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How Engineers Can Reduce Vehicle Emissions

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How Engineers Can Reduce Vehicle Emissions

Liz Berdugo, P.E.

COURSE CONTENT

Cars are a major source of air pollution in the United States. Vehicle emissions contribute to health and environmental problems such as air toxics, urban smog, and global warming. But there are many steps that engineers can take to help reduce these problems. To become part of the solution, read on.

The Problem

Air Toxics

Toxic air pollutants, also known as air toxics or hazardous air pollutants, are those pollutants that are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects. Congress identified 188 toxic air pollutants in the 1990 Clean Air Act Amendments.

A minor amount of air toxics are released from natural sources such as volcanic eruptions and forest fires. Most air toxics originate from human-made sources. While this includes stationary sources (e.g., factories, refineries, power plants), and indoor sources (e.g., some building materials and cleaning solvents), we concern ourselves in this course with mobile sources (e.g., cars, trucks, buses, nonroad equipment such as forklifts). In a 2001 rulemaking, the Environmental Protection Agency (EPA) identified 21 air toxic compounds emitted from mobile sources.

One fact is clear: vehicles are such an integral part of our society that virtually everyone is exposed to their emissions. Motor vehicles emit several pollutants that EPA classifies as known or probable human carcinogens. Benzene, for instance, is a known human carcinogen, while formaldehyde, acetaldehyde, 1,3-butadiene and diesel particulate matter are probable human carcinogens. Studies are underway to determine whether other toxic substances are present in mobile source emissions.

Where do these toxics originate? Some toxic compounds are present in gasoline and are emitted to the air when gasoline evaporates or passes through the engine as unburned fuel. Benzene, for example, is a component of gasoline. Cars emit small quantities of benzene in unburned fuel, or as vapor when gasoline evaporates. A significant amount of automotive benzene comes from the incomplete combustion of compounds in gasoline such as toluene and xylene that are chemically very similar to benzene. Like benzene itself, these compounds occur naturally in petroleum and become more concentrated when petroleum is refined to produce high octane gasoline.

Formaldehyde, acetaldehyde, diesel particulate matter, and 1,3-butadiene are not present in fuel but are by-products of incomplete combustion. Formaldehyde and acetaldehyde are also formed through a secondary process when other mobile source pollutants undergo chemical reactions in the atmosphere.

People exposed to toxic air pollutants at sufficient concentrations and durations may have an increased chance of getting cancer or experiencing other serious health effects. These health effects can include damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory and other health problems.

Our exposure to mobile source emissions is not limited to breathing contaminated air. People are exposed to toxic air pollutants in many ways that can pose health risks, such as by:

- Eating contaminated food products, such as fish from contaminated waters; meat, milk, or eggs from animals that fed on contaminated plants; and fruits and vegetables grown in contaminated soil on which air toxics have been deposited.
- Drinking water contaminated by toxic air pollutants.
- Ingesting contaminated soil. Young children are especially vulnerable because they often ingest soil from their hands or from objects they place in their mouths.
- Touching (making skin contact with) contaminated soil, dust, or water (for example, during recreational use of contaminated water bodies).

Once toxic air pollutants enter the body, some persistent toxic air pollutants accumulate in body tissues. Like humans, animals may experience health problems if exposed to sufficient quantities of air toxics over time. Predators typically accumulate even greater pollutant concentrations than their contaminated prey. As a result, people and other animals at the top of the food chain that eat contaminated fish or meat are exposed to concentrations that are much higher than the concentrations in the water, air, or soil.

Urban Smog

Urban smog is a second problem that vehicle emissions contribute to. Urban smog, also known as ground level ozone (O_3), is a gas composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground level is created by a chemical reaction between oxides of nitrogen (NO_x) and volatile organic compounds (VOC) in the presence of sunlight. Ozone has the same chemical structure whether it occurs miles above the earth or at ground level. It can be "good" or "bad" depending on its location in the atmosphere. "Good" ozone occurs naturally in the stratosphere approximately 10 to 30 miles above the earth's surface and forms a layer that protects life on earth from the sun's harmful rays. In the earth's lower atmosphere, ground-level ozone is considered "bad."

VOC + NOx + Sunlight = Ozone

Motor vehicle exhaust and industrial emissions, gasoline vapors, and chemical solvents as well as natural sources emit NO_x and VOC that help to form ozone. Sunlight and hot weather cause ground-level ozone to form in harmful concentrations in the air. The length of the ozone season varies from one area of the United States to another.

Southern and Southwestern states may have an ozone season that lasts nearly the entire year.

Many urban areas tend to have high levels of ground-level ozone, but even rural areas are also subject to increased ozone levels because wind carries ozone and the pollutants that form it hundreds of miles away from their original sources, causing air pollution over wide regions. Millions of Americans live in areas where ozone levels exceed EPA's health-based air quality standards, primarily in parts of the Northeast, the Lake Michigan area, parts of the Southeast, southeastern Texas, and parts of California.

Ground-level ozone can adversely affect everyone. It triggers a variety of health problems. Even at very low levels it may cause permanent lung damage after long-term exposure, and it damages plants and ecosystems.

Potential health problems include:

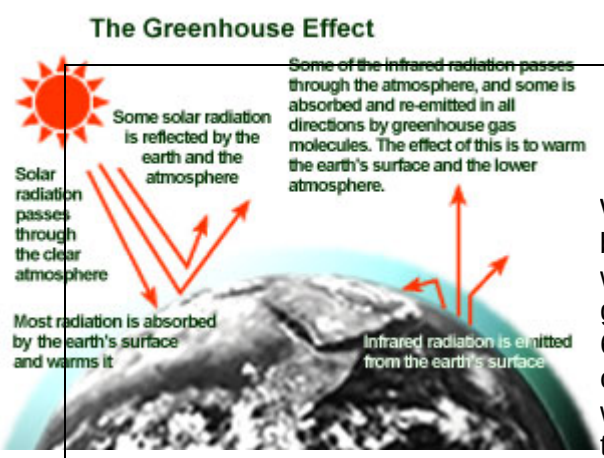
- Ozone can irritate lung airways and cause inflammation much like sunburn. Other symptoms include wheezing, coughing, pain when taking a deep breath, and breathing difficulties during exercise or outdoor activities. People with respiratory problems are most vulnerable, but even healthy people that are active outdoors can be affected when ozone levels are high.
- Repeated exposure to ozone pollution for several months may cause permanent lung damage. Anyone who spends time outdoors in the summer is at risk, particularly children and other people who are active outdoors.
- Even at very low levels, ground-level ozone triggers a variety of health problems including aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses like pneumonia and bronchitis.

Potential plant and ecosystem damage includes:

- Ground-level ozone interferes with the ability of plants to produce and store food, which makes them more susceptible to disease, insects, other pollutants, and harsh weather.
- Ozone damages the leaves of trees and other plants, ruining the appearance of cities, national parks, and recreation areas.
- Ozone reduces crop and forest yields and increases plant vulnerability to disease, pests, and harsh weather.

Global Warming

Vehicle emissions contribute to a third problem, that of global warming. Energy from the sun drives the earth’s weather and climate, and heats the earth’s surface; in turn, the earth radiates energy back into space. Atmospheric greenhouse gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse.



Without this natural "greenhouse effect," temperatures would be much lower than they are now, and life as known today would not be possible. Instead, thanks to greenhouse gases, the earth's average temperature is a more hospitable 60°F. However, problems may arise when the atmospheric concentration of greenhouse gases increases. Global warming is the sustained increase in the average temperature of the earth's atmosphere. Over time, this increase may be sufficient to cause climatic change, including raising sea levels, altering precipitation patterns and changing water supplies and crop yields. Global warming could also affect human health, harm wildlife and damage fragile ecosystems.

Greenhouse gases are primarily carbon dioxide, methane, and nitrous oxide. Some greenhouse gases occur naturally in the atmosphere, while others result from human activities. Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Certain human activities, however, add to the levels of most of these naturally occurring gases.

Carbon dioxide is released to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned.

Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock.

Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

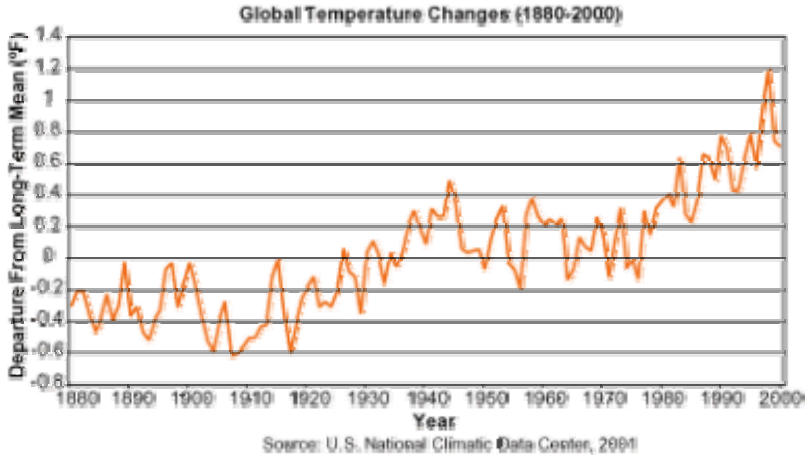
Very powerful greenhouse gases that are not naturally occurring include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6), which are generated in a variety of industrial processes.

Once, all climate changes occurred naturally. Plant respiration and the decomposition of organic matter release more than 10 times the CO_2 released by human activities; but these releases have generally been in balance during the centuries leading up to the industrial revolution with carbon dioxide absorbed by terrestrial vegetation and the oceans. However, during the Industrial Revolution, we began altering our climate and environment through changing agricultural and industrial practices. Before the Industrial Revolution, human activity released very few gases into the atmosphere, but now through population growth, fossil fuel burning, and deforestation, we are affecting the mixture of gases in the atmosphere.

Fossil fuels burned to run cars and trucks, heat homes and businesses, and power factories are responsible for about 98% of U.S. carbon dioxide emissions, 24% of methane emissions, and 18% of nitrous oxide emissions. Increased agriculture, deforestation, landfills, industrial production, and mining also contribute a significant share of emissions. In 1997, the United States emitted about one-fifth of total global greenhouse gases.

Since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases have enhanced the heat-trapping capability of the earth's atmosphere.

Global mean surface temperatures have increased 0.5-1.0°F since the late 19th century. The 20th century's 10 warmest years all occurred in the last 15 years of the century. Of these, 1998 was the warmest year on record. The snow cover in the Northern Hemisphere and floating ice in the Arctic Ocean have decreased. Globally, sea level has risen 4-8 inches over the past century. Worldwide precipitation over land has increased by about one percent. The frequency of extreme rainfall events has increased throughout much of the United States.



Increasing concentrations of greenhouse gases are likely to accelerate the rate of climate change. Scientists expect that the average global surface temperature could rise 1-4.5°F (0.6-2.5°C) in the next fifty years, and 2.2-10°F (1.4-5.8°C) in the next century, with significant regional variation. Evaporation will increase as the climate warms, which will increase average global precipitation. Soil moisture is likely to decline in many regions, and intense rainstorms are likely to become more frequent. Sea level is likely to rise two feet along most of the U.S. coast.

What can engineers do?

The effects that mobile source emissions have on humans and the environment are daunting. But, individual driving habits make a big difference in the amount of pollution a car produces. There are four major ways in which engineers can reduce toxic air pollutants from vehicles. By combining these strategies, you can very effectively reduce the amount your car pollutes. In addition, your car will last longer and you will save money. Most importantly, you will serve as a leader in your workplace and community and develop first-hand knowledge of this important aspect of environmental engineering.

Maintain Your Vehicle

On-Board Diagnostics

OBD stands for "on-board diagnostics," a computer-based system built into all model year 1996 and newer light-duty cars and trucks (less than 8500 lbs. gross vehicle weight rating). OBD monitors the performance of some of the engines' major components, including individual emission controls. The system provides owners with an early warning of malfunctions by way of a dashboard "Check Engine" light (also known as a Malfunction Indicator Light or MIL, for short). By giving vehicle owners this early warning, OBD protects not only the environment but also consumers, identifying minor problems before they become major repair bills.

When you turn on the ignition, the "Service Engine Soon" or "Check Engine" light should flash briefly, indicating that the OBD system is ready to scan your vehicle for any malfunctions. After this brief flash, the light should stay off while you drive as long as no problems are detected. If so, you'll be glad to know that your vehicle is equipped with an early warning system that could save you time, money, and fuel in addition to helping protect the environment!

If the light comes on and stays on, the OBD system has detected a problem. Your vehicle might have a condition that wastes fuel, shortens engine life, or causes excessive air pollution. If left unaddressed, these conditions could also damage your vehicle and lead to increasingly expensive repairs. For example, OBD can identify a loose or missing gas cap (which wastes fuel and contributes to smog) or engine misfire (which can lead to severe or permanent engine damage).

- If the light stays on, the vehicle is just telling you to seek attention soon. When you reach your destination, make sure the gas cap is not loose or missing. If the light does not go out after a few short trips following gas cap replacement or tightening, have your vehicle serviced by a qualified repair technician soon! Delaying assistance could lead to more expensive damage.
- If the light is blinking, a severe engine problem such as a catalyst-damaging misfire is occurring and should be addressed as soon as possible. You can still drive safely, but should minimize your time on the road. Try not to drive the vehicle at high speed or with excess weight (such as towing or carrying heavy equipment).
- Ask your repair shop if they employ trained OBD technicians. A modern repair shop or dealership should have an OBD scan tool (a small, hand-held scanning device) to diagnose the cause of your vehicle's problem. These technicians will have the proper tools and will know best how to diagnose your vehicle.
- The technician will connect the scan tool to your vehicle's computer (usually through a connector under the dashboard) and download information that can pinpoint the problem. The technician can then repair the vehicle based on manufacturer recommendations. OBD actually helps technicians do their job more quickly and reliably, helping you avoid unnecessary repairs and trips back to the shop.
- Warranty coverage varies depending on components and individual manufacturer warranty provisions. In most cases, however, responding sooner rather than later is likely to minimize the individual owner's repair liability. The Clean Air Act requires an 8-year or 80,000-mile warranty on the major emissions control components such as the catalytic converter, and a 2-year or 24,000-mile warranty on other emissions control components.

- If the light goes off before you take the vehicle to the shop, usually nothing is required. If the problem that caused the light to come on is addressed, the OBD computer will turn the light off. This is not an indication of a faulty OBD system. In fact, the system is doing its job by verifying that a problem temporarily existed but has since been corrected; perhaps a loose gas cap was tightened or a fouled spark plug was cleared. Your vehicle needs no special attention unless the light comes on again.

Routine Maintenance

Today's vehicles are highly sophisticated and efficient. OBD helps to ensure these vehicles are running in top shape, but you still need to maintain your vehicle according to the manufacturer's recommended schedule. Keep up with routine maintenance and get regular engine tune-ups.

You will reduce your car's emissions and enhance its performance if you follow the manufacturer's recommended maintenance guidelines. By taking proper care of your car, you will also extend its life, increase its resale value, and optimize its "gas mileage" or fuel economy.

Check your owner's manual for recommended maintenance schedules. The owner's manual that comes with your car contains a wealth of information. It outlines recommended maintenance intervals, product specifications, and operating procedures. The manual also explains the manufacturer's warranty of the emission control system. Contact the manufacturer or a nearby dealer to obtain a copy of the owner's manual if you do not have one.

Every car has some items that need to be checked on a regular basis and others that need to be replaced periodically. Those that need to be checked on a regular basis include the air filter, vacuum and coolant hoses, oil, oil filter, fluids, and belts. It's also important to keep the tires properly inflated and aligned. Periodic wheel alignments and keeping tires inflated to the maximum recommended pressure will minimize tire wear and help your car get the best possible fuel economy. Be sure to have your car serviced by a skilled technician who understands modern emission control systems. If a modern car has high emissions, it is usually due to a defined malfunction that needs to be fixed. The type of simple adjustments that once occurred during tune-ups will no longer correct the problem. Finally, be aware that pollution will increase dramatically if you tamper with your car's emission control system or use leaded gasoline in a vehicle designed for unleaded gasoline. These activities are illegal — for individual vehicle owners as well as for fleet operators and auto technicians. Today's vehicles are designed with emission controls as integral components of the power train. Any tampering with this system will not only drastically increase emissions but is likely to have a negative effect on vehicle performance and durability. Use of leaded gasoline in a vehicle designed for unleaded gasoline can irrevocably damage the emission control system. Fortunately, such fuel-switching practices are becoming increasingly rare as leaded gasoline becomes harder to find.

Many drivers ask about use of "premium" or "super" grade gasolines. These fuels contain additives to increase octane. Octane is a measure of how much a fuel can be compressed in an engine before it spontaneously combusts. It is not a measure of fuel

power or quality. Only a small percentage of vehicles require high-octane gasoline for optimum performance (these are generally turbocharged or high-performance vehicles). Check your owner's manual to see what type of fuel is recommended for your car. Unless your car needs high-octane gasoline, use of "premium" will not improve performance or emissions — it will just cost you more. And finally, remember to always turn off the engine before refueling and always make sure the gas cap is securely tightened.

Properly Changing Your Own Motor Oil

For years, motor oil commonly was reused or discarded in ways that neither protected the environment nor conserved its resource value. In the United States alone, an estimated 200 million gallons of used motor oil are improperly disposed of by being dumped on the ground, tossed in the trash (ending up in landfills), and poured down storm sewers and drains. Just one gallon of used oil has the potential to contaminate up to one million gallons of drinking water. Additionally, used oil that ends up in the country's rivers, lakes, and streams can threaten aquatic life.

If all of the used oil that is improperly disposed of were properly managed, the United States could save thousands of barrels of oil each day. Used oil that is properly handled can be re-refined into lubricants, processed into fuel oils, and used as raw materials for the refining and petrochemical industries.

If you choose to change your own motor oil rather than having it changed at a service station, the following steps will help ensure that you do it correctly and prevent harm to the environment:

- Turn off the engine, block the wheels, and set the parking brake before getting under your car. To avoid burns, make sure that the engine is not too hot. Consult your owner's manual for directions.
- Remove the drain plug on the bottom of the engine's oil pan and allow the used oil to drain from your car into a suitable container, such as a drip pan.
- If you are changing your oil filter, do it next and follow the directions below, and on the filter. Regardless, replace the drain plug in the bottom of the engine's oil pan. Make sure that it's tight.
- Carefully add the new engine oil. Although most cars take four to five quarts of oil, always check your owner's manual for the amount of oil required and the recommended grade of motor oil to be used. Do not overfill it.
- With the parking brake still set, and in a well-ventilated area, start the engine of the car. The oil pressure light may be on, but should go out after a few seconds. Once the light goes out, allow the engine to run for a few minutes.
- Turn off the engine and check the oil level. Also, check around the oil filter and drain plug for oil leaks.
- So you know when to change your oil next, write down the date and mileage, as well as grade and brand of motor oil you installed.
- Use a funnel or carefully pour the used oil from the drip pan into a suitable recycling container (see below). Reuse the drip pan; don't rinse the residual oil down the drain.
- Protect the environment and conserve resources by taking your used oil to your nearest public used oil collection center, such as a service station or lube center.

Also look for the “oil drop.” This is a petroleum industry symbol indicating that used oil is collected for recycling/reuse.

After draining the oil from your car’s crankcase, pour the oil into a clean, leak proof container with a screw-on top. Many household containers are suitable, including original motor oil containers. Never use containers that held household chemicals, such as bleach. Make sure that the container has a secure lid so it cannot spill. Containers specifically designed for carrying motor oil also may be purchased at automotive supply stores.

If you don’t take your used oil to a recycling center immediately, never temporarily store it in any container that once held food, beverages, or chemicals. Regardless of the type of container used for carrying or storing used oil, be sure it is clean, clearly labeled “Used Oil,” and kept out of the reach of children and pets.

Take the container to the nearest used oil collection center. If your community doesn’t have a collection center, check with your local service station or an automobile maintenance facility (such as a lube center, repair shop, or car dealership).

Where it’s practical and cost effective, empty used oil filters are also being collected for recycling. Check with the used oil collection facility where you take your used motor oil to see if it accepts used oil filters, or if it can direct you to a place that does. If you don’t have any facilities in your area that recycle used oil filters, the empty used filter usually can be wrapped in newspaper and disposed of with your regular household trash. Check with your trash collection service before discarding the filter because some states don’t allow used oil filters to be land filled.

Whether you recycle or dispose of your used oil filter, it must be drained of used oil. Special handling is required to properly drain an oil filter:

- Use a filter wrench (if necessary) to loosen the oil filter. Carefully remove the used filter.
- Drain the filter of any oil. Using a sharp tool, puncture a hole in the dome end of the filter or through the antidrain back valve located on the flat end of it. The most effective method for properly draining the filter is to puncture the antidrain back valve or the filter dome and allow the used oil to flow into a container appropriate for recycling it. (Antidrain back valves are present in most automotive and light duty truck filter models. The valve consists of a rubber flap that creates a vacuum to prevent oil from draining back into the engine when it is not running. Puncturing the filter breaks the vacuum and allows the “trapped” oil to be recovered for recycling.)
- Place the flat end of the punctured filter on the used oil collection container and drain as much used oil as possible out of the filter. It is important for used oil filters to be drained a minimum of 12 hours near engine operating temperature and above room temperature (approximately 60 degrees F).
- Install the new oil filter according to the manufacturer’s instructions. Coat the rubber seal on it with a small amount of oil, and then replace it. Do not use a filter wrench to tighten the new filter as this may damage the filter. Instead, tighten it snugly with your fingers, following the directions supplied with the filter.

Save Gas and Increase Mileage Efficiency

The most effective way to reduce emissions from your vehicle is to use it less. Vehicle travel in this country is doubling every 20 years. Traffic trends that see more and more cars driving more and more miles will soon begin to outpace technological progress in vehicle emission control. Several options are available to help you reduce the amount you drive. These include consolidating trips, telecommuting, carpooling, using public transit, and choosing clean transportation alternatives such as biking or walking.

By planning errands, you will get the most out of time you do spend behind the wheel. For example, call ahead to confirm that the product you need is in stock before you drive to the store. Practice trip chaining. This means combining errands into one trip. Consolidate trips to destinations that are near one another. Once you arrive, park and walk between destinations. Save errands for one afternoon and plan your trip so you don't retrace your route. You not only save gas this way, but you reduce wear-and tear on your car. Ridesharing can be an ideal way to reduce your personal contribution to pollution. Every time you share a ride and eliminate a trip, you help the environment. Try pairing up for trips to work or to social events — even an occasional carpool or ride on public transportation will make a difference. Use transportation modes other than driving whenever you can. Walk, bike, take a bus, or carpool when possible. Use your car only when necessary. Public transportation authorities often have carpooling information as well as transit services. If you own more than one vehicle, whenever possible drive the one that gets the best gas mileage.

If you must drive your car, you can greatly improve your mileage by driving wisely. These eight points can help improve your mileage:

- Go easy on the brakes and gas pedal. Avoid "jackrabbit" starts by accelerating gradually whenever possible. Also, anticipate stops to avoid sudden braking.
- Avoid long idles. Turn off the engine if you expect to idle for more than 30 seconds. Instead of idling at a drive-up window, park the car and go in. Idling burns more gas than restarting the engine.
- Avoid carrying unneeded items in the trunk. Also, reduce drag by placing items inside the car or trunk rather than on roof racks. Your car burns more gas and emits more pollution when the engine is operating under high load; that is, when it is working especially hard. Extra load is created by carrying extra weight or creating drag.
- Avoid high speeds. You can improve your gas mileage about 15 percent by driving at 55 mph rather than 65 mph.
- Use your air conditioning only when necessary. Use of a vehicle air conditioner increases load on the engine. This can increase emissions and decrease fuel economy. Try opening the window or the fresh air vent to cool the inside of your vehicle. Also, park in the shade if you can to prevent the car from heating up in the sun. Besides keeping the interior temperature of your car more comfortable, you will lessen the pollution and waste that occurs when gasoline evaporates from the engine and gas tank.
- Use overdrive. If your car is equipped with overdrive gearing (on 5-speed manual transmissions and 4-speed automatic transmissions), be sure to make use of the overdrive gear as soon as your speed is high enough. If you have a manual

transmission, the lower the shift speed, the better the fuel economy. Your owner's manual will give you further information.
- Emission control systems take longer to warm up and become fully operational in cold weather. However, idling will not help. Modern vehicles need little warm-up; they're most efficient when being driven. Idling for long periods in cold weather can actually cause excessive engine wear, so limit car warm-ups in winter.
- Spilled gasoline pollutes the air when it evaporates. Watch what you do at the gas station to prevent spills and overfill. It's best to avoid "topping off," especially in hot weather.

Even a perfectly maintained car will pollute more than necessary if it is driven carelessly. Your car's emissions will be lower if you apply common sense to your driving and follow basic rules of the road.

Retrofit Your Air Conditioner

The ozone layer protects the earth from the sun's harmful ultraviolet (UV) rays. If you'll recall, we discussed earlier in this course how this "good" ozone occurs naturally in the stratosphere. But the ozone layer is slowly being depleted. You've probably heard about this, but did you know that the chlorofluorocarbon (CFC)-based refrigerants used in your car's air conditioning system may be part of the cause? When released into the air, CFCs from your car's air conditioning system damage the ozone layer.

CFCs break down and destroy ozone molecules in the stratosphere. As the ozone layer is destroyed, more and more UV rays reach the earth. Too much UV radiation causes human health problems, such as skin cancer, cataracts, and weakened immune systems. UV radiation also can damage crops, livestock, and ecosystems.

CFCs are in the process of being phased-out. Over 160 countries, including the United States, have signed an agreement to stop making several ozone-depleting substances, including CFC-12 (also known as Freon-12). This agreement, known as the Montreal Protocol, became a law in the United States under the federal Clean Air Act.

Since the end of 1995, CFC refrigerants have not been manufactured in the United States. Scientists predict that if all countries comply with the Montreal Protocol, the ozone layer will recover by 2050.

How can you determine if your vehicle's air conditioning system uses CFC-12? There are a few simple ways:

- If your vehicle was made before 1992, the air conditioning system uses CFC-12.
- If your vehicle was made in 1992, 1993, or 1994, your air conditioning system might use CFC-12. In 1992, a few vehicle manufacturers began using a refrigerant called HFC-134a that does not destroy ozone. The older the car, the more likely that CFC-12 is being used. You can find a refrigerant identification label on the air conditioning compressor or elsewhere inside the engine compartment. You can also ask your service technician or vehicle manufacturer.

- If your vehicle was made in 1995 or later, it does not use CFC-12. By 1995, all vehicle manufacturers were using the new, ozone-safe HFC-134a refrigerant in every vehicle made.

What can you do if your CFC-based air conditioning system needs to be repaired? You have two choices; retrofit, or repair and recharge with CFC-12.

Although some cars are not candidates for retrofits, most cars' air conditioning systems can be converted by installing new parts that allow them to use an environmentally acceptable refrigerant. Retrofitting will help protect the ozone layer and may:

- Save you money on future repairs and on the purchase of refrigerant.
- Increase the value of your vehicle.
- Save you the expense and inconvenience of trying to locate CFC-12 as supplies run out.

The other option is to keep using CFC-12 for repairs until the current supply is depleted. This may be the most economic option if you are not planning to keep your car for very long. There are no laws requiring you to retrofit your air conditioning system.

If you are considering a retrofit, there are a few things that you should know. First, there are two types of retrofits available:

1.a. High-performance retrofit with HFC-134a: The vehicle manufacturer recommends specific procedures and parts to be used, including HFC-134a as the refrigerant.
1.b. Economy retrofit with HFC-134a: HFC-134a is still used as the refrigerant, but this retrofit typically does not include all the procedures or parts recommended by the vehicle manufacturer. Vehicle manufacturers do not recommend economy retrofits.
2. Economy retrofit with blends: This system uses a blend of refrigerants that contains a mixture of several chemicals. Vehicle manufacturers do not approve of or recommend retrofits using refrigerants other than HFC-134a.

The high-performance retrofit might be more expensive than the economy retrofits but could save you money in the long run.

Second, you should know that retrofits entail labeling, replacing service fittings, and adding and recycling refrigerant. All retrofitted systems must include refrigerant labels that specify which refrigerant is used. This helps prevent contamination of air conditioning systems and refrigerant supplies. All retrofitted systems must use unique fittings that match the refrigerant used. During the retrofit procedure, the original refrigerant (CFC-12) is removed and recycled. New refrigerant is then added. Depending on the retrofit, additional parts may have to be replaced or the system components altered. Note that technicians handling air conditioner refrigerants must be certified by the U.S. Environmental Protection Agency (EPA).

And third, there are a few important points to keep in mind regarding refrigerants:

- The new refrigerants listed as acceptable by EPA may not work in every vehicle. Ask your vehicle manufacturer, service technician, or refrigerant manufacturer if you should retrofit or continue to use CFC-12.

- Be sure the refrigerant used in your vehicle is meant to be a substitute for CFC-12, not a substitute for HFC-134a. Do not retrofit your vehicle if it already uses HFC-134a; this would void your warranty and could damage the system.
- Make sure your service facility uses refrigerants listed as acceptable by EPA. A list of acceptable refrigerants is available through EPA's Hotline at 1-800-296-1996. EPA reviews refrigerants to ensure they are not flammable and do not pose risks to human health or the environment. EPA does not, however, test or judge how well a refrigerant will work in a particular vehicle. Refrigerants currently undergoing EPA review may be legally sold but may ultimately be judged unacceptable by EPA. A prudent vehicle owner will insist that the refrigerant used has final EPA acceptance.
- Vehicle manufacturers only recommend using HFC-134a for retrofitting, because (1) it is the only refrigerant that meets manufacturers' performance and durability requirements, (2) it is widely available and inexpensive, and (3) you will be able to obtain service for an air conditioning system using HFC-134a almost anywhere in the United States.
- Use of refrigerants other than HFC-134a may void air conditioning warranties.

Also, beware of flammable refrigerants. It is illegal to replace CFCs with refrigerants consisting primarily of pure propane, butane, other hydrocarbons, or other flammable substances. Vehicles presently designed to use CFC-12 should NEVER be retrofitted or repaired with a flammable refrigerant. Use of flammable refrigerants poses a safety risk and can void the warranties on air conditioner systems or replacement parts. Automobile insurance may not protect owners against liability for damages as a result of using illegal flammable refrigerants.

Finally, in considering your options, take into account cost, performance, and availability when deciding whether to retrofit. Be aware that the actual cost of your repair in retrofit might vary depending on your location, as well as parts, supplies, and labor required. For specific comparisons of warranties, special parts, initial costs, future costs, performance, environmental safety, and refrigerant availability, search document 430F97052 at http://nepis.epa.gov to see the EPA's brochure *It's Your Choice: Retrofitting Your Car's A/C System*.

Choose the Right Vehicle

What should engineers consider when buying a new car? First, it is important to understand your needs and buy accordingly. Get only the options you really need. Optional equipment that adds weight to your car can decrease your gas mileage (especially heavy options such as four-wheel drive). Automatic transmissions generally degrade fuel economy. Larger engines and higher horsepower typically result in lower gas mileage. If you need the additional power and torque, be aware your gas mileage will suffer during all types of driving. Check the gas mileage ratings of similar vehicles. Buy a fuel efficient model in the size category that meets your needs. The Federal Gas Mileage Guide, issued annually and free of charge at all auto dealerships, compares gas mileage of similar models.

There are several new cars on the market, often called clean air vehicles that get improved gas mileage and emit much lower levels of pollution. The concept of driving a clean air vehicle to some people may sound a bit "granola" at first. But looking at the power behind these vehicles reveals a new perspective - one of amazing technological

advancement, and the ability to solve the serious air pollution problem.

Many areas where people live fail to meet federal or state air quality standards - a rapidly increasing health hazard to you, your children, their children, and so on. Sure, new cars are cleaner than they used to be, but there are a lot more of them on the road today driving more miles than ever. So our pollution problem continues to worsen. It's simple math - we have to drive less or we have to drive cleaner if we want to reduce pollution.

The good news is that driving clean is easy, and it doesn't mean you'll sacrifice performance, convenience or style. In fact, it often means that you get much more for your money through a better warranty on your vehicle or savings in fuel costs.

Following are a few different ways to go cleaner with your next new car. You can buy a cleaner gas car – one with a Partial Zero Emissions Vehicle (PZEV) or better emission rating. The pollution controls are so tight and the burning of fuel is so efficient on these vehicles that they can actually be cleaner than a hybrid or alternate fuel vehicle. You can buy a hybrid. Hybrid electric vehicles combine an internal combustion engine with a battery and electric motor to maximize fuel economy and produce fewer emissions. You can buy a car that uses a different fuel. Vehicles are available that utilize compressed natural gas, methanol, ethanol, or propane as fuel - a cleaner alternative to gasoline. You can buy an electric vehicle (EV). Although there are currently no full size EVs available, many people choose to buy a smaller EV, like a GEM, for their around-the-town traveling. There are several smaller EVs on the market - and they are all zero emission. You can buy a fuel cell vehicle. Fuel cells produce electricity through a chemical reaction between hydrogen and oxygen, and produce no harmful emissions. We'll take a look at each in detail below.

Cleaner Gas Cars

Many new gasoline vehicles are designed to produce much lower levels of emissions. These vehicles are rated Partial Zero Emission Vehicles (PZEVs) by the California Air Resources Board (ARB). PZEVs are so clean because they meet the ARB's most stringent tailpipe emission standard - Super Ultra Low Emission Vehicle, and have a 15-year/150,000-mile warranty and zero evaporative emissions. In many instances a car buyer may pay only $100 more for a cleaner vehicle model that comes with a better warranty. It is even possible to be driving a clean car and not know it!

There is nothing new with the mechanics - just a much cleaner version of the conventional internal combustion engine vehicle. Automakers are continually finding new technologies that improve their vehicles. Tremendous benefits have resulted alone by industry's ability to simplify, refine, and reduce the costs of their emission control systems. PZEVs are primarily four cylinder engines; however there are some five and six cylinder models available. Many PZEVs utilize various combinations of multiple catalysts, several oxygen sensors, exhaust gas recirculation, and an air pump.

Gasoline vehicles with a PZEV rating are mass-produced in a variety of makes and models and are available to the public today. There were 35 PZEV or Advanced Technology PZEV models in 2005. They have an immediate impact on air quality

because they are popular models at affordable prices. In addition, the extended warranty provides you with the added security that your vehicle will be maintained for a longer period of time.

Cars with a PZEV emissions rating have such tight pollution controls, and the burning of fuel is so complete, that in very smoggy urban areas, exhaust out of the tailpipe can actually be cleaner than the air outside. Gasoline vehicles meeting PZEV emissions standards sometimes have even lower emissions than hybrid or alternative fuel vehicles.

Hybrid Electric Vehicles

Hybrid electric vehicles (HEVs) commercially available today combine an internal combustion engine with a battery and electric motor. This combination offers the extended range and rapid refueling of a conventional vehicle, while reducing energy requirements and emissions of conventional vehicles. The practical benefits of most HEVs include improved fuel economy and lower emissions compared to conventional vehicles. The inherent flexibility of HEVs allows them to be used in a wide range of applications, from personal transportation to commercial hauling.

Today's hybrid electric vehicles refuel at the gas station. These vehicles use both gasoline and electricity that is generated on-board the vehicle. As a result, refueling is the same as for conventional vehicles, although generally required less often due to improved fuel economy. Future HEVs may refuel at both the gas station and plug in, and thus offer more electric drive miles, improve efficiency, and reduce operating costs.

Many configurations are possible for HEVs. Essentially, a hybrid combines an energy storage system, a power unit such as a spark ignition engine, and a vehicle propulsion system. The primary options for energy storage include batteries, ultra capacitors, and flywheels. Although batteries are by far the most common energy storage choice, research is still being done in other energy storage areas. Propulsion can come entirely from an electric motor, such as in a series configuration, or the engine might provide direct mechanical input to the vehicle propulsion system in a parallel configuration system. A hybrid's efficiency and emissions depend on the particular combination of subsystems, how these subsystems are integrated into a complete system, and the control strategy that integrates the subsystems. A hydrogen fuel cell hybrid, for example, would produce only water as a by-product and run at greater overall efficiency than a battery-electric vehicle that uses wall-plug electricity.

Auto manufacturers have begun to produce HEVs with comparable performance, safety, and cost to conventional vehicles. By combining gasoline with electric power, hybrids have the same or greater range than traditional combustion engines, thus reducing the number of trips to the gasoline station. Improved fuel economy reduces greenhouse gas emissions and provides savings to help offset the incremental capital cost of the vehicle.

Hybrid-electric vehicles meet all federal motor vehicle safety requirements. The batteries in HEVs are sealed and all high-voltage circuits are protected from casual contact. High-voltage circuits are marked, color-coded and posted with warnings to advise of their presence. These vehicles pose no additional risks over a conventional vehicle.

Not all HEVs are created equal, however. Various hybrid concepts are being applied to vehicles, and some "mild" hybrids are not much better than their non-hybrid counterparts. However, "full" HEVs are substantially more efficient than conventional vehicles. When in doubt, search for hybrids at www.driveclean.ca.gov under the Vehicle Search section for a list of "full" hybrids that offer maximum benefits to the environment and your wallet.

More efficient cars can make a big difference to society in terms of environmental benefits, and the serious deterioration of urban air has motivated regulators to require cleaner cars. HEVs can reduce dependency on fossil fuels because they can run on alternative fuels. Engines can be sized to accommodate average load, not peak load, which reduces the engine's weight. Fuel efficiency is greatly increased (hybrids consume significantly less fuel than vehicles powered by gasoline alone) and emissions are decreased. Hybrids will never be true zero-emission vehicles, however, because of their internal combustion engine. But hybrids certified to the ARB's super ultra low emission standard can significantly reduce ozone precursor emissions and global-warming pollutants by a third to a half, and future models may cut emissions by even more.

Alternative Fuel Vehicles

An Alternative Fuel Vehicle (AFV) is a vehicle that can operate on a fuel other than gasoline or petroleum based diesel, such as biologically produced diesel (biodiesel), electricity (discussed below), ethanol, hydrogen, methanol, natural gas, or propane.

Alternative fuels can be derived from renewable biological feedstock or are a by-product of petroleum production. For example ethanol can be fermented from corn or wood waste, while natural gas or propane is produced in conjunction with crude oil production. Some alternative fuels can also reduce vehicle maintenance requirements. For example, spark plugs from a propane-fueled vehicle last from 80,000 to 100,000 miles and engines can last 2 to 3 times longer than gasoline- or diesel-fueled engines.

Depending on the fuel, a vehicle may be configured with either dedicated or bi-fuel systems. Vehicles with dedicated systems are designed to run exclusively on a particular alternative fuel while bi-fuel vehicles have two separate fueling systems that can operate on either the alternative or conventional fuel.

AFVs range in function and size from small passenger cars to large 18-wheeler trucks or transit buses. Off-road products such as forklifts, and agricultural and construction equipment are also available with alternative fuel systems. Alternative fuel vehicle availability varies by fuel type. Currently light duty vehicles capable of using compressed natural gas (CNG), ethanol, and blended biodiesel are in production. Various heavy-duty vehicles using CNG, liquefied natural gas, propane, or biodiesel are available. Alternative fuel conversion kits are available for propane. The majority of propane-fueled vehicles are the result of aftermarket conversion.

Different alternative fuels are dominant in different regions of the country. Propane is the most widely available, with stations in every state, while ethanol blends are concentrated in the Midwest and plains states. Generally, refueling times are comparable with those needed for gasoline or diesel refueling.

Alternative fuel vehicles meet federal motor vehicle safety requirements. The pressurized containers of fuels such as liquefied propane and compressed natural gas go through rigorous safety testing.

AFVs produce fewer emissions than those powered by gasoline or diesel fuel. Emission reductions of up to 80 percent for pollutants such as carbon monoxide, carbon dioxide, non-methane organic gas, oxides of nitrogen, or particulate matter can be achieved. The amount of emission reductions varies by alternative fuel type and pollutant. Alternative fuels such as alcohols, natural gas, propane, and electricity are inherently cleaner than conventional gasoline and diesel because they do not contain toxics such as benzene. In addition, they are made of simpler chemical compounds which yield lower levels of complex combustion by-products such as 1,3-butadiene. Using alternative fuels also helps reduce the nation's dependence on imported oil.

Electric Vehicles

Electric vehicles (EVs) are often confused with hybrid electric vehicles. Electric vehicles (EVs) are cars that run solely on electricity stored in batteries. EVs are a kind of alternative fuel vehicle. EVs are the only truly zero emission car available today because they have no tailpipe exhaust and no evaporative emissions from fuel systems.

Manufacturers have developed a broad spectrum of EVs - from neighborhood electric cars which can be used for short trips around town to full function electric cars which can be used for longer trips and have the body of conventional cars. The availability and styles of these vehicles vary from year to year, but with battery technology getting more sophisticated, manufacturers will have the ability to design electric vehicles with extended range, faster charging, and more power.

The heart of an EV has three main components: the batteries, the electric motor controller, and the electric motor. The controller takes power from the batteries and delivers it to the motor. The batteries of an EV can vary in type, number, voltage and placement. The different battery types available now are nickel-cadmium, nickel metal hydride, lithium Ion, and lead acid. To recharge the batteries, there is a charger component on the car which takes the electricity from a power source (ultimately the power plant) and converts the current from alternating current (AC) to direct current (DC).

Since EVs are fueled by electricity, they can be recharged at a charger installed at your home or workplace, or that can be found at many other locations such as Costco and your local shopping mall. There were two types of chargers, however in 2006 all vehicles being produced will use the same system. Charging time varies depending on how “empty” the battery is, how much energy the battery holds (equivalent to how big the tank is) and other factors. In general, it takes approximately two to five hours to recharge vehicles that are ¼ to ¾ full and approximately six to eight hours to recharge vehicles that are on ”empty.” While this time period is longer than fueling a regular vehicle, since the owner can be working, sleeping, or shopping during recharge, it doesn’t require the owner to stand by and wait.

EVs meet all federal motor vehicle safety requirements. The batteries are sealed and all high-voltage circuits are protected from casual contact. High-voltage circuits are

marked, color-coded and posted with warnings to advice of their presence. They pose no additional risks over a conventional vehicle.

There can be many advantages to driving an EV. Depending on your location, you may be able to drive an EV alone in a high-occupancy vehicle (HOV) lane and bypass all of the traffic, you may get free parking in some areas, and there may be cash incentives towards the lease or purchase of the vehicle from ARB or local agencies. In addition, there are tax incentives from the Federal government, you can recharge at your home or work --you don't have to make a trip to the gas station, fuel costs are less than a conventional car (fuel costs for a gasoline vehicle can be over five times greater than an EV), maintenance costs are lower because there are fewer moving parts to service and repair, and there is no noisy engine.

Electric vehicles are the cleanest and most environmentally friendly car around. They have no tail pipe exhaust, no evaporative emissions, no emissions system which can degrade or fail with time, and no emissions from the refining of fuel and service stations. EVs reduce pollutants by more than 90 percent when compared to the cleanest conventional gasoline-powered vehicles (even when factoring in the emissions from power plants generating the electricity to charge the vehicle).
With widespread use, EVs can reduce emissions of carbon dioxide that contribute to global warming, lessen our cancer risk from exposure to toxic air contaminants, and reduce oil consumption and dependence on imported oil.

Fuel Cell Vehicles

A breakthrough "clean machine," the fuel cell harnesses the chemical energy of hydrogen and oxygen to generate electricity in an electrochemical process without combustion or pollution. Fuel cells can be used in vehicles in one of two ways: the fuel cell alone can power the vehicle making it a fuel cell EV (a type of alternative fuel vehicle); or the fuel cell can be used in combination with an electric motor making it a kind of hybrid-electric vehicle. Both types of fuel cell vehicles (FCVs) drive quietly, powerfully, and cleanly.

An individual fuel cell consists of two electrodes, one positively charged (anode) and one negatively charged (cathode), with a substance that conducts electricity (electrolyte) sandwiched between them. Oxygen from the air passes over the cathode and hydrogen over the anode, generating electricity and water. The hydrogen fuel for a fuel cell EV can be supplied in several ways. Some vehicles carry a tank of pure hydrogen. Others could be equipped with a "fuel reformer" that converts hydrocarbon fuels—such as methanol, natural gas, or gasoline—into a hydrogen-rich gas. Individual fuel cells must be combined into groups called fuel cell stacks in order to achieve the necessary power required for motor vehicle applications.

Fuel cells can provide much more electric power than the 12-volt batteries in conventional automobiles. Therefore, FCVs can be equipped with more sophisticated and powerful electronic systems than those found in conventional gasoline vehicles. For example, some vehicle manufacturers are designing vehicles that use electronic steering and braking. Eliminating the steering column and wheel may make these vehicles safer. Internal combustion engines in automobiles convert less than 20% of the energy in gasoline into power that moves the vehicle. Vehicles using electric motors powered by hydrogen fuel cells are much more energy efficient, utilizing 40-60% of the fuel's energy.

Even FCVs that reform hydrogen from gasoline can use about 40% of the energy in the gasoline.

Fuel cell vehicles makers will seek to develop the cars with levels of safety, comfort, and cost comparable to those of a conventional vehicle. Meeting consumers' cost expectations, especially when the vehicles are introduced may be difficult. But incentives, rebates, and possible auto manufacturer price adjustments will help to reduce the purchase price of these vehicles.

Developing the infrastructure for producing and distributing the fuel for fuel cell vehicles is a major task, and there are many questions and challenges to be addressed. Depending on how the hydrogen for a fuel cell is produced – for example, from hydrocarbon fuels, or through electrolysis of water using electricity generated from fossil fuels – there can be some pollutants associated with the fuel production. If the hydrogen is generated from renewable resources, like solar or wind-generated electricity for use in electrolysis, then the entire system is pollution-free and renewable.

Fuel cells could dramatically reduce urban air pollution and decrease oil imports. The U.S. Department of Energy projects that if a mere 10% of automobiles nationwide were powered by fuel cells, regulated air pollutants would be cut by one million tons per year and 60 million tons of the greenhouse gas carbon dioxide would be eliminated. Fuel cell vehicles have the potential to strengthen our national energy security by reducing our dependence on foreign oil. The U.S. uses about 20 million barrels of oil per day, at a cost of about $2 billion a week. In fact, half of the oil used to produce the gasoline you put in your tank is imported. DOE projects that the same number of fuel cell cars would cut oil imports by 800,000 barrels a day — about 13 percent of total imports. These possibilities make FCVs a promising technology for the future.

In this course you've learned that vehicles are a significant source of air pollution in the United States. Their emissions contribute to health and environmental problems. Fortunately, you have also learned that there is something engineers can do to help reduce these problems. By maintaining your vehicle, saving gas and increasing mileage efficiency, considering a retrofit to your vehicle's air conditioner, and choosing the right vehicle, you can be part of the solution, serving as a role model and source of information to others in your workplace and community.

