REGIONAL SCHOOL BUS STUDY

A Comparison Of Alternative Fuels For School Transportation Fleets

January 2012

SCRCOG

SOUTH CENTRAL REGIONAL COUNCIL OF GOVERNMENTS

PLANNING FOR OUR REGION'S FUTURE

REGIONAL SCHOOL BUS STUDY

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EXECUTIVE SUMMARY

School buses are an important part of our transportation system, as they provide a safe and reliable means for many children throughout the nation to get to and from school. However, exhaust from diesel engines contains numerous pollutants that not only contribute to poor outdoor air quality, but also can leak into passenger cabins of buses, amassing in concentrations that are much higher than outdoor air. Diesel exhaust has serious health impacts for all who are exposed to it, but children are particularly susceptible to its harmful effects and disproportionately suffer from asthma, respiratory irritations, and other possible long-term conditions. The vast majority of school buses in Connecticut and the SCRCOG region are diesel-powered. However, there have been a number of recent advances in alternative fuel technology and corresponding opportunities for bus operators to benefit from the use of alternative fuel technology to reduce diesel emissions, improve air quality, limit health risks, improve efficiency, extend vehicle life, and increase energy independence.

Four of the most commonly used alternative fuels have been tested and used for school bus operations. They include: biodiesel, compressed natural gas, electricity, and propane. The use of hydrogen and ethanol is still being developed for this application. There are many issues to consider before selecting an alternative fuel including initial and lifecycle costs, environmental/health impacts, ability to maintain an alternative fuel vehicle, ability to obtain and distribute fuel, safety of fuel storage and handling, and availability of government funding. The attractiveness of an alternative fuel choice can depend on geographic location and advantages and disadvantages for the use of each fuel type will vary based on the particular needs and operation of a fleet. There are several examples of how school bus operators have successfully adopted alternative fuel technologies for use with their fleets.

Since diesel exhaust from school buses is a critical issue, there are a number of government policies and programs engaged with education, research, implementation, and assessment of alternative fuel technology. Connecticut has an emissions standard for school buses as well as an anti-idling policy. The state also offers several funding programs for school bus fleet improvements.

The preferred alternative fuel and means and timescale of implementation will vary significantly from fleet to fleet depending on operations, resources, and proximity to fuel sources. It is recommended that operators familiarize themselves with health issues associated with diesel powered buses and available alternative fuel technologies. The next step would be a more detailed analysis of costs and benefits can be done considering specific characteristics of and opportunities available to a fleet. There are a number of opportunities available for utilizing alternative fuel technologies, and assistance with these projects is readily available, once the desire is recognized.

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1 INTRODUCTION AND BACKGROUND

1.1 Introduction

School buses play an important role in our transportation system. They provide the benefits of carpooling on a large scale, removing up to ninety cars from the roads for each route (depending on capacity) and providing a safe and reliable means for students to get to and from school. However, exhaust from diesel fuel contains a number of pollutants and carcinogens, which collect in high concentrations in school bus cabins, and have a disproportionate impact on children's health. In Connecticut, 80% of public school students (nearly 460,000 of 575,000) ride buses to school. (1) There are 7,030 school buses registered in Connecticut, (2) and it is estimated that 99% of these are diesel fueled. (3) The amount of time a child spends on the bus every day varies from 20 minutes to several hours per day, and the children of Connecticut collectively spend 50 million hours on buses each year. (4) Since alternative fuel and emissions control technology for traditional diesel engines has significantly improved in the past few decades, there are now several options available for reducing air pollution and limiting children's exposure to harmful emissions.

The South Central Regional Council of Governments (SCRCOG) commissioned this study to examine the potential for use of alternate fuels for the regional school bus transportation fleets and any associated implementation issues. The study includes background information on clean school bus issues, descriptions of most commonly available alternative fuel technologies, discussions of current practices in the country and Connecticut, and recommendations for consideration and implementation.

1.2 Background

1.2.1 Air Pollution and Heath Considerations

Air pollution created by diesel-powered engines, particularly older ones, is a serious problem with considerable health implications. Diesel exhaust contains hundreds of chemicals (in gas or particle form), dozens of which are classified as "human toxicants, carcinogens, reproductive hazards, or endocrine disruptors." (5)The Clean Air Task Force has estimated that diesel pollution was responsible for the following health impacts in Connecticut in 2005: 110 premature deaths, 140 non-fatal heart attacks, 4,091 asthma attacks, 14,420 Work Loss Days, 85,127 Minor Restricted Activity Days, and 7,562 asthma issues and respiratory symptoms in children. (6) Additionally, the EPA has concluded that there is a higher risk for lung cancer and other types of lung diseases associated with long-term exposure to diesel exhaust. (7) There are two components of diesel exhaust that have particularly harmful health impacts and are regulated by the EPA. One is nitrogen oxides (NOx), which significantly contribute to ground level ozone (smog) and have been linked to health problems including respiratory irritation, breathing difficulty, aggravation of respiratory illnesses, permanent lung damage, and diminished lung function growth in children. The other is fine particles, which, in addition to being associated with similar respiratory issues to those listed for ground level ozone, also have been linked to irregular heartbeat, nonfatal heart attacks, and premature death for those with heart or lung disease. (8) Connecticut already has issues with background air quality; The EPA intends to classify the entire state as a nonattainment area for ground-level ozone according to 2008 standards, (9) and New Haven and Fairfield Counties as nonattainment areas for fine particles. (10)

Diesel exhaust is currently regulated as a "mobile source" emission, and school buses only contribute a modest proportion to all diesel exhaust emissions in Connecticut. (11) However, studies have shown that as children ride in school bus cabins, they are exposed to particulate matter concentrations 10 times higher (or more) than normal outside air. (12) This is due to the problem of "self-pollution," or exhaust from a vehicle engine entering its passenger cabin.[1] (13) The most critical factors that influence pollution concentrations in passenger cabins include idling and queuing practices, bus ventilation, and outdoor concentrations along routes. Other factors may include engine model, age of engine, maintenance history, engine location, elevation, passenger load, and climate. (14) In addition to being exposed to higher concentrations of pollutants, children also suffer more harmful impacts (as compared to adults) since they breathe faster, inhale more air per body weight, and do not have immune systems that are as fully developed. (15) School buses may be one of the safest, most cost effective options for getting kids to school, but children who ride them are being disproportionately exposed to air pollutants from diesel exhaust, which can cause or exacerbate poor health conditions.

[1] Although in-vehicle exposure to air pollution is significant, air pollution within motor vehicles is not yet regulated, and acceptable exposure limits for exhaust pollutants have not been established.

1.2.2 Types of School Buses in Operation

There are federal motor vehicle safety standards for school bus manufacture which provide for seven types of school bus vehicles. There are four main types of school buses in operation within the Region. They are summarized as follows:

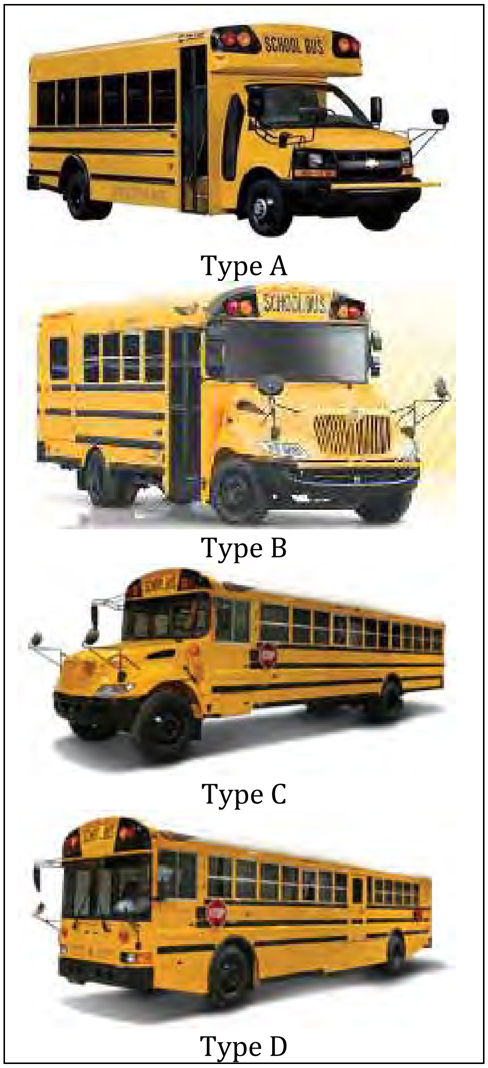


Figure 1:School Bus Types

TYPE A

Small cutaway-van type buses designed to carry 10 or more passengers. These buses retain the driver's door from the cutaway van chassis, and are based on light-duty van chassis.

TYPE B

Based on cutaway-van chassis or stripped chassis type B buses are similar to Type A buses, but somewhat larger.

TYPE C

These buses use medium-duty flat-back cowl truck chassis, with the engine in front of the vehicle with the entrance door behind the front wheels. These are referred to as "conventional" school buses

TYPE D

These buses use medium-duty truck chassis with front, mid, or rear locations, with the engine behind the windshield and beside the driver's seat (for front-engine buses) or with the engine behind the rear heels (for rear-engine buses). The entrance door is ahead of the front wheels. These are similar in appearance to transit buses.

Over the past decade, Type A/B bus sales averaged about 20% of total school bus sales, while Type C buses represent about 57% of sales, and Type D sales are the remaining 23%. Based on 2006 State Department of Motor Vehicle Statistics, the median age for a school bus in Connecticut is 5 years, with 30% of buses in the fleet less than five years old and 70% of buses in the fleet less than ten years old. (16) It is important to understand existing fleet characteristics, since diesel exhaust composition varies considerably according to engine type (heavy-duty, light-duty, etc.), age, operating conditions (idle, accelerate, decelerate), and fuel formulation. (17)

1.2.3 SCRCOG Region School Bus Operation

About half of the municipalities in the SCRCOG region contract private firms to provide transportation for their school districts. The other half provide transportation services themselves. The SCRCOG region consists of fifteen member municipalities. Table 1 lists the member municipalities and their corresponding school bus operators. Note that each town in the region has its own distinct school district. We attempted to conduct a detailed survey of operators in the SCRCOG region. The survey would have provided for a better understanding of the region's fleet characteristics, operational issues, and experiences with or barriers to the adoption of alternative fuel technology. However, none of the agencies were responsive to our repeated requests for information. We have obtained information on a statewide level from the Department of Transportation and from the Department of Energy and Environmental Protection on the programs available and some of the projects that have been initiated. We have obtained additional program and project information from Federal agencies such as the Environmental Protection Agency, and the Department of Energy. This research has identified funding sources, provided considerations for implementing the use of alternative fuels, and demonstrated some of the benefits that have been realized.

Table 1: SCRCOG Municipalities and Bus Operators

School District	Transportation Provider
Bethany	Owner/Operators
Branford	First Student
East Haven	Durham School Services
Guilford	Student Transportation of America
Hamden	First Student
Madison	Durham School Services
Meriden	New Britain Transportation
Milford	Durham School Services
New Haven	First Student
North Branford	DATTCO Inc.
North Haven	M & J Bus Company
Orange	Owner/Operators
Wallingford	Durham School Services
West Haven	Winkle Bus Co.
Woodbridge	Owner/Operators

The information presented for this study is designed to help the region's School District officials, transportation providers, and bus users understand the current issues with diesel fuel use in school buses and consider alternatives. This knowledge will assist officials in making informed decisions regarding the school bus transportation they offer in their districts.

2 Types of Alternative Fuels Available

Table 2: October 2011 Nationwide Average Fuel Prices (18)

	Gasoline Gallon Equivalents	Dollars per Million Btu
Gasoline	$3.46	$29.94
Diesel	$3.42	$29.64
CNG	$2.09	$18.08
Ethanol (E85)	$4.51	$39.04
Propane	$4.23	$36.62
Biodiesel (B20)	$3.57	$30.96
Biodiesel (B99-B100)	$4.12	$35.68

Table 3: 2007 Average Purchase Cost for Transit Buses (19)

Type	Cost
Diesel bus (40-ft, low floor)	$328,000
CNG bus (40-ft, low floor)	$395,000
Hybrid bus (40-ft, low floor)	$483,000
Hybrid shuttle bus (22 ft)	$284,000
Battery electric shuttle bus (22 ft)	$197,000
Electric Trolley Bus (40 ft)	$850,000
Fuel Cell Bus	$3,000,000

School buses are particularly well suited to use alternative fuels since they are typically maintained and fueled at a central location and operate on predictable routes and schedules. They also transport children, who could greatly benefit from the reduced emissions that some alternative fuels would provide for.[2] (20) This study considers the six most common alternative fuels: ***Biodiesel, Electricity, Ethanol, Hydrogen, Natural Gas, and Propane.*** Each of these fuels has a unique set of benefits, drawbacks, and implementation issues.

When evaluating options for implementing alternative fuel technology, costs are one issue to consider. These include the costs for vehicles or vehicle modifications, specialized fueling station equipment, maintenance/operations, and fuel. **Error! Reference source not found.** shows recent average fuel prices on an energy equivalent basis. However, there are grants and tax credits available in many cases which can offset some of these costs. Other issues to consider are availability of fuel, ability to maintain specialized vehicles, environmental/health impacts, and safety of fuel handling and storage. There are a number of school bus and transit bus operators who are already using alternative fuel technology for their fleets. We can use the knowledge and experience from both of these applications to assess opportunities for using alternative fuel technologies for more school buses. In particular, shows recent average purchase prices for various types of transit buses, which provides a reasonable initial estimate for comparable school bus vehicles.

[2] Since they serve so many children, reducing emissions for school buses would also provide a greater health benefit per dollar investment as compared to reducing emissions from other vehicles such as 18-wheelers.

2.1 Biodiesel

Biodiesel fuels are developed from plant or animal fat-based oils[3], which are renewable, nontoxic, and biodegradable. They can be blended with petroleum diesel or composed entirely of alternative fuels, and their use can considerably reduce emissions and pollutants compared to traditional diesel fuel. Biodiesel fuels generally cost more than petroleum diesel. However, due to fluctuations in petroleum prices this is not always the case. There are several blends of biodiesel fuel produced in accordance with ASTM specifications that are readily available on the market. B100 is a pure 100 percent biodiesel fuel which can be used to power diesel engines if modifications have been made to some of the components to ensure material compatibility.[4] (21) There are some operational and maintenance issues associated with the use of biodiesel blends that contain more than 20 percent biodiesel. These issues include lower energy content per gallon (versus petroleum diesel), possible gelling at low temperatures, clogging fuel filters if used after petroleum diesel (due to cleaning property), and the potential for biological contamination. B20 is a blend of 20 percent biodiesel and 80 percent petroleum diesel and is the most common biodiesel fuel blend in the United States. Biodiesel blends containing 20 percent or less biodiesel can be used to fuel diesel engines with no or very minor modifications. (22) Since biodiesel can be used immediately in existing diesel vehicles, it may be the quickest and most cost effective way to begin implementing the use of alternative fuels in the region's school bus fleets.

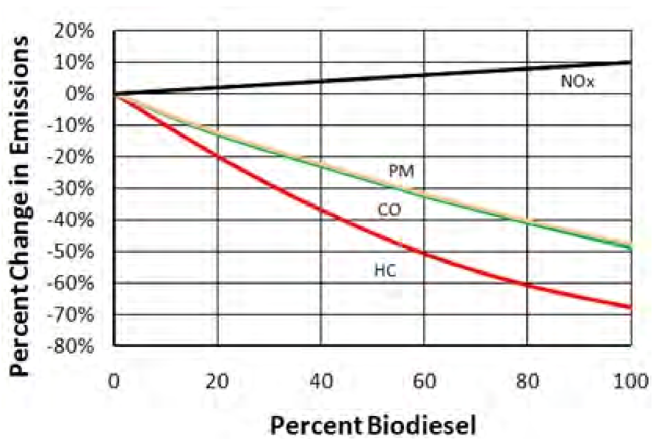


Figure 2:Average Emissions Impact of Biodiesel for Heavy-Duty Highway Engines (23)

The use of biodiesel reduces emissions of particulate matter (PM), carbon monoxide (CO) and hydrocarbons (HC) compared to petroleum diesel, although nitrogen oxides (NOx) emissions increase slightly (see Figure 2). The emission reduction benefits are proportional to the percentage of biodiesel contained in the fuel blend. Although most regulated pollutant emissions would decrease with the use of biodiesel, the increase in NOx

[3] Soy oil is the most common source in the United States.

[4] Biodiesel can degrade or compromise natural rubbers, plastics such as polyvinyl chloride (PVC) and polystyrenes, and metals such as copper-based material, zinc, tin, lead, and cast iron.

emissions is problematic, particularly in nonattainment areas like Connecticut, since it contributes to ground level ozone. (24) There are some safety benefits to using biodiesel: since it is a nontoxic fuel it provides enhanced environmental protection in the case of a spill and since it has a higher flashpoint than petroleum diesel it provides a lower risk of accidental combustion. (25) Another important benefit to using biodiesel is the decreased reliance on foreign oil since biodiesel can be produced domestically. (26) Currently in the United States, 60 percent of our petroleum is imported.

Although there are benefits to using biofuels on a small/regional scale, the widespread use of food crops to produce fuel is controversial (the food vs. fuel debate). It has been estimated that the total U.S. production of vegetable oils and animal fats could only replace 15 percent of our current demand for diesel fuel. (27) Greater demand for biofuels could cause a shift in production from food crops to fuel crops (causing increased food prices and food shortages) as well as conversion of forest or other undeveloped land to farmland. Growing additional fuel crops will also cause greater environmental impacts as more pesticides and fertilizers are used in crop production. Also, studies have found that it takes more energy to produce biodiesel than the amount of energy contained in the biodiesel that is produced. (28) Therefore, a widespread shift to biofuels as a replacement for petroleum products does not appear feasible until production from another source (such as algae) is advanced further.

2.2 Compressed Natural Gas (CNG)

The most significant benefits from using CNG as an alternative fuel source are that it produces fewer emissions than petroleum fuels, there is an abundant supply that is domestically produced, and it is competitively priced with diesel fuel. Compared to gasoline-powered vehicles, Natural Gas Vehicles have similar power, acceleration, and speed performance characteristics. However, they produce fewer tailpipe emissions, have a longer service life, and require less maintenance. (30) Vehicle emissions tests for CNG and diesel transit buses found that

Figure 3:CNG school bus in Kansas City, KS (29)

CNG engines produced 84percent less particulate matter emissions and 49% lower NOx emissions versus comparable diesel engines. (31) Although vehicle operation is similar, driving ranges can be less for Natural Gas Vehicles. This is because the fuel is a gas and it takes up more space to store the equivalent energy to a gallon of gasoline.[5] CNG is also promising as an alternative fuel source for vehicles since there is already a wide distribution network for natural gas in the country, Connecticut, and the SCRCOG region. Although there are not many public CNG fueling stations in Connecticut (about six) there are more stations that serve private fleets. (32) Fueling stations can be "slow-fill" which is more appropriate for overnight fueling, or "fast-fill" which can take 10 to 15 minutes to fill an 80 gallon tank. An extensive selection of Natural Gas vehicles are available that run as "dedicated" (exclusively on CNG), as "bi-fuel" (with two individual fueling systems that allow for power from natural gas or gasoline), or as "dual fuel" (with two fuel sources being used simultaneously). CNG buses now make up 26 percent of new transit bus orders in the U.S. (33) They typically cost about $65,000 more than a conventional diesel-powered bus, but that cost can be offset by grants, fuel savings, lower maintenance costs, and a longer service life.

2.3 Electricity

The greatest benefit to electric vehicles is their significant reduction in emissions compared to diesel-fueled vehicles. The EPA actually considers all-electric vehicles "zero-emission vehicles" since they do not produce any tailpipe exhaust (although electricity production does contribute to air pollution). This is a particularly desirable trait for school buses, since riders' exposure to emissions produced by the school bus would be completely eliminated. There are three different types of electric-powered vehicle models: all electric, hybrid, and plug-in electric hybrid. All-electric vehicles are powered from an array of batteries that need to be charged periodically from an external power source. Electric

Figure 4:Plug-in hybrid electric bus in SC (34)

[5] This fuel tank size issue is more problematic for conversion vehicles since Natural Gas Vehicles accommodate the fuel storage requirements in the design (CNG storage for buses is typically accommodated on the vehicle roof).

power is readily available from grid, although battery charging can be time consuming and charging equipment is not always easily accessible. Therefore, all-electric vehicles are particularly good for predictable and short-range trips. Hybrid electric vehicles are powered with an internal combustion engine and an electric motor. Since the batteries in a hybrid vehicle are charged with regenerative braking and the internal combustion engine, no external charging is necessary. Hybrids provide better fuel economy with similar performance as compared to diesel-powered vehicles (while reducing emissions by as much as 60%). (35) Plug-in electric hybrid vehicles are powered in the same manner as hybrid electric vehicles, except they have the option to charge the battery from an external power source, thus further reducing gasoline fuel consumption. Charging times for electric and plug-in hybrid vehicles can vary considerably based on the battery type and charging equipment, but can range from less than 30 minutes to 20 hours. (36) Electric or hybrid school buses can cost more than twice what a new diesel-powered bus would with additional higher maintenance costs (37), and plug in hybrids can cost even more (38). However, some of the cost difference can be recouped through fuel savings, tax credits, or other government funding programs.

2.4 Ethanol

Ethanol is an alternative fuel, most commonly made from starch-based plant materials (90 percent of production in the United States is derived from corn). Ethanol's primary advantage is that it is domestically produced and can therefore reduce our reliance on foreign oil supplies. Ethanol is distributed in various blends with gasoline. Blends that contain up to 10 percent ethanol (E10) can be used in any gasoline-powered vehicle and are found in gasoline pumps everywhere. More than 90 percent of gas sold in the United States contains up to 10 percent Ethanol, to satisfy air quality standards, meet the renewable fuel standard, or to boost octane. (40) The process to allow E15 to be sold for general consumption is just beginning, as the idea has won initial approval from the EPA. E85 (blends which contain from 51 to 83 percent ethanol) is considered an alternative fuel according to the EPA and can be used in "flexible fuel vehicles" which are specially designed to tolerate higher concentrations of ethanol. Vehicles achieve about 27 percent lower gas mileage with E85 than with traditional

Figure 5:Fueling a flexible fuel vehicle (39)

gasoline, but E85 is usually less expensive so the costs per mile are comparable. (41) Fueling stations that offer E85 are more concentrated in the Midwest, where production primarily occurs (there is currently only one station in Connecticut that offers E85). Transport of ethanol is most commonly done by truck or rail, since pipeline infrastructure has not yet been developed. (42) In evaluating the tailpipe emissions for E85 versus gasoline, studies have found on average that all regulated pollutants either decrease or show no significant change for E85 versus gasoline. (43)

The federal government has initiated a number of actions to promote ethanol production and consumption. First, the Energy Independence and Security Act of 2007 included a mandate requiring refiners to blend up to 36 billion gallons of ethanol into gasoline by 2022. Second, automakers who build flexible fuel vehicles are given fuel economy credits. Third, Tax credits of 51-cents per gallon are provided for companies who blend ethanol into gasoline.[6] (45) Figure 6 shows U.S. corn production and use for ethanol over the past 25 years. Some of the concerns about ethanol are that fuel crop production may displace food crop production (the same issue as with Biodiesel production), ethanol requires a lot of energy to produce[7] and contains less energy than gasoline, and some studies have linked ethanol to increased greenhouse gas emissions. (46) The chemical process for converting cellulosic material to ethanol is currently the focus of intensive research, as longer-term ethanol production will more likely shift away from food crops. Cellulose materials include plant stalks, leaves, trunks, branches, and husks and can be obtained from crop residues, forestry residues, grasses, paper and food waste, and trees. (47) These sources are abundant and could be grown or collected without conflicting with food production.

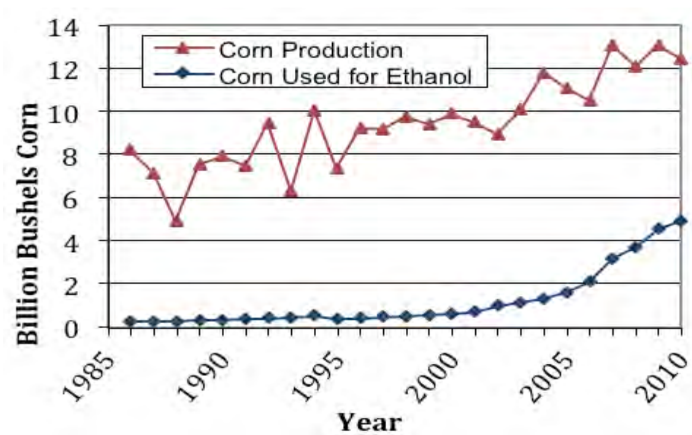


Figure 6:US Corn Production and Use for Ethanol (44)

The use of ethanol blended with diesel fuel (E-diesel) is still considered an experimental fuel, as special permission from the EPA is required for on-road use. (48) There are also no

[6] This subsidy expired December 30, 2011

[7] Recent studies have shown that ethanol provides 23 to 40 percent more energy than its production process requires.

ASTM specifications for E-Diesel, so it cannot be legally sold at the retail level, although it could be possible to use E-Diesel to serve centrally fueled fleets. Blends of E-diesel with 10 to 15 percent ethanol are flammable at typical ambient temperatures, increasing the risk of fire or explosion over diesel fuel. There are also other vehicle operation concerns. A number of modifications to fuel storage design and transfer processes would be preferable to reduce safety risks and changes to vehicle fuel system and engine materials would be required to alleviate performance issues. (49) One company has developed a proprietary blend of ethanol diesel fuel that can be used in place of diesel fuel with no vehicle or engine modifications. (50) There are currently a number of pilot programs to use this blend in school bus fleets throughout the country.

2.5 Hydrogen

Hydrogen has been classified as an alternative fuel by the EPA; however it is not an energy source itself, but rather a means to store energy produced from another source, much like a battery. Currently, hydrogen is most commonly produced through natural gas reforming using steam (this method accounts for 95 percent of US hydrogen production), but several other processes are being studied. Hydrogen can be used to power a fuel cell vehicle. A fuel cell requires hydrogen and oxygen to produce electricity, which is used to power an electric motor, and generates water and heat as byproducts. The major advantage of hydrogen fuel cell vehicles (like electric vehicles) is that they produce no tailpipe emissions. (52) This is a particularly desirable characteristic for school buses, as it would eliminate riders' exposure to self-pollution. There are several challenges relating to hydrogen fuel cell technology that are the subject of ongoing research: storing hydrogen on board vehicles without taking up excessive space or adding excessive weight, transferring hydrogen from a production facility to end user vehicles[8], producing hydrogen with minimal cost and emissions, and reducing fuel cell vehicle cost. (53) Figure 7 shows one of the few hydrogen fueling stations in the country.

Figure 7: Hydrogen fueling station in California (51)

[8] The infrastructure to do this is poorly developed. There are a few existing pipelines, concentrated near refineries and chemical plants, and transport as pressurized or liquefied hydrogen via truck or rail is expensive. Additionally, there are only a few hydrogen fuel stations in the country.

The major criticism of hydrogen as an alternative fuel is the inefficiency of its fueling process. To power a fuel cell vehicle, energy would be used to produce hydrogen, which is then transported and delivered to end users. Hydrogen is then converted back to electricity in a fuel cell vehicle to power an electric motor. If energy was instead used to produce electricity directly, it could be distributed through the existing electric grid to charge batteries in electric vehicles to fuel the same type of motor with greater efficiency. Hydrogen fuel cell vehicles are primarily still in the development phase and may not be available for widespread use for several more decades. There has not been much application of fuel cell technology to school bus transportation. Cost and durability are critical issues for the school bus market, and these issues have not yet been resolved for fuel cells.[9] (54) However, there have been several trials of fuel cell buses in transit applications, including one for CT Transit in Hartford, for which lessons learned can be applied to the school bus market. (55)

2.6 Propane

Figure 8: Arizona school bus converted into a bi-fuel propane vehicle. (56)

Propane is also known as Liquefied Petroleum Gas (LPG) and is a high-energy, clean burning fuel. It is stored as a liquid in a pressurized tank and turns into a gas when it is released for combustion. It is a byproduct of oil refining and natural gas processing and most propane in the U.S. is produced domestically. (57) Where natural gas service is not available, propane is often used for a variety of purposes including home heating, water heating, cooking, etc. Although propane vehicle technology is well established and commonly used worldwide, less than two percent of propane use in the U.S. is for transportation. (58) Propane vehicles can either be dedicated or bi-fuel, but most have been converted from gasoline vehicles. Figure 8 shows the propane storage tank for a school bus converted into a bi-fuel vehicle. Propane vehicles have operating characteristics similar to gasoline vehicles, except driving range is reduced because of the

[9] Initial cost for a fuel cell bus is approximately 10 times higher than diesel powered bus, with much higher lifecycle cost as well.

25 percent lower energy content of propane and lower efficiency of a propane fuel system. However, the recent introduction of liquid propane injection engines offers the potential for greater fuel efficiency. (59)

There are several benefits to using propane as compared to diesel fuel for school bus fleets including lower emissions, lower maintenance costs, longer engine life, and reduced dependence on foreign oil. It has been found that manufactured heavy-duty propane vehicles have emission reductions of about 60% for NOx and close to 100 percent for particulate matter as compared to vehicles powered with diesel fuel. It has also been found that manufactured propane vehicles provide greater emission reductions than converted propane vehicles. (60) Propane is extremely safe since it has the "lowest flammability range of all alternative fuels" and propane tanks are "20 times more puncture resistant than gasoline tanks." (61) Proximity to propane production and distribution facilities and the availability of existing infrastructure are important issues to consider when evaluating the option to add propane vehicles to a fleet. Currently in Connecticut, propane is used in about 13.7 percent of Connecticut households for various uses. There are nine main wholesale supply points which serve the Connecticut propane market. These are primarily located in northeastern states and include ports, rail terminals, pipeline terminals, refineries, and reserve supplies. (62) Connecticut also has 77 registered propane dealers (63) and 16 propane fueling stations. (64) Therefore, it seems feasible that propane use in Connecticut could be expanded to fuel school bus fleets in order to realize the benefits that this alternative fuel could provide.

3 Current Practices

Throughout the country, school bus operators have been wrestling with the problem of diesel exhaust emissions while also managing issues of cost, durability, maintenance, and infrastructure. There are a number of case studies available to demonstrate how alternative fuel technologies have been applied to school bus operations throughout the country. There are also a number of policies and programs that address clean school bus issues. These current practices are discussed in the following sections.

3.1 Case Studies

The most feasible alternative fuels to use for school bus fleets at this time include biodiesel, compressed natural gas, electricity, and propane. The following are case studies from school districts around the country who have successfully implemented the use of these technologies into their operations.

3.1.1 Use of Biodiesel

Las Vegas is located in Clark County, Nevada, the 14th largest county in the country that has over two million residents and 40 million visitors a year. (65) Since Las Vegas has experienced a high growth rate and is a major tourist destination, air quality and energy are major concerns for the area. In 1993, the Las Vegas Regional Clean Cities Coalition (LVRCC) was established to address these issues. This organization uses contributions and grants from its stakeholders to fund operations and projects, and is responsible for increasing the use of alternative fuel technology for a number of fleets in the Las Vegas area including the Clark County School District. (66) The district is the fifth largest in the nation, encompasses over 8,000 square miles, and provides transportation to approximately 138,000 students. The district uses biodiesel (B20) for *all* of its buses (approximately 1,450) and has recently retrofitted almost 1,000 of them with Closed Crankcase Ventilation (CCV) systems and Diesel Oxidation Catalysts (DOC). (67) The switch to biodiesel has displaced their use of 600,000 gallons of petroleum annually.

Source: greenfleetmagazine.com

Because there is not a good supply of local soybeans (the most common feedstock for biodiesel fuel) LVRCC project partners originally tried to take advantage of the proximity to and large supply of recycled cooking oil from the county's restaurants and casinos. (68) After it was found that vehicles performed better using a blend made from soybean oil, the use of cooking oil was abandoned. This change allowed the district to use a one dollar per gallon tax incentive for using soy oil. The district is pleased with their use of biodiesel since it satisfies the Nevada requirement that 90 percent of vehicles purchased run on alternative fuels, they experience the same mileage as they would with diesel, and they are providing for improved air quality. (69)

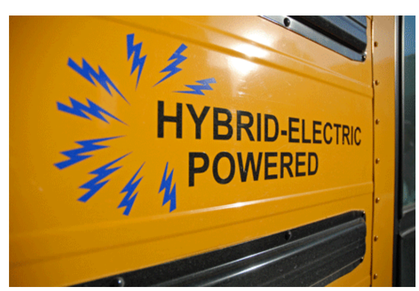
3.1.2 Use of Compressed Natural Gas

Tulsa Public Schools is the largest school district in Oklahoma with 40,000 students in 173 square miles. In 1988, as part of a pilot program to evaluate feasibility of alternative fuels, the district converted 24 conventional school buses to compressed natural gas (CNG). With the assistance of several successful bond issues and zero-interest loans from the State, the district continued to convert buses after the program ended. (70) In 1997, the school system won a U.S. Department of Energy State Energy Program Special Projects grant and partnered with Oklahoma Natural Gas to add additional school buses and medium/heavy-duty vehicles to their fleet. (71)

Tulsa Public Schools currently operates about 190 CNG vehicles. The district estimates the cost savings from using CNG instead of gasoline or diesel at an average of $300-$500 per vehicle annually. (72) To serve their vehicle fleet, the school system has its own CNG fueling station, which has 380 slow fill stations and four fast-fill stations. In addition to using CNG, the school district uses biodiesel (B20) to fuel all 285 of its conventional buses, and is considering the addition of an electric bus for testing. (73)

3.1.3 Use of Hybrid Electric

A large number of collaborating partners are involved in the Kentucky Hybrid Electric School Bus Program, a project that is planned to replace 213 diesel-powered school buses with hybrid electric school buses throughout the state from 2010 to 2013. These partners include the Kentucky Department of Education, local school districts, the Kentucky Department of Energy Development and Independence, the Kentucky Finance and Administration



Source: hybridreview.blogspot.com

Cabinet, the Kentucky Department for Air Quality, the Kentucky Clean Fuels Coalition, the Kentucky National Energy Education Development program, and Hybrid electric school bus manufacturers. (74) In August 2009, the project was awarded $13 million by the U.S. Department of Energy to cover the cost difference between hybrid electric buses and traditional diesel buses. The project will reduce fuel consumption by about 30-40 percent from a conventional diesel bus, while increasing gas mileage from 7.5 to 12 miles per gallon and reducing in diesel exhaust emissions. The lifecycle for each bus will also be extended from 14 to 18 years. Upon project completion, Kentucky will have the largest hybrid electric school bus fleet in the nation, and will use the project to collect performance data and engage students on energy issues. (75)

3.1.4 Use of Propane

Gloucester County Public Schools in Virginia obtained funding from the American Recovery and Reinvestment Act through the Environmental Protection Agency's National Clean Diesel Program to obtain the first propane school buses in the State for their fleet. Until fairly recently, it was difficult to obtain propane school buses, as companies that performed conversions of traditional diesel buses were difficult to find. However, Bluebird has now developed a manufactured propane school bus that is available for purchase. Gloucester County has recently purchased five of these Bluebird buses that run exclusively on propane. Their experience with the propane buses is that they have similar driving ranges, they cost about ten cents less per mile to operate, and they run more quietly than their traditional diesel buses. They hope to obtain five additional buses when additional government grants are awarded. The school district also uses biodiesel fuel in the rest of their fleet in an effort to limit children's exposure to emissions. (76)

3.2 Policies and Programs

Because of the great number of benefits that can be realized with the implementation of alternative fuel technology, there are many government agencies at the federal, state, and local level that are engaged with this issue. They administer environmental regulations, fund research programs, offer project grants, provide data and information, and give organizational and technical assistance. Together these agencies are working to reduce air pollution, improve health conditions, limit consumption of fossil fuels, and provide energy security.

Source: streetsblog.org

3.2.1 CT State Law Regarding School Bus Emissions Reduction

In 2009, Connecticut enacted statutes regarding purchasing emissions control devices required in school buses and procurement of contracts. The Title 14, Chapter 246a, § 14-164o statutes mandate either a diesel engine retrofit to reduce particulate matter, or an engine or vehicle that has already been certified to meet minimum emission standards. The statutes also require procurement contracts to ensure these measures are met. Specific requirements are that each full-sized school bus manufactured in 1994 or later that transports children be equipped with emissions control systems including either a closed crankcase filtration system and a level 1, level 2, or level 3 device, use of an engine that meets the Model Year 2007 emissions standard, or the use of alternative fuel that has been certified to reduce particulate matter emissions by at least 85 percent versus ultra-low sulfur diesel fuel. (77) This mandate requires the highest level of protection available for current diesel technology. The Connecticut Clean School Bus Program was created to ensure all Connecticut school bus fleets would meet this standard by 2010.

3.2.2 U.S. Environmental Protection Agency's Clean School Bus Program

The Environmental Protection Agency has created the Clean School Bus Program with the goal of limiting children's exposure to diesel exhaust and reducing pollution generated by diesel school buses. They achieve these goals by encouraging anti-idling policies, replacing old buses with "cleaner" new buses, and retrofitting buses that cannot be immediately replaced. Many school districts, including several in Connecticut, have received grants from this program administered by the State Department of Energy and Environmental Protection.

Source: epa.gov

The Connecticut Clean School Bus Program was created to carry out three objectives (78):

1. Establish grants for retrofitting full-sized school buses that are projected to be in service on or after September 1, 2010
2. Develop and implement an outreach plan and educational materials, and
3. Assist bus operators in retrofitting their school buses.

Grants from this program have provided for over 1,200 school buses in Connecticut to be retrofitted with emission control devices (such as diesel particulate filters or diesel oxidation catalysts) and equipment to reduce levels of exhaust that get into the bus cabin (closed crankcase ventilation system). Program managers believe their efforts to date have "effectively satisfied the demand for school bus retrofits in Connecticut. (79) Table 4 shows typical emission reductions and costs for retrofitting an existing school bus. School districts in the SCRCOG region that have completed retrofits or replacements include Hamden and New Haven. (80) Additional information on these projects is shown in Table 5.

Table 4: Estimated Emission Reductions and Cost for Diesel Retrofit Devices (81)

Technology	Typical Emission Reductions (%)				Typical Costs
	PM	NOx	HC	CO	
Diesel Oxidation Catalyst (DOC)	20-40		40-70	40-60	Material: $600-$4,000 Installation: 1-3 hours
Diesel Particulate Filter (DPF)	85-95		85-95	50-90	Material: $8,000-$50,000 Installation: 6-8 hours
Partial Diesel Particulate Filter (pDPF) Partial or Flow-through	Up to 60		40-75	10-60	Material: $4,000-$6,000 Installation: 6-8 hours
Selective Catalytic Reduction (SCR)*		Up to 75			$10,000-$20,000 Urea $.80/gal
Closed Crankcase Ventilation (CCV)*	varies				
Exhaust Gas Recirculation (EGR)*		25-40			
Lean NOx Catalyst (LNC)*		5-40			$6,500-$10,000

*May be combined with DOC or DPF systems to reduce PM, HC and CO emissions

Table 5: Connecticut Clean School Bus Program Projects in the SCRCOG Region (82)

Project Location	Year	Description	Cost
City of New Haven	2006	Project participants included representatives from CTDEP, CTDMV, City of New Haven, New Haven Board of Education, First Student, Inc., EPA Region 1, and NESCAUM. Retrofit all 181 First Student school buses used for the New Haven schools with Diesel Oxidation Catalysts, and Closed Crankcase Ventilation systems. Also run all buses on Ultra Low Sulfur Diesel fuel.	Initial Project Cost Estimate: $701,250.00
Town of Hamden	2008	Project participants included school officials, Town officials, and First Student, Inc. Retrofit 57 First Student school buses with Diesel Oxidation Catalysts.	Grant amount: $300,000 (received by Local Governments for Sustainability for five communities)

3.2.3 Connecticut Clean Fuel Program

The Connecticut Clean Fuel (CCF) program is administered by the Connecticut Department of Transportation and provides funding for the purchase of diesel retrofit technology and alternative fuel vehicles (including those powered by compressed natural gas, propane, electricity, or hydrogen). The following public entities are eligible to apply for these program funds: state agencies, town governments, city governments, municipal governments, municipal utilities, and transit districts. Table 6 shows bus purchases that have been made with Connecticut Clean Fuel program funding to date.

Table 6: Recent Connecticut alternative fuel school bus purchases (83)

Municipality	Qty.	Vehicle/Fuel Type	Year
Fairfield	2	Blue Bird Model AB 84 Passenger CNG School Bus	2007
New Britain	1	IC Corp CE PB105 Plugin Hybrid Electric Diesel School Bus	2009
Middletown	1	IC Corp CE PB105 Plugin Hybrid Electric Diesel School Bus	2011
Estuary Transit District - Centerbrook	2	Ford/StarTrans Senator Hybrid Electric Body-on-Chasis Bus	2011

3.2.4 U.S. Department of Energy's Clean Cities Program

Most alternative fuel vehicle implementation projects have been conducted in partnership with the Clean Cities Program. Clean Cities is the U.S. Department of Energy's program for encouraging alternative transportation, and is organized into a number of local coalitions. Clean Cities coalitions develop collaborations between public and private stakeholders to reduce petroleum consumption in a region by replacing it with alternative fuels, reducing its use with improved vehicle technology and altered driving practices, and by eliminating demand for it with use of travel demand management strategies and shift to alternative transportation modes. (84) The Greater New Haven Clean Cities Coalition is active in the SCRCOG region and is currently working on a project to develop alternative fueling stations and deploy alternative fuel vehicles throughout the state of Connecticut. (85)

3.2.5 Connecticut's Anti-Idling Efforts

Anti-idling legislation has been in place in Connecticut since 1983. However, the Department of Environmental Protection realized in 2002 that there was an additional need to draw attention to health impacts of idling school buses and to work with school bus

operators to reduce exposure to harmful emissions. (86) In January of 2002 the DEP (now the DEEP) and Connecticut School Transportation Association (COSTA) developed a voluntary policy which instructed all operators and drivers to shut off their engines as soon as they reach a location, and to not idle while waiting for passengers. It also instructs drivers to only idle long enough on initial startup to reach the correct operating temperature and defrost windows. (87) In February 2002, the Connecticut General Assembly passed RCSA 22a-174-18 to revise air pollution regulations to specifically prohibit the idling of school buses for longer than 3 minutes unless an exempted condition is met, such as when the outdoor temperature is below 20 degrees Fahrenheit. (88) CT DEEP is also involved in a number of other enforcement, education, and outreach efforts related to anti-idling.

4 RECOMMENDATIONS

School bus operations vary considerably for municipalities in the SCRCOG region. Each municipality has its own school district with its unique arrangement for providing student transportation. Some districts own and operate their own fleets, while others have contracted a private company to perform those services. There are also considerable variations in the areas these school districts serve, such as urban, dense New Haven (where air quality issues are a significant concern) and more rural areas such as Bethany and Guilford (where issues of efficiency and durability may be more of a concern). Therefore, opportunities for implementing alternative fuel technology for school bus operations will vary widely from municipality to municipality in the SCRCOG region.

Key Considerations for Use of Alternative Fuels:

1. Diesel exhaust from school buses is a critical issue with important health implications.
2. Fleet operations and priorities vary significantly within the SCRCOG region.
3. There are unique advantages and disadvantages for each potential alternative fuel.
4. Feasibility of alternative fuel projects will vary from fleet to fleet.
5. There are a number of government agencies and programs to assist with alternative fuel projects.

There are a number of local, state, and federal agencies that provide information and assistance to school bus operators related to Clean School Bus issues and there are several programs offered to help fund clean school bus projects. As a first step, it would be beneficial for school district officials and school bus operators to familiarize themselves with the numerous health issues related to diesel exhaust emissions and to assess the exposure and liability risks posed by existing school bus vehicles and operations. The next step is to perform a cost/benefit analysis for various potential scenarios to determine how and when to implement an alternative fuel technology. As with many new technologies, initial purchase costs and long-term maintenance costs will diminish as the technology becomes more established, making opportunities to use the technology more feasible for those with limited financing. In the case of school bus transportation, however, the decision to implement alternative fuel technologies should not be based solely on financial considerations due to the related public health concerns, local political pressures, and availability of government funding.

Another hurdle for implementing new fuel technologies throughout the region is that a decentralized operation model is currently in place. Each town that provides their own transportation could find it difficult to develop alternative fueling infrastructure and maintenance capabilities due to the resources and expertise required. In addition, municipalities that do not provide their own school bus fleets and instead use independent contractors will have to work closely with their providers to implement any fleet changes.

Use of biodiesel fuel (B20) would be the quickest and easiest choice for initial use of alternative fuels. Depending on fuel availability and fueling station infrastructure, fleets could begin using Biodiesel in the very near term with minor modifications to operations and no changes to existing vehicles. Operators could then consider modifications to existing vehicles, or future purchases of new alternative fuel vehicles. The benefits of any alternative fuel would have to be considered along with the availability of the fuel, fueling station infrastructure, and ability to service and maintain the vehicle.

There are many promising options for utilizing alternative fuel technologies to reduce diesel emissions, improve air quality, limit health risks, improve efficiency, extend vehicle life, and increase energy independence. The information and resources are available to assist school bus fleet operators with adopting alternative fuel technology, once the desire to do so is realized.

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