The Hybrid Electric School Bus *Feasibility Study*

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Advanced ENERGY

909 Capability Drive, Suite 2100
Raleigh, NC 27606-3870
919-857-9000
www.advancedenergy.org/hybridbus

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INTRODUCTION

You see them every morning and every afternoon. They are the most visible symbol of our education system. The familiar stop sign, square windows revealing cherub faces and bi-fold door that releases a babbling stream of children when it arrives.

School buses are part of our daily routine. In fact, there are more than 500,000 school buses in the United States that transport 25 million children on approximately 10 billion student trips each year. But do you ever think about what lies under those big yellow hoods? What type of engine powers the wheels? How much fuel does it use? Are the emissions that exit the tailpipe a problem?

Nationwide, school buses consume 1.1 billion gallons of diesel fuel every year. Burning all this fuel produces thousands of tons of air pollutants.

Nationwide, school buses consume 1.1 billion gallons of diesel fuel every year. Burning all this fuel produces thousands of tons of air pollutants. By every measure, school buses represent a major segment of our country's transportation sector.

Like the rest of the transportation sector, school bus fleets are facing the same challenges of higher fuel costs and more stringent emission limits. There are several ways to address these challenges: more efficient engines, additional pollution controls and non-petroleum based fuels. A solution promoted in the passenger car market is hybrid technology.

A hybrid vehicle has at least two methods of storing energy. For example, the Toyota Prius stores energy in gasoline and electric batteries. On-board electronics optimize efficiency and minimize emissions by shifting power between the gasoline engine and electric motor in response to driving needs. Locomotives have used hybrid technology for decades, and hybrid transit buses are now available. However, none of the school bus manufacturers currently offer a hybrid. This report is part of an effort to change the school bus market.

Manufacturers have not seen a demand for hybrid school buses that would encourage them to offer this option. With assistance from the N.C. State Energy Office, Advanced Energy is organizing multiple school districts across the country to create this demand. This report summarizes earlier studies that demonstrated the technical and economic feasibility of hybrid school buses, addresses the specific challenges that face the transportation industry as a whole and shows why hybrids are an excellent solution.

Focusing on the school bus market is important for several reasons. The school bus market cannot respond like typical automobile markets. The targeted consumer base for passenger vehicles is huge, and consumers purchase automobiles for various reasons. The public is purchasing hybrid vehicles to improve the fuel economy and the environment, as well as for social value. School buses are purchased in a bid process and are selected based on lowest cost. Safety is the most important concern. Districts are often concerned about environmental impact and fuel consumption but are limited in how these can be specified. The number of new buses produced each year is small compared to the number of new passenger vehicles manufactured each year. There are also very few major school bus manufacturers making the market relatively small and conservative. However, the school bus market represents a significant portion of the transportation sector. This presents a leverage point where small change can have large benefits.

In addition, the project focuses on the most common variety of school bus, Type C, instead of the entire market. These are also called "conventional" buses. Type A and B buses are smaller and Type D look more like transit buses.

Type C school buses are the most common and are often referred to as "conventional" buses. The Hybrid Electric School Bus Project (HESB) focuses on this type of bus.

THE CHALLENGES

This study addresses two major challenges to the transportation industry: fuel consumption and air quality. The two are related because reducing fuel consumption usually reduces tailpipe emissions.

FUEL CONSUMPTION

On a global basis, the world depends on oil. Generally speaking, oil is pumped out of wells in the ground, shipped to a refinery, made into gasoline and diesel, piped to a terminal with large storage tanks then trucked to individual dispensing locations. So what if that supply chain was suddenly broken?

If consumers do not have fuel for their vehicles, economies would grind to a halt. In the United States, tractor trailers haul most of the goods to retail stores. If those trucks cannot use diesel, then they stop driving, leaving stores without goods for their customers. In fact, 96 percent of all transportation in the United States relies on oil. Other world economies likewise depend heavily on this resource.

Just as in personal investing, it is important to diversify. Most financial advisors frown on having all of your money in the stock market, but if you do, they advise investing in mutual funds to spread your risk. The energy source for the transportation sector of our economy is not diversified. This dependence on a sole source reduces our ability to effectively respond to disruptions.

However, depending on one energy source for nearly all our transportation needs would not be significant if there were enough of that resource to meet demand. In the past, oil supplies have been more than adequate to satisfy demand, and prices have been stable or dropping in real terms. But increased rates of consumption by modern economies have strained supplies.

Oil Demand

United States' oil consumption has grown dramatically over the last 50 years. The exponential rise reflects the growth of our country both in terms of population and industrialization. However, more people driving more miles in less fuel efficient vehicles is the real culprit. A plot for world oil consumption would show a similar trend.

India and China have rapidly growing economies, enabling their skilled workers to afford personal cars. The U.S. Energy Information Administration states that the Chinese passenger car market grew tenfold between 1990 and 2000.

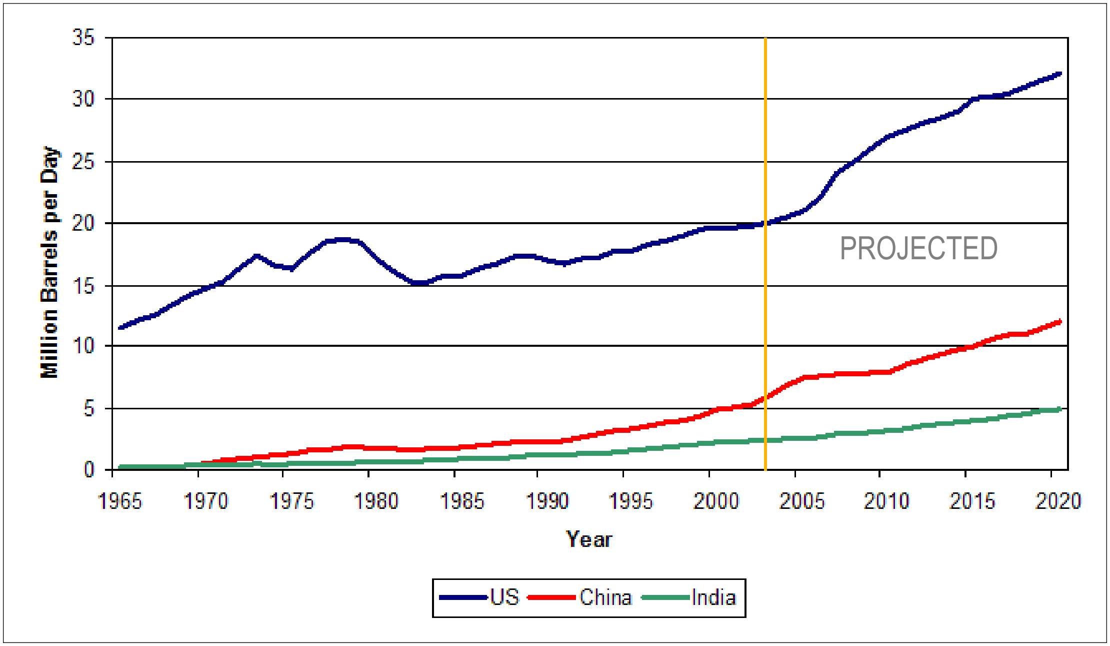
WHAT ARE PROVEN RESERVES?

The amount of extractable oil depends on the price of oil. If the market price increases, then oil that may require more processing to extract becomes economical. Proven reserves in some countries are overestimated for political reasons. Shell and other oil companies recently decreased their proven reserve estimates, causing a shock to the industry.

Transporting manufactured goods from factory to port require fuel. These countries are also oil importers like the United States. Neither country currently demands as much oil as we do. However, the growth rate for China's oil demand has increased in the last decade to more than 7 percent per year. India's annual increase in oil demand is nearly 5 percent. If there were plenty for everyone, such drastic increases in consumption would be no problem.

Oil Supply

Geologically, the world holds an amazing amount of oil. There are staggering amounts of proven reserves in various locations throughout the world. Proven reserves are an important factor when evaluating world oil supply, but they are not the whole story. Oil production is more important. Owning a commodity is not the same as extracting that commodity and selling it. The history of world oil production has the beginning of a classic bell-shaped curve and it appears that we may be near the peak. In fact, geologists predict that peak oil production will occur between Fall 2005 and sometime in the next 50 or 100 years. They all agree that easily extractable oil is limited.



Historical and projected oil use for United States, China and India

These predictions of peak oil do not include non-traditional sources. Tar sands contain bitumen, a highly viscous hydrocarbon liquid that can be refined into lighter weight oil. To retrieve the oil requires mining the sand and processing it using natural gas. Another method involves injecting steam underground to loosen the bitumen so it can be pumped to the surface. The world's largest tar sand deposits are in Alberta, Canada and Venezuela. Oil shale is another type of non-traditional oil deposit that requires mining for extraction. Like tar sands, it contains bitumen and requires processing to extract the oil.

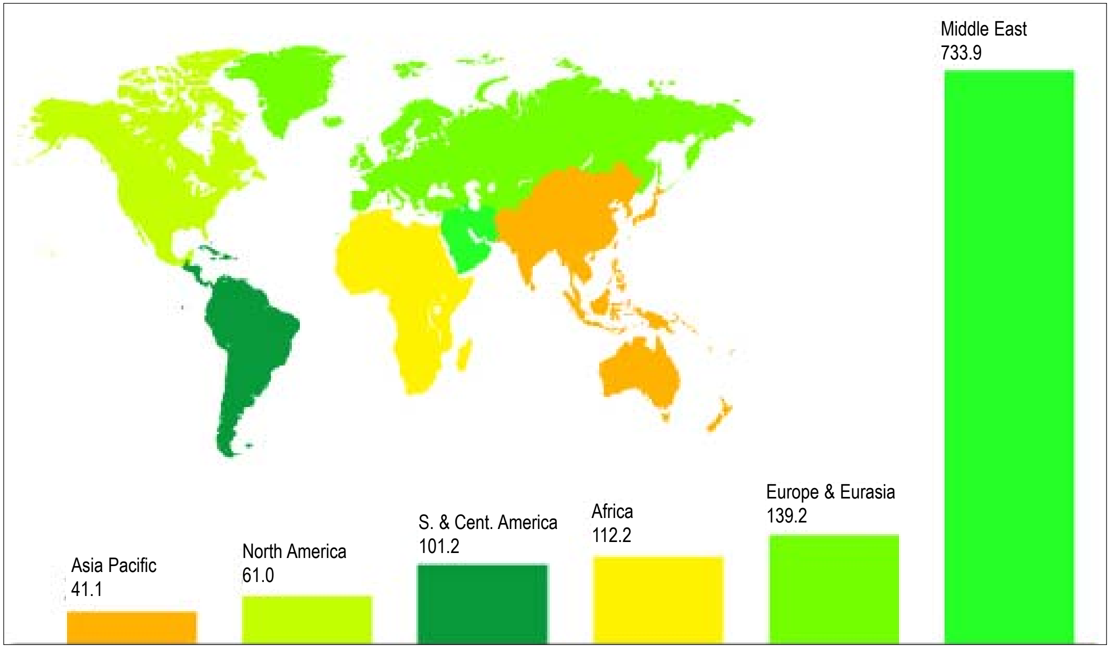
The United States, Russia, Brazil and China have large deposits of oil shale. However, mining this resource could damage environmentally sensitive areas. Neither is economical, but the estimated reserves are vast.

Therefore, although there are uncertainties about the exact amount of oil remaining, the world will not run out of oil. Oil will just become more expensive. As prices rise, new production techniques change the amount of proven reserves. Also as prices rise, non-traditional sources may become economically viable. It all hinges on cost.

Oil Price

The Organization of Petroleum Exporting Countries (OPEC) is a cartel that works to maintain stable oil production and influence oil prices. One of the dominant OPEC members is Saudi Arabia. The modern history of this nation is intertwined with oil and is the subject of many books. Saudi Arabia's ruling family controls 45 percent of the world's proven reserves.

Another important factor to consider when discussing world oil supplies is production capacity. As mentioned earlier, oil comes from wells and is piped to waiting ships, transported across the oceans, processed then trucked to dispensing locations. All of this supporting infrastructure has production limits and can only operate so fast. This limitation applies from



BP Statistical review of World Energy 2005

Proven reserves at the end of 2003 in thousand million barrels

the wellhead to the shipping lanes. An example of the importance of production capacity is in Iraq. This nation has huge amounts of proven reserves but has been limited in production capacity because of attacks on its pipelines and wells. Iraq has plenty of oil but cannot get it to shipping ports.

This highlights another reason why Saudi Arabia dominates OPEC and world oil markets. Until recently, Saudi Arabia was the only country with excess production capacity. When the world needed more oil, the royal family ordered production increases and the wells and pipelines and refineries responded. This is no longer true. Increasing demand has even pushed the Saudi production infrastructure to its limit. The loss of this cushion in production capacity will make oil prices more volatile in the future.

For these reasons and many others not discussed here, Saudi Arabia dominates the global oil market. And this is a single global market. In other commodities, local production may be less influenced by global changes. But oil is truly a global commodity. Multinational companies ship oil from Venezuela to China and from Mexico to Europe. Events in Australia affect production in Alaska.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Emissions exit the vehicle's exhaust pipe and mingle with ambient air.

Clearly, there are many, many other factors that affect world oil prices: international treaties, wars, national policies, environmental considerations, etc. But the main factors are:

- World demand for oil is increasing
- The existing supply infrastructure may have trouble meeting this demand
- The market is dominated by a single supplier

These factors illustrate the instability of the situation.

Change Management

Our capitalistic society does an amazing job of balancing supply and demand. Sometimes, the balancing act is smooth and allows time for economies to adjust. For example, steady rises in inflation are absorbed while the economy chugs along. Other times, the balancing is abrupt and causes significant disruptions.

Many experts believe that increasing competition for oil will be a disruptive balancing act. The long supply chain described above is vulnerable to attack at many points. The U.S. may be forced into a military solution to protect existing supplies or secure new supplies. Without a surplus or cushion in production, even weather events such as an extremely cold winter or a devastating hurricane in the Gulf of Mexico could cause price spikes that some industries may not be able to survive. The risk of such a disruption is greater now than in the past because demand has increased faster than the infrastructure can supply. As discussed above, we cannot drill our way out of this problem.

Therefore, changes in our transportation sector will occur. Increasing demand and decreasing supply guarantee this fact. These changes will affect all other sectors of our world economy. Will these changes be smooth or disruptive? That depends on how we manage the change.

AIR QUALITY

Another significant challenge facing the transportation industry is its impact on air quality. Without going into too much detail, an internal combustion engine gets its power from a series of controlled explosions that drive the pistons. Each little explosion in the right mixture of air and fuel generates pollutant emissions. These emissions exit the vehicle's exhaust pipe and mingle with the ambient air, air that children breathe and that circulates around the globe. The next sections explore the components of these emissions and their impacts on our health and environment.

School Bus Diesel Emissions

The majority of school buses use diesel fuel. Diesel combustion is similar to gasoline combustion, and both processes produce the same pollutants. However, the amounts and mixtures are different. The table below shows a list of pollutants emitted by diesel combustion.

Volatile Organic Compounds (VOCs)

VOCs are a family of pollutants and include some you may be familiar with like benzene, formaldehyde, toluene, styrene and xylene. (Some organizations refer to specific classes of VOCs like hydrocarbons or total organic compounds.) These chemicals are volatile because they evaporate into the air at normal conditions. When you smell gasoline or diesel, you actually smell the VOCs. Paints sometimes still use VOCs in their mixture to speed the drying process. Some of these VOCs present in fuel are consumed in the combustion process and some pass through with the other exhaust gases. Some other types of VOCs are actually produced by the combustion process as well.

Many VOCs are toxic and damage various human organs and tissues. VOCs lead to the formation of ground level ozone (see the following section on the ozone) when combined with nitrogen oxides in the presence of sunlight.

The main method for reducing VOCs from engines is proper tuning of the combustion process. If the engine is running properly and is well maintained, then combustion is more complete and fewer VOCs are emitted in the exhaust.

Nitrogen Oxides

Our atmosphere is approximately 75 percent nitrogen. The extremely high temperatures of the combustion process lead to the combination of nitrogen with oxygen, primarily from the combustion air. Nitrogen oxides (NOx) exhausted to the ambient air forms ozone (see the following section) when combined with VOCs in the presence of sunlight.

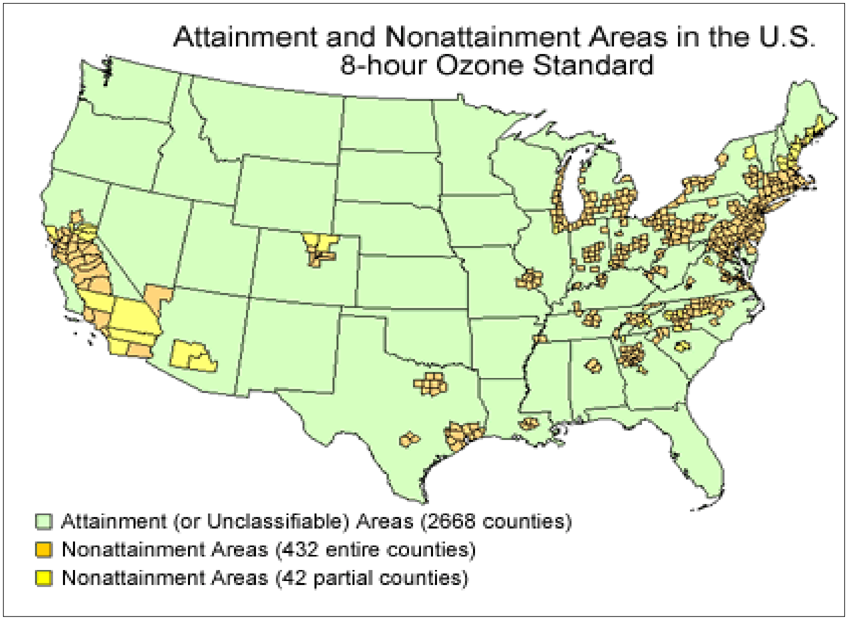
NOx can be controlled by lowering the combustion temperature or causing the pollutant to change to a less potent form. Engine makers sometimes lower the combustion temperature by circulating some of the exhaust gases back into the engine. This is called exhaust gas recirculation (EGR). The common method to change NOx into a less harmful form involves adding an expensive catalyst to the exhaust system.

Ozone

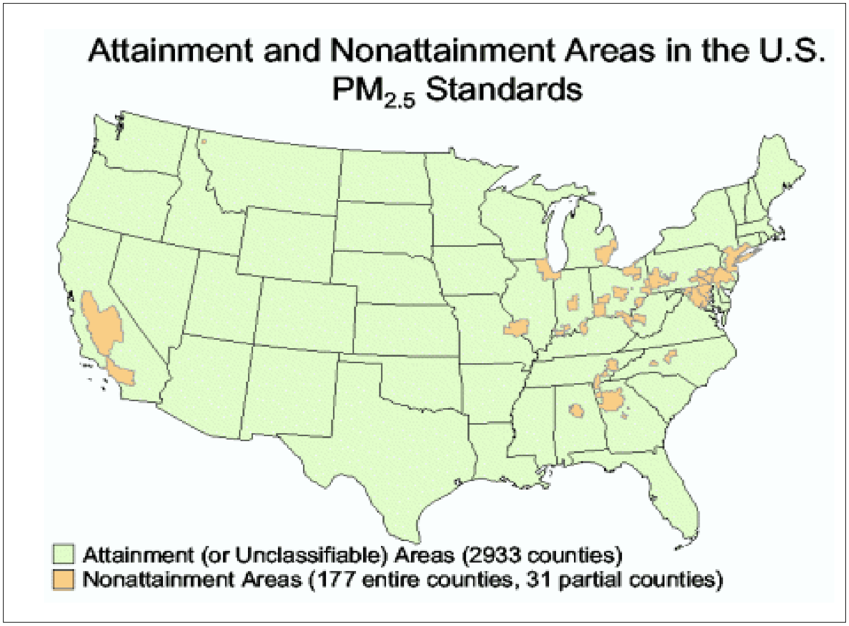
The U.S. Environmental Protection Agency is responsible for protecting our air quality. They established that certain levels

Pollutants from Diesel Combustion

Name	Abbreviation	Impact
Volatile Organic Compounds	VOCs	Toxic, leads to ozone
Nitrogen Oxides	NOx	Acidic, leads to ozone
Carbon Monoxide	CO	Immediate dizziness
Particulate Matter	PM	Reduced lung function
Sulfur Dioxide	SO2	Acidic, creates haze
Carbon Dioxide	CO2	Greenhouse effect



Ozone Nonattainment Areas



Particulate Matter Nonattainment Areas

of pollutants in our air are not harmful. They have also established monitors that measure the pollutant levels. One of the pollutants of concern is ground level ozone. As explained previously, the majority of ozone is not emitted by any process, but is formed when VOCs and NOx combine in the atmosphere. Sunlight “cooks” the soup and we get ground level ozone. This process is rather complicated and involves several chemical steps. The required sunlight explains why ozone levels are worse during the summer instead of the winter.

Certain areas of the country have unhealthy levels of ozone in the air. These are called nonattainment areas because they do not attain the standards. Most of these areas are around large cities or along interstates. The figure on page 10 shows a national map of counties designated as nonattainment for ozone.

Ozone is a strong oxidizer. Breathing high levels of ozone can damage lung tissue and reduce respiratory function. It can irritate the lungs, cause excessive coughing and has been linked to increased cases of asthma. The only way to reduce ozone emissions is to reduce the precursors. As mentioned above, the precursors to ozone are VOCs and NOx.

Carbon Monoxide

Like VOCs, carbon monoxide (CO) is formed during incomplete combustion. Most of the carbon in the fuel is converted to carbon dioxide (CO2 is described below). The best method for minimizing CO emissions is to properly maintain the engine and improve the combustion efficiency through better engine design.

CO is a very dangerous pollutant. It is odorless and colorless. When breathed into our lungs, CO actually combines more quickly than oxygen with our blood. If too much is breathed, the body does not get the oxygen it needs to survive.

Particulate Matter

Particulate matter (PM) is a general term for any sort of airborne particle. Examples include dust from dirt roads, pollen and campfire

GOOD UP HIGH, BAD NEARBY

Ozone occurs in two layers of the atmosphere. The layer closest to the Earth’s surface is the troposphere, the main ingredient of urban smog. Here, ground-level or “bad” ozone is an air pollutant that is harmful to breathe and it damages crops, trees and other vegetation.

The troposphere generally extends to a level about six miles up, where it meets the second layer, the stratosphere.

The stratosphere, or “good” ozone layer, extends upward from about six to 30 miles and protects life on Earth from the sun’s harmful ultraviolet rays.

WHAT IS A MICRON?

The black smoke you see from older or poorly maintained diesel engines is particulate matter, which is measured in microns. A micron is one millionth of a meter. Relatively speaking, a grain of salt is about 60 microns and a human hair can be 100 microns in diameter. The eye can see particles of about 40 microns.

smoke. PM is typically divided by sizes. Larger diameter particles fall out of the air more quickly than smaller particles. Therefore particles with diameters less than 10 microns (PM10) and 2.5 microns (PM2.5) are of special concern. There are various sources of PM in an internal combustion engine. The black smoke you see from older or poorly maintained diesel engines is particulate matter.

PM10 is small enough to enter the respiratory system and lead to conditions such as asthma. PM2.5 is small enough to inhibit oxygen exchange in the lungs. The medical community is placing more blame on fine particulates for a range of ailments including lung cancer and heart disease.

As it does for ozone, the EPA measures the level of PM2.5 in the ambient air. The figure on page 10 shows the areas that are nonattainment for PM2.5. This means that the air in those areas contains unhealthy levels of very small diameter particulate matter.

Some particulate matter from combustion processes can be trapped on a filter. In some cases, particulate matter can be combusted again to remove it before it exits the exhaust system. Proper engine maintenance can also reduce PM emissions.

Sulfur Dioxide

This pollutant forms when sulfur in the fuel combines with oxygen in the high temperatures of the engine. Once SO2 enters the ambient air, it combines with moisture and rain water to form a mild acid (i.e., acid rain). Acid rain acidifies lakes and streams particularly at higher elevations and damages the plants and animals that live there. It also accelerates the decay of building materials and paints and reduces visibility that degrades the value of scenic vistas.

The formation of SO2 can be reduced by reducing the amount of sulfur in the fuel. The EPA therefore limits the amount of sulfur allowed in diesel fuel. This limit was recently reduced by 95 percent so that by 2007, all diesel fuel sold for use in on-road vehicles (off-road vehicles include farm tractors, bull dozers and cranes) will use ultra low sulfur diesel (ULSD). As explained below, some emission control devices require the engines to use ULSD.

Carbon Dioxide

As mentioned above, the main product of fuel combustion is carbon dioxide, CO2. Power plants, steel mills, chemical plants, cars, trucks and buses emit large amounts of CO2. Most scientists believe that putting all this CO2 into the atmosphere is increasing the greenhouse effect. The earth's atmosphere naturally provides a greenhouse effect that is required for life to exist. However, putting so much CO2 into the air may change our atmosphere in ways that are harmful to the planet. Potential affects include rising ocean levels, more powerful hurricanes or other severe weather events.

This is a complicated process and scientists do not understand it fully, but already see signs of change. Some would argue that any measured changes (rise in ocean levels, increases in ambient CO2 levels, etc.) are due to natural cycles and are not caused by modern society. This report does not make a judgment on this debate but presents this information for consideration.

The amount of CO2 produced from a combustion process is directly related to the quantity of fuel burned. Therefore, to reduce CO2 emissions, less fuel should be burned. This is usually achieved by improving the efficiency of the particular process. In vehicles, increased efficiency means higher fuel economy or higher miles per gallon.

Children's Health

As explained above, the pollutants emitted from vehicle exhaust have a wide range of health effects: reduced lung function, increased risk of developing asthma, triggering asthma attacks and increased risk of heart problems. Children are especially susceptible to poor air quality because they breathe a much larger volume of air (50 percent more) relative to their size than adults. While an adult may show no signs of discomfort at a certain pollution level, that same level could send a child to the hospital. Many studies document the link between elevated ambient pollution levels and increased patient visits to hospitals and doctor's offices.

Regulatory Limits

Regulatory agencies on both the federal and state levels are well aware of the air quality problems caused by vehicle exhaust. For mobile sources like trucks and buses, the EPA protects air quality by setting limits on the amount of pollution that a single engine can produce. Current regulations require more stringent limits to be implemented on a fixed timeline as shown in the figure at left. (Engine power is sometimes measured in units of brake-horsepower or bhp.) These limits are forcing manufacturers to develop new technologies and produce cleaner engines. (See the following section for more about possible solutions.)

On a state and local level, agencies work to reduce traffic problems and prevent idling emissions. In nonattainment areas, authorities and planning organizations must demonstrate that new roads and the associated vehicle emissions will not harm air quality. These regulatory approaches are supplemented by other incentives to reduce urban sprawl, encourage carpooling and strengthen mass transit. Despite regulatory and voluntary efforts, areas of the nation still have poor air quality. This means that there is still work to do to improve these areas.

Children are especially susceptible to poor air quality.

POSSIBLE SOLUTIONS

Earlier sections of this report explained the challenges facing the transportation industry: the entire transportation sector essentially relies on one energy source. That energy source will become more expensive as supplies decline. Air pollution emitted by vehicles have adverse health affects (especially for children) and government agencies are working to solve these issues. Despite these efforts, we still have problems.

In summary, we need vehicles that are cleaner and use less petroleum-based fuel. The family of possible solutions can be divided into control technologies and alternative fuels.

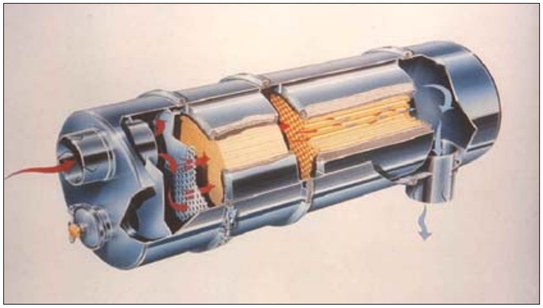
CONTROL TECHNOLOGIES

Control technologies focus only on the air quality challenge by reducing the level of pollutants emitted from each vehicle. Following are several common control technologies.

Diesel Particulate Filter

As explained above, combustion typically produces some amount of particulate matter. That amount varies with the type of fuel combusted and the maintenance level of the engine. A poorly maintained or older diesel engine can produce a large amount of PM10 and PM2.5. One method of controlling these emissions is through a diesel particulate filter (DPF).

A DPF (also called a particle trap) filters PM as the exhaust passes through the filter. Physically, they look like vehicle mufflers and are mounted in line with the exhaust system. They can reduce particulate emissions by 80 to 90 percent. Just like an air filter in your home or an oil filter for your engine, these filters collect enough material over time that



Flow through a particulate filter

WHAT IS A CATALYST?

A catalyst is a material that assists in a chemical reaction but is not consumed during that reaction. In emission control technologies, the catalyst often is the shape of a wire mesh or foam that includes a rare metal like platinum.

This explains some of the expense of catalytic systems. Catalysts can become unusable if certain materials (e.g., sulfur) get stuck to their surface.

Spiracle filter

they require cleaning or replacement. Most DPFs used for on-road applications actually burn or oxidize the trapped PM to clean the filter. This oxidation process requires a catalyst but also removes most VOCs and CO emissions.

Thousands of DPFs are currently in active duty. These units have proven effective in a wide range of applications, including school buses. However, only vehicles manufactured after 1995 can us them. Also, any vehicle using a DPF must use ultra low sulfur diesel fuel (see the previous section on Sulfur Dioxide in Air Quality) to avoid fouling the catalyst. There are a wide range of manufacturers. Typical systems cost between $5,000 and $10,000 per vehicle and should last for 150,000 miles.

Diesel Oxidation Catalyst

From the outside, a DOC looks like a DPF or a fat muffler. A DOC uses a catalyst applied to a porous support material to assist in oxidation. As the exhaust emissions pass through the DOC the CO and VOCs are converted to CO2 and other less harmful pollutants. These devices also remove some combustible PM.

DOCs must be used with ULSD so that the sulfur does not foul the catalyst. These units are relatively inexpensive ($1,000 to $2,000 each), have long lives (150,000 miles) and can be retrofit to any diesel engine.

Closed Crankcase Ventilation Filter

Typical engines have some method to ventilate the crankcase. The engine’s pistons fit snugly in the cylinder. However, during combustion, some of the high pressure gases escape from the cylinder and “blow by” into the engine. These gases would collect and increase pressure on the backside of the cylinder if they were not vented to the atmosphere. Typical practice is to vent this exhaust near the engine instead of through the main exhaust system. Several school bus emission studies found that crankcase ventilation was the main source of pollutants entering the passenger compartment of the bus.

Several companies now sell filters for crankcase ventilators that trap particulate matter. These filters are disposable and must be replaced every 10,000 miles at a cost of only $200 each.

Other Technologies

The previously mentioned technologies are the most popular and are simple to retrofit on existing engines. Other technologies are being proposed by manufacturers as means to meet some of the emission standards. These include fuel modifications or additives, additional catalytic emission control devices and engine modifications through exhaust gas recirculation.

Some engine manufacturers will have exhaust gas recirculation (EGR) systems on all their new engines beginning in 2007. EGR recirculates a portion of the exhaust back into the engine. This actually lowers NOx emissions by lowering the combustion temperature. Manufacturers are making this change to comply with EPA standards.

CNG bus at the pump

ALTERNATIVE FUELS

All of the control technologies discussed above only address the air quality challenge of the transportation industry. Some of these technologies would actually cause the vehicles to consume slightly more fuel. However, there are fuels other than petroleum-based diesel. And most of these fuels also have reduced emissions when compared to conventional diesel. This report only addresses alternatives to diesel but there are alternatives that are appropriate to the passenger car market as well.

Compressed Natural Gas

Compressed natural gas (CNG) is a popular alternative to diesel for heavy duty vehicles. Natural gas is a fossil fuel obtained from wells and is composed mostly of methane. Natural gas deposits are typically located near oil or coal fields. Methane is also produced from biological processes such as decomposition or animal digestion. For practical use as a vehicle fuel, it must be compressed to reduce the volume. On a vehicle, CNG is stored in tanks and has high pressure piping that routes the fuel to the specially modified engine.

There are very large deposits of natural gas in the United States and Canada. However, deregulation and issues with the supply chain have caused volatility and drastic increases in the price over the last decade. Energy companies are investigating imports of liquefied natural gas to stabilize the price and meet consumer demand.

Emissions from CNG engines are excellent when compared to conventional engines. For heavy and medium-duty applications, CNG shows a 90 percent reduction of carbon monoxide, a 90 percent reduction of particulate matter and a 50 percent reduction of NOx relative to diesel.

As a transportation fuel, CNG has several drawbacks. The refueling and maintenance infrastructure is much more expensive than that required for convention diesel. A typical high pressure refueling station may cost $300,000 or more. Because the fuel is a highly flammable gas, any maintenance garage that serves CNG vehicles must have special fire protection equipment and other explosion prevention modifications. These upgrades add to the fleet’s operating cost.

In addition, fleet experience with CNG indicates that the fuel economy is lower than that of conventional diesel. Therefore, a CNG bus is less efficient than a conventional diesel bus. There is also evidence that CNG buses are less reliable than conventional buses and require more maintenance.

Propane

Many consumers are familiar with propane because they use it in their backyard gas grill. Propane is a fossil fuel and is often referred to as liquefied petroleum gas or LPG. It is a byproduct of natural gas processing and crude oil refining.

Unlike its cousin methane, propane becomes a liquid with very low pressurization at ambient temperatures. This means that propane requires a much smaller volume to store a large amount of energy. Propane trucks and buses do not require high pressure fuel lines like CNG vehicles.

Propane combustion produces less pollution than diesel combustion. It reduces NOx by 90 percent and particulate matter by at least 80 percent when compared to diesel. It also shows substantial reductions of other pollutants. Propane has been used as a vehicle fuel for over 60 years in cars and light and heavy duty trucks.

Biodiesel

Biodiesel is a liquid fuel just like petroleum diesel. Petroleum diesel comes from refining oil that is pumped out of the ground, but biodiesel can be made from vegetable oils, animal fats or recycled restaurant greases. There are a wide variety of crops that can be used as sources for biodiesel including soy beans, rapeseed (canola) and wild mustard. These biological sources are renewable unlike fossil fuels.

Alternative Fuels Data Center

Biodiesel can be made from soy beans.

Biodiesel is produced by a chemical process where the fats and oils react with an alcohol and a catalyst. This reaction produces biodiesel and glycerol, a byproduct that can be used in pharmaceuticals and cosmetics. There is also some filtering required to remove water and other contaminants.

Biodiesel does have a few drawbacks. At low temperatures, it forms a gel instead of a liquid. This gums up fuel lines and makes the engine hard to start. Biodiesel is also a detergent for petroleum diesel combustion products. It basically cleans the fuel system when first operated in a vehicle that was previously operated on conventional diesel. This requires frequent fuel filter changes for the first few months of operation. There have also been reports of some component failures in older engines. With current technologies and market development, biodiesel is more expensive than petroleum diesel and requires tax breaks to be cost competitive.

To counter some of these drawbacks, biodiesel is typically blended with petroleum diesel. The percentage of biodiesel varies from two percent to 20 percent and is typically marketed as B2 or B20. So B20 would have 20 percent biodiesel and 80 percent petroleum diesel. B20 does not have any problems with gelling. In most regions of the country, it is still slightly more expensive than petroleum diesel. Despite this premium, B20 is a very popular alternative to petroleum diesel. It is used in airports, municipal fleets, transit buses and is publicly available in hundreds of stations across the country.

Diesel trucks and buses have much lower pollutant emissions when they use B20. Particulate matter, VOCs, and sulfur dioxide are drastically reduced. Some studies show that using B20 causes a slight increase in NOx emissions when compared to conventional diesel. The overall emission benefits, however, certainly outweigh this slight increase.

Battery Electric

In a conventional bus the energy that moves the vehicle is stored in the fuel, but in an electric vehicle this energy is stored in batteries. An electric vehicle (EV) has an electric motor that drives the wheels. It also has an electronic controller that routes the power from the battery to the motor in response to the driver’s push on the accelerator. EVs can have excellent acceleration because motors can generate very high power at low speeds. Instead of filling up at the pump, battery electric vehicles recharge by plugging in to an electrical charging station.

The big disadvantage to a battery electric bus is the limited range. Batteries are heavy relative to the amount of energy they can store. This means they have low energy density compared to diesel fuel. If a battery electric bus tried to store the equivalent of a tank of diesel, it would be too heavy to move and there would be little room for passengers.

The emissions benefits of battery electric buses are excellent. There are no tailpipe emissions so pollution is not generated by the bus at all. However, the power plant that produces the electricity to recharge the batteries does produce emissions. The total pollutant emissions generated from recharging a battery electric bus are much lower than those generated from driving a conventional diesel because power plants are very clean relative to the amount of energy they produce.

Battery electric vehicles have a higher initial cost than their diesel equivalent. This is primarily due to the battery cost. However, electricity is much less expensive than diesel as an energy source. Therefore, the operating costs of a battery electric vehicle are much lower. High initial cost is a significant barrier to many potential purchasers.

There are a few battery electric buses currently in operation. Several cities across the country use battery electric trolleys in their downtown areas. These vehicles are well suited for the short range trips in stop and go traffic where low or zero emissions are a priority. Due to the inherent limitations in range, battery electric vehicles are not suitable for most bus routes.

Fuel Cells

A fuel cell vehicle is an electric vehicle. Instead of receiving electricity from the batteries, the electric motor is driven by electricity created by the fuel cell. Fuel cells generate electricity by combining oxygen and hydrogen. In the fuel cell itself, there are no moving parts. However, most designs for vehicle applications require additional pumps and other equipment for proper operation. Fuel cell vehicles also have an additional energy storage device such as a battery that assists the fuel cell under heavy loads.

There are many different designs and types of fuel cells. The most common type being developed for transportation applications requires

RECHARGE IN MOTION?

A common question about electric vehicles is "Why don't EVs have a way to make electricity and recharge the batteries as they drive?" Some folks also suggest putting a windmill on top and recovering energy from the wind as you drive.

A little thinking about this reveals that the conservation of energy, a fundamental law of physics, states that this can't happen. It's like standing in a sail boat while it's calm and blowing yourself along. The windmill would slow you down and require more energy from the batteries than it could generate.

storing hydrogen on the vehicle and combining it with oxygen from the air. Therefore, the "fuel" for a fuel cell is hydrogen. This hydrogen can come from many sources including biologic sources or fossil fuels such as natural gas. It can even be generated from water by a process called electrolysis. The most economical hydrogen source using today's technology is natural gas. Methane in natural gas can be processed so that the hydrogen is removed and stored separately.

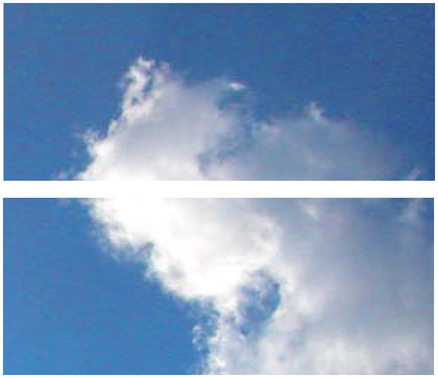
All these efforts are still in the research phase. Fuel cells are proving to be too fragile for transportation applications. Then there are issues with the hydrogen generation and storage. Our current fuel distribution system is not capable of dispensing hydrogen. And like CNG, to store enough on board a vehicle requires extremely high pressures and expensive containers. However, fuel cells are currently a hot topic and there are lots of research dollars being spent in an effort to develop the "Hydrogen Highway." Fuel cells are still decades away from practical deployment at reasonable costs.

One research area for fuel cell vehicles is the hybrid drive train. Since fuel cells require some additional energy storage mechanism to meet high power requirements, these vehicles will essentially be hybrid systems. The development of hybrid vehicles (see the next section) is a first step toward eventual production of fuel cell vehicles.

California Governor Arnold Schwarzenegger stands with General Motors Vice Chairman Bob Lutz while refueling the HUMMER H2H.

Alternate Fuels Conclusion

In summary, there are several practical alternative fuels available for school buses. All of them are currently more expensive than conventional diesel, but most of them offer emission benefits. Some advocates recommend combining alternative fuels with additional control technologies to achieve the cleanest alternative that uses the least petroleum. These combinations, however, result in much higher operating costs that most fleet operators cannot tolerate. ■



THE HYBRID SOLUTION

This report has reviewed two major challenges facing the transportation industry and how these challenges also face school buses. There are retrofit devices that can reduce the harmful pollutant emissions, and there are alternative fuels that reduce oil consumption. There is another option that addresses both challenges: the hybrid solution.

DEFINITION OF A HYBRID

A hybrid vehicle has two or more methods for storing energy to move the vehicle. The modern hybrid uses an electric motor in addition to a gasoline or diesel engine. Typically, an electric battery stores and supplies energy for the electric motor and the fuel tank stores energy for the engine. Before we get in to the details on the technology, we first need to generally understand how a hybrid reduces fuel consumption.

Engine Efficiency

The words engine and motor are sometimes used for the same object. In this report, an "engine" is powered by gasoline or diesel and "motor" always refers to an electric motor. In a conventional vehicle, the engine provides all the power. The driver decides to go faster and pushes the accelerator. The system responds by sending more fuel to the engine and increasing its speed. The load on the engine varies as well. If the vehicle is going up a hill or if the vehicle is carrying a lot of weight, then the load will be more than if the vehicle is light or moving on level ground.

Because of the basic nature of an engine, its performance varies with speed and load. There is a maximum load that it can respond to at each speed, and it operates with a certain efficiency at each speed and load. The transmission allows the engine to change gears and try to optimize this performance at each speed and load. Therefore, as the driver works the accelerator and brakes, the engine is operating at various efficiencies. Most of the time, an engine operates at less than its maximum efficiency. Engine efficiencies are typically lowest at high loads and low speeds, i.e., starting from a full stop.

A hybrid reduces fuel consumption by allowing the engine to operate closer to its maximum efficiency. To do this, part of the load in a hybrid is provided by an electric motor. Motors are very efficient at most speeds and loads. They are also capable of providing high power at low speeds. This capability makes them well matched for the needs of a vehicle.

ELECTRIC MOTORS

In an electric motor, electricity flows in and causes the motor to turn. It transforms electric energy into mechanical energy. Motors can also operate as generators where they transform mechanical energy into electric energy. An engine transforms the chemical energy in the fuel into mechanical energy.

Hybrids also reduce fuel consumption by allowing the engine to be smaller. Since the electric motor is now providing some of the required load, the engine does not need to provide as much power. Engine power increases with size, but engine efficiency typically decreases as the engine gets larger. In a hybrid, the engine is smaller and is operated more efficiently than that of a comparable conventional vehicle.

A hybrid vehicle therefore contains all the parts and pieces of a conventional vehicle. It also has an electric motor, batteries and some additional electronics to coordinate between the motor and engine. The transmission in a hybrid can also be different than that of a conventional vehicle. Some of the details of the technology are explained in the following sections.

Parallel and Series

Hybrid vehicles have two common configurations: parallel and series. In the parallel configuration, the engine and/or the motor can provide power to the transmission at the same time. Electronic controls adjust the balance of power delivery based upon maximum efficiency and battery energy level. Commercial passenger cars available today are considered parallel hybrids.

In a series hybrid, only the electric motor actually drives the wheels. The engine turns a small generator that creates electricity that recharges the batteries. Again, electronic controls adjust the engine load as required to optimize efficiency and minimize emissions.

Charging the Batteries

The figures above show electrical energy moving to and from the batteries. In a series configuration, the engine powers a small generator that provides most of the energy to the batteries. In a parallel configuration, the drive motor sometimes acts as a generator. The electronic controls allow some of the engine power to flow to the generator and charge the batteries this way. The controls constantly monitor the status of the batteries and adjust the engine operation to keep the batteries charged.

Hybrids can also charge the batteries through regenerative braking. In a conventional vehicle, when the driver presses the brake pedal, the brake pads are pushed against metal surfaces attached to the wheels. These metal surfaces and the pads themselves get very hot since some of the energy of the moving vehicle has now flowed into those pads. This heat then flows out into the ambient air. Essentially, all that braking energy is wasted.

When the driver of a hybrid presses the brake pedal, some of the energy actually flows back into the batteries. Mechanical energy from the transmission flows into the motor (which is now behaving as a generator) and is transformed into electrical energy that enters the batteries. Since generators are hard to turn, this creates a load on the transmission that slows the wheels of the vehicle. Hybrids also have conventional brakes with pads and metal surfaces as well. The electronic controls adjust how much energy is returned to the batteries through regenerative braking.

Hybrids can also be designed such that the vehicle receives some energy from the electric grid. This is known as a plug-in hybrid. Plug-in hybrids have slightly different control software than regular hybrids, a few more batteries, and some method for plugging in to a charging station. The typical practice is to plug in the vehicle when it is parked overnight and electricity is inexpensive. This reduces the fuel consumption even further and drastically improves the fuel economy. Owners of the Toyota Prius can now purchase an aftermarket kit that allows them to convert their standard hybrid into a plug-in.

The control software of a regular hybrid keeps the batteries as fully charged as possible during driving. This type of battery management is known as charge sustaining. Plug-in hybrids can be operated differently. They can operate in charge depleting mode and drain the batteries to perhaps 20 percent capacity. This allows for more of the plug-in hybrid's energy to come from the batteries.

A hybrid vehicle contains all the parts and pieces of a conventional vehicle. It also has an electric motor, batteries and some additional electronics to coordinate between the motor and engine.

Both standard and plug-in hybrids may operate as all-electric vehicles for some distance, and they can be categorized by this all-electric distance. For example, a hybrid electric vehicle (HEV) with an all-electric range of 10 miles is known as an HEV-10. A hybrid with a 30 mile all-electric range (an HEV-30) would have more electric energy storage capacity.

This section has explained some of the details of hybrid technology. This explanation shows how a hybrid reduces fuel consumption and at the same time reduces emissions. Hybrids are proven technology in the passenger car and transit bus markets. But would a hybrid school bus have the same benefits and does the technology make economic sense to pursue? Both of these questions are answered in the following sections.

TECHNICAL FEASIBILITY

As part of the Hybrid Electric School Bus Project (HESB), Advanced Energy and its project collaborators evaluated the technical feasibility of the concept. Using standard auto industry software and design considerations from school transportation directors and school bus manufacturers, we considered multiple design options and driving scenarios. The details about this effort are given in a separate report (HESB Preliminary Technical Feasibility Report) and a summary follows.

Baseline Modeling

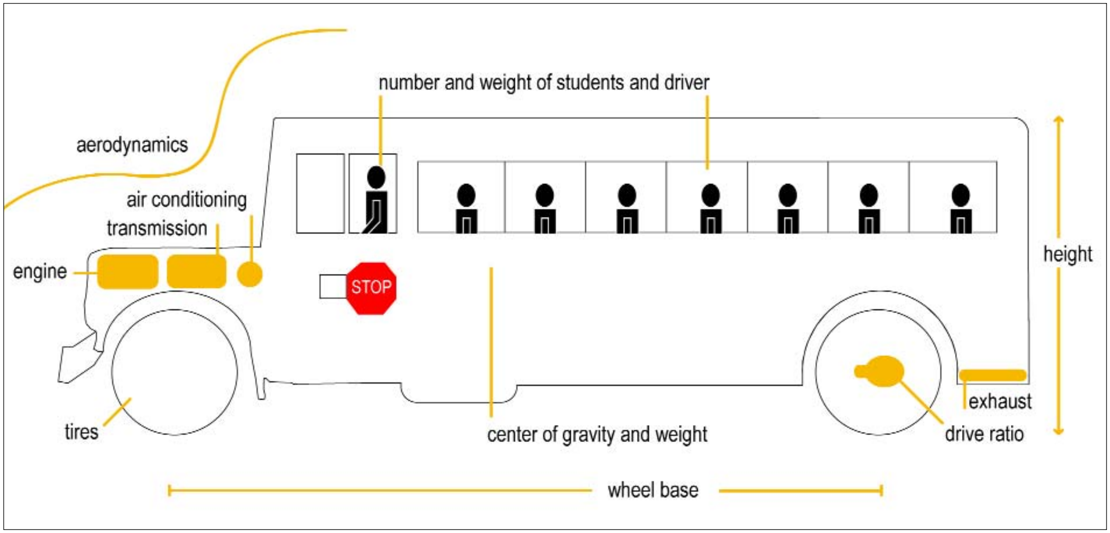
The Technical Feasibility used a computer program to predict the performance of hybrid school buses. This software is known as ADVISOR and was developed by the National Renewable Energy Laboratory. Most major manufacturers use this program to simulate hybrid and other advanced vehicle drive systems.

A key input to the program is the drive cycle. This represents the acceleration requirements, hill profiles and top speeds that a vehicle may experience during a typical trip. For example, the Federal Urban Driving Schedule (FUDS) shows the typical start and stop driving experienced in urban driving conditions. The government standardized this drive cycle so that auto manufacturers would have a common standard when developing fuel economy values. Likewise, there are drive cycles for highway driving, suburban heavy vehicles and European standards. As part of this project, the Institute for Transportation Research and the Environment headquartered at North Carolina State University is developing a drive cycle specifically for school buses. However, the most appropriate drive cycle available at the time of the Technical Feasibility Report is called the West Virginia Suburban Cycle, so named because it was developed by West Virginia University.

Before modeling hybrid school buses, it was necessary to establish a baseline for comparison. Prior to this project, school buses had not been simulated in ADVISOR. Therefore, using input from district transportation directors and the school bus manufacturers, Advanced Energy developed a baseline model. The first assumption was the type of school bus. There are several types of buses that range from the small, short buses to larger, transit-style buses. The most common school bus is a Type C and has the engine in front and the pupil entrance door behind the front wheels.

Each of these parameters requires a numerical input. Advanced Energy used either industry available data or values from industry experts. The software then uses these inputs to simulate the performance of the vehicle over the specified drive cycle. The performance depends on the forces that apply to the vehicle like air resistance and gravity. It also depends on the engine and transmission efficiency. The emissions depend on the engine efficiency and the fuel consumed over the drive cycle.

ADVISOR predicts fuel economy, emissions, vehicle accelerations and other parameters that can be used to refine the vehicle drive system. For the baseline model, the simulated school bus performance was compared to actual school bus performance determined by school transportation directors upon receipt of a new vehicle. The predicted performance was well within range of the values expected for



Inputs to the technical model

an actual school bus. This verified the accuracy of the baseline model and proved that ADVISOR could accurately model conventional diesel powered school buses.

Hybrid Modeling

As explained above, there are series and parallel hybrid drive configurations and there are standard and plug-in hybrids. One of the benefits of simulation software is the ability to try different scenarios. Therefore, Advanced Energy simulated a wide variety of drive systems and components for the hybrid school bus. Several parameters established during the baseline modeling were held constant for the hybrid modeling. These included the bus type, drive cycle and accessory load (e.g., air conditioning).

Component choices for the hybrid drive systems include motor size, engine size, battery type and transmission type. The selection of these components determines the vehicle weight. The simulated performance of each configuration was verified to meet the minimum requirements of the school bus specifications.

The results of this modeling showed that both series and parallel hybrid drive systems would significantly improve fuel economy and emissions over the baseline school bus. This study also demonstrated that plug-in hybrid school buses would have improved performance over standard hybrids. The figures below show the increase in fuel economy and the reduction in emissions for some of the modeled configurations.

Therefore, the Technical Feasibility Study demonstrated that plug-in hybrid school buses have substantial fuel economy and emission benefits when compared to conventional diesel school buses. But just because a technology will perform does not mean that it is cost effective. This need to demonstrate economic viability led to the Business Feasibility Study.

BUSINESS FEASIBILITY

The Business Feasibility Study addressed the economics of hybrid school buses from the perspective of a school district. It evaluated the impact of initial cost, fuel economy, emissions value and operating costs on the lifecycle cost of the vehicle. It also required inputs derived from

WHAT IS DISCOUNTING

If you invested money earning a certain interest rate today, the value of that money at a future time can be calculated. Likewise, you can work backwards from a future expense or investment using a certain interest rate and determine what amount you would need today to equal that future amount. Calculating the present value of future amounts is called discounting.

the Technical Feasibility Study like fuel economy and battery type. It compared lifecycle costs for a conventional, standard hybrid and plug-in hybrid school bus.

The lifecycle cost of a project represents the present value of all the costs and benefits associated with purchasing, operating and maintaining an investment over the life of the investment. For this study, the benefits include the value of avoided emissions. Future costs are discounted to their present value equivalent using the investor's Minimum Acceptable Rate of Return (MARR) as the discount rate. This methodology accounts for the time value of money.

The Business Feasibility Study did not attempt to accurately calculate all the costs associated with operating and maintaining a school bus. Rather, the calculations focused on those costs that would be different between the baseline bus and the hybrid options. Identical costs were not included. For example, driver compensation will not be affected by the choice of drivetrain. Primarily, these unconsidered costs fall under maintenance. For example, every school bus will require seat repair, new tires, repairs to the air conditioner, steering adjustments, and new exterior paint. However, these costs will be same regardless of the drivetrain. Costs in this category were not included in the analysis. Therefore, the lifecycle maintenance cost only included areas where there would be a cost differential between the options.

The total lifecycle cost for a school bus includes several categories: initial cost, infrastructure, fuel and maintenance. The Business Feasibility Study also assigned a "cost" to the pollutants emitted by the bus. That report was accompanied by a spreadsheet that tabulated the costs for each of these areas and applied the appropriate discounting. Some of the details of the spreadsheet are presented in the following sections.

Model Development

The Business Feasibility Study relied on calculations to estimate the total lifecycle cost of the various options. However, this model was a Microsoft Excel workbook with several worksheets. Advanced Energy selected this format so that school districts could customize the analysis for their particular situation. But just like the Technical Feasibility Study, there is a baseline analysis which uses generic inputs obtained from school district personnel. Some of these inputs are in the table below.

The model evaluated three options: conventional, hybrid, and plug-in hybrid. All the options are assumed to be Type C, 65 passenger school buses. The conventional option is a standard, diesel-only school bus available for sale today. The hybrid and plug-in options had the configurations defined in the Technical Feasibility Study.

The initial cost of a school bus is simply the price paid by a school district. For a conventional diesel available today, this cost varies across the country and varies with the options selected by the particular district or state agency. For example, new buses in Florida have air conditioning, new

Business Model Variables

Input	Description	Baseline Value
Annual Mileage	Miles per year	12,000
Bus Lifetime	Years until the district replaces the vehicle	15
Today's Diesel Price	Fuel cost paid by the district	$1.70 per gallon
Real Discount Rate	Inflation-adjusted rate of return	3.0 percent

buses in New York have certain exhaust system requirements and new buses in Iowa have different requirements. Prices vary across the nation, but for Type C, 65 passenger buses, the average price is around $60,000 per bus.

The initial cost of a hybrid electric school bus is expected to be higher than that for a comparable conventional diesel school bus. Manufacturers must make a higher profit on the first few vehicles to recover some of their investment in the development process. Development costs include engineering, testing and factory changes.

Even though no hybrid school buses have been sold yet, Advanced Energy was able to develop cost estimates based on discussions with manufacturers and a review of the passenger and transit bus hybrid markets. The cost of an item decreases with economies of scale. The Business Feasibility Study includes an evaluation of the potential market for hybrid electric school buses and estimates the number of vehicles for particular segments of the school bus market. It uses an initial cost of $80,000 when the manufacturers produce the vehicles at relatively high volumes.

Infrastructure costs include any garages or refueling pumps required to operate and maintain the vehicle. For conventional diesel school buses, this cost is assumed to be zero since the maintenance garage and other support equipment has already been purchased. There are no new requirements for a conventional bus. Likewise for a hybrid bus, there are no new infrastructure requirements. Hybrids use diesel fuel just like conventional buses and require the same types of diagnostic equipment. There may be additional technician training required for a new hybrid buses but these costs are expected to be approximately the same as that of a conventional bus.

Plug-in hybrids, however, require a connection to the electrical grid. As mentioned above, this connection is more than just a wall outlet plug and would have some associated cost. The Business Feasibility Study includes this infrastructure cost since it represents a differential cost between the options.

Hybrid school buses are more fuel efficient than conventional school buses. Hybrids consume less fuel and have lower fuel costs than conventional vehicles. The difference in lifecycle

Hybrid buses are more fuel efficient than conventional school buses.

costs is based on total mileage and the fuel efficiency for each vehicle type. In the Business Feasibility Study, fuel costs for the plug-in hybrid also included the cost of electricity used to recharge the batteries. For the baseline case, the plug-in hybrid saved over $17,000 in fuel costs over the life of the bus when compared to the conventional option. This is possible because when combined with the efficiency of an electric motor, electricity is much less expensive as a transportation fuel than diesel. The plug-in option allows the bus to use a less expensive energy source as "fuel."

Since the Business Feasibility Study only addressed differential costs among the options, the maintenance areas addressed were related to oil changes, brake repairs, and transmission maintenance. The engines in hybrids are subject to lower average loads and overall reduced operating time due to the absence of idling. This extends the mileage between required oil changes. Also, regenerative braking reduces brake wear and could double brake life when compared to conventional vehicles. Hybrid vehicles also have reduced transmission wear. All these factors are considered in the Business Feasibility Study.

When all of these costs are added together, the Business Feasibility Study showed that plug-in hybrid electric school buses have a lower lifecycle cost than conventional diesel school buses.

Battery replacement is a maintenance issue specific to hybrids. Some battery types last longer than others but may be more expensive. The baseline model assumed that the hybrid batteries would require replacement only once during the life of the bus. The Business Feasibility Study contains references for the battery type and replacement costs.

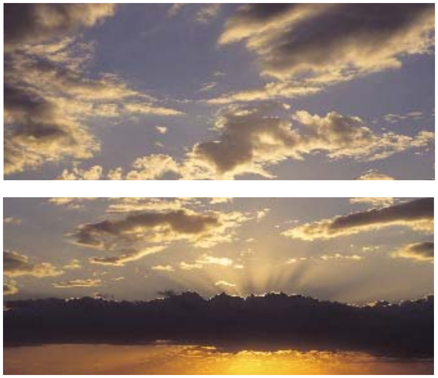
As explained previously in the description of the air quality challenges facing the transportation industry, air pollution has serious health and environmental consequences. Therefore, avoided air pollution emissions have value. The Environmental Protection Agency has estimated this value on a per ton basis for several pollutants including those considered in this project. The Technical Feasibility Study calculated the emission reductions possible from hybrid and plug-in hybrid buses. (Note that emissions from plug-ins included emissions from electric power plants.) The Business Feasibility Study then compared the cost of these emissions among the three options. As with other inputs to the business model, the value placed on a particular avoided emission may depend on circumstances specific to the district conducting the evaluation.

Results

When all of these costs are added together, the Business Feasibility Study showed that plug-in hybrid electric school buses have a lower lifecycle cost than conventional diesel school buses. Therefore, even with a higher initial cost, the lower fuel cost, maintenance cost and the value of avoided emissions make the plug-in option favorable. For the baseline case, the standard hybrid option has a higher lifecycle cost than the conventional option.

The Business Feasibility Study also evaluated several alternative cost scenarios to determine if certain costs influenced the results more than others. These evaluations showed that initial cost is important along with battery life and cost. And of course, if diesel prices continue to rise, then the hybrid options become a better investment and have even lower lifecycle costs than the conventional option.

For more information on the individual feasibility studies for this project, visit www.advancedenergy.org/hybridbus. ■



CONCLUSION

School district fleet managers are feeling the same pain as the rest of the transportation sector. Fuel prices are increasing. Government environmental regulations are requiring better pollution controls on their existing buses. Budgets are tight and parents want safe, clean transportation for their children in addition to more teachers and computers in the classrooms. To top it all off, petroleum prices will increase as inexpensive, conventional reserves are rapidly depleted by a growing world.

This report explained two of the challenges facing the transportation sector and elaborated on some of the possible solutions. Additional emission controls reduce impacts on air quality but do not reduce petroleum consumption. Alternative fuels improve air quality but have drawbacks including higher operating costs.

Hybrid electric school buses represent the optimal solution to address these challenges. Operating costs are lower, emissions are lower and fuel consumption is reduced. As documented in the Technical Feasibility Study and the Business Feasibility Study, these benefits are multiplied for a plug-in hybrid school bus.

The goal of this project is to change the school bus marketplace. Passenger vehicles and transit buses have hybrid options; school buses should too. To that end, Advanced Energy has organized a Buyers' Consortium of school districts and other bus purchasers. Members of this group have committed to buying a hybrid bus when it becomes available and are pursuing funding to cover the incremental cost above the price of a conventional diesel bus.

The Buyers' Consortium represents at least 20 new buses. This level of demand is enough to promote interest among the manufacturers. In the fall of 2005, the Buyers' Consortium will issue an Invitation to Bid on a plug-in hybrid school bus. After an initial evaluation, Advanced Energy will continue to promote the technology as costs come down. In a few years, the hope is that hybrid school buses will be as common as hybrid passenger cars. So the next time you see a big yellow bus, call your school board and ask them when they are getting a plug-in hybrid. ■

ACKNOWLEDGMENTS

The Hybrid Electric School Bus Project is a team effort and would not be possible without participation of the Advisory Group and the Buyers' Consortium. The Advisory Group is composed of school bus manufacturers, funding agencies and school districts. The Buyers' Consortium is a select group of school districts that have agreed to pursue funding for this project and purchase a bus. The school districts have created the demand, and the manufacturers have responded.

Funding for this project comes from the U.S. Department of Energy, the N.C. State Energy Office, Duke Power, Progress Energy and Advanced Energy.

This project represents a unique coordination among all parties to improve the air quality for our nation.

ADVANCED ENERGY

As a collaborator and partner, Advanced Energy looks for ways to engage various stakeholders that can work with us to stimulate markets with innovative technologies and projects that have positive benefits to the communities in which we work.

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Advanced Energy
909 Capability Drive, Suite 2100
Raleigh, NC 27606-3870
919-857-9000
www.advancedenergy.org

THE HYBRID ELECTRIC SCHOOL BUS PROJECT

Nationwide, school buses consume 1.1 billion gallons of diesel fuel every year. Like the rest of the transportation sector, school bus fleets are facing the same challenges of higher fuel costs and more stringent emission limits. One solution to the challenges of the transportation industry is the hybrid vehicle.

Manufacturers have not seen a demand for hybrid school buses that would encourage them to offer this option. With assistance from the N.C. State Energy Office, Advanced Energy is organizing multiple school districts across the country to create this demand.

This report summarizes earlier studies that demonstrate the technical and economic feasibility of hybrid school buses, addresses the specific challenges that face the transportation industry as a whole and shows why hybrids are an excellent solution. Visit www.advancedenergy.org/hybridbus for more information about the project.

Advanced Energy
ENERGY

Advanced Energy
909 Capability Drive, Suite 2100
Raleigh, NC 27606-3870
919-857-9000
www.advancedenergy.org

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