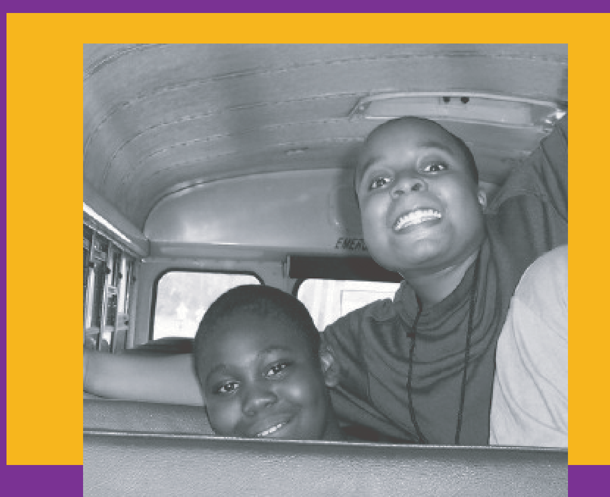
A Case for the Healthy School Bus: Lessons from the Field

Results of a Cabin Air Quality Demonstration Project on Diesel School Buses in Charlotte, North Carolina

December 2006



Southern Alliance for Clean Energy
Carolinas Clean Air Coalition

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Text of this report and more information on diesel can be found online at www.cleanenergy.org/schoolbusreport.cfm. A video documenting the Atlanta school bus monitoring study is also available online at www.cleanenergy.org/programs/hottopic.cfm?ID=10.

Southern Alliance for Clean Energy (SACE) is a not-for-profit, nonpartisan organization that promotes responsible energy choices that create global warming solutions and ensure clean, safe, and healthy communities throughout the Southeast. For more information, go to www.cleanenergy.org.

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Carolinas Clean Air Coalition (CCAC) is a not-for-profit organization that works to restore clean and safe air to the Charlotte region through coalition building, public policy advocacy and community outreach. For more information, go to www.clean-air-coalition.org

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Executive Summary

First developed in 1898, diesel engines are known for their durability, reliability and fuel economy. Yet as modern health science has evolved over the years, we have come to understand that these engines emit large quantities of dangerous pollutants that threaten public health and our environment. Diesel exhaust contributes to elevated ambient outdoor concentrations of particulate matter, ground-level ozone and global warming. Only in the last several years have we become aware of diesel exhaust affecting in-cabin air quality in school buses.

In November 2006, Southern Alliance for Clean Energy, Carolinas Clean Air Coalition and Clean Air Task Force, in partnership with Charlotte-Mecklenburg Schools and Gaston County Schools, conducted a monitoring demonstration project to measure diesel particulate matter (also referred to as diesel soot in this report) levels on school buses, specifically how school bus self-pollution affects the air quality inside the buses that carry our children on their daily ride to and from school. This demonstration was designed to highlight findings of a multi-city study conducted by Clean Air Task Force and partners in Chicago, Atlanta, Houston, and Ann Arbor.[1] This report summarizes the results of the Charlotte demonstration and provides recommendations for policy changes and voluntary actions that will improve the quality of the air that our children breathe on school buses.

In North Carolina more than 13,000 school buses transport our kids to and from school every day. Some efforts have been taken to clean up those engines, but emissions from more than 85% of the state's school buses remain uncontrolled. Moreover, more than 2,000 of those buses were built in 1990 or earlier.[2] Because children breathe in more air per pound of body weight than adults do, they are more susceptible to the impacts of dirty air.[3]

The results of the demonstration in Charlotte supported by the results in the four other cities where tests were conducted, show that by retrofitting the yellow buses that children ride every day with diesel particulate filters, closed crankcase ventilation systems and clean fuels, school districts can virtually eliminate all particulate matter self-pollution inside the cabin of a school bus. The studies also found that diesel oxidation catalysts do not effectively reduce this same pollution in the school bus cabin. **We conclude that more widespread use of diesel particulate filters and closed crankcase ventilation systems, in concert with other clean air programs, could significantly reduce controllable unhealthy pollution inside the cabin from school buses and provide our children with a healthier ride to and from school.**

Our public representatives, air quality and health agencies and school officials should

continue to work together to expand programs to reduce the health risk that school buses pose to our children. We need a strategic, multi-level plan to address the air quality on school buses and from diesel engines in all sectors. That strategy should draw upon public education, local outreach, voluntary action, financial incentives and focused regulation.

Diesel pollution is a serious public health risk. Burning diesel fuel releases a toxic cocktail of chemicals. Children breathe these chemicals when riding the bus and when standing near idling buses. Right now, we have all the tools we need to take decisive steps to reduce the health risk to children throughout North Carolina. This report tells how.

Specifically, we recommend that state and local representatives:

- **Enforce established local school bus idling policies and implement no-idling policies for all other diesel equipment;**
- **Replace or rebuild all engines after they have been on the road for no more than a decade;**
- **Prioritize funding and use of diesel particulate filters over diesel oxidations catalysts;**
- **Retrofit all existing diesel school buses with two specific pollution-control technologies - diesel particulate filters and engine crankcase filtration systems;**
- **Switch school buses to blends of biodiesel;**
- **Establish a technical assistance program to help school systems in their efforts to secure funding for retrofits;**
- **Create a long-term source of funding for reducing emissions from diesel engines by expanding the Mobile Source Emissions Grant Program and/or creating a new program to provide state level funding for diesel emissions reductions in all state or locally owned or contracted diesel vehicles and private fleets in North Carolina;**
- **Develop clean contract specifications that require contractors who perform work in the state to install pollution control equipment and use bio-diesel in all of their diesel equipment.**

Introduction

Air pollution is all around us. It is emitted from power plants, fires, industrial and manufacturing facilities, and the tailpipes of our cars, trucks, buses and construction and agricultural equipment. Air pollution invades our homes and schools, impacts our health and restricts our daily activities. There are different types of pollutants that cause many, often deadly, adverse health impacts. One of the most significant but often overlooked sources of air pollution is the diesel engine.

Diesel engines are often called the workhorses of the American economy. They play a major role in the transportation of our goods and services, public utilities and public transportation. We depend on the diesel engine to perform the "heavy-lifting" for our economy, but with that strength, diesel engines dump literally tons of harmful pollutants into our atmosphere.

Over 40 "hazardous air pollutants" as classified by the U.S. Environmental Protection Agency (EPA), fine particulate matter, and nitrogen oxides that contribute to the formation of smog are found in diesel exhaust.

The emissions from diesel engines are made up of a toxic mixture of particles, metals, and gases. Over 40 hazardous air pollutants (as classified by the U.S. Environmental Protection Agency [EPA]), fine particulate matter and nitrogen oxides, that contribute to the formation of smog, are found in diesel exhaust.[4] Particulate matter (PM) (referred to as soot throughout this report) found in diesel exhaust is a complex mixture of liquid and solid droplets suspended in the air. PM is emitted from various stationary and mobile sources.

These particles vary in chemical composition and size, from coarse particles, 10 microns in diameter and less (PM_{10}), to fine particles, less than 2.5 microns in

Photo courtesy of Clean Air Task Force

diameter ($PM_{2.5}$), to ultrafine particles, particles less than 0.1 micron. Fine particles, less than one-thirtieth the width of a human hair, and ultrafine particles pose the most significant threat to human health due to their small size. Both $PM_{2.5}$ and ultrafine particles are discussed in this report.

The pollution, or soot, from these engines is all around us. We breathe it in when we pass a construction site, road-building project, the local garbage truck, tour buses outside of concert venues or ride on school buses. This pollution builds up along transportation corridors, bus depots, around public facilities and creates elevated levels of pollution throughout the state. Everyone is affected by diesel soot, but those most susceptible are children, the elderly, drivers of diesel vehicles, individuals who work around diesel engines, such as constructions workers, and individuals with asthma and other respiratory or pulmonary diseases.

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For children riding school buses, the impacts from daily inhalation of diesel soot can have life-long consequences. Nationally, students spend an average of one hour a day riding the bus.[5] Riding a school bus is the safest way for a child to travel to school in terms of accident rates. *In 2003, only six children died as occupants of school buses nationally; in contrast, more than 800 children are killed on average every year making the trip to school in some other way by car, on foot, or by bicycle.*[6] However, the long travel times and soot exposure may compromise their health and interfere with their learning potential.

Advanced pollution control technologies, cleaner fuels and model management practices are currently being implemented throughout the state considerably reducing diesel soot, but more is needed. Only 15 cities or counties in North Carolina have taken action to reduce emissions from their local school bus fleets. Of the approximately 13,600 yellow school buses in the state, only 1,159 (12%) school buses are retrofitted or will be retrofitted soon with pollution control devices.[7]

Although these steps are encouraging, there are thousands of children still riding on unhealthy school buses in the state. The Union of Concerned Scientists' recent report, *2006 Pollution Report Card*: *Grading America's School Bus Fleet*, gave an "Above Average" grade for the state's clean up program in comparison to other states. Yet a grade of "C" was given for the amount of emissions from the state's school buses. Further, according to their analysis, only 2.9% of emissions from school buses in North Carolina are reduced to date.[8] The tools needed to combat the harmful diesel soot on school buses are within reach, but political will and additional funding are critical to significantly reduce the diesel soot on the state's school buses and provide a healthy ride to school for all children.

This report provides the results of a school bus air quality monitoring demonstration conducted with Charlotte-Mecklenburg Schools (CMS) and Gaston County Schools. These two school districts are proven leaders in reducing emissions from their school bus fleets. However, most other fleets in the state lag behind. We provide recommendations on simple, cost-effective solutions that can help all school districts and diesel vehicle owners reduce diesel soot.

Of the approximately 13,600 yellow school buses in the state, only 1,159 (12%) school buses are retrofitted with pollution control devices.

What's in the Pipeline?

The good news is *new* diesel engines are getting cleaner! The U.S. Environmental Protection Agency (EPA) mandated the phase-in of cleaner engines beginning in 2007 for highway, or on-road, diesel engines. The highway diesel rule requires strict engine emissions standards of diesel vehicles and also requires a reduction in the amount of sulfur in diesel fuel, from 500 parts per million (ppm) to 15ppm. This cleaner fuel, ultra-low sulfur diesel or ULSD, is now available nationally as of October 2006. By 2010, all new engines must meet the new standards.

The EPA also adopted new engine and fuel standards for non-road diesel engines – those engines found in construction equipment, agricultural equipment, trains and many marine vessels. These engine and fuel standards will be phased in between 2008 and 2015.

However, the new engine standards will take over 25 years to become fully effective and there are more than 11 million existing diesel engines in use today in the United States that are not affected by these federal rules. This means that these engines will continue to spew out clouds of pollution until they are retired – perhaps in some 25-30 years (the average life span for a diesel engine), unless action is taken by local and state officials and individual companies.

In addition to federal mandates, North Carolina runs the only statewide grant program to address emissions from mobile engines in the Southeast. The program, the Mobile Source Emissions Reduction Grant program (MSERG), was enacted in 1993 by the state legislature to reduce emissions from on-road and off-road vehicles to help the state meet the national ambient air quality standards (NAAQS) for ozone and carbon monoxide. The program, which began in 1995, is funded by a tax of 1/64 of a cent per gallon of the gasoline sold. Since that time, the program has supported an average of approximately $600,000 per year in projects to reduce mobile source emissions, including school bus retrofits.[9]

Highlight on Charlotte-Mecklenburg Schools[10]

- ***Largest school bus fleet in North Carolina***
- ***1,141 average number of buses***
- ***Travel 138,000 miles/day***
- ***Uses 3.2 million gallons of diesel fuel/year***
- ***Transport 80,000 students per year***

(Note: approximate number per year based on 2005-2006 data)

Furthermore, Charlotte-Mecklenburg Schools with the largest school bus fleet in North Carolina (approximately 1,141 buses) are a proven leader in implementing measures to reduce emissions from their school bus fleet. Beginning in 1995, CMS purchased eight buses that run on Compressed Natural Gas (CNG). Following those efforts in 2003, they began retrofitting their diesel buses with pollution control devices. To date, CMS has retrofitted 234 buses with Diesel Oxidation Catalysts (DOCs) and 40 buses with DPFs. Another 360 buses were purchased with DOCs pre-installed. They anticipate replacing some 383 buses (model year 1995 or older) in 2006-2007 with buses that meet the EPA's 2007 engine standards. Lastly, with a donation from Donaldson Company for this study, they also have a closed crankcase ventilation system on one bus. Following these efforts, CMS will only have 167 buses with uncontrolled emissions.[11]

CMS has also taken the initiative to better manage their fleet. In 2006, CMS applied for and was awarded a $60,000 grant for Global Positioning System (GPS) units that will allow them to better monitor their routes and idling behavior.

Gaston County Schools, a neighboring school district to CMS, is taking another route to clean up their buses – bio-diesel. Bio-diesel is a renewable, biodegradable fuel made from any type of animal or vegetable oil. The school began making bio-diesel from the school cafeteria's waste grease in October 2005. Some local restaurants are now also donating their waste grease to help the school district. ***Gaston County Schools is the first school system in the state to produce its own bio-diesel.*** Displacing a percentage of their petroleum-based diesel will help save the school district thousands of dollars on diesel fuel and reduce their emissions. Gaston County Schools also received a 2006 grant from the North Carolina Division of Air Quality's Mobile Source Emissions Reduction Grant program to install approximately 95 diesel oxidation catalysts on their buses.[12]

Highlight on Gaston County Schools[13]

- ***6th largest school bus fleet in North Carolina***
- ***210 buses***
- ***Travels >11,000 miles/day***
- ***Uses ~30,000 gallons of diesel fuel/year***
- ***Transports 731, 500 students per year***

Who's at Risk?

Our children. Children typically spend more time outdoors and breathe in more air per pound of body weight than adults.[14] As a result, exposure to particulate matter and other chemicals in diesel exhaust can have a more dramatic impact on children's developing body systems. In North Carolina more than 26 counties do not meet the federal health limits for ozone and three counties exceed the federal health limits for particulate matter.[15] Diesel engines are a significant source of the pollution contributing to these air quality problems.

Scores of medical studies show that fine particles and toxins in diesel exhaust are associated with cardio-vascular disease, lung cancer, short-and-long term respiratory problems, can trigger asthma attacks, irritate the eyes, nose, throat, and bronchial system, and cause neurophysiologic and respiratory symptoms, such as nausea, lightheadness, and coughing.[16,17,18] A review of numerous epidemiological studies by the American Heart Association concludes that there is a direct link between fine particles and health impacts with no discernable lower threshold –suggesting that there is no safe level of exposure to fine particles.[19]

According to a 2005 report by the Clean Air Task Force, diesel exhaust is responsible for some 300 deaths, 340 heart attacks, 6,500 asthma attacks, and 39,500 lost workdays each year in North Carolina with the greatest impact on Charlotte, Raleigh and Greensboro residents.[20]

In addition, diesel exhaust across the state poses a risk of cancer that is hundreds of times higher than EPA's acceptable risk level of one in one million.[21] Details of the cancer and non-cancer risks for all counties in North Carolina, as well as a citizen guide to action are available at http://www.catf.us/publications/view/82.

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School Bus Testing Methods

Buses Tested

In November 2005, Clean Air Task Force (CATF) for Southern Alliance for Clean Energy and Carolinas Clean Air Coalition performed a demonstration of the causes of cabin air pollution and the effectiveness of pollution control devices on local school buses operated by Charlotte-Mecklenburg Schools and Gaston County Schools. The demonstration was part of a five-city study conducted by Clean Air Task Force to investigate cabin exposures to diesel soot and the effectiveness of pollution control equipment on school buses. For the five-city study, more than ten retrofit combinations were tested with many combinations tested on multiple runs (see results of sister studies at http://www.catf.us/publications/view/82). Below is a list of tests conducted in the Charlotte demonstration alone:

1. A bus with both a diesel particulate filter (DPF) and a closed crankcase ventilation system by Donaldson Company, the Spiracle™, and run on ultra-low sulfur diesel fuel (ULSD), hereafter referenced as the bus retrofitted with a DPF/Spiracle;™ [22]
2. A bus retrofitted with a diesel oxidation catalyst (DOC), hereafter referenced as the DOC bus;
3. A bus retrofitted with a Spiracle™ only, hereafter referenced as the Spiracle™ bus; and
4. A bus retrofitted with a Spiracle™ and run on bio-diesel (B99 - 99% bio-diesel/1% regular diesel) provided by Gaston County Schools, hereafter referred to as the Biodiesel/Spiracle™ bus

Note: All buses were model year 1997 buses with International engines.

Pollution Control Equipment or Retrofits

Diesel particulate filters (DPFs) are multi-stage catalyzed mechanical filters that collect particles as the exhaust gases pass through the walls of the filter. The heat from the exhaust allows the particles to break down into less harmful substances.[23] This device (which must operate in tandem with ULSD) can achieve a 80-98% reduction in particulate matter, hydrocarbons and carbon monoxide from the tailpipe.[24] Ultra-low sulfur diesel fuel (ULSD) is diesel fuel with no more than 15 parts per million (ppm) of sulfur.

A closed crankcase ventilation system (CCV) is an engine retrofit that captures and returns oil to the crankcase and directs exhaust to the intake system for re-combustion. Based on our previous in-cabin emissions testing conducted in Atlanta, engine emissions inside the cabin were elevated. The CCV system is designed to reduce direct engine emissions emitted inside the cabin of the bus.[25]

Diesel oxidation catalysts (DOCs) are porous catalyzed ceramic devices that chemically break down pollutants in the exhaust stream into water vapor and other gases. DOCs are estimated to provide a 20 to 50 percent reduction in particulate matter.[26]

L. Bruce Hill, principal investigator, with volunteer. They are tracking measurements of ultrafine particles with a PTrak monitor.

Measurement of Cabin Pollutants

The three goals of the larger study were 1) to characterize particle pollutants inside school buses, 2) identify the sources of these pollutants, and 3) investigate the effectiveness of available pollution control devices. The Charlotte demonstration was aimed at demonstrating the methods and results to the public, media and local officials. The comparative approach of the study, collecting wind direction and weather data and measuring the real-time concentrations of three pollutants, made it possible to detect multiple sources of emissions affecting air quality and human exposure levels inside the bus cabin.

In determining pollution levels, the study considered the following factors: bus engine age, operation and condition; window ventilation, idling and queuing behavior; ride duration; and outdoor air quality. We measured ultrafine particles (less than $PM_{2.5}$), fine particles ($PM_{2.5}$), and black carbon (elemental carbon). We tested the buses while idling and during a typical neighborhood route ("bus rides"). Ultrafine particles were measured using a TSI Ptrak monitor in particles per cubic centimeter (particles/cc) of ambient air. $PM_{2.5}$ particles were measured using the TSI Dust Trak monitor (in the front, middle, and rear of the bus cabin) and black carbon levels were measured with a Magee Scientific Aethalometer. Both the lead car and the school bus were equipped with similar instrumentation.

During bus route testing, a lead car drove in front of the bus to establish baseline levels in the outdoor air of the pollutants to be measured. Windows were rolled down in the car at all times to gauge concentrations of diesel soot from sources other than the bus that could potentially impact cabin air quality. We followed an actual school bus route used by CMS. The route primarily ran through residential neighborhoods, but did travel and cross several major roads. None of the school district students rode on the buses during testing.

The data provided in this report reflect raw values from the instruments, with outdoor concentrations subtracted from the bus route data. Furthermore, the Dust Trak monitor was calibrated with Arizona road dust and may therefore overestimate $PM_{2.5}$ levels by about a factor of two to three.

For more on this and other methodological details, see Clean Air Task Force's report at http://www.catf.us/publications/view/82.

Volunteers taking a wind measurement outside the school bus door.

Testing Equipment: TSI/Dust trak, TSI/Ptrak monitor and Magee Scientific Aethalometer

Results and Recommendations

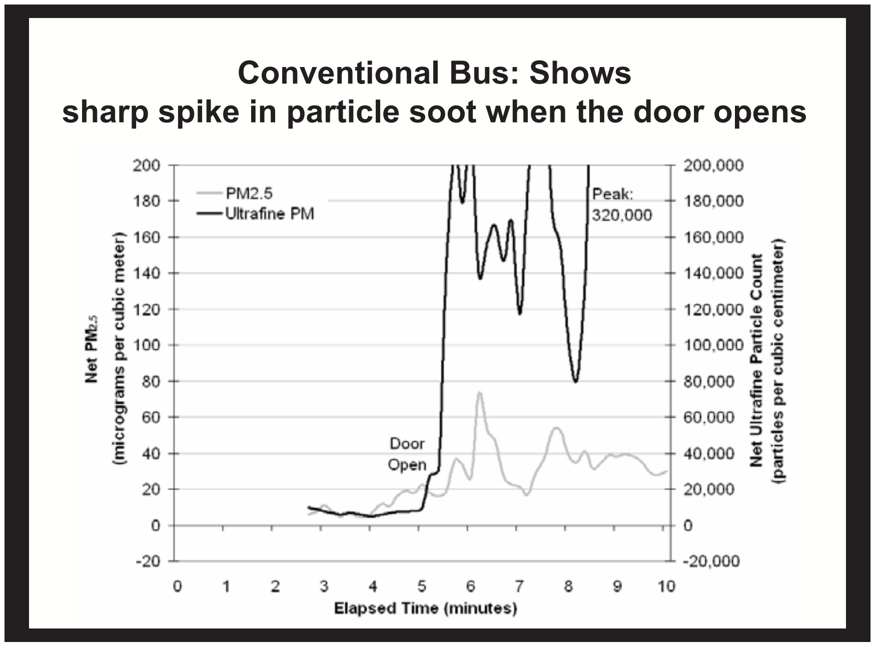
The conventional yellow school bus has carried our nation's children to school for more than 50 years—indeed it is a cultural icon and a symbol of sound public education. And though most of the safety standards that apply to school buses have improved significantly during this period, there is one threat that continues to be inadequately addressed – diesel exhaust inside the yellow school bus.

Below are our recommendations for action based on the results of air quality tests on school buses in five cities since 2003 by Clean Air Task Force, including Charlotte, North Carolina in November 2005. The graphs and data in this report are primarily from the school bus monitoring demonstration in Charlotte, but they should be evaluated within the context of CATF's detailed white paper with more comprehensive test results (see http://www.catf.us/publications/view/82) in order to fully understand the basis for the results and recommendations. The Charlotte data, although limited, mirrors the results of measurements taken in each of the other four cities. In addition, the recommendations provided here are applicable for school buses nationwide and for other types of diesel engines – school buses, tour and transit buses, long-haul trucks, and our local service vehicles, such as garbage trucks.

We call on the North Carolina Department of Natural Resources, the North Carolina Department of Public Instruction, the North Carolina Department of Health and Human Services, and our city and county officials throughout North Carolina to set concrete benchmarks and goals for reducing diesel emissions on the state's school bus fleet.

RESULT 1: Idling tests show clear increases in pollution inside a conventional bus.

RECOMMENDATION 1: Enforce established local school bus idling policies and implement no-idling policies for all other diesel equipment.



Graph 1: When the door opens during an idle test, diesel soot floods in from the tailpipe and engine.

Note: 1) Wind was blowing from the rear of the bus toward the front door, blowing the tailpipe emissions plume toward the front door and entering the bus. 2) Plotted "Net" concentrations normalize the data for differing outdoor conditions on different test days. To do this, the background (ambient particle concentrations) was subtracted from the measurements. Therefore, the results are all excess particle levels above ambient outdoor levels on a given test day.

Idling of diesel vehicles is a common practice. In general, idling refers to the practice of leaving an engine on while the vehicle remains parked. This practice is generally exercised based on a myth that the vehicle needs to warm up to operate properly. However, diesel technology is significantly more advanced than it was fifty or even twenty years ago. According to engine manufacturers, excess idling can cause engine damage, including build up of carbon in the engine, reduced fuel economy, and decreased oil life.[27]

How does the wind affect cabin air quality?

Wind speed and direction relative to the tailpipe, engine, and doorway is critical relative to the magnitude of self-pollution. Because the wind effect is variable from run to run, stop to stop, direct comparisons of concentrations between bus runs are strongly discouraged. For example, in the DOC bus run from this study, cabin particulate matter concentrations are higher than for the conventional bus. It is impossible using this methodology to determine if this is due to the influence of wind or if it is a primary result of the magnitude of the emissions between the two buses. However, the test does show that the DOC does not adequately control soot levels relative to the DPF retrofitted bus.

When a vehicle such as a school bus idles, diesel soot from the tailpipe and the engine blows inside the cabin. The pollution then builds up inside the cabin and remains at elevated levels for the duration of a trip. Graph 1 shows the concentration of soot as it builds inside the school bus cabin. When the door is opened, as is typically done prior to students loading a bus, diesel soot enters the cabin and concentrations of soot increase throughout the duration of idle.

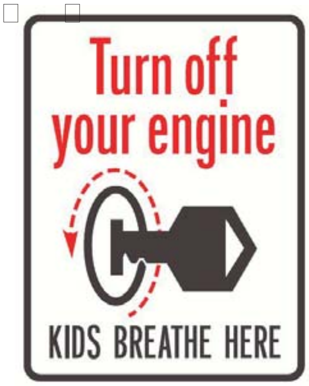
During idling tests on conventional buses without emissions controls, all types of diesel soot particles that were measured in the study, including ultrafine particles and fine particles were documented to build up inside the cabins of buses, especially when lined up with the front of a bus nosed in tight to the bus in front of it. When the buses run, the bus tailpipe pollutes the cabin of the bus behind it. Levels of fine, ultrafine, and black carbon particles increase when emissions enter the cabin from the engine and the tailpipe (of the bus itself and the bus in front of it) when the door opens. This result repeats and reinforces similar results seen in the four other cities studied by Clean Air Task Force (see http://www.catf.us/publication/view/82).

In addition to elevated diesel soot particles found inside the school bus cabins during idle conditions, idling also wastes fuel and money. The U.S. Environmental Protection Agency estimates that school buses burn a half-gallon of fuel per hour of idling.[28] If a school bus fleet of 100 buses reduced idling by 30 minutes, that fleet would save 4,500 gallons of fuel per year or $11,250 in fuel cost savings (assumes $2.50/gallon).

All school districts in North Carolina and some cities and states across the country are implementing "no-idling" or idling reduction policies. Reducing idle time reduces diesel soot inside vehicles, as referenced above, and also reduces outdoor air pollution around school buses and areas where they idle. When buses idle outside schools, especially when lined up with open doors, diesel soot can enter air intakes, doors, and windows, thereby creating an unhealthy learning environment for students.

In 2005, North Carolina Department of Public Instruction (NC DPI) issued a notice to all school superintendents and transportation directors advising the development of idling policies by each school system. Further, NC DPI advised school systems, that "in order to be eligible to receive any mid-year transportation allotment resulting from increased fuel prices, a LEA "local education authority" must have a reduced idling policy in place at the beginning of the school year. For the 2005-2006 school year, the policy must be in place no later than January 10, 2006. The local policy must, at a minimum, prohibit all unnecessary school bus idling on school grounds and prohibit the warming up of buses longer than five minutes. As always, any increase in allotments will be subject to the availability of funds."[29] In addition to limiting idle time, bus drivers should be encouraged to keep the bus doors shut at all times.

Currently, all school districts in the state have adopted policies to reduce idling due to the directive by NC DPI. To support these policies, we encourage all school districts to create stringent enforcement measures to ensure effectiveness of the policy. In addition, students can get involved with monitoring both buses and vehicles, keeping record of idling time, and issuing warnings to idling vehicles. It can provide an excellent learning opportunity to teach students about air quality.



The North Carolina legislature also recently passed

The Schoolchildren's Health Act of 2006. The Act states that the State Board of Education must "establish guidelines to reduce students' exposure to diesel emissions that can occur as a result of unnecessary school bus idling, nose-to-tail parking, and inefficient route assignments."[30] We call on the State Board to not only establish guidelines, but to encourage school systems to take advantage of state funds to reduce diesel soot from school buses.

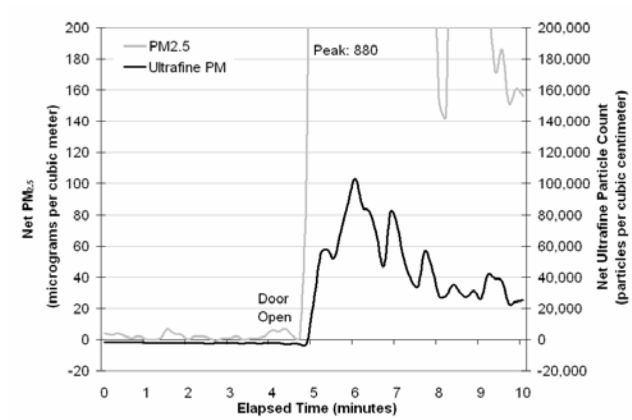
Finally, we encourage all school systems to proactively enforce their established idling reduction policies by engaging and educating their students and teachers on the benefits of clean air quality. We also recommend that city and county governments establish idling reduction policies that support and strengthen school policies and effectively reduce emissions from all vehicles. Eliminating unnecessary idling improves air quality, protects our health, reduces fuel consumption (and our oil imports), and saves money.

RECOMMENDATION 2: Replace or rebuild all engines after they have been on the road for no more than a decade.

As shown from the results of the Charlotte demonstration in Graph 1, buses that have not been retrofitted with pollution control devices emit significant levels of fine particles from both the engine crankcase and the tailpipe. Also, vehicles built prior to 1990 emit more than six times more nitrogen oxide, particulate matter and hydrocarbons than newer models. In North Carolina, 37% of the school buses were built more than ten years ago.[31] Operating older buses means that these engines will continue to emit harmful diesel soot until they are retired. State and school administrators and transportation directors must take the initiative to address these emissions. These older engines should be immediately replaced and all buses should be replaced every ten years.

RESULT 2: All measured diesel soot inside the cabin was elevated in the DOC bus. The DOC retrofit is therefore ineffective at reducing cabin exposures to diesel soot.

DOC Retrofit Bus: Shows sharp increase in cabin particle soot concentration when the door is opened



Graph 2 : When the door opens during an idle test, diesel soot floods in from the tailpipe and engine.

The graph above illustrates ultrafine particles and $PM_{2.5}$ concentrations on a bus retrofitted with a DOC while idling in the bus depot prior to the bus run. All measured diesel soot particles were elevated in the bus equipped with the DOC.

These investigations and those in the other four cities studied demonstrate that fine particulate matter ($PM_{2.5}$) peaks are largely attributable to emissions from the engine crankcase and the ultrafine particle concentrations are emitted from the tailpipe.[32] Soot from both the engine and the tailpipe enter the cabin when the door is open. The $PM_{2.5}$ concentrations during this test were considerably higher than on the conventional idle test, which could be due either to an artifact of the wind conditions or initially higher

Diesel particulate filter (DPF)

emissions on the DOC retrofit bus. However, this result suggests that the DOC is ineffective at improving cabin air quality.

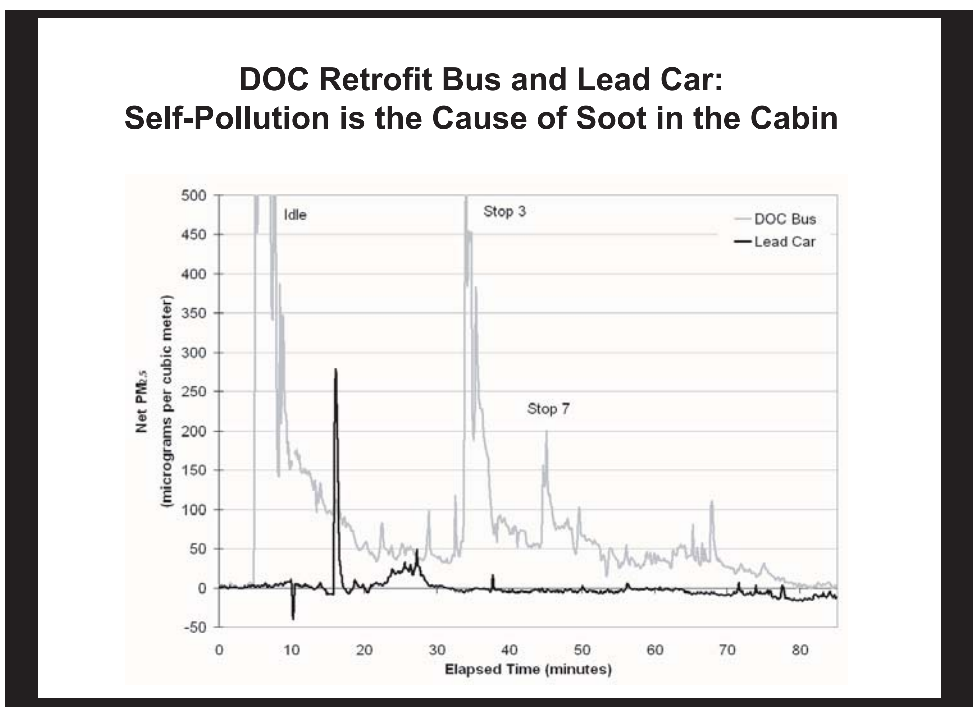
Graph 3 shows $PM_{2.5}$ concentrations of a bus retrofitted with a DOC compared to the concentrations measured by the lead car. The lead car monitors are designed to provide a control to detect any external sources that would impact air quality in both the lead car and the bus as it follows. The generally low levels in the lead car demonstrate that the soot in the bus is not coming from the roadway, but instead from the DOC bus itself.

Further, $PM_{2.5}$ is significantly elevated inside the DOC bus at both the front and middle monitors. The front monitors, shown in the graphs of this report, measure soot as it enters the bus (closer to the source of emissions) and the middle monitors reflect the average levels on the bus. As a result, the lower levels in the middle of the bus are due to the dilution of soot concentrations as it moves further into the bus. Our findings suggest that exposures are therefore typically higher in the front of the bus than in the middle or rear. Also, during the DOC test, lead car concentrations remained at ambient levels, indicating that the soot inside the bus is directly attributable to the bus itself (rather than from the roadway in front of the bus as measured in the car).

RECOMMENDATION 3: Prioritize funding and use of diesel particulate filters over diesel oxidation catalysts.

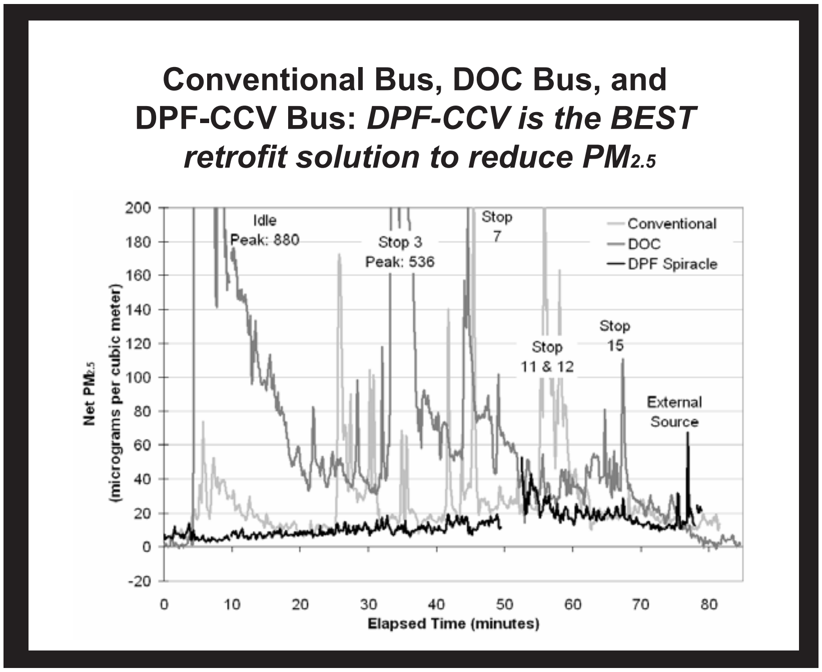
Since 2004, through the Mobile Source Emissions Reduction Grant program, the North Carolina Department of Environment and Natural Resources has awarded more than $900,000 for approximately 1,200 diesel oxidation catalysts (DOCs) for school buses and DOCs and closed crankcase ventilation systems (CCVs) for approximately 150 school buses. Federal funds have also been awarded to various entities for the installation of DOCs in North Carolina. Based on various databases, upon completion, more than 1,500 buses will be retrofitted with DOCs.[33-36]

DOCs have been widely used and preferred for use as a strategy to reduce diesel soot on school buses because they do not require use in combination with ultra-low sulfur diesel fuel (as DPFs do and which only became available nationally in October 2006) and are lower in cost.

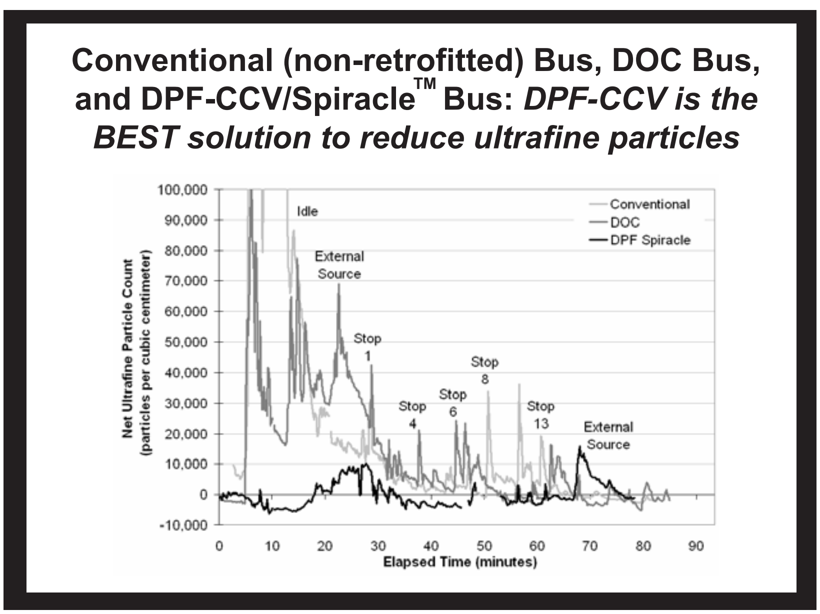


Graph 3: The lead car shows little pollution in the roadway in front of the bus. This clearly demonstrates self-pollution (the bus is responsible for its own cabin pollution.)

However, as shown here, DOCs do not effectively reduce $PM_{2.5}$ emissions inside the cabin of the bus where direct exposure of diesel soot to children is greatest. Based on these results and results from the other cities where tests were conducted, we recommend the use of DPFs over DOCs to reduce diesel soot inside the cabins of school buses.



Graph 4: $PM_{2.5}$ emissions shown here are elevated on both the conventional and DOC retrofit bus. However, emissions on the DPF-CCV bus are close to outdoor concentrations. Emissions typically flooded into the bus when the door was opened at bus stops (shown by the various peaks in the graph).



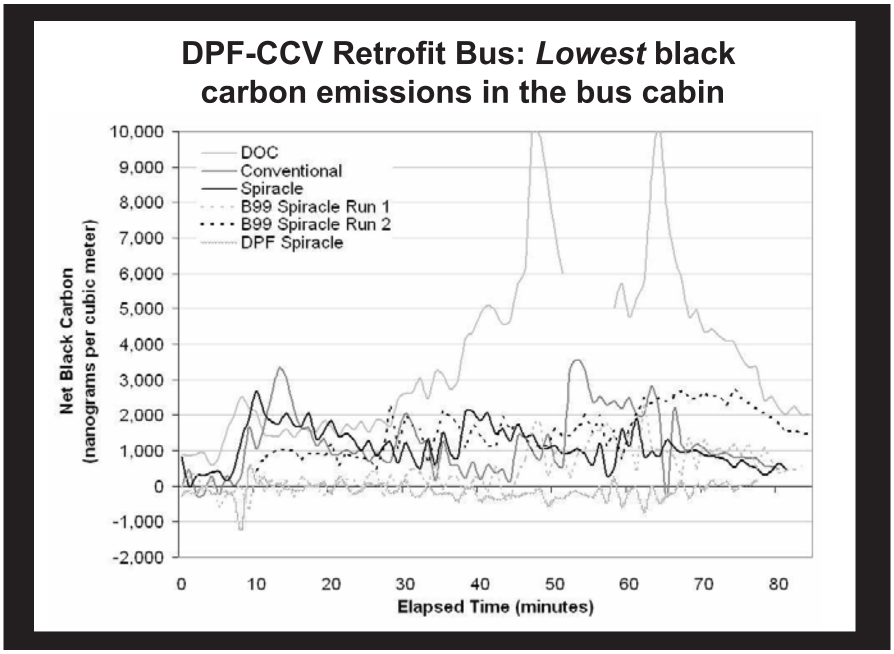
Graph 5: Ultrafine particles shown here are elevated on both the conventional and DOC retrofit bus. However, emissions on the DPF - CCV bus are close to outdoor concentrations. Emissions typically flooded into the bus when the door was opened at bus stops (shown by the various peaks in the graph).

RESULT 3: The retrofit combination of a diesel particulate filter and a closed crankcase ventilation system demonstrate virtual elimination of all diesel soot inside the school bus cabin.

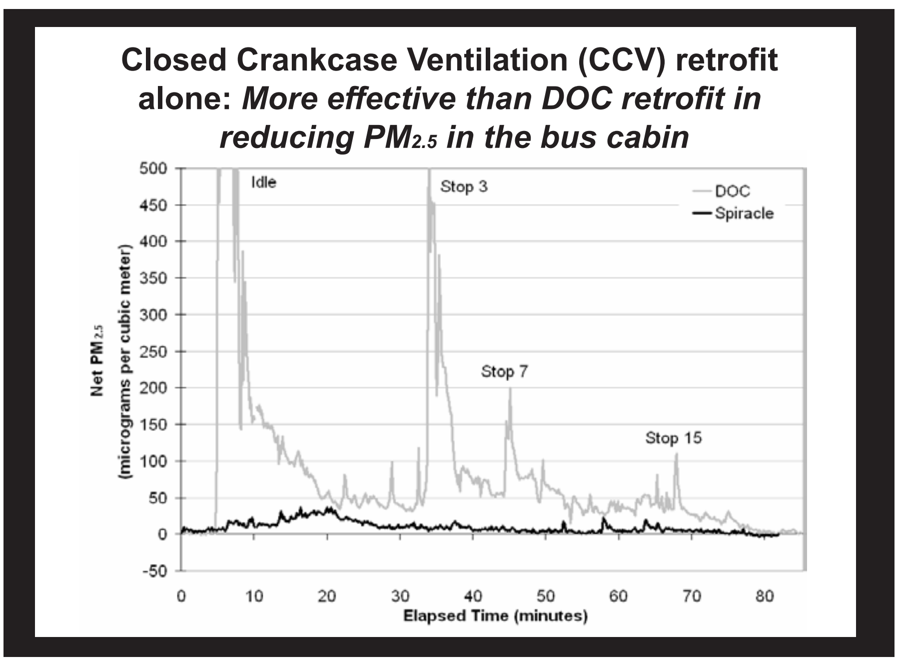
Graphs 4 and 5 show $PM_{2.5}$ and ultrafine particle emissions from a conventional bus, a bus retrofitted with a DOC, and a bus retrofitted with both a DPF and closed crankcase ventilation system (CCV), the Donaldson Spiracle.™ The DPF and Spiracle™ retrofit provide the greatest reduction of $PM_{2.5}$ and ultrafine particles inside the bus.

Graph 4 also illustrates that significant fine particle emissions ($PM_{2.5}$) remain on both the conventional bus and the bus retrofitted with only a DOC, whereas the fine particles were nearly eliminated from the bus retrofitted with a diesel particulate filter (DPF) and the Spiracle.™

Graph 6 illustrates black carbon levels on all conventional and retrofitted bus configurations from the Charlotte demonstration. Concentrations of black carbon were elevated on all buses except the bus retrofit with a DPF and CCV. Black carbon is a significant contributor to global warming and is the main component of diesel soot, making up 94 percent of a diesel soot particle. Diesel soot gathers on snowy surfaces, attracting more sunlight, which in turn melts more snow and ice. According to NASA studies, this soot is twice as potent as carbon dioxide in changing global surface temperature in the Northern Hemisphere and the Arctic.[37]



Graph 6: Black carbon concentrations shown here are elevated on all bus configurations except the bus retrofitted with both a DPF and CCV.



Graph 7: $PM_{2.5}$ emissions show here on the CCV retrofit bus are close to outdoor concentrations whereas the emissions are elevated on the DOC retrofit.

RESULT 4: The closed crankcase ventilation system, used alone on a conventional bus, in combination with a DPF or a DOC, or on the bio-diesel-fueled bus, minimized $PM_{2.5}$, inside the school bus cabin.

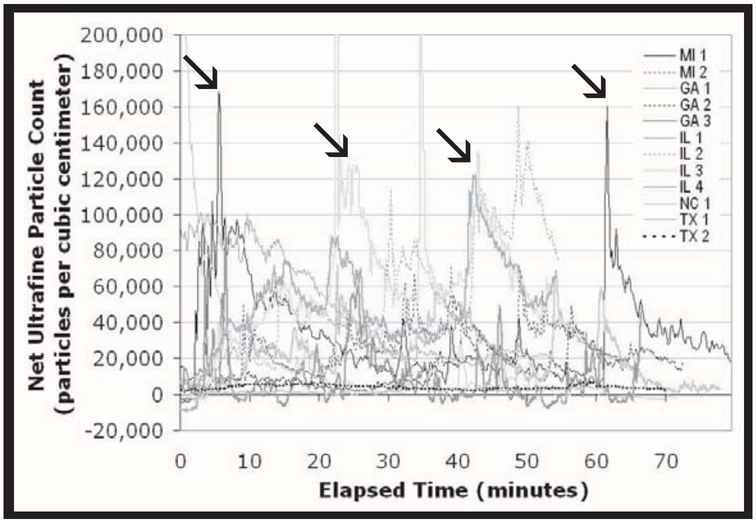
Engine crankcase emissions are a major source of in-cabin diesel soot.[40] In tests of both a DPF and DOC used alone, $PM_{2.5}$ emissions remained inside the cabin of the bus (Graph 7). With a CCV subsequently installed on the buses, the $PM_{2.5}$ emissions decreased to outdoor emissions levels (see results of sister studies at http://www.catf.us/publications/view/82).

In all of our tests, including previous tests conducted in other locations, the CCV used alone, in combination with a DPF or a DOC, or on the bio-diesel-fueled bus, minimized or eliminated diesel soot, particularly $PM_{2.5}$, inside the school bus cabin.[41] CCVs do not reduce any other particle parameters.

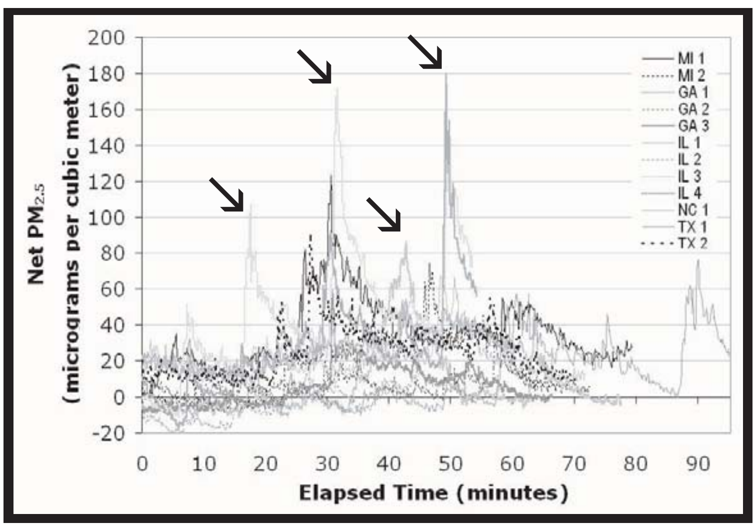
Although new buses that meet the EPA's 2007 standards are coming on the market, crankcase engine emissions may or may not be controlled on them. Therefore, we cannot be assured that diesel soot inside all new buses is cleaned up and installation of CCVs will be necessary.

Note: The Donaldson Spiracle™ is only one brand of closed crankcase device. New brands are becoming available including ones made by World NCI and Engine Control Systems.[38,39]

Conventional Buses



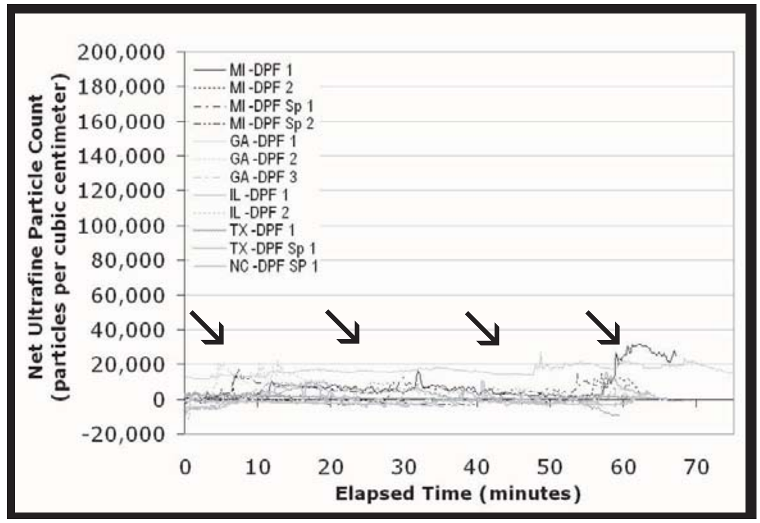
Graph 8: Elevated ultrafine particle concentrations inside conventional buses tested in the five-city study by CATF. Courtesy of Clean Air Task Force.



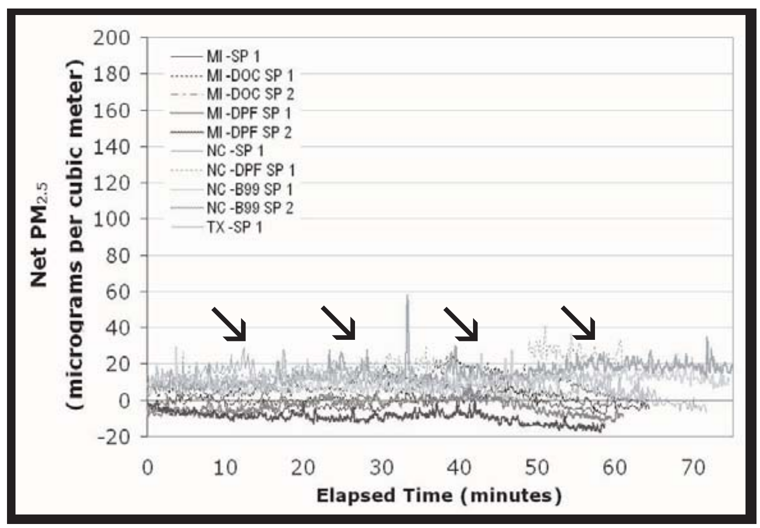
Graph 10: $PM_{2.5}$ elevated inside conventional buses tested in the five-city study by CATF. Courtesy of Clean Air Task Force.

Further, Graphs 8 and 9 illustrate results from all cities where tests were conducted by Clean Air Task Force. On the top left, ultrafine particles are significantly elevated on all conventional buses tested. On the top right, ultrafine particles measured close to outdoor concentrations on all buses retrofit with a DPF alone or in combination with a CCV indicating virtual elimination of all diesel soot inside the bus.

Retrofitted Buses



Graph 9: Ultrafine particles, largely eliminated inside buses retrofit with a DPF alone or in combination with a CCV in the five-city study by CATF. Courtesy of Clean Air Task Force.



Graph 11: $PM_{2.5}$ concentrations largely eliminated inside buses retrofit with a CCV alone or in combination with other retrofits or fuels. Courtesy of Clean Air Task Force.

Similarly, Graphs 10 and 11 illustrate results from all cities for $PM_{2.5}$. As with ultrafine particles, $PM_{2.5}$ concentrations were elevated in all conventional buses but were reduced to ambient concentrations in all buses with a CCV alone or in combination with other retrofits or fuels.

RECOMMENDATION 4: Retrofit all existing diesel school buses with two specific pollution-control technologies– diesel particulate filters and closed crankcase ventilation systems.

The retrofit combination of a diesel particulate filter with the closed crankcase ventilation system (Spiracle™ used in this test) demonstrated elimination of all diesel soot particles ($PM_{2.5}$, ultrafine particles and black carbon) in the Charlotte demonstration and in all other cities where tests were conducted. The consistent evidence and effectiveness of these technologies in all cities confirms results found in the Charlotte demonstration. We recommend this retrofit combination, a DPF and a closed crankcase ventilation system, as the best solution for reducing diesel soot inside school buses. These devices should be installed on all applicable school buses in North Carolina.

Currently, only one school system in North Carolina, Charlotte-Mecklenburg Schools, has installed DPFs (40 units) on their school buses.[43] DPFs must be run with ultra-low sulfur diesel fuel and the fuel has only recently become available nationally. Now that the fuel is available, DPFs should be prioritized for purchase by local school districts and through the Mobile Source Emissions Reduction Grant program. Specifically, we encourage the state to prioritize funding for CCVs on all existing school buses and on those existing buses already installed with DOCs. In addition, all new buses purchased by the North Carolina Department of Public Instruction should have CCVs pre-installed.

Closed Crankcase Ventilation System (Spiracle™)

Non-results based Recommendations:

RESULT 5: Bio-diesel/Spiracle™ tests conducted during this project produced inconclusive results relative to the benefit of the fuel used alone.

In the Charlotte project, we conducted two bus runs with a bus equipped with a Spiracle™ CCV and using bio-diesel (B99) fuel. Results relative to the fuels alone were inconclusive both because the project methodology does not allow for quantitative intercomparison of runs, and a limited number of runs were tested. However, $PM_{2.5}$ levels were reduced relative to the conventional bus presumably due to the effect of the Spiracle.™ Ultrafine particles were elevated on the bio-diesel/Spiracle™ bus relative to the DPF/Spiracle™ combination.

Bio-diesel is diesel fuel made from any animal or vegetable oil and can be locally produced. Bio-diesel is also renewable and cleaner burning than petroleum-based diesel fuel. Common sources of bio-diesel are soybeans, cottonseed, sunflower, palm, canola, corn, peanut, poultry fat, algae, and used restaurant grease or spent cooking oil. Bio-diesel can be blended in various percentages with petroleum diesel and used in any diesel school bus or other diesel vehicle. Use of bio-diesel reduces air toxins and greenhouse gases in various percentages based on the blend level. The largest benefits are observed in higher blends.[42]

RECOMMENDATION 5: Switch school buses to blends of bio-diesel.

Although our project and tests of a bus run on bio-diesel (B99) did not show reductions in diesel soot inside the bus, other studies[44] conclude that use of bio-diesel in proportions greater than B20 can reduce overall emissions and even greater emissions (relative to conventional diesel) reduction when used in combination with pollution control devices.[45] However, some engineering issues are associated with the high bio-diesel mixes, due to the inherent solvency of bio-diesel, that may require retrofitting of some engine components.

RECOMMENDATION 6: Establish a technical assistance program to help school systems in their efforts to secure funding for retrofits.

Applying for federal and state money can be a complicated process, particularly for many school systems, whose primary focus is handling everyday activities with its students. The North Carolina Division of Air Quality and the North Carolina Department of Public Instruction should work together and with local air districts to provide school districts with the assistance they need to apply for funding for school bus retrofits.

RECOMMENDATION 7: Create a long-term source of funding for reducing emissions from diesel engines by expanding the Mobile Source Emissions Reduction Grant Program and/or creating a new program to provide state level funding for diesel emissions reductions in all state or locally owned or contracted diesel vehicles and private fleets in North Carolina.

The Texas Emission Reduction Program (TERP) is one of the two most well known state diesel emissions reduction funding programs in the United States. The program has funded more than 670 projects at a cost of approximately $315 million to date. Funding for the program is generated from a $25 per vehicle title transfer fee, which funds 73% of the program, a 2% surcharge on the sale of heavy-duty diesel equipment (16% of funding), a 2.5% surcharge on the sale or lease of vehicles >14,000 pounds (6% of funding), and a fee on commercial motor vehicles (3% of funding).[46]

The Carl Moyer Memorial Air Quality Standards Program is the other well known state funding program for diesel emissions reduction. This program generates approximately $140 million/year from tire fees, a percentage of vehicle registrations, and budget appropriations.[47]

To assist with the cost of pollution control devices for diesel fleet owners and/or to replace or rebuild high-polluting engines, North Carolina should consider implementing a similar program to TERP and the Carl Moyer programs. The North Carolina Mobile Source Emissions Reduction Program should also be expanded. The program should allocate funds specifically to clean up ALL school buses in the state. All children who ride school buses in the state should have equal opportunity to ride in a clean school bus. Funding for MSERG should also be increased. We recommend that the percentage of gas tax be increased to ensure that ALL school bus cabins are cleaned up with close crankcase ventilation systems and DPFs or CCVs if buses are already retrofitted with a DOC.

Lastly, particulate matter should be included in the list of criteria pollutants considered in the grant process.

Southern Alliance for Clean Energy's biodiesel fueling truck.

RECOMMENDATION 8: Develop clean contract specifications that require contractors who perform work in the state to install pollution control equipment and use bio-diesel in all of their diesel equipment.

Several states have adopted clean diesel specifications and/or created clean diesel specifications for certain large construction or road-building projects. In Massachusetts, a diesel retrofit program was implemented for the Central Artery/Tunnel ("Big Dig") project that specified the use of advanced pollution control devices, primarily diesel oxidation catalysts, and use of emulsified diesel fuel on construction equipment that includes bulldozers, large excavators, front-end loaders, cement trucks, and dump trucks. For this project, more than 200 pieces of equipment were retrofit with diesel oxidation catalysts or diesel particulate filters. The program was administered by the Massachusetts Turnpike Authority and funded by the Massachusetts Highway Department and individual contractors. An estimated 33 tons of particulate matter per year will be reduced during the six year project.[48]

In Connecticut, a diesel retrofit program was established for the I- 95 New Haven Harbor Crossing Improvement Program (I- 95 NHHC) that requires diesel construction equipment to be either retrofit with emission control devices and/or use clean fuels.[49] Also, a project in Lower Manhattan (NY) was established that requires use of ultra-low sulfur diesel fuel and best available control technology on all non-road construction equipment used in state fleets and contracts operating at the World Trade Center site. Additional projects with similar requirements have also been established in Illinois and statewide in New York.[50]

These programs are leading the way for cleaner equipment and fuel use across the country. We encourage North Carolina to step forward and design and implement similar programs to reduce diesel emissions from non-school bus sector vehicles, including those vehicles used in the construction, agriculture, forestry, rail, and marine sectors.

Conclusion: North Carolina Can Do More to Protect Our Children's Health on School Buses

Aggressive state, local, and school-based actions are critical to cleaning up existing sources of diesel soot—including buses, trucks, trains, ships, construction and farm equipment. If implemented, the recommendations provided here will improve local air quality, reduce the negative health and economic consequences of diesel pollution, and provide a safer ride to school for children in North Carolina.

In addition to being essential to our public health clean air is critical to the economy of North Carolina—from preserving our forests, waterways, and coastline for the enjoyment and recreation of our citizens and visitors to ensuring stable agricultural resources. There is not a single person who does not wish to have clean air, cleaner water, or a household free of toxic chemicals. The challenge comes in deciding what is most important to us as community and what is preventing us from making the decisions to have a clean environment. The answers we most often hear against taking action to reduce pollution are the economic costs or fear of changing our direction. But, is it fair that our children, who are most vulnerable to the effects of poor air quality, should have to pay the price for our economic priorities or fear of change? With today's technology and American resourcefulness, we can make room for both economic growth and a clean and healthy environment. Cleaning up our state's school buses is one crucial way we can do that for our children.

Data Table

Below are the numerical results of the demonstration tests conducted in Charlotte:

Charlotte 11-05	PM2.5 (ug/m3)					Ultrafine PM (pt/cc)			
	Min	Max	Mean	Median		Min	Max	Mean	Median
AMBIENT REMOVED									
Conventional Bus									
PM2.5 Front	6	243	29.7	19	*Ultrafine PM Front*	-2,718	317,545	15,923.6	3,936
PM 2.5 Middle	6	68	20.7	18	*Ultrafine PM Middle*				
PM 2.5 Rear 3									
PM 2.5 Rear 4									
AMBIENT			13		*AMBIENT*			16,000.0	
B-99 Spiracle Bus Run 1									
PM2.5 Front	-10	325	10.3	9	*Ultrafine PM Front*	-1,405	71,982	7,139.5	4,550
PM 2.5 Middle	2	29	9.83	9	*Ultrafine PM Middle*	290	65,340	6,626.6	4,950
PM 2.5 Rear 3	-2	31	4.45	4					
PM 2.5 Rear 4	0	658	8.66	5					
AMBIENT			10.406		*AMBIENT*			12,000.0	
B-99 Spiracle Bus Run 2									
PM2.5 Front	6	80	15.65	15	*Ultrafine PM Front*	2,891	133,073	15,689.6	14,273
PM 2.5 Middle	4	58	14.6	14	*Ultrafine PM Middle*	2,610	50,250	11,096.3	10,975
PM 2.5 Rear 3	-8	105	8.63	8					
PM 2.5 Rear 4	-21	201	11.05	9					
AMBIENT			11.25		*AMBIENT*			13,000.0	
DOC Bus									
PM2.5 Front	-1	536	62.54	45	*Ultrafine PM Front*	-5,282	76,755	11,425.3	4,473
PM 2.5 Middle	4	258	66.02	57	*Ultrafine PM Middle*	-4,100	34,270	8,769.3	5,470
PM 2.5 Rear 3	-6	89	32.41	31					
PM 2.5 Rear 4	-8	126	35.7	29					
AMBIENT			42.587		*AMBIENT*			23,257.4	
DPF with Spiracle Bus									
PM2.5 Front	4	67	13.61	12	*Ultrafine PM Front*	-5,609	31,200	577.6	-664
PM 2.5 Middle	7	47	18.98	18	*Ultrafine PM Middle*	-4,156	21,000	5,220.2	5,370
PM 2.5 Rear 3	2	44	11.64	11					
PM 2.5 Rear 4	0	39	12.06	10					
AMBIENT			10.287		*AMBIENT*			12,981.4	
Spiracle Bus									
PM2.5 Front	-4	37	9.42	7	*Ultrafine PM Front*	5,136	83,582	22,321.4	14,645
PM 2.5 Middle	-7	29	7.64	7	*Ultrafine PM Middle*	4,850	103,900	22,453.6	13,130
PM 2.5 Rear 3	-9	21	1.99	1					
PM 2.5 Rear 4									
AMBIENT			25.759		*AMBIENT*			8,857.9	

Provided by Clean Air Task Force

Resources

U.S. EPA
http://www.epa.gov/cleanschoobus/antiidling.htm#myths

Southern Alliance for Clean Energy
http://www.cleanenergy.org/programs/programs.cfm?ID=20&parent=1&ps=YesDiesel

Carolinas Clean Air Coalition
http://www.clean-air-coalition.org

Georgia Diesel Working Group
http://www.cleandieselgeorgia.org

Clean Air Task Force (CATF)
http://www.catf.us

Union of Concerned Scientists (UCS) Clean School Bus Program
http://www.cleanschoolbus.org

National Resources Defense Council (NRDC)
http://www.nrdc.org/air/transportation/hdiesel.asp

California Air Resources Board (CARB)
http://www.arb.ca.gov/research/schoolbus/schoolbus.htm

Diesel Technology Forum
http://www.dieselforum.org/retrofit

Clean Diesel Fuel Alliance
http://www.clean-diesel.org

Donaldson Company
http://www.donaldson.com/emissions

International Truck and Engine-Green Diesel Technology
http://www.greendieseltechnology.com

Voluntary Diesel Retrofit Program
http://www.epa.gov/otaq/retrofit

Clean School Bus USA - Basic Information on Retrofit Options
http://www.epa.gov/otaq/schoolbus/retrofit.htm

Clean Diesel Independent Review Panel
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Health Assessment Document for Diesel Engine Exhaust:
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Characterizing the Range of Children’s Pollutant Exposure during School Bus Commutes, CARB 2003
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Children’s Exposure to Diesel Exhaust on School Buses, EHHI 2002
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No Breathing in the Aisles, NRDC 2001
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Closing the Diesel Divide: Protecting Public Health from Diesel Air Pollution, Environmental Defense
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Speeding the Transition to Cleaner Diesel Engines to Help Americans Breathe Easier Today, Environmental Defense 2004
http://www.environmentaldefense.org/documents/3799_DieselWhitePaper0604.pdf

Sick of Soot: Reducing the Health Impacts of Diesel Pollution in California, Union of Concerned Scientists 2004
http://www.ucsusa.org/clean_vehicles/big_rig_cleanup/sick-of-soot-solutions-to-californias-diesel-pollution.html

Endnotes

1 For results of the full study including results and methodology see the Clean Air Task Force Report at http://www.catf.us/publications/view/82 and Southern Alliance for Clean Energy's report, *A Safer Ride to School: How to Clean Up School Buses and Protect Our Children's Health*, http://www.cleanenergy.org/schoolbusreport.cfm.

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15 Includes Early Action Compact (EAC) areas. 26 full counties and six partial areas do not meet the federal health standards. *8-Hour Ground-level Ozone Designations: Region 4: State Designations,* November 21, 2006, U.S. EPA, http://www.epa.gov/ozonedesignations/regions/region4desig.htm. November 29, 2006 and *Fine Particle ($PM_{2.5}$) Designations: Region 4: State Designations*, March 2, 2006, U.S. EPA, http://www.epa.gov/pmdesignations/regions/region4desig.htm. November 29, 2006.

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20 Clean Air Task Force, *Diesel and Health in America: The Lingering Threat*. February 2005. http://www.catf.us/goto/SACEdieselhealth.

21 Ibid.

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26 U.S. EPA. *Technical Highlights: Questions and Answers on Using a Diesel Oxidation Catalyst in Heavy-Duty Trucks and Buses*, EPA 420-F-03-016, June 2003.

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