NO BREATHING IN THE AISLES

DIESEL EXHAUST **INSIDE** SCHOOL BUSES

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CLEAN AIR

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Diesel Exhaust Inside School Buses

Principal Authors and Researchers
Gina M. Solomon, M.D., M.P.H.
Todd R. Campbell, M.E.S., M.P.P.
Gail Ruderman Feuer
Julie Masters
Artineh Samkian
Kavita Ann Paul

Contributor
Jesus Santos Guzman, M.D., M.S.

School Bus Monitoring Study Development and Oversight
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Editorial Assistance
Faith Salie and Christine Steele

Production
Virginia Calvano
Bonnie Greenfield

Cover Artists
David Vegezzi, vegezzistudio.com (design)
Matt Cooper (photos)

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INTRODUCTION

It's a common occurrence to see and smell a black cloud of smoke rising from behind a diesel school bus. We expect that inhaling these fumes outside the bus would be dangerous for our health—and it is. But does that same diesel exhaust pose a risk to children sitting inside the bus on their way to and from school? We initiated this study of diesel exhaust levels inside school buses to answer this question in light of the overwhelming evidence that diesel exhaust causes cancer and premature death and exacerbates asthma and other respiratory illnesses. In fact, government regulators estimate, based on lifetime risks, that diesel exhaust is responsible for a surprising 125,000 cancers nationwide.[1] Studies in California reveal that more than 70 percent of the risk of cancer from air pollution comes from diesel exhaust alone.[2]

We designed and performed this study to measure the level of diesel exhaust to which children are typically being exposed as they ride on buses to and from school each day, and to determine whether years of such exposure poses a health risk to a young child. The results were startling: A child riding inside of a diesel school bus may be exposed to as much as 4 times the level of toxic diesel exhaust as someone standing or riding beside it. Under federal law, these exposures translate into a *significant* risk of cancer to children. In fact, these exposures pose from 23 to 46 times the cancer risk level considered significant under federal law. What's more, these troubling results suggest that diesel exhaust on school buses could contribute to respiratory problems among sensitive children, such as asthmatics. Importantly, most of the buses we tested did not emit a significant amount of visible black smoke, as one would usually expect from a dirty diesel bus. The message is clear: Even a "smokeless" diesel school bus may be exposing children to potentially dangerous levels of diesel exhaust.

The harmful health effects of diesel exhaust have been studied and well documented for decades. In recent years, an increasing number of health authorities have recognized the cancer-causing effects of diesel exhaust, including the U.S. Environmental Protection Agency (EPA) and the state of California.[3] Aside from its cancer-causing properties, diesel exhaust is also known to be a major source of fine particles, which can lodge deep in the lungs and exacerbate asthma, a condition most prevalent among children.[4] In addition, smog-forming oxides of nitrogen, or "NOx," which are also emitted from diesel engines in mass quantities, have recently been linked to decreased lung function growth in children.[5] Indeed, children are generally more susceptible than adults to the negative health effects of air pollution. Among other reasons, a child's organs are still developing and are far less capable of defending the body from airborne toxics and pollutants.

Unfortunately, the vast majority of the nation's school bus fleets run on diesel fuel. Moreover, many of the these fleets contain a significant percentage of buses that are 15 years of age or older and that are much more polluting than even the diesel buses manufactured today. In fact, some fleets contain buses manufactured prior to 1977, before federal highway safety standards were even adopted. Ironically, this means that our children—among the most vulnerable members of our society—are riding on some of the highest polluting vehicles on the road today.

There is, however, some good news. Cleaner alternatives to diesel buses, such as those that run on natural gas and propane, are widely available and are being used by an increasing number of school districts across the country. In addition, federal, state and local governments have set aside funds earmarked exclusively to help public and private school fleet operators cover the incremental costs of purchasing these cleaner alternatives. These funding sources are still relatively limited, however, and parents, educators, and school administrators across the country need to pressure their elected officials to make replacement of old, dirty diesel school buses a top budgetary priority.

There are also interim solutions to help clean up existing diesel school buses prior to when they can be replaced. Initial testing shows that diesel aftertreatment technologies, such as particulate traps, can be a cost-effective means of reducing emissions from existing diesel vehicles like school buses. Because they have not yet been fully proven to reduce the risks posed to children, in our view, they should not be considered the ultimate solution. They can, however, be a valuable short-term measure. One current barrier to the widespread retrofit of school buses with particle traps is that the traps require the use of low-sulfur diesel fuel (and work best when the fuel has a sulfur content of 15 part per million or less), which is available so far in limited supplies only in Southern California, the San Francisco Bay Area of California, Houston, and New York City. Low-sulfur diesel fuel will be available more widely in the future in order to comply with the rule EPA adopted in December 2000 mandating the sale of lower-sulfur diesel fuel nationally in 2006. This rule is essential to an effective retrofit strategy and must not be weakened or repealed by EPA in the future.

Finally, there are immediate measures available to school districts and bus drivers which may be appropriate in individual situations. Our study reveals that diesel exhaust levels are highest in the rear of the bus and when the windows of the bus are closed. To the extent practicable, therefore, keeping the windows on the bus open and seating children in the front of the bus before filling the rear seats are additional options available to reduce exposures to children riding on diesel school buses.

This report is intended to inform parents, educators, school administrators, and federal, state and local policy makers of the hazards children face from exposure to diesel exhaust inside school buses and the cleaner alternatives which are readily available. Our major recommendations to address the risks posed by diesel school buses are:

1. School districts should immediately modify their purchasing practices to replace aging diesel school buses with cleaner alternative fuel school buses such as natural gas;
2. Federal, state, and local agencies and legislative bodies should make additional funding available for the purchase of cleaner alternative fuel school buses;
3. Local air quality management districts should adopt rules similar to the rule scheduled for adoption by the South Coast Air Quality Management District (SCAQMD) in Southern California in March 2001, that require local school districts to purchase only alternative fuel school buses.

4. Where low-sulfur diesel fuel is available, school districts should retrofit existing diesel school buses not scheduled for short-term retirement with particulate traps to reduce exposures. We also urge EPA to require that low-sulfur diesel fuel be made available in advance of 2006 so that school buses—and other heavy-duty vehicles—can be retrofitted with traps to reduce their hazardous emissions. Alternatively, we urge the California Air Resources Board and other states, where possible, to require the sale of low-sulfur diesel fuel in their states before 2006.

5. School officials should ensure that bus drivers, to the extent feasible, keep windows open on school buses and seat students toward the front of the bus before filling the rear seats.

6. If a child has asthma or another respiratory illness, a parent may wish to check whether the child's breathing symptoms worsen after riding on a diesel school bus and, if so, consult with the child's physician.

We urge parents and educators troubled by the findings in this report to contact their school board officials, elected officials, and federal, state, and local air quality regulators to take these actions. We have included sample letters in Appendix G of this report.

HIGHLIGHTS

- This monitoring study was designed to measure the level of diesel exhaust to which children are typically being exposed as they ride on buses to and from school each day, and to determine whether years of such exposure poses a health risk to a young child.
- A child riding inside of a diesel school bus may be exposed to as much as 4 times the level of toxic diesel exhaust as someone riding in a car immediately in front of that same bus.
- Diesel exhaust levels are higher in the back of the bus as compared to the front of the bus and are highest when the windows on the bus are closed.
- Diesel exhaust levels inside the bus increase while driving uphill and sometimes while driving downhill.
- We estimate that for every one million children riding the school bus for 1 or 2 hours each day during the school year, 23 to 46 children may eventually develop cancer from the excess diesel exhaust they inhale on their way to and from school. This means a child riding a school bus is being exposed to as much as 46 times the cancer risk considered "significant" by EPA and under federal law.
- The National Institute for Occupational Safety and Health, the International Agency for Research on Cancer, United States Environmental Protection Agency, and the National Toxicology Program have all consistently agreed that there is a relationship between diesel exhaust exposure and lung cancer.[6]
- The state of California listed diesel exhaust as a known carcinogen in 1990, and in 1998 the California Air Resources Board (CARB) listed diesel particulate as a Toxic Air Contaminant (TAC), also based on its carcinogenicity.[7]

- Over 40 individual chemical compounds in diesel exhaust have separately been listed as TACs.[8] These chemicals are also identified by the EPA as compounds that cause cancer.
- According to California studies, approximately 70 percent of the cancer risk from air pollution in the state comes from diesel-particle pollution.[9]
- Two national associations of regulators have estimated, based on lifetime risk, that diesel exhaust is responsible for 125,000 cancer cases in the United States.[10]
- According to a recent study published by the Health Effects Institute, more than 98 percent of the particles emitted from diesel engines are fine particles, less than 1 micron in diameter.[11] Numerous studies have found that fine particles impair lung function, aggravate respiratory illnesses such as bronchitis and emphysema, and are associated with premature deaths.[12]
- Children are among those most susceptible to the health effects of diesel exhaust exposure as a result of the child's developing body and lungs, narrower airways, faster metabolism, and faster breathing rate than adults.[13]
- A recent study by the USC Keck School of Medicine linked both NOx and PM pollutants to a potentially significant decrease in lung function growth among children living in Southern California.[14]
- While children make up only 25 percent of the population, they represent 40 percent of all asthma cases.[15] Research indicates that diesel exhaust may increase the frequency and severity of asthma attacks and may lead to inflammation of the airways that can cause or worsen asthma.[16]
- Cleaner alternatives to diesel, such as natural gas and propane, are already widely available for school bus applications. In addition, more advanced technologies, including hybrid-electric buses that run on natural gas instead of diesel, battery-electric buses, and fuel cells, will be available in the future.
- A recent study of commercial buses in Boulder, Colorado demonstrated a 97 percent reduction in PM and a 58 percent reduction in NOx when the same buses were run using compressed natural gas (CNG) instead of diesel.[17]
- Although a CNG school bus costs more than a diesel school bus (roughly $30–$40,000 more), operational and maintenance costs tend to be lower than those for a similar fleet operating on diesel, enabling fleets to recoup their initial investment.[18]
- Approximately 130 school districts and other school bus fleet operators throughout the country currently operate a total of over 2,600 natural gas and propane school buses in their combined fleets, which have resulted in lower emissions and noise. [19]
- Current government estimates show that new diesel school buses emit 51 times more air toxics than a new natural gas school bus.[20]
- Even the cleanest diesel engine certified for school bus applications in the 2001 model year will emit about 2 times more NOx and 3.5 times more PM than the equivalent year 2001 natural gas engine. [21]
- International Trucking Company's proposed "green" diesel engine, once certified, will emit 1.6 to 1.7 times more NOx than its natural gas counterparts and has not been

tested to determine whether the new engine design has sufficiently reduced the toxicity of the exhaust.[22]

- To reduce diesel emissions from school buses in the short-term, school districts can retrofit their existing diesel school buses with particulate traps at an estimated cost of $6,000 per bus if they can purchase low-sulfur diesel fuel, which is necessary for the traps to function properly.[23]
- A growing number of states have created funds earmarked for cleaner school bus purchases, including California; Governor Davis set aside $50 million in the state's 2000–2001 budget for the purchase of "lower-emitting" school buses.
- The South Coast Air Quality Management District in Southern California has proposed its sixth in a series of rules requiring public fleets to purchase only alternative fuel vehicles; this rule would require the purchase of only alternative fuel school buses.[24]

CHAPTER 1

EXHAUST EXPOSURES ON CALIFORNIA SCHOOL BUSES– STUDY RESULTS

Diesel exhaust is a hazardous substance that has been linked to cancer and respiratory disease, particularly after repeated exposure over time. Many children and adults report that they notice the unpleasant smell of diesel exhaust when riding in school buses. Some people report that the smell is stronger in the back of the bus, or when the bus is idling at a traffic light or bus stop, suggesting a direct effect of emissions from the bus. This study was designed to evaluate a child's exposure to diesel exhaust on school buses, and to determine whether riding diesel buses to school for years may pose a health risk to young children. In particular, this study compares the diesel exhaust in the air inside school buses with the diesel exhaust in the air inside passenger cars driving immediately in front of these same school buses.

STUDY DESIGN

A team of researchers from NRDC and the U.C. Berkeley School of Public Health designed a study to test levels of diesel exhaust inside school buses. NRDC and U.C. Berkeley rented school buses that currently are used to transport children every day in the Los Angeles area. Each bus drove an actual elementary school bus route of about 45 minutes duration for 4–6 repetitions over a period of five hours. The researchers used equipment to sample continuously the air inside the buses for evidence of diesel exhaust and also tested for comparison outside the bus and in a passenger car traveling ahead of the bus. The bus routes included typical periods of idling, going uphill, going downhill, traveling slowly with frequent stops, driving in quiet residential neighborhoods, and moving quickly along boulevards. Altogether, we collected nearly 20 hours of sampling results on four school buses.[25] In order to determine other factors that may affect a child's exposures inside the bus, we compared the air in the front and the back of the interior of the bus and compared the air quality with the windows open and closed. The monitoring instruments were checked to assure comparability by running the instruments side-by-side before and after the testing.

Because the bus was virtually empty rather than loaded with children, the engine may have been under less strain and the diesel emissions may have been lower than on buses loaded with children. We were unable to account for this possible source of under-estimation in our analysis. This study also did not evaluate the additional diesel exhaust children would be exposed to at bus stops or in front of the school while waiting to load the bus. Therefore, this study could underestimate a child's exposure from riding to school each day. We also did not perform this sampling protocol on any very old or very new buses, so variability related to the age of the bus is not directly addressed in this study.

Two types of sampling equipment allowed continuous measurements of fine particles in the air ($PM_{2.5}$) and black carbon. Because it is not possible to directly quantify diesel exhaust, scientists test for indicators that are characteristic of diesel exhaust. Diesel exhaust contains gases, vapors, and tiny sooty particles. The particles are considered to be among the most toxic components of the exhaust, and are so small that they penetrate deep into the lungs. The DataRAM™ Real-Time Aerosol Monitor (Monitoring Instruments for the Environment, Inc., Bedford, Mass.) provides minute-by-minute measurements of fine particles in air ($PM_{2.5}$). We used DataRAM instruments in both the car and the bus to compare tiny particles in each vehicle. More particles were measured in the bus than in the car; these additional particles were most likely from diesel exhaust. Details about the DataRAM are provided in Appendix D.

The second instrument measures an even more specific indicator of diesel exhaust. The Aethalometer™ Real-Time Aerosol Analyzer (Andersen Instruments, Inc., Atlanta, GA) provides minute-to-minute measurements of black carbon particles in the air. Black carbon particles are a telltale emission from diesel engines; diesel, in turn, is the major source of black carbon particles in air. The Aethalometer therefore confirms that the tiny airborne particles of smoke actually come from a diesel engine. Details about the Aethalometer are provided in Appendix C. Comparison of the Aethalometer readings in the car and the bus allowed a very accurate continuous measurement of the difference in black carbon particles between the two vehicles and a very good estimate of the diesel smoke attributable to the school bus. When run side by side under a variety of conditions, the aethalometers generally provided measurements that were within one percent of each other.

Because black carbon is only one portion of the entire mixture that comes out of a diesel tailpipe, it is necessary to multiply the black carbon measurements with a correction factor to derive an estimate of the total diesel particulate. The results below are measurements of black carbon from the Aethalometer, adjusted to represent estimates of total diesel exhaust particulate.[26]

RESULTS

There were significantly higher levels of black carbon particles inside the school buses compared to outside the buses on the same streets and compared to inside passenger cars

There were higher levels of diesel exhaust inside the school buses where children ride.

driving along the same streets immediately ahead of the buses. This means that there were higher levels of diesel exhaust inside the school buses where children ride. The levels were variable, but some patterns emerged:

- Diesel exhaust is higher in the back of the bus compared to the front of the bus;
- When some windows on the bus are open, the levels of diesel exhaust go down, and when all of the windows are closed, the levels rise;
- Driving uphill increased the level of diesel exhaust inside the bus;
- Driving downhill sometimes resulted in higher levels of diesel exhaust than did driving on the flats—this may be because the drivers shifted into a lower gear and used the engine to slow the bus on steep hills or because smoke lingered in the bus from a recent uphill ascent.
- Levels of diesel exhaust in the bus did not rise when the bus stopped and idled—in fact, the levels often decreased on idling;
- There was significant variability among individual buses sampled. Even two buses from the same model year had different levels of diesel exhaust.
- A child sitting in the back of the bus with the windows closed would receive an average exposure to diesel exhaust that is up to 4 times greater than a child riding in a passenger car immediately ahead of the same bus. In addition, the extra exposure to a child inside the bus was between 1.6 and 14 micrograms per cubic meter (mcg/m^3) higher than the exposure that same child would get from breathing the average outdoor air in California. Indeed, the California Air Resources Board estimated that the average outdoor concentration of diesel exhaust in California in 1995 was 2.2 mcg/m^3. Thus, for the time a child is in a school bus, his or her exposure to diesel exhaust may be up to 8-1/2 times the *average* statewide air levels. Figure 1 illustrates, as an example, the average readings we obtained inside one 1986 school bus compared with simultaneous measurements inside a passenger car driving directly ahead of the bus.

FIGURE 1

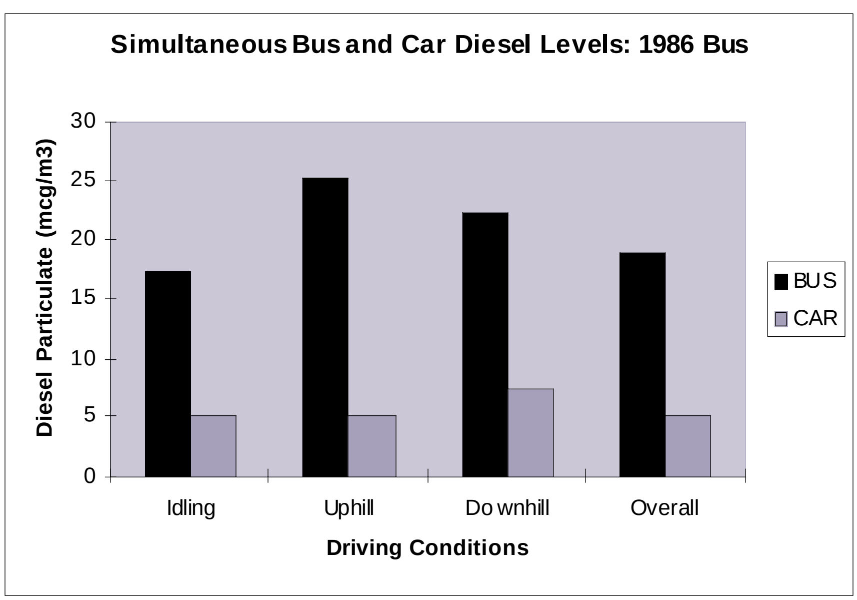
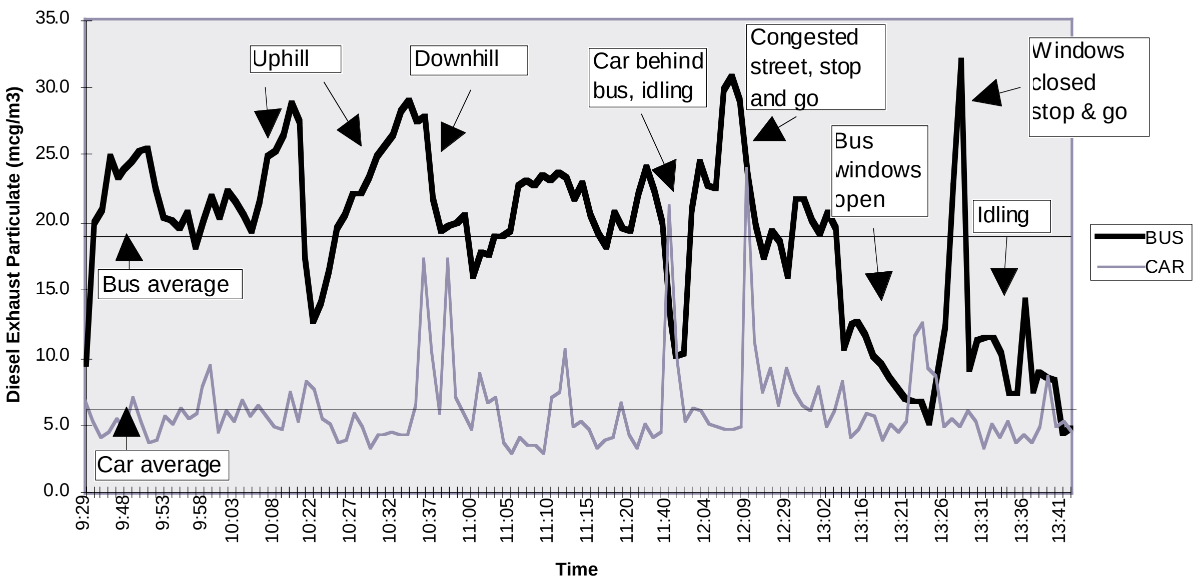


Figure 2 shows an example of minute-by-minute measurements of black carbon simultaneously inside the back of a 1986 bus and inside a passenger car driving immediately ahead of the bus. Some of the sources of variability are marked. The only times when the levels of diesel exhaust particles in the car briefly exceeded the levels in the bus were when the car was behind the bus for a few minutes idling at a school, and when four windows in the bus were opened to ventilate the interior of the bus.

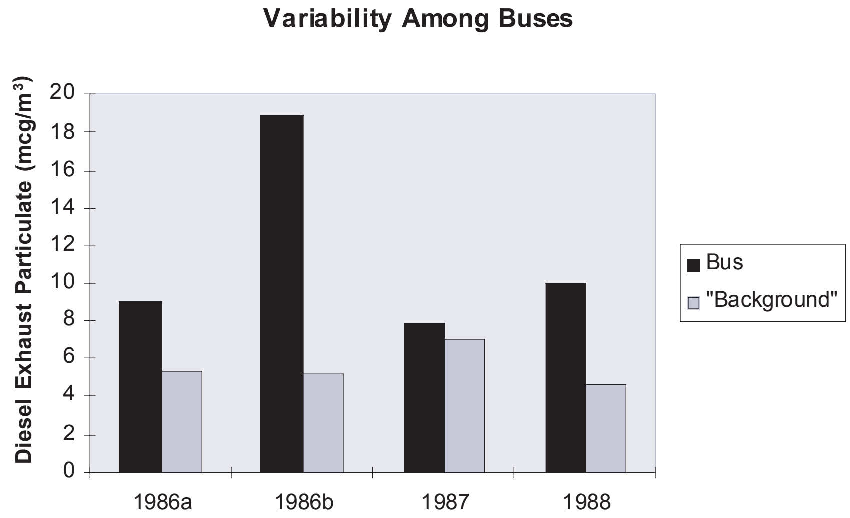
FIGURE 2

Real-Time Bus and Car Comparisons



There was also clear evidence of variability between buses. For example, two 1986 buses rented from the same bus company were found to have very different average levels of diesel exhaust inside the buses (see Figure 3). In Figure 3, all of the concentrations represent average levels measured in the bus, minus the average ambient levels measured in the car or outdoors. Thus, age alone does not necessarily predict a “smoky” bus.

FIGURE 3



Two factors that significantly affected the levels of diesel exhaust measured on the bus were whether the sampling was done in the front or the back of the bus and whether the bus windows were open or closed. As an example, the data in Figures 4 and 5 below show that on one 1986 bus, the average excess concentration of diesel exhaust in the bus dropped to less than half the previous level when some windows on the bus were opened. When the windows were closed, the levels tended to be slightly higher in the back of the bus compared to the front of the bus.

FIGURE 4

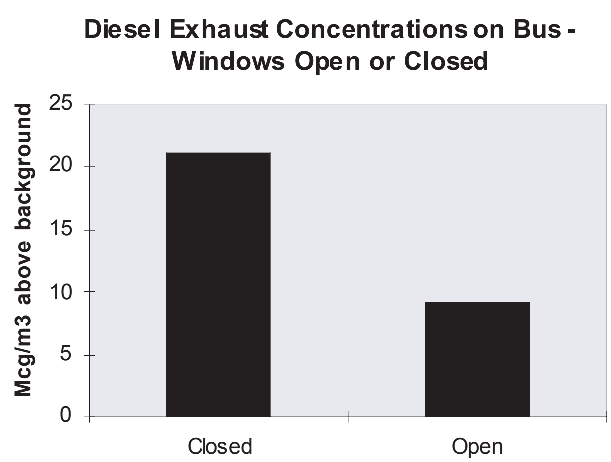
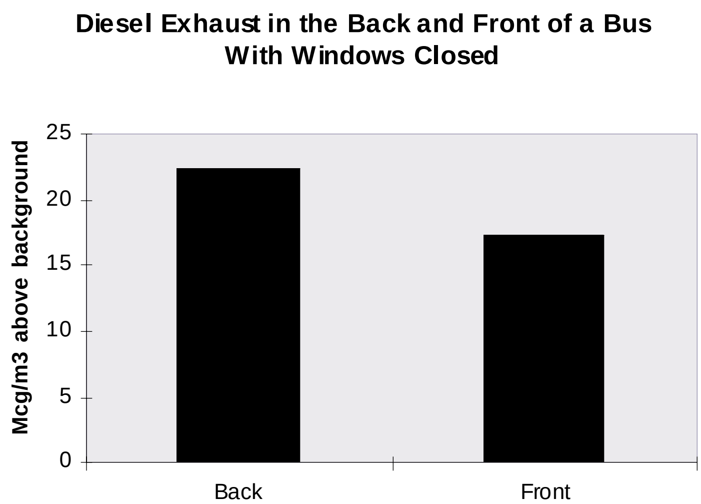


FIGURE 5



INTERPRETATION OF THE RESULTS

Diesel exhaust contains many chemicals that are hazardous to children's health. In particular, diesel exhaust has been associated with asthma. However, we cannot estimate whether the levels we measured may or may not trigger asthma in sensitive children, because not enough is known about what air levels may trigger these attacks. There is some concern that exposures on school buses could pose a possible health risk to some children with asthma.

Diesel exhaust exposure has been identified by the state of California as a cause of cancer. The California Air Resources Board (CARB) has specifically estimated the risk of cancer at various diesel exhaust exposure levels. The CARB calculations were focused on estimating cancer risk to people over a lifetime of exposure at average ambient air levels. Since children only spend a limited amount of time in a school bus, the calculations require modification to estimate the risk to children.

We estimated the cancer risks faced by children riding buses such as these for 1 or 2 hours per day, 180 days per school year, for 10 years. The risk assessment calculations are found in Appendix B of this report. We estimate that the exposure of children to diesel exhaust from riding school buses to and from school is likely to result in 23 to 46 additional cancer cases out of a million children exposed. The U.S. Environmental Protection Agency generally takes regulatory action to address cancer risks that exceed one additional cancer case out of a million people exposed. **Accordingly, a child riding a school bus may be exposed to 23 to 46 times the cancer risk considered "significant" by EPA and under federal environmental laws.**[27] Under California's Proposition 65 (Safe Drinking Water and Toxic Enforcement Act), this level of exposure

A child riding a school bus may be exposed to 23 to 46 times the cancer risk considered "significant" by EPA and under federal environmental laws.

could trigger an obligation to provide warnings to the children that they are being exposed to a cancer-causing chemical. Since there are 23.7 million children who ride the bus to school in the United States, many cancers could potentially be avoided by preventing exposures to diesel exhaust onboard school buses.

CHAPTER 2

THE SERIOUS HEALTH IMPACTS OF DIESEL EXHAUST

Diesel exhaust poses a significant health hazard; children are among the most susceptible to its deleterious effects.

Millions of people are exposed on a daily basis to a significant risk from diesel exhaust. Diesel exhaust has been demonstrated in more than 30 human epidemiological studies to increase cancer risk. Diesel exhaust contains hundreds of constituent chemicals, dozens of which are recognized as human toxicants, carcinogens, reproductive hazards, or endocrine disruptors.[28] Diesel particles also contribute to premature deaths, increase respiratory illnesses, and exacerbate asthma cases. Nitrogen oxides (NOx), another significant component of diesel exhaust, is a major contributor to ozone production and smog, and has recently been connected with decreased lung function growth in children.[29] Unfortunately, children are among those most susceptible to the health effects of diesel exhaust, yet school bus fleets continue to include some of the oldest and most polluting buses on the road today.[30]

DIESEL EXHAUST AND THE INCREASED RISK OF CANCER

Over two dozen well-designed occupational studies have demonstrated that long-term exposure to diesel exhaust significantly increases the human incidence of long-term lung cancer and possibly of bladder cancers. The National Institute for Occupational Safety and Health, the International Agency for Research on Cancer, EPA, and the National Toxicology Program have all consistently agreed that there is a relationship between diesel exhaust exposure and lung cancer.[31] In addition, the state of California listed diesel exhaust as a known carcinogen in 1990 under its Safe Drinking Water and Toxic Enforcement Act (Proposition 65), and in 1998 the California Air Resources Board (CARB) listed diesel particulate as a Toxic Air Contaminant (TAC), also based on its carcinogenicity. Over 40 individual chemical compounds in diesel exhaust have separately been listed as TACs.[32] Many of these chemicals are also identified by EPA as compounds that cause cancer.[33]

A March 2000 study by the South Coast Air Quality Management District (SCAQMD) in Southern California estimated the average cancer risk attributed to the carcinogenic components in the air of the South Coast to be about 1,400 in a million.[34] Significantly, according to the SCAQMD study, 71 percent of that cancer risk comes from diesel-particulate pollution, and a more recent CARB report showed similar findings statewide.[35] What's more, the SCAQMD estimates that the average diesel school bus used in Southern California emits 430 times more air toxics than a new natural gas school bus.[36]

TABLE 1
Cancer Risk Assessments of Diesel Exhaust

ORGANIZATION	YEAR	CONCLUSION
National Institute for Occupational Safety and Health	1988	potential occupational carcinogen
International Agency for Research on Cancer (WHO)	1989	probable human carcinogen
State of California	1990	known to cause cancer
U.S. Environmental Protection Agency (Draft)	1998	"highly likely" human carcinogen
California EPA (Staff Recommendation)	1998	"may cause an increase in the likelihood of cancer"
California Air Resources Board	1998	diesel particulate emissions are a toxic air contaminant
National Toxicology Program	1998	"diesel exhaust particulate is reasonably anticipated to be a human carcinogen"

Sources: NIOSH and IARC: HEI 1995, p. 19; state of California: listing under the Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65); U.S. EPA: EPA 1998b, p. 12–29; Cal EPA: Cal EPA 1998a, p. ES-27; CARB: CARB 1998.

The SCAQMD and CARB findings prompted two national organizations—the State and Territorial Air Pollution Program Administrators (STAPPA) and the Association of Local Air Pollution Control Officials (ALAPCO)—to extend the evaluation of cancer risk from diesel particulate to other cities across the country. The results were just as grim. STAPPA and ALAPCO estimated, based on lifetime risk, that diesel exhaust is responsible for a shocking 125,000 cancers in the United States.[37] In fact, this figure is extremely conservative according to S. William Becker, Executive Director of STAPPA/ALAPCO, and "the actual number of cancers could easily be ten times higher."[38] Table 2 below presents STAPPA/ALAPCO's findings on estimated cancers from diesel particles in 20 U.S. metropolitan areas.

TABLE 2
Estimated Cancers from Diesel Particulates

ENTIRE UNITED STATES	**125,110**
20 Largest Metropolitan Areas	
Metropolitan Area	Cancers
Los Angeles	16,250
New York	10,360
Chicago	4,535
Washington/Baltimore	3,750
San Francisco	3,510
Philadelphia	3,085
Boston	2,900
Detroit	2,810
Dallas/Fort Worth	2,470
Houston	2,270
Atlanta	1,930
Miami/Fort Lauderdale	1,880
Seattle	1,765
Phoenix	1,510
Cleveland	1,500
Minneapolis	1,460
San Diego	1,430
St. Louis	1,320
Denver	1,220
Pittsburgh	1,210

Source: State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials, Cancer Risk from Diesel Particulate: National and Metropolitan Area Estimates for the United States, March 15, 2000.

NONCANCER HEALTH IMPACTS FROM DIESEL EXHAUST

Diesel exhaust is a major source of fine particles and of oxides of nitrogen (NOx), which have been linked to a growing number of noncancer health impacts, including lung damage, premature death, infections and asthma.

Diesel engines account for an estimated 79 percent of the particulate pollution from all on-road sources.[39] Even worse, according to a recent study published by the Health Effects Institute, more than 98 percent of the particles emitted from diesel engines are fine particles, less than 1 micron in diameter.[40] Such fine particles are particularly hazardous because they can bypass respiratory defense mechanisms and lodge deep in the lungs.[41] Numerous studies have found that fine particles impair lung function, aggravate respiratory illnesses such as bronchitis and emphysema, and are associated

Diesel engines account for an estimated 79 percent of the particulate pollution from all on-road sources.

with premature deaths.[42] Also, dozens of studies link airborne fine-particle concentrations to increased hospital admissions for respiratory diseases, chronic obstructive lung disease, pneumonia, and heart disease.[43] Notably, recent studies have found that the respiratory responses associated with diesel exhaust are not solely a function of the diesel particles, but are also affected by the toxic organic compounds contained in the gaseous and vapor phase of the diesel exhaust.[44] These preliminary yet important findings suggest that strategies to reduce risk from diesel exhaust that focus solely on reducing particles may not adequately control respiratory impacts.

Premature death due to long-term exposure to particulate matter and other air pollution has also been a subject of much research. In December 1993, Harvard researchers published the results of a 16-year community health study that tracked the health of 8,000 adults in six U.S. cities with differing levels of air pollution. After adjusting for age and smoking, researchers found that residents of the most polluted city had a 26 percent higher mortality rate than those living in the least polluted city.[45] This translated into a one- to two-year shorter lifespan for residents of the most polluted cities.[46] Another major study corroborated these findings. This study correlated American Cancer Society data on the health of 1.2 million adults with air pollution data in 151 U.S. metropolitan areas and found that people living in the most polluted area had a 17 percent greater risk of mortality than people living in the least polluted city.[47] In May 1996, NRDC released a study entitled "Breath-Taking: Premature Mortality Due to Particulate Air Pollution in 239 American Cities," which was based on the risk relationships identified in the American Cancer Society and Harvard studies. In this study, NRDC applied the known risk relationships to a variety of urban areas where particle levels had been adequately monitored. We found that nationally over 50,000 premature deaths per year may be attributable to the existing levels of particles in the air.

Diesel exhaust is also believed to exacerbate asthmatic conditions.

Diesel exhaust is also believed to exacerbate asthmatic conditions. Asthma is a very common and potentially life-threatening disease with a range of symptoms and degrees of severity. Unfortunately, asthma is on the rise and, as discussed below, is most prevalent among children. In the United States, there are an estimated 10.3 million people living with asthma, nearly half of whom are children.[48] Research indicates that diesel exhaust may increase the frequency and severity of asthma attacks and may lead to inflammation of the airways that can cause or worsen asthma.[49] In addition, recent research indicates that diesel exhaust may increase susceptibility to allergens. For example, minor allergic reactions to pollen can turn into major inflammatory and allergic responses when pollen and diesel exhaust exposures occur together.[50] When exposed to similar levels of Cedar pollen, people who lived in areas with higher levels of air pollution had enhanced allergic reactions compared with people who lived in rural areas, indicating the possibility of a synergistic effect between air pollution and other allergens.[51] Other researchers found that diesel particles significantly increase levels of inflammatory substances in the upper airways of healthy people in response to ragweed exposure.[52]

CHILDREN'S INCREASED SUSCEPTIBILITY

Children are among those most susceptible to the health effects of diesel exhaust exposure. There are many reasons for this increased susceptibility, including the fact that a child's developing body is less capable of defending itself against pollutants such as diesel particles, which can penetrate deep in the lungs. Children also have narrower airways, and their lungs are still developing. Irritation caused by air pollutants that would produce only a slight response in an adult can result in potentially significant obstruction in the airways of a young child.[53] In addition, children typically have a faster metabolism and breathe at twice the rate of an adult, thereby receiving and retaining greater doses of pollution; they also tend to breathe through their mouths, thereby bypassing the natural filtering protection of the nose.[54] Finally, compared with adults, children spend more time playing outdoors when air pollution levels are at their peak, and due to their height, they are closer to the ground where concentrations of pollutants are likely to be higher.[55]

Children are among those most susceptible to the health effects of diesel exhaust exposure.

HEALTH EFFECTS AND CHILDREN

Children raised in heavily polluted areas face the prospect of reduced lung capacity, prematurely aged lungs and increased risk of bronchitis and asthma.[56] Both particulate matter (PM) and NOx, two pollutants emitted from diesel engines in large quantities, have been linked to harmful effects among children. Most recently, a USC study from the Keck School of Medicine linked both NOx and PM pollutants to a potentially significant decrease in lung function growth among children living in Southern California.[57]

Elevated levels of particulate pollution have also been linked with an increased incidence of respiratory symptoms in children.[58] In an ongoing study comparing air pollution in six U.S. cities and the respiratory health of individuals living in those cities, the frequencies of coughs, bronchitis, and lower respiratory illnesses in preadolescent children were significantly associated with increased levels of acidic fine particles.[59] Illness and symptom rates were twice as high in the community with the highest air pollution concentrations compared with the community with the lowest concentrations. As pediatrician Dr. Ruth A. Etzel noted, "The lungs of those who lived in heavily polluted cities are expected to be blacker because of the airborne particles that are being deposited."[60] In addition, one study suggested that children with preexisting respiratory conditions (wheezing, asthma) are at an even greater risk.[61]

One concern that has prompted numerous research endeavors is the increased incidence of asthma among children. While children make up only 25 percent of the population, they represent about 40 percent of all asthma cases.[62] In addition, new cases of childhood asthma nationwide rose nearly 60 percent during the 1980s and 1990s.[63] During this period the severity of childhood asthma also increased. According to the Centers for Disease Control and Prevention, there are 4.8 million children with asthma in the United States—over five percent of the population under age 18.[64] African-American and Latino children have a higher risk of asthma than white children.[65] Moreover, African-American children are four times more likely to die from asthma compared to Caucasian children.[66]

Research shows a definite correlation between air pollutants, such as diesel exhaust, and asthma attacks among children.

Research shows a definite correlation between air pollutants, such as diesel exhaust, and asthma attacks among children. Most recently, a California Environmental Protection Agency (Cal EPA) study of hospital records in Sacramento from 1992 through 1994 found a 14 percent increase in the number of asthma-related hospital admissions and emergency-room visits by low-income children during periods of persistently high ozone levels.[67] Ozone is created when NOx and hydrocarbons from diesel engines and other sources react in sunlight. Studies have also shown that the proximity of a child's school or home to major roads is linked to asthma, and the severity of children's asthmatic symptoms increases with proximity to truck traffic.[68]

Notably, asthma is the leading cause of school absenteeism attributed to chronic conditions.[69] Children with asthma miss an average of 3.3 more school days than healthy children without asthma.[70] Asthma has been associated with poorer academic performance (i.e., reading skills),[71] more activity limitations, and an increased chance of dropping out before finishing high school.[72] Asthmatic children have twice the need for special education programs as nonasthmatic children.[73]

In summary, diesel exhaust poses a significant health threat, particularly to children. Diesel exhaust and the many chemicals, gases, and particles it contains pose short-term risks of respiratory problems, such as asthma exacerbations in susceptible individuals. Over the longer term, diesel exhaust has been linked to decreases in lung function, cancer, and premature death. The scientific evidence associating diesel exhaust and human health problems is quite extensive. To date, there is no evidence that the emissions from even the newest diesel engines are safe.

CHAPTER 3

Cleaner Alternative Fuel School Buses Are Available Today

There is a broad range of options for cleaner school bus purchases today—and into the future – including compressed natural gas (CNG), liquefied natural gas (LNG), propane, hybrid-electric, battery-electric, and fuel cells.

Diesel-fueled engines power the vast majority of the nation's school bus fleets. This does not have to be the case, however, given the cleaner, reliable alternatives that are available on today's heavy-duty engine market. Cleaner alternative fuels available today include natural gas and propane, while the options of tomorrow include hybrid-electric buses that run on natural gas instead of diesel, battery-electric and fuel cells. Alternative fuels have been in existence for nearly 100 years but have only garnered wide acceptance over the past two decades as a strategy to combat air pollution and toxics. A tremendous amount of research and development has gone into cleaner alternative fuel vehicle technologies to provide us with reliable, lower emission alternatives for school buses and other heavy-duty vehicles. Alternative fuel technologies represent the cleanest available options for heavy-duty applications and should play an integral part in our emission-reduction strategy. These technologies have been most successful in markets—including transit and school buses, waste haulers, street sweepers, and distribution center trucks—where the vehicles travel short distances and are centrally fueled.

Alternative fuels, such as natural gas, are inherently cleaner burning than diesel.

ALTERNATIVE FUEL TECHNOLOGIES

Alternative fuel technologies continue to provide cleaner modes of transportation than present and emerging diesel products, as demonstrated by their superior reductions in smog-forming chemicals, soot, and cancer risk. Alternative fuels, such as natural gas, are inherently cleaner burning than diesel. For example, CNG vehicles emit extremely small amounts of particulate matter. In fact, a recent study conducted on commercial buses in Boulder, Colorado demonstrated a 97 percent reduction in PM and a 58 percent reduction in NOx when the same buses were run using CNG instead of diesel.[74] Also, natural gas engines, in comparison to diesel engines, already meet the NOx emission levels that heavy-duty vehicles are required to meet by 2002. In addition, there is overwhelming evidence that diesel exhaust poses a high cancer risk, while no government or public health body has concluded that there is a link between natural gas combustion and cancer, despite the widespread use of natural gas in power plant combustion, home heating and cooking. Natural gas vehicles have also been proven to stay clean over their useful lives. Several recent studies indicate that, while diesel vehicles emit substantially more NOx and PM in real world conditions than when certified, natural gas vehicles remain at near-certification levels.[75] In addition, because natural gas is lighter than air, there is less potential for ground water contamination.

Alternative fuel engines, such as natural gas, are expected to maintain their lead over diesel engine technology, as alternative fuels are inherently cleaner and can apply the same advanced emissions control technologies (e.g., sophisticated fuel management, exhaust gas recirculation, and aftertreatment) that are being designed to clean up today's newest diesel engines. Ultimately, with the development and maturation of hybrid-electric and zero-emission vehicles utilizing battery-electric and fuel cell technologies, all vehicles that depend upon a combustion engine for power will likely become obsolete. There is no question that fuel cells and other zero-emission technologies present the cleanest form of heavy-duty transportation on the horizon. Until zero-emission technologies are certified and readily available in the heavy-duty vehicle market, however, natural gas and other alternative fuels like propane represent the most cost-effective and cleanest options for heavy-duty applications.

THE CLEANEST ALTERNATIVES OF TODAY

Compressed Natural Gas

Use of CNG buses can also generate operational cost savings.

Natural gas engine technology is in widespread use today. It is composed primarily of methane (CH_4), and may be derived from either gas wells or from crude oil production. Natural gas is stored either in a compressed or liquefied form. Compressed natural gas (CNG) has the advantage of being distributed by natural gas pipelines throughout the continental U.S., and is used extensively in power plants, factories, and other industries.

Natural gas is believed to be more abundant than petroleum fuels, including diesel, and is domestically available. In fact, about 90 percent of the natural gas used by the U.S. is domestically produced, and almost 100 percent is produced in North America.[76] Use of CNG buses can also generate operational cost savings. Although a CNG school bus costs more than a diesel school bus (roughly $30–$40,000 more), fleet managers who operate CNG fleets report that operational and maintenance costs tend to be lower than for a similar fleet operating on diesel. This is primarily due to CNG being a cleaner-burning fuel that requires fewer oil changes and less overall maintenance. Thus, initial investment costs can be recouped over time due to CNG's lower operation and maintenance costs.[77]

In fact, as discussed in Chapter 4, school districts that use CNG school buses, such as Antelope Valley in California, have realized significant cost savings. Furthermore, the incremental cost associated with CNG school buses is expected to decrease as the volume of sales increases nationwide. Already, approximately half of all bus sale orders in California (school and transit buses combined), for example, are for CNG buses.[78] For these reasons, as we detail in Chapter 4, over 100 school districts across the country operate approximately 1,400 CNG school buses in their combined fleets.

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Fleet operators must also consider the need for a natural gas refueling station.[79] According to Southern California Gas Company,[80] large refueling stations for fleets of 10 or more buses range in price from $100,000 to $300,000, depending on whether a slow-fill or a fast-fill fueling station is required and the number of gallons of fuel which can be pumped per hour. Fast-fill compressors cost substantially more than slow-fill compressors, but school districts rarely require fast-fill capabilities because a typical school bus fleet does not operate many hours and can easily rely on an overnight fueling strategy. For smaller CNG fleets (e.g., under 10 buses), modular refueling units are most cost-effective. One manufacturer, Fuel Maker, has available two different models for smaller fleets. The initial cost to install these units ranges from $6,000 to $8,000 per bus, and fleets have the ability to later expand to accommodate additional buses at a cost of approximately $3,000 per bus.[81] Larger units are available from Fuel Maker, which can accommodate up to 10 school buses, at a cost of under $100,000.[82]

Government funding sources to date have failed to provide the incentives necessary for school bus fleets to make the capital investment required for the construction of a natural gas fueling station. School bus fleets, however, are ideal candidates for fueling infrastructure funding because they fuel in one central location.

Liquefied Natural Gas

Liquefied natural gas (LNG) as a fuel of choice is garnering appreciation for its speed of fueling (30 to 60 gallons per minute), fuel storage capacity, lightweight properties, and long-range capabilities. Unlike CNG, LNG is cryogenically stored at temperatures of –260 degrees Fahrenheit under normal atmospheric conditions and, lacking a pipeline infrastructure, is delivered to fleet facilities by truck. Liquefaction stations that liquefy pipelined natural gas on-site are under development, but the technology faces some economic hurdles and the fuel quality may not be suitable for heavy-duty application (e.g., school buses).[83] Nevertheless, on-site liquefaction may mature as the demand for LNG increases for truck and bus fleets throughout the nation. The advantage of LNG lies in its density, reducing the volume needed for storage by 60 percent in comparison to CNG. Because LNG tanks have a tendency to vent if a school bus remains out of use for an extended period of time, the best application for this promising technology may be for school districts that operate year-round.

Propane

At least three school districts in Texas currently operate approximately 1,300 propane buses in their combined fleets, with great success.

Liquefied petroleum gas (LPG) is comprised of a simple mixture of hydrocarbons, mainly propane gas, and is produced as a by-product derived from the processing of natural gas and crude oil, mostly in the U.S. According to the Alternative Fuels Data Center, LPG has been used as a transportation fuel around the world for more than 60 years. Refueling time is comparable to gasoline. Propane engines also tend to last two to three times longer than diesel or gasoline engines, due to less carbon buildup. Propane, however, has not been shown to be as cost-effective as CNG. Nevertheless, as we detail in Chapter 4, at least three school districts in Texas currently operate approximately 1,300 propane buses in their combined fleets, with great success.

THE CLEAN ALTERNATIVES OF TOMORROW

Hybrid-Electric Buses

Hybrid-electric vehicle technologies are unique in that they are powered by two distinct sources: a traditional combustion engine powered by a fuel (e.g., CNG, diesel, gasoline, or propane), and an energy reservoir or battery. Thus, unlike technologies that depend upon one dedicated power or fuel source, a hybrid-electric bus alternates its power usage from a smaller combustion engine to a battery pack depending on the vehicle's current mode of operation. The strategy of a hybrid, therefore, aims to deliver better fuel economy and offer lower emissions. Hybrid-electric vehicles will not eliminate the air toxics problem, however, if the combustion engine runs on diesel fuel. Future hybrid-electric bus technologies must instead combine the emissions benefits of cleaner alternative fuels, such as CNG, with the fuel efficiency benefits of a hybrid electric drivetrain. Though hybrid-electric buses have been widely touted as the "next generation" of cars, buses, and other vehicles, the technology still is very young, and the establishment of emissions testing procedures and protocols by EPA and CARB is required to ensure that potential emission benefits from hybrid-electric technologies actually occur in real-world conditions. Hybrid-electric buses are currently being introduced in the transit bus and passenger vehicle markets but is not expected to enter the school bus market for some time.

Battery-Electric Buses

Battery-electric vehicles are powered exclusively by an energy reservoir or battery. Battery-electric vehicles tend to experience low maintenance and fuel costs, operate quietly, and do not produce tailpipe emissions or air toxics. Hence, battery-electric vehicles are commonly known as "zero-emission vehicles." One manufacturer introduced battery-powered school buses as a research and development project in 1996 at a premium price of $230,000 per unit. Despite providing superior emissions benefits and meeting the range needs of most urban school districts, these buses experience limited battery lifetime and high battery replacement costs. Battery technology, however, is advancing in passenger vehicle and transit bus markets (with about 200 thirty-foot battery-electric shuttle buses operating in the U.S.).[84] Given the success of the electric bus program in the Santa Barbara Metropolitan Transit District in California, the South Coast Air Quality Management District in California partially funded a $400,000 project being conducted by Santa Barbara Electric Bus Work to further advance battery-electric school bus technology and reduce vehicle costs to $146,000-$160,000 per unit.[85] Battery-electric school bus purchases should rise as the technology advances, and costs should decrease.

Fuel Cell Buses

There are a number of competing fuel cell technologies out on the market today, but the fuel cell attracting the most interest relies on Proton Exchange Membrane (PEM) technology. PEM fuel cell technology is based on the conversion of chemical energy into a usable form of energy and heat that occurs without any combustion phase. Fuel cell technology results in near-zero emissions, with the potential for zero emissions when pure hydrogen is used. Fuel cells are similar to batteries in their use of chemicals separated by an electrolyte that reacts and produces an electric current.[86] Unlike a battery, fuel cells are not charged. Instead, the reactants are fed continuously to the cell. Fuel cells run on pure hydrogen but have the potential to operate on a variety of other fuel types when reformed into pure hydrogen. These fuel types include methanol, ethanol, and natural gas.[87] Automobile manufacturers and oil companies are also researching ways to operate PEM fuel cells that can reform gasoline and diesel fuel into pure hydrogen. Although fuel cells are not available on the market today for school bus application, there are demonstration transit buses powered by hydrogen fuel cells operating in several countries. Most of the major automakers have committed to commercializing fuel cell passenger cars within the next few years.

CHAPTER 4

CLEAN FUEL SCHOOL BUS SUCCESS STORIES ACROSS AMERICA

Approximately 130 school districts are operating natural gas and other alternative fuel school buses to protect their students' health

As Table 3 shows, approximately 130 school districts and other school bus fleet operators throughout the country currently operate cleaner, alternative fuel school buses in their fleet. This chapter will highlight the positive experiences of five school districts in California, Oklahoma, Pennsylvania, Indiana, and Texas that operate natural gas and propane buses. In addition to lower emissions, these fleets have found great success with alternative fuel buses in terms of cost and reliability.

CASE STUDY: ANTELOPE VALLEY SCHOOLS TRANSPORTATION AGENCY, CA[88]

Antelope Valley Schools is located in Lancaster, California, and serves about 35,500 students. Prior to 1992, Antelope Valley's school bus fleet was deteriorating, with buses as old as 35 years of age. The school buses emitted so much pollution and black smoke that the school district accumulated fines of up to $3,000 per day for violations of California's emissions laws. The Chief Executive Officer of Antelope Valley Schools Transportation Agency (AVSTA), Ken McCoy, looked to clean alternative fuels as the solution. Relying heavily on grant funding, the first natural gas school bus arrived at AVSTA in 1992. Today they operate 19 CNG buses and plan to increase their clean alternative fuel bus procurements in the future while exploring hydrogen fuel cell options with government agencies.

But for now, CNG is clearly the fuel of choice for AVSTA. According to McCoy, their CNG buses are economically competitive with diesel because they have comparable fuel costs and fewer oil changes. McCoy has found no advantages to diesel over CNG, except for the greater availability of fueling stations. Since AVSTA owns its own fueling station, they are able to keep CNG fuel costs to a minimum. An onsite

TABLE 3
School Districts in the Nation Operating Alternative Fuel School Buses [89]

STATE	APPROX. NO. OF BUSES STATEWIDE	SCHOOL DISTRICTS/FLEET OPERATOR
Arizona	60	Cartwright SD; Deer Valley SD; Karney SD; Osborn SD; Paradise Valley SD; Peoria SD; Tucson SD; Washington SD
California	600	Acalanes Union High School; Alta Loma Elementary SD; Anderson Union High School; Antelope Valley School Transportation; Apple Valley Unified SD; Banning Unified SD; Beaumont Unified SD; Bennett Valley Union Elementary SD; Berkeley Unified SD; Campbell Union Elementary SD; Chaffey Joint Union High SD; Chula Vista Elementary SD; Clovis Unified SD; Colton Joint Unified SD;Covina Valley Unified SD; Elk Grove Unified SD; Elverta Joint Elementary SD; Eureka City Schools; Flosom-Cordova Unified SD; Fremont Unified SD; Fresno Unified SD; Fullerton Union High SD; Goleta Union SD; Grant Union High Hayward Unified SD; Hemet Unified SD; Hesperia Unified SD; Hueneme SD; Jefferson Union High SD; Kern County Supt. of Schools; Kern High SD; Kings Canyon Unified SD; Lemoore Union High SD; Lompoc Unified SD; Los Angeles Unified SD; Lucerne Valley Unified SD; Mark West Union SD; Montebello Unified; Monterey Peninsula SD; Moreno Unified SD; Mountain View Elementary SD; Mt. Baldy Joint SD; Mt Diablo Unified SD; Napa Valley Unified SD; Oceanside Unified SD; Old Adobe Union Elementary SD; Ontario-Montclair SD; Oxnard Union High School; Palo Alto Unified SD; Paradise Unified SD; Paris Unified SD; Paso Robles Public School; Petaluma City/Joint Union SD; Poway Unified SD; Pupil Transportation Cooperative; Ravenswood City Elementary SD; Realto Unified SD; Redlands Unified SD; Redwood City SD; Rincon Valley Unified SD; Rio Linda Unified SD; Sacramento City Unified SD; Sanger Unified SD; San Dieguito Union High School; San Juan Unified SD; San Luis Obispo Unified SD; San Marcos Unified SD; San Ramon Valley Unified SD; Santa Monica-Malibue Unified SD; Saucelito Elementary SD; Sequoia Union High SD; Snowline Joint Union SD; South Bay Union SD; Southwest Transportation Agency; Sunol Glen Unified SD; Sweetwater Union High SD; Tahoe/Truckee Unified SD; Tehachaipi Unified SD; Torrance Unified SD; Tulare County Org.; Vacaville Unified SD; Vallejo City Unified SD; Val Verde Unified SD; Ventura Unified SD; Victor Valley Elementary SD; Victor Valley Union High SD; Visalia Unified SD; Vista Unified SD; Walnut Valley Unified SD; West County Trans. Agency
Colorado	10	Boulder SD (Pending); Cherry Creek SD
Connecticut	10	Newington; Norwich DS
Georgia	1	Marietta SD
Indiana	183	Evansville-Vanderburgh School Corporation
Massachusetts	4	Weston SD
Nevada	8	Washoe County School District
New York	27	Shenendehowa Central SD
North Carolina	14	Char-Meck SD
Oklahoma	240	Choctaw-Nicome SD; Nickel Hills SD; Oklahoma City SD; Sand Springs SD; Tulsa Public SD
Pennsylvania	130	Lower Merion SD; Mill Creek SD
Texas	1,300	Alvin SD; Dallas SD; Northside Independent SD
Utah	27	Alpine Valley; Jordan SD
Washington	8	Turnwater SD
West Virginia	12	Wood County Public School
Wisconsin	40	Shawano

TOTAL: 2,674

Drivers and children find the CNG buses less noisy and smoky than diesel buses.

CNG fueling station and well trained in-house mechanics contribute to their CNG fleet's low operational costs. McCoy recommends purchasing a CNG fueling station equipped with fast-fill capabilities. This has allowed AVSTA to open their station to the public, resulting in additional revenue for the school district. McCoy cautions, however, that owning a fast-fill station may not be ideal if there is no public demand for CNG.

Bus drivers and students have given positive feedback on Antelope Valley's CNG school bus fleet. Drivers and children find the CNG buses less noisy and smoky than diesel buses. McCoy encourages other districts to talk with fleet managers who operate clean alternative fuel programs and pursue government funding available to school districts. He finds the district's newest CNG buses to be "unbelievable in…operating economics and viability" and vests the most confidence in his CNG buses: "If I were choosing fuel, it would be CNG only, based on the bottom line."

CASE STUDY: TULSA PUBLIC SCHOOL DISTRICT, OKLAHOMA[90]

The Tulsa Public School District is the largest school district in the state with an average daily attendance of 44,000 students. In 1988, the Tulsa Public School District was asked to participate in a pilot alternative fuel program financed by the state of Oklahoma. After the passage of a school bond in 1990, the district ordered 132 new buses, including 44 dedicated CNG and 48 gasoline engines, to be converted to bi-fuel (CNG and gasoline). Now the district has 55 dedicated CNG buses and 92 bi-fuel buses. The district also has 35 CNG certified mechanics.

According to Larry Rodriguez, Alternative Fuel Technician at the Tulsa Public School District, "The switch has probably saved the district around $1.6 million if one considers the fuel differential, engine longevity, and other matters. It has definitely been worth it." There were some initial bumps in the road, but over the past four years the district has secured three $50,000 grants from the state of Oklahoma and the Department of Energy to cover the conversion of the buses. The state also discounted the sale of natural gas until last July, when natural gas became deregulated and the price increased from $0.33 a gallon to $0.79 a gallon. Fuel savings still average around $1,000 per year per vehicle based upon 15,000 annual miles per bus. The district also used an interest-free loan from the Alternative Fuels Loan Program to expand its CNG compressor stations, to purchase two parking/fueling lots, and to cover additional vehicle conversion costs. The loan was repaid through the fuel cost savings between conventional fuels and natural gas.

CASE STUDY: LOWER MERION SCHOOL DISTRICT, PENNSYLVANIA[91]

Lower Merion is entering its fifth year of using CNG school buses and was recently a recipient of the National Clean Cities Award for these purchases. It purchased its first school bus in 1996 in response to the community's concern over air and noise pollution in the neighborhood. The fleet has now grown to 63 CNG buses, and three more are on order. The school district has constructed two refueling stations and has committed to purchasing only natural gas for all new school buses. The operation site is located in a residential area, so switching to natural gas has improved the quality of life for much of the community.

The district funded the purchase of CNG buses partly through the incentives offered by the Energy Policy and Clean Air Act Amendments. The district received small grants from the Department of Energy, and the local utility company contributed $35,000 towards the construction of a fueling station. However, most of the funding came from the community. In total, the district received over $1 million in funding. The school district also received technical support from the U.S. Department of Energy, the Pennsylvania Department of Environmental Protection, and PECO Energy Company.[92]

Mike Andre, Director of Transportation at the Lower Merion School District, supports alternative fuels. Andre notes, "What we really need. . . is to change our perspectives about fuel. The U.S. government needs to start supporting alternative fuel." Andre also dismissed the notion that natural gas school bus engines are not as durable as diesel school bus engines. "My CNG fleet is about to surpass 3 million miles."

CASE STUDY: EVANSVILLE-VANDERBURGH SCHOOL CORPORATION, INDIANA[93]

The CNG buses have paid for themselves as a result of fuel cost savings.

In 1986, Evansville-Vanderburgh School Corporation in Indiana decided to switch to natural gas for their school buses. The Corporation is now operating a fleet of 183 CNG buses, making it one of the largest CNG school bus fleets in the nation. Evansville-Vanderburgh initially bought the buses without any outside funding, using money from their annual budget. The buses have since paid for themselves as a result of fuel cost savings. Curtis Fritz, chief garage manager at Evansville-Vanderburgh School Corporation, noted that maintenance costs have gone down. Fritz reported that the drivers like the way the CNG buses drive and get much better mileage on the engines. With diesel buses, drivers would have to change the oil every 2,500 miles, but now they only have to change the oil every 5,000 miles.

Recently, though, Evansville-Vanderburgh has faced increased CNG fuel prices. The price has doubled within the past year from $0.37 a gallon to $0.70 a gallon. This has put some added pressure on future CNG purchases. Even with these increased costs, however, Fritz reports that Evansville-Vanderburgh "…has had a positive experience with the CNG buses," and is very happy with the switch.

CASE STUDY: NORTHSIDE INDEPENDENT SCHOOL DISTRICT, TEXAS[94]

Northside Independent School District in San Antonio, Texas is the fifth largest school district in Texas with 44 elementary schools, 12 middle schools, 10 high schools, and 11 special education schools. Currently, Northside Independent has a fleet of 472 school buses, which transport 33,000 students to and from school each day. The district operates 440 of these school buses on propane and the remainder on bi-fuel (propane/gas). The district is dedicated to operating a 100 percent alternative fuel fleet and has the largest dedicated propane school bus fleet in the country.

Northside Independent switched to propane in 1981, largely because of the high price of gasoline. Given its lower price and local abundance, propane was the easiest solution. The district is currently in its 20th year of operating propane school buses and they have no complaints. Maintenance costs are low, the engines get good mileage, and drivers like the buses. In fact, no additional training on how to use or drive the bus was required.

Initially, Northside Independent received grants from the Texas Railroad Commission and Alternative Fuel Energy Division to cover some of the costs of converting to propane. Recently, the Railroad Commission stopped funding Northside Independent in order to provide incentives for other school districts to switch to alternative fuels. Nevertheless, the school district is still committed to operating its entire fleet on alternative fuels.

CHAPTER 5

So-Called "Clean" and "Green Diesel" School Buses Remain Dirtier Than Alternative Fuel School Buses

Currently available "clean" diesel school buses are significantly dirtier than their alternative fuel counterparts

Some engine manufacturers argue that new diesel school buses which run on current California reformulated diesel fuel (required in most of California since 1993 and also called CARB diesel) are "clean" diesels and should no longer be considered a public health threat. These claims run counter, however, to actual emissions of air toxics, NOx, and PM from current diesel school buses. Diesel engines—new and old—continue to pose serious health threats. With particular significance for school children, the South Coast Air Quality Management District (SCAQMD) estimates that a new diesel school bus emits 51 times more air toxics than a new natural gas school bus.[95]

Diesel engines—new and old—continue to pose serious health threats… a new diesel school bus emits 51 times more air toxics than a new natural gas school bus.

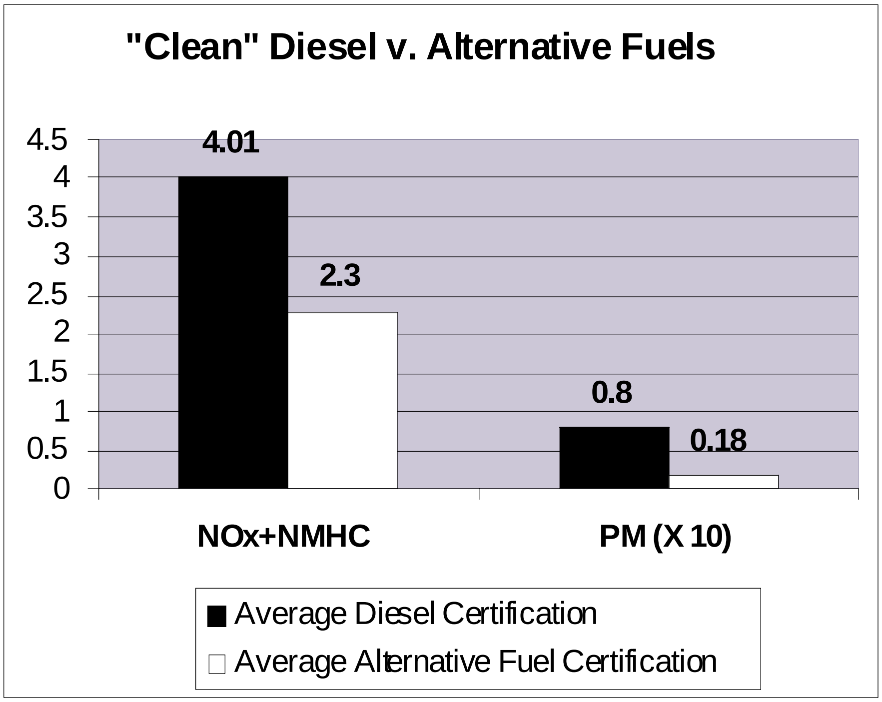
Moreover, the cleanest diesel engine on the market today still can only meet the EPA emissions standards set in 1994 for heavy-duty engines (4 grams per brake horsepower-hour (g/bhp-hr) for NOx and 0.10 g/bhp-hr for PM). As Table 4 below shows, even the cleanest diesel engine certified for school bus applications in the 2001 model year (MY)—the Cummins 5.9 liter engine—will emit nearly 2 times more NOx and 3.5 times more PM than the equivalent natural gas engine certified in 2000.[96] Similarly, the larger Cummins diesel school bus engine certified in 2001 (the 8.3 liter) emits 2.3 times more NOx and 5 times more PM than the equivalent natural gas engine certified in 2000.[97] In terms of global warming emissions, the Department of Energy found that natural gas buses, on average, reduce carbon dioxide (CO_2) emissions by 15–20 percent when compared to a diesel school bus.[98] Some natural gas engines may emit slightly higher carbon monoxide (CO) emissions than their diesel engine counterparts. The increase in CO is marginal, however, and does not outweigh the significant NOx, and PM, and other benefits achieved with natural gas engines.[99] Certification data for other diesel, CNG, and propane engines are contained in Appendix E of this report.

TABLE 4
Certified Emissions Levels for Cummins Diesel and Natural Gas Engines in G/Bhp-Hr

POLLUTANT	CUMMINS DIESEL 5.9L MY 01	CUMMINS CNG 5.9L MY 00[100]	CUMMINS DIESEL 8.3L MY 01	CUMMINS CNG 8.3L MY 00[101]
NOx	3.4	1.8	3.9	1.7
PM	0.07	0.02	0.05	0.01
NMHC	0.10	0.06	0.10	0.2
CO	0.6	2.7	0.5	0.6

The gap between diesel and natural gas emissions *in use* (i.e., under real world conditions) is even greater than these certified levels. In one recent study conducted by West Virginia University, in-use NOx emissions from diesel vehicles were found to be six times higher than the NOx emissions from natural gas powered vehicles, even though all the vehicles tested had been certified as meeting the *same* emission standards.[102] In that same study, average in-use PM emissions from the tested diesel vehicles were found to be 10 times higher than the PM emissions from the natural gas-powered vehicles.[103] On average, diesel school bus engines certified for purchase today can emit over 6 times more PM in use than new natural gas and other alternative fuel engines certified for sale by CARB and EPA.[104] In fact, the emissions reductions achieved by operating a new natural gas school bus over a new diesel-powered school bus is equivalent to removing 21–28 new cars from the road for NOx or removing 85 to 94 new cars from the road for PM.[105]

FIGURE 6



Even with the use of CARB diesel, currently available diesel school bus engines cannot meet the reduced emissions of natural gas engines. A recent study comparing emissions from a new diesel engine running on pre-1993 diesel fuel (used nationally) and CARB diesel revealed that the CARB diesel only slightly reduced emissions of NOx and PM, and that more than 95 percent of the remaining PM emissions were ultra-fine (less than 1 micron in size).[106] Dioxins, known human carcinogens, were also detected in both the federal diesel and the CARB diesel.[107] Finally, levels of toxic air contaminants such as benzene, toluene, 1,3-butadiene, formaldehyde, and polycyclic aromatic hydrocarbons (PAHs) were not significantly reduced by use of the newer diesel fuel.[108] Thus, even the most advanced diesel engine available, with California reformulated diesel fuel, remains far from clean.

Even the most advanced diesel engine available, with California reformulated diesel fuel, remains far from clean.

The bottom line is that alternative fuel school buses, such as natural gas, are much cleaner than currently available diesel school buses in terms of air toxics, NOx, and PM emissions. Diesel engine technology will continue to improve in emissions performance with advanced engine modifications and the use of aftertreatment, but alternative fuel technology will also take advantage of these advances and retain its clean lead over diesel.

International Truck's proposed "green" diesel school bus is still dirtier than a comparable natural gas bus

In January 2000, International Truck Company and Engine Corporation (International) introduced its so-called "green" diesel school bus, which has lower NOx and PM emissions than currently certified diesel engines as a result of optimized engine calibration and the use of a particulate trap designed to run on ultra-low sulfur fuel (5 ppm or less). While this school bus has not yet been certified, International is hoping to have the bus available for sale in August 2001. International claims that its new "green" diesel engine will achieve reductions of 25 percent in NOx and 90 percent in PM emissions over current heavy-duty diesel engine standards. While the advancements of International's "green" diesel engine technology promise a marked improvement over current certified diesel engine models, "green" diesel engines still will not be as clean as currently available and certified alternative fuel engines.

The "green" diesel engine will emit 1.6 to 1.7 times more NOx than its natural gas counterparts.

First, as Table 5 shows, the "green" diesel engine will emit 1.6 to 1.7 times more NOx than its natural gas counterparts. Second, there is some uncertainty over whether the "green" diesel engine will be able to reach even its projected NOx and PM emission targets, because the engine was originally designed to run on ultra-low sulfur diesel fuel (5 ppm or less) which is not available anywhere in the United States. In December 2000, EPA adopted regulations requiring a reduction in sulfur content in diesel fuel nationally to 15 ppm by 2006 – but neither EPA nor California has proposed to lower the sulfur content any further or any earlier. Two refiners, British Petroleum (BP) and Equilon Enterprises (also known as Royal Dutch/Shell Group), have made commitments to make low-sulfur diesel fuel (at 15 ppm) available to California school bus fleets upon request by 2002.[109] BP has also made commitments to deliver 30 ppm sulfur diesel to the Houston, Texas metropolitan area.[110] In addition, some 30 ppm sulfur diesel fuel is available in New York City courtesy of Tosco.[111] Absent a regulation requiring the sale of low-sulfur fuel on an expedited basis, however, additional capital investments to produce and provide low-sulfur diesel on a local, regional, or national scale are not expected to be made by refiners until 2006.[112]

Beyond fuel quality and availability issues, substantial concerns remain as to the durability and in-use performance of PM aftertreatment equipment for the full useful life of a school bus. Currently, data on in-use emissions and durability performance for PM aftertreatment is extremely limited for school buses, making it unclear as to whether these technologies will continue to achieve a lower emissions performance in the real world. In fact, we estimate, using historical data on in-use diesel engine performance and assuming the 85 percent control efficiency applied by CARB, that in use the "green" diesel engine may emit roughly 2.3 times more PM than its natural gas counterparts.[113] Thus, despite the promised PM emission benefits of "green" diesel technology, uncertainty remains as to real world PM emissions performance over the long-term.

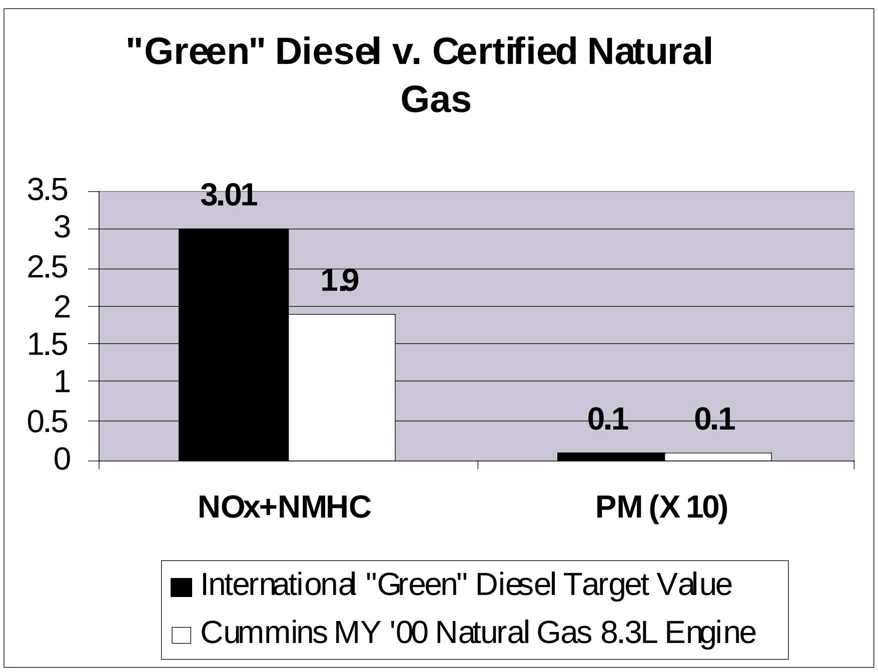
TABLE 5
Comparison of Natural Gas School Buses and "Green" Diesel School Bus

POLLUTANT	JOHN DEERE 8.1L CNG MY 01	CUMMINS 8.3L CNG MY 00	INTERNATIONAL "GREEN DIESEL"[114]
NOx	1.8	1.7	3.0
PM	0.01	0.01	0.01
NMHC	0.2	0.2	0.12
CO	1	0.6	0.1

Note: International's concept engine has not yet been certified; the certification numbers provided in Table 5 are the manufacturer's target estimates. The John Deere 8.1 liter natural gas engine for MY 2001 has been certified for transit bus use at 280 hp, but can be recalibrated at 250 hp for use in school buses upon request.[115]

In addition, the "green" diesel engine has not yet been evaluated to determine whether the modifications to the engine have reduced the toxicity of the exhaust sufficiently to protect our children. As is discussed in Chapter 2, diesel exhaust is a toxic air contaminant and poses a risk of lung cancer. Because of the complex interactions among diesel's many toxic constituents, a 90 percent PM reduction in diesel exhaust will not necessarily translate into a linear 90 percent reduction in diesel toxicity.

FIGURE 7



When taken together, the greater emissions of smog-forming chemicals (NOx and nonmethane hydrocarbon (NMHC) combined), uncertainty as to long-term PM emissions, and remaining concerns about toxicity cause the environmental and public health community to continue to promote alternative fuels like natural gas and propane over the proposed “green” diesel school bus engine to ensure that children are adequately protected.

EPA’s new heavy-duty engine standards will dramatically reduce diesel emissions, but not until the 2007 to 2010 phase-in of the new standards

While a Consent Decree with most of the major engine manufacturers will result in a reduction in NOx and NMHC emissions in new diesel engines by October 2002 (to 2.5 g/bhp-hr), the greatest NOx and PM reductions for new diesel engines will be phased in between 2007 and 2010, under regulations recently adopted by EPA.[116] Under these standards, new diesel engines will need to meet a more stringent 0.2 g/bhp-hr standard for NOx (a 95 percent reduction) and a 0.01 g/bhp-hr standard for PM (a 90 percent reduction). While we strongly support the new standards adopted by EPA, these standards are at least seven years away, and no current diesel engines—certified or in concept —can meet these standards.

Moreover, manufacturers of natural gas engines expect that by the time diesel engines become cleaner (likely by 2007), alternative fuel engines will become cleaner as well. For example, the same particulate traps being developed for diesel engines can also be installed on natural gas engines and would reduce particulate emissions virtually to zero. Thus, while diesel engines will continue to become cleaner over time, there will be a continuing challenge for the diesel industry to keep up with the public health benefits of alternative fuels.

CHAPTER 6

Aftertreatment, Repowers, and Rebuilds: How We Can Make Our Existing Diesel School Bus Fleet Cleaner

As this report details, the best long-term protection for children's health is for school districts to transition their diesel school bus fleets to alternative fuels such as natural gas and propane, and ultimately to zero emission technologies. There are at least three short-term options, however, for school districts to reduce the emissions of their existing diesel school bus fleet prior to retirement: aftertreatment, repowers, and rebuilds.

PM Aftertreatment. School districts can choose to retrofit their existing diesel school buses with PM aftertreatment technology (particulate traps) if they can purchase low-sulfur diesel fuel, which is necessary for the traps to function properly. PM traps essentially collect, or "trap," particles from the exhaust stream into a filter and, over time, literally burn (also referred to as regeneration or oxidation) the collected particles off the trap when the engine reaches a certain temperature. The California Air Resources Board (CARB) anticipates that particulate traps, when properly operated using low-sulfur diesel fuel, could reduce diesel PM emissions by 90 percent with an 85 percent control efficiency.[117] CARB also estimates that diesel PM traps will cost approximately $6,000 per bus with an incremental cost of $0.05 per gallon of low-sulfur diesel fuel.[118] The cost of low-sulfur diesel fuel sold elsewhere in the country may be higher. For example, in New York City, the price for 30 ppm sulfur diesel fuel can be 12 cents per gallon more than for conventional diesel fuel.[119] In California, $12.5 million from the State's Low Emission School Bus Program (see Chapter 7 for details) has been set aside specifically to help school districts pay for the retrofit of existing fleets and for the incremental costs of low-sulfur diesel fuel.[120] More funding is needed, however, both in California and throughout the country.

The principal impediment to a nationwide retrofit program is that low-sulfur diesel fuel (15 ppm or less) will not be widely available until 2006, pursuant to EPA's

December 2000 regulation. In addition, concerns have been raised by engine manufacturers that even the 15 ppm sulfur content required by 2006 may be too high for PM aftertreatment devices to function at optimal levels or remain durable over time. Also, although PM aftertreatment technology coupled with low-sulfur diesel fuel has demonstrated the *potential* to reduce particulate emissions overall, further testing is necessary to ensure that the particle traps are durable over a school bus's full useful life. Testing of particulate traps on school buses is also essential to determine whether the school bus driving cycle (which is different from other applications like refuse haulers and transit buses) generates the heat required to properly regenerate the trap. Currently, the South Coast Air Quality Management District (SCAQMD) in Southern California is testing school bus engines from three school districts to determine whether this technology will perform properly under a school bus operating cycle. Preliminary results are promising, but also indicate that school bus models prior to 1991 may experience calibration problems or failures.[121]

Repowers. Repowering a school bus refers to the removal of the aging bus engine and replacement with a new engine that meets or surpasses current emission standards. As part of this process, an aging diesel engine can be replaced with a new alternative fuel engine and fuel system at a reasonable price. The SCAQMD is currently considering the repowering of existing diesel engines to run on alternative fuels as a strategy for school districts that traditionally purchase used buses from other school districts to reduce their emissions. Whether this option is viable, however, will depend upon the cost of the repowering and the availability of grant funding in each region.

Rebuilds. Rebuilding an existing bus engine, using modern equipment, is another option to reduce excessive emissions from an existing school bus. However, it may be harder to receive grant funding for rebuilds due to the uncertainty over emissions benefits. The benefits of rebuilds may turn out to be marginal and subject to durability issues, given that modern equipment may not always work properly with an engine built several years earlier. This strategy is probably the least likely to improve school bus emissions performance.

CHAPTER 7

Funding Is Available to Help School Districts Switch To Alternative Fuel School Buses, But More Is Needed

This chapter provides information on existing funding sources that have been made available by state and federal policy makers to help finance alternative fuel projects. Unfortunately, most of these funding sources are either limited in the amount of dollars available for school bus fleets or are geared toward fleets that operate more hours per day. If we are ever to successfully convert our nation's school bus fleets to clean alternative fuels, our federal, state, and local officials must make significant amounts of money available specifically to help finance the conversion of school bus fleets.

There is some good news: Recently, several states have created funds earmarked for cleaner school bus purchases. Most significantly, Governor Davis of California set aside $50 million in the state's 2000-2001 budget solely for the purchase of "lower-emitting" school buses. We highlight below California's Lower-Emission School Bus Program, along with several other state and federal funding sources. In addition, we provide a more comprehensive listing of existing funding sources for alternative fuel projects in Appendix F of this report. Further information may be obtained by contacting your state or local air quality or pollution control district.

Several states have created funds earmarked for cleaner school bus purchases.

California—Lower-Emission School Bus Program

The California Air Resources Board (CARB) received an allocation of $50 million from the 2000-2001 State Budget to reduce school children's exposure to harmful diesel exhaust emissions. The CARB staff, in coordination with the California Energy Commission and local air pollution control districts, developed guidelines to help school districts replace hundreds of the highest-polluting buses with new, lower-emitting buses. Significantly, $25 million of this fund is earmarked specifically for the purchase of alternative fuel buses that meet the state's "optional low-NOx" standard. This means that many schoolchildren across the state of California will soon be riding on some of the cleanest buses commercially available. Additionally, $12.5 million of this fund is available to retrofit over 1,800 existing diesel buses with particulate-reducing filters, defray the added cost of low-sulfur diesel, and provide funds to help develop alternative fuel infrastructure.[122]

While this funding is significant, it is only enough to convert a fraction of the highly polluting buses currently in operation throughout the state. To truly make a difference, this funding program must become a recurring item in California's state budget and serve as a model for other state and federal policy makers to follow.

Arizona – SB 2001

Arizona Senate Bill 2001 created a $2.9 million fund to help school districts throughout the state cover the incremental cost of purchasing new alternative fuel vehicles or converting existing buses and vehicles to alternative fuels. In addition, several rebates and tax incentives are available in Arizona for the purchase and use of alternative fuel vehicles and the construction of public refueling stations. Unfortunately, school districts have to compete with other fleet operators for these latter incentives.[123]

California—Carl Moyer Memorial Program

The Carl Moyer Memorial Air Quality Standards Attainment Program (Carl Moyer Program) provides grants to cover the incremental costs of purchasing trucks, buses, and other vehicles that cut current NOx emissions by 25-30 percent or more. The program was funded at $25 and $19 million in FY 1999-2000 and FY 2000-2001, respectively, and is expected to double to $50 million in FY 2001-2002.

Although the majority of the fund is available to myriad public and private entities (including school districts) on a competitive basis, two to three million dollars of the 2001-2002 fund is expected to be allocated solely to school districts for conversion to alternative fuels. In addition, local air districts must match $1 for every $2 granted in Carl Moyer funds.

The incentive program often makes the purchase of a CNG bus less expensive *than its diesel counterpart,*

California—Compressed Natural Gas School Bus Incentive Program (through MSRC)

The Compressed Natural Gas School Bus Incentive Program is administered through the Mobile Source Air Pollution Reduction Review Committee of the South Coast of California. The program provides $40,000 towards the purchase of a Bluebird or Thomas Built CNG school bus—enough to cover the incremental cost of the CNG bus over a conventional diesel bus. In fact, the incentive program often makes the purchase of a CNG bus *less expensive* than its diesel counterpart, because it provides as much as

$15,000 above the incremental cost. The program was initially funded at $2.8 million, and over $900,000 remains available. Unfortunately, as with the California Low-Emission School Bus Program, future funding for this program is uncertain.

Georgia—Clean Fuels Grant Program

The Clean Fuels Grant Program is available to local governments and authorities throughout Georgia to facilitate the introduction and expansion of clean alternative fuel fleet operations. Local governments and authorities must have a demonstrated commitment to the use of clean alternative fuels to receive the grants, which are funded up to $50,000 per cycle. Vehicles must operate full-time on the clean alternative fuel, and infrastructure supported through the grant program must facilitate multiple users through the Fuel Net Atlanta Program. The program is administered by the Georgia Environmental Facilities Authority (GEFA), which has been working with the natural gas and propane industries to produce directories of all stations offering refueling capabilities for both CNG and propane.[124]

Iowa—Department of Natural Resources

The Iowa Department of Natural Resources, which operates the Iowa Energy Bank, provides low-interest loan financing for alternative fuel vehicle conversions and purchases by state and local governments, school districts, community colleges, and nonprofit organizations. Financing is made available through local and regional banks.[125]

New Mexico—Energy, Minerals, and Natural Resources Department

The Energy, Minerals, and Natural Resources Department (EMNRD) administers a Transportation Program, which provides grant funds on a competitive basis for projects which will reduce the overall energy demand and consumption of petroleum products. EMNRD provides funding for alternative fuel vehicle purchases and training or similar activities.

The state also authorized a $5 million loan fund for alternative fuel vehicle conversions by state agencies, institutions of higher learning, and school districts. However, the legislature has not yet appropriated any money for this fund.[126]

New York—Clean Water/Clean Air Bond Act Funding[127]

With approximately 60,000 school buses, New York is home to more school buses than any other state in the nation. New York has two programs that can help school districts shift these school buses from diesel to cleaner alternatives. Pursuant to the Clean Water/Clean Air Bond Act of 1996, New York has authorized up to $55 million in state funding for clean-fuel transit or school buses and their refueling or recharging infrastructure. Under a 1997 state law, private companies that purchase clean-fuel school buses or invest in refueling or recharging infrastructure are eligible for tax credits to offset a portion of their incremental costs, depending on the technology, fuel, and cost of the vehicle or infrastructure investment.

Unfortunately, school districts have been slow to take advantage of these programs. As of January 2001, the New York State Energy Research and Development Authority has allocated roughly $29 million of the Bond Act funding, but none has been spent on school buses. Likewise, it does not appear that any private school bus company has taken advantage of the state's tax credits.

Oklahoma—Alternative Fuels Act

Through the Alternative Fuels Act, Oklahoma offers a state income tax credit of 50 percent of the cost of converting vehicles to alternative fuels or installing refueling equipment for alternative fuel vehicles. The tax credit is available until January 2002 and can be used for conversions to CNG, LNG, LPG, ethanol, methanol, or electricity. The Act provides several other tax incentives for the use of alternative fuel vehicles.

The Alternative Fuels Act also established a revolving loan fund for the conversion of government fleets to alternative fuels. It provides no-interest loan funding for converting vehicles to run on alternative fuels (up to $5,000 per converted vehicle) and for the construction of refueling facilities (up to $100,000 for fueling stations). Repayment is made from fuel savings during a maximum 7-year period. If the alternative fuels price does not remain below the price of the conventional fuel that was replaced, however, repayment is suspended. Eligible applicants include state, county, municipalities, school districts, mass transit authorities, and public trust authorities.[128]

Pennsylvania—Alternative Fuels Incentive Grants (AFIG) Program

The Pennsylvania Department of Environmental Protection's Bureau of Air Quality established the AFIG Program to reduce Pennsylvania's dependence on imported oil and improve air quality through the use of alternative fuels. The AFIG Program currently pays 30 percent of the cost for converting vehicles to alternative fuels, 30 percent of the incremental cost for the alternative fuel option on a new factory-equipped vehicle, and 30 percent of the cost to install refueling equipment.

The program is funded at approximately $3-$4 million every year and is available to school districts, among other fleet operators.[129]

Texas—The Houston-Galveston Area Council (H-GAC)

The H-GAC provides assistance to local governments and state agencies that are required to convert their fleets to an alternative fuel. H-GAC will pay up to 80 percent of the incremental cost of purchasing an alternative fuel vehicles or converting a vehicle to run on an alternative fuel. Recipients must provide the 20 percent local match. These funds are provided through the CMAQ federal grant program.[130]

CHAPTER 8

LOCAL AIR QUALITY AGENCIES CAN ADOPT FLEET RULES REQUIRING SCHOOL DISTRICTS TO PURCHASE ONLY CLEAN ALTERNATIVE FUEL BUSES

C urrently there are no local, state, or federal laws requiring school districts or private school bus contractors to purchase clean, alternative fuel school buses instead of dirtier diesel buses.

Currently there are no local, state, or federal laws requiring school districts or private school bus contractors to purchase clean, alternative fuel school buses instead of dirtier diesel buses. That could soon change, however, if a rule proposed by the South Coast Air Quality Management District in California (SCAQMD) is adopted in March, 2001. The proposed rule would require all school districts and private school bus contractors operating in California's South Coast Air Basin—which includes Los Angeles, Orange, Riverside and San Bernardino Counties—to purchase only cleaner, alternative fuel buses. The proposed rule would not force school districts to convert their existing fleets all at once, but rather would apply as new buses are purchased according to the fleet operator's own schedule. This would assure that school districts are not overly taxed financially. In addition, school districts would not be required to purchase an alternative fuel bus if local, state, or federal funding is not available to cover the incremental cost. There is an expectation, however, that, as discussed in Chapter 7, there will be sufficient funding to ensure that this contingency is satisfied. In the case where no funding is available, the school district would be required to place a particulate trap on a new diesel bus. We support the SCAQMD proposed rule and urge other air quality agencies around the country to adopt similar rules to protect their children's health.

While EPA has adopted new standards for heavy-duty trucks and buses that, when fully implemented by 2010, will substantially reduce the public's exposure to diesel exhaust in California and across the country, an alternative fuel school bus approach is necessary for the following reasons: (1) to ensure that children are protected prior to 2010, and (2) because the EPA rule focuses only on NOx and PM, and the cleaner diesel engines have not been tested to ensure that toxic emissions have been sufficiently reduced. Thus, while we strongly support EPA's rules, including tighter standards and cleaner diesel fuel, it is imperative that EPA and state and local air quality agencies encourage engine makers to achieve these essential NOx reductions sooner, create incentives for inherently clean alternative fuels and advanced technologies, and develop a comprehensive program of real-world emissions guarantees.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

Given the abundance of studies linking diesel exhaust to cancer, premature death, exacerbation of asthma, and other respiratory illnesses, transitioning our school bus fleet from diesel buses to cleaner alternative fuels like natural gas and propane should be a top priority of policy makers throughout the country. The alarming results of our study—that these risks are significantly higher for children who ride on diesel school buses—merely underscore the need to convert the nation's school bus fleets to cleaner alternative fuels, and to do so on an expedited basis. Fortunately, an increasing number of school districts are making the switch to cleaner alternatives, but much more still needs to be done.

School districts should immediately modify their purchasing practices to replace aging diesel school buses with cleaner alternative fuel school buses like natural gas or propane.

We strongly recommend the following to reduce the health risks our children face from exposure to diesel exhaust:

1. School districts should immediately modify their purchasing practices to replace aging diesel school buses with cleaner alternative fuel school buses like natural gas or propane.
    - A sample letter to a local school district is included in Appendix G and a sample resolution adopting an alternative fuel school bus purchase policy is included in Appendix H.
2. Federal, state, and local agencies and legislative bodies should make additional funding available for the purchase of clean alternative fuel school buses.
    - A sample letter to local, state, or federal regulators is included in Appendix G.
3. Local air quality management districts should adopt rules which mandate that local school districts purchase only alternative fuel school buses similar to the rule scheduled for adoption by the South Coast Air Quality Management District in Southern California.
    - A sample letter to an air quality agency is included in Appendix G.
4. Where low-sulfur diesel fuel is available, school districts should retrofit existing diesel school buses not scheduled for short-term retirement with particulate traps to reduce risks prior to their replacement. We also urge EPA to require that low-sulfur diesel fuel be made available in advance of 2006 so that school buses—and other heavy-duty vehicles—can be retrofitted with traps to reduce their hazardous emissions. Alternatively, we urge the California Air Resources Board and other

states, where possible, to require the sale of low-sulfur diesel fuel in their states before 2006.

5. School officials should ensure that bus drivers, to the extent feasible, keep windows open on school buses and seat students toward the front of the bus before filling the rear seats.
6. If a child has asthma or another respiratory illness, a parent may wish to check whether the child's breathing symptoms worsen after riding on a diesel school bus and, if so, consult with the child's physician.

APPENDIX A

SCHOOL BUS MONITORING STUDY PROTOCOL

January 10, 2001

PURPOSE

1. To quantify a child's exposure to diesel exhaust particles during school bus commutes by measuring diesel exhaust levels inside buses and comparing these levels to simultaneous measurements inside a passenger car driving ahead of the bus.
2. To obtain measurements for various exposure scenarios by:
   - Monitoring on several commonly available bus model years;
   - Monitoring in the front and back of the buses;
   - Monitoring with high air exchange (windows open) and low air exchange (windows closed);
   - Comparing idling versus moving, and uphill versus downhill versus driving on the flat.

EQUIPMENT

(2) Aethalometer™ Real-Time Aerosol Analyzers
(2) fully charged automotive batteries
(2) power inverters
(1) 3- to 5-foot-long sampling tube
(1) 15- to 20-foot-long sampling tube
(1) cigarette lighter power adapter with attachment to inverter
(1) set of cables to attach automotive battery power source to inverter
(5) bungee cords/straps for securing instruments to seats
(1) cushion for bus Aethalometer
(2) covers for Aethalometers
DataRam™ Real-Time particulate monitors
(2) Gillian™ air pumps for DataRam
(1) small screwdriver for adjusting pump flow
(2) cyclone particle precollectors ($PM_{2.5}$)
(1) stopwatch
(1) log book and pens
(1) full-length, 50- to 66-passenger school bus with no children on board rented for 5 hours

(1) passenger car to serve as lead car
(2) detailed route maps and directions
(1) tape measure
(1) roll of duct tape
(1) adjustable wrench
(1) extra floppy disk

BUS ROUTE

Selection criteria for a bus route will include: (1) a route, or portion of a route, that is currently used to transport school children by bus in California; (2) a route that is approximately 60 minutes in length to allow for several repetitions in the sampling period; (3) a geographic area where there is minimal likelihood of windy conditions; (4) a route that includes few roads with heavy diesel vehicle traffic; (5) a route that includes at least one hill, and (6) a route that begins and ends at an elementary school.

Cal EPA's Air Resources Board has previously published average statistics for urban school bus driving patterns based on a report by Valley Research titled, "Study of the Driving Patterns of Transit Buses and School Buses Using Instrumented Chase Cars." One hour of school bus driving typically included: 18 minutes of idling, 8 service stops, 10 idling events, 17.5 mph average trip speed, and 2.4 minutes at a speed greater than 50 mph. Therefore, in order to model typical bus activity, we will attempt to select a route that mimics these conditions to the degree feasible.

MONITORING PROCEDURE

Instrument Locations

One Aethalometer will be set up in the middle of the bus with a 20 foot long tube that can extend to the front or back of the bus. The sampling tube will be attached to the back of the seat closer to the middle on the driver's side of the bus. The three sampling locations will include: (1) Back—last row of seats, driver's side aisle; and (2) Front—fourth row of seats, driver's side aisle. A second Aethalometer will be located in the back seat of a passenger car that will travel directly ahead of the bus. The sampling tube will be affixed between the driver's and passenger's seats in the front of the car. The Aethalometers will measure levels of black carbon averaged over 1 minute time periods.

Two DataRams will be used to monitor fine particle concentrations. One DataRam will be located on the bus adjacent to the first Aethalometer sampling tube. The other DataRam will be in the back seat of the passenger car that will be driving ahead of the school bus. During the initial and final idling periods, one DataRam and the bus Aethalometer sampling inlet will be moved into the bus loading zone area to measure concentrations in the bus stop.

INSTRUMENT SET-UP

Aethalometer

1. Load one Aethalometer on bus, on a pillow, fourth row of seats, driver's side.

2. Load second Aethalometer in passenger car, back seat, driver's side.

3. Strap Aethalometers securely into place in vehicles.

4. On bus, attach inverter to battery using cables, turn on inverter, and plug Aethalometer into inverter.

5. In car, attach inverter to cigarette lighter using adapter; turn on inverter, and plug Aethalometer into inverter.

6. Verify there is sufficient disc space and sampling ribbon in each Aethalometer.

7. Attach plastic sampling hoses to input valve on back of each Aethalometer.

8. Turn on both Aethalometers and observe warm-up sequence (10 minutes).

9. Set Aethalometer flow rates to approximately 4 liters per minute.

10. Affix inlet of bus sampling hose to back seat, aisle, driver's side, using duct tape.

11. Affix inlet of car sampling hose to front seat between driver and passenger.

Data-RAMs

1. Connect the sampling train for the pDR-1200, including pump, cyclone, and zeroing device.

2. Turn on pump and adjust to approximately 4 liters per minute.

3. Turn on pDR-1200, zero, and calibrate the instrument.

4. Remove the zeroing device.

5. Touch "Next" button on pDR-1200, then at "Logging Disabled" screen, touch "Enter." Screen should read "Log Intrvl 60s," and provide a "Tag #." Record the Tag number in the logbook. Touch "Next" repeatedly until given the option "Start Run: Enter"—touch "Enter."

6. Affix pDR-1200 in place in back seat of passenger car.

7. Zero DataRAM per instructions and secure in bus, last row of seats, driver's side.

MONITORING

1. Check clock time on each Aethalometer, and on each DataRAM; person recording activity in the logbook should synchronize watches with the on-bus Aethalometer and record any differences with the car Aethalometer and the DataRAMs.

2. Note the manufacturer, age and model, passenger capacity, and Vehicle Identification Number (VIN) of the school bus in the logbook.

3. Collect 10 minutes of data on-site idling prior to departure; during idling, the front door of the bus should remain open.

5. Drive designated route with passenger car leading and bus following immediately behind;
6. Use stopwatch to time bus stops at 1 minute per stop, and 5 minutes at the final stop of the route; during stops, the front door of the bus should remain open.
7. At 1 minute intervals, record bus position and activity in the logbook; bus position should include intersection names, streets, schools, or other landmarks; bus activity should include whether the bus is idling or traveling fast/slow, uphill, flat, or downhill; additional observations should include whether the streets are congested or quiet and the presence of any other diesel vehicles within one block.
8. One run in the middle of the day will include sampling in the front of the bus; this will require moving the DataRAM and the Aethalometer sampling tube to the fourth row, driver's side aisle.
9. For one 15 minute period of relatively steady-state driving conditions, four windows on each side of the bus should be opened half-way; this period should be noted in the logbook.
10. Collect 10 minutes of data on-site idling after completion of daily sampling; during idling, the front door of the bus should remain open.

INSTRUMENT COMPARISON

To assure that both DataRAMs and both Aethalometers are comparable, these instruments will need to be operated side-by-side for a period of at least 2 hours under a variety of air conditions. All instruments will be loaded into a passenger car, connected according to the protocol above and driven around in a variety of traffic conditions for a period of not less than 2 hours.

ANALYSIS

1. Download data from the DataRAMs and Aethalometer onto an IBM-compatible computer.
2. Perform time-adjustments to account for any differences in instrument clocks and sampling hose length.
3. Compare data from instrument side-by-side comparisons, including graphs and time-weighted averages; determine whether any correction factor is needed, and apply such correction factor if necessary.
4. Observe data for any unexplained, isolated, low or high values; check data quality for those points using Aethalometer diagnostics; discard data points only if they are single isolated values more than two standard deviations above or below the mean, with no explanatory factors recorded in the logbook at that time, and with questionable data quality.
5. Overlay the data from the two Aethalometers and from the two DataRAMs and graph

them on the same table; using the logbook, mark events during high and low periods.

6. Calculate time-weighted averages for in-car and in-bus data; compare these averages.
7. Using the logbook and map, designate portions of the route “uphill”, “downhill”, “flat” and calculate time-weighted averages for these different conditions in the bus and car.
8. Using the logbook, designate portions of the route “idling”, “stop-and-go”, and “steady driving” and calculate time-weighted averages for these conditions in the bus and car.
9. Subtract the overall time-weighted average of black carbon calculated on the car from that calculated on the bus; apply appropriate correction factors[131] to convert black carbon to elemental carbon, and to convert elemental carbon to diesel exhaust particulate;[132] compare with Cal EPA significant risk number adjusted for school bus scenario (see attached risk assessment) to calculate excess cancer risk to a child attributable to riding that school bus.

APPENDIX B

POTENTIAL CANCER RISK TO CHILDREN IN SCHOOL BUSES

Assumptions

Average number of hours per day a child may spend on a school bus—1-2 hours/day[133]
Average number of days per year a child may ride the bus to school—180 days/school year[134]
Number of years a child may spend riding the school bus—10 years
Amount of air a child breathes per day—452 liters/kg[135]
Amount of air an adult breathes per day—232 liters/kg[135]

Conversion Factors Derived From Assumptions

0.14 factor to convert from 70 yrs to 10 yrs (10/70)
0.042 factor to convert from 24 hour to 1 hour per day exposure (1/24)
0.083 factor to convert from 24 hour to 2 hour per day exposure (2/24)
0.49 to convert from 365 days/yr to 180 day school year (180/365)
1.95 to convert from adult air consumption rate to child air consumption rate (452/232)

Cancer Risk From Diesel Exhaust Exposure 24 Hours Per Day for a 70-Year Lifetime (Unit Risk)

Unit risk—3.0×10^{-4} at 1 microgram per cubic meter (mcg/m^{3}) (3 cancers per 10,000 people exposed for a lifetime) according to the California Air Resources Board

Calculation of Unit Risk Number for School Bus Scenario

1 hour per day
$(3.0 \times 10^{-4}) \times (0.14) \times (0.042) \times (0.49) \times (1.95) = 1.7 \times 10^{-6}$ unit risk at 1 mcg/m^3

2 hours per day
$(3.0 \times 10^{-4}) \times (0.14) \times (0.083) \times (0.49) \times (1.95) = 3.3 \times 10^{-6}$ unit risk at 1 mcg/m^3

Explanation of Unit Risk

A child riding a bus containing 1 microgram per cubic meter (mcg/m^3) of additional diesel exhaust particulate for between 1 and 2 hours per day, 180 days per year, over 10 years, would face an additional cancer risk of between 1.7 and 3.3 potential excess cancers per million children so exposed. If the levels of diesel exhaust particulate on the bus exceed 1 mcg/m^3, then the risk would be proportionately greater, whereas if the levels are lower, the risk would be less.

Calculation of Excess Risk Attributable to School Buses Based on Monitoring Data

Crown 1986(b) - 6.7 mcg/m^3 above ambient level of diesel exhaust (black carbon)
Conversion factor from black carbon measured by Aethalometer to elemental carbon = 1.32[136]
Conversion factor from elemental carbon to diesel exhaust particulate = 1.56[137]

1 hour per day
$(6.7\ mcg/m^3) \times (1.32) \times (1.56) \times (1.7 \times 10^{-6}) = 2.3 \times 10^{-5}$

2 hours per day
$(6.7\ mcg/m^3) \times (1.32) \times (1.56) \times (3.3 \times 10^{-6}) = 46 \times 10^{-5}$

Explanation of Calculation of Excess Risk Attributable to School Bus

A child riding a school bus with the highest average black carbon values we found would face an excess risk of 23–46 potential cancers per million children so exposed. This risk assumes that child is riding the bus every school day for 10 years.

APPENDIX C

Magee Scientific Company
1829 Francisco Street, Berkeley, CA 94703 USA
tel: +1 (510) 845-2801 ; fax: +1 (510) 845-7137
E-mail: Mail@Mageesci.com

THE AETHALOMETER

Real-Time Measurement of Aerosol Black Carbon ('BC' or 'EC')

The Aethalometer(TM) is an instrument that measures the pollutant species of suspended carbonaceous particulates. Aerosol Black Carbon ("BC," or "EC" for Elemental Carbon) is a ubiquitous component of combustion emissions. It is most obvious in diesel exhaust, but it is emitted from all combustion sources together with other species such as toxic and carcinogenic organic compounds.

The Aethalometer is an instrument that uses a continuous filtration and optical transmission technique to measure the concentration of BC in near-real-time. The Aethalometer is fully automatic and completely self-contained. It is constructed in a standard 19-inch enclosed chassis and includes the filtration and analysis chamber with automatically-advancing quartz fiber tape; the sample aspiration pump and air mass flow meter or controller (typical flowrates are 2 to 6 LPM); and temperature-stabilized optics and electronics. The instrument is operated by an embedded computer with display screen and keypad that controls all instrument functions and records the data to a built-in 3.5" floppy diskette. Power consumption is approximately 60 W at either 115 or 230 VAC. Weight is approximately 35 lbs. (15 kg.) and dimensions are 19" rack width, 11" (26 cm.) height and 12" (30 cm.) depth.

Applications

In occupational health studies, the Aethalometer can be used to monitor the exposure of workers to exhaust emissions and fumes arising from fuel combustion. Examples include the underground mining environment, railroad and truck drivers, vehicle repair garage technicians, etc. The Model AE2- series Aethalometer (Andersen RTAA-900) was specially designed to respond to UV-absorbing filterable material, which is found to include components present in fresh diesel exhaust.

In the indoor environment, the Aethalometer can be used to monitor the infiltration and trapping of emissions in a building as well as the production and circulation of internal emissions. (The 'classic' example is that of a building whose air intake is next to the truck unloading dock).

In urban locations, the Aethalometer monitors combustion-derived particulates when high concentrations due to traffic and other emissions may threaten public health. Its rapid response allows data to be collected on a (typical) 1- to 5-minute timebase, providing immediate identification of source strength and dispersion patterns. The speciation of inhalable aerosol particulates (PM2.5) in real time is a current topic of considerable interest to the US EPA and governmental air quality management organizations in U.S. states. A standard for allowable BC concentrations has been legislated by the German Government, and instruments are being installed across Germany with matching interest in other European countries.

Aethalometer Model Series

The “classic” Aethalometer AE1-series (Andersen RTAA-800) measures BC (“Elemental Carbon”) using optical absorption at 880 nm. Aerosol Black Carbon is the only commonly-found species that has a strong absorption: the absorption is quantitative and the instrument's response can be calibrated as a mass concentration of BC.

The “dual channel” AE2-series (Andersen RTAA-900) combines this measurement with a simultaneous measurement of optical absorption at 370 nm in the near ultraviolet. Many aromatic organic species have strong absorbance at this wavelength, and the UV channel responds very strongly to species such as those present in tobacco smoke, fresh diesel exhaust, etc.

APPENDIX D

PORTABLE MONITOR/DATA LOGGER

MIE, Inc.
Tel: (781) 275-1919
Fax: (781) 275-2121
Toll free No.: (888)643-4968
Website: www.mieinc.com

DataRAM™
Real-Time Aerosol Monitor

Real-Time measurement of Airborne particulate Concentrations

The DataRAM Real-Time Aerosol Monitor measures mass concentrations of airborne dust, smoke, mists, haze, and fumes and provides continuous real-time readouts. With optional accessories, the DataRAM can also provide respirable, PM-2.5, or PM-10 correlated measurements.

Designed for High Sensitivity

A high-sensitivity nephelometric monitor, the DataRAM samples the air at a constant, regulated flow rate by means of a built-in diaphragm pump. The DataRAM's light scattering configuration is optimized for the measurement of airborne particle concentrations, maximizing the unit's sensitivity. The detected signal is processed by state-of-the-art lock-in circuitry followed by high-resolution digitization, achieving ultimate detectability of atmospheric Rayleigh scattering fluctuations.

The Widest Measurement Range of Any Real-Time Particulate Monitor

In addition to its high sensitivity, the DataRAM has the widest measurement range of any real-time aerosol monitor-from 0.0001 mg/m3 (0.1µg/m3) to 400 mg/m3. The DataRAM is capable of measuring mass concentrations of airborne particles in industrial and ambient environments ranging from exceptionally pristine to extremely polluted. The DataRAM's auto-ranging digital display provides both real-time and time averaged concentrations.

DataRAM with Omnidirectional Sampling Inlet for Ambient Monitoring

The DataRAM incorporates several technological advances which guarantee exceptional long-term stability. Near infrared source output feedback control provides drift-free operation and excellent temperature stability. For either manual or preprogrammed/automatic zeroing of the monitor, an electronically controlled latching solenoid valve diverts the entire filtered air stream though the optical sensing stage in order to achieve “zero” air reference. In addition, instrument span checks (secondary calibration) can be performed simply by turning a knob on the DataRAM's back panel, which inserts a built-in optical scattering/diffusing element into the filtered air stream. On-screen diagnostic indicators and automatic shut-off for low battery conditions also help ensure the monitor's correct operation and data storage.

After passing through the optical sensing stage, all the particles are retained on a HEPA filter. Part of the filtered air stream is then continuously diverted through and over all optically-sensitive areas (lens, light traps, etc.) to form a continuous air curtain which protects against particle deposition. This design, in conjunction with a highly reliable diaphragm pump, ensures long-term maintenance-free operation. A membrane filter(with special holder included) can be substituted for the HEPA cartridge for gravimetric and/or chemical analysis of the particles collected downstream of the sensing stage.

DataRAM with Cyclone Precollector for Respirable Particle Measurements

Integral Large-Capacity Data Logger The DataRAM has built-in large-capacity data logging capabilities. Stored information includes time and date, average concentrations, maximum and minimum values over selected periods, STEL concentration, and tagging codes. Logged information can be retrieved either by scrolling through the DataRAM's display or by down-loading to an external device such as a personal computer or printer. DataRAM can be powered by a rechargeable internal battery or an external power source.

Several optional accessories are available for use with the DataRAM for a wide range of sampling applications. A cyclone precollector allows respirable particle measurements. An omnidirectional air sampling inlet (with or without a PM-10/2.5 head) is available for ambient monitoring.

Specifications

- Concentration measurement ranges (auto-ranging)1:
  0.1 to 999.9 µg/m3(resolution: 0.1µg/m3)
  1.00 to 39.99 µg/m3(resolution: 0.01mg/m3)
  40.0 to 399.9 mg/m3(resolution: 0.1mg/m3)
- Scattering coeffcient range: 1.5 x 10 -7 to 6 x 10 -1 m -1 (approximate) @ l = 880 nm
- Concentration display averaging/updating interval 2: 1 or 10 seconds
- Precision/repeatability over 1 hour (2-sigma)3:
  + 0.3 µg /m3 for 10 second averaging
  + 1.0 µg /m3 for 1 second averaging
- Accuracy 1: + 5% of reading + precision
- Particle size range of maximum response : 0.1 to 10µm
- Sampling flow rate 2: 1.7 to 2.3 liters/minute
- Alarm level adjustment range 2: 0.1 µg/m3 to 399.9 mg/m3

- Alarm averaging time : real time (1 or 10 seconds), or STEL (15 minutes)
- Data logging averaging periods 2: 1 second to 4 hours
- Total number of data points in memory: 10,000 (each point: average, minimum, and maximum concentrations)
- Logged data:
- For each data point: average, minimum, and maximum concentrations; time/date; and data point number Run summary: tag number of logged points; start time/date; total elasped run time; averaging time; data logging averaging period; calibration factor; STEL concentration; STEL occurrence time after start; overall average concentration; overall maximum and minimum concentrations with data point number
- Number of data tags: 10
- Real time and date data: seconds; minutes; hours; day of month; month and year (with leap year compensation)
- Clock accuracy: + 1 minute/month, or better
- Elasped time range: 1 second to 99 days
- Time keeping and data storage duration: > 10 years
- Readout display: LCD 120 x 64 dots, 15 characters x 8 lines, 57.6 x 38.4 mm active area
- Internal battery: rechargeable sealed lead-acid; 6.5 Ahr; 6 V nominal
- Operating time with new and initial full battery charge4: > 24 hours
- Operating time with DataRAM charger: continuous and unlimited
- Charging input power: 115/230 VAC, 50/60 Hz, 50 VA
- External DC power (optional): 6 V @ 3 A
- Analog output (auto ranging)5:
  0 to 5 V, for 0 to 4 mg/m^3
  0.5 to 5 V, for 4 to 40 mg/m^3
  0.5 to 5 V, for 40 to 400 mg/m^3
- Digital output: RS232C, 9600 baud; 8 data bits, 1 stop bit; parity: none
- Alarm output: switched. 1 A @ 10 V maximum, resistance < 0.1 W
- Alarm sound intensity: 90 dB @ 1 m
- Fuse: 1 A, fast
- Operating environment: 0° to 40° C (32° to 104° F), 0 to 95% RH, noncondensing
- Storage environment: –20° to 60° C (–4° to 140° F)
- Dimensions: 134 mm (5.28 in) H x 184 mm (7.25 in) W x 346 mm (13.63 in) D
- Weight: 5.3 kg (11.7 lbs)
- Standard accessories included: universal voltage battery charger, standard HEPA filter cartridge, analytical filter holder, PC communications software disk, digital output cable, carrying case, and instruction manual

APPENDIX E

Emissions Comparisons of ARB Certified Diesel, CNG, Propane (LPG) School Bus Engines and Non-Certified "Green" Diesel School Bus Engine Technology

Pollutants and EPA Emission Standards	’00/’01 Certified Emissions (g/bhp-hr) for School Bus Engine[138] and Fuel Type[139]										Uncertified[140]
	Cummins 5.9L (DSL) '01	Cummins 5.9L (CNG) '00	Cummins 5.9L (LPG) '00	John Deere 6.8L (CNG) '01	Inter-national 7.6L (DSL) '01	John Deere 8.1L (CNG) '01	Caterpillar 3126 (DSL) '01	Cummins 8.3L (DSL) '01	Cummins 8.3L (CNG) '00	Inter-national 8.7L (DSL) '01	International Green Diesel (<5ppm)
NOx (4.0 g/bhp-hr)	3.4	1.8	2.3	2.4	4	1.8	3.8	3.9	1.7	3.9	3
PM (0.1 g/bhp-hr)	0.07	0.02	0.01	0.04	0.1	0.01	0.09	0.05	0.01	0.09	0.01
CO (15.5 g/bhp-hr)	0.6	2.7	1	1.9	1.7	1	1.2	0.5	0.6	1.2	0.12
NMHC (1.2 g/bhp-hr)	0.1	0.06	0.8	0.3	0.19	0.2	0.58	0.1	0.2	0.1	0.1

Pollutants (g/mi)	Calculated Emissions Using '00-'01 Cert. Emissions for School Bus Engines[141]										Uncertified
	Cummins 5.9L (DSL)	Cummins 5.9L (CNG)	Cummins 5.9L (LPG)	John Deere 6.8L (CNG)	Inter-national 7.3L (DSL)	John Deere 8.1L (CNG)	Catepillar 3126 (DSL)	Cummins 8.3L (DSL)	Cummins 8.3L (CNG)	Inter-national 8.7L (DSL)	International Green Diesel (<5ppm)
NOx in (g/mi)	14.62	7.38	9.43	9.84	17.2	7.38	16.34	16.77	6.97	16.77	12.9
PM (g/mi)	0.301	0.082	0.041	0.164	0.43	0.041	0.387	0.215	0.041	0.387	0.043
CO (g/mi)	2.58	11.07	4.1	7.79	7.31	4.1	5.16	2.15	2.46	5.16	0.516
NMHC (g/mi)	0.418	0.246	3.28	1.23	0.836	0.82	2.507	0.418	0.82	0.418	0.43

Pollutants (lbs or tons)	Calculated Useful Life Emissions Using '00-01 Cert. Data for School Bus Engines[142]										Uncertified
	Cummins 5.9L (DSL)	Cummins 5.9L (CNG)	Cummins 5.9L (LPG)	John Deere 6.8L (CNG)	Inter-national 7.3L (DSL)	John Deere 8.1L (CNG)	Catepillar 3126 (DSL)	Cummins 8.3L (DSL)	Cummins 8.3L (CNG)	Inter-national 8.7L (DSL)	International Green Diesel (DSL <5ppm)
NOx (tons)	3.644	1.840	2.351	2.453	4.288	1.840	4.073	4.180	1.737	4.18	3.216
PM (lbs)	150.1	40.9	20.4	81.8	214.4	20.4	192.9	107.2	20.4	192.9	21.4
CO (tons)	0.643	2.759	1.022	1.942	1.822	1.022	1.286	0.536	0.613	1.286	0.129
NMHC (tons)	0.104	0.061	0.818	0.307	0.208	0.204	0.625	0.104	0.204	0.104	0.107

APPENDIX F

Examples of Available Funding Sources for Conversion to Alternative Fuels[143]

STATE OR FEDERAL ENTITY	FUNDING SOURCE	INCENTIVE DESCRIPTION
Arizona	Senate Bill 2001	Allocated $2.9 million to help school districts cover the incremental cost of purchasing new alternative fuel vehicles or converting existing buses and vehicles to alternative fuels.
Arkansas	Department of Economic Development	$250,000 available to help cover the cost of converting vehicles to alternative fuels. Up to $2,000 rebate available for CNG and electric vehicle conversions, and up to $1,000 for LPG, methanol, and ethanol conversions.
California	Carl Moyer Memorial Air Quality Standards Attainment Program	Provides grants to cover the incremental costs of purchasing trucks, buses, and other vehicles that cut current NOx emissions by 25-30 percent or more. $50 million is expected to be in the general fund in FY 2001-2002, with $2-$3 million of that money allocated solely to school bus purchases.
California	Compressed Natural Gas School Bus Incentive Program (through MSRC)	Provides $40,000 towards the purchase of a Bluebird or Thomas Built CNG school bus. Program was initially funded at $2.8 million, and over $900,000 remains available.
California	California Energy Commission	Approximately $3 million in funds available for alternative fuel and electric vehicle infrastructure.[144]
California	Motor Vehicle Registration Fees: AB 2766(Sher)	Funding from $4 vehicle registration fee. All funds used to reduce emissions from mobile sources.
California (Bay Area)	Transportation Fund For Clean Air (TFCA)	Approximately $20 million per year, generated through a vehicle registration surcharge, funds public agency projects that focus on reducing motor vehicle emissions.[145]
California (South Coast)	Clean Fuels Program—California South Coast AQMD	Funding comes from a $1 vehicle registration fee—about $10-$12 million annually. SCAQMD also obtains $4 in matching funds for every $1 from industry and other public agencies.[146]
Colorado	Various State Incentives	Cash rebates provided to public sector and non-profit fleets, and income tax credit added for the construction of alternative fuel refueling facilities.
Georgia	Clean Fuels Grant Program	Available to local governments and authorities that have demonstrated a commitment to the use of clean alternative fuels to facilitate the introduction and expansion of clean alternative fuel fleet operations. Recipients are funded up to $50,000 per cycle.
Iowa	Department of Natural Resources	Provides low-interest loan financing for alternative fuel vehicle conversions and purchases by state and local governments, school districts, community colleges, and nonprofit organizations.
Maryland	Clean Cities Program	Offers rebates of $4,000 for alternative fuel vehicle purchases and $2,000 for purchase of CNG bi-fuel vehicles. Also offers operation and maintenance training for CNG vehicles and information on CNG fueling stations.
New Mexico	Energy, Minerals, and Natural Resources Department	Provides grant funds on a competitive basis for projects which will reduce the overall energy demand and consumption of petroleum products, including alternative fuel vehicle purchases and training or similar activities. A $5 million loan fund for alternative fuel vehicle conversions by state agencies, institutions of higher learning, and school districts has also been authorized by the state but has not yet been funded.
New York	Clean Water/Clean Air Bond Act	$55 million appropriated for clean fuel buses. Includes state assistance for the purchase of AFVs and refueling/recharging infrastructure for state agency fleets. Tax credits and other incentives are also available from the state.
New York	Clean City Challenge	Approximately $250,000 is available annually for the incremental cost of AFVs and converted vehicles, the installation of refueling or recharging equipment, and garage modifications.
Oklahoma	Alternative Fuels Act	Offers state income tax credit of 50 percent for the cost of converting vehicles to alternative fuels or installing refueling equipment for alternative fuel vehicles. Also, provides no-interest loan funding for converting vehicles to run on alternative fuels (up to $5,000 per converted vehicle) and for the construction of refueling facilities (up to $100,000 for fueling stations). Available to school districts, among other fleet operators.

STATE OR FEDERAL ENTITY	FUNDING SOURCE	INCENTIVE DESCRIPTION
Pennsylvania	Greater Philadelphia Clean Cities Program (GPCCP)	Administers grants to users of alternative fuels and conducts education and out-reach to fleet managers and the public. Funding is available for heavy-duty vehicles.
Pennsylvania	Alternative Fuels Incentive Grants (AFIG) Program	Pays 30 percent of the cost for converting vehicles to alternative fuels, 30 percent of the incremental cost for the alternative fuel option on a new factory-equipped vehicle, and 30 percent of the cost to install refueling equipment. Funded at approximately $3-$4 million every year. Available to school districts, among other fleet operators.
Texas	The Houston-Gaveston Area Council (H-GAC)	Pays up to 80 percent of the incremental cost of purchasing an alternative fuel vehicle or converting a vehicle to run on an alternative fuel.
Texas	The Texas General Land Office (GLO)	Makes low-cost, in-kind natural gas available to school districts for use as an alternative vehicle fuel.
Utah	Office of Energy Services	Offers zero-interest loans to public agencies for the incremental costs of AFVs and for refueling equipment.
Virginia	Literary Fund	Permits loans from the Literary Fund for constructing and equipping school bus fueling facilities supplying CNG or other alternative fuels. Tax credits from $200 to $5,000 are also available.
West Virginia	Clean State Program	Up to $10,000 available to convert fleets to alternative fuels. Applicants limited to county governments, incorporated municipalities, transit authorities and school boards.
U.S. IRS	Federal Tax Deduction	Tax deductions of up to $50,000 provided for qualified clean fuel buses. Also, tax deductions of up to $100,000 per location are available for qualified clean fuel refueling property or recharging property for electric vehicles.
U.S. Dept. of Energy	State and Alternative Fuel AFV Credit Program	Credits which can be traded or sold are allocated to state fleet operators and covered Alternative Fuel Provider fleet operators when AFVs are acquired over and above the amount required, or earlier than expected.
U.S. Dept. of Energy	Clean Cities Program	Coordinates voluntary efforts between locally based government and industry to accelerate the use of alternative fuels and expand AFV refueling infrastructure.
U.S. Dept of Energy	Urban Consortium Funds	Funds city, county, and tribal projects that best define and demonstrate innovative and realistic energy efficient and environmentally responsible technologies. Many AFV projects have received funding from this program.
U.S. EPA	Air Pollution Control Program	Provides up to 60% federal funds to implement plans to prevent and control air pollution.
U.S. EPA	Congestion Mitigation and Air Quality Improvement	$9.1 billion national program designed to help states control transportation and meet national air quality standards for air criteria pollutants. Eligible projects include vehicle refueling and conversions to AFVs.

APPENDIX G

Sample Letter to Air Board

[Date]

Dear State and Local Air Agency:

I write to urge you to adopt a rule that would require all school districts and private school bus contractors in our air basin to purchase only clean, alternative fuel powered school buses, instead of buses powered by diesel.

Diesel exhaust has been identified by a growing number of health agencies, including the Environmental Protection Agency, as a substance known or likely to cause cancer. In addition, diesel particles contribute to premature deaths, increase the severity of respiratory illnesses, and exacerbate asthmatic conditions. Children are among those most at risk from the hazards of diesel exhaust, yet school bus fleets include some of the oldest and most polluting buses on our roads today. What's more, I am concerned about a recent study that found schoolchildren are exposed to as much as four times more pollution when riding *inside* a diesel school bus than when riding in a car right in front of that same bus.

Our children should be riding on the cleanest buses available. By adopting a rule that requires only the purchase of cleaner alternative fuel school buses, such as those powered by natural gas, you will help ensure that our children have a healthier and safer future. So-called "green diesel" school buses are a risky option because they fail to meet the cleanest emissions standards achievable by natural gas technology. Many local transit authorities around the country are making the switch to clean alternative fuel buses over diesel. Don't our children deserve the same protection?

Please stand up for our children by adopting a rule that requires the purchase of only clean, alternative fuel buses and takes dirty diesel school buses out of our communities. Our children are worth the investment.

Sincerely,

Sample Letter to School District

[Date]

Dear Local School District:

As a parent whose child attends a school within your district, I am writing to urge you to purchase only clean alternative fuel school buses, instead of diesel.

Diesel exhaust has been identified by a growing number of health agencies, including the Environmental Protection Agency, as a substance known or likely to cause cancer. In addition, diesel particles contribute to premature deaths, increase the severity of respiratory illnesses, and exacerbate asthmatic conditions. Children are among those most at risk from the hazards of diesel exhaust, yet school bus fleets include some of the oldest and most polluting buses on our roads today. What's more, I am concerned about a recent study that found schoolchildren are exposed to as much as four times more pollution when riding *inside* a diesel school bus than when riding in a car right in front of that same bus.

Our children need the cleanest available technologies and the assurance that clean buses remain clean. By adopting a policy to purchase only clean alternative fuel school buses, you will help ensure our children have a healthier future. So-called "green diesel" school buses are a risky option because they fail to meet the cleanest emission standards achievable by natural gas technology. School districts across the country operate alternative fuel buses, such as those powered by natural gas, with great success. I urge you to follow their lead in cleaning up our school bus fleet.

Please stand up for our children by purchasing only clean, alternative fuel school buses. Our children are worth the investment.

Sincerely,

Sample Letter to Elected Officials

[Date]

Dear Governor and Elected Officials:

I am writing to urge you to set aside funds in our state/federal budget for the purchase of clean alternative fuel school buses.

Diesel exhaust has been identified by a growing number of health agencies, including the Environmental Protection Agency, as a substance known or likely to cause cancer. In addition, diesel particles contribute to premature deaths, increase the severity of respiratory illnesses, and exacerbate asthmatic conditions. Children are among those most at risk from the hazards of diesel exhaust, yet school bus fleets include some of the oldest and most polluting buses on our roads today. What's more, I am concerned about a recent study that found schoolchildren are exposed to as much as four times more pollution when riding *inside* a diesel school bus than when riding in a car right in front of that same bus.

Our children should be riding on the cleanest buses available, but our school districts have limited budgets and cannot always carry the incremental costs associated with a conversion to cleaner, alternative fuel buses. By making public funds available to school districts for the purchase of cleaner alternative fuel school buses, you will help to protect our children, while also ensuring that school districts do not have to choose between clean buses and educational materials. The state of California, with the help of Governor Davis, set aside $50 million dollars in its 2000–2001 budget for the purchase of cleaner school buses. I urge you to follow California's lead and set aside funds to clean up our school bus fleets.

Please stand up for our children by making available the necessary funds for school districts to purchase alternative fuel powered school buses. Our children are worth the investment.

Sincerely,

APPENDIX H

Sample School Board Resolution in Support of an Alternative Fuel School Bus Policy

WHEREAS diesel exhaust has been identified by a growing number of health authorities, including the United States Environmental Protection Agency (EPA) and the state of California, as a pollutant known or likely to cause cancer, and over 40 individual chemical components of diesel exhaust separately have been identified by the EPA as compounds that cause cancer or reproductive harm;

WHEREAS the state of California concluded that more than 70 percent of the risk of cancer from air pollution comes from diesel exhaust alone, and the State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials—two national public health organizations—estimate that diesel exhaust is responsible for 125,000 cancers nationwide;

WHEREAS diesel exhaust is also known to be a major source of fine particles, which aggravate heart and respiratory problems, increase the risk for asthma attacks and cause premature death, and of oxides of nitrogen (NOx), which combine with hydrocarbons to form smog and have been connected to decreased lung function growth in children;

WHEREAS children are known to be among those most susceptible to the negative health effects of diesel exhaust exposure because, among other things, a child's developing body is less capable of defending itself against pollutants such as diesel particulate; children typically breathe at twice the rate of an adult, thereby receiving and retaining greater doses of pollution, and children tend to breath through their mouths, thereby bypassing the natural filtering protections of the nose;

WHEREAS cleaner alternatives to new diesel school buses exist that are widely available, have been proven to be durable, and emit less NOx, particulate matter and air toxics than a new diesel school bus.

BE IT RESOLVED THAT:

We hereby adopt a policy to purchase, lease, or contract only school buses that run on cleaner, alternative fuels, such as natural gas, instead of on diesel fuel.

ENDNOTES¶

[1] State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials, "Cancer Risk from Diesel Particulate: National and Metropolitan Area Estimates for the United States," March 15, 2000.

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[25] The four buses we tested ranged in model year from 1986 to 1988. According to information received from the CARB, the California Department of Education and the California Highway Patrol, at least 35 percent of all school buses in service in California are MY 1988 or older.

[26] The conversion from black carbon (BC) to total diesel particulate (DEP) is performed by the following formula: (BC x 2.06) = DEP. The correction of 2.06 comes from a correction of 1.32 converting BC to elemental carbon (EC) and a correction of 1.56 to convert EC to DEP. The first correction factor is derived from Babich, P., et al., "Method Comparisons for Particulate Nitrate, Elemental Carbon, and $PM_{2.5}$ Mass in Seven U.S. Cities," *J. Air & Waste Mgm. Assn.*, 50: 1095-1104., 2000. The second correction factor is derived from an estimate of the proportion of EC in DEP (64%) derived from "The Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air

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[27] Section 112 of the Clean Air Act establishes a one in one million annual per-capita risk (1 X 10<-6>) as the threshold for acceptable risk. 42 U.S.C. § 7412(f)(2)(A) "If standards promulgated pursuant to subsection (d) and applicable to a category or subcategory of sources emitting a pollutant (or pollutants) classified as a known, probable or possible human carcinogen do not reduce lifetime excess cancer risks to the individual most exposed to emissions from a source in the category or subcategory to less than one in one million, the Administrator shall promulgate standards under this subsection for such source category."
In addition, the Food Quality Protection Act, the only law designed specifically to protect children from environmental contaminants, requires EPA to ensure that there is a reasonable certainly that no harm will result from aggregate exposure to a pesticide from food and all other exposures. This standard has been interpreted to mean that a significant risk exists when there is a 1 in 1 million chance that an effect will occur. 21 U.S.C. § 346a(b)(2)(A)(ii); Letter from Lynn Goldman, Assistant Administrator of the EPA, to Representative Henry Waxman (Mar. 17, 1998). The Food and Drug Administration (FDA) has also generally used a standard of 1 in 1 million or less. 50 Fed. Reg. 51,551, 51,557 (1985) (to be codified at 20 C.F.R. 700) ("FDA cannot, with assurance, state that the 1 in 100,000 level would pose an insignificant level of risk of cancer to people. FDA can state, and comments agree, that the 1 in 1 million level represents an insignificant level of risk of cancer to people.")

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[106] An issue has been raised that CNG may also have a significant number of ultra-fine particles. Although it is appropriate to raise this concern and to address it if further study shows it to be serious, the evidence is very incomplete at present and is overwhelmed by the massive body of evidence regarding the harmful effects of diesel exhaust. In fact, according to the U.S. Department of Energy, there is no definitive study on the issue of CNG ultrafine particles. Regardless, we have every expectation that technologies being designed to control diesel particles, including smaller particles, will be as effective in reducing particulate emissions from natural-gas engines. In fact, they may be more effective due to the inherently low sulfur

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[136] Babich, P., M. Davey, G. Allen, P. Koutrakis, "Method Comparisons for Particulate Nitrate, Elemental Carbon, and PM2.5 Mass in Seven U.S. Cities," *J. Air & Waste Mgmt. Assn.*, 50:1095-1104, 2000.

[137] The fraction of diesel exhaust particulate that is composed of elemental carbon ranges from approximately 40–70%. Cantrell BK; Watts WF. Diesel Exhaust Aerosol: Review of Occupational Exposure. Applied Occupational and Environmental Hygiene, 12: 1019-1027, 1997. The Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant, California Air Resources Board, 1998, uses 64% as an estimate; therefore, we multiplied our results by 100/64, or 1.56.

[138] School bus engines typically used in school bus fleets according to A-Z Bus Sales.

[139] Certified emissions data from ARB's *2000/2001 Model Year Heavy-Duty On-Road Certification Listing*. Values are expressed in grams per brake-horsepower-hour (g/bhp-hr), a measure of the mass emissions released per unit of energy consumed by the engine.

[140] Non-certified emission numbers provided by International Truck Company using ultra-low sulfur diesel set at 5ppm sulfur or less. California and the federal government currently have no plans to adopt ultra-low sulfur diesel levels at 5ppm. USEPA has recently adopted a heavy-duty diesel rule that would adopt a low sulfur diesel standard set at 15ppm by mid-year 2006. Emission numbers provided by International Truck, therefore, are fairly uncertain and still have to pass durability testing.

[141] Calculated from certified emissions data using ARB conversion factors of 4.3 bhp-hr/mi for diesel engines and 4.1 bhp-hr/mi for CNG and LPG (ARB 1996). Data from the US Environmental Protection Agency suggests that applying the same conversion factor for all pollutants is inappropriate and has identified empirically-derived estimates that would widen the gap between CNG and diesel for particulate emissions (U.S. EPA 1992).

[142] The calculated emissions shown in the above table assume that the useful life of a school bus is equal to 15 years and accumulates approximately 13,300 miles of service per year (SCAQMD 1999).

[143] Information on all funding sources other than California-specific sources was obtained from the Deparment of Energy's website: http://www.fleets.doe.gov/fleet_tool.cgi?18770,benefits,2,52005.

[144] www.cec.org

[145] www.arb.gov

[146] Source of information: conversations with Larry Watkins, and Connie O'Day of the South Coast Air Quality Management District.