CLEAN CARS, CLEANER AIR

HOW STRICT LOW-EMISSION AND ZERO-EMISSION VEHICLE STANDARDS CAN CUT AIRBORNE TOXIC POLLUTION IN NORTH CAROLINA

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EXECUTIVE SUMMARY

Toxic air pollutants – including those from light-duty cars and trucks – pose a major public health threat in North Carolina. This report concludes that North Carolina could enjoy significant reductions in emissions of those pollutants, as well as emissions of smog-forming chemicals, were it to adopt California's Low-Emission Vehicle II (LEV II) vehicle emission standards.

Mobile sources – defined as cars, trucks and other non-stationary machinery – are major contributors to the toxic air pollution problem. The U.S. Environmental Protection Agency 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. Mobile sources are responsible for the vast majority of emissions of certain air toxics, such as benzene.

Analysis of 1996 data from the EPA's National-Scale Air Toxics Assessment shows that residents of most of North Carolina's 100 counties suffer from levels of toxic air pollution that pose excessive cancer risks to the population and may jeopardize the respiratory, reproductive and developmental health of residents as well.

Specifically:

- Ambient concentrations of 1,3-butadiene in 96 North Carolina counties exceed EPA standards for cancer risk. Concentrations of formaldehyde exceed the EPA's cancer benchmark in 65 counties, benzene concentrations exceed the benchmark in 63 counties, and acetaldehyde concentrations exceed the benchmark in three heavily populated counties: Mecklenburg, Durham and Guilford.
- All four chemicals are known or probable human carcinogens. North Carolina ranks seventh, ninth, 10th, and 12th, respectively, among the lower 48 states in on-road emissions of 1,3-butadiene, benzene, formaldehyde, and acetaldehyde.

While the past several decades have seen increasingly stringent limits on air pollution from automobiles, the effect of those tighter standards has been muted by dramatic increases in vehicle miles traveled. In North Carolina, for instance, the annual number of vehicle miles traveled has increased more than 160 percent since 1970.

In 1999, the EPA and the state of California adopted separate standards to further limit emissions from cars and light-duty trucks. Those standards were intended to address a variety of air pollution problems, including the emission of toxic chemicals into the air.

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, including air toxics. It also includes a provision that ensures that a certain percentage of cars sold in future years will be zero-emission or near-zero-emission vehicles.

The LEV II program holds the potential for substantial environmental and public health benefits for North Carolina – over and above the benefits gained through Tier 2. Specifically:

- LEV II would result in significant reductions in emissions of air toxics.
  - Should North Carolina adopt the LEV II program beginning in model year 2006, light-duty vehicles would annually release about 42 percent less toxic pollution by 2020 than vehicles certified to today's emission standards, and 14 percent less toxic pollution than vehicles certified to Tier 2 standards.
  - Those emission reductions are the equivalent of taking approximately 1.67 million of today's cars off the state's roads.
- LEV II would result in lower emissions of other important pollutants.
  - Emissions of smog-forming nitrogen oxides and volatile organic compounds (VOCs) would both decline in the long run under LEV II. By 2020, VOC emis-

    sions from light-duty vehicles would be approximately 36 percent less under LEV II than today's emission standards, and 12 percent less than under Tier 2.

  - Unlike Tier 2, LEV II does not "make room" for the expanded use of diesel in the light-duty vehicle fleet. Diesel is responsible for a significant portion of the toxic particulate matter in the nation's air.

- The zero-emission vehicle (ZEV) requirement is an integral feature of the LEV II program.
  - The ZEV requirement in LEV II makes the pollution reduction goals of the program more attainable. About half of the projected reductions in air toxics emissions attained from LEV II can be attributed to vehicles covered by the ZEV requirement.
  - The ZEV requirement would also fuel the development of even cleaner technologies such as electric, fuel cell and hybrid-electric vehicles. ZEV technologies are the only ones that offer the potential of a permanent solution to the state's mobile source air toxics and smog problems and are the only ones that couple those benefits with significant reductions in global warming emissions.

The LEV II program will come at some additional cost to automakers and consumers. However, those costs are minor when compared to those of other air pollution reduction programs and average vehicle costs. Moreover, the rules will result in a net economic gain for the state over the long term by reducing public health costs and enhancing the state's energy security. With its concentration of research facilities and high-tech businesses, North Carolina is also well-situated to take advantage of the economic investment in advanced vehicle development that will be stimulated by adoption of the ZEV program.

We recommend that the state of North Carolina adopt the LEV II program and ZEV requirement at the earliest opportunity. Further, we recommend that the state take additional actions to encourage the deployment of ZEVs and other ultra-clean vehicles and to reduce air toxic health threats from other sources in the state.

1. INTRODUCTION

North Carolina has experienced a population boom over the last three decades, adding nearly 3 million people – or 58 percent – to its population since 1970.

But that growth in population has been dwarfed by the increase in the number of miles traveled annually on North Carolina's highways. Between 1970 and 1997, the number of annual vehicle miles traveled in the state jumped by more than 160 percent – nearly triple the rate of population growth.[1]

The result has been the development of increasingly severe air pollution problems in large regions of the state. In 2000, North Carolina ranked third in the nation for the number of occasions on which the EPA's eight-hour health standard for ozone was violated, with approximately 240 such violations being recorded.[2]

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

Residents of nearly every North Carolina 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.

To limit air pollution from automobiles, the federal government has adopted increasingly stringent standards over the last few decades on motor vehicle emissions. In 1999, it did so again, adopting "Tier 2" standards that will dramatically reduce emissions of a range of air pollutants. But while the new standards will likely go far to address the region's smog problem, they are not sufficient to protect North Carolina residents from exposure to air toxics.

Thankfully, there is an alternative. The state of California – long a leader in automobile emissions reductions – has adopted a different set of emissions standards that take an aggressive posture toward air toxics while also helping to combat the state's smog problem. Those standards, called the Low-Emission Vehicle II (LEV II) rule, also include a cutting-edge requirement that automakers sell significant numbers of zero-emission or near-zero emission vehicles in the near future. Recognizing the benefits of the California approach, four states – New York, Massachusetts, Maine and Vermont – have adopted California's air pollution and zero-emission vehicle standards for themselves.

This report will show that adopting the LEV II standards in North Carolina would lead to a significant reduction in air toxics emissions over the next two decades while helping to encourage the development of technologies that could eventually eliminate toxic emissions from automobiles altogether.

This approach will not be without short-term costs. But the long-term benefits – in improved public health, reduced environmental pollution and enhanced economic and energy security – are well worth the investment.

2. AIR TOXICS IN NORTH CAROLINA

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 60 percent of all benzene emitted into North Carolina's air in 1996.[3]
- **1,3-Butadiene**, a probable human carcinogen, which is suspected of causing respiratory problems. On-road vehicles are responsible for 54 percent of emissions in North Carolina.
- **Formaldehyde**, a probable human carcinogen with respiratory effects. On-road vehicles are responsible for 29 percent of emissions in North Carolina.
- **Acetaldehyde**, a probable human carcinogen that has caused reproductive health effects in animal studies. On-road vehicles are responsible for 19 percent of emissions in North Carolina.
- **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.[4]

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, and is classified by California as a toxic air contaminant.

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.[5] 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 as a goal reducing the cancer risk from airborne toxins to one case of cancer for every one million residents following a lifetime of exposure. But twelve years later, North Carolina continues to rank near the top in the United States in emissions of several key air toxics and many North Carolina residents still face cancer risks from air toxics that are well above the Clean Air Act cancer risk goal.

Specifically:

- Ambient concentrations of 1,3-butadiene in 96 North Carolina counties exceed levels established by the EPA intended to limit cancer risk to one new case of cancer for every one million residents over a lifetime of exposure. Concentrations of formaldehyde exceed the EPA's cancer benchmark in 65 counties, benzene concentrations exceed the benchmark in 63 counties, and acetaldehyde concentrations exceed the benchmark in three heavily populated counties: Mecklenburg, Durham and Guilford. (See Table 1. See also Appendix D for a full list of counties and ambient air concentrations.)

- North Carolina ranks seventh, ninth, 10th, and 12th, respectively, among the lower 48 states in on-road emissions of four major air toxics: 1,3-butadiene, benzene, formaldehyde, and acetaldehyde. (See Table 2.)
- Mecklenburg, Durham, Guilford, Buncombe and Forsyth counties have the highest ambient concentrations from on-road mobile sources of the four primary air toxics. These five counties also rank in the ninety-fifth percentile or higher of counties nationally in ambient concentration from on-road mobile sources for each of the substances.
- Rural counties in North Carolina collectively emit more of the four most preva-

Table 1: Rank of North Carolina's Top 25 Counties for Ambient Concentrations of Selected Air Toxics in 1996 (in $\mu g/m^3$)[6]

	1,3 Butadiene		Formaldehyde		Benzene		Acetaldehyde		
County	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Average Rank
Mecklenburg	0.074	2	0.500	1	0.863	1	0.542	1	1.3
Durham	0.066	3	0.419	3	0.765	2	0.480	2	2.5
Guilford	0.062	4	0.431	2	0.749	4	0.476	3	3.3
Buncombe	0.079	1	0.395	6	0.751	3	0.352	9	4.8
Forsyth	0.062	5	0.407	4	0.707	5	0.421	6	5.0
Wake	0.055	10	0.381	7	0.676	6	0.448	4	6.8
Gaston	0.053	11	0.402	5	0.650	7	0.439	5	7.0
Cabarrus	0.060	7	0.366	8	0.643	8	0.376	7	7.5
Cumberland	0.059	8	0.308	9	0.612	9	0.364	8	8.5
Alamance	0.050	12	0.306	10	0.569	10	0.350	10	10.5
Catawba	0.056	9	0.301	11	0.560	11	0.294	12	10.8
Orange	0.044	13	0.297	12	0.528	13	0.348	11	12.3
New Hanover	0.060	6	0.256	15	0.534	12	0.248	17	12.5
Davidson	0.030	17	0.280	13	0.410	15	0.291	13	14.5
Henderson	0.034	16	0.274	14	0.422	14	0.283	14	14.5
Rowan	0.034	15	0.241	16	0.393	16	0.243	18	16.3
Cleveland	0.027	20	0.220	18	0.333	19	0.227	19	19.0
Randolph	0.023	25	0.217	19	0.335	18	0.253	16	19.5
Lincoln	0.021	29	0.224	17	0.321	20	0.253	15	20.3
Wayne	0.037	14	0.170	24	0.338	17	0.158	29	21.0
Iredell	0.025	23	0.194	20	0.304	22	0.196	21	21.5
Burke	0.029	19	0.183	21	0.306	21	0.169	27	22.0
Rockingham	0.021	28	0.174	22	0.259	25	0.174	25	25.0
Lee	0.025	24	0.160	27	0.268	24	0.155	30	26.3
Onslow	0.029	18	0.140	31	0.276	23	0.140	37	27.3
CANCER RISK THRESHOLD	**0.0036**		**0.077**		**0.130**		**0.450**		
COUNTIES EXCEEDING THRESHOLD	**96**		**65**		**63**		**3**		

lent air toxics from on-road mobile sources than the rural counties of any other state in the lower 48. North Carolina rural counties also rank first in ambient concentrations from on-road mobile sources of 1,3-butadiene and benzene and third in ambient concentrations from on-road mobile sources of formaldehyde and acetaldehyde.

- Fifteen counties in North Carolina rank in the ninetieth percentile or higher of counties nationally in ambient concentration from on-road mobile sources in at least two of the four major air toxics. Forty North Carolina counties rank in the seventy-fifth percentile or higher of counties nationally in ambient concentration from on-road mobile-sources in at least three of the four most prevalent air toxics.

Air toxics are clearly a serious public health problem for North Carolina. 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.[8]

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.[9]

Achieving the Clean Air Act’s cancer risk reduction goal, and protecting the health of North Carolina 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 the best option available to North Carolina to meet this threat.

Table 2: Rank Among Lower 48 States for Emissions of Selected Air Toxics from On-Road Mobile Sources in 1996[7]

	1,3 Butadiene		Formaldehyde		Benzene		Acetaldehyde		
State	Emissions (tons/yr)	Rank	Emissions (tons/yr)	Rank	Emissions (tons/yr)	Rank	Emissions (tons/yr)	Rank	Average Rank
Texas	1,867	1	5,797	2	12,078	1	1,859	2	1.5
California	1,430	2	7,236	1	8,631	3	2,001	1	1.8
Ohio	1,141	3	3,893	3	8,639	2	1,332	3	2.8
Florida	979	4	3,330	4	7,633	4	1,079	5	4.3
Michigan	850	8	3,007	5	6,900	5	1,022	7	6.3
Georgia	965	5	2,932	7	6,373	6	966	8	6.5
Illinois	735	11	2,709	9	5,906	7	1,321	4	7.8
Pennsylvania	883	6	2,877	8	5,889	8	931	9	7.8
New York	846	9	2,997	6	5,528	11	922	11	9.3
North Carolina	**859**	**7**	**2,655**	**10**	**5,643**	**9**	**875**	**12**	**9.5**
Indiana	744	10	2,570	11	5,564	10	927	10	10.3
Colorado	670	12	2,243	14	4,342	15	1,060	6	11.8
Missouri	647	14	2,281	13	4,879	12	755	13	13.0
Virginia	650	13	2,316	12	4,461	13	717	16	13.5
Tennessee	643	15	1,996	15	4,352	14	669	18	15.5

3. AUTO EMISSIONS STANDARDS

A common theme runs through the history of automobile emissions standards in the United States. Whenever the time has come to take action to protect the environment and public health from vehicle emissions, California has led the rest of the nation.

That should be no surprise. With its automobile-centered culture and smog-conducive climate, California has typically felt the negative effects of vehicle emissions earlier and with greater severity than elsewhere in the country.

In 1961, California required installation of the first automobile emissions control device in the country. In 1966, it was the first state to adopt tailpipe emissions standards for specific pollutants. Three years later, the state issued the first set of pollutant-specific air quality standards. In the latter two cases, the federal government followed suit within two years with similar regulations.

In 1970, the federal government took a major step forward with the passage of the original Clean Air Act, which called for the first national tailpipe emissions standards and set the overall framework that has governed automobile emission regulation since.[10] 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.

But even as federal air pollution rules grew more stringent, federal law preserved a special place for California. 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. 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 was not sitting still. In 1990, the state adopted its low-emission vehicle (LEV) and zero-emission vehicle (ZEV) standards. The LEV standards, which were far tighter than the prevailing federal standards at the time, allowed manufacturers to certify vehicles to a series of emissions "bins," provided that their fleets met an overall average standard for non-methane organic gas (NMOG) – a class of pollutants that includes many air toxics and smog precursors – that declined over time. The law also required automakers to manufacture a certain percentage of ZEVs, beginning with 2 percent in 1998 and increasing to 10 percent by 2003.[11]

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 the ZEV requirement 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.

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" 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.[12]

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 zero-emission vehicles.

How Standards Are Enforced

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 3.)

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 under both California and federal standards. In certain cases, 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 3: Federal and California Light-Duty Vehicle Classes[13]

CA Vehicle Class	Weight	US 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

While many think of pollution as primarily coming from a vehicle's tailpipe, there are other sources as well. Approximately half of all hydrocarbon emissions from vehicles come from evaporative emissions – those emissions that emanate from engines, fuel systems and other parts of the vehicle both while it is running and while it is sitting still.[14]

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.[15]

Both the California and federal programs include new limits on evaporative emissions, although the federal standards are much weaker than the California standards. 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.

NMOG, NMHC and VOCs

Historically, federal and California regulations have used a variety of measures to gauge the release of toxic and smog-forming pollutants from motor vehicles. The Tier 2 and LEV II rules both 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. Some previous standards have been communicated in terms of non-methane hydrocarbons (NMHC), which do not include non-hydrocarbon reactive gases. Still other standards are communicated in terms of volatile organic compounds (VOCs), which include all the components of NMOG but exempt some non-reactive hydrocarbons. All three measures include a similar mix of air toxics, but not necessarily the same ones.

The three measures yield roughly equivalent amounts of motor vehicle emissions and are often used interchangeably. In this report, overall tailpipe and evaporative emissions reductions are presented in terms of NMHC. These values were then converted to NMOG to analyze emissions of specific air toxics and VOCs. For a more detailed discussion of this topic, see Appendix A.

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 NOx standard is to be phased in for cars and LLDTs beginning in 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, which will be phased in beginning in 2004, and the full Tier 2 standards, which will be phased in beginning in 2008. All vehicles will comply with the new standards beginning in 2009.[16]

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

Table 4: Tier 2 Tailpipe Emission Standards (grams/mile)[17]

Bin No.	NOx	NMOG	CO	Formaldehyde	PM	Notes
11	0.9	0.280	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 (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.

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.

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, 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.

California 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.

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 light light-duty trucks (LLDTs) must meet a fleet average of 0.053 g/mi NMOG when tested at 50,000 miles intermediate life, while heavy light-duty trucks (HLDTs) must meet a fleet average of 0.085 g/mi. Those averages gradually decline to 0.035 g/mi for cars and LLDTs and 0.043 for HLDTs by 2010. (See Table 5.)

As is the case in Tier 2, manufacturers can certify their cars to any one of a number of

Table 5: LEV II Fleet Average NMOG Standards for Light-Duty Vehicle Classes (grams/mile)[18]

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	0.04	0.05
2009	0.038	0.047
2010+	0.035	0.043

Table 6: LEV II Light-Duty Emission Bins at Intermediate and Full Useful Life (grams/mile)[19]

Bin	NMOG	CO	NOx	Formaldehyde	PM
LEV[20]	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

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, the following emissions bins apply. (see Table 6)

It must 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.[21]

Evaporative Emission 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.[22] (See Table 7.)

How They Stack Up

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 much 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 California cars will eventually release significantly less NMOG – and, therefore,

Table 7: 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

fewer air toxics – than cars certified under Tier 2. An analysis of the potential reduction in air toxics in North Carolina 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, North Carolina will experience a significant decline in VOC releases as the LEV II program progresses. (See next chapter 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 California's fleet-average standard for NMOG tightens, 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 Massachusetts Department of Environmental Protection and the New York State Department of Environmental Conservation confirms the long-term NOx reduction benefits of LEV II. The Massachusetts DEP estimated that adoption of LEV II would result in a 19 percent reduction in NOx emissions compared to Tier 2 levels by 2020.[23] New York's DEC estimated that LEV II would attain a fleet average for NOx that is nearly 29 percent lower than the final fleet average attained by Tier 2 upon full implementation of both programs.[24]

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

  Use of the higher NOx emission levels in Bins 6 and 7 would require manufacturers to also certify some vehicles to cleaner bins in order to meet the federal fleet average requirement for NOx.

  The more significant difference, however, is in Bin 7's standard for particulate matter, which is double that of the highest LEV II bin. Some analysts suggest that such an approach would open the door for greater sales of diesel vehicles, which are a major source of particulate pollution.[25]

- **LEV II will generate greater reductions in evaporative emissions than Tier 2.** The California 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.[26]

4. EMISSIONS REDUCTIONS IN NORTH CAROLINA

Air Toxics Reductions Under LEV II

Using EPA emissions estimating models, along with methods and data from environmental agencies in several states, it is possible to estimate that adoption of the LEV II standards would result in a 42 percent reduction in light-duty emissions of air toxics by 2020 compared with today's emission standards. Adoption of LEV II would also result in a 14 percent reduction in light-duty air toxics emissions compared with the federal Tier 2 standards.

Tailpipe NMHC Emission Benefits

By the year 2020, state adoption of LEV II would result in a reduction of about 11 million pounds – or 16 percent – of annual tailpipe non-methane hydrocarbon (NMHC) emissions in North Carolina when compared to Tier 2 standards. (See Table 8.) NMHC emissions are closely related to emissions of NMOG, which includes the bulk of EPA-regulated mobile source air toxics.

Most of the difference between the two standards comes from passenger cars, which were already subject to stringent emissions limits before Tier 2 and LEV II, meaning that older LDVs and LLDTs still on the road in 2020 will make up a smaller percentage of the pollution from vehicles in those weight classes than will older HLDTs. Moreover, the high percentage reduction under LEV II reflects the program's phase-in of more stringent limits on NMOG releases from LDVs and LDT1s over time – an aggressive posture not found in Tier 2.[27]

Evaporative NMHC Emission Benefits

The LEV II program would also bring about significant reductions in evaporative NMHC emissions – the source of about half of all NMHC released into the air from motor vehicles.

By 2020, light-duty vehicles in North Carolina would release about 5.7 million fewer pounds of NMHC – or about 8 percent – under LEV II evaporative emission standards as opposed to those in Tier 2. (See Table 9)[28]

Total NMHC Reductions

Combining the tailpipe and evaporative emission benefits of LEV II leads to the conclusion that total light-duty NMHC emissions would be about 16.8 million pounds per year less in North Carolina by 2020 – or 12 percent – under LEV II as opposed to Tier 2. (See Table 10.)

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. With the exception of diesel particulate matter, which is addressed in the next section, the NMOG category of emissions includes the bulk of EPA-regulated mobile source air toxics from light-duty vehicles.

Table 8: Estimated North Carolina Tailpipe NMHC Emissions in 2020 Under Tier 2 and LEV II (in thousand pounds)

Vehicle Class	Tier 2	LEV II	Difference	Pct. Difference
LDV	18,080	13,239	4,841	27%
LDT 1/2	31,078	27,460	3,618	12%
LDT 3/4	19,040	16,437	2,602	14%
TOTAL	**68,198**	**57,136**	**11,061**	**16%**

Table 9: Light-Duty Evaporative NMHC Emissions in 2020 Under Tier 2/LEV II (in thousand pounds)

Vehicle Class	Tier 2	LEV II	Difference	Pct. Difference
LDV	22,974	20,995	1,979	9%
LDT 1/2	33,738	31,066	2,672	8%
LDT 3/4	15,040	13,971	1,069	7%
TOTAL	**71,752**	**66,031**	**5,720**	**8%**

Table 10: Total NMHC Emissions from Light-Duty Vehicles in 2020 under Tier 2/ LEV II (in thousand pounds)

	NMHC Emissions
LEV II	123,167
Tier 2	139,949
Total Difference	**16,782**
Pct. Difference	**12%**

These specific chemicals are not measured individually. But chemical speciation profiles, which detail the chemical composition of NMOG, allow us to determine the potential reductions in emissions of particular air toxics.

Applying EPA-generated speciation profiles to the LEV II-generated NMHC emission reductions detailed above yields a projected total annual reduction of 4 million pounds – or approximately 14 percent – of the 10 air toxics listed in Table 11 under LEV II.[29]

The benefits of LEV II are even clearer when compared to the projected emissions of vehicles meeting present-day auto emission standards. Were neither the Tier 2 nor LEV II programs to take effect in North Carolina, the light-duty vehicle fleet would be expected to emit approximately 42.7 million pounds of toxics into the state's air in 2020. ***Thus, LEV II would represent a total reduction of 17.8 million pounds of air toxics – or 42 percent – versus current emissions standards.***[30]

Table 11: Air Toxics Emissions by Light-Duty Fleet Under Tier 2/LEV II, 2020 (in thousand pounds)

	Tier 2	LEV II	Difference
1,3- BUTADIENE	407	341	66
N-HEXANE	2,298	2,068	230
FORMALDEHYDE	894	749	145
ACETALDEHYDE	407	341	66
ACROLEIN	49	41	8
BENZENE	4,774	4,119	656
TOLUENE	11,507	9,893	1,615
ETHYLBENZENE	1,764	1,525	239
XYLENE	6,412	5,508	904
STYRENE	276	232	45
TOTAL AIR TOXICS	28,789	24,815	**3,974**
PCT. DIFFERENCE			**14%**

Estimating that the average car on the road today in North Carolina produces approximately 10.7 pounds of air toxics per year, the total emissions reductions under LEV II will be equivalent to taking approximately 1.67 million of today's cars off the road by 2020.[31]

The amount of emissions savings under LEV II would continue to increase after 2020 as more vehicles certified to pre-LEV II emission standards and the higher NMOG limits in the early years of the LEV II program reach the end of their useful lives.

Reductions in Volatile Organic Compounds

As noted above, 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.

However, those declining standards will also lead to reductions in the other main precursor of smog: volatile organic compounds, or VOCs.

In addition to containing a variety of toxic substances, the NMOG category of emissions also includes many volatile compounds that react with NOx in the atmosphere and sunlight to form smog. By reducing NMOG emissions through LEV II, North Carolina can enjoy commensurate reductions in VOCs. By 2020, adoption of the LEV II standards would result in an annual reduction of approximately 69.6 million pounds of VOC emissions – or 36 percent – compared to present-day emission standards. LEV II would also result in a reduction of 16.9 million pounds of VOC emissions – or 12 percent – when compared to Tier 2 standards. (See Table 12)

The Impact of Diesel

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 emissions from light-duty vehicles would make up 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 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.[32]

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 might be tempted to take advantage of that leniency due to the greater fuel efficiency of diesel engines.

The EPA projects that 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.[33]

In contrast, California's LEV II emissions standards would not make room for the widespread introduction of light-duty diesel vehicles to the marketplace. Combined with standards that reduce the sulfur content of gasoline, California's standards will lead to steep reductions in light-duty PM emissions.

Cost

Adopting the LEV II standards will not be without costs to automakers or consumers. However, those costs appear minor when compared to the price of an average vehicle or to the economic benefits that will result from improved public health.

Table 12: VOC Emissions Under LEV II vs. Tier 2, 2020 (thousand pounds)

Vehicle Class	Tier 2	LEV II	Difference	Pct. Difference
Exhaust	67,988	56,960	11,027	16%
Evaporative	73,895	68,003	5,891	8%
Total VOC	**141,882**	**124,964**	**16,919**	**12%**

The best gauge of the added cost of LEV II versus Tier 2 comes from a cost analysis by the California Air Resources Board (CARB). This analysis projected the additional cost of upgrading a 2003 model year vehicle certified to the ULEV bin in the original LEV I standards to a ULEV or SULEV under LEV II. The LEV I ULEV bin includes NMOG emission levels that are roughly comparable to the final Tier 2 standards, but NOx levels that are between four and twelve times higher than Tier 2. Thus, CARB's estimate – while the best available – likely overstates the additional cost of upgrading Tier 2 vehicles to meet the LEV II standards.[34]

CARB estimated that the incremental per-vehicle cost of LEV II would range from as little as $71 to upgrade an LDT1 to meet the LEV II ULEV standard to $304 to upgrade a heavy light-duty truck to meet the LEV II SULEV standard.[35] These figures include CARB's $25 per vehicle estimated cost of complying with LEV II's evaporative emission standards. (See Table 13.)

The LEV II standards also appear to be cost-effective when compared to other means of reducing pollution. CARB estimated that

Table 13: Incremental Per Vehicle Cost of LEV II ULEVs and SULEVs Versus LEV I ULEVs

	LEV II ULEV	LEV II SULEV
LDV	$96	$156
LDT1	$71	$130
LDT2-4	$209	$304

the additional cost would translate to approximately $1.00 for every pound of pollution reduced, compared to $5.00 per pound for other mobile source reduction programs and $10.00 per pound for many stationary source programs.[36]

The increase in cost under LEV II also appears small when compared to the average cost of a new motor vehicle, currently about $24,800.[37] The cost of adopting the program, then, translates to less than one percent of vehicle price in almost all cases.

Unfortunately, CARB did not go on to estimate the societal benefits – in reduced public health costs, averted sick days, and the like – that would result from adoption of LEV II. However, EPA did conduct such an analysis for its adoption of Tier 2 standards. EPA estimated that its Tier 2 standards will lead to the annual avoidance of 4,300 premature deaths nationwide, 2,300 cases of bronchitis, and numerous lost work days, hospital visits and other costs.[38] The net economic benefit of the policy to society at full implementation in 2030, EPA estimated, would be between $8.5 billion and $20 billion.[39]

Because the marginal cost of eliminating pollution increases as pollution controls tighten, it would be improper to extrapolate the potential societal benefit of the LEV II program from the EPA analysis. If, however, LEV II were to reduce air toxics concentrations in North Carolina – and the risks of cancer and other health problems that they pose – it is reasonable to assume that the program would result in a significant additional net economic benefit to the state.

5. THE ZERO EMISSION VEHICLE REQUIREMENT

The zero-emission vehicle (ZEV) requirement in 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.

The ZEV requirement – as it has developed in California and been adopted by other states – is a complicated program. It has also had a tortuous history, thanks in large part to the consistent and vehement opposition of the automobile and oil industries, which have employed litigation, lobbying and public relations strategies to undo the program and prevent its spread.

Yet California's experience with the ZEV program to date has already spurred innovation in a wide range of zero-emission and low-emission vehicle technologies, from traditional electric cars to new options such as fuel-cell and hybrid-electric vehicles.

The History of ZEV

The original zero-emission vehicle program was unveiled as part of California's Low-Emission Vehicle program in 1990. As originally constructed, the plan was to have required that two percent of cars sold in California would be ZEVs by 1998, five percent by 2001, and ten percent by 2003.

In 1996, the California Air Resources Board amended the ZEV regulations in keeping with a memorandum of agreement it negotiated with seven major auto manufacturers. The agreement called for the lifting of all ZEV requirements prior to 2003 in exchange for automakers' pledge to produce for sale between 1,250 and 3,750 advanced battery electric vehicles between 1998 and 2000.[40]

In 1998, the board again amended the ZEV program, creating partial ZEV (PZEV) credits for vehicles that achieve near-zero emissions (commensurate with the SULEV emission standard) and have zero evaporative emissions. The credits served to reduce the number of "pure ZEVs" that would have to be sold by manufacturers in 2003, while increasing the overall number of cleaner vehicles on the road.

As California was adjusting its ZEV rules, a set of eastern states were positioning themselves to adopt the LEV standards and the ZEV rules that come with them. By 1996, four eastern states – New York, Massachusetts, Maine and Vermont – had adopted some or all of the LEV/ZEV program.

In the early 1990s, it looked for a time as though the LEV and ZEV programs would take hold throughout the northeast. Acting as the Ozone Transport Commission (OTC – a body created under the 1990 Clean Air Act), the northeastern states petitioned EPA to mandate adoption of the LEV program from Maine to Virginia.

The OTC's petition was later thrown out in one of many legal actions filed by automakers against the LEV program in the northeast. However, the EPA and automakers negotiated to develop a voluntary program that could supplant LEV/ZEV in the northeastern states that hadn't already adopted it.

In 1998, that voluntary program – the National Low-Emission Vehicle (NLEV) program – took effect, requiring automakers to sell cars meeting roughly the same standards as the original California LEV program across the country by 2001. However, the program did not include the ZEV requirement. And it came with a promise from the northeastern states that hadn't already adopted LEV that they would not adopt California standards that would take effect before the 2006 model year.

In 2001, CARB again altered the ZEV program, reducing the percentage of pure ZEVs required in the initial years of the program to two percent and allowing manufacturers to claim additional ZEV credits. Those changes are now making their way through the regulatory process.

In the northeastern states that had adopted the ZEV program, meanwhile, state officials have proposed an alternative compliance strategy that would delay the introduction of pure ZEVs, while encouraging the early introduction of vehicles meeting PZEV criteria.[41] The plan had not been finalized by the time this report went to press.

In its short history, then, the ZEV program has been through several incarnations, weathered many political and legal battles, and remains in flux even now.

For the purpose of this report, we will assume that the version of the ZEV program that would be considered for adoption by North Carolina is the version that was adopted by CARB in 2001, for which detailed regulations are currently being finalized.

How It Works

The percentages of ZEV and near-ZEV vehicles called for under California's ZEV program do not represent actual percentages of cars sold. Rather, automakers have many opportunities to earn credits toward the ZEV requirements that reduce the actual number of ZEVs they must produce.

In recent years, CARB has moved toward policies that reduce the number of pure ZEVs required of automakers, while increasing the number of extremely clean vehicles eligible for partial ZEV (or PZEV) credits.

The complexity of California's credit scheme makes it impossible to predict how many of each type of ZEV or PZEV vehicle will be on the road by 2020. Moreover, rapid changes in technology could render even CARB's initial assumptions invalid.

The key elements of the program are as follows:

- **Pure ZEVs** – The California rules require that two percent of the cars sold by large volume manufacturers by 2003 be "pure ZEVs"; those with no tailpipe or fuel-related evaporative emissions. Currently, that means electric cars, but it is expected that this will soon lead to commercial introduction of hydrogen fuel cells. In early years of the program, manufacturers can meet the requirement either with "full function" ZEVs, or with "city" or "neighborhood" electric vehicles that have a smaller range and travel at lower speeds. Credits for neighborhood electric vehicles are scheduled to decrease over time, so that by 2006 they will count for only 0.15 of a full-function ZEV.[42]
- **Advanced technology PZEVs (AT-PZEVs)** – Manufacturers will be allowed to satisfy up to two percent of ZEV requirement by marketing AT-PZEVs powered by compressed natural gas, hybrid-electric motors, methanol fuel cells, or other very clean means. Such vehicles must meet the strict SULEV emissions standards, have "zero" evaporative emissions, and have their emissions control systems under warranty for 150,000 miles.[43] Current hybrid-electric vehicles such as the Toyota Prius do not yet meet those standards. If manufacturers fail to fulfill the two percent allocated to AT-PZEVs, they must sell pure ZEVs instead.
- **Partial ZEV (PZEV) credits** – The California law also allows manufacturers to meet up to 6 percent of the 10 percent ZEV requirement by marketing cars that meet 150,000 mile SULEV emissions standards and the state's zero evaporative emissions criteria. These cars, which can be powered by internal combustion engines, are eligible for partial credit toward the ZEV mandate. Under the 2001 rules, their introduction will be phased in between 2003 and 2006.
- **Other credits** – Automakers can also receive additional credits for early introduction of ZEVs or for including technologies that enhance vehicle performance, such as fast recharging, extended range, and extended warranties on batteries or fuel cells.
- **Scope** – In the initial years of the program, the ZEV requirement applies only to pas-

senger cars and light trucks in the LDT1 category. Beginning in 2007, heavier sport utility vehicles, pickup trucks and vans will be phased into the sales figures used to calculate the ZEV requirement

Another important change adopted by CARB in 2001 is a gradual ratcheting up of the ZEV requirement from 10 percent to 16 percent over the next two decades as shown in Table 14.

Table 14: ZEV Percentage Requirement[44]

Model Years	Minimum ZEV Requirement
2003-2008	10 percent
2009-2011	11 percent
2012-2014	12 percent
2015-2017	14 percent
2018+	16 percent

However, the ample opportunities for additional credits and multipliers available to manufacturers will significantly reduce the amount of vehicles that must be sold – particularly in the early years of the program.

Assuming that North Carolina implements the ZEV requirement beginning in 2006 – and that implementation takes place in a similar fashion as it is expected to in California – approximately 44,000 pure ZEVs would be on the road in North Carolina in 2020, along with approximately 239,000 AT-PZEVs and 1.7 million PZEVs, based on a CARB projection of how automakers will satisfy the ZEV requirement over the next 20 years.[45] (See Table 15.)

Even with the small number of pure ZEVs required by the new version of the California standards, the overall ZEV program has the potential to bring two major benefits to North Carolina. It makes possible the significant reductions in air toxics and other pollutants called for by LEV II and it fosters the development of new technologies that can make automobiles much cleaner in the years to come.

Emissions Benefits

As noted above, the ZEV requirement is separate from the overall fleet-average emissions goals set out by the LEV II standards. In other words, automakers must meet the LEV II emission targets, regardless of how many, or what type, of ZEVs they put on the road. On the other hand, it can be argued that meeting LEV II's increasingly stringent emissions requirements will only be possible with the significant number of ultra-clean cars required under the ZEV program. Between the 2004 and 2010 model years, California's fleet-average standard for non-methane organic gases is scheduled to be reduced by 34 percent for cars and LDT1s and 50 percent for LDT2-4s. Coincidentally, these are the same years when the ZEV requirement is in the process of phase-in.

Using CARB's predictions of how automakers will comply with the ZEV rule, and applying them to North Carolina, the tailpipe NMHC emissions of ZEV, PZEV and AT-PZEV vehicles on the road in the state in 2020 would be approximately 1.2 million pounds. The same number of vehicles meeting the anticipated fleet average for NMOG under Tier 2 would emit 9.8 million pounds.

As stated in the previous section, the LEV II standards would result in a reduction of 16.8 million pounds of NMHC in 2020 when compared to Tier 2. ***Thus, more than half of the NMHC emissions savings gained under LEV II versus Tier 2 can be attributed to vehicles manufactured to fulfill the ZEV requirement.*** (See Table 16.)

Table 15: Estimated ZEVs and PZEVs in Use in North Carolina: 2020

	Cars	Percentage of light-duty fleet
ZEVs	44,000	0.7%
AT-PZEVs	239,000	3.8%
PZEVs	1,721,000	27.7%

Table 16: Tailpipe NMHC Emissions for Vehicles Used to Comply with ZEV Requirement vs. Comparable Tier 2 Vehicles, 2020 (in thousand pounds)

	NMHC (thousand lbs.)
ZEV, PZEV, AT-PZEV emissions	1,200
Tier 2 vehicle emissions	9,791
Difference	**8,591**
Total emissions savings LEV II vs. Tier 2	**16,782**
Pct. of savings due to vehicles covered by ZEV requirement	**51%**

The above analysis underestimates the impact of the ZEV requirement on air quality. First, the ZEV program's requirements 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 ZEV mandate will persist for a longer period of time than even conventional LEV II cars.

Second, those rules also require PZEVs and AT-PZEVs to have zero fuel-related evaporative emissions, reducing diurnal-plus-hot-soak NMOG emission standards by a further 30 percent for passenger cars and 17 to 23 percent for light-duty trucks from LEV II levels.[46] The tighter evaporative emission standards alone would lead to an additional reduction of approximately 800,000 pounds of NHMC emissions by the year 2020, over and above the evaporative emissions benefits obtained under LEV II.

In sum, the ZEV requirement, by mandating the sale of significant numbers of ultra-clean vehicles, brings the aggressive emission-reduction goals of the LEV II program within closer technological reach for the rest of the vehicle fleet. And its own particular rules for useful life and evaporative emissions result in additional emission reductions that would not occur were it not for the ZEV requirement.

Air Toxic Pollution Associated With Zero-Emission Vehicles

One argument often lodged against ZEVs – and electric vehicles in particular – is that the pollution caused by power plants that use coal, oil, natural gas or nuclear fuel to generate electricity for vehicles reduces or outweighs the environmental benefits of eliminating emissions from the vehicles themselves.

This argument sets up an unfair comparison with conventional vehicles. The "upstream" pollution caused by petroleum extraction, refining, storage and distribution is rarely factored into the analysis of emissions from internal combustion vehicles. Including oil spills, leaking underground storage tanks, and air emissions from refineries into a calculation of the environmental impacts of internal combustion engines would only serve to underscore the urgency of moving away from fossil fuels for transportation.

Because ZEVs use energy more efficiently than internal combustion engines, their upstream environmental impacts are generally less than those of conventional vehicles. However, in the case of electric vehicles, much depends on the source of electricity in the area in which the vehicles will operate. The approximately 44,000 zero-emission vehicles anticipated to be on the state's roads in 2020 would result in a 0.3 percent increase in demand for electricity in North Carolina compared to 1999 utility sales figures, should all of them be exclusively powered by electricity.[47]

At present, North Carolina generates more than 60 percent of its electricity from coal, a notoriously dirty source of power that is responsible for emissions of sulfur dioxide, nitrogen oxides, carbon dioxide and a slew of toxic substances, such as particulate matter and mercury, into the state's air.[48] There is reason to believe, however, that electric generation in North Carolina will be significantly cleaner in 2020 than it is today.

The imposition of tougher air pollution standards and the continued shift toward natural gas for electric generation promise to make electric power plants cleaner on a per-kilowatt-hour basis. There is also the potential for widespread adoption of renewable energy sources – such as solar and wind – for electricity generation.

Moreover, significant public pressure has mounted in recent years to clean up the state's old dirty coal-fired power plants, many of which are exempt from modern pollution controls. These plants pose significant environmental and public health risks and must be required to meet the same clean air standards as modern power plants – regardless of the potential for increased future demand from ZEVs.

The upstream impact of the ZEV requirement will be limited by other factors as well. First, only a small percentage of cars on the road in 2020 will be required to be "pure ZEVs." Should automakers choose to fill the ZEV requirement with PZEVs and AT-PZEVs, they will be able to use a variety of fuels to power them — including compressed natural gas, hybrid-electric motors, and methanol fuel cells – whose emissions would be regulated under LEV II.

Second, there is growing belief that hydrogen fuel cell vehicles – not electric vehicles – will become the "pure" ZEVs of choice within the next two decades. If that were to be the case, the need for off-site generation of electricity to power vehicles would be eliminated entirely, except for any electricity used to extract hydrogen for use as a fuel.

All of these factors serve to minimize the potential long-term pollution displacement effects that would result from the widespread adoption of ZEVs.

Stimulating Technology

The most important benefit of the ZEV program has little to do with reducing emissions in the near term. In its 12 years in existence in California, the ZEV program has proven to be a catalyst for the development of new technologies that could make automobiles even cleaner in the years to come.

The enactment of the original ZEV program in California in 1990 led to an almost immediate spike in interest among automakers in advancing electric 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.[49] 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.[50]

The renewed research effort had a major impact on the state of electric vehicle technology. Between 1996 and 2000, as a result of California's memorandum of agreement with the automakers, approximately 2,300 electric vehicles of seven different models took the road in California, demonstrating their viability as a transportation alternative.[51]

Other alternative technologies advanced as well. In 1999, Honda offered the first hybrid-electric vehicle, the Insight, for sale in the U.S. The "Big 3" American automakers have been working in conjunction with the federal government on a research effort to develop their own market-ready hybrids by 2003.[52] In 2001, the gasoline-powered California version of the Nissan Sentra became the first vehicle to qualify for PZEV credit. Other vehicles – such as the Honda Accord, Honda Civic GX and Toyota Prius, have achieved SULEV status, one of the main criteria for qualifying as a PZEV.

Hydrogen fuel cells are another technology that has recently made significant advances. Fuel cells use hydrogen to create a chemical reaction that generates electricity to power a vehicle. Fuels such as gasoline and methanol can be used to generate the hydrogen needed, or hydrogen itself can be used as a fuel. When hydrogen is used, the only "emissions" from the fuel cell are water and heat. Other base fuels generate small amounts of hydrocarbon emissions, but produce far less pollution than conventional vehicles because of their superior efficiency.

Until recent years, fuel cells have been mainly used in specialized applications such as space travel. But over the last several years, public-private partnerships at the federal level and in California have worked to bring fuel-cell vehicles to the demonstration stage. The California program, the California Fuel Cell Partnership, aims to demonstrate more than 70 fuel cell-powered cars and buses in the state by 2003.[53]

Automakers are already working toward the introduction of fuel-cell vehicles into their fleets, with Ford planning to market such a vehicle beginning in 2004, and other manufacturers planning to follow suit.[54]

The technological state of the art with regard to ZEVs and near-ZEVs is clearly far advanced from where it was when California adopted the ZEV requirement in 1990. Electric vehicles have moved from car-show concepts to daily reality for more than 2,000 Californians. Hybrid and fuel-cell vehicles have gone from the drawing board to concept development to, in the case of hybrids, mass production. California's ZEV requirement has clearly played a role in driving those technological developments.

However, the California experience has not only demonstrated the effectiveness of the ZEV requirement in spurring technological innovation, it has also proven the reverse – that without a specific requirement in effect, progress toward advanced technology vehicles will languish.

In 1996, California and the seven major automakers reached an agreement that would lift the ZEV percentage requirement until 2003 in exchange for a commitment by manufacturers to produce a certain number of electric vehicles. The agreement was billed as a way to guarantee that electric cars would make their way onto California's roadways quickly, with the hope that, once established, the vehicles would gain a foothold.

What state officials did not anticipate, however, is that once the agreement expired, automakers would quickly cease producing electric cars – despite evidence of continuing consumer demand.

The decision of the automakers to stop manufacturing electric cars in the absence of a specific government mandate was a setback to the long-term success of the ZEV program. "(C)ontinuity of ZEV production is critical. Market acceptance cannot build, and volume production cannot be achieved, if ZEVs continue to be available only in boom and bust cycles," wrote CARB in a 2000 report.[55] Had CARB maintained some form of ZEV mandate for 1998 through 2003, instead of reaching a voluntary agreement with the automakers, chances are that such a "boom and bust" cycle could have been avoided.

Whether the issue is safety, the adoption of emission control technologies, or the development of advanced technology vehicles, the automobile industry has proven time and time again that it requires a strong push from state and federal agencies before it adopts practices to protect public health and safety. The ZEV requirement, then, is a necessary step to hasten the development of technologies that will make North Carolina's air cleaner for decades to come.

An Investment Worth Making

The primary argument against the ZEV requirement is that it costs too much. Automakers must spend millions to develop new technologies. And the cars that result are much more expensive than the average consumer can afford.

Because few ZEV or near-ZEV cars have yet made it into general production, there is some truth to this argument. CARB estimates that incremental costs for ZEVs in 2003 will range from $7,500 for city electric vehicles to more than $20,000 for freeway-capable vehicles with advanced batteries.[56] However, CARB noted that if existing electric vehicles were to be produced in volume and if gasoline prices should increase significantly (to $1.75 per gallon), the life-cycle cost of a freeway-capable electric car would begin to approach that of a conventional car.[57] CARB's study also found that hybrid-electric vehicles and PZEV vehicles have significantly lower incremental costs than electric vehicles.

To help with the purchase of ZEVs during the term of the memorandum of agreement, California provided $5,000 per car subsidies to automakers, which then applied the subsidy to their ZEV lease or deducted it from the sticker price.[58] In 2000, California passed a new law under which consumers will be eligible for grants of up to $9,000 toward the purchase of a new ZEV.[59]

There are other costs associated with ZEVs as well. Widespread use of electric vehicles will require some public charging infrastructure to augment charging stations in homes and in offices. Fuel cells that rely on hydrogen as a base fuel will require the availability of hydrogen fueling stations.

But the infrastructure costs – and vehicle costs as well – are offset by the profound environmental and economic benefits that come from a reduced dependence on fossil fuels for transportation use. Subsidizing the development and deployment of advanced technology vehicles is a sound long-term investment to reduce future costs from public health and environmental damage.

Environmentally, in addition to the reductions in emissions noted above, ZEV and near-ZEV vehicles can play a major role in reducing the incentive to drill for oil in sensitive natural areas and eliminate many of the negative "upstream" impacts of oil production, from oil spills to pollution from refineries to leaking underground storage tanks. In addition, the ZEV requirement provides incentives for manufacturers to meet higher energy-efficiency standards for zero-emission vehicles and AT-PZEVs, which can not only ease demand for oil or electricity but also can reduce emissions of greenhouse gases responsible for global warming.

The global warming benefits of the ZEV program alone make it worth consideration. An analysis produced for CARB's 2000 biennial review of the ZEV program found that electric and hybrid-electric vehicles produced the lowest emissions of carbon dioxide among seven vehicle-fuel combinations studied.[60] Hydrogen fuel cells, which were not studied, have the potential for even greater reductions in carbon dioxide emissions, provided that the hydrogen extraction process is highly energy efficient or powered with renewable energy. With the number of vehicle miles traveled expected to increase in North Carolina and elsewhere over the next two decades, the introduction of significant numbers of electric, fuel cell or extremely efficient internal combustion engines (such as hybrid electrics) will be needed to prevent further increases in carbon emissions from the light-duty fleet.

Economically, the introduction of ZEVs would cushion the economy from the impact of intermittent oil-price shocks, reduce dependence on foreign oil, and safeguard North Carolina from severe social disruption should the oil supply become significantly strained within the next two decades, as some experts predict. The development and production of ZEVs can also help spur the economy, provided that the United States acts aggressively to take leadership in this emerging market.

With its concentration of high-tech research facilities and companies, North Carolina is already taking advantage of the economic benefits of clean vehicle development. In July 2001, H Power Corporation opened a 90,000-square-foot facility in Monroe to manufacture its stationary, mobile and portable fuel cells.[61] Porvair, PLC, a maker of porous materials used in fuel cell applications, operates a 136,000-square-foot manufacturing plant in Hendersonville.[62] Universities including North Carolina State and the North Carolina Agricultural and

Technical State University are currently engaged in aspects of fuel cell research.[63] Creating a steady, expanding, local market for these technologies can only help lure additional companies, capital and research funding to the state's emerging alternative fuel industry.

Finally, the adoption of the ZEV requirement can help hasten the development of alternative fuel sources for other uses – from home heating to manufacturing – bringing added stability and efficiency to those sectors as well.

These benefits more than justify the financial and regulatory investment that has been made as a result of California's ZEV requirement.

A Role for North Carolina

North Carolina's adoption of LEV II and the ZEV requirement would not, in and of itself, bring about the massive technological shift described above. However, the state has a key role to play in making such a shift happen.

North Carolina is home to 2.8 percent of all passenger cars and trucks registered in the U.S.[64] Were it to join the other states that have already adopted the ZEV requirement, the program would affect states with more than 20 percent of the nation's passenger cars.

In addition, by becoming the first state in the southeast to adopt the program, North Carolina can set a strong example for how fast-growing states can adapt to rapidly developing air pollution problems. Like many other states in the southeast, North Carolina's population is expected to continue to grow over the next several decades. Aggressive steps, such as adoption of the LEV/ZEV program, will be needed to ensure that North Carolina's air pollution problems – which already threaten the health of millions of state residents – do not continue to worsen in the years to come.

In short, North Carolina is well situated to adopt a policy that would not only reap major benefits for its own citizens, but help build the solid, sustainable base of demand that will be required for ZEVs to become an economically viable alternative in the years to come.

6. POLICY RECOMMENDATIONS

North Carolina should join Massachusetts, New York, Vermont and Maine in adopting the California Low-Emission Vehicle II standards.

Adoption of the LEV II standards and the ZEV requirement is one of the most effective steps North Carolina can take to protect citizens from the health dangers posed by air toxics, reduce the emission of smog-forming pollutants, and strengthen the state's long-term economic and environmental security.

North Carolina should consider other incentives for ZEV development and use.

Even under the LEV II program, it will be several years before North Carolina residents have the opportunity to purchase or own a ZEV or near-ZEV vehicle. There are several ways the state can encourage the speedy introduction of ultra-clean vehicles.

- Direct subsidies or tax credits for consumers.
- Requirements that government or public agencies purchase zero emission and alternative fuel vehicles for appropriate uses.
- Encouragement of voluntary labeling systems (such as one in Maine) that can help environmentally conscious consumers identify the cleanest cars.
- Providing assistance for the development of charging infrastructure for electric vehicles or other infrastructure improvements.

We acknowledge that it may be politically difficult with the recent economic downturn to create new incentives such as direct subsidies. But it is important for state officials to realize that a thoughtful and effective approach to the introduction of ZEVs will require carrots as well as sticks. The experience of California and other states should help state officials decide what works and what doesn't in encouraging ZEV use.

Adopt Other Policies to Reduce Emissions of Toxic Substances into North Carolina's Air

Light-duty cars and trucks make up a significant portion of air toxics releases in North Carolina. But other state and federal policies will likely also be needed to fully protect state residents from the dangers posed by air toxics. 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 air toxics emissions that would result from adoption of the LEV II standards.

APPENDIX A: METHODOLOGY AND SOURCES

Assumptions

This report is intended to present an estimate of anticipated reductions in toxic air pollution that would take place annually in North Carolina beginning in 2020 under the LEV II standards as opposed to federal Tier 2 emission controls. Estimates of these relative benefits – as well as other conclusions reached by this report – were derived using a simplified methodology that does not reflect all factors that can influence vehicle emissions. It is intended as a measure of the relative policy implications of the LEV II and Tier 2 standards, not a projection of future toxic pollution in North Carolina.

Two assumptions underlie this analysis:

- **This study focused on emissions from light-duty vehicles only.** New standards for medium-duty passenger vehicles are part of the updated Tier 2 and LEV II rules. However, the rules still primarily focus on light-duty vehicles, which make up the vast majority of vehicle miles traveled in the U.S. As a result, this analysis understates the relative emissions benefits of both the Tier 2 and LEV II programs.
- **This study assumes that no light-duty vehicles are powered by diesel.** This assumption is largely true at present, because diesel-powered vehicles make up less than one percent of overall car and light truck sales. However, as noted earlier, the EPA projects that light-duty diesel vehicles could increase to as much as 9 percent of all new car sales and 24 percent of all light truck sales by 2015 under one scenario.

  Because these projections of future diesel penetration of the light-duty fleet are highly speculative – and because the use of diesel fuel results in a different mix of air toxics emissions than gasoline, introducing a complicating factor to the analysis – this study assumed that the light-duty fleet on the road in 2020 will continue to be gasoline-powered vehicles. Including projections of increased use of diesel would increase the gap between the effects of Tier 2 and LEV II on toxic pollution.

Total Air Toxics Emissions and Ambient Concentrations

Data for overall on-road emissions and ambient air concentrations of acetaldehyde, 1,3-butadiene, benzene and formaldehyde were taken from the EPA's National-Scale Air Toxics Assessment. The data represent estimated 1996 emissions and concentrations. States and counties were ranked for overall emissions and ambient concentrations based on the average of their rank for emissions and concentrations of each of the four air toxics studied.

Emissions Estimation

Overall NMHC Emissions

Estimates of relative reductions in non-methane hydrocarbon (NMHC) emissions are based on methodologies for the calculation of carbon monoxide and evaporative hydrocarbon emissions developed by Cambridge Systematics for their 1999 analysis of the relative benefits of the Tier 2 and LEV II programs for the Massachusetts Department of Environmental Protection.

Emission factors for the Tier 2 program were based on a scenario in which Tier 1 standards were in effect in North Carolina for model year 1996-2000 vehicles, NLEV standards were in effect for 2001-2003 vehicles, and Tier 2 standards were phased in for model year 2004 and above vehicles. Emission factors for the LEV II program were based on the above scenario, except with the imposition of Tier 2 standards from 2004-2005 and LEV II standards beginning in 2006.

To estimate tailpipe emissions, the EPA's MOBILE5b model was run to derive baseline, by-model-year emission factors in

2020 for model year 1996 through 2020 vehicles *exclusive* of the effects of the NLEV and Tier 2 programs. National default settings – including an average vehicle speed of 24.6 miles per hour and the default breakdown of travel fractions by model year – were used based on sample input files created by EPA for a version of MOBILE5b designed to model the impact of Tier 2 evaporative emission controls (T2EVAP). Exceptions to the national defaults were made to account for southern ambient temperatures, gasoline Reid vapor pressure (RVP) of 7.8 psi (commensurate with summertime gasoline RVP standards in effect in much of North Carolina's urban areas per "Guide on Federal and State RVP Standards for Conventional Gasoline Only," U.S. EPA, March 2001), state inspection and maintenance (I/M) and anti-tampering programs and oxygenated fuels data as detailed in "Guidelines for Evaluating the Air Quality Impacts of Transportation Facilities," North Carolina Department of Environment and Natural Resources, October 1999. For the purpose of maintaining simplicity in the modeling process, all North Carolina counties were assumed to use oxygenated fuels.

For each model year, the NMHC final emission rate (FER) from the MOBILE5b run was adjusted based on the difference between the certification standard in effect for the program studied and the baseline Tier 1 certification standard. Certification standards at 100,000/120,000 miles for all four programs studied (Tier 1, NLEV, Tier 2, LEV II) were taken from Cambridge Systematics' report for the Massachusetts DEP.

The equation used for each vehicle category and model year is as follows:

$$FER = ZML_{Tier1} * R_c + (FER_{Tier1} - ZML_{Tier1}) * [R_c + (1-R_c) * (1-DRBEN)]$$

Where:

FER is the final emission rate for each model year under the scenario being studied.

ZML_{Tier1} is the zero-mile emission level under the Tier 1 program (estimated as the FER_{Tier1} output through MOBILE5b for 2020 model year vehicles)

R_c is the ratio of the control certification standard (NLEV/Tier2 or NLEV/Tier2/LEV II) to the Tier 1 certification standard.

FER_{Tier1} is the final emission rate for baseline Tier 1 vehicles, computed from MOBILE5b as $FER_{Tier11} = (BEF + TAMPER) * SALHCF$

DRBEN is the proportion of certification ratio benefits applied to the deterioration rate, assumed for this analysis to be 1.0. In other words, this analysis assumes that the deterioration rate of emissions systems will be reduced from Tier 1 levels at the same rate as the reduction in certification standards.

The resulting FERs for each model year were then weighted by the model year travel fractions in MOBILE5b to derive an emission factor for the entire fleet. This process was then repeated for all five classes of vehicles studied (LDV, LDT1-4).

This process mirrors the method used by Cambridge Systematics to model the carbon monoxide emission benefits of the LEV II and Tier 2 programs with one significant difference: the value of DRBEN, assumed in Massachusetts to be 0.5 was assumed to be 1.0 here. This assumption serves to magnify the tailpipe emission benefits of both the Tier 2 and LEV II programs as well as the difference between them. However, this more liberal assumption results in deterioration rates that more closely mimic those derived by EPA's Tier 2 modeling for the Charlotte metropolitan area as published in "Development of Light-Duty Emission Inventory Estimates in the Notice of Proposed Rulemaking for Tier 2 and Sulfur Standards," U.S. EPA, March 1999, Tables G-16 and G-20. Thus, they more accurately reflect real conditions than the more conservative assumption made in Massachusetts.

For evaporative emissions, a similar methodology was used, with by-model-year baseline outputs prior to Tier 2/LEV II evaporative emission controls output from MOBILE5b and then reduced in proportion to the reduction of certification standards for each program. This reduction was only applied to the "evaporative" (diurnal plus hot soak) and resting portions of evaporative emissions – other components of evaporative emissions are not reduced by the new standards. It was also applied only to that proportion of vehicles covered by the new standards during phase-in years. Percentage reductions in standards were taken directly from the Massachusetts DEP analysis. By-model-year emission factors were then weighted and combined as with tailpipe emissions above.

The resulting tailpipe and evaporative emission factors are shown in Table A-1.

Table A-1. Emission Factors for Light-Duty Tailpipe and Evaporative Emissions in North Carolina, 2020 (grams/mile)

	Tier 2		LEV II	
	Tailpipe	Evaporative	Tailpipe	Evaporative
LDV	0.24	0.305	0.176	0.279
LDT1	0.3	0.318	0.235	0.306
LDT2	0.268	0.294	0.246	0.267
LDT3	0.506	0.399	0.437	0.371
LDT4	0.506	0.399	0.437	0.371

Once emission factors were derived for both tailpipe and evaporative emissions, they were multiplied by the total light-duty VMT projected for 2020 for each vehicle class (as derived below) to arrive at an estimate of total emissions.

MOBILE5b – unlike later models, such as the EPA's Tier 2 model and MOBILE6 – is incapable of modeling the effects of gasoline sulfur content on vehicle emissions. Adapting the Tier 2 model for this analysis was rejected as too time consuming, while MOBILE6 was made publicly available by EPA only as this analysis was nearing completion. However, because lower sulfur limits adopted by EPA along with the Tier 2 rule are expected to reduce deterioration of emission systems, the more liberal assumption made above with relation to deterioration rates corrects for this weakness in MOBILE5b.

Air Toxics

Estimated emissions of individual air toxics were calculated by converting total estimated NMHC emissions into estimated NMOG emissions, then multiplying by speciation percentages in EPA's Speciate database. The speciation profiles chosen were profile #1313 for tailpipe emissions and profile #1305 for evaporative emissions. Both profiles are based on 1990 baseline gasoline. No attempt was made to account for differences in speciation profiles based on the use of oxygenated gasoline.

In both profiles, the total organic gas (TOG) percentages in the EPA's speciation model were converted to NMOG by eliminating the methane portion of the profile. In addition, the profiles were used to estimate an NMHC to NMOG conversion factor based on the percentage of TOG represented by non-hydrocarbon organic gases (alcohols, ethers, ketones and aldehydes). This factor was 1.027 for exhaust and 1.030 for evaporative emissions. NMHC emissions were multiplied by the conversion factor, and then by the percentages in the NMOG portion of the speciation profile to derive individual air toxics emissions.

Volatile Organic Chemicals

Speciation profiles were also employed to derive a NMOG to VOC conversion factor, by calculating the percentage of NMOG represented by compounds exempted by the EPA from its definition of VOCs per Code of Federal Regulations 40 CFR 51.100(s)(1). This factor was found to be 0.971 for exhaust and 1.0 for evaporative emissions. The factor was then multiplied by total NMOG emissions to derive total VOC emissions.

Number of Cars Taken Off the Road

An estimate was made of the number of present day cars that would be taken off the road to equal the additional air toxics pollution reductions in LEV II. The "car" used for this comparison is based on composite emission factors output from MOBILE5b for year 2002 light-duty vehicles, multiplied by the estimated number of vehicle-miles traveled by a light-duty car in 2020 per the methodology below, and then the chemical speciation profiles listed above. This calculation yields an average per-car amount of air toxics emissions. The total air toxics reductions under LEV II were then divided by this per-car amount to arrive at the number of cars that would be taken off the road.

Fleet Characteristics and Vehicle Miles Traveled

Unless otherwise noted, fleet and vehicle miles traveled data attributed to the EPA are from "Fleet Characterization Data for MOBILE6: Development and Use of Age Distributions, Average Annual Mileage Accumulation Rates and Projected Vehicle Counts for Use in MOBILE6," published April 1999.

The total number of light-duty vehicles in use in 2020 in the state was determined by taking the national in-use vehicle fleet estimates from EPA and multiplying them by the percentage of cars and trucks registrations for the state in 2000 per Ward's Automotive Yearbook 2001. The number of light-duty trucks in each class was determined by multiplying the total number of light-duty trucks by ratios of truck classes established by EPA for MOBILE6.

Vehicle counts were further broken down by model year using age distribution percentages for each vehicle class established by EPA.

Vehicle miles traveled data are based on the estimate of 47-state VMT for 2020 prepared by EPA corrected to take account for VMT in Alaska, California and Hawaii. Total VMT was then disaggregated into national VMT by vehicle subgroupings (LDV, LDT1/2 and LDT3/4) using ratios in worksheet T2MODAQA of EPA's Tier 2 model, and further broken down into individual vehicle classes using the vehicle stock splits in EPA's MOBILE6 fleet characterization data.

Two correction factors were applied to determine what portion of VMT should be applied to vehicles of each model year and to account for different driving habits at the state versus national level.

A vehicle age factor was applied consisting of the vehicle mileage accumulation rates developed by EPA divided by the average VMT per vehicle for 1996 per Ward's Automotive Yearbook 2001.

A state correction factor was applied consisting of the average VMT per vehicle for the state in 1999 divided by the national average VMT for 1999 (per Ward's and the "Highway Statistics 1999" published by the U.S. Department of Transportation).

The result was a state-specific estimate of the number of miles traveled per vehicle by vehicles in each class and each model year for the year 2020. This number was then multiplied by the estimated fleet composition numbers to arrive at the total number of VMT traveled by vehicles in each class and each model year during 2020.

ZEV Program Analysis

Estimates of tailpipe emissions for ZEV-compliant vehicles were obtained by multiplying the average estimated VMT of vehicles in each model year and class in 2020 by the number of ZEV-compliant vehicles in each model year anticipated to be on the road in North Carolina in 2020, and then multiplying the result by an emission factor created for SULEV vehicles per the methodology above. Emissions from an identical number of Tier 2 LDVs were calculated in a similar way to allow direct comparison. Estimates of evaporative emissions from ZEV-compliant vehicles were obtained in a similar fashion and compared to evaporative emissions from a similar number of LEV II LDVs.

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.

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.

NMHC – Non-methane hydrocarbons. Category of emissions that includes many air toxics. Includes most of the NMOG category, but not aldehydes, ketones, alcohols and ethers

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.

OTC – Ozone Transport Commission. A group of northeastern states formed by Clean Air Act of 1990 to promote coordinated smog-reduction policies.

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: EPA LIST OF REGULATED MOBILE SOURCE AIR TOXICS

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

Source: Federal Register: March 29, 2001 (Volume 66, Number 61), pages 17229-17273.

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[i] Polycyclic Organic Matter includes organic compounds with more than one benzene ring, and which have a boiling point greater than or equal to 100 degrees centigrade. A group of seven polynuclear aromatic hydrocarbons, which have been identified by EPA as probable human carcinogens.

APPENDIX D: AMBIENT CONCENTRATIONS OF KEY AIR TOXICS IN NORTH CAROLINA COUNTIES, 1996

County Rankings for Ambient Concentrations of Selected Air Toxics from On-Road Mobile Sources

	1,3 Butadiene		Formaldehyde		Benzene		Acetaldehyde		
County	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Average Rank
Mecklenburg	0.074	2	0.500	1	0.863	1	0.542	1	1.3
Durham	0.066	3	0.419	3	0.765	2	0.480	2	2.5
Guilford	0.062	4	0.431	2	0.749	4	0.476	3	3.3
Buncombe	0.079	1	0.395	6	0.751	3	0.352	9	4.8
Forsyth	0.062	5	0.407	4	0.707	5	0.421	6	5.0
Wake	0.055	10	0.381	7	0.676	6	0.448	4	6.8
Gaston	0.053	11	0.402	5	0.650	7	0.439	5	7.0
Cabarrus	0.060	7	0.366	8	0.643	8	0.376	7	7.5
Cumberland	0.059	8	0.308	9	0.612	9	0.364	8	8.5
Alamance	0.050	12	0.306	10	0.569	10	0.350	10	10.5
Catawba	0.056	9	0.301	11	0.560	11	0.294	12	10.8
Orange	0.044	13	0.297	12	0.528	13	0.348	11	12.3
New Hanover	0.060	6	0.256	15	0.534	12	0.248	17	12.5
Davidson	0.030	17	0.280	13	0.410	15	0.291	13	14.5
Henderson	0.034	16	0.274	14	0.422	14	0.283	14	14.5
Rowan	0.034	15	0.241	16	0.393	16	0.243	18	16.3
Cleveland	0.027	20	0.220	18	0.333	19	0.227	19	19.0
Randolph	0.023	25	0.217	19	0.335	18	0.253	16	19.5
Lincoln	0.021	29	0.224	17	0.321	20	0.253	15	20.3
Wayne	0.037	14	0.170	24	0.338	17	0.158	29	21.0
Iredell	0.025	23	0.194	20	0.304	22	0.196	21	21.5
Burke	0.029	19	0.183	21	0.306	21	0.169	27	22.0
Rockingham	0.021	28	0.174	22	0.259	25	0.174	25	25.0
Lee	0.025	24	0.160	27	0.268	24	0.155	30	26.3
Onslow	0.029	18	0.140	31	0.276	23	0.140	37	27.3
Harnett	0.015	45	0.168	25	0.248	27	0.213	20	29.3
Union	0.016	43	0.162	26	0.235	30	0.187	22	30.3
Nash	0.025	22	0.137	35	0.256	26	0.137	39	30.5
Caldwell	0.020	32	0.148	29	0.238	29	0.147	33	30.8
Davie	0.014	47	0.171	23	0.232	31	0.183	24	31.3
Pitt	0.025	21	0.125	41	0.243	28	0.123	47	34.3
Stanly	0.020	30	0.140	32	0.227	32	0.132	44	34.5
Rutherford	0.016	42	0.139	33	0.205	36	0.145	34	36.3
Person	0.017	41	0.137	36	0.214	34	0.145	35	36.5
Stokes	0.011	53	0.144	30	0.196	39	0.164	28	37.5
Polk	0.010	59	0.151	28	0.193	42	0.185	23	38.0
Robeson	0.017	40	0.126	40	0.205	37	0.136	40	39.3
Wilson	0.019	34	0.123	42	0.210	35	0.123	46	39.3
Chatham	0.011	58	0.137	37	0.197	38	0.171	26	39.8
Edgecombe	0.022	26	0.115	51	0.214	33	0.110	51	40.3
Granville	0.011	57	0.131	38	0.182	46	0.151	31	43.0
Haywood	0.021	27	0.116	48	0.194	40	0.089	59	43.5
Surry	0.018	37	0.119	45	0.193	43	0.110	50	43.8
Alexander	0.012	52	0.123	43	0.184	44	0.138	38	44.3
McDowell	0.019	35	0.119	46	0.193	41	0.097	56	44.5
Hoke	0.011	56	0.120	44	0.179	48	0.148	32	45.0
Watauga	0.018	36	0.116	47	0.183	45	0.102	53	45.3

	1,3 Butadiene		Formaldehyde		Benzene		Acetaldehyde		
County	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Ambient Concentration	State Rank	Average Rank
Mitchell	0.013	50	0.130	39	0.174	51	0.135	42	45.5
Madison	0.009	62	0.137	34	0.171	52	0.144	36	46.0
Johnston	0.012	51	0.114	52	0.174	50	0.129	45	49.5
Lenoir	0.019	33	0.100	57	0.181	47	0.085	62	49.8
Vance	0.017	39	0.103	56	0.175	49	0.095	57	50.3
Transylvania	0.015	44	0.107	55	0.167	53	0.097	55	51.8
Caswell	0.009	65	0.116	49	0.163	55	0.135	43	53.0
Franklin	0.009	63	0.111	53	0.158	58	0.135	41	53.8
Wilkes	0.014	46	0.098	59	0.162	56	0.090	58	54.8
Pasquotank	0.020	31	0.086	62	0.164	54	0.059	72	54.8
Craven	0.017	38	0.088	61	0.160	57	0.073	64	55.0
Scotland	0.013	49	0.094	60	0.158	59	0.099	54	55.5
Yancey	0.009	64	0.115	50	0.141	62	0.120	48	56.0
Yadkin	0.010	61	0.109	54	0.156	60	0.117	49	56.0
Richmond	0.013	48	0.083	64	0.147	61	0.083	63	59.0
Moore	0.011	54	0.086	63	0.140	63	0.089	60	60.0
Avery	0.008	67	0.099	58	0.128	64	0.108	52	60.3
Greene	0.008	66	0.077	65	0.119	65	0.089	61	64.3
Sampson	0.008	69	0.062	66	0.100	67	0.065	65	66.8
Carteret	0.011	55	0.057	71	0.102	66	0.049	79	67.8
Brunswick	0.008	68	0.059	68	0.095	69	0.061	69	68.5
Halifax	0.010	60	0.057	72	0.100	68	0.051	78	69.5
Anson	0.007	74	0.058	69	0.089	70	0.060	70	70.8
Ashe	0.007	75	0.060	67	0.086	73	0.060	71	71.5
Jackson	0.008	71	0.058	70	0.089	71	0.051	77	72.3
Columbus	0.006	76	0.055	76	0.086	72	0.063	66	72.5
Montgomery	0.005	84	0.057	73	0.084	76	0.062	67	75.0
Martin	0.007	72	0.052	79	0.086	74	0.052	76	75.3
Alleghany	0.006	79	0.056	74	0.082	77	0.055	75	76.3
Beaufort	0.008	70	0.049	81	0.085	75	0.046	82	77.0
Pender	0.005	86	0.055	75	0.077	80	0.062	68	77.3
Warren	0.006	80	0.053	78	0.081	78	0.055	74	77.5
Macon	0.007	73	0.051	80	0.081	79	0.046	83	78.8
Swain	0.006	78	0.054	77	0.077	81	0.049	80	79.0
Bladen	0.004	90	0.049	82	0.072	82	0.058	73	81.8
Graham	0.006	77	0.046	83	0.067	83	0.039	89	83.0
Duplin	0.005	85	0.041	85	0.065	84	0.043	85	84.8
Clay	0.005	87	0.041	86	0.062	85	0.043	86	86.0
Camden	0.004	93	0.040	88	0.059	86	0.044	84	87.8
Cherokee	0.005	88	0.037	89	0.058	87	0.039	88	88.0
Jones	0.003	98	0.041	87	0.056	89	0.047	81	88.8
Currituck	0.004	92	0.041	84	0.053	92	0.042	87	88.8
Hertford	0.005	82	0.034	92	0.056	90	0.030	92	89.0
Pamlico	0.004	89	0.036	90	0.057	88	0.035	90	89.3
Perquimans	0.005	81	0.033	93	0.055	91	0.029	93	89.5
Gates	0.004	94	0.035	91	0.048	93	0.033	91	92.3
Dare	0.005	83	0.021	98	0.041	97	0.014	98	94.0
Northampton	0.004	95	0.028	94	0.042	95	0.026	95	94.8
Bertie	0.003	97	0.027	95	0.042	94	0.026	94	95.0
Washington	0.004	91	0.024	97	0.041	96	0.021	97	95.3
Chowan	0.003	96	0.025	96	0.040	98	0.022	96	96.5
Tyrrell	0.001	99	0.007	99	0.010	99	0.006	99	99.0
Hyde	0.000	100	0.003	100	0.005	100	0.003	100	100.0

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18. Walsh, 9. The LEV II NMOG fleet averages are measured at 50,000 miles rather than 120,000 miles useful life.
19. Walsh, 7.
20. 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.
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27. The low percentage difference for the LDT1/2 category also reflects a conservative assumption regarding implementation of the LEV II program in North Carolina. This analysis assumes that LEV II emissions standards will be implemented on the same schedule as California, only beginning in 2006. This results in an anomaly in which Tier 2 certification standards are actually more stringent for LDT2 vehicles for two years during the phase-in of the program, minimizing the relative benefits of LEV II for those vehicles. In reality, this situation is unlikely to occur. State officials could choose to apply Tier 2 limits where they are more stringent than LEV II, as California officials have done in their implementation of LEV II. This would result in LEV II emission levels for LDV2s that are lower than those shown here.

28. This analysis assumes that Tier 2 evaporative emission controls begin phase-in in 2004, while LEV II controls are phased in beginning in 2006. Should state officials choose to begin implementation of Tier 2 evaporative controls during the 2004-2005 model years under the LEV II scenario, the difference between the two programs would be even greater. See previous footnote for a related discussion.

29. The chemical composition of vehicle exhaust varies greatly depending on the vehicle and the type of fuel used. The speciation profiles used in this analysis are based on 1990 baseline gasoline and do not account for the use of oxygenated gasoline. The results presented here are intended to be suggestive of the air toxics reductions that could be expected under LEV II.

30. "Current emission standards" includes implementation of NLEV program for model years 2001 and after.

31. Estimate of "average car" toxic emissions based on applying speciation profile to composite LDV fleet tailpipe and evaporative emission factors for 2002 generated from EPA's MOBILE5b model, multiplied by estimated average vehicle-miles traveled in 2020.

32. U.S. Environmental Protection Agency, "Tier 2/Sulfur Regulatory Impact Analysis," December 1999, III-36.

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34. The NMOG standards for the ULEV bin under LEV I are 0.055 g/mi for LDVs and LDT1s; 0.07 for LDT2s; 0.143 for LDT3s; and 0.167 for LDT4s, compared to an anticipated fleet average under Tier 2 of 0.09 g/mi. The NOx standards are 0.3 g/mi for LDVs and LDT1s; 0.5 for LDT2s; 0.6 for LDT3s; and 0.9 for LDT4s, compared with the 0.07 g/mi fleet average standard under Tier 2. From Walsh, 5-6.

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46. Based on maximum non-fuel evaporative emissions of 0.35 grams per test for passenger cars, 0.50 grams per test for light-duty trucks 6,000 lbs. GVW and under, and 0.75 grams per test for light-duty trucks from 6,001 to 8,500 lbs. Source: California Code of Regulations, title 13, section 1976(b)(1)(E).

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