Cleaner Cars, Cleaner Air:

How Low-Emission Vehicle Standards Can Cut Air Pollution in Maryland

Elizabeth Ridlington
Tony Dutzik
Brad Heavner

MaryPIRG Foundation

February 2005

Acknowledgments

The authors wish to thank David Bookbinder, Pamela Irwin, and Dan Becker of the Sierra Club for peer review of this report. Our thanks to Coralie Cooper of Northeast States for Coordinated Air Use Management for reviewing the methodology. Chantelle Fisher provided invaluable assistance in assembling data for emissions estimates.

We express our deepest gratitude to the Energy Foundation, the Clayton Baker Trust, and the Town Creek Foundation for their financial support of the MaryPIRG Foundation.

The authors alone bear responsibility for any factual errors. The recommendations are those of the MaryPIRG Foundation and do not necessarily reflect the views of those who provided editorial or technical review.

The Maryland Public Interest Research Foundation (MaryPIRG Foundation) is a non-profit, nonpartisan 501(c)(3) organization dedicated to protecting the environment, the rights of consumers, and good government in Maryland.

For additional copies of this report, send $10 to:
MaryPIRG Foundation
3121 Saint Paul Street, #26
Baltimore, MD 21218

For more information on MaryPIRG and the MaryPIRG Foundation, please contact our office at 410-467-0439 or visit the MaryPIRG web site at www.marypirg.org.

Table of Contents

Executive Summary 5
Introduction 7
Air Pollution in Maryland 9
Smog 9
Air Toxics 9
Automobile Emission Standards 12
How Vehicle Compliance Is Evaluated 13
Tailpipe Emissions 13
Evaporative Emissions 14
Key Pollutants: Organic Gases, NOx 15
Tailpipe Emission Standards 15
Federal Tier 2 Rule 15
LEV II Rule 15
Evaporative Emissions Standards 17
Advanced Technology Requirements 18
How the Programs Compare 19
Emissions Reductions in Maryland 22
Reductions in Smog Precursors 22
Reductions in Air Toxics 22
Diesel Particulate Matter 23
Policy Recommendations 25
Appendix A: Methodology and Sources 26
Total Air Toxics Emissions and Human Exposure 26
Emissions Estimation 27
Appendix B. Glossary of Abbreviations 30
Appendix C. List of EPA-Regulated Mobile Source Air Toxics 31
Appendix D. Air Toxics Cancer Risk by Maryland County 32
Appendix E. Emission Reductions by County. 34
Appendix F. Emissions Reductions by Vehicle Class 36
Notes 38

Executive Summary

Air pollution—including that from light-duty cars and trucks—poses a major public health threat in Maryland. Maryland could enjoy significant reductions in emissions of smog-forming and toxic pollutants if it adopted more stringent vehicle emission standards.

Ground-level ozone, better known as smog, and toxic air pollutants threaten the health of Maryland's residents.

- Smog, which forms from emissions of nitrogen oxides (NOx) and volatile organic compounds (VOCs), can lead to asthma, bronchitis, increased susceptibility to bacterial infections, and other respiratory problems.
- The Maryland Department of the Environment estimates that mobile sources emit 38 percent of the state's NOx and 27 percent of its VOCs.

Maryland residents are exposed to levels of toxic air pollution that pose excessive cancer risks and that may jeopardize the respiratory, reproductive and developmental health of residents as well.

- In the most recent data available from the EPA's National-Scale Air Toxics Assessment, human exposure levels of formaldehyde and benzene in every Maryland county exceeded cancer risk limits established by the EPA.
- On-road sources were responsible for 62 percent of the cancer risk from benzene pollution and 78 percent of the cancer risk from 1,3-butadiene pollution.

The U.S. EPA and the state of California have developed separate emission standards to further limit pollution from cars and light-duty trucks. Those standards address a variety of air pollution problems, including the emission of NOx, VOCs, and toxic chemicals.

The California standards, known as LEV II, are much stronger than those of the EPA, known as Tier 2. LEV II includes tight limits on tailpipe and evaporative emissions of several air pollutants. It also includes a provision that ensures that a certain percentage of cars sold in Maryland include advanced technology to further reduce emissions.

LEV II holds the potential for substantial environmental and public health benefits for Maryland, over and above the benefits gained through Tier 2.

- Were Maryland to adopt LEV II beginning in 2008 (when model year 2009 vehicles go on sale), light-duty vehicle emissions of both smog-forming NOx and VOCs would decline. By 2025, VOC emissions from light-duty vehicles would be approximately 13 percent less than under Tier 2. Emissions of NOx would be 11 percent lower.
- Further, light-duty vehicles would annually release 12 to 15 percent less toxic pollution by 2025 than vehicles certified to Tier 2 standards. On a pollutant by pollutant level, LEV II produces air toxics emissions reductions of 57 to 79 percent versus today's pollution levels.
- Those emission reductions are the equivalent of taking approximately 190,000 of today's cars off the state's roads in 2025.

LEV II provides additional benefits.

- Unlike Tier 2, LEV II ensures that any new light-duty diesel vehicles meet strict standards for emissions of toxic particulate matter. Diesel is responsible for a significant portion of the particulate matter in the nation's air.
- The advanced technology requirement in LEV II makes the pollution reduction goals of the program more attainable. In addition, this requirement helps fuel the development of even cleaner technologies such as hybrids and fuel-cell vehicles. These types of technologies are the only ones that offer the potential of a permanent solution to the state's mobile source air toxics and smog problems.

To reduce pollution from cars and light trucks, the Maryland Department of the Environment should adopt the LEV II program. Further, the state should take additional actions to encourage the deployment of clean vehicles and to reduce air pollution health threats from other sources in the state.

Introduction

As Maryland's population rises and residents drive more miles each year, the state's air pollution problems have become more serious. In 2003, concentrations of ground-level ozone were higher than the EPA's eight-hour health standard on 57 occasions.[1] In both 2001 and 2002, there were more than 200 violations of the ozone standard. Further, in 2003, the Baltimore-Towson area tied with Riverside, California, for having the highest recorded 8-hour concentration of ozone in the nation—nearly double the health standard.

Exposure to smog can cause asthma, emphysema, and other serious respiratory problems.

While the state's problems with smog have gained increasing notice from the public and decision-makers in recent years, smog is by no means the only air pollution problem that threatens the health of Maryland's residents. Airborne toxic pollutants—like benzene, particulate matter and formaldehyde—also pose a significant public health threat, putting many Maryland residents at increased risk of contracting cancer and respiratory ailments, and possibly leading to reproductive and developmental health effects as well.

Residents of every Maryland county are exposed to concentrations of airborne toxic contaminants that pose an excessive cancer risk under the guidelines set by federal law. Mobile sources, and especially highway vehicles like cars and trucks, are a major source of that pollution.

This pollution does not have to be an inevitable result of driving, however. Much cleaner vehicles are available, the result of technology developed in response to tighter emissions standards in other states.

Hybrid vehicles such as the Toyota Prius and Ford Escape hybrid emit significantly less smog-forming pollution and fewer cancer-causing air toxics, and demonstrate some of the newest technology that can reduce pollution. Many versions of conventional gasoline-powered vehicles such as the Ford Focus, Honda Accord, and Dodge Stratus are equipped with advanced pollution controls that lower emissions without any perceptible change to the vehicle.

Unfortunately, relatively few of these cleaner trucks and cars are in use in Maryland. Placing more of these advanced-technology vehicles on Maryland's streets and highways and establishing tighter emissions limits are essential to reducing air pollution in the state.

Maryland can increase the number of advanced-technology vehicles in use in the state and improve air quality by adopting the Low-Emission Vehicle II standards (LEV II) in place of weaker federal emissions standards. Recognizing the benefits of LEV II, eight states—New York, New Jersey, Connecticut, Rhode Island, Massachusetts, Maine, and Vermont, in addition to California—have adopted or are in the process of adopting the LEV II standards.

Adopting the LEV II standards in Maryland would lead to a significant reduction in emissions of smog-forming chemicals and toxic air pollutants over the next two decades while encouraging the further development of technologies that could eventually eliminate smog-precursor and toxic emissions from automobiles altogether.

Air Pollution in Maryland

Smog

Ground-level ozone, commonly known as smog, is the nation's most prevalent air contaminant. During 2003, the eight-hour health standard for ground-level ozone was exceeded 57 times in Maryland, an unusually low number due to mild weather.[2] The previous year was more typical, with 275 violations. In 15 Maryland counties, including those where most of the state's residents live, ozone levels are high enough to damage human health and so the U.S. Environmental Protection Agency has designated those areas as violating ground-level ozone standards.[3]

Chemically identical to the atmospheric ozone that protects us from the sun's harmful radiation, ground-level ozone is a colorless, odorless gas. It forms when nitrogen oxides (NOx) mix with volatile organic compounds (VOCs) in the presence of sunlight. The Maryland Department of the Environment estimates that mobile sources—cars, trucks, and other non-stationary engines—emit 38 percent of nitrogen oxides (NOx) and 27 percent of volatile organic compounds (VOCs) released in Maryland.[4]

Inhaling ground-level ozone can be extremely dangerous. The ozone gas inflames and burns sensitive lung tissue. The swelling and associated scarring decrease oxygen intake and can lead to asthma, bronchitis, emphysema, increased susceptibility to bacterial infections, and other respiratory problems. High concentrations of ozone can restrict the activity of even the healthiest individuals. For at-risk populations, such as children, the elderly, outdoor workers, and people with respiratory problems, ground-level ozone poses an immediate and severe health threat. Ozone pollution in the Eastern United States contributes to more than 6 million asthma attacks and 159,000 respiratory emergency room visits each year.[5]

Air Toxics

The federal Environmental Protection Agency lists 188 chemicals as hazardous air pollutants (HAPs). Of those, EPA has identified 21 as coming primarily from "mobile sources"—cars, trucks and other non-stationary machinery. At least 10 of those are produced in significant quantities by light-duty cars and trucks:

- **Benzene**, which can cause leukemia and a variety of other cancers, as well as central nervous system depression at high levels of exposure. On-road vehicles produced an estimated 57 percent of all benzene emitted into Maryland's air in 1999.[6]

- **1,3-Butadiene**, a probable human carcinogen, which is suspected of causing respiratory problems. On-road vehicles were responsible for 69 percent of emissions in Maryland.

- **Formaldehyde**, a probable human carcinogen with respiratory effects. On-road vehicles were responsible for 68 percent of emissions in Maryland.

- **Acetaldehyde**, a probable human carcinogen that has caused reproductive health effects in animal studies. On-road vehicles were responsible for 57 percent of emissions in Maryland.

- **n-Hexane**, which is associated with neurotoxicity and whose links to cancer are unknown.

- **Acrolein**, a possible human carcinogen that can cause eye, nose and throat irritation.

- **Toluene**, a central nervous system depressant suspected of causing developmental problems in children whose mothers were exposed while pregnant. Its cancer links are unknown.

- **Ethylbenzene**, which has caused adverse fetal development effects in animal studies. Its cancer links are unknown.

- **Xylene**, a central nervous system depressant that has caused developmental and reproductive problems in animal studies.

- **Styrene**, a central nervous system depressant that is a possible human carcinogen.[7]

In addition, airborne **particulate matter**—the motor vehicle component of which comes largely from diesel-fueled vehicles—has also been recognized as a cause of lung cancer and respiratory problems.[8]

Mobile sources—which include cars, trucks and other highway and non-road motorized machinery—are major emitters of air toxics. EPA estimates that mobile sources emit 41 percent of all air toxics by weight and that on-road vehicles are responsible for approximately half that amount.[9] Several air toxics—such as benzene and toluene—are also volatile organic compounds (VOCs), which play an important role in the chemical reaction that creates smog.

In 1990, the U.S. Congress mandated that the EPA take steps to address emissions of airborne toxic chemicals. In the Clean Air Act amendments of that year, Congress set a goal of reducing the cancer risk from airborne toxins to one case of cancer for every one million residents following a lifetime of exposure. But, years later, many Maryland residents are still exposed to significant levels of air toxics.

In 1996, the most recent year for which complete data is available, human exposure levels of formaldehyde and benzene in all Maryland counties exceeded levels established by the EPA intended to limit cancer risk to one new case of cancer for every 1 million residents over a lifetime of exposure. Exposures of 1,3-butadiene exceeded the EPA's cancer benchmark in all but four Maryland counties and acetaldehyde exposure exceeded the benchmark in all but seven counties. (See Table 1. Appendix D contains a full list of the cancer risk from air toxics by county.)

Though updated information on human exposure to air toxics is not available, updated emissions data is. A comparison of emissions data from 1996 and 1999 shows little change in emissions of air toxics from on-road motor vehicles, suggesting that Maryland residents continue to be exposed to these substances in dangerous amounts.

Table 1. Statewide Cancer Risk from Air Toxics[10]

Air Toxic	Estimated Average Human Exposure (micrograms per cubic meter)	Factor by which Estimated Exposure Exceeds Health-Protective Threshold for Cancer	Percent of Added Cancer Risk from On-Road Sources	Percentage Change in On-Road Emissions, 1996-1999
Acetaldehyde	0.82	2	58%	-2%
Benzene	1.77	14	62%	-8%
1,3-Butadiene	0.08	2	78%	11%
Formaldehyde	1.19	15	44%	-6%

Emissions of acetaldehyde, benzene, and formaldehyde have declined slightly, but not by enough to alter the magnitude of the cancer risk they present to Maryland's residents.

Air toxics are clearly a serious public health problem for Maryland. But while that threat has gained increasing recognition in recent years, it has not been adequately addressed at the federal level.

The 1970 Clean Air Act directed EPA to set health-based ambient air quality standards for six "criteria" pollutants—carbon monoxide, ground-level ozone, lead, nitrogen oxide, particulate matter and sulfur dioxide. With the Clean Air Act amendments of 1990, Congress established the one-in-a-million cancer risk goal for toxic air contaminants and directed EPA to address emissions of three specific mobile source air toxics: benzene, formaldehyde and 1,3-butadiene.[11]

Despite a 54-month timeframe for developing regulations for those chemicals, it took the agency until 2001 to issue a mobile source air toxics rule—and even that rule did not take additional action to limit air toxic emissions from mobile sources. A group of environmentalists and states filed suit against the EPA in May 2001 to get the agency to fulfill the congressional mandate, but the court ruled that the EPA's rules were acceptable.[12]

Achieving the Clean Air Act's cancer risk reduction goal, and protecting the health of Maryland residents, will likely require additional action—especially action that addresses the significant threats posed by increased emissions from light-duty vehicles. The LEV II standards are an effective option available to Maryland to meet this threat.

Automobile Emission Standards

In 1970, the federal government adopted the Clean Air Act, which called for the first national tailpipe emissions standards and set the overall framework that has governed automobile emission regulation since.[13] The 1970s and 1980s saw the progressive tightening of existing air quality standards, the installation of new pollution control equipment, and the elimination of leaded gasoline—all of which led to significant reductions in automobile emissions.

All vehicles except those sold in California were required to comply with these national standards. From the very early days of air pollution regulation, California has been empowered to issue its own vehicle emissions standards because of the state's urgent air pollution problems.

With the Clean Air Act of 1990, the federal government further tightened emissions standards at the federal level. The law also required the EPA to reassess the need for even tighter standards for the 2004 model year and beyond.

The 1990 act also preserved the right of states to adopt more protective emission standards based on those adopted in California. By the mid-1990s, New York and Massachusetts had adopted the California rules, with Vermont and Maine following suit later. More recently, New Jersey, Connecticut, and Rhode Island have adopted the California standards. States were barred from issuing standards that differed from the federal or California rules—a provision intended to prevent automakers from being forced to market 50 different cars in 50 states.

While Congress was acting to tighten air pollution standards at the national level, California, too, was revising its standards. In 1990, the state adopted its low-emission vehicle (LEV) standards. The LEV standards, which were far tighter than the prevailing federal standards at the time, allowed manufacturers to choose among a number of emission categories—or "bins"—when certifying their vehicles. Each of the bins represented different levels of allowable emissions, enabling automakers to produce a mix of vehicles, some of which emit more pollution and others less. However, the mix of vehicles was required to meet an overall, fleetwide average standard for non-methane organic gas (NMOG)—a class of pollutants that includes many air toxics and smog precursors—that declined over time, ensuring that automakers certified most of their vehicles to cleaner emission bins. The law also required automakers to manufacture a certain percentage of zero-emission vehicles.[14]

In 1994, following up on the 1990 Clean Air Act Amendments, the U.S. EPA issued its Tier 1 rule, which phased in tighter emissions standards for cars and some light trucks. Several years later, in an effort to stave off the implementation of California's standards by other states, the auto industry and federal government agreed to a new National Low Emission Vehicle (NLEV) program that went into effect in the northeastern states in 1999 and nationwide in 2001. The NLEV standards include further reductions in tailpipe emissions, mirroring the reductions included in California's original LEV standards. However, the NLEV program did not include requirements for any advanced technology vehicles.

In 1999, both California and the federal government adopted tough new standards designed to limit air pollution emissions from a wide range of motor vehicles beginning in the 2004 model year. The California program was called LEV II; the federal program, Tier 2.

There are many similarities between the two programs. In fact, they have more in common than not.

Both adopted the "bin" certification system pioneered in California's 1990 LEV I standards. The system gives manufacturers the flexibility to produce a mix of higher- and lower-polluting vehicles as long as their entire fleet meets overall emission reduction targets. Both programs also eliminated the "SUV loophole" that exempted many light trucks from the tough emissions standards in place for passenger cars (although a similar loophole still exists in federal fuel efficiency standards). And both established tighter emission levels for vehicles regardless of the type of fuel they use.[15]

But there are several key differences between the two programs. Among these are:

- The two programs measure compliance against different benchmark pollutants.
- There is significant difference in the reductions required for "evaporative emissions"—those emissions that come from sources other than vehicle exhaust.
- The federal standards do not require the production and sale of technology-stimulating near-zero emission vehicles.

How Vehicle Compliance Is Evaluated

Tailpipe Emissions

For both the California LEV II and the federal Tier 2 programs, the amount of emissions permitted for a vehicle depends on its vehicle class and weight. With the 1999 changes, the Tier 2 and LEV II programs have adopted a generally similar set of classifications for passenger cars (known as PCs or LDVs) and light trucks (LDTs). (See Table 2.)

To determine if vehicles are in compliance with clean air standards, vehicles are tested according to standardized test procedures, with their engines aged to simulate conditions at their "full useful life," which is currently defined as 120,000 miles. LEV II calls for some vehicles to have an extended warranty through 150,000 miles. In certain cases, the regulations also stipulate "intermediate life" standards, which are measured at 50,000 miles.

For the sake of clarity, this report will refer to vehicles by their federal classifications. Occasionally, we will refer to "heavy" and "light" light-duty trucks. Heavy light-duty trucks (or HLDTs) comprise the LDT3 and LDT4 categories in the federal classifications, while light light-duty trucks (LLDTs) represent the LDT1 and LDT2 categories. Further, whenever standards are mentioned, they should be assumed to be for the full (120,000 mile) useful life, unless otherwise stated.

Table 2: LEV II and Tier 2 Light-Duty Vehicle Classes[16]

CA Vehicle Class	Weight	Federal Vehicle Class	Weight
PC	All passenger cars	LDV	All passenger cars
LDT1	0-3,750 lbs. LVW	LDT1	0-6,000 lbs. GVW 0-3,750 lbs. LVW
LDT2	3,751 lbs. LVW- 8,500 lbs. GVW	LDT2	0-6,000 lbs. GVW 3,751-5,750 lbs. LVW
		LDT3	6,001-8,500 lbs. GVW 0-5,750 lbs. ALVW
		LDT4	6,001-8,500 lbs. GVW 5,751-8,500 lbs. ALVW

LVW: Loaded Vehicle Weight=actual vehicle weight plus 300 lbs.
GVW: Gross Vehicle Weight=maximum design loaded weight
ALVW: Adjusted Loaded Vehicle Weight=average of GVW and actual vehicle weight

Evaporative Emissions

While many think of pollution as coming from a vehicle's tailpipe, there are other sources as well. Approximately half of all hydrocarbon emissions (hydrocarbons include smog-forming and toxic chemicals) from vehicles come from evaporative emissions that emanate from engines, fuel systems and other parts of the vehicle both while it is running and while it is sitting still.[17]

Those emissions include:

- **Running losses** (about 47 percent of evaporative emissions) - Running losses include leakage from the fuel and exhaust systems as the car is being driven.
- **Hot soak emissions** (about 38 percent) - Hot soak emissions include releases from the carburetor or fuel injector that occur when a car is cooling off following a trip.
- **Diurnal emissions** (about 10 percent) - Emissions that take place due to "breathing" of the gas tank caused by changes in ambient temperature (i.e. the car being heated and cooled by the sun).
- **Resting losses** (about 4 percent) - Leakage from a car while it is resting.[18]

Both the California and federal programs include new limits on evaporative emissions, although the federal standards are much weaker than the California standards. (Automakers have stated that they intend to comply with the LEV II evaporative emission standards nationwide, but, except in states that have adopted LEV II, they cannot be required to do so.) Compliance with evaporative emission standards is determined by putting a vehicle through a set testing procedure that simulates changing ambient temperatures and the effects of engine cooling following a drive.

Key Pollutants: Organic Gases, NOx

Hydrocarbons in gasoline and diesel fuel create pollution when they are incompletely burned in a vehicle's engine or when they leak into the air. Hydrocarbons include many toxic pollutants, and many also can react with other chemicals to form smog.

Air pollution regulations use a variety of measures to gauge the release of these toxic and smog-forming pollutants from motor vehicles. The Tier 2 and LEV II rules measure tailpipe emissions of non-methane organic gases (NMOG), a class of pollutants that includes hydrocarbons (except methane) and various other reactive organic substances such as alcohols, ketones, aldehydes and ethers. Other standards are communicated in terms of volatile organic compounds (VOCs), which include all the components of NMOG except some nonreactive hydrocarbons. The measures include a similar but not identical mix of air toxics. Because the measures yield roughly equivalent amounts of motor vehicle emissions, they often are used interchangeably.

Both LEV II and Tier 2 also establish standards for nitrogen oxides (NOx), a component of smog. Other benchmark pollutants include carbon monoxide (CO), formaldehyde, and particulate matter (PM).

Tailpipe Emission Standards

Federal Tier 2 Rule

The foundation of the Tier 2 rule is a fleet average emission standard for nitrogen oxides (NOx)—a key precursor of smog—of 0.07 grams/mile, a significant reduction from earlier federal standards. The phase-in of the NOx standard for cars and LLDTs began in model year 2004, with the standards to be fully phased in for the 2007 model year. HLDTs and medium-duty passenger vehicles (MDPVs, a class of larger passenger vehicles that includes conversion vans) will be subject to interim standards, the phase-in of which began in model year 2004, and the full Tier 2 standards, which will be phased in beginning in model year 2008. All vehicles will comply with the new standards beginning in model year 2009.[19]

The new rules also give manufacturers an incentive to certify their vehicles to Tier 2 standards ahead of schedule by allowing them to bank credits toward future compliance with the rules.

Manufacturers will have the flexibility to certify their vehicles to one of a number of "bins," provided that their fleets meet the 0.07 g/mi average NOx requirement. In practice, the bins will allow manufacturers to produce some vehicles that emit more than 0.07 g/mi of NOx, as long as they also manufacture vehicles certified to bins with tighter NOx requirements.

The bins are structured to ensure that emissions of other air pollutants—including NMOG (which includes many air toxics), carbon monoxide (CO), formaldehyde, and particulate matter for diesel vehicles (PM)—are reduced along with NOx. (See Table 3.)

The Tier 2 standards guarantee that, at full phase-in, light-duty cars and trucks will emit no more than 0.09 g/mi of NMOG—the highest level allowed in any permanent bin. In fact, average emissions will likely be less, as automakers certify some vehicles to bins 1 through 4 in an effort to balance out higher NOx-emitting vehicles in their fleets.

LEV II Rule

In contrast to the federal rules based on NOx, the California LEV II standards are based on fleet average emissions of non-methane organic gases (NMOG)—which include some smog precursors as well as many air toxics.

Table 3: Tier 2 Tailpipe Emission Standards (grams/mile)[20]

Bin No.	NOx	NMOG	CO	Formaldehyde	PM	Notes
11	0.9	0.28	7.3	0.032	0.12	a,c
10	0.6	0.156/0.230	4.2/6.4	0.018/0.027	0.08	a,b,d
9	0.3	0.09/0.18	4.2	0.018	0.06	a,b,e
8	0.2	0.125/0.156	4.2	0.018	0.02	b, f
7	0.15	0.09	4.2	0.018	0.02	
6	0.1	0.09	4.2	0.018	0.01	
5	0.07	0.09	4.2	0.018	0.01	
4	0.04	0.07	2.1	0.011	0.01	
3	0.03	0.055	2.1	0.011	0.01	
2	0.02	0.01	2.1	0.004	0.01	
1	0	0	0	0	0	

Notes:

a) This bin is deleted at the end of the 2006 model year for most vehicles (end of 2008 model year for LDT3-4 and MDPVs).

b) Higher NMOG, CO and formaldehyde values apply for LDT3-4 and MDPVs only.

c) This bin is only for MDPVs.

d) Optional NMOG standard of 0.280 g/mi applies for qualifying LDT4s and qualifying MDPVs only.

e) Optional NMOG standard of 0.130 g/mi applies for qualifying LDT2s only.

f) Higher NMOG standard deleted at end of 2008 model year.

Table 4: LEV II Fleet Average NMOG Standards for Light-Duty Vehicle Classes (grams/mile)[21]

Model Year	All PCs; LDTs 0 – 3,750 lbs. LVW	LDTs 3,751 lbs. LVW – 8,500 lbs. GVW
2004	0.053	0.085
2005	0.049	0.076
2006	0.046	0.062
2007	0.043	0.055
2008	0.040	0.050
2009	0.038	0.047
2010+	0.035	0.043

The LEV II standards require all cars and light-duty trucks to meet a steadily declining fleet average NMOG requirement beginning in 2004. In the first year, cars and the lightest light-duty trucks had to meet a fleet average of 0.053 g/mi NMOG when tested at 50,000 miles intermediate life, while heavy light-duty trucks (HLDTs) had to meet a fleet average of 0.085 g/mi. By 2010, those averages will gradually decline to 0.035 g/mi for cars and California LDT1s and 0.043 for heavier light-duty trucks. (See Table 4.)

As is the case in Tier 2, manufacturers can certify their cars to any one of a number of emissions "bins"—as long as their fleet average emissions of NMOG meet the standards. The declining NMOG fleet averages will result in manufacturers certifying a greater proportion of their cars to cleaner bins as the years go by.

In the early years of LEV II, manufacturers can still certify a portion of their vehicles to the earlier LEV I standards, but the fleet averages in LEV II still apply. After 2006, new emissions bins apply. (See Table 5.)

It should also be noted both federal and California standards impose new limits on emissions from medium-duty passenger vehicles (e.g. large passenger vans). Because medium-duty vehicles make up only a small portion of the U.S. vehicle fleet, this analysis focuses primarily on light-duty vehicles, which make up 90 percent of all vehicle miles traveled in the U.S.[23]

Evaporative Emissions Standards

In addition to limiting tailpipe emissions, both the Tier 2 and LEV II standards include new rules to limit evaporative emissions. Both rules keep in place limits on running loss emissions that are the same for California and the rest of the nation. The main difference is in limits on diurnal and hot-soak emissions. Those emissions are measured by two sets of tests. The three-day diurnal-plus-hot-soak test measures the evaporative emissions produced during a set of vehicle operations. The two-day test is a supplemental testing procedure designed to ensure adequate purging of the emission control canister during vehicle operation.[24] LEV II sets tighter standards for evaporative emissions. (See Table 6.)

Table 5: LEV II Light-Duty Emission Bins at Intermediate and Full Useful Life (grams/mile)[22]

Bin	NMOG	CO	NOx	Formaldehyde	PM
LEV*	0.075/0.09	3.4/4.2	0.05/0.07	0.015/0.018	NA/0.01
ULEV	0.04/0.055	1.7/2.1	0.05/0.07	0.008/0.011	NA/0.01
SULEV	NA/0.01	NA/1.0	NA/0.02	NA/0.004	NA/0.01
ZEV	0	0	0	0	0

LEV=low-emission vehicle; ULEV=ultra low-emission vehicle; SULEV=super low-emission vehicle
*LEV II allows manufacturers to certify up to four percent of their heavy (California LDT2) fleet to a higher NOx standard of 0.10 g/mi.

Table 6: Evaporative Emission Standards for Three-Day Diurnal Plus Hot Soak Test (in grams/test)

Class	California	Federal
Passenger cars	0.5	0.95
Light-duty trucks <6,000 lbs. GVW	0.65	0.95
Light-duty trucks 6,000-8,500 lbs GVW	0.9	1.2

Advanced Technology Requirements

In addition to establishing rules for tailpipe and evaporative emissions, the LEV II standards include a requirement that a portion of the cars automakers manufacture and sell be partial zero emission or advanced technology vehicles, and eventually zero emission vehicles. This requirement of the LEV II standards makes possible much of the emission reductions gained through the program, while promoting the development and use of advanced technology cars that could lead to further emission reductions in the future.

Technically, LEV II requires that 10 percent of all vehicles sold in California be zero-emission vehicles beginning in model year 2005. In actuality, though, percentages of vehicles called for under LEV II do not represent real percentages of cars sold. Rather, automakers have many opportunities to earn credits that reduce the actual number of true ZEVs they must sell.

The key elements of the LEV II advanced technology, or ZEV, requirement are:

- **Pure ZEVs** – The LEV II rules require that between model years 2005 and 2008, automakers must sell a total of 250 hydrogen fuel-cell vehicles—which have no tailpipe or fuel-related evaporative emissions—in California and other states that have adopted the LEV II program. The fuel-cell vehicle requirement rises to 2,500 nationally between model years 2009 and 2011 and then to 25,000 vehicles in California between model years 2012 and 2014, and 50,000 vehicles in California between model years 2015 and 2017.[25]

  LEV II would not require the sale of any additional fuel-cell vehicles in Maryland until 2012 at the earliest. However, adopting LEV II in Maryland would allow automakers to claim California credit for fuel-cell vehicles placed in Maryland, increasing the likelihood that a limited number of fuel-cell vehicles would find their way onto the state's highways. In addition, beginning in 2012, automakers may be required to sell several hundred fuel-cell vehicles per year in Maryland, with the numbers increasing steadily thereafter.[26]

  In addition, the LEV II program gives automakers the flexibility to substitute sales of other zero-emission vehicles—such as battery-electric vehicles—for the fuel-cell vehicle requirements.

  Prior to enforcement of the ZEV sales requirements for model year 2009, CARB will undertake a review of fuel-cell vehicle technology to ensure that it is feasible and available for the general market. If the review board determines that fuel-cell vehicles are not yet marketable, the sale requirement will be delayed.[27]

- **Partial ZEV (PZEV) credits** – LEV II also allows manufacturers to meet up to three-fifths of the 10 percent ZEV requirement by earning credits from the sale of conventional, gasoline-powered cars that meet SULEV emissions standards, the state's zero evaporative emissions criteria, and have their emission control systems certified and under warranty for 150,000 miles.[28] The Ford Focus, Honda Accord, and DaimlerChrysler Sebring, for example, are sold as PZEV versions in California. Each PZEV receives a credit equal to 0.2 of a pure ZEV.
- **Advanced technology PZEVs (AT-PZEVs)** – Manufacturers will be allowed to satisfy up to two-fifths of the 10 percent ZEV requirement by marketing vehicles that meet PZEV criteria and that also include advanced features such as hybrid-electric drive or run on alternative fuels such as compressed natural gas. This includes vehicles like the Toyota Prius and Ford Escape. The value of an AT-PZEV under the program is determined by adding credits earned through a variety of advanced technologies to the baseline PZEV credit of 0.2.

Table 7. PZEV and AT-PZEV Percentage Requirement

Model Years	Minimum Requirement
2005-2008	10 percent
2009-2011	11 percent
2012-2014	12 percent
2015-2017	14 percent
2018-	16 percent

The total percentage of vehicles that must meet ZEV, PZEV, or AT-PZEV requirements increases over time, helping to reduce emissions in coming years. (See Table 7.)

How the Programs Compare

Although both the LEV II and Tier 2 programs will result in substantial reductions in emissions, a direct comparison between the programs shows that LEV II is significantly stronger:

- **The LEV II program will lead to greater tailpipe emissions reductions upon full phase-in**. As noted above, the federal Tier 2 program will result in maximum fleet-average NMOG emissions of 0.09 grams/mile. Vehicles certified to Tier 2 standards will likely have somewhat lower emissions of NMOG than the 0.09 g/mi upper limit, as manufacturers certify their vehicles to cleaner bins in order to meet the fleet-average NOx requirement. The declining fleet average NMOG standard in LEV II, however, ensures that vehicles meeting LEV II standards will eventually release significantly less NMOG—and, therefore, fewer air toxics—than cars certified under Tier 2. An analysis of the potential reduction in air toxics in Maryland that would result from adoption of LEV II follows in the next chapter.

  A similar situation is likely to occur for the two chemical precursors of smog: volatile organic compounds and nitrogen oxides. Because VOC emissions are closely tied to emissions of NMOG, Maryland will experience a significant decline in VOC releases as the LEV II program progresses. (See the next section, "Emissions Reductions in Maryland," for a more detailed analysis.)

Reductions in NOx emissions are expected to be similar for the early years of both the Tier 2 and LEV II programs. However, as the LEV II fleet-average standard for NMOG tightens—and as the required number of advanced technology vehicles increases—more super-low-emission and zero-emission vehicles will be required to meet the standards, driving down NOx emissions significantly.

Detailed analysis conducted by the Northeast States for Coordinated Air Use Management (NESCAUM) confirms the hydrocarbon and air toxics reduction benefits of LEV II over Tier 2. NESCAUM concluded that LEV II will reduce hydrocarbon emissions by 16 percent more than Tier 2 and toxic air pollutants by 25 percent.[29]

- **Tier 2 could allow for continued use of dirtier vehicles.** Even at full phase-in, the Tier 2 program preserves the use of three bins—bins 6, 7, and 8—that permit greater emissions of certain pollutants than the LEV II standards.

  Though manufacturers who want to produce some vehicles to bin 6, bin 7 or bin 8 emission standards would also have to certify some vehicles to cleaner bins in order to meet the federal fleet average requirement for NOx, Tier 2 would nonetheless allow greater emissions of particulate matter.

  Bin 7's standard for particulate matter is double that of the highest LEV II bin. By contrast, the LEV II standard would require that any light-duty vehicles achieve stringent emission standards protective of public health.

- **LEV II will generate greater reductions in evaporative emissions than Tier 2.** The LEV II fleetwide emission standards represent a nearly 80 percent reduction in evaporative emissions from previous standards, while the federal Tier 2 standards represent only a 50 percent reduction.[30] Further, the advanced-technology requirements of LEV II require PZEVs and AT-PZEVs to have zero fuel-related evaporative emissions, generating additional reductions in diurnal-plus-hot-soak NMOG emissions.

- **Vehicles certified under LEV II's advanced technology requirement will maintain their low emissions longer than Tier 2-compliant vehicles.** LEV II's standards for PZEVs and AT-PZEVs require that automakers certify those vehicles to the ultra-low SULEV emissions bin for 150,000 miles useful life, not 120,000. Because emission control systems degrade over time and with wear, the emission reductions generated by vehicles covered by the advanced-technology mandate will persist for a longer period of time than conventional LEV II or Tier 2 cars. The added requirement that the emission systems of PZEVs and AT-PZEVs be placed under warranty for 150,000 miles makes it more likely that these systems will be properly maintained and provides an additional financial benefit for consumers.

- **The ZEV, PZEV and AT-PZEV requirements of LEV II mean that automakers have an incentive to develop new technologies that will produce even greater emissions benefits in future.** The enactment of the original LEV requirement in California in 1990 led to an almost immediate spike in interest among automakers in advancing vehicle technology. A study conducted for CARB by researchers from the University of California-Davis found that patent applications for electric vehicle-related technologies skyrocketed beginning in 1993 after a long decline during the 1980s and early 1990s.[31] The researchers also found that spending on joint federal government/ industry electric vehicle programs increased from $18 million in 1990 to $100 million in 2000.[32]

The technological advances achieved by these research efforts helped pave the way for the current generation of hybrid-electric vehicles that have become so popular with consumers. Hybrid-electric vehicles such as the Toyota Prius and Ford Escape are now commonplace and more models soon will be available to consumers. Other new technologies, such as hydrogen fuel-cell vehicles (which use hydrogen to create a chemical reaction that generates electricity to power the engine) are in development or have made their way onto the road in demonstration projects.

Emissions Reductions in Maryland

Using EPA emissions estimating models, it is possible to estimate the emissions reductions from light-duty vehicles under LEV II compared with federal Tier 2 emission standards.

We modeled the vehicle emissions that would result under the different emissions standards for some of Maryland's most populous counties, which are in the Baltimore and Washington metropolitan areas. We chose the following counties for our analysis: Anne Arundel, Baltimore, Carroll, Harford, Howard, Montgomery and Prince George's counties and Baltimore City.

Reductions in Smog Precursors

Emissions of both nitrogen oxides (NOx) and volatile organic compounds (VOCs) will decrease under LEV II. The declining NMOG certification standards in LEV II will eventually force automakers to certify increasing numbers of cars to cleaner emission "bins"—a move that will lead to long-term reductions in emissions of NOx, an important ozone precursor. Those declining NMOG standards will also lead to reductions in the other main contributor to smog: VOCs.

Emissions of NOx could be reduced by 11 percent by 2025 in Anne Arundel, Baltimore, Carroll, Harford, Howard, and Montgomery counties and Baltimore City. In Prince George's County, NOx emissions could drop by 10 percent compared to Tier 2 standards.

By reducing NMOG emissions through LEV II, Maryland can enjoy commensurate reductions in VOCs, which react with NOx in the atmosphere and sunlight to form smog. By 2025, adoption of the LEV II standards would result in an annual reduction of approximately 2,069 tons of VOC emissions—or 13 percent—compared to Tier 2 emission standards. (See Table 8.)

Reductions in Air Toxics

The EPA regulates 21 mobile source air toxics (see Appendix C), of which a smaller number, approximately 10, are present in detectable levels in light-duty vehicle exhaust and evaporative emissions.

LEV II offers reductions in both tailpipe

Table 8: NOx and VOC Emissions Under LEV II vs. Tier 2, 2025

	Tier 2 (tons)	LEV II (tons)	Difference (tons)	Reduction (%)
NOx	14,346	12,803	1,543	11%
VOCs	15,683	13,613	2,069	13%

and evaporative emissions. Analysis for selected Maryland counties of 1,3-butadiene, acetaldehyde, acrolein, benzene, and formaldehyde emissions from light-duty vehicles leads to the conclusion that total vehicle emissions could be reduced by 12 to 15 percent in those counties in 2025 under LEV II as opposed to Tier 2. (See Table 9.)

The benefits of LEV II are even clearer when compared to current vehicle emissions. Light-duty vehicles in 2005 are expected to emit 1,653 tons total of 1,3-butadiene, acetaldehyde, acrolein, benzene, and formaldehyde. In 2025, under the LEV II standard, light-duty vehicles will emit 782 tons of those air toxics. On a pollutant by pollutant level, LEV II produces air toxics emissions reductions of 57 to 79 percent versus today's pollution levels.

Estimating that the average car on the road in Maryland in 2005 produces approximately 22 pounds of VOCs per year, the VOC emissions reductions under LEV II in 2025 will be equivalent to taking approximately 190,000 of today's cars off the roads.[33]

Diesel Particulate Matter

No discussion of mobile-source air toxics would be complete without referencing one of the most dangerous pollutants: diesel particulate matter (PM).

Currently, light-duty vehicles are responsible for only a small portion of the particulate matter emitted into the nation's air. The EPA estimates that even without the Tier 2 standards, light-duty vehicles would emit only 1.4 percent of all emissions of PM by 2007.

However, there is little certainty as to what portion of light-duty vehicles will run on diesel fuel in the years to come. In making its Tier 2 rule, the EPA posited a

Table 9: Light-Duty Vehicle Emissions of Selected Air Toxics in 2025 Under Tier 2 and LEV II for Selected Maryland Metropolitan Counties

	Tier 2 (tons)	LEV II (tons)	Difference (tons)	Reduction (%)
1,3- Butadiene	65.5	56.7	8.8	13%
Acetaldehyde	49.7	43.7	5.9	12%
Acrolein	3.0	2.6	0.5	15%
Benzene	495.8	432.8	63.0	13%
Formaldehyde	167.7	146.5	21.2	13%

scenario in which as many as 9 percent of all passenger cars and 24 percent of light trucks sold in 2020 are running on diesel.[34]

As noted above, the Tier 2 rule allows some greater flexibility for manufacturers to produce diesel-fueled vehicles because of more lenient particulate matter standards. In one bin, PM standards are double the maximum level allowed in any bin under LEV II. Manufacturers may take advantage of that leniency on PM to benefit from the greater fuel efficiency of diesel engines. The EPA projects that its tighter limits on sulfur in gasoline (enacted at the same time as Tier 2) will offset the increased production of light-duty diesel vehicles, such that its Tier 2 standards will result in total light-duty PM emissions remaining roughly the same in 2020 as today.[35]

Unlike Tier 2, LEV II ensures that any new light-duty diesel vehicles meet strict standards for emissions of particulate matter. Combined with standards that reduce the sulfur content of gasoline, the LEV II standards will lead to steep reductions in light-duty PM emissions.

Policy Recommendations

Maryland should join New Jersey, New York and six other states in adopting the Low-Emission Vehicle II standards.
The Maryland Department of the Environment could adopt the LEV II standards to reduce emissions of smog-forming pollutants and to protect citizens from the health dangers posed by air toxics.

Maryland should consider additional ways to reduce air pollution from vehicles.
Even under the LEV II program, it will be several years before significant numbers of clean vehicles are on the road. There are several ways the state can encourage the speedy introduction of ultra-clean vehicles.

- Require that government or public agencies purchase zero emission and alternative fuel vehicles for appropriate uses.
- Strengthen efforts to reduce the growth in vehicle miles traveled, such as telecommuting and carpooling incentives, rail transit, and walkable development.

Maryland should seek to reduce air pollution from all sources.
Light-duty cars and trucks make up a significant portion of air toxics releases in Maryland. But other state and federal policies will likely also be needed to fully protect state residents. Strengthening the U.S. EPA's Mobile Source Air Toxics rule and moving to require the state's old, coal-fired power plants to meet modern air pollution standards are among the steps that can be taken to complement the reductions in emissions that would result from adoption of the LEV II standards.

Appendix A. Methodology and Sources

Total Air Toxics Emissions and Human Exposure

Data for overall 1996 on-road emissions and human exposures of acetaldehyde, 1,3-butadiene, benzene and formaldehyde were taken from the EPA's 1996 National-Scale Air Toxics Assessment. The data represent estimated 1996 emissions and estimated exposures. Data for 1999 emissions were taken from the EPA's National Emissions Inventory.

To characterize potential cancer risks, we adopted the methodology EPA used in its peer-reviewed Cumulative Exposure Project and compared exposure concentrations of air toxics to benchmark concentrations for cancer.[36] As in the Cumulative Exposure Project, concentrations posing a one-in-one-million cancer risk were used as benchmark concentrations for cancer effects. Benchmark concentrations were derived from the toxicity data EPA used in the NATA project for acetaldehyde, benzene, 1,3-butadiene, and formaldehyde.

Cancer risk is defined as the probability of contracting cancer following exposure to a pollutant over a 70-year period (assumed human lifespan) at the estimated exposure concentration. This estimate of risk focuses on the additional lifetime cancer risk predicted from exposure to the pollutant beyond that due to any other factors.

We used the annual average human exposure concentrations derived from EPA's inhalation exposure model. These estimates typically are 20-30% lower than EPA's estimates of ambient air concentrations of the pollutants. As a result, the cancer risk estimates we present are more conservative than risk estimates based on ambient air concentrations.

To estimate potential cancer risks, we compared the annual average human exposure concentrations to the cancer benchmark concentrations. The one-in-one-million benchmark values used in the report serve as yardsticks to assess potential cancer risks posed by air toxics. The benchmarks are not "safe" or "no risk" levels but rather represent concentrations below which there is believed to be little risk to the population. These values are meant to serve as general indicators of air quality and the sources responsible for the pollutants. To estimate the percent of added cancer risks from mobile sources, we divided EPA's estimate of the mobile source contribution to the average human exposure concentration by the average human exposure concentration.

Emissions Estimation

The emission estimates in this report are based on grams-per-mile emission factors output by the U.S. Environmental Protection Agency's MOBILE6.2 mobile source air emissions model. In modeling the impacts of the Tier 2 and LEV II emission standards, we generally followed modeling guidance laid out by U.S. EPA in *Modeling Alternative NLEV Implementation and Adoption of California Standards in MOBILE6*, 5 June 2002, and used input files designed by EPA and accompanying that guidance. In several instances, we modified EPA-provided input files to reflect recent changes to the LEV II program. In addition, we followed a modified modeling protocol to address shortcomings in the way MOBILE6 deals with evaporative emissions.

Inputs to the model were primarily based on MOBILE6 inputs and other information provided by the Maryland Department of the Environment on 9 September 2004. County- or region-specific inputs were used for anti-tampering and inspection and maintenance programs, vehicle registration distributions, diesel vehicle fractions, and climatic conditions. MOBILE6 defaults were used for all other inputs, except for fuel composition.

In order to model emissions of air toxics, MOBILE6 requires the provision of more detailed fuel composition data than was included in the input files provided by MDE. For counties using reformulated gasoline, fuel composition data was based on data for RFG-South from U.S. EPA, *User's Guide to MOBILE6.1 and MOBILE6.2 Mobile Source Emission Factor Model*, August 2003, 151-152, and on data for Baltimore, Maryland from U.S. EPA, *RFG Property and Performance Averages for Baltimore, MD*, downloaded from www.epa.gov/otaq/regs/fuels/rfg/properf/balt-md.htm, 1 October 2004. Data for 2003 were used for all years modeled.

Separate MOBILE6 input files were developed for each of the following Maryland counties and regions:

- Baltimore metro area (including Baltimore City and Anne Arundel, Baltimore, Carroll, Harford and Howard counties)
- Montgomery County
- Prince George's County

Three separate MOBILE6.2 runs were conducted for each county: one reflecting continued operation of the Tier 2 federal emission standards until 2025, one reflecting implementation of LEV II emission standards beginning in model year 2009, and a third reflecting an alternative approach to modeling the evaporative emission benefits of the Zero-Emission Vehicle portion of the LEV II program.

Adjustments to EPA-provided input files and modeling guidance

EPA-provided input files reflecting the agency's guidance for modeling the impact of the LEV II program were modified in several ways to reflect Maryland's unique implementation schedule. First, the EPA-provided files for LEV II program implementation were modified to reflect the earlier implementation of National Low-Emission Vehicle (NLEV) emission standards in Maryland during model years 1999 and 2000. Second, the files were modified to assume the implementation of Tier 2 standards for model years 2004 through 2008, with LEV II program standards picking up in model year 2009.

For both LEV II modeling runs, EPA's modeling guidance was altered to reflect different assumptions about the role of the program in reducing evaporative emissions. In its most recent guidance for modeling the LEV II program, EPA makes two assumptions: 1) that automakers will voluntarily comply with the more stringent LEV II evaporative emission standards nationwide, and 2) that vehicles (PZEVs and AT-PZEVs) that must be certified to LEV II's "zero evaporative emission" standard (which prohibits evaporative emissions from the fuel system but which allows such emissions from other parts of the vehicle) would experience no reduction in evaporative emissions versus conventional vehicles.

With regard to the first assumption, automakers may be assumed to comply with the LEV II standards nationwide. However, this voluntary agreement does not have the force of law and compliance cannot be enforced. As a result, it appears reasonable to factor in the differences between the LEV II and Tier 2 evaporative emission standards when considering the potential benefits of LEV II for Maryland.

The second assumption reflects a shortcoming in the MOBILE6 model itself. MOBILE6 is incapable of modeling alternative evaporative emission standards other than zero. Thus, an analyst using MOBILE6 must choose between two options: assuming PZEVs have zero evaporative emissions and assuming that they have the same evaporative emissions as other vehicles. Neither assumption reflects reality.

In producing the estimates for this report, we made post-processing adjustments to MOBILE6 outputs for evaporative emissions only. In developing the baseline Tier 2 emission estimates, we assumed that vehicles would comply with Tier 2—and not LEV II—emission standards. To do so, we multiplied the diurnal and hot soak emission factors of model year 2004 and newer vehicles subject to the Tier 2 evaporative standard by the factor by which the federal diurnal-plus-hot-soak standard exceeds that of LEV II—1.9 for passenger cars, 1.46 for light light-duty trucks, and 1.33 for heavy light-duty trucks. Phase-in percentages for the Tier 2 evaporative standard were based on Northeast States for Coordinated Air Use Management, *Comparing the Emission Reductions of the LEV II Program to the Tier 2 Program*, October 2003.

To account for the "zero evaporative emission" standard for PZEVs, we applied post-processing adjustments to the results of the LEV II modeling run. In this "LEV II Alternate" scenario, we multiplied the diurnal and hot soak emission factors of model year 2009 and subsequent vehicles certified to the PZEV, AT-PZEV and ZEV standards by the factor by which the LEV II "zero evaporative" standard is lower than the regular LEV II standard—70 percent for passenger cars according to Northeast States for Coordinated Air Use Management, *Comparing the Emission Reductions of the LEV II Program to the Tier 2 Program*, October 2003. Percentages of PZEV, AT-PZEV and ZEV vehicles for model years 2009-2025 were based on methodology described in Natural Resources Council of Maine, Environment Maine Research and Policy Center, *Cars and Global Warming*, Fall 2004.

Modeling procedures

Each of the MOBILE6.2 runs was completed to produce database output. For the LEV II runs, records reflecting vehicles in model years 2004 through 2008 were deleted and replaced with comparable records from the Tier 2 modeling run, reflecting the fact that vehicles sold during this period were subject to Tier 2, and not LEV II standards.

Separate emission factors were produced for each of the five classes of gasoline-powered light-duty vehicles as well as three classes of light-duty diesel powered vehicles. Aggregate emission factors for each vehicle class and model year were calculated as follows:

- The percentage of a given year's VMT accounted for by a given vehicle on a given highway facility was calculated by multiplying the percentage of registered vehicles of that model year (REGDIST) with the number of miles traveled on that highway segment (MILES) and then dividing by the sum of (REGDIST*MILES) for vehicles of all model years on that facility (user-created field, REGDISMIL). This resulted in a user-created field, MYVMTFRAC.

- Emission factors were then weighted by multiplying the grams per-mile emission factor for that emission type and facility (GM_MILE) by the percentage of VMT on that facility for that emission type (FACVMT). This resulted in a user-created field, WTGMI.
- The product of the weighted emission factor (WTGMI) with the weighted VMT fraction (MYVMTFRAC) was a weighted emission factor for each vehicle type in each model year (user-created field REGWTGMI), which was then summed across the 25 model years in each MOBILE6.2 scenario to create an aggregate emission factor for each vehicle type in each year.
  In equation form: (See Figure 1)

Where "SCENYR" represents the year of the modeling scenario being run and the annual emission factor being the sum of all REGWTGMI for a vehicle type in a given year.

Separate scenarios for each model year were run reflecting conditions in January and July. Emission factors for other months were estimated using mathematical interpolation between these two points, as recommended by EPA.

The monthly emissions factors were then multiplied by monthly VMT figures per vehicle type to produce aggregate emissions.

Baseline county-by-county VMT data was obtained from *2003 Travel-Millions of Annual Vehicle Miles*, Maryland State Highway Administration, available at www.sha.state.md.us/SHAServices/trafficReports/Vehicle_Miles_of_Travel.pdf. We assumed a 2 percent annual growth in VMT, per Mike Baxter, Maryland State Highway Administration, personal communication, 27 October 2004. Seasonal variation in VMT was calculated based on national VMT per month for 2001 through 2003, as reported in Federal Highway Administration, *Traffic Volume Trends*, June 2002, June 2003, and June 2004. VMT was then split by the ratio of monthly VMT driven by five different vehicle categories for January and July of each vehicle model year modeled, obtained from MOBILE6.2 run with default inputs and further distributed using information from *EPA*, *Fleet Characterization Data for MOBILE6: Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates and Projected Vehicle Counts for Use in MOBILE6*, September 2001. VMT figures for other months were estimated using mathematical interpolation between January and July.

To produce aggregate emissions, the emission factor for each vehicle category per pollutant per month per model year was multiplied by the corresponding VMT for each vehicle category per month per model year. Emissions for each pollutant from all vehicle types were summed annually.

Figure 1: Formula used to calculate aggregate emission factors for each vehicle class and model year.

$$\text{REGWTGMI} = \left(\frac{(\text{REGDIST} \times \text{MILES})}{\sum_{\text{SCENYR}-25}^{\text{SCENYR}} (\text{REGDIST} \times \text{MILES})}\right) \times (\text{GM\_MILE} \times \text{FACVMT})$$

Appendix B.
Glossary of Abbreviations

ALVW – Adjusted loaded vehicle weight (average of gross vehicle weight and actual vehicle weight).

AT-PZEV – Advanced technology partial zero-emission vehicle. Class of ultra-clean vehicles under California standards that run on alternative fuels.

CARB – California Air Resources Board.

CO – Carbon monoxide.

G/MI – Grams per mile.

GVW – Gross vehicle weight (maximum design loaded weight).

HAP – Hazardous air pollutant. Also known as air toxics.

HLDT – Heavy light-duty truck.

I/M – Inspection and maintenance programs.

LDV – Light-duty vehicle (i.e. passenger car).

LDT – Light-duty truck.

LEV – Low-Emission Vehicle program adopted in California in 1990. Also, the dirtiest bin to which vehicles may be certified under the LEV II standards.

LEV II – Low-Emission Vehicle program adopted in California in 1999.

LLDT – Light light-duty truck.

LVW – Loaded vehicle weight (vehicle weight plus 300 pounds).

MDPV – Medium-duty passenger vehicle.

NLEV – National Low-Emission Vehicle program adopted as a result of voluntary agreement between automakers, state governments and the EPA.

NMOG – Non-methane organic gas. Category of emissions that includes many air toxics. Includes non-methane hydrocarbons and other organic gases such as aldehydes, ketones, alcohols and ethers.

NOx – Nitrogen oxides, a major precursor of smog.

PC – Passenger car.

PM – Particulate matter, a toxic air pollutant.

PZEV – Partial zero-emission vehicle. Class of ultra-clean vehicles under California standards that may include vehicles run by internal combustion or other engines.

SULEV – Super low-emission vehicle. A certification bin under the LEV II standards that is cleaner than ULEV but not as clean as ZEV. AT-PZEVs and PZEVs must meet SULEV emission standards.

ULEV – Ultra-low-emission vehicle. A certification bin under the LEV II standards that is cleaner than LEV but not as clean as SULEV.

VOC – Volatile organic compounds. Organic compounds that evaporate into the air. Includes many air toxics.

VMT – Vehicle miles traveled.

ZEV – Zero-emission vehicle.

Appendix C.
List of EPA-Regulated Mobile Source Air Toxics

Acetaldehyde
Acrolein
Arsenic Compounds
Benzene
1,3-Butadiene
Chromium Compounds
Dioxin/Furans
Diesel Particulate Matter and Diesel Exhaust Organic Gases
Ethylbenzene
Formaldehyde
n-Hexane
Lead Compounds
Manganese Compounds
Mercury Compounds
MTBE
Naphthalene
Nickel Compounds
Polycyclic Organic Matter[i]
Styrene
Toluene
Xylene

[i] Polycyclic Organic Matter (POM) includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100 degrees Celsius. A group of seven polynuclear aromatic hydrocarbons, which have been identified by EPA as probable human carcinogens, are often used as surrogates for the larger group of POM compounds.

Source: U.S. Environmental Protection Agency, *List of Mobile Source Air Toxics (MSATs)*, downloaded from www.epa.gov/otaq/regs/tosics/msatlist.pdf, 15 September 2004.

Appendix D.
Air Toxics Cancer Risk by Maryland County

County	Estimated Average Human Exposure (micrograms per cubic meter)	Factor by which Estimated Exposure Exceeds Health-Protective Threshold for Cancer	Percent of Added Cancer Risk from On-Road Sources	Percentage Change in On-Road Emissions, 1996-1999	Estimated Average Human Exposure (micrograms per cubic meter)	Factor by which Estimated Exposure Exceeds Health-Protective Threshold for Cancer	Percent of Added Cancer Risk from On-Road Sources	Percentage Change in On-Road Emissions, 1996-1999
	Acetaldehyde				**Benzene**			
Allegany	0.21	0	57%	39%	0.82	6	38%	65%
Anne Arundel	0.87	2	50%	-4%	1.63	13	57%	-14%
Baltimore	1.01	2	57%	-6%	1.99	15	65%	-15%
Baltimore City	1.4	3	61%	-5%	3.29	25	75%	-16%
Calvert	0.27	1	52%	-13%	0.79	6	37%	-17%
Caroline	0.13	0	56%	-32%	0.58	4	22%	-15%
Carroll	0.49	1	58%	-11%	1.11	9	49%	-11%
Cecil	0.46	1	61%	-7%	0.97	7	46%	-13%
Charles	0.5	1	57%	17%	1.05	8	45%	16%
Dorchester	0.17	0	39%	-22%	0.7	5	20%	1%
Frederick	0.46	1	56%	25%	1.08	8	46%	18%
Garrett	0.08	0	56%	52%	0.55	4	15%	98%
Harford	0.61	1	59%	5%	1.26	10	54%	0%
Howard	0.87	2	57%	0%	1.69	13	58%	-9%
Kent	0.38	1	49%	-33%	0.8	6	35%	-35%
Montgomery	0.83	2	57%	-4%	1.67	13	58%	-16%
Prince George's	0.73	2	58%	-1%	1.6	12	60%	-15%
Queen Anne's	0.27	1	55%	-29%	0.75	6	36%	-34%
Somerset	0.13	0	41%	-36%	0.6	5	18%	-20%
St. Mary's	0.23	1	48%	-15%	0.78	6	31%	8%
Talbot	0.18	0	50%	-18%	0.75	6	32%	5%
Washington	0.38	1	62%	16%	1.02	8	46%	35%
Wicomico	0.24	1	56%	-18%	0.8	6	36%	6%
Worcester	0.14	0	45%	8%	0.67	5	18%	42%
Statewide	0.82	2	58%	-2%	1.77	14	62%	-8%

County	Estimated Average Human Exposure (micrograms per cubic meter)	Factor by which Estimated Exposure Exceeds Health-Protective Threshold for Cancer	Percent of Added Cancer Risk from On-Road Sources	Percentage Change in On-Road Emissions, 1996-1999	Estimated Average Human Exposure (micrograms per cubic meter)	Factor by which Estimated Exposure Exceeds Health-Protective Threshold for Cancer	Percent of Added Cancer Risk from On-Road Sources	Percentage Change in On-Road Emissions, 1996-1999
	1,3-Butadiene				**Formaldehyde**			
Allegany	0.04	1	57%	74%	0.53	7	27%	18%
Anne Arundel	0.07	2	64%	5%	1.24	16	38%	-7%
Baltimore	0.08	3	79%	3%	1.37	18	47%	-9%
Baltimore City	0.19	6	89%	3%	2.02	26	55%	-8%
Calvert	0.02	1	68%	2%	0.52	7	30%	-14%
Caroline	0.01	0	59%	-12%	0.33	4	23%	-41%
Carroll	0.03	1	69%	4%	0.8	10	40%	-12%
Cecil	0.03	1	73%	7%	0.7	9	39%	-6%
Charles	0.03	1	60%	41%	0.76	10	35%	17%
Dorchester	0.03	1	28%	3%	0.46	6	17%	-33%
Frederick	0.04	1	67%	46%	0.76	10	36%	24%
Garrett	0.01	0	33%	103%	0.33	4	14%	31%
Harford	0.04	1	72%	20%	0.9	12	42%	3%
Howard	0.06	2	68%	10%	1.24	16	42%	-3%
Kent	0.01	0	56%	-20%	0.59	8	31%	-32%
Montgomery	0.07	2	73%	5%	1.19	15	40%	-6%
Prince George’s	0.06	2	79%	7%	1.07	14	41%	-4%
Queen Anne’s	0.01	0	64%	-19%	0.49	6	31%	-29%
Somerset	0.02	1	28%	-17%	0.4	5	16%	-44%
St. Mary’s	0.03	1	52%	12%	0.5	6	27%	-26%
Talbot	0.03	1	56%	8%	0.44	6	28%	-29%
Washington	0.04	1	68%	41%	0.61	8	39%	-1%
Wicomico	0.03	1	64%	9%	0.51	7	31%	-29%
Worcester	0.03	1	28%	46%	0.4	5	17%	-6%
Statewide	0.08	2	78%	11%	1.19	15	44%	-6%

Appendix E.
Emission Reductions by County

Pounds of emissions in 2025.

Table E-1. Anne Arundel County

	Tier 2	LEV II	Difference	Reduction
Acetaldehyde	19,574	17,230	2,344	12%
Acrolein	1,189	1,004	186	16%
Benzene	195,545	170,617	24,928	13%
1,3-butadiene	25,817	22,314	3,503	14%
Formaldehyde	66,155	57,760	8,394	13%
NOx	5,655,578	5,040,642	614,936	11%
VOCs	6,188,364	5,373,062	815,302	13%

Table E-2. Baltimore City

	Tier 2	LEV II	Difference	Reduction
Acetaldehyde	8,772	7,721	1,050	12%
Acrolein	533	450	83	16%
Benzene	87,630	76,459	11,171	13%
1,3-butadiene	11,569	9,999	1,570	14%
Formaldehyde	29,646	25,884	3,762	13%
NOx	2,534,438	2,258,866	275,572	11%
VOCs	2,773,196	2,407,834	365,362	13%

Table E-3. Baltimore County

	Tier 2	LEV II	Difference	Reduction
Acetaldehyde	13,538	11,917	1,621	12%
Acrolein	823	694	128	16%
Benzene	135,245	118,004	17,241	13%
1,3-butadiene	17,856	15,433	2,423	14%
Formaldehyde	45,755	39,949	5,806	13%
NOx	3,911,576	3,486,267	425,310	11%
VOCs	4,280,068	3,716,180	563,889	13%

Table E-4. Carroll County

	Tier 2	LEV II	Difference	Reduction
Acetaldehyde	3,024	2,662	362	12%
Acrolein	184	155	29	16%
Benzene	30,210	26,359	3,851	13%
1,3-butadiene	3,989	3,447	541	14%
Formaldehyde	10,220	8,924	1,297	13%
NOx	873,751	778,747	95,004	11%
VOCs	956,063	830,104	125,959	13%

Table E-5. Harford County

	Tier 2	LEV II	Difference	Reduction
Acetaldehyde	5,469	4,814	655	12%
Acrolein	332	280	52	16%
Benzene	54,635	47,670	6,965	13%
1,3-butadiene	7,213	6,234	979	14%
Formaldehyde	18,484	16,138	2,345	13%
NOx	1,580,173	1,408,359	171,814	11%
VOCs	1,729,034	1,501,238	227,796	13%

Table E-6. Howard County

	Tier 2	LEV II	Difference	Reduction
Acetaldehyde	8,772	7,721	1,050	12%
Acrolein	533	450	83	16%
Benzene	87,630	76,459	11,171	13%
1,3-butadiene	11,569	9,999	1,570	14%
Formaldehyde	29,646	25,884	3,762	13%
NOx	2,534,438	2,258,866	275,572	11%
VOCs	2,773,196	2,407,834	365,362	13%

Table E-7. Montgomery County

	Tier 2	LEV II	Difference	Reduction
Acetaldehyde	17,035	14,904	2,131	13%
Acrolein	1,006	840	167	17%
Benzene	169,825	147,267	22,558	13%
1,3-butadiene	22,337	19,160	3,177	14%
Formaldehyde	57,919	50,290	7,630	13%
NOx	4,883,533	4,332,745	550,787	11%
VOCs	5,351,122	4,619,947	731,174	14%

Table E-8. Prince George's County

	Tier 2	LEV II	Difference	Reduction
Acetaldehyde	23,137	20,474	2,663	12%
Acrolein	1,465	1,256	209	14%
Benzene	230,865	202,806	28,059	12%
1,3-butadiene	30,681	26,759	3,922	13%
Formaldehyde	77,499	68,135	9,363	12%
NOx	6,718,652	6,041,890	676,762	10%
VOCs	7,314,226	6,370,547	943,679	13%

Appendix F.
Emissions Reductions by Vehicle Class

Pounds of emissions in 2025.

Anne Arundel, Baltimore, Carroll, Harford, Howard Counties and Baltimore City

Table F-1. VOCs

	Tier 2	LEV II	Reduction
LDV	5,320,120	4,502,729	15%
LDT 1/2	8,435,810	7,306,275	13%
LDT 3/4	4,885,344	4,475,814	8%

Table F-2. NOx

	Tier 2	LEV II	Reduction
LDV	3,585,164	3,569,488	0%
LDT 1/2	7,770,425	6,822,256	12%
LDT 3/4	5,679,916	4,805,077	15%

Table F-3. 1,3-Butadiene, Acetaldehyde, Acrolein, Benzene, Formaldehyde

	Tier 2	LEV II	Reduction
LDV	13,781	11,356	18%
LDT 1/2	27,461	24,133	12%
LDT 3/4	17,221	16,024	7%

Montgomery County

Table F-4. VOCs

	Tier 2	LEV II	Reduction
LDV	1,561,937	1,309,839	16%
LDT 1/2	2,398,860	2,070,511	14%
LDT 3/4	1,367,914	1,250,659	9%

Table F-5. NOx

	Tier 2	LEV II	Reduction
LDV	1,062,028	1,057,058	0%
LDT 1/2	2,207,094	1,926,406	13%
LDT 3/4	1,593,553	1,336,037	16%

Table F-6. 1,3-Butadiene, Acetaldehyde, Acrolein, Benzene, Formaldehyde

	Tier 2	LEV II	Reduction
LDV	4,107	3,358	18%
LDT 1/2	7,829	6,852	12%
LDT 3/4	4,837	4,482	7%

Prince George's County

Table F-7. VOCs

	Tier 2	LEV II	Reduction
LDV	2,060,460	1,745,649	15%
LDT 1/2	3,290,319	2,856,458	13%
LDT 3/4	1,946,801	1,793,319	8%

Table F-8. NOx

	Tier 2	LEV II	Reduction
LDV	1,407,784	1,402,439	0%
LDT 1/2	3,043,690	2,691,912	12%
LDT 3/4	2,252,599	1,937,796	14%

Table F-9. 1,3-Butadiene, Acetaldehyde, Acrolein, Benzene, Formaldehyde

	Tier 2	LEV II	Reduction
LDV	5,362	4,454	17%
LDT 1/2	10,764	9,480	12%
LDT 3/4	6,815	6,379	6%

Notes

1. Emily Figdor, *Danger in the Air: Unhealthy Levels of Smog in 2003*, U.S. Public Interest Research Group Education Fund, September 2004.

2. Ibid.

3. Federal Register, Environmental Protection Agency, *40 CFR Parts 50, 51, and 81: 8-Hour Ozone National Ambient Air Quality Standards; Final Rules*, 30 April 2004.

4. Percentages are based on 2002 projections in Maryland Department of the Environment, *Modification to the Rate of Progress Plan for the Baltimore Region: Revision of Mobile Emission Estimates with MOBILE6, SIP Revision 03-06*, 27 October 2003.

5. Abt Associates, *Out of Breath: Health Effects from Ozone in the Eastern United States*, 1999.

6. U.S. Environmental Protection Agency, *AirData: Emissions Summary Report-Hazardous Air Pollutants*, data from 1999 downloaded from www.epa.gov/air/data ntisumm.html?st~MD~Maryland, 29 September 2004.

7. All health data from California Air Resources Board Toxic Air Contaminant Fact Sheets, downloaded from http://arbis.arb.ca.gov/toxics/tac/toctbl.htm, 16 November 2001.

8. U.S. Environmental Protection Agency, Technology Transfer Network, National Air Toxics Assessment, *What About Diesel PM?*, downloaded from www.epa.gov/ttn/atw/nata/perspect.html, 29 September 2004.

9. Travis Madsen and Jasmine Vasavada, *Invisible Threats: Hazardous Air Pollutants and Cancer in New Jersey*, NJPIRG Law and Policy Center, 28 November 2001.

10. Emily Figdor, *Dangers of Diesel: How Diesel Soot and Other Air Toxics Increase Americans' Risk of Cancer*, U.S. Public Interest Research Group Education Fund, October 2002.

11. Michelle Toering and Rob Sargent, *Every Breath We Take: How Motor Vehicles Contribute to High Levels of Toxic Air Pollution in Massachusetts*, MASSPIRG Education Fund, 8 July 1999.

12. *Coalition of Environmental Organizations and States Sue EPA on Inadequate Mobile Source Toxics Rule*, press release, 24 May 2001, downloaded from www.nescaum.org; and State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials, "Court Upholds EPA's Mobile Source Air Toxics Rule," *Washington Update: This Week in Review*, 28 April to 1 May 2003.

13. U.S. Environmental Protection Agency, *Milestones in Auto Emissions Control*, Fact Sheet OMS-12, August 1994; U.S. Environmental Protection Agency, *The History of Reducing Tailpipe Emissions*, publication EPA420-F-99-017, May 1999; California Air Resources Board, *California's Air Quality History – Key Events*, downloaded from www.arb.ca.gov/html/brochure/history.htm, updated 21 April 2000.

14. Michael Walsh, *California's Low Emission Vehicle Program Compared to U.S. EPA's Tier 2 Program*, 20 January 2000.

15. Anne G. Dillenbeck, *Driving Clean Transportation: LEV II: A Policy that Works*, INFORM, 2000.

16. U.S. Environmental Protection Agency, *Tier 2 Study White Paper*, April 1997; Michael Walsh, *California's Low Emission Vehicle Program Compared to U.S. EPA's Tier 2 Program*, 20 January 2000.

17. New York State Department of Environmental Conservation, *Federally Mandated Emissions Tests Begins Jan. 2 Upstate*, press release, 11 December 1997.

18. Dr. John Holtzclaw, *Traffic Calming Cleans*, Sierra Club, downloaded from www.sierraclub.org/sprawl/articles/hwyemis.asp, 6 September 2001. Based on CARB data. Great Lakes Commission, *Scope Study for Expanding the Great Lakes Toxic Emission Regional Inventory to Include Estimated Emissions from Mobile Sources*, Chapter 4-1, downloaded from www.glc.org/air/scope/scope006.htm, 5 September 2001.

19. Michael Walsh, *California's Low Emission Vehicle Program Compared to U.S. EPA's Tier 2 Program*, 20 January 2000; and EPA, *Control of Air Pollution from New Motor Vehicles, Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements, Final Rule*, Federal Register, 10 February 2000.

20. Federal Register, Vol. 65, No. 28, 10 February 2000.

21. California Air Resources Board, *California Low-Emission Vehicle Regulations, with Amendments Effective 14 August 2004.* The LEV II NMOG fleet averages are measured at 50,000 miles rather than 120,000 miles useful life.

22. Ibid.

23. From VMT fractions included in EPA's Tier 2 model, spreadsheet T2MODAQA.XLS.

24. See note 14.

25. California Environmental Protection Agency, Air Resources Board, *ARB Modifies Zero Emission Vehicle Regulation*, press release, 24 April 2003.

26. California Environmental Protection Agency, Air Resources Board, *Resolution 03-4*, adopted 24 April 2003.

27. California Environmental Protection Agency, Air Resources Board, *2003 Amendments to the California Zero Emission Vehicle Program Regulations, Final Statement of Reasons*, January 2004.

28. In this case, "zero" evaporative emissions refers to emissions from fuel. Hydrocarbon evaporative emissions also come from other sources, including paint, adhesives, air conditioning refrigerants, vinyl, tires, etc. California Air Resources Board, *California Evaporative Emission Test Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles*, I.E.1(2), adopted 5 August 1999.

29. Northeast States for Coordinated Air Use Management, *Comparing the Emissions Reductions of the LEV II Program to the Tier 2 Program*, October 2003.

30. See note 14.

31. A.F. Burke, K.S. Kurani, and E.J. Kenney, *Study of the Secondary Benefits of the ZEV Mandate*, August 2000.

32. Ibid.

33. Estimate of "average car" VOC emissions based on multiplying grams per mile emissions factors for passenger cars in Anne Arundel, Baltimore, Baltimore City, Carroll, Harford, and Howard counties by 12,000 miles per year.

34. U.S. Environmental Protection Agency, *Tier 2/Sulfur Regulatory Impact Analysis*, December 1999.

35. Ibid.

Harriet Eckstein Graphic Design