Environmental Impact

A school transportation fleet does not exist in a closed system. There are neighborhoods and parks through which the buses travel every day. What impact do those buses have on the environment of the communities they serve? Using biodiesel reduces air pollution across the entire fleet. Clean air is an important component of a healthy environment in every community.

Biodiesel is the only alternative fuel to have a complete evaluation of emissions submitted to the Environmental Protection Agency, which has released test results as shown in the table below.

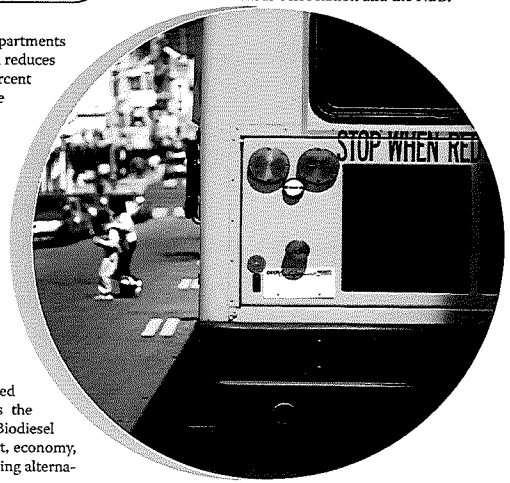
Average Biodiesel Emissions Compared to Petroleum Diesel

Emission Type	B100	B20
Total Unburned Hydrocarbons	67% reduction	20% reduction
Carbon Monoxide	48% reduction	12% reduction
Life Cycle Carbon Dioxide	78% reduction	16% reduction
Particulate Matter	47% reduction	12% reduction
Nitrous Oxides	10% increase	-2% decrease 2% increase

In addition, a 1998 study sponsored by the U.S. Departments of Energy and Agriculture concluded that biodiesel reduces life cycle carbon dioxide (CO_2) emissions by 78 percent compared to diesel. Carbon dioxide is a greenhouse gas associated with global climate change.

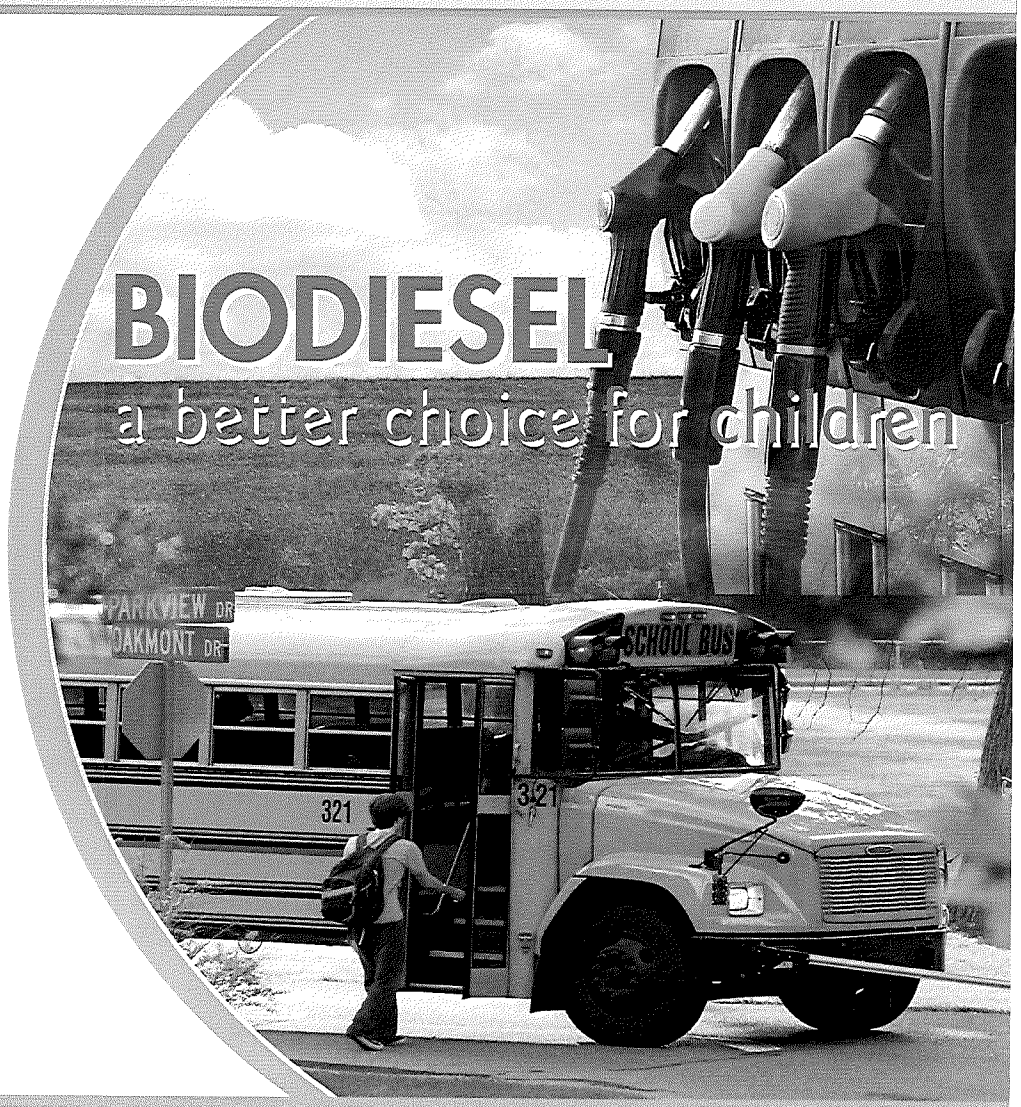
Biodiesel is an excellent choice for schools concerned about the energy balance of their decisions. Biodiesel is made from renewable resources, typically soybeans. Using oil from soybeans to make biodiesel generates more energy than producing the biodiesel itself. In other words, the energy output outweighs the energy input — for every unit of energy it takes to produce a gallon of biodiesel, over three units of energy are gained. Biodiesel can be made from any vegetable oil or animal fat and new feedstocks are being developed for plentiful biodiesel supply.

As school districts debate the many factors involved in transportation decisions, biodiesel emerges as the leading alternative choice to petroleum diesel. Biodiesel promotes positive changes in the health, equipment, economy, and environment of its users and is the fastest growing alternative fuel in the United States today.



All statistics and studies were retrieved from the Alternative Fuels Data Center, www.eere.energy.gov/afdc, the U.S. Environmental Protection Agency, www.epa.gov, the National Biodiesel Board, www.biodiesel.org, and LECG, Inc. For more information about biodiesel, go to those websites and to the Clean Cities web site at www1.eere.energy.gov/cleancities.

This document was supported in whole or in part, by a U.S. Department of Energy award (DE-FG-36-04 GO14240). This support does not constitute an endorsement by DOE of the views expressed in the article. Other partners include the Missouri School Boards' Association and the NBB.

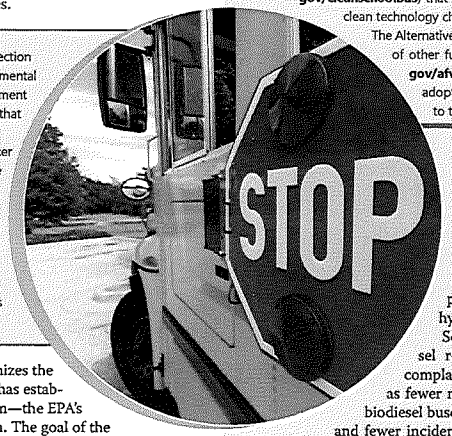


Keeping our Children Safe

Every weekday morning, 24 million children in the United States step into school buses to transport them from home to school. Every afternoon they go home the same way, spending on average an hour and a half each day on the bus. School buses drive more than four million miles per year and are the safest way for our children to get to school; but they could be safer.

Just under ninety percent of the 454,000 school buses on the road today use diesel, a fuel that produces more pollutants with health implications than its fast-growing alternative counterpart - biodiesel. Diesel exhaust contains particulate matter that poses a health risk including contributing to asthma and bronchitis. Children are more susceptible to air pollution than healthy adults because their respiratory systems are still developing and they have faster respiration rates.

In 2002, the U.S. Environmental Protection Agency's National Center for Environmental Assessment released a Health Assessment Document for Diesel Engine Exhaust that concludes that long-term inhalation exposure is likely to pose a lung cancer hazard to humans, as well as damage the lungs in other ways depending on exposure. Short-term exposure can cause irritation and inflammatory symptoms of a transient nature. The assessment also indicates that evidence for exacerbation of existing allergies and asthma symptoms is emerging. EPA/600/8-90/057F, 2002.



The Federal government recognizes the risks of diesel fuel exhaust and has established a program to reduce them—the EPA's Clean School Bus USA program. The goal of the program is to reduce both children's exposure to diesel exhaust and the amount of air pollution created by diesel school buses. The current administration has proposed major expansion of the Clean School Bus USA program to help school districts reduce children's exposure to diesel exhaust. Some school districts have used this program to offset any additional costs to use biodiesel.

The Clean School Bus USA program is designed to bring together partners from business, education, transportation and public health organizations to work toward the following goals:

- Encouraging policies and practices to eliminate unnecessary public school bus idling
- Upgrading (retrofitting) buses that will remain in the fleets with better emission control technologies and/or fueling them with cleaner fuels.
- Replacing the oldest buses in the fleets with new, less polluting buses.

Biodiesel as a Solution

One of the easiest and best options for school districts to implement to protect student health is to switch to biodiesel, a cleaner transportation fuel made from renewable resources. It is recognized by EPA as one of the Clean Fuel/Clean Technology options under the Clean School Bus program. It can be used in existing equipment and stored in existing facilities without modification, in any blend from one to 20 percent. In some applications and warm climates, even higher blends may be used year-round. Because of its benefits, many school districts across the nation have decided to use biodiesel for their transportation needs.

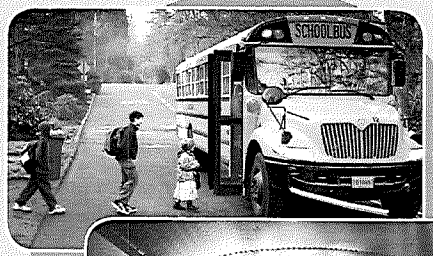
FUNDING There are several funding opportunities to pay for biodiesel fuel. Consider the EPA Clean School Bus USA Program (**www.epa.gov/cleanschoolbus**) that financially supports schools making clean technology changes to their transportation fleets. The Alternative Fuels Data Center provides a listing of other funding opportunities at **www.afdc.gov/afv/funding/shtml.** Many states have adopted legislation to aid school districts to transition to biodiesel blends.

Health Benefits

Scientific research confirms that biodiesel exhaust contains significantly decreased levels of air toxins identified as potential cancer causing compounds, as well as reduced particulates and unburned hydrocarbons.

School districts that use biodiesel report a decrease in student complaints about headaches, as well as fewer missed school days. Drivers of biodiesel buses also report fewer headaches and fewer incidences of asthmatic attacks. The health of students and workers is a compelling reason for choosing biodiesel.

City of Hammond Schools, Hammond, Indiana
61 school buses, 3 diesel support vehicles
John Molnar, Transportation Director
"As a school transportation director, I am very concerned about health issues related to diesel fuel. I could easily relate to the health risk issues based on the carbon particulate deposits that surrounded our vehicles, work site and electronic equipment. In addition, my office receives many complaints from schools and employees about diesel fumes making people ill. I did a lot of reading and joined our local Clean Cities organization to help me determine how I could inexpensively reduce these risks. After looking at the many alternatives, I chose biodiesel (B20) for the following reasons:
1) There is no need to change our fueling infrastructure.
2) The soybean supply is local and plentiful.
3) Nothing needs to be done or changed for our vehicles.
4) The EPA has recognized biodiesel as an alternative fuel.
5) No additional training for our staff.
6) Our vehicles essentially became bi-fuel."



Economics of Biodiesel

The first question for many school districts is "What's the cost?" The answer is that biodiesel is a good option economically, because it is not necessary to invest in costly new vehicles or retrofit current vehicles. Any fleet can immediately become an alternative fuel fleet.

The most important consideration is the cost of the fuel itself. Biodiesel blends may cost a few more cents a gallon for the common blend of B20 (20 percent biodiesel/80 percent diesel). Due to federal fuel blenders tax incentive, the cost to the end user has become more competitive with diesel prices in recent years. Many school districts have reported, however, that decreased maintenance costs have offset any price differential.

Medford, New Jersey School District
61 school buses, 3 large vehicles and numerous small diesel engine vehicles
Joe Biluck, Director of Operations and Technology
The school district has been using biodiesel for more than 10 years.
"Biodiesel offers the best option to increase our reliance on domestic, renewable fuels while producing significant results in terms of emission reduction," said Biluck. "Biodiesel's primary attraction is its ease of integration coupled with the fact it is a technology that is not capital intensive and can be applied to older units as well as today's vehicles."

There are other cost benefits to consider besides fuel costs. Consider, for example, the cost to the nation of acquiring and processing fuel. Currently, the United States imports more than half of the petroleum we consume. If the dollars we currently send overseas were spent on domestic fuel, the U.S. economy would be strengthened. A recent study shows that $13.6 billion will be kept in the U.S. - as opposed to spending on foreign oil - with the predicted growth of biodiesel by 2015. Using biodiesel also supports American farmers, since the major biodiesel feedstock is soybeans, with other oilseeds crops also serving as feedstocks. And using biodiesel promotes U.S. energy security.

Equipment Impacts/ Ease of Use

Another consideration is the impact that switching to biodiesel has on the equipment of current fleets. Biodiesel has a proven track record. In terms of horsepower, fuel economy, and torque, biodiesel is equivalent to diesel. Biodiesel increases the lubricity of the fuel, which can lead to longer engine life, lower maintenance costs, less equipment downtime, and protection against fuel injector failure. Biodiesel exceeds diesel in cetane number, resulting in superior ignition. Biodiesel is nontoxic, biodegradable, and has a higher flash point than diesel, making it more versatile where safety is concerned.

Biodiesel has superior detergent characteristics; using biodiesel can initially reduce particulate, gum and varnish buildup in engine parts, leading to clogged filters. Cleaning or replacing filters regularly upon switching to biodiesel eliminates any potential problems. Continuing to use biodiesel keeps fuel lines clear.

Biodiesel works well, even in cold climates. Similar antifreeze precautions need to be taken as those with diesel. See www.biodiesel.org/cold for information on precautions and handling in cold weather, as well as, testimonies from year round users of B20 on cold weather.

For districts that have already begun to make changes to their fleets, biodiesel can be used with ultra-low sulfur diesel, particulate traps, catalytic converters, and in diesel hybrid vehicles. ULSD fuel is now required, and biodiesel adds lubricity - even in as little as a 2 percent blend (B2), which is lost in switching to ULSD fuel.

Another advantage is that no additional parts are needed when biodiesel is used. Fleets can keep their spare part inventories, current vehicles, and fueling infrastructures.

Quality fuel should be top priority. Biodiesel should meet ASTM D 6751 before fuel distributors blend it with diesel. For more information, visit www.biodiesel.org/resources/fuelquality-guide. Also, visit BQ-9000.org to find biodiesel producer and supplier companies who adhere to the strictest quality standards.

BIODIESEL EMISSIONS

Biodiesel is the first and only alternative fuel to have a complete evaluation of emission results and potential health effects submitted to the U.S. Environmental Protection Agency (EPA) under the Clean Air Act Section 211(b). These programs include the most stringent emissions testing protocols ever required by EPA for certification of fuels or fuel additives. The data gathered complete the most thorough inventory of the environmental and human health effects attributes that current technology will allow.

EPA has surveyed the large body of biodiesel emissions studies and averaged the Health Effects testing results with other major studies. The results are seen in the table below. To view EPA's report titled "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions" visit: www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf.

AVERAGE BIODIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL, ACCORDING TO EPA

Emission Type	B100	B20
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
Nox	+10%	+2% to -2%
Non-Regulated		
Sulfates	-100%	-20%*
PAH (Polycyclic Aromatic Hydrocarbons)**	-80%	-13%
nPAH (nitrated PAH's)**	-90%	-50%***
Ozone potential of speciated HC	-50%	-10%

*** Estimated from B100 result**
**** Average reduction across all compounds measured**
***** 2-nitroflourine results were within test method variability**

(more)

The ozone (smog) forming potential of biodiesel hydrocarbons is less than diesel fuel. The ozone forming potential of the speciated hydrocarbon emissions is 50 percent less than that measured for diesel fuel.

Sulfur emissions are essentially eliminated with pure biodiesel. The exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to diesel.

Criteria pollutants are reduced with biodiesel use. Tests show the use of biodiesel in diesel engines results in substantial reductions of unburned hydrocarbons, carbon monoxide, and particulate matter. Emissions of nitrogen oxides stay the same or are slightly increased.

Carbon Monoxide -- The exhaust emissions of carbon monoxide (a poisonous gas) from biodiesel are on average 48 percent lower than carbon monoxide emissions from diesel.

Particulate Matter -- Breathing particulate has been shown to be a human health hazard. The exhaust emissions of particulate matter from biodiesel are about 47 percent lower than overall particulate matter emissions from diesel.

Hydrocarbons -- The exhaust emissions of total hydrocarbons (a contributing factor in the localized formation of smog and ozone) are on average 67 percent lower for biodiesel than diesel fuel.

Nitrogen Oxides -- NOx emissions from biodiesel increase or decrease depending on the engine family and testing procedures. NOx emissions (a contributing factor in the localized formation of smog and ozone) from pure (100%) biodiesel increase on average by 10 percent. However, biodiesel's lack of sulfur allows the use of NOx control technologies that cannot be used with conventional diesel. Additionally, some companies have successfully developed additives to reduce Nox emissions in biodiesel blends.

Biodiesel reduces the health risks associated with petroleum diesel. Biodiesel emissions show decreased levels of polycyclic aromatic hydrocarbons (PAH) and nitrated polycyclic aromatic hydrocarbons (nPAH), which have been identified as potential cancer causing compounds. In Health Effects testing, PAH compounds were reduced by 75 to 85 percent, with the exception of benzo(a)anthracene, which was reduced by roughly 50 percent. Targeted nPAH compounds were also reduced dramatically with biodiesel, with 2-nitrofluorene and 1-nitropyrene reduced by 90 percent, and the rest of the nPAH compounds reduced to only trace levels.

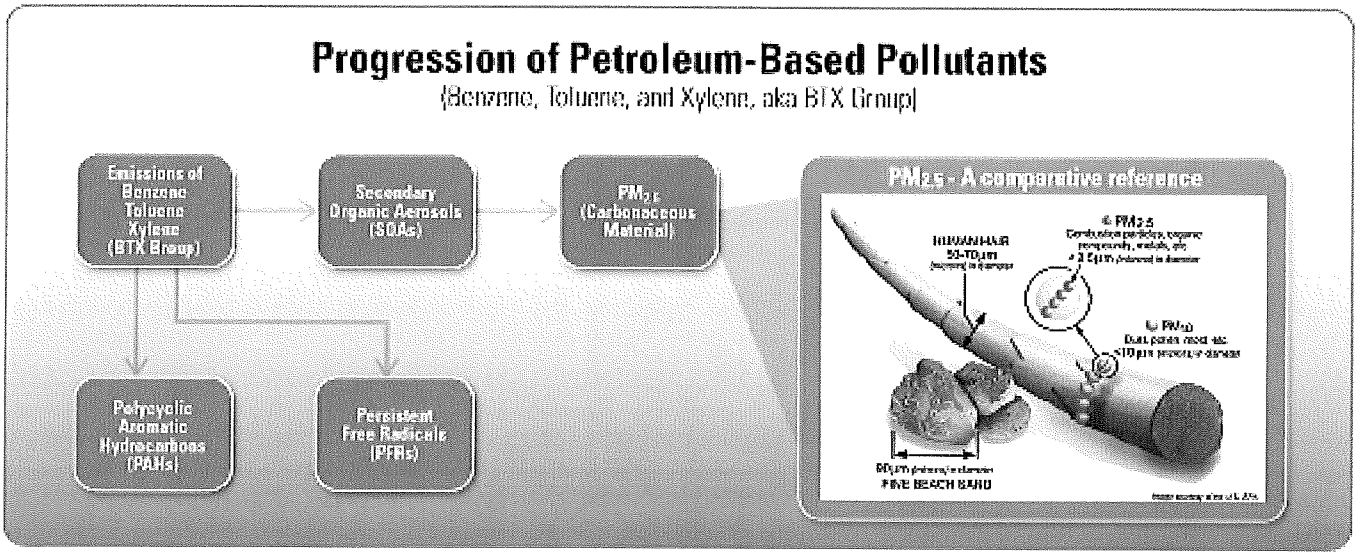
URBAN AIR INITIATIVE

How Healthy Is Your Air?

Do you or does someone you love live in or near a city? Do you commute to work or run errands in traffic? Then you should know about a growing body of research showing that automobile exhaust is far more dangerous than most people realize. What's more, it doesn't have to be that way.

Toxic compounds that are used to boost octane in gasoline are getting into our air and are being linked to serious health problems ranging from asthma to cancer, as well as heart disease and neurological disorders.

These toxic aromatic compounds include benzene, toluene and xylene (known as the BTX group), among others. One of the biggest concerns with these compounds is the ultra-fine particulate matter they produce through tailpipe emissions. Many times smaller than the width of a human hair, ultra-fine particulates (UFPs) persist in the air longer and are much smaller than PM2.5, the regulatory standard of air quality measurement. UFPs can penetrate deeper into the lungs, which can allow toxic compounds to go directly into the bloodstream. The illustration below demonstrates how much smaller UFPs are than dust or pollen. UFPs are one of the most dangerous and harmful pollutants that come from motor vehicle emissions.



Benzene, toluene, and xylene react and combine with other elements in the atmosphere to create harmful pollutants.

Q: How significant are the health risks from particle pollution in transportation exhaust?

A: In testimony given by EPA Administrator Lisa Jackson in August 2010, she said, "Particle pollution is linked to a wide variety of serious health effects and premature deaths in people with heart and lung disease. Americans throughout the country are suffering from the effects of pollution in our air, especially children, who are more vulnerable to these chemicals."

Q: Are toxic aromatic emissions considered a link to cancer?

A: According to the Northeast States for Coordinated Air Use Management (NESCAUM), "50 percent of cancer risk and 74 percent of non-cancer risk related to breathing outdoor air results from mobile source air toxic emissions."

Q: How much toxic aromatic air pollution comes from transportation fuels today?

A: EPA estimates that 85 percent of aromatic benzene in the air we breathe comes from motor vehicle exhaust. Recent EPA calculations show eliminating just 0.15 percent of particulates derived from aromatics is worth $15 billion in health-related benefits that millions of people living near urban air sheds can enjoy. Today's gasoline contains on average 25 percent toxic aromatic compounds, with one of the predominant components being toluene (methylbenzene).

Q: How did toxic aromatics get into gasoline?

A: One of the greatest successes of 1970's original Clean Air Act was mandating the removal of lead from gasoline. However, the phasing out of lead resulted in a new problem of how to boost octane and prevent engine knock. Unfortunately, the petroleum industry responded by dramatically increasing the volume of toxic aromatics in gasoline. Though benzene, toluene and xylene were known health hazards, at the time they were still considered safer than lead.

Q: Will replacing toxic aromatic compounds increase the price of gasoline?

A: Not necessarily. Because aromatic compounds are derived from crude oil, aromatics increase the price of gasoline due to higher refining expenses. Also, producing these compounds during the refining process actually reduces the total yield from each barrel of oil. Renewable octane-boosting alternatives such as ethanol can provide a lower cost per gallon while displacing aromatics.

Source: U.S. Department of Energy, National Renewable Energy Laboratory

Q: Why should EPA act to replace toxic aromatics in gasoline?

A: The health benefits of reducing air toxics involve ethical, environmental and economic issues. The EPA estimates that reducing air toxics as required by the Clean Air Act will save nearly 230,000 people from early death by the year 2020 and save nearly $2 trillion in health-related expenses. The EPA conclusion, in its report Mobile Source Air Toxics Emission Reduction, was verified by the Council of Clean Air Compliance Analysis, an independent panel of distinguished economists, scientists and health experts.

Q: Does Congress have to approve the replacement of toxic aromatics with healthier options?

A: No. Congress has already acted by voting overwhelmingly for clean octane provisions in the Clean Air Act Amendments of 1990. The Clean Air Act clearly gives EPA the statutory authority and obligation to reduce aromatic pollutants in motor vehicle exhaust. The EPA recognizes that simply enforcing the existing Clean Air Act can significantly improve human health, but the EPA still needs to take action.

Q: What health effects research is happening now?

A: The Urban Air Initiative is leading a range of research efforts looking at emissions, health effects, costs and a number of other issues to reduce aromatics and add ethanol into the fuel supply. Now is the time to act, and we are doing something about it!

Q: Where can I learn more about air toxics?

World Health Organization (WHO), Air Quality and Health
http://www.who.int/mediacentre/factsheets/fs313/en/

Mobile Source Air Toxics
http://www.epa.gov/oms/toxics.htm

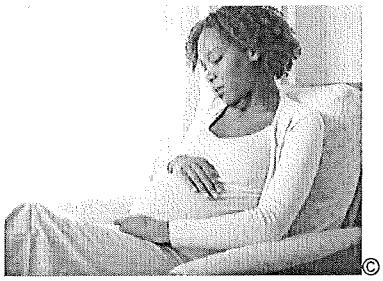
Centers for Disease Control and Prevention
www.cdc.gov/ephtracking

Helping Asthmatic Children
http://pediatrics.aappublications.org/content/123/3/1051.abstract

The Hidden Toll of Auto Exhaust
http://online.wsj.com/article/SB10001424052970203733504577024000381790904.html?grcc=88888Z0&mod=WSJ_hpp_sections_health

Breathing smog in pregnancy linked to child's behavior problems

Updated: Mar 23, 2012 9:40 AM CDT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By Kathleen Doheny
HealthDay Reporter

THURSDAY, March 22 (HealthDay News) -- Women exposed to higher levels of certain air pollutants while pregnant are more likely to have children with anxiety, depression and attention problems by ages 6 and 7, new research suggests.

"This study provides new evidence that prenatal exposure to air pollution at levels encountered in New York City can adversely affect child behavior," said Frederica Perera, a professor of environmental health sciences and director of the Columbia Center for Children's Environmental Health at the Columbia University Mailman School of Public Health.

She led the new study, published online March 22 in *Environmental Health Perspectives*.

The researchers looked at pollutants known as polycyclic aromatic hydrocarbons (PAH). They are created by the burning of fossil fuels and are common in urban environments. Traffic emissions are a major source of these pollutants.

The study is believed to be the first to link behavior problems in school-age children with two measures of prenatal PAH exposure: air concentrations and a PAH-specific marker found in mothers' blood samples and umbilical cord blood. The PAH, inhaled by the mom during pregnancy, can cross the placenta, experts know.

Perera's team followed the children of 253 inner-city women who gave birth between 1999 and 2006. None of the mothers smoked.

The researchers measured the concentrations of PAH in the environment of the mothers for 48 hours during trimester two or three. They also took blood samples from the mothers and the umbilical cords.

In addition, the women answered questions about their children's behavior, including describing any attention problems, anxiety or depression. The attention problems would not qualify as attention-deficit/hyperactivity disorder, Perera noted.

The investigators found a link between higher PAH exposure levels and behavior problems. "Symptoms of anxiety and depression were 45 percent higher in the higher exposure group versus the lower," Perera said. Attention problems were 28 percent greater in the higher PAH exposure group.

When the researchers took into account other sources of pollutants such as tobacco smoke and diet, the link remained. However, although the study found an association between prenatal PAH exposure and childhood behavior problems, it did not prove a cause-and-effect relationship.

The level of problems were those that could result in referral to a doctor for further evaluation, Perera noted.

Several mechanisms could explain the link, she said. Oxidative stress is one. Or, the chemicals may be "endocrine disrupters, which are capable of affecting the normal signaling that occurs in early brain development."

Perera plans to follow the children until they are age 12.

"The study by itself is not convincing to me," said Dr. Victor Klein, an obstetrician-gynecologist who specializes in high-risk pregnancies and is director of patient safety and risk reduction at North Shore-LIJ Health System in Great Neck, N.Y. He reviewed the study and said that "further research has to be done."

Meanwhile, Klein said, it's "common sense" to try to keep your environment as pollution-free as possible, especially when pregnant. However, that can be easier said than done. He tells women to exercise, watch their diet and get good prenatal care.

Another expert, Dr. Andrew Adesman, chief of developmental and behavioral pediatrics at the Steven & Alexandra Cohen Children's Medical Center of New York in New Hyde Park, wondered if the study would apply to pregnant women living outside New York City. "On one hand, I don't think people will be surprised that pollution poses a potential risk," he said. "What is striking here is they have been able to document and quantify it."

The broader message, Adesman said, is the need for society to clean up the air and to reduce our dependence on fossil fuels.

Perera said that to reduce exposure to pollutants, pregnant women should not smoke and should ask others not to smoke in their homes and offices. When cooking, she said, ventilate with a fan. Avoid other toxic chemicals such as pesticides. And, in addition, eat a healthy diet full of antioxidant-rich foods such as fruits and vegetables, she advised.

More information

To learn more about staying healthy during pregnancy, visit womenshealth.gov from the U.S. Department of Health and Human Services.

URBAN AIR INITIATIVE INC.

CFDC CLEAN FUELS DEVELOPMENT COALITION

A Clean High Octane Choice

E30 98 RON

Multiple engineering studies are calling for future fuel properties to meet the challenges of new vehicle technology and emissions regulations. As we identify the fuel properties that would provide solutions to these challenges, we must also keep the cost to consumers in mind. Successful solutions must have market potential, credible supporting data, and the support of regulators and industry. The purpose of this paper is to present a viable plan for providing a high performance, low-emissions fuel for tomorrow's vehicles that also provides the health benefits of lower emissions for today's vehicles.

What About Tomorrow's Vehicles?

Tomorrow's vehicles will have to meet historically high fuel efficiency and emissions standards. Meeting these standards will naturally bring about advancements in vehicle and engine design. It seems logical that development of future fuels needs to be done simultaneously with engine development. The auto industry needs to know what the octane and emissions profile of future consumer fuels will be so they can design engines that work with those fuels to meet the required mileage/carbon dioxide (CO2) per mile and emissions reductions. To design the high-performance engines that will work with future low-emissions consumer fuels, the auto industry needs a corresponding certification fuel today, when they are designing tomorrow's engines. It would, obviously, be difficult to optimize an engine to run on a clean, high-octane consumer fuel if there wasn't a corresponding certification fuel and vice versa.

What Do Tomorrow's Fuels Need to Look Like?

Tomorrow's fuels need to

- have consistent fuel properties that automakers can rely on to help their more-finely-tuned engines meet efficiency and emissions requirements.
- have high octane values for the higher compression ratios that new engines need to meet fuel efficiency (CO2 per mile) regulations.
- produce cleaner emissions to meet regulatory requirements and reduce health risks.
- be as inexpensive to the consumer as possible.

Where Do We Start?

We start with a good base fuel. With regulations getting tighter, the base fuel E10 needs to be consistent so the

automakers and the fuel suppliers will know what they are starting with. The base fuel needs to meet a set of measurable criteria. The formulas, indices, and test methods used to measure those criteria need to be applicable to current technology and produce usable performance-related data. The base fuel needs to be optimized to burn as efficiently and cleanly as possible to increase efficiency and decrease emissions in as many of today's and tomorrow's vehicles as possible and to maximize the benefits of adding ethanol.

One of the reasons that setting measurable criteria for today's base fuels is important is that most gasoline by itself, before the ethanol is added, doesn't have enough octane to be sold to consumers, and the fuel properties of the gasoline by itself can vary substantially. Thus, while the E10 fuels that go to the consumer have the octane and other emission values of ethanol, their contribution to efficiency and emission levels may fluctuate. With tighter efficiency and emissions regulations and more finely-tuned engines, less variability in the base fuels would logically provide a more ideal response.

Can We Really Get High Octane AND Low Emissions?

There is no question that "efficiency enhancements (to engines) such as higher compression ratios and forced induction (turbocharging) profit from more octane." (Road and Track) There is also more than one way to increase octane levels in gasoline; but many of the available octane boosters have a negative effect on emissions and emission-control equipment in vehicles. Ethanol, however, provides high octane levels while at the same time reducing overall emissions, especially some of the more toxic polycyclic aromatic hydrocarbons (PAHs).

An E30 blended fuel will give the auto industry a clean, high octane fuel to design to. An E30 blended fuel is backed by creditable data; mid-level ethanol blended fuels have already shown market potential; and there is growing consensus that this is a solution to efficiency and emissions regulations that could be supported by regulators, the auto industry, and the oil industry. The sections below demonstrate how a mid-level blended fuel like a E30 could be the most viable solution available to meeting the challenges of new vehicle technology and emissions regulations while also decreasing emissions in today's vehicles.

Will There Be Enough Ethanol For An E30 Fuel?

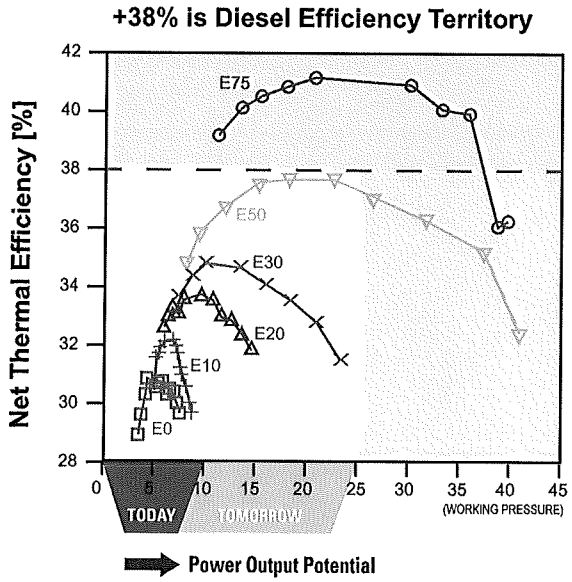
Before we look at the details of this potential solution, it is prudent to address a question that many people might ask: Will there be enough ethanol for an E30 fuel. The simple answer is yes. Future fuel sales for light-duty vehicles are not anticipated to increase significantly; and as new, more efficient vehicles continue to enter the market there could even be a slight reduction in fuel sales for these vehicles. The Renewable Fuels Standard (RFS) and the natural course of supply and demand in the market indicate that there will be sufficient ethanol to meet the ethanol demands for an E30 blended fuel. In addition, the influx of new vehicles into consumer's hands is relatively slow, especially when many consumers are keeping their cars longer, as they are now. Furthermore, just as today not all vehicles are designed for premium gasoline, not all vehicles would be designed for an E30 blended fuel. Many on-road vehicles, plus off-road vehicles and small engines, will still be designed to the E10 base fuel.

Engine Efficiency and Octane From Ethanol

The main challenge of new vehicle technology is improving engine efficiency. Octane is the fuel property that is essential for helping automakers increase engine efficiency. Ethanol has high octane levels and is widely used in fuels as an octane booster. Figure 1 shows the power output potential of engines using fuels with varying amounts of ethanol. The data is from tests that supported Society of Automotive Engineers (SAE) paper 2012-01-1277. It shows that efficiency is increased with increased ethanol. The primary reason for the increased efficiency is twofold. First, ethanol burns more efficiently than gasoline; and second, octane enables the engine to operate at higher loads which allows higher efficiency. Today, most non-turbocharged vehicles will not operate beyond a power output potential of 10, as

indicated in Figure 1. New high compression engines or engines equipped with turbocharging still don't operate much into the gray area on the right.

Figure 1



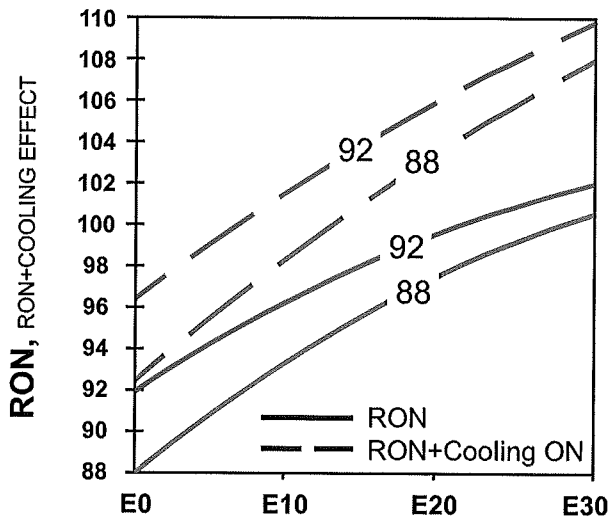
Efficiency Demonstrated per SAE 2012-01-1277

It can also be seen in Figure 1 that higher ethanol blends can perform in diesel-efficiency territory. However, it is hard to imagine that future engines could be economically built to be flexible enough to take advantage of both high and low blends of ethanol. Therefore, this data shows that an E30 blended fuel provides the most opportunity for higher power output potential at a blend level that is practical.

What About That Cooling Effect?

A new awareness is rising among engineers about performance versus measured benefits of ethanol in mid-level blended fuels like E30. The SAE 2012-01-1274 paper has shown that the measured octane (research octane number or RON) from E0 to E30 is significantly higher than the measured octane performance from E30 to E85. However, the current octance measurements, do not show the benefits of ethanol's cooling effect. In Figure 2, SAE 2012-01-1277 paper shows that an E30 fuel blended with today's regular, consumer fuels (88 RON) has a 100 RON octane value, and demonstrates the increased octane value of cooling effect. This results in an increased RON value for E30 to near 108. With the cooling effect applied, there is nothing in a gallon of gasoline that offers the same octane potential as ethanol.

Figure 2



Effective Octane with Cooling Effect per SAE 2012-01-1277

What's the Next Step Toward Improved Efficiency With Ethanol?

Based on the data shown here and other supporting data, Urban Air Initiative, Inc. is promoting the following solutions.

1. Maintain E10 as the base fuel but make blending improvements that benefit the vehicles on the road today, as well as off-road vehicles and small engines.

2. For on-road vehicles, all fuel blends above E10 are created by simply adding ethanol.

As stated in the introduction, fuel improvements need to be made simultaneously with advances in new engine and vehicle technology.

The message about the importance of octane and the sources of octane also needs to be communicated so that it is understood better, especially since its importance will increase with new vehicles.

Getting the Octane Message Out

Getting the octane message to consumers will take time and a concerted effort. It is also likely that more regulators and policy makers need to understand octane at a higher level. It may be true for older cars that higher octane values or using the designed-for octane isn't critical, but for newer vehicles with higher compression ratios, the negative impact of using a fuel with an octane value lower than the vehicle is designed for is important. In new high efficiency vehicles, not using the fuel with the correct octane level will have a measurable negative impact on the performance of the vehicle.

In older vehicles and many vehicles on the market today the source of octane is significant; consumers may not benefit on a cost-per–mile basis for higher octane if they are purchasing premium gasoline from the petroleum companies (which often contains octane from sources with a high aromatic content). Some new studies are showing, however, that in today's vehicles small additional amounts of ethanol may offer equal mileage with a lower cost per gallon. This means lower cost per mile for consumers. This also benefits the consumer by ensuring that the octane is from a known and low-emissions source.

Switching Gears: What About Emissions?

Today, regulated emissions like carbon monoxide (CO), volatile organic carbons (VOCs), and nitrous oxides (NOx) are tightly controlled with even stricter regulations anticipated in the near future. There is also growing concern about health risks from the aromatic hydrocarbons in emissions, especially polycyclic aromatic hydrocarbons (PAHs), some of which are not regulated. Urban Air Initiative was started to raise awareness about the health risks of PAH's. Multiple automotive studies are also raising similar concerns; and several are calling for cleaner fuels to be developed.

What is Particulate Matter?

Particulate matter is the particles that are emitted from a vehicle's tailpipe. The particulate matter in the emissions from gasoline spark-ignited engines is too small to see since from the tailpipe they are smaller than the spectrum of light. Ultrafine particulates (UFPs), for example, have 100 times more surface area than particulate matter that is 2.5 microns in diameter. The smaller a particle is, the farther it can penetrate into the lungs. Multiple health studies are connecting serious health concerns from UFPs to human proximity to freeways. Another growing concern is that some of particulate matter is regulated and some isn't.

What Are Aromatic Hydrocarbons?

Aromatic hydrocarbons are a form of benzene and significantly contribute to smog-forming emissions. Different aromatic hydrocarbons evaporate at different temperatures. Aromatic hydrocarbons that evaporate (distill) at higher temperatures pose increased health concerns because they are the building blocks for higher levels of particulate matter and PAHs.

The temperature at which all of a fuel has evaporated (distilled) is called the final boiling point. T90 is the temperature at which 90% of the fuel has evaporated. The T90 and T95 of a fuel is a good indicator of the aromatic make-up of a fuel. To reduce the level of the more toxic aromatics in a fuel, regulators can set limits on the T95 distillation temperature and the final boiling point.

Does the Data Support the Concerns?

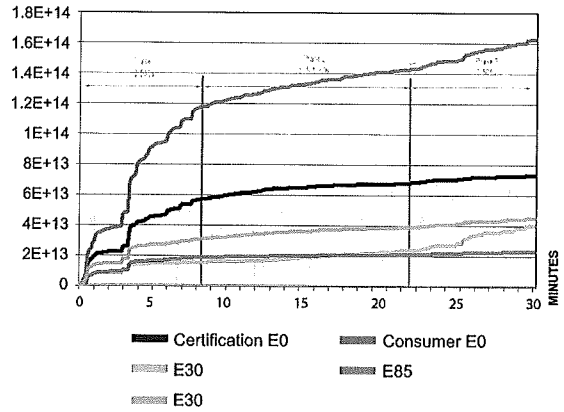
Several sources of data support the link between health concerns and emission levels, but two studies by Honda Motors have been key to Urban Air Initiative's assessment of the health issues surrounding particulate emissions.

Honda Motors' SAE papers 2010-01-2115 and 2010-01-2117 identified a means of calculating the propensity of fuel to form particulates. This study wasn't focused on ethanol; it was primarily focused on fuel make-up and particulate matter formation. As Urban Air Initiative began to utilize this calculation, it became clear that many consumer fuels need to change. When consumer fuels average two to three times more particulate matter than certification fuels, some of these studies are even more concerning, especially in urban areas.

In 2012, Urban Air Initiative took three vehicles to a certified testing laboratory in Ann Arbor, Michigan. Figure 3 shows the particulate accumulation over a Federal Test Procedure (FTP) drive cycle (11-mile city drive cycle). The particulate accumulation of the E0 consumer fuel was more than double the particulate accumulation of the E0 certification fuel. (E0 means 0% ethanol, E30 means 30% ethanol, etc.) The decrease in particulate accumulation from the E0 consumer fuel to the E30 and E85 consumer fuels was due to simply adding ethanol to the E0 consumer fuel. Figure 3 clearly shows a very significant drop in particulate accumulation simply from adding ethanol. It is interesting to note that simply adding ethanol to the E0 consumer fuel created fuels with particulate accumulations less than the E0 certification fuel.

Figure 3

Particulate Accumulation over the FTP 75 City Drive Cycle

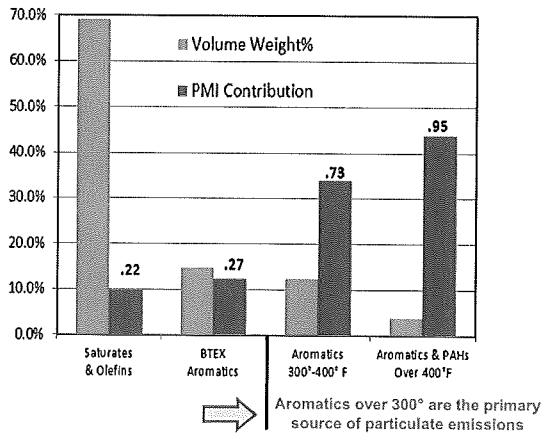


Fuel Property Effects on Particulates with a GM EcoTech Engine per SAE 2013-01-1124

Data from 2009 and 2011 State of Texas gasoline surveys show that the average aromatic content in regular 87 octane gasoline is 25 percent. The average was the same for premium gasoline but with much more variation. This suggests that high aromatic content is one way to ensure minimum octane requirements.

Utilizing Honda's predictive modeling index (PMI) in the 2011 State of Texas survey, Figure 4 shows the PMI contribution of the aromatics from 46 fuel samples. (The PMI predicts particulate number trends and total particulate mass regardless of engine type or test cycle.)The lower-distillation temperature aromatics [the BTEX (benzene, toluene, ethyl benzene, and xylenes) aromatics] are about 15% of the gasoline volume by weight with a 12% PMI contribution. Aromatics that distill (evaporate) at higher than 300°F are also about 15% of the gasoline volume by weight but with a 75% PMI contribution. The discrepancy is even larger for aromatics that distill at temperatures above 400°F. The results of this survey should be central in the discussion about cleaner fuels. Decreasing the final boiling point and T95 temperature limits must be included in the discussion about reducing the levels of these toxic emissions.

Figure 4



How Do We Clean Up Those Most Toxic Emissions?

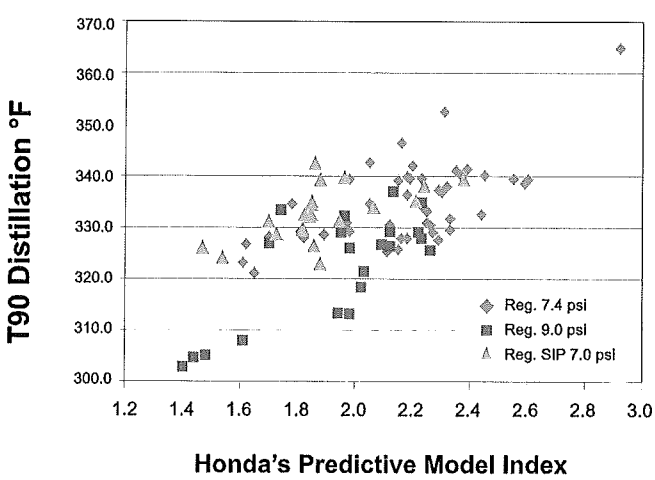
As previously described, the T90 to T95 distillation temperatures of a fuel are directly related to the aromatic make up of a fuel. Higher T90 distillation temperatures correlate to higher levels of the more toxic aromatics.

Figure 5 shows the T90 temperatures of 88 fuels from the State of Texas survey. The fuels were grouped by their average Reid vapor pressure (RVP): 7.4 psi, 9 psi, and 7 psi. RVP is a required measure of the volatility of gasoline. It is defined as the absolute vapor pressure exerted by a liquid at 100°F (37.8 °C) as determined by the test method ASTM-D-323. To reduce evorporative emissions due to seasonal temperature changes, refineries adjust the RVP seasonally to maintain gasoline standards.

In Figure 5, the regular 87-octane fuels from the Dallas and Houston area (7 psi RVP) had a lower average T90 distillation temperature than the fuels with an RVP of 7.4 psi. However, the PMI average was no better than the 9.0 RVP fuels. Today, the average PMI seen in certification fuels test is 1.4-1.5 on average. From the noted increases in testing, particulate emissions in the State of Texas are two to three times higher than currently-used certification fuels.

Figure 5

Multiple Samples from a 2011 State of Texas Gasoline Survey



Where Does Ethanol Fit Into Cleaner Emissions?

Ethanol provides cleaner emissions in multiple ways.

- Ethanol by itself does not contribute to the formation of particulate matter.
- Diluting fuel by simply adding ethanol has created significant reductions in PAH and particulate matter emissions.
- The percentage reduction in emissions from simply adding ethanol can be greater than percentage of ethanol added to a fuel. (For example, in SAE paper 2010-01-2129, adding 20% ethanol resulted in a 30-40% reduction of emissions.)

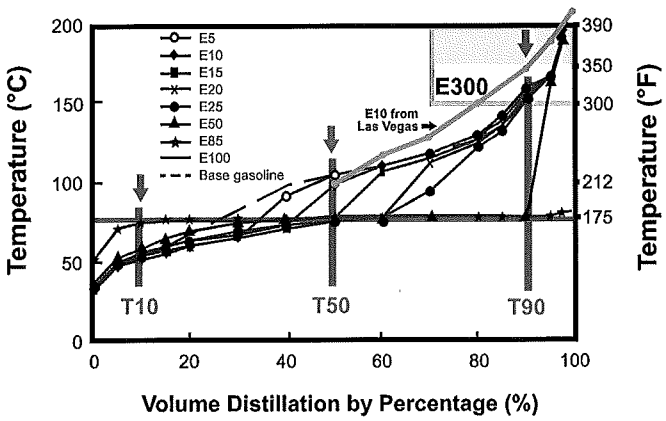
Other Issues: Reid Vapor Pressure

Current regulations focus on reducing RVP to reduce evaporative emissions; but reducing RVP with aromatics has a negative effect on particulate matter emissions. Vehicle technology has been the focus of improving cold starts and reducing particulate matter emissions, but fuel is also an important factor. In blending with ethanol, the vapor pressure generally peaks at E8 to E10 but with additional ethanol added the vapor pressure decreases.

Other Issues: Is The Drivability Index Up-to-Date?

Currently, the ASTM standard D4814 Drivability Index (DI) includes an adjustment for adding ethanol. (The DI is used to ensure the cold-start and warm-up performance of a vehicle. See Figure 6 for the DI equation.) However, because ethanol evaporates at or near T50 and the adjustment for ethanol is made at the end of the DI rather than to the T50 temperature, higher distillation aromatics can be added to a fuel and still be within the regulated limits. To really make the most improvement to vehicle emissions from fuel, the DI should be adjusted to accurately account for the particulate emissions.

Figure 6



Driveability Index: 1.5*T10 + 3*T50 + T90 + 2.4*Vol% Ethanol

What's the Next Step Toward Reduced Emissions With Ethanol?

As proposed for increasing octane levels for improved engine efficiency, maintaining an improved E10 as the base fuel and simply adding ethanol for higher-octane fuels will, by itself, reduce the aromatic content and particulate matter emissions because of the inherent lack of aromatics in ethanol.

In addition, based on the data shown here and other supporting data, Urban Air Initiative is proposing the following distillation temperature limits for fuel for gasoline engines.

- A 360°F T95 distillation temperature limit
- A 380°F final boiling point

Conclusion

The improvements that a mid-level ethanol blend like E30 makes to the octane and emissions profiles should be of great interest to everyone who is working hard to meet the new efficiency and emissions standards.

An E10/E30 solution also offers a valuable market approach for current and future off-road vehicles, small engines, and vintage vehicles.

An E10/E30 solution is a viable plan backed by credible supporting data; it has already shown market potential; and it is a balanced plan that consumers, the auto industry, the oil industry, and regulators could support.

The low cost of ethanol already gives consumers a break at the pump. Utilizing ethanol to help improve engine efficiency and vehicle emission levels could also give consumers a break at the car lot.

Figure 7

Ethanol's Clean High Octane Advantage

"Nothing in the Gasoline Distillation Range can Match Ethanol's Octane"

Reference CRC Project No. CM-137-1b (cites SAE paper 2012-01-1277)

	Compression Ratio	Fuels GHG Impact	CO2 Reduction at the Wheel	Emissions Benefit	Consumer $$
Premium Gasoline +5 Octane / = Energy	+1	↑	↓	↕	??
E30 (ethanol +E10) +10 Octane	+2	↓	↓	↓	↓

Figure 7 summarizes the goals of reaching higher octane levels for improved mileage benefit, and compares the differences between current consumer premium fuel and consumer regular fuel with ethanol added.

A Clean High Octane Choice

E30 98 RON

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