more stringent than the Tier 2 evaporative standards. In addition to the above evaporative standards, ZEV, AT PZEVs and PZEVs must meet a zero evaporative emission standard. The California Air Resources Board estimates that by 2010 over 37 percent of the vehicles sold in LEV states will be subject to the zero evaporative emissions standard.

* Bin 11 is only for medium duty passenger vehicles and will be deleted at the end of 2008. Bin 10 and higher NMOG, CO and HCHO values apply for certain vehicles and will be deleted at the end of 2006 or 2008 (depending on the vehicle type). Bin 9 and higher NMOG standards apply only to certain vehicles will be deleted at the end of 2006 or 2008 (depending on the vehicle).

VI. Methodology and Assumptions Used to Calculate Emissions Reduction Benefits for the LEV II and Tier 2 Programs

This section describes the methodology used to estimate emissions reductions achieved by the adoption of the LEV II program in New York, Massachusetts, and Vermont relative to emissions under the Tier 2 program. As indicated previously, modeling analyses were performed to predict future HC, toxics and CO_2 emissions from the motor vehicle fleet in New York, Massachusetts and Vermont under both the LEV II program and the federal Tier 2 program. Light duty vehicles weighing less than 6,500 lbs were included in the analysis. Heavier vehicles in light duty truck categories 3 and 4 were not included in the analysis since these vehicles are not affected by the ZEV mandate. Assumptions about the emissions performance of light-duty vehicles under the federal base case and the California LEV II program were input to MOBILE6, EPA's most recent mobile source emission factor model, to estimate how motor vehicle fleet emission rates might differ under the two programs. Assumptions concerning the CO_2 emissions characteristics of different vehicles were taken from the Argonne National Laboratory's GREET model.[26] These emissions assumptions were then combined with estimates of future light-duty vehicle travel in the three states to predict future emission levels for two projection years (2010 and 2020).

Key assumptions are discussed for: (1) overall program structure and vehicle sales mix; (2) approach to estimating toxics emissions; and (3) approach to estimating CO_2 and other greenhouse gas (GHG) emissions.

A. Program Structure and Sales Mix

Under the California LEV II program, the ZEV requirement begins in 2005 (at the time this analysis was done, the ZEV component was to begin in 2003), with the requirement that the new vehicle fleet include a minimum of 10 percent ZEVs or equivalent as obtained through ZEV credits. The ZEV credit requirement increases from 10 to 16 percent between model years 2009 and 2018, and remains at 16 percent thereafter. In any given year, a maximum of 6 percent of the ZEV credit may be obtained through PZEVs; at least half of the remaining credit (2 percent in 2008 and 5 percent in 2018) must be obtained through ZEVs. The rest can be obtained with AT PZEVs.
In this analysis, the Northeast ZEV requirement was assumed to begin in 2004. Under the Northeast ZEV program, manufacturers have the option of meeting a phase-in schedule known as the Alternative Compliance Plan (ACP).[27] Under the ACP, a smaller number of ZEVs are required in the early years and additional credit multipliers are

[26] The GREET model (Greenhouse Gases, Regulated Emissions, and Energy use in Transportation) was developed by Argonne National Laboratory. It allows researchers to estimate emissions of CO2 equivalent GHGs, consumption of total energy, and emissions of five criteria pollutants. The model allows researchers to evaluate various engine and fuel combinations on a consistent fuel-cycle basis.
[27] "Structure for the ZEV Alternative Compliance Plan," December 26th, 2001.

provided for early implementation (years 2002 through 2006). The ZEV requirement will be synchronized with the California requirement beginning in model year 2007.

Because manufacturers can use different strategies to comply with the ZEV mandate, NESCAUM analyzed several different compliance scenarios for this component of the LEV II program. Table 5 describes the five scenarios analyzed, showing the percentage of ZEV *credits* obtained by vehicle type in 2007 and 2008 (not the actual percentage of vehicles produced) for the LEV II scenarios. The scenarios are described as follows:

- Scenario 1 – Transition from current LEV I to Federal Tier 2 implementation in 2004 through 2006, consistent with the national Tier 2 phase-in schedule.

- Scenario 2 – LEV II implementation with automakers meeting the minimum two percent ZEV credit and two percent AT PZEV requirement.

- Scenario 3 – LEV II implementation with automakers meeting the minimum two percent ZEV credit, and meeting half the remaining credits with AT PZEVs and half with PZEVs.

- Scenario 4 – LEV II implementation with automakers meeting the full ZEV credit requirement with full-function ZEVs.

- Scenario 5 – LEV II implementation with automakers meeting the full ZEV credit requirement with ZEVs, where half the credits are met with full-function ZEVs (FFEVs) and half are met with smaller "city" electric vehicles (CEVs) that have limited speed and range.

Table 5. Scenarios Analyzed for Tier 2 and LEV II Implementation

		ZEV –FFEV	ZEV - CEV	AT PZEV	PZEV
Scenario	Program	Full-Function Zero-Emission Vehicles	City Electric Vehicles	Advanced Tech. Partial ZEVs	Partial ZEVs
1	Tier 2				
2	LEV II	2%		2%	6%
3	LEV II	2%		4%	4%
4	LEV II	10%			
5	LEV II	5%	5%		

Note that under Scenarios 3, 4 and 5, a hypothetical "ramp-up" schedule is established to smoothly increase the ZEV percentage in 2004 through 2007.

Table 6 shows the ZEV credits assumed for each type of vehicle by model year. These assumptions are consistent with assumptions made by staff of the California Air Resources Board (CARB) in a developing a worksheet of hypothetical sales scenarios, with adjustments for model years 2003 through 2006 to reflect early implementation credits under the Alternative Compliance Plan.[28] Obviously, the breakdown of credits in future years cannot be predicted with certainty, since it will depend on the mix of actual vehicles produced by automakers.

Table 6. Assumed ZEV Credits by Vehicle Type

Model Year	ZEV – FFEV	ZEV - CEV	AT PZEV	PZEV
2003	10.63	4.00	3.72	1.20
2004	10.63	4.00	1.86	0.60
2005	7.04	2.89	1.07	0.35
2006	5.59	2.64	0.71	0.23
2007	3.75	1.99	0.62	0.20
2008	3.44	1.38	0.54	0.20
2009	3.34	1.40	0.54	0.20
2010	3.20	1.42	0.54	0.20
2011	3.20	1.42	0.54	0.20
2012 - 2020	2.90	1.40	0.54	0.20

A detailed spreadsheet file showing the assumed mix of light-duty vehicles and trucks under the different scenarios analyzed is included as Appendix A. Note that while our assumptions for the heavier class of light-duty trucks (LDT2) are included in the spreadsheet, these assumptions actually do not vary by scenario since LDT2 vehicles are not directly subject to the ZEV requirement.[29] Assumptions about vehicle mix were designed to meet the LEV program's NMOG targets, thereby providing a fair comparison among scenarios, and do not necessarily represent an actual sales mix scenario that might be implemented by automakers. Note that under Scenarios 2 and 3, however, technology requirements force the NMOG average below the required target for the model year.

Separate mixes were calculated for New York and Massachusetts, since the automobile vs. light truck share of the overall light-duty vehicle sales base is expected to be significantly different in New York.[30] Since the proportion of automobiles in Vermont is forecast to be close to that of Massachusetts and since Vermont has much lower VMT than New York or Massachusetts, the Massachusetts sales mix assumptions were also

[28] As obtained from Paul Hughes, April 2002.

[29] Light-duty vehicles (LDV) include all passenger cars. Class 1 light-duty trucks (LDT1) include trucks up to 3,750 lb. gross vehicle weight rating (GVWR). LDV and LDT1 must meet the same emissions standards and ZEV requirements under the California program. Class 2 light-duty trucks (LDT2) include trucks between 3,750 and 6,000 lb. GVWR. These vehicles must meet less stringent NMOG fleet certification average and evaporative standards, and do not need to generate ZEV credits. However, the California ZEV program now requires that beginning with a phase-in period from 2007 through 2011, LDT2 vehicles must be included in a manufacturer's sales base for calculating the required number of ZEV vehicle credits.

[30] Based on "fleet implementation calculator" information received from the states via NESCAUM in May 2002, the estimated percentage of automobiles (LDV) of all light-duty vehicles (LDV + LDT1 + LDT2) is 69 percent in New York, 60 percent in Massachusetts and 62 percent in Vermont.

used for the Vermont analysis. As a result, because the New York sales base for calculating ATV sales requirements is not expanded as much as the Massachusetts or Vermont sales bases (i.e., the percentage of LDT2 vehicles forecast in New York is smaller), the required percentage of ATV sales within the LDV + LDT1 fleet is correspondingly smaller. For example, Scenario 2 assumes 54 percent PZEV and 11 percent AT PZEV sales in New York in 2020, compared to 68 percent and 12 percent (respectively) in Massachusetts and Vermont.

B. Calculation of Air Toxics Emissions

Emissions of air toxics were estimated based on VOC emissions predicted by the MOBILE6 model. For each scenario, an implementation schedule (94+ LDG IMP and T2 EXH PHASE-IN files) was defined consistent with the sales mix assumptions shown in Appendix A. A corresponding set of 50,000-mile certification standards (T2 CERT file) was also included for the CA LEV implementation schedules.

VOC exhaust and evaporative emissions outputs from the MOBILE6 model were then multiplied by toxics fractions for four air toxics: benzene, formaldehyde, acetaldehyde and 1,3 butadiene. (Of these four, only benzene is released with evaporative emissions.) The toxics fractions used in this study were taken from recent research by the U.S. Department of Energy,[31] which provides updated information compared to the factors reported by EPA using its Complex model.[32] The toxics ratios assumed for purposes of this analysis are shown in Table 7.

As this analysis was being conducted, EPA released a new draft version of MOBILE6 (MOBILE 6.2) that reports toxics emissions. However, EPA reports that the toxics ratios used in this model are still based on the early-1990s research referenced above and have not been updated. Therefore, we felt it appropriate to use the more recent DOE fractions for this analysis.

Table 7. Ratio of Toxic Emissions to Total VOC Emissions

Exhaust				Evaporative
Benzene	1-3 Butadiene	Formaldehyde	Acetaldehyde	Benzene
0.0564	0.0062	0.0125	0.00048	0.0113

1. MOBILE6 Inputs

The MOBILE6 model has only recently been released, and each of the Northeast states is in the process of developing MOBILE6 input files. Where available, state-specific data were used for inputs that would have a potentially significant impact on the

[31] U.S. Department of Energy. Argonne National Laboratory. *Fuel-Cycle Emissions for Conventional and Alternative Fuel Vehicles: An Assesment of Air Toxics,* August 2000.
[32] U.S. EPA. *Final Regulatory Impact Analysis for Reformulated Gasoline,* December 1993.

results, such as inspection and maintenance (I/M) programs. Emission factors were developed separately for four regions:

- Massachusetts
- New York "downstate" (primarily the New York City metropolitan area)[33]
- New York "upstate" (rest of New York State)
- Vermont

State-specific inputs were used for fuel and temperature parameters. State-specific I/M program inputs were also used for Massachusetts. Since MOBILE6 I/M files were not yet available from New York State, Massachusetts I/M program inputs — which represent a centralized I/M program — were used for downstate New York. Upstate New York and Vermont do not have I/M programs, and therefore no I/M program inputs were used in these cases.

With the exception of these inputs, national defaults embedded in MOBILE6 were used for other model parameters. The use of defaults rather than state-specific assumptions in these instances is unlikely to create a significant difference in the relative benefits calculated for the LEV II vs. Tier 2 programs.

2. Effect of Extended Durability Requirements

The California ZEV program requires that all vehicles obtaining ZEV credits, including PZEVs and AT PZEVs, be certified to 150,000-mile durability standards instead of 120,000-mile standards as required for Tier 2 and other LEV II vehicles. Since PZEVs are expected to make up a significant percentage of the vehicle fleet, this requirement is likely to lead to additional reductions in VOC and toxics emissions beyond those estimated in the current analysis. The benefits of the 150,000-mile standard were not estimated in this study for two reasons. First, solid information to quantify these benefits was not readily available. CARB has developed a methodology for estimating increases in emissions over vehicle life ("deterioration rates") as embedded in its EMFAC2000 model, but the methodology is not directly transferable to the calculation of emissions in the MOBILE6 model. Second, the effects of the durability standard are likely to be related to the specific I/M programs in place and to the effectiveness of I/M and on-board diagnostics (OBD) in identifying and repairing high-emitting vehicles. The status of I/M program varies in the Northeast; Massachusetts and downstate New York have enhanced I/M programs, while upstate New York and Vermont currently have no I/M program. Therefore, the benefits of the enhanced durability standard may vary across the region.

3. Evaporative Emissions

The Tier 2 program phases in more stringent evaporative emissions standards that reduce diurnal + resting loss evaporative emissions by roughly 50 percent compared to

[33] The downstate counties include New York, Kings, Queens, Bronx, Richmond, Nassau, Suffolk, Westchester, Rockland, and Putnam.

Tier 1 and LEV I vehicles. The California LEV II program includes even more stringent evaporative emissions standards that are about 75 percent lower than the certification standard for Tier 1 and LEV I vehicles. In addition, all vehicles that achieve ZEV credits (ZEVs, PZEVs and AT PZEVs) must be certified to "near-zero" evaporative emissions standards. These standards are shown in Table 8a. The LEV II program also has a slightly more advanced phase-in schedule for its evaporative standards than the Tier 2 program (also shown in Table 8b).

Table 8a. Evaporative Emissions Standards

Three-Day Diurnal + Hot Soak Emissions, g/test

Vehicle Class	Tier 1/LEV I	Tier 2	LEV II	LEV II PZEV/ZEV
LDV	2.00	0.95	0.50	0.35
LDT1, LDT2	2.00	0.95	0.65	0.50

Table 8b. Phase-in Schedule for Enhanced Evaporative Standards

Model Year	Tier 2	LEV II
2003	0%	0%
2004	25%	40%
2005	50%	80%
2006	75%	100%
2007	100%	100%

Because MOBILE6 is not capable of modeling enhanced evaporative emissions standards beyond the Tier 2 requirements, post-processing adjustments of MOBILE6 output were made to account for the LEV II standards. To do this, evaporative emissions outputs for Tier 2 vehicles were obtained by model year. For LEV II and LEV II advanced technology vehicles, evaporative emissions were then reduced in proportion to the ratio of LEV II to Tier 2 certification standards. These ratios are shown in Table 8c. The proportions in model years 2004 through 2006 reflect the different phase-in schedules for the two programs as well as the different certification standards being introduced.

Table 8c. Ratio of Evaporative Emissions for LEV II vs. Tier 2 Vehicles

	LEV II		LEV II zero-fuel evap. (PZEV, AT PZEV)	
Model Year	**LDV**	**LDT1 & 2**	**LDV**	**LDT1 & 2**
2003	1.00	1.00	1.00	1.00
2004	0.81	0.84	0.77	0.81
2005	0.54	0.62	0.46	0.54
2006	0.41	0.54	0.29	0.41
2007 - 2020	0.53	0.68	0.37	0.53

It is possible that the LEV II evaporative standards could lead to actual reductions in emissions that are either larger or smaller than the proportionate reduction in certification standards. One case in which benefits might be smaller is if the proportion of high emitters (e.g., due to component failures) is not reduced in proportion to the change in certification standards. However, it is also likely that the technology introduced to meet the enhanced and near-zero evaporative standards will be less prone to failure than the technologies currently in use. A recent report by CARB staff suggests that the enhanced evaporative standards already introduced under the LEV I program have reduced the incidence of high emitters by about 50 percent. An additional reason why the proportional adjustment method could underestimate benefits is because the "near-zero" vehicles (including all PZEVs and AT PZEVs) must be certified to 150,000-mile durability standards instead of 120,000-mile standards. The greater durability requirement is likely to lead to lower evaporative emissions over the life of the vehicle. Furthermore, the more stringent evaporative emissions standards may help to reduce other sources of evaporative emissions, including resting, running, and crankcase emissions, not covered in the diurnal + hot soak test.

As mentioned previously, the approach used to estimate evaporative emissions in this report differs from that used by EPA in a previous analysis of the emissions benefits of the LEV II program. EPA's analysis assumed that cars sold in all 50 states will meet LEV II evaporative emissions standards. In addition, EPA assumed that no vehicles under the LEV scenario would meet the near-zero evaporative emissions standards required of advanced technology vehicles. In this analysis, by contrast, we assume that advanced technology vehicles will meet near-zero evaporative emissions standards. We also assume that cars in the Tier 2 program cars will be certified to Tier 2 evaporative standards, and not LEV II evaporative standards.

C. Calculation of Vehicle-Miles of Travel

To calculate total emissions emission factors were combined with estimates of vehicle-miles of travel (VMT) for each region analyzed. For New York State, current VMT estimates and 2010 and 2020 forecasts were obtained by county and vehicle type from the Department of Environmental Conservation (NYDEC). Consistent with MOBILE6, VMT estimates were developed separately for upstate and downstate New York. For Massachusetts, forecasts of total VMT were obtained from the state through 2020; these were allocated to different vehicle types based on EPA forecasts which account for the growing percentage of light trucks in the light-duty vehicle fleet.[34] For Vermont, no official forecasts of 2010 or 2020 VMT were available, so total VMT estimates were extrapolated from historical data provided by the state and allocated by vehicle type using the same methodology as for Massachusetts. VMT estimates by state, year and vehicle type are shown in Table 9.

Table 9. VMT Estimates (Daily, in Millions of Miles)

Calendar Year	**LDV**	**LDT1**	**LDT2**
Massachusetts			
2003	68.9	51.7	17.2
2010	60.0	69.2	23.1
2020	57.6	86.2	28.7
Vermont			
2003	10.5	7.9	2.6
2010	8.7	10.1	3.4
2020	7.7	11.5	3.8
New York - Upstate			
2003	112.4	64.2	35.2
2010	129.8	74.3	40.7
2020	151.6	86.8	47.7
New York - Downstate			
2003	90.2	53.0	31.5
2010	103.5	60.7	36.2
2020	120.1	70.4	42.0

D. Calculation of Greenhouse Gas Emissions

The GREET Model Version 1.5a, developed by Argonne National Laboratory and the University of Chicago, was used to calculate CO_2 and other GHG emissions for different vehicle technologies. GREET is a full-fuel-cycle model that accounts for "upstream" emissions in the production and transport of fuel, as well as "downstream" emissions resulting from vehicle operation. GREET was used with its default inputs, with two primary exceptions: first, custom assumptions were developed for the relative efficiencies of various vehicle technologies; and second, an electricity generating mix specific to the Northeast was used. These and other key assumptions used in this modeling process are discussed in more detail below.

[34] The methodology for allocating Massachusetts VMT by vehicle class is the same as used in the 1999 study by Cambridge Systematics for NESCAUM of the benefits of the CA LEV II program.

1. Vehicle Technology Assumptions

PZEV vehicles are assumed to be conventional gasoline engine vehicles with advanced emissions control technology. Approximately ten production vehicles have already been certified to PZEV standards, so it is assumed that other gasoline-engine vehicles will be able to meet this standard as well.

Advanced technology vehicles (AT PZEVs and ZEVs) are assumed to be the following:

- AT PZEVs are assumed to be grid-independent gasoline-electric hybrids, similar to the Honda Insight or Toyota Prius which are being sold today. These vehicles do not yet meet all of the PZEV criteria, but are expected to in the near future.

- ZEVs are assumed to be battery-electric vehicles through 2009, transitioning to hydrogen fuel cell vehicles (H2FC) between 2010 and 2013. Hydrogen fuel is assumed to be produced from natural gas at centralized power plants.

Numerous other vehicle/fuel technologies could have been evaluated. For example, alternative-fuel vehicles running on compressed natural gas (CNG), liquid propane gas (LPG) or methanol could potentially meet the AT PZEV standards. "Grid-connected" hybrid vehicles can obtain additional credits for a zero-emission range (running on batteries) of 20 to 60 miles. Fuel cell vehicles may also be powered by methanol or gasoline via an on-board reformer, although these would not necessarily meet ZEV standards. The technologies evaluated here were selected because they were viewed as the most likely to be commercialized among the technologies capable of meeting California ZEV requirements.

2. Energy Efficiency

CO_2 emissions depend upon both the consumption of energy (upstream and downstream) to power the vehicle and the carbon content of the fuels used in this process. Energy efficiency can be thought of in two separate components:

- The efficiency of energy use by the vehicle, i.e., the distance traveled per unit of energy (British thermal unit or kilowatt-hour) in the fuel that is put into the vehicle.

- The overall efficiency of the fuel production process, including extraction, generation and transmission.

The energy efficiency ratio (EER) of advanced technology vehicles to conventional gasoline vehicles is one of the required inputs of the GREET model. Energy efficiency is measured as the energy content of the fuel used in operating the vehicle per unit distance traveled. It can be thought of as a miles-per-gallon (MPG) equivalent. The EER does not reflect upstream energy consumption, which is estimated separately in the GREET model.

EERs for ATVs are somewhat uncertain given the emerging nature of the technologies being developed. To identify appropriate EERs for this analysis, a literature review was undertaken. Experts were contacted and reports reviewed from organizations involved in advanced vehicle technology research, including the Office of Transportation Technologies at the Department of Energy, the Center for Transportation Research at Argonne National Laboratory, the California Air Resources Board and the Institute of Transportation Studies at the University of California at Davis.

The following EERs were selected for this analysis:

- **Hybrid-electric vehicles (AT PZEVs):** 1.4:1. This is approximately the ratio of fuel economy on the EPA combined cycle for the 2003 Honda Civic hybrid compared to the automatic-transmission gasoline Civic, and for the Toyota Prius compared to the automatic-transmission Toyota Corolla.[35] Hypothetical evaluations of a compact, midsize and SUV hybrid by Argonne National Laboratory also show an EER of about 1.4.[36] The anticipated Ford Escape hybrid, a small sport-utility vehicle, is rumored to obtain 35 MPG, which gives it an EER of 1.6 compared to the V6 Escape.

- **Battery-electric vehicles (ZEVs)**: 2.65:1. This is the midpoint of a range of values (2.4 to 2.9) estimated by Arthur D. Little in a report to the California Air Resources Board on projections of battery-electric EERs for both the short term and the long term.[37] Other comparisons of actual battery-electric vehicles with similarly-sized gasoline vehicles typically show EERs in the range of 2 to 4, so 2.65 is viewed as a reasonably conservative estimate.[38]

- **Hydrogen fuel cell vehicles (ZEVs)**: 2.6:1. EERs for fuel-cell vehicles are somewhat more speculative since production-ready vehicles do not yet exist and fuel cell systems are still undergoing rapid development. However, the Department of Energy (DOE) has evaluated the efficiency of hydrogen fuel-cell systems.[39] Current and projected efficiency for such a system is estimated to

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[35] U.S. Department of Energy and U.S. Environmental Protection Agency. “Model Year 2002 Fuel Economy Guide.” DOE/EE-0250. Internet: www.fueleconomy.gov
[36] Argonne National Laboratory and Electric Power Research Institute. "EPRI Hybrid Electric Vehicle Working Group: HEV Costs and Emissions." Downloaded May 3, 2002. from: www.transportation.anl.gov/ttrdc
[37] Unnasch, Stefan, and Louis Browning. "Refinement of Selected Fuel-Cycle Emissions Analyses." Prepared for CARB by Arther D. Little, February 2000.
[38] c.f. Singh, Margaret. "Total Energy Cycle Use and Emissions of Electric Vehicles." Prepared for Transportation Research Board Annual Meeting, January 1999; EPA Green Vehicle Guide, www.epa.gov/autoemissions/about.htm, April 2002; U.S. Department of Energy. "Fleet Testing - (Task 4) Final Report." Prepared by Electric Transportation Applications, July 2001.
[39] U.S. Department of Transportation. “Fuel Cells for Transportation: FY 2001 Progress Report.” www.cartech.doe.gov/research/fuelcells/

range from 55 to 60 percent of the energy content of the fuel, as compared to 20 to 25 percent for a gasoline engine (running at 25 percent power output). This suggests an EER of about 2.6.

As a baseline to compare energy use, conventional gasoline vehicle fuel economy was assumed to remain constant over the period of the analysis. Average fuel economy by vehicle class has remained roughly constant over the past decade, and in the absence of policy initiatives to raise fuel efficiency standards or a sustained, long-term increase in the price of oil, this trend is expected to continue. Average fuel consumption rates by vehicle class included in the GREET model, as derived from DOE estimates, are 22.4 MPG for LDVs and 16.8 MPG for LDT1 and LDT2 (up to 6,000 lb. GVWR).

3. Emissions from Powerplants

The GREET model was also used to estimate CO_2 emissions from electricity-generating powerplants. A mix of fuel types specific to New England was used in place of the GREET model defaults, based on recent data from the Energy Information Administration (EIA).[40] This mix is shown in Table 10. "Other" fossil fuels, including municipal solid waste, tires and other fuels, make up 4.5 percent of this mix; for the purposes of the GREET model, these fuels were included in the same category as residual oil. Other key assumptions include the percentage of natural gas and coal electricity generation from combined cycle (CC) plants, which are considerably more efficient than other plants. In this analysis, 45 percent of natural gas and 20 percent of coal generating capacity, the default values contained in GREET, is assumed to be from combined cycle plants. In this analysis, no distinction is made between "marginal" and "average" emissions rates.

Table 10. Mix of Fuels for Electricity Generation

Fuel Type	Percent
Residual Oil and "Other" Fossil Fuel	27.5%
Natural Gas	18.0%
Coal	16.3%
Non-Fossil	38.2%
Total	100.0%

The electricity generation mix for the Mid-Atlantic region, which includes New York state, is significantly different (including more coal and non-fossil fuels and less residual oil) than that of New England, but produces nearly identical CO_2 emissions

[40] U.S. Department of Energy and U.S. Environmental Protection Agency. "Carbon Dioxide Emissions from the Generation of Electric Power in the United States," July 2000. www.eia.doe.gov

according to the EIA. Hence, for simplicity, the New England mix was used throughout this analysis.

The future electricity generating mix may be affected by a number of factors, including prices of different fuels, regulatory conditions, market demand and technological developments, which are difficult to forecast. In the absence of reliable forecasts, the mix is assumed to remain the same in future years for purposes of this analysis. This assumption may overestimate GHG emissions from electric vehicles in future years, since GHG emissions from New England powerplants have been declining slightly given trends toward greater reliance on natural gas (which has a lower carbon content) and renewable resources as well as more efficient technology. In addition, several Northeast states have adopted policies or regulations aimed at reducing future power sector GHG emissions.

4. City Electric Vehicles

Two different scenarios of electric vehicle sales were evaluated, one including all full-function EVs (FFEVs) and one including primarily "city" EVs. CEVs typically are two-passenger vehicles with a maximum range of 55 to 70 mph and a range of 50 to 80 miles.[41] CEVs might produce different emissions impacts than FFEVs for a number of reasons:

- CEVs may be driven a shorter average distance than a typical vehicle, since it is likely to be used primarily for urban trips, which are shorter on average than other trips, and because its range and speed is limited.

- CEVs are smaller than the average vehicle, and therefore replace compact conventional vehicles at the more fuel-efficient end of the vehicle fleet. The resulting GHG emissions benefit per vehicle would be less than the benefit for an average-sized FFEV with the same energy efficiency ratio.

- CEVs are likely to operate primarily on urban driving cycles, where electric vehicles have a greater relative efficiency advantage over conventional gasoline vehicles. In contrast to the previous two points, this effect would tend to magnify the CO_2 reductions achieved by CEVs relative to FFEVs.

To account for the lesser range of CEVs, an adjustment was made. To estimate VMT under urban conditions, data from the 1995 Nationwide Personal Transportation Survey (NPTS) were used. Specifically, an analysis of the NPTS data showed that average VMT per capita in urban locations (defined based on a set of population density measures) was 62.5 percent of average VMT per capita in all locations (5,359 vs. 8,523

[41] California Air Resources Board. "Staff Report: 2000 Zero Emission Vehicle Program Biennial Review." August 2000, p. 54.

miles per year).[42] VMT totals were therefore allocated between CEVs and other LDVs to maintain this same proportion of VMT per vehicle.

In the current analysis, adjustments were not made for vehicle size class efficiency or for urban driving cycles. A review of class-average fuel economy shows that CAFE combined-cycle MPG for compact cars is around 30, not significantly different from the LDV class average of 28.5. Also, the effects of vehicle size and driving cycle are likely to somewhat offset each other.

5. GHG Emission Rates

The results of the GREET model for energy consumption, CO_2 emissions, and total GHG emissions for the different technologies evaluated are shown in Tables 11a and 11b. Table 11b shows the GHG emissions factors used by model year for each vehicle class, based on a phase-in transition from battery-electric to fuel cell vehicles between 2010 and 2013.

Table 11a. Energy Consumption and Greenhouse Gas Emissions[43]

	Total					**Percent Change Relative to Conv. Gasoline**		
Total	**Conv. gasoline**	**Hybrid-electric**	**Battery-electric**	**Hydrogen fuel cell**		**Hybrid-electric**	**Battery-electric**	**Hydrogen fuel cell**
LDV								
Total energy (Btu/mi)	6,347	4,534	6,138	3,277		-29%	-3%	-48%
CO_2 (g/mi)	448	320	311	188		-29%	-31%	-58%
GHGs (g/mi CO_2 equiv.)	473	341	322	194		-28%	-32%	-59%
LDT1, LDT2								

[42] Ross, Catherine L., and Anne E. Dunning. "Land Use Transportation Interaction: An Examination of the 1995 NPTS Data." Prepared for U.S. Department of Transportation by the Georgia Institute of Technology, October 1997.
[43] The complete technology packages evaluated using the GREET model are as follows:
1) Conventional gasoline vehicle on Federal stage 2 reformulated gasoline (FRFG2)
2) Grid-independent SIDI HEV on FRFG2
3) Battery electric vehicle
4) Fuel cell vehicle: hydrogen, gaseous, natural gas

Total energy (Btu/mi)	6,347	4,534	6,138	3,277		-29%	-3%	-48%
CO_2 (g/mi)	448	320	311	188		-29%	-31%	-58%
GHGs (g/mi CO_2 equiv.)	473	341	322	194		-28%	-32%	-59%

Table 11b. GHG Emissions Rates Used in Analysis (g/mi CO_2 equivalent)

Model Year	**FFEV Technology**			**LDV**			LDT1, LDT2		
	BEV	**H2FC**		**ZEV**	**AT PZEV**	**All Other**	**ZEV**	**AT PZEV**	**All Other**
<=2003						473			473
2004	100%	0%		322	341	473	322	341	473
2005	100%	0%		322	341	473	322	341	473
2006	100%	0%		322	341	473	322	341	473
2007	100%	0%		322	341	473	322	341	473
2008	100%	0%		322	341	473	322	341	473
2009	100%	0%		322	341	473	322	341	473
2010	80%	20%		296	341	473	296	341	473
2011	60%	40%		271	341	473	271	341	473
2012	40%	60%		245	341	473	245	341	473
2013	20%	80%		220	341	473	220	341	473
2014	0%	100%		194	341	473	194	341	473
2015	0%	100%		194	341	473	194	341	473
2016	0%	100%		194	341	473	194	341	473
2017	0%	100%		194	341	473	194	341	473
2018	0%	100%		194	341	473	194	341	473
2019	0%	100%		194	341	473	194	341	473
2020	0%	100%		194	341	473	194	341	473

Appendix A: Sales Mix Summary
Scenario 1 = LEV I Transition to Tier 2 **All States**

PC + LDT1 (0 - 3,750 LVW)

MY	Tier 1	TLEV I	LEV I	ULEV I	Tier 2 - 7	Tier 2 - 5	Tier 2 - 3	Tier 2 - 1
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.090	0.090	0.055	0.000
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.95	0.00
1994	100%							
1995	85%	15%						
1996	80%	20%						
1997	65%	28%	5%	2%				
1998	36%	40%	18%	6%				
1999	13%	35%	46%	6%				
2000			94%	6%				
2001			85%	15%				
2002			80%	20%				
2003			64%	37%				
2004			30%	45%	1%	21%	3%	
2005			13%	37%	3%	43%	5%	
2006			5%	20%	4%	64%	8%	
2007					5%	85%	10%	
2008					5%	85%	10%	
2009					5%	85%	10%	
2010					5%	85%	10%	
2011					5%	85%	10%	
2012					5%	85%	10%	
2013					5%	85%	10%	
2014					5%	85%	10%	
2015					5%	85%	10%	
2016					5%	85%	10%	
2017					5%	85%	10%	
2018					5%	85%	10%	
2019					5%	85%	10%	
2020					5%	85%	10%	

MY	NMOG Exhaust Fleet Avg
1994	0.250
1995	0.231
1996	0.225
1997	0.202
1998	0.156
1999	0.113
2000	0.073
2001	0.070
2002	0.068
2003	0.062
2004	0.062
2005	0.068
2006	0.077
2007	0.087
2008	0.087
2009	0.087
2010	0.087
2011	0.087
2012	0.087
2013	0.087
2014	0.087
2015	0.087
2016	0.087
2017	0.087
2018	0.087
2019	0.087
2020	0.087

Appendix A: Sales Mix Summary

Scenario 1 = LEV I Transition to Tier 2 **All States**

LDT2 (3,751 - 5,750 LVW)

MY	Tier 1	TLEV I	LEV I	ULEV I	Tier 2 - 7	Tier 2 - 5	Tier 2 - 3	Tier 2 - 1	NMOG Exhaust Fleet Avg
NMOG Exh. Std.	0.320	0.160	0.100	0.050	0.090	0.090	0.055	0.000	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.95	0.00	
1994	100%								0.320
1995	85%	15%							0.296
1996	80%	20%							0.288
1997	65%	28%	7%						0.260
1998	37%	40%	23%						0.205
1999	14%	35%	49%	2%					0.151
2000			98%	2%					0.099
2001			95%	5%					0.098
2002			90%	10%					0.095
2003			85%	15%					0.093
2004			68%	7%	1%	21%	3%		0.093
2005			43%	7%	3%	43%	5%		0.090
2006			15%	10%	4%	64%	8%		0.085
2007					5%	85%	10%		0.087
2008					5%	85%	10%		0.087
2009					5%	85%	10%		0.087
2010					5%	85%	10%		0.087
2011					5%	85%	10%		0.087
2012					5%	85%	10%		0.087
2013					5%	85%	10%		0.087
2014					5%	85%	10%		0.087
2015					5%	85%	10%		0.087
2016					5%	85%	10%		0.087
2017					5%	85%	10%		0.087
2018					5%	85%	10%		0.087
2019					5%	85%	10%		0.087
2020					5%	85%	10%		0.087

Scenario 2 = LEV II with 2% ZEV, 2% ATPZEV, 6% PZEV **Massachusetts and Vermont**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**		
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	**NMOG Exhaust**	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	**Fleet Avg**	**Target**
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			55%	20%	8%		17%				0.057	0.053
2005			35%	15%	23%		27%	1%			0.052	0.049
2006			25%		21%	12%	40%	2%	0.2%		0.043	0.046
2007					37%	15%	44%	3%	0.5%		0.039	0.043
2008					39%	10%	47%	4%	0.6%		0.038	0.040
2009					33%	10%	51%	5%	0.8%		0.034	0.038
2010					30%	10%	54%	5%	0.9%		0.032	0.035
2011					32%	5%	57%	6%	1.0%		0.032	0.035
2012					31%		61%	7%	1.3%		0.030	0.035
2013					31%		61%	7%	1.3%		0.030	0.035
2014					31%		61%	7%	1.3%		0.030	0.035
2015					24%		64%	10%	1.8%		0.026	0.035
2016					24%		64%	10%	1.8%		0.026	0.035
2017					24%		64%	10%	1.8%		0.026	0.035
2018					18%		68%	12%	2.2%		0.021	0.035
2019					18%		68%	12%	2.2%		0.021	0.035
2020					18%		68%	12%	2.2%		0.021	0.035

Scenario 3 = LEV II with 2% ZEV, 4% ATPZEV, 4% PZEV

Massachusetts and Vermont

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**	**NMOG Exhaust**	
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000		
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	**Fleet Avg**	**Target**
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			50%	25%	8%		17%				0.055	0.053
2005			35%	15%	18%	5%	27%	1%			0.050	0.049
2006			25%		23%	10%	40%	2%	0.2%		0.044	0.046
2007					44%	12%	39%	5%	0.5%		0.042	0.043
2008					37%	18%	36%	7%	0.6%		0.040	0.040
2009					38%	12%	40%	9%	0.8%		0.038	0.038
2010					32%	15%	42%	10%	0.9%		0.035	0.035
2011					35%	10%	44%	10%	1.0%		0.035	0.035
2012					39%		48%	12%	1.3%		0.035	0.035
2013					39%		48%	12%	1.3%		0.035	0.035
2014					39%		48%	12%	1.3%		0.035	0.035
2015					32%		51%	14%	1.8%		0.031	0.035
2016					32%		51%	14%	1.8%		0.031	0.035
2017					32%		51%	14%	1.8%		0.031	0.035
2018					26%		55%	17%	2.2%		0.027	0.035
2019					26%		55%	17%	2.2%		0.027	0.035
2020					26%		55%	17%	2.2%		0.027	0.035

Scenario 4 = LEV II with 10% FFEV ZEV **Massachusetts and Vermont**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**		
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	**NMOG Exhaust**	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	**Fleet Avg**	**Target**
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			45%	30%	11%		14%		0%		0.055	0.053
2005			20%	30%	30%		20%		0%		0.051	0.049
2006			5%	20%	31%	15%	28%		0.9%		0.044	0.046
2007					28%	45%	25%		2.0%		0.041	0.043
2008					16%	65%	16%		3.0%		0.040	0.040
2009					13%	65%	18%		3.6%		0.038	0.038
2010					7%	70%	19%		4.0%		0.035	0.035
2011					8%	68%	20%		4.2%		0.035	0.035
2012					11%	62%	22%		5.4%		0.035	0.035
2013					11%	62%	22%		5.4%		0.035	0.035
2014					11%	62%	22%		5.4%		0.035	0.035
2015					14%	54%	26%		6.3%		0.035	0.035
2016					14%	54%	26%		6.3%		0.035	0.035
2017					14%	54%	26%		6.3%		0.035	0.035
2018					19%	45%	29%		7.1%		0.035	0.035
2019					19%	45%	29%		7.1%		0.035	0.035
2020					19%	45%	29%		7.1%		0.035	0.035

Appendix A: Sales Mix Summary

Scenario 5 = LEV II with 5% FFEV, 5% CEV

Massachusetts and Vermont

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**	**NMOG Exhaust**	
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	**Fleet Avg**	**Target**
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35		
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			50%	25%	1%	10%	14%		0%	0%	0.053	0.053
2005			30%	20%	14%	15%	20%		0%	1%	0.049	0.049
2006			15%	10%	27%	18%	28%		0.5%	1.0%	0.046	0.046
2007					30%	42%	25%		1.0%	1.9%	0.042	0.043
2008					19%	60%	16%		1.5%	3.7%	0.040	0.040
2009					16%	60%	18%		1.8%	4.3%	0.038	0.038
2010					10%	65%	19%		2.0%	4.5%	0.035	0.035
2011					10%	64%	20%		2.1%	4.8%	0.035	0.035
2012					14%	56%	22%		2.7%	5.6%	0.035	0.035
2013					14%	56%	22%		2.7%	5.6%	0.035	0.035
2014					14%	56%	22%		2.7%	5.6%	0.035	0.035
2015					19%	46%	26%		3.1%	6.5%	0.035	0.035
2016					19%	46%	26%		3.1%	6.5%	0.035	0.035
2017					19%	46%	26%		3.1%	6.5%	0.035	0.035
2018					24%	36%	29%		3.6%	7.4%	0.035	0.035
2019					24%	36%	29%		3.6%	7.4%	0.035	0.035
2020					24%	36%	29%		3.6%	7.4%	0.035	0.035

Scenario 2 = LEV II with 2% ZEV, 2% ATPZEV, 6% PZEV

New York State

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**		
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	**NMOG Exhaust**	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	**Fleet Avg**	**Target**
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			55%	20%	8%		17%				0.057	0.053
2005			35%	15%	3%	20%	26%	1%			0.045	0.049
2006			25%		22%	18%	32%	2%	0.2%		0.046	0.046
2007					41%	20%	35%	3%	0.5%		0.043	0.043
2008					36%	22%	38%	4%	0.6%		0.040	0.040
2009					31%	22%	41%	5%	0.8%		0.037	0.038
2010					28%	22%	44%	5%	0.9%		0.035	0.035
2011					31%	16%	46%	5%	0.9%		0.035	0.035
2012					34%	8%	50%	7%	1.3%		0.035	0.035
2013					34%	8%	50%	7%	1.3%		0.035	0.035
2014					34%	8%	50%	7%	1.3%		0.035	0.035
2015					37%		52%	9%	1.7%		0.034	0.035
2016					37%		52%	9%	1.7%		0.034	0.035
2017					37%		52%	9%	1.7%		0.034	0.035
2018					33%		54%	11%	2.1%		0.031	0.035
2019					33%		54%	11%	2.1%		0.031	0.035
2020					33%		54%	11%	2.1%		0.031	0.035

Scenario 3 = LEV II with 2% ZEV, 4% ATPZEV, 4% PZEV **New York State**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**	**NMOG Exhaust**	
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000		
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	**Fleet Avg**	**Target**
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			50%	25%	8%		17%				0.055	0.053
2005			35%	15%	8%	15%	26%	1%			0.050	0.049
2006			25%		22%	18%	32%	2%	0.2%		0.044	0.046
2007					39%	25%	31%	4%	0.5%		0.042	0.043
2008					32%	32%	28%	7%	0.6%		0.040	0.040
2009					28%	32%	31%	9%	0.8%		0.038	0.038
2010					22%	35%	33%	9%	0.9%		0.035	0.035
2011					25%	30%	35%	10%	0.9%		0.035	0.035
2012					28%	22%	37%	11%	1.3%		0.035	0.035
2013					28%	22%	37%	11%	1.3%		0.035	0.035
2014					28%	22%	37%	11%	1.3%		0.035	0.035
2015					33%	12%	39%	14%	1.7%		0.031	0.035
2016					33%	12%	39%	14%	1.7%		0.031	0.035
2017					33%	12%	39%	14%	1.7%		0.031	0.035
2018					36%	4%	42%	16%	2.1%		0.027	0.035
2019					36%	4%	42%	16%	2.1%		0.027	0.035
2020					36%	4%	42%	16%	2.1%		0.027	0.035

Scenario 4 = LEV II with 10% FFEV ZEV **New York State**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				**Group 2**		**Group 3**		**Group 4**			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**		
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	**NMOG Exhaust**	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	**Fleet Avg**	**Target**
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			45%	30%	3%	8%	14%		0%		0.053	0.053
2005			20%	30%	22%	8%	19%		0%		0.049	0.049
2006			5%	20%	31%	22%	21%		0.9%		0.046	0.046
2007					26%	55%	17%		2.0%		0.043	0.043
2008					11%	78%	8%		2.9%		0.040	0.040
2009					7%	80%	10%		3.4%		0.038	0.038
2010						86%	11%		3.8%		0.035	0.035
2011						85%	11%		4.0%		0.035	0.035
2012						82%	13%		5.1%		0.034	0.035
2013						82%	13%		5.1%		0.034	0.035
2014						82%	13%		5.1%		0.034	0.035
2015					4%	75%	15%		5.9%		0.035	0.035
2016					4%	75%	15%		5.9%		0.035	0.035
2017					4%	75%	15%		5.9%		0.035	0.035
2018					8%	68%	17%		6.8%		0.035	0.035
2019					8%	68%	17%		6.8%		0.035	0.035
2020					8%	68%	17%		6.8%		0.035	0.035

Scenario 5 = LEV II with 5% FFEV, 5% CEV **New York State**

PC + LDT1 (0 - 3,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**		
NMOG Exh. Std.	0.250	0.125	0.075	0.040	0.075	0.040	0.010	0.010	0.000	0.000	**NMOG Exhaust**	
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.50	0.50	0.35	0.35	**Fleet Avg**	**Target**
1994	100%										0.250	0.250
1995	85%	15%									0.231	0.231
1996	80%	20%									0.225	0.225
1997	65%	28%	5%	2%							0.202	0.202
1998	36%	40%	18%	6%							0.156	0.157
1999	13%	35%	46%	6%							0.113	0.113
2000			94%	6%							0.073	0.073
2001			85%	15%							0.070	0.070
2002			80%	20%							0.068	0.068
2003			63%	37%							0.062	0.062
2004			50%	25%	1%	10%	14%		0%	0%	0.054	0.053
2005			30%	20%	12%	18%	19%		0%	1%	0.049	0.049
2006			15%	10%	22%	30%	21%		0.5%	1.0%	0.046	0.046
2007					25%	55%	17%		1.0%	1.8%	0.043	0.043
2008					12%	75%	8%		1.4%	3.6%	0.040	0.040
2009					9%	75%	10%		1.7%	4.1%	0.038	0.038
2010					3%	80%	11%		1.9%	4.3%	0.035	0.035
2011					2%	80%	11%		2.0%	4.6%	0.035	0.035
2012					4%	75%	13%		2.5%	5.3%	0.035	0.035
2013					4%	75%	13%		2.5%	5.3%	0.035	0.035
2014					4%	75%	13%		2.5%	5.3%	0.035	0.035
2015					8%	68%	15%		3.0%	6.2%	0.035	0.035
2016					8%	68%	15%		3.0%	6.2%	0.035	0.035
2017					8%	68%	15%		3.0%	6.2%	0.035	0.035
2018					13%	60%	17%		3.4%	7.0%	0.035	0.035
2019					13%	60%	17%		3.4%	7.0%	0.035	0.035
2020					13%	60%	17%		3.4%	7.0%	0.035	0.035

Scenarios 2 through 5 (LEV II) **All States**

LDT2 (3,751 - 5,750 LVW)

	Group 1				Group 2		Group 3		Group 4			
Model Year	**Tier 1**	**TLEV I**	**LEV I**	**ULEV I**	**LEV II**	**ULEV II**	**PZEV**	**ATPZEV**	**ZEV - FF**	**ZEV - CEV**	**NMOG Exhaust**	
NMOG Exh. Std.	0.320	0.160	0.100	0.050	0.075	0.040	0.010	0.010	0.000	0.000	**Fleet Avg**	**Target**
Evap. Std.	2.00	2.00	2.00	2.00	0.95	0.95	0.65	0.65	0.50	0.50		
1994	100%										0.320	0.320
1995	85%	15%									0.296	0.295
1996	80%	20%									0.288	0.287
1997	65%	28%	7%								0.260	0.260
1998	37%	40%	23%								0.205	0.205
1999	14%	35%	49%	2%							0.151	0.150
2000			98%	2%							0.099	0.099
2001			95%	5%							0.098	0.098
2002			90%	10%							0.095	0.095
2003			85%	15%							0.093	0.093
2004			55%	20%	25%						0.084	0.085
2005			25%	25%	50%						0.075	0.076
2006			10%	15%	45%	30%					0.063	0.062
2007					40%	60%					0.054	0.055
2008					25%	75%					0.049	0.050
2009					20%	80%					0.047	0.047
2010					8%	92%					0.043	0.043
2011					8%	92%					0.043	0.043
2012					8%	92%					0.043	0.043
2013					8%	92%					0.043	0.043
2014					8%	92%					0.043	0.043
2015					8%	92%					0.043	0.043
2016					8%	92%					0.043	0.043
2017					8%	92%					0.043	0.043
2018					8%	92%					0.043	0.043
2019					8%	92%					0.043	0.043
2020					8%	92%					0.043	0.043