AMERICAN LUNG ASSOCIATION®

American Lung Association Energy Policy Development: Transportation Background Document

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Table of Contents

Introduction

The American Lung Association convened a series of workshops to discuss issues related to energy use and policy in the U.S., including the impacts of different energy sources on human and, especially, lung health. The goal of the workshops was to better define the American Lung Association's positions on key energy policy issues. The workshops were divided into three categories: (1) electricity generation, (2) heat (e.g., heating of residential and commercial buildings), and (3) transportation.

This paper focuses on transportation, providing a primer on fuel production and use for transportation, and its environmental impacts, for those participating in the transportation workshop. This paper discusses onroad transportation sources, both light-duty (cars and light trucks used for personal transportation) and heavy-duty (trucks, buses) as well as nonroad locomotives, marine vessels, and aircraft used for passenger and freight movement. This paper does not specifically address nonroad diesel equipment used for construction, mining, agriculture, and industry. However, the air impacts and environmental policy issues related to this equipment are similar to the issues addressed here relative to diesel trucks, locomotives, and marine vessels.

Below we provide an overview of transportation fuel use and emissions and then consider transportation-related health impacts and policy issues. The paper concludes with a list of recommended readings.

Transportation Overview

In 2008 the U.S. transportation sector consumed 27 quadrillion British thermal units (Btus) of energy – 28 percent of total energy use in the economy (DOE 2010d). Ninety four percent of this energy was derived from petroleum, and was consumed primarily by vehicles in the form of gasoline and diesel fuel (EIA 2010a). The transportation sector consumes 72 percent of all petroleum used in the U.S.

The transportation sector is comprised of both highway vehicles (cars and trucks) and nonroad vehicles such as locomotives, marine vessels, and aircraft. Transportation defined broadly also includes energy expended to move oil, natural gas, and other fluids through pipelines.

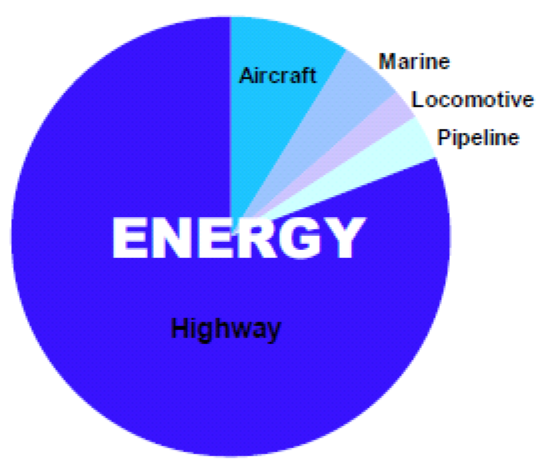


Figure 1. Transportation Energy Use by Mode.

Highway vehicles include both light-duty vehicles – cars and light trucks used primarily for personal transportation – and heavy-duty trucks and buses which are primarily commercial vehicles and are used for freight and passenger transportation. The vast majority of light-duty vehicles operate on gasoline, while virtually all heavy-duty vehicles, both highway and nonroad, operate on diesel fuel. Aircraft, marine vessels, and locomotives also operate virtually exclusively on diesel fuel.

Pipelines require energy to move liquid and gaseous fuel. Most oil and refined product pipelines are operated by pumps that are driven by electric motors. Most natural gas pipelines are operated by compressors driven by internal combustion engines powered by natural gas (Shell 2010).

Comparing Transportation Modes

See Figure 1 for a breakdown of transportation energy use by mode. As shown, 81 percent of energy used for transportation in 2008 was consumed by highway vehicles; aircraft consumed 9 percent, marine vessels consumed 5 percent, pipelines consumed 3 percent and locomotives consumed 2 percent. The percentage of total transportation energy consumed by highway vehicles has been relatively constant for the last 25 years.

Highway Vehicles. In 2008, there were 238 million light-duty vehicles registered in the U.S. These vehicles traveled 2.7 trillion miles and consumed 133 billion gallons of gasoline. In 2008, the average U.S. light-duty vehicle traveled 11,432 miles and burned 557 gallons of gasoline. In 1970, light trucks (pickups, SUVs, vans) comprised less than 14 percent of the light-duty fleet, but their percentage has risen steadily over time; in 2008, 42 percent of light-duty vehicles were light trucks.

In 2008, there were 9 million heavy trucks registered in the U.S. These vehicles traveled 227 billion miles and burned 37 billion gallons of diesel fuel. In 2008, the average U.S. heavy truck traveled 25,253 miles and consumed 4,718 gallons of diesel fuel.

In 2008, the number of miles traveled by the U.S. highway fleet declined, compared to the previous year, for the first time in 28 years. Between 1985 and 2005, total fleet miles grew at an average annual rate of 3.4 percent.

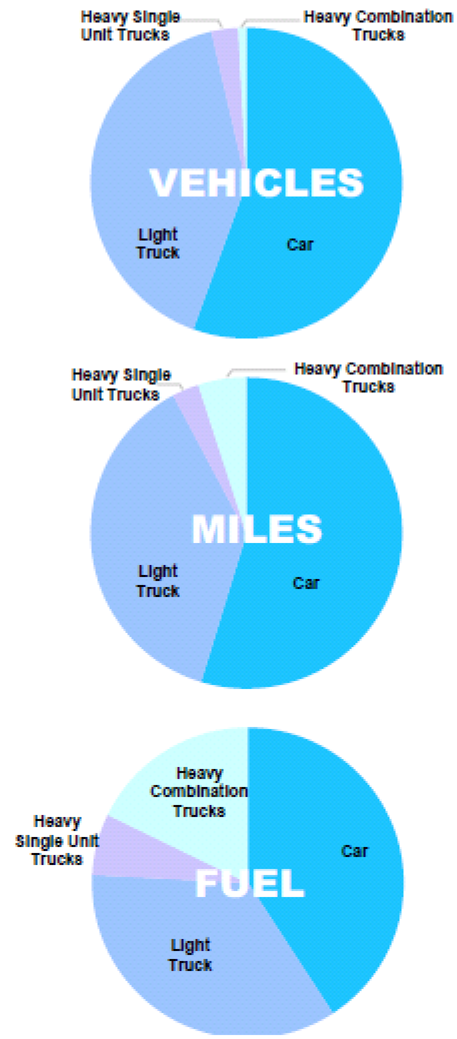


Figure 2. Vehicles, Fleet Miles and Fuel Use for Highway Vehicles

See Figure 2 for a comparison of highway vehicles, vehicle miles, and fuel use[1] by vehicle type in 2008. As shown, while heavy trucks accounted for less than 4 percent of vehicles and less than 8 percent of vehicle miles, they consumed almost one quarter of all fuel used by the highway fleet. Over the last thirty years, the percentage of total vehicles and fleet miles

[1] In this figure fuel use is shown as percentage of total energy used, not percentage of total gallons used. This accounts for the fact that a gallon of diesel fuel contains approximately 15 percent more energy than a gallon of gasoline.

accounted for by heavy trucks has remained fairly constant, but the percentage of total highway fuel consumed by these vehicles has increased (from 17 percent in 1978), because their fuel economy has remained fairly flat while the fuel economy of light-duty vehicles has increased.

The majority of fuel used by heavy trucks is consumed by the largest, combination trucks (i.e. tractor-trailers). These trucks, which are used to haul freight, typically drive many more miles annually than light-duty vehicles or heavy single-unit trucks, and due to their size and weight they use more fuel per mile. In 2008 heavy trucks (mostly combination trucks) carried 1.3 trillion ton-miles of freight[2].

Public Transit. According to the American Public Transportation Association (APTA), there are more than 7,700 organizations that provide public transportation in the U.S., some of which operate more than one mode. Seventy two hundred of these organizations (93 percent) provide demand-response "paratransit" bus service, and 1,100 operate fixed-route bus service. There are also 15 heavy urban rail (i.e. subway) systems, 33 urban light rail systems, and 23 commuter rail systems operating from the suburbs into urban areas (APTA 2010). In 2008, five percent of workers used transit for daily commuting, and 59 percent of all transit trips were work related.

In 2008, 53 percent of all public transit trips were taken by bus, 34 percent were taken by heavy urban rail, and 9 percent were taken by light rail and commuter rail (APTA 2010). The largest transit system in the country is operated by the Metropolitan Transportation Authority (MTA) in New York City. MTA's operations encompass the MTA New York City Transit subway system and fixed-route and paratransit bus systems, as well as two commuter rail lines. In 2008, 32 percent of all U.S. public transit trips were taken on MTA buses and trains.

A 2007, report by APTA identified public transportation users as, on average, poorer than the U.S. average. The median household income was $39,000, compared to $44,400 for all Americans (2004 $). However, roughly one in five had household incomes below $15,000 (APTA 2007). Not included in the APTA assessments, school bus fleets are a common form of public transit that have a unique, and particularly vulnerable, group of users.

From 1995 to 2008, public transportation ridership increased by 38 percent – out pacing both the increase in the population and the increase in personal vehicle miles traveled (VMT); total ridership in 2008 was the highest it had been in 52 years. Total ridership fell by 3.8 percent in 2009 – likely due to the poor economy and exacerbated by service cut-backs resulting from lower state and local funding (APTA 2010).

Aircraft. In 2008, U.S. and international major air carriers operated over 7,800 aircraft which flew over 8 billion revenue miles (824 billion passenger miles), and carried over 35 billion ton-miles of freight. The general aviation fleet (not-for-hire aircraft with more than 20 seats, on-demand and commuter operations, and agricultural aircraft) contained an additional 228,663 aircraft which accumulated 26 million hours of flight time. Air transportation has been getting steadily more efficient in the last 20

[2] One ton-mile is defined as one ton of freight carried one mile. This is the metric usually used to compare freight operations.

years. The average energy intensity (Btu/passenger-mile[3]) of major air carriers was 37 percent lower in 2008 than it was in 1988. Part of the improvement was due to more efficient aircraft and part of it was due to more efficient operations – the average passenger load factor was 79 percent in 2008 compared to 62 percent in 1988[4].

Marine. In 2008, there were approximately 40,000 marine vessels operating to, from and between U.S. ports. These vessels carried 521 billion ton-miles of freight. Water-borne freight tonnage dropped by 3 percent in 2008, compared to the previous year. The long-term trend, however, is for increased freight shipments by water. Between 1987 and 2007, water-borne freight tonnage increased at an average annual rate of 1.5 percent.

Rail. The seven largest rail companies in the U.S., based on annual gross revenue, are designated Class I railroads; together these companies operate 67 percent of rail industry mileage and take in 94 percent of rail industry revenue (see Table 1 and Figure 3). In 2008, the Class I railroads operated 24,000 locomotives and 450,000 freight cars, which they used to carry 1.8 trillion ton-miles of freight. Over the last twenty years, rail freight tonnage has increased at an average annual rate of 1.9 percent, while freight ton-miles have increased at an average annual rate of 3.9 percent. This is because the average length of haul has increased by 30 percent.

Table 1. U.S. Class I Railroads

Railroad	Revenue ton-miles (billions)
Burlington Northern & Santa Fe	664
Union Pacific	563
CSX Transportation	248
Norfolk Southern	195
Canadian National, Grand Trunk	53
Kansas City Southern	30
Soo Line	24

[3] One passenger-mile is defined as one passenger carried one mile. This is the metric usually used to compare different passenger transit modes

[4] Passenger load factor = occupied seats ÷ available seats

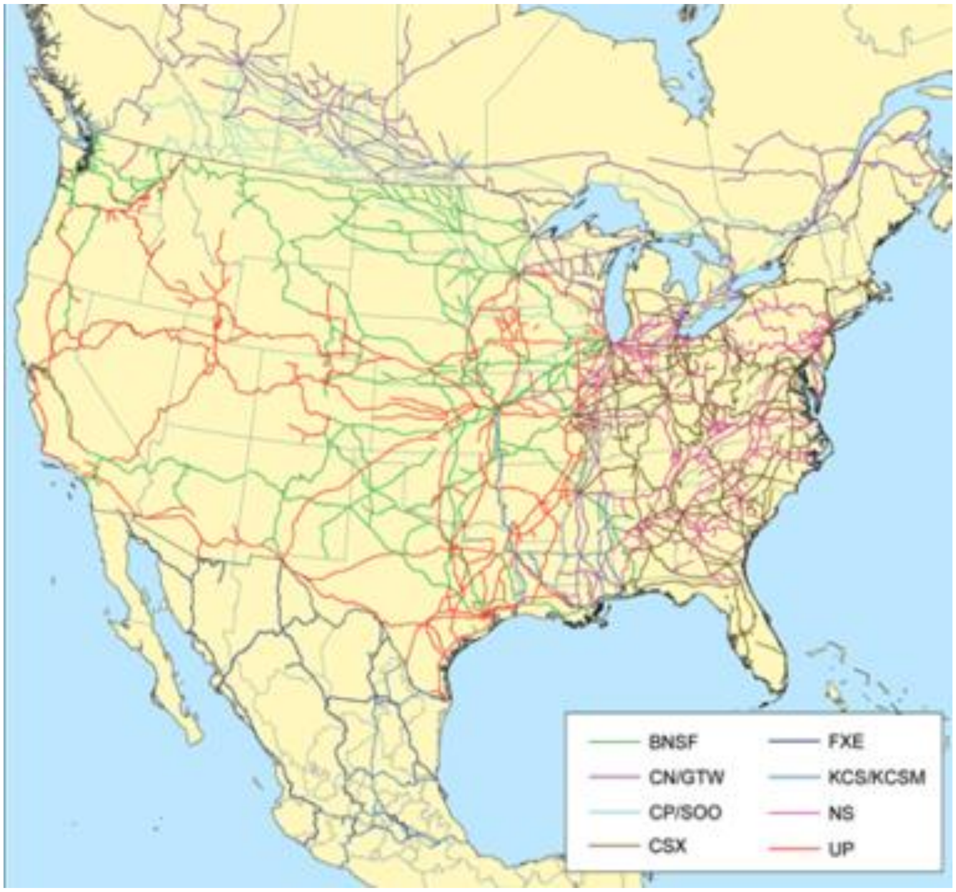


Figure 3. U.S. Class I Freight Railroads

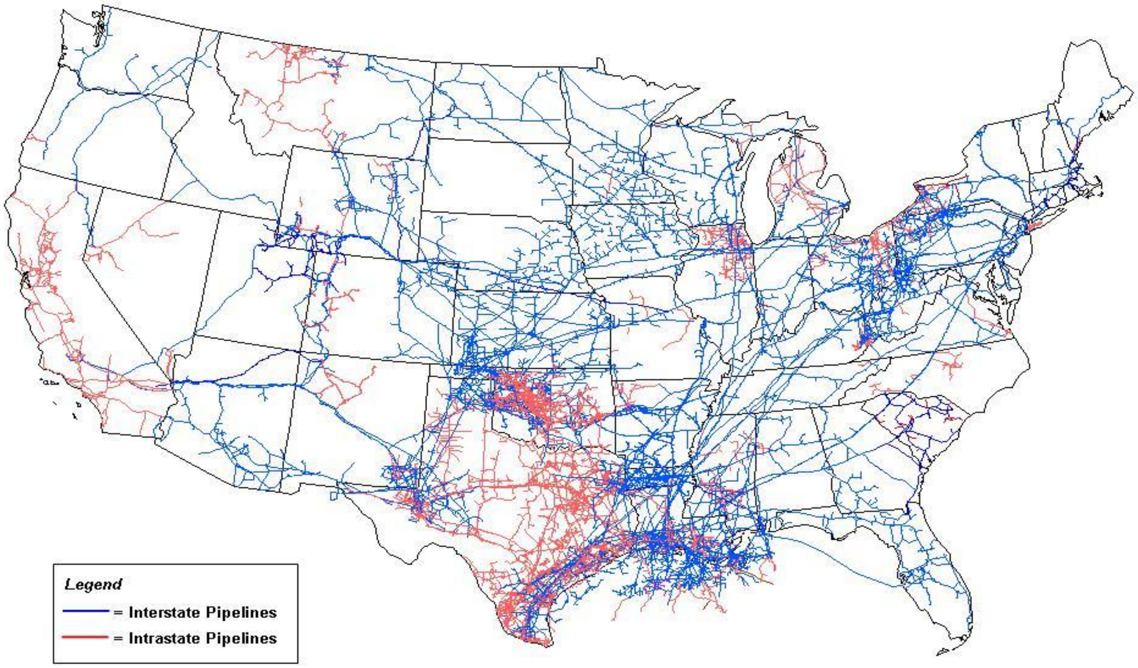
Pipelines. There are over 500,000 miles of pipelines installed throughout the U.S. that carry crude oil, natural gas, and refined petroleum products from the well head to the refinery and between regional markets. See Table 2 for a breakdown of pipeline mileage by type, and Figure 4 for a map of major pipeline routes.

Table 2. U.S. Pipeline System

Type	Miles
Crude Oil	
Gathering Lines	30,000 – 40,000
Trunk Lines	55,000
Refined Products	95,000
Natural Gas	
Gathering Lines	20,000
Transmission Lines	278,000
Distribution mains [1]	1,800,000

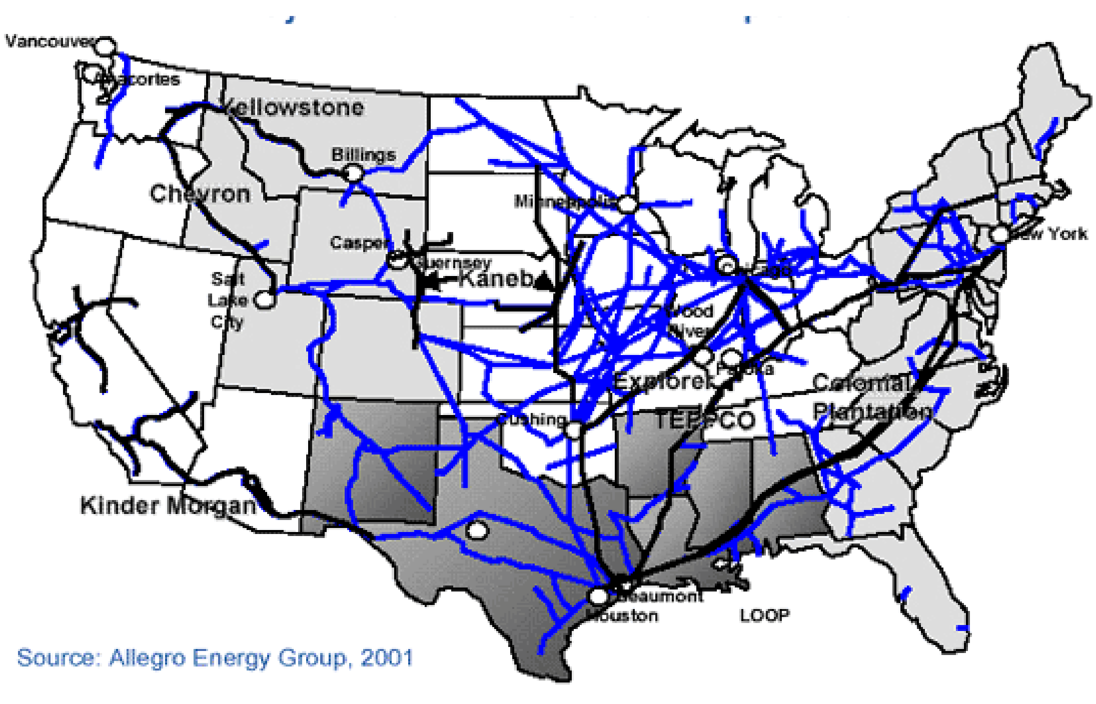
Source: www.pipeline101.com

[1] Distribution to houses and business within cities; operated by local gas utilities



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

Natural Gas Pipelines



Refined Product Pipelines

Figure 4. Major U.S. Natural Gas and Refined Products Pipeline Routes

See Figure 5 for the proportion of total freight carried by each mode in 2008. As shown, 43 percent of total ton-miles of freight were carried by rail roads, 31 percent were carried by highway trucks, 13 percent were carried by pipeline, 12 percent were carried by water, and 1 percent was carried by air.

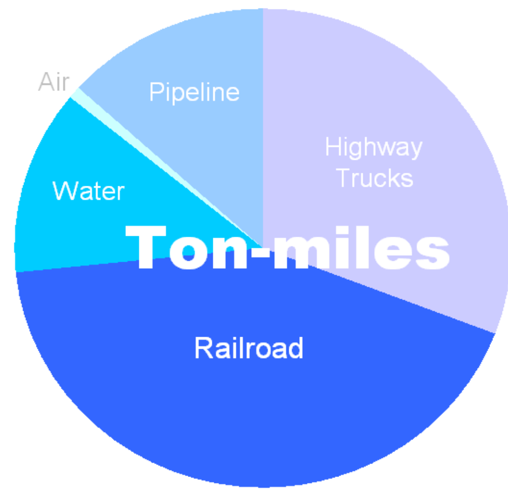


Figure 5. Percentage of Freight (ton-miles) Moved by Mode in 2008

Comparing Energy Intensity

As shown in Figure 6, railroads are the most efficient way to carry freight, followed by water transport. On average trucks have more than three times the energy intensity of railroads – that is, they use three times as much energy to carry a ton of freight one mile. By comparison, the efficiency of passenger transportation varies, not surprisingly, with the number of passengers that are transported relative to the size of the vehicle – what is often referred to as the "load factor."

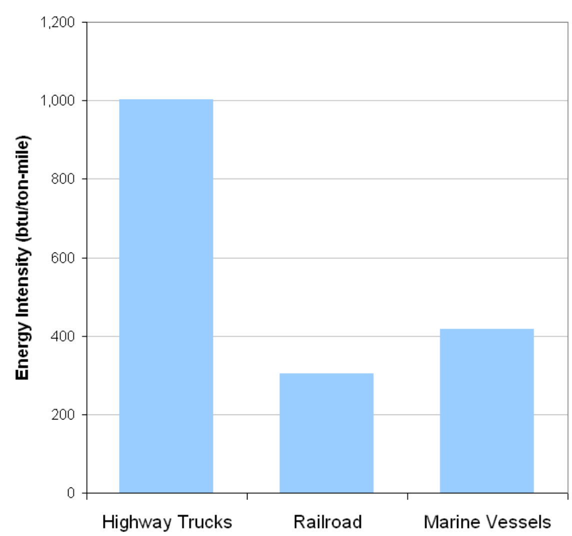


Figure 6. Energy Intensity of Freight Modes

Figure 7 includes a comparison of the energy intensity of different passenger modes. As shown, single commuters using a personal car use the most energy per passenger-mile, while a four-person car pool is one of the most efficient ways to move people to work. The average efficiency of fixed route public transportation is highly variable from city to city because it is dependent on how many people use the system. The average energy intensity of transit buses shown in Figure 7 is based on the U.S. average passenger load of only 11 people. Transit buses typically have 40 or more seats, so that in dense cities, particularly during peak periods when buses are full, they are a very efficient mode; the same is true of trains. Air travel is less efficient than the other fixed-route "public" modes (bus, train).

However, the most efficient mode may not always be the cleanest due to differences in emissions rates on a grams per gallon basis (as discussed below, new cars and trucks have to meet more stringent emissions standards the heavy diesel vehicles used for other modes of transportation (i.e., bus or rail)). To show how they can differ, included in Figure 7 are estimates of the emissions intensity of NOx in grams per passenger-mile. While a passenger in a single commuter car is less efficient on an energy (Btu) basis than a passenger onboard an AMTRAK train, the intensity of NOx emissions from the car on a passenger-mile basis is about a quarter of the emissions intensity from the train on the same basis. That situation exists because diesel locomotive engines have significantly higher emissions rates (grams of NOx per gallon of fuel) than modern gasoline cars.

Similar to the energy intensity discussion above, variability in NOx rates within the modes is attributable to utilization rates. For example, while diesel commuter rail trains and diesel AMTRAK trains have the same emissions rate (270 g NOx/gallon); they have different utilization rates (i.e. more passengers are carried on commuter rails per gallon of fuel burned). This is likely due to the fact that 1) commuter rail trains generally do not have café cars and sleeping cars, and 2) the average load factor (occupied seats divided by available seats) is higher for commuter rail trains because they are clustered around cities with heavy use during rush hour and do not make long distance trips across the country. The higher utilization drives lower NOx intensity for commuter rail compared to AMTRAK. Further, Figure 7 is based on U.S. averages, and there is significant variability in train fuel use and utilization depending on where in the country they are used. For example, in the Northeast corridor AMTRAK has high utilization and runs almost exclusively on electric power. As a result, AMTRAK trains running in the Northeast corridor would have a NOx intensity competitive with, and likely lower than, commuter rail.

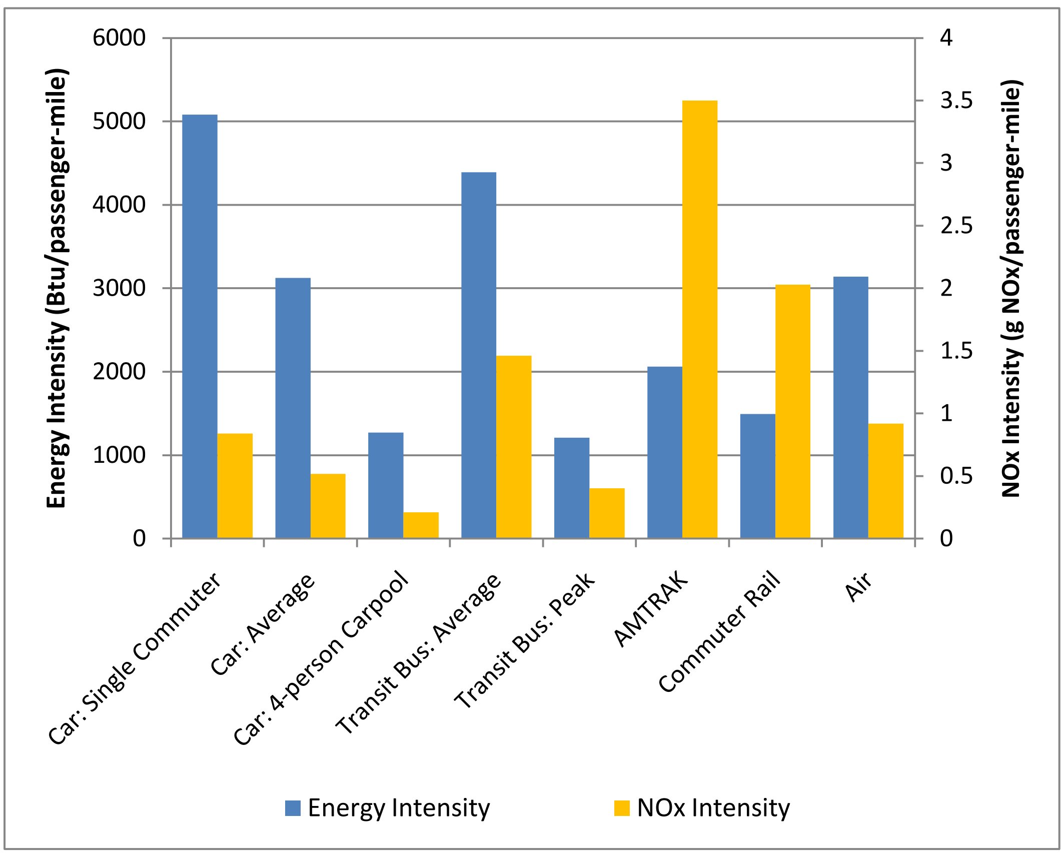


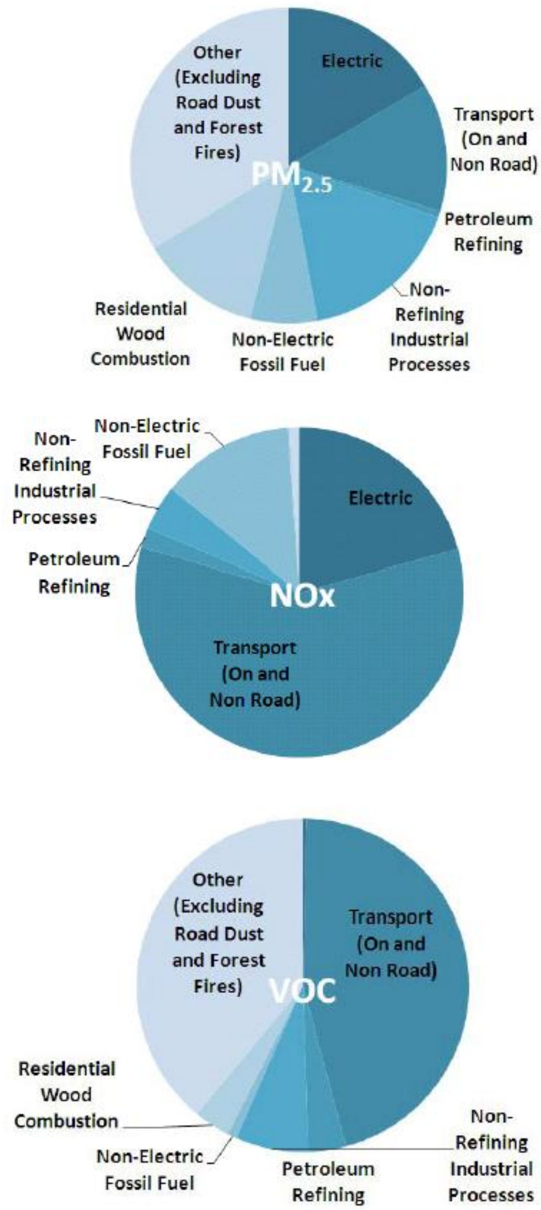
Figure 7. 2006 Energy and NOx Emissions Intensity of Passenger Modes (MJB&A 2008)

Transportation Air Emissions

The most significant health impacts associated with transportation are associated with tailpipe emissions from the combustion of gasoline and diesel fuel in automotive engines. As shown in Figure 8, collectively, transportation sector emissions (including both on road vehicles and non road vehicles and equipment) make up about 13 percent of primary fine particulate matter ($PM_{2.5}$) emissions[5], 59 percent of nitrogen oxide (NOx) emissions, and 46 percent of volatile organic compound (VOC) emissions. The transportation sector is responsible for about a third of carbon dioxide (CO_2) emissions from the U.S. economy. Overall, transportation sources are not a significant source of national sulfur dioxide (SO_2) or mercury emissions, which are largely the result of electric power generation. However, because they burn high sulfur residual fuel, ocean-going marine vessels can be a significant local source of SO_2 emissions; this is particularly true in cities with large, active ports, such as Los Angeles, New York, New Orleans, and Houston.

Emissions from petroleum refining, transport, and storage add another one to two percent of national $PM_{2.5}$ and NOx emissions, and four percent of VOC emissions.

Approximately one third of transportation PM emissions, half of NOx emissions, and 95 percent of VOC emissions come from gasoline engines (mostly cars and light trucks). Approximately two thirds of transportation PM emissions, and half of NOx emissions, come from diesel engines – highway trucks, marine vessels, locomotives, and aircraft.[6]



Source: EPA

Figure 8. Contribution of Transportation to Air Emissions (Excluding Fugitive Emissions, and Forest Fires)

Particulate matter (PM) refers to a mix of very tiny solid and liquid particles. Researchers categorize particles

[5] In this figure total $PM_{2.5}$ emissions do not include fugitive dust, such as road dust, or emissions from natural and structural fires.

[6] While aircraft burn diesel fuel, most are powered by turbine (jet) engines. These external combustion engines are very different than the internal combustion "diesel engines" in trucks, locomotives, and marine vessels. Air craft jet engines are similar to the small, natural gas or diesel-fueled "peaking turbines" used to generate electricity.

according to size, grouping them as coarse, fine and ultrafine. They also vary in chemical composition.

Even short-term exposure to PM can kill. Peaks or spikes in PM can last for hours to days. Deaths can occur on the very day that particle levels are high, or within one to two months afterward. PM does not just make people die a few days earlier than they might otherwise—these are deaths that would not have occurred if the air were cleaner (EPA 2009e).

The Environmental Protection Agency released the most recent review of the current research on particle pollution in December 2009 (EPA 2009e). The Agency had engaged a panel of expert scientists, the Clean Air Scientific Advisory Committee, to help them assess the evidence, in particular research published between 2002 and May 2009. EPA concluded in the published Integrated Science Assessment, that particle pollution caused multiple, serious threats to health. Their findings are highlighted in the box at right.

EPA Concludes Fine Particle Pollution Poses Serious Health Threats

- ✓ Causes early death (both short-term and long-term exposure)
- ✓ Causes cardiovascular harm (e.g. heart attacks, strokes, heart disease, congestive heart failure)
- ✓ Likely to cause respiratory harm (e.g. worsened asthma, worsened COPD, inflammation)
- ✓ May cause cancer
- ✓ May cause reproductive and developmental harm

Source: U.S. Environmental Protection Agency, *Integrated Science Assessment for Particulate Matter*, December 2009. EPA 600/R-08/139F.

Diesel particles have been studied separately from other ambient particles because of some distinctive characteristics. While mostly carbon, diesel particles also carry with them dozens of hydrocarbons also present in diesel exhaust, which are adsorbed onto the carbon core. More than forty potential components of diesel exhaust (for example benzene and formaldehyde) are designated as hazardous air pollutants by EPA; fifteen of these substances are also listed by the International Agency for Research on Cancer as known, probable, or possible human carcinogens (EPA 2002; IARC 2010). Ultrafine diesel particles in the ambient air carry these toxins deep into the lung when inhaled. There is also growing evidence that diesel exhaust may worsen the effect of inhaled allergens (EPA 2004).

While transportation sources only account for eight percent of total primary $PM_{2.5}$ nationally, the nature and location of these PM emissions magnify their impact on human exposure. While most power plant and many industrial emission sources release combustion exhaust at the top of tall exhaust stacks, virtually all exhaust from transportation vehicles is emitted at ground level where people live, work, and breathe. Individuals who live or work near heavily trafficked roadways, or near locations with heavy concentrations of diesel vehicles – for example freight truck depots, rail yards, ports, and airports – have the greatest exposure.

These near-roadway exposures are of growing concern, and may affect many more people than previously thought. The Health Effects Institute (HEI) in 2010 published the most recent review of the health effects from exposures to traffic-generated air pollutants. They concluded that as much as 30 to 45 percent of people in large North American cities live in areas that were impacted by traffic-related air pollution, a zone they identified as 300 to 500 meters from the roadside. The HEI review concluded that the evidence showed traffic-generated pollution causes asthma attacks in children and may cause the onset of asthma, premature death, impaired lung function and cardiovascular disease (HEI 2010).

In 2005, the Clean Air Task Force estimated that by 2010, national exposure to diesel fine particles would annually result in 15,000 hospital admissions, 15,000 emergency room visits for asthma attacks, 27,000 non-fatal heart attacks, 2.4 million lost work days, and 21,000 premature deaths (CATF 2005).

SO_2, VOC and NOx emissions from transportation vehicles also directly impact lung health and contribute to ground-level ozone and fine particle air pollution, as well as regional haze.

- **Direct impacts.** NOx and SO_2 can trigger asthma attacks and make breathing difficult. NOx can increase the risk of developing infectious disease.
- **Ozone.** Even more critical than their direct impacts are the roles of NOx and VOCs in forming ozone. The East, Midwest, and Southeastern states have long struggled to meet the national ozone standards, in part because of NOx and VOC emissions from transportation sources. Ozone can trigger serious respiratory problems, including airway irritation, aggravation of asthma, increased susceptibility to respiratory illnesses like pneumonia and bronchitis, and permanent lung damage with repeated exposures, as well as premature death.
- **Secondary Particle Pollution.** In addition to the primary PM emitted directly from vehicle tail pipes, SO_2 and NOx emissions react in the air to form additional fine particles (secondary PM). Fine particle air pollution can cause or contribute to asthma attacks, heart attacks, stroke, as well as increase the risk of premature death in infants and young children as well as adults.
- **Nitrogen Deposition.** NOx emissions are also associated with nitrogen deposition, which can impair water quality by overloading a water body with nutrients.

CO_2 is the most prevalent of anthropogenic greenhouse gas emissions, although ozone is also a potent greenhouse gas. Greenhouse gases trap heat in the atmosphere and at elevated concentrations lead to global climate change.

Environmental Justice

Underlying the broader health impacts of transportation and the American Lung Association's policy positions are concerns about environmental justice. In its *Interim Guidance on Considering Environmental Justice During the Development of an Action*, EPA has defined environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies" (EPA 2010g). EPA goes on to say:

- Fair treatment means that no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental, and commercial operations or programs and policies.

- Meaningful Involvement means that: 1) potentially affected community members have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; 2) the public's contribution can influence the regulatory agency's decision; 3) the concerns of all participants involved will be considered in the decision-making process; and 4) the decision-makers seek out and facilitate the involvement of those potentially affected.

Broad, national-level policy decisions impact public health and air quality, but transportation can impact different communities differently. For example, poor and disadvantaged communities bear a disproportionate burden of diesel PM exposure because of the location of many major transportation facilities (major highways, rail yards, freight depots, ports) in and near their neighborhoods. Others include limited transportation options for access to services and employment.

EPA Regulation of Pollutants from New Vehicles and Engines

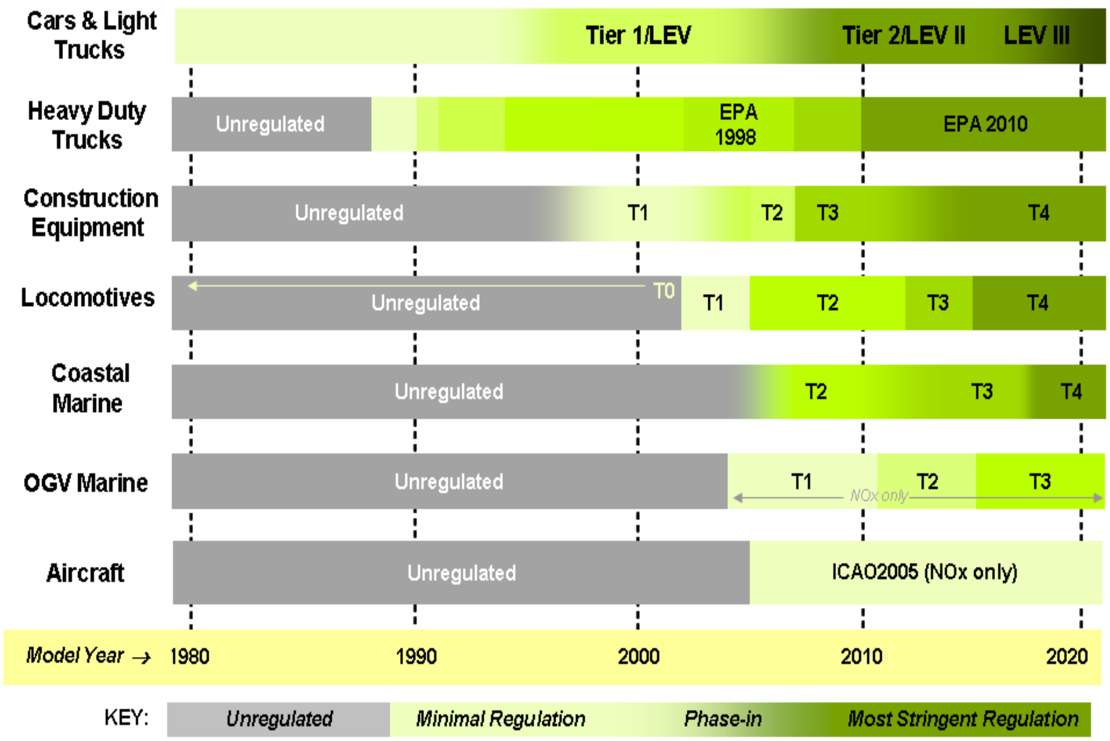
Under the Clean Air Act, EPA regulates the allowable level of exhaust emissions from new vehicles and engines. There are four pollutants regulated for all transportation sources: PM, NOx, carbon monoxide (CO), and VOC. EPA does not yet regulate CO_2 emissions from new engines and vehicles but they have proposed rules to do so in the future – see below discussion.

EPA emission standards for cars and light trucks are expressed as allowable mass of emissions per mile driven – grams per mile (g/mi) – and certification is based on testing of the entire vehicle. EPA uses a different approach with heavy-duty vehicles. EPA regulates emissions from heavy-duty engines, not vehicles; emissions limits are expressed as allowable mass per unit of work done – grams per brake horsepower-hour (g/bhp-hr). Heavy-duty vehicles are regulated differently than light-duty vehicles because heavy-duty vehicle markets are much more complicated. Heavy-duty vehicles and engines come in a much broader range of configurations and sizes. The heavy-duty vehicle industry also has a more complicated structure, with more manufacturers and greater disaggregation in the manufacturing process.

EPA imposes a separate regulatory regime (testing procedures and numerical emissions limits) for different types of heavy-duty engines. There are separate standards for engines used in heavy-duty highway trucks, nonroad construction and agricultural equipment, locomotives, marine vessels, and aircraft.

Emissions limits for all types of new transportation vehicles have been tightened over the years. While EPA first imposed emissions limits on new cars in the 1970s, emissions from heavy-duty highway engines were first regulated in the 1988 model year, and new engines for marine vessels were not regulated until the 2004 model year. See Figure 9 for a timeline of emissions regulation by vehicle type. The more stringent limits have significantly cut emissions; for example, the average new car sold in 2010, and subject to EPA Tier 2 limits, emits 88 percent less NOx and 90 percent less PM than a car sold ten years ago (subject to Tier 1 limits). Similarly, the average new heavy-duty highway engine sold in 2010 emits 95 percent less NOx and 90 percent less PM than an engine sold ten years ago.

The EPA Tier 2 light-duty vehicle standards allow manufacturers to sell some cars that emit more than others. Manufacturers are allowed to certify each vehicle model into one of eight "bins" with different emission limits for each pollutant. For example, Bin 5 vehicles must emit no more than 0.07 g/mi NOx, 0.09 g/mi non-methane organic gases (NMOG) and 0.01 g/mi PM. Bin 8 vehicles (the most lenient standard) can be more than twice as dirty – they are allowed to emit up to 0.20 g/mi NOx, 0.125 g/mi NMOG, and 0.02 g/mi PM. The most stringent standard is Bin 1, which is a zero emission vehicle. While different models can be certified to more lenient standards, the sales-weighted average NOx emissions for all vehicles sold by each manufacturer can be no more than 0.07 g/mi – equivalent to Bin 5.



NOTES: EPA Tier 2 and California LEV II light-duty standards were phased in over several model years based on fleet average requirements.

Construction equipment and coastal marine vessel standards were phased in over several model years based on engine size.

OGV = Ocean-going vessel (cruise ship, tanker, cargo vessel). These vessels have very large and unique engines that are different than the engines in smaller harbor craft (ferries, tugs, work boats), and they also burn residual fuel. EPA T1-T3 standards only apply to U.S.-flagged vessels.

Beginning in calendar year 2000, Tier 0 locomotive standards apply retroactively to locomotive engines built from 1973 – 200, 1 when the engine is rebuilt or remanufactured.

Figure 9. Timeline of EPA Emission Standards for New Vehicles and Engines

EPA emission standards are separate from fuel economy standards, which are discussed below. Emission standards for light-duty vehicles are expressed as a limit on allowable grams of pollutant per mile. So getting more miles to the gallon would not necessarily significantly reduce NOx, PM, and VOC emissions. This is especially true because vehicles meet the most stringent emission standards primarily by treating the emissions before they leave the car (with a three-way catalyst) rather than by reducing emissions generated by the engine.

EPA Tier 2 standards apply to all light- and medium-duty passenger vehicles up to 10,000 pounds gross vehicle weight (GVWR) no matter what fuel they use – the same numerical limits apply to gasoline-, diesel-, natural gas-, and ethanol-fueled vehicles. The GVWR limit of 10,000 pounds includes all cars and most pickup trucks and vans, and even the largest SUVs. The largest pickups and vans (i.e. Ford F350) have GVWR above 10,000 pounds and are considered medium heavy-duty trucks, subject to heavy-duty engine standards. Most of these large pickups and vans have diesel engines.

The California Air Resources Board (CARB) sets their own emission standards for light-duty vehicles sold in California, which have traditionally been more stringent than EPA standards. Fourteen other states have formally adopted California standards for new light-duty vehicles in lieu of EPA standards, effective between model year 2008 and 2011[7]. At the same time that EPA was phasing in Tier 2 standards (model year 2004 – 2010), California phased in Low Emissions Vehicle (LEV) II standards.

Under California LEV II standards, cars can be certified into one of four categories: LEV, ultra-low emission vehicle (ULEV), super ultra-low emission vehicle (SULEV) and partial zero emission vehicle (PZEV). Not all cars certified to California standards are cleaner than those certified to EPA Tier 2 standards. The numerical emissions limits for a LEV-certified vehicle are the same as EPA Tier 2/Bin 5. ULEV emission limits are the same as EPA Tier 2/Bin 3 for NMOG and CO, but less stringent for NOx. SULEV limits are the same as EPA Tier 2/Bin 2 for NMOG and NOx, but more stringent for CO. PZEV has the same numerical limits as SULEV, but imposes a longer emissions warranty period and tighter controls on evaporative emissions (NMOG) from the vehicle fuel system. See Table 3 for a comparison of EPA Tier 2 and California LEV II standards.

Table 3. Comparison of EPA Tier 2 and California LEV II Emission Limits

	Emissions Limits - g/mi								
LEVEL	EPA Tier 2				LEVEL	Califonia LEV II			
	NOx	NMOG	CO	PM		NOx	NMOG	CO	PM
Bin 8	0.20	0.125	4.2	0.02					
Bin 7	0.15	0.09	4.2	0.02					
Bin 6	0.10	0.09	4.2	0.01					
Bin 5	**0.07**	**0.09**	**4.2**	**0.01**	**LEV**	**0.07**	**0.09**	**4.2**	**0.01**
Bin 4	0.04	0.07	2.1	0.01					
Bin 3	0.03	0.055	2.1	0.01	**ULEV**	0.07	0.055	2.1	0.01
Bin 2	0.02	0.01	2.1	0.01	**SULEV** [1]	0.02	0.01	1.0	0.01
Bin 1	0.0	0.0	0.0	0.0	**ZEV**	0.0	0.0	0.0	0.0

[1] PZEV has the same numerical limits as SULEV, but a longer emissions warranty period and tighter controls on evaporative emissions

Under LEV II, manufacturers can certify individual vehicles to LEV, ULEV, SULEV, or PZEV standards, but were held to increasingly stringent sales-weighted fleet average requirements between model year 2004 and 2010 for both NMOG and NOx. In model year 2010 the California LEV II fleet average requirements for NMOG are about twice as stringent as EPA Tier 2 fleet

[7] State (effective model year): New Jersey (2009), Connecticut (2008), Washington (2009), Vermont (2009), New York (2009), Maine (2009), Rhode Island (2009), Massachusetts (2009), Oregon (2009), Arizona (2011), Pennsylvania (2008), Maryland (2011), Florida (pending legislative approval), New Mexico (2011)

average requirements (Dieselnet 2010).

In 2010, CARB proposed LEV III light-duty vehicle standards to be phased in between the 2014 and 2022 model years. LEV III will add several more certification categories, will combine NOx and NMOG into a single numerical limit for both pollutants, and will introduce even more stringent fleet average requirements. It will also further tighten PM limits, will increase the emission durability warranty period (to 150,000 miles), and will further tighten standards for evaporative emissions. The proposed LEV III fleet average standard for NMOG + NOx in 2022 will reduce emissions of these pollutants from new cars by approximately 73 percent compared to the actual sales-weighted fleet average for new cars sold in California in 2008 (Dieselnet 2010).

Current emissions limits for new highway vehicles (both light-duty and heavy-duty) are fairly stringent; current emissions limits for new nonroad diesel engines (construction, locomotive, marine) are significantly less stringent. Limits on these engines will not be as stringent as current limits on new highway diesel engines until Tier 4 standards are imposed between model years 2012 and 2017 (see Figure 9).

As vehicle fleets turn over to new, cleaner, vehicles total emissions per vehicle and per mile are significantly reduced. However, a lag in the imposition of stricter standards, and slower turn-over rates, means that current diesel fleets – both highway trucks and nonroad equipment - are much “dirtier” than the light-duty highway fleet, and will remain so for many years. EPA estimates that the light-duty Tier 2 regulations will reduce NOx emissions from light-duty vehicles by 42 percent in 2010 and 61 percent in 2015, compared to a baseline projection without them (EPA 1999).

Due to slower turn-over of the heavy-truck fleet, EPA estimates that the EPA 2010 heavy-duty engine standards will take longer to reduce diesel emissions; it will take until about 2025 before virtually all highway truck miles will be operated with “clean” EPA 2010 compliant trucks (EPA 2000). Locomotive and marine fleets will not even begin to turn over to the “cleanest” vehicles until 2015, and will likely not turn over completely until 2045 or later.

Regulation of Aircraft

About 70 percent of aircraft engine emissions are CO_2, and a little less than 30 percent are water vapor. NOx, CO, sulfur oxides (SOx), VOC, particulates, and other trace components including hazardous air pollutants make up less than 1 percent each (FAA 2005). Current worldwide regulations target aircraft emissions up to 3,000 feet (one kilometer) in the air. These regulations assume that anything emitted above 3,000 feet would be deposited into a part of the atmosphere that has significantly smoother air, meaning pollutants would not be affected by turbulent air that could mix them toward the ground. Thus, even though 90 percent of aircraft fuel is burned at cruise altitudes, only those pollutants that are emitted during takeoff and landing are regulated (MIT 2010).

As with other air pollutant emissions, aircraft emissions impact human health and contribute to premature mortality. The adverse health impacts of aircraft emissions are primarily from fine particulate matter. It is estimated that 8,000 global premature mortalities per year are attributable to aircraft cruise emissions. This represents one percent of global air quality-related premature mortalities from all sources (MIT 2010). In the U.S., roughly 160 annual premature mortalities are attributed to aircraft emissions. One-third of these are estimated to occur within the greater Southern California region. Other health impacts related to particulate matter, such as chronic bronchitis, non-fatal heart attacks, respiratory and cardiovascular illnesses are also associated with aircraft emissions (MIT 2009). Annual aircraft emissions in 2002 consisted of 73,153 metric tons of NOx and 1,948 metric tons of PM 2.5, based on landing and take-off emission inventories for the 148 commercial service airports in U.S. nonattainment areas (MIT 2009).

EPA regulates emissions from highway and non-road engines under Title II of the Clean Air Act (42 U.S.C. 7401-7671q). EPA's authority for setting aircraft engine emissions is contained in section 231 of Title II (MIT 2009). In 2005, EPA published the most recent standards for NOx for new commercial aircraft engines. These standards are equivalent to the NOx emission standards of the United Nations International Civil Aviation Organization (ICAO), and took effect on December 19, 2005. The 2005 NOx standards generally represent about a 16 percent reduction (or increase in stringency) from the earlier NOx standards. These regulations apply to aircraft engines designed and certified after the effective date on commercial aircraft that include small regional jets, single-aisle aircraft, twin-aisle aircraft, and 747s and larger aircraft (EPA 2009b).

While EPA long ago required the removal of lead in gasoline used in cars and other land-based non-road equipment, the Agency is in the early stages of regulating the use of lead in gasoline sold for aviation. Lead is not used in jet fuel, the fuel most commercial aircraft use. However, leaded aviation gasoline, known as AvGas, is used in smaller piston-engine powered aircraft, which are generally used for instructional flying, air taxi activities, and personal transportation. Lead emissions from aircraft using AvGas make up approximately half of EPA's national inventory of lead air emissions. EPA estimates that between 1970 and 2007, 34,000 tons of lead were emitted by piston-engine powered aircraft.

Emissions of lead from aircraft are a health concern, particularly for populations living, working or attending school near airports. The health effects of lead, once inhaled or ingested, are especially dangerous to children. Exposure to lead at an early age has been linked to effects on IQ, learning, memory, and behavior. In 2008, EPA substantially strengthened the national ambient air quality standards (NAAQS) for lead, finding that serious health effects occur at much lower levels of lead in blood than previously identified (EPA 2010h).

In April 2010, EPA released an advance notice of proposed rulemaking (ANPR) on emissions of lead from piston-engine powered aircraft. In this notice, EPA invited comment on the data available for evaluating lead emissions, ambient concentrations and potential exposure to lead from the use of AvGas. The ANPR responded to a 2006 Friends of the Earth petition that urged EPA to make a finding that lead emissions from general aviation aircraft endanger public health and welfare and issue a proposed new emission standard (EPA 2010h). EPA granted a 60-day extension to the comment period for the ANPR based on a request by a coalition of industry groups known as the AvGas Stakeholder Group (Lynch 2010). In June 2010, this group called on the Federal Aviation Administration(FAA) to lead a public-private partnership for finding an unleaded replacement to AvGas, based on its expected phase-out in future EPA regulations (EEA 2010). Presently the AvGas Stakeholders Group is working with the FAA, EPA and Congress on future aircraft fuels development (Lynch 2010). In addition, EPA is currently reviewing airport-specific lead inventories for 2008.

Regulation of Fuel Economy & CO_2 from New Vehicles and Engines

Since 1975, the fuel economy of new light-duty vehicles has been regulated by the National Highway Traffic Safety Administration (NHTSA) under the Corporate Average Fuel Economy (CAFE) program. Under CAFE not all models sold need to have the same fuel economy; all new vehicle models are tested and each manufacturer has to meet a sales-weighted fleet average fuel economy target. Under this system manufacturers can sell cars that have worse fuel economy than the average target value as long as they sell an equal number of cars with better fuel economy than the average.

Between 1978 and 1990, the CAFE fleet average standard for new cars was increased incrementally from 18 miles per gallon (MPG) to 27.5 MPG – where it remained, unchanged, for the past twenty years (through the 2010 model year). CAFE also includes fleet average standards for light trucks, which for the 2008 model year was 22.5 MPG (DOE 2010d). However, through 2008 light truck fuel economy standards did not apply to vehicles with a gross vehicle weight rating (GVWR) over 8,500 pounds (e.g., large pickups, vans, and SUVs).

In 2006, NHTSA established new requirements for light truck average fuel economy to apply between the 2008 and 2011 model years. In addition to specifically including larger vehicles with GVWR between 8,500 and 10,000 pounds, the new format applied different numerical standards for vehicles with different "footprint" (footprint = width x wheel base). The "reformed" standard rose to 24.1 MPG (fleet-wide average) for the 2011 model year (DOE 2010d).

In March 2010, NHTSA and EPA issued a joint rulemaking which establishes a new program to regulate fuel economy and greenhouse gas emissions from new cars and light trucks for model years 2012 – 2016. This new program assigns both a fuel economy target (MPG) and an equivalent target for CO_2 emissions in terms of maximum allowable grams CO_2 per mile (g/mi)[8]. The new program assigns different average fuel economy targets for vehicles with different footprints. The larger the vehicle, the lower the targets are for fuel economy, and the higher they are for CO_2 emissions. For example, a typical compact car might have a footprint of 40 square feet, and the fuel economy target for the 2016 model year would be 41.4 MPG (214 g CO_2/mile), while a full-sized car might have a footprint of 53 square feet and the fuel economy target would be 32.8 MPG (269 g CO_2/mile). A large pickup or SUV might have a footprint as large as 67 square feet – if so, the fuel economy target would be 24.7 MPG (358 g CO_2/mile).

EPA and NHTSA have begun to develop two new rules for fuel economy and green house gas reductions. One program would further develop fuel economy and CO_2 standards for light-duty vehicles from model year 2017 through model year 2025, and the other would set CO_2 emission and fuel economy standards for the first time for heavy-duty highway vehicles, beginning in the 2014 model year (EPA 2010c). In

[8] Assuming a constant value for the amount of carbon contained in a gallon of gasoline.

October 2010, the two agencies issued an interim technical report that reviewed the status of technologies that could be used to further improve light-duty vehicle fuel economy. The interim report estimated costs and benefits related to scenarios representing three percent, four percent, five percent and six percent annual increases in vehicle fuel economy (equivalent to 47 – 62 MPG in 2025) (EPA 2010c). The agencies expect to propose a rule for both programs by the end of September 2011, and issue final rules by the end of July 2012 (EPA 2010c).

EPA also announced its intention to review "for adequacy" the current non-greenhouse gas emissions regulations for new motor vehicles, new motor vehicle engines, and motor vehicle fuels, including tailpipe emissions standards for nitrogen oxides and air toxics, and sulfur standards for gasoline. If the EPA Administrator finds that new emissions regulations are required, EPA intends to promulgate such regulations "as part of a comprehensive approach toward regulating motor vehicles."

Production of Transportation Fuels

In 2009, petroleum-based products accounted for almost 94 percent of the energy consumed by the transportation sector. As shown in Figure 10, biofuels and natural gas accounted for almost six percent and electricity accounted for less than one percent of energy consumed by the sector. About 64 percent of the petroleum was consumed in the form of gasoline, about 21 percent in the form of distillate fuel oil (diesel fuel), and about 11 percent in the form of jet fuel. The remainder of petroleum-based energy consumed by the transportation sector was in the form of residual fuel oil and other petroleum products.

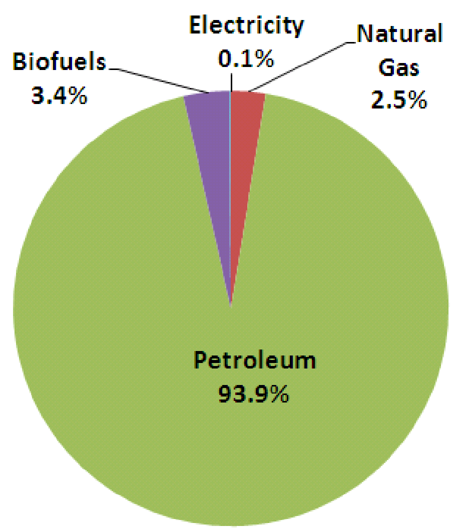


Figure 10. 2009 Energy Consumption by the Transportation Sector (EIA 2010)

Given its dominance in the market, this section focuses on the impacts of petroleum-based fuel production. The next section discusses recent trends in the transportation sector, including the growth of biofuels and the increased focus on electric vehicles.

Petroleum Extraction

Crude oil is removed from the ground by drilling deep wells and pumping it up to the surface. The crude oil is then transported to a refinery where it is refined into a number of fuel products. Air pollutants, particularly methane and other impurities in the crude, can be vented to the atmosphere (intentionally or unintentionally) and impact air quality. Additionally, the large engines used in drilling, production, and transportation processes burn natural gas or diesel and produce emissions that can particularly impact local communities.

In addition to the impacts on local air quality due to petroleum extraction, site accidents can result in significant releases of oil to the environment, threatening air and water quality as well as sensitive ecological areas on land. The Deepwater Horizon accident in the summer of 2010 provided a clear example of the magnitude of the harm that can be caused by an accident at a petroleum extraction site. The Deepwater Horizon event occurred at a time when oil industry experts and government officials were assuring the public about the safety of deepwater oil drilling.

Refining

Petroleum refining is an energy intensive process that uses physical, thermal and chemical processes to separate crude oil into its major fractions, which are then processed further into finished petroleum products. Fuels account for almost 90 percent of the petroleum products produced in the U.S., while finished products and petrochemical feedstocks each account for about 5 percent (STAPPA 2006).

The petroleum refining industry consumes large amounts of energy from byproducts of the refining process. About 65 percent of the energy it consumes for heat and power comes from refinery gas, petroleum coke and other oil-based byproducts. The combustion of these and other fossil fuels (primarily natural gas) produces a significant amount of air pollution including fine particulates, SO_2, NOx, and air toxics.

In addition to the emissions from on-site energy consumption, the refining process results in the release of air pollutants. Of particular concern are air toxics released in the catalytic cracking process. These air toxics vary by facility and process operations but may include: acetaldehyde, arsenic, antimony, benzene, beryllium, cadmium compounds, carbonyl sulfide, carbon disulfide, chlorine, dibenzo furans, formaldehyde, hexane, hydrogen chloride, lead compounds, mercury compounds, nickel compounds, phenol, 2,3,7,8 tetrachlorodibenzo-p-dioxin, toluene, and xylenes (mixed) (EPA 2001). The health effects associated with exposure to these air toxics can include cancer, respiratory irritation, and damage to the nervous system.

Table 4 summarizes the major sources and the primary air pollutants of concern.

There are 137 refineries operating in the U.S. with about 11 currently idle. These refineries have a capacity of 17.6 million barrels per day. Refineries are geographically concentrated. Texas, Louisiana and California are home to 45 percent of U.S. refineries and 57 percent of U.S. refining capacity (See Table 5). The next largest state by capacity is Illinois with 6 percent of capacity from four refineries.

Table 4. Major Air Emissions Sources at Petroleum Refineries

Combustion Device	Description	Typical Fuel	Primary Emissions of Concern
Industrial Boilers	On average smaller than boilers used for electricity generation, industrial boilers provide onsite steam and electricity to industrial facilities. Across the industrial sector, industrial boilers are the largest source of air emissions.	Petroleum Byproducts, Natural Gas	SO_2, NOx, PM, Air Toxics (dependent on fuel source)

Combustion Device	Description	Typical Fuel	Primary Emissions of Concern
Process Heaters	A process heater is an enclosed device in which solid, liquid, or gaseous fuels are combusted for the purpose of heating a process material (e.g., crude oil).	Oil, Byproduct Refinery Gases, Natural Gas	SO_2, NOx, PM, Air Toxics
Catalytic Cracking Units	Process unit that breaks down (cracks) longer chain molecules into smaller ones by heating and using catalysts.	Byproduct Refinery Gases, Natural Gas	Air Toxics, VOCs, SO_2, NOx, PM
Flares	Petroleum refineries use flares to combust vapors rather than discharging them to the atmosphere. Frequent flaring in routine, non-emergency situations or to bypass pollution control systems can produce excess emissions and violate permit conditions.	Refinery Process or Waste Gases	SO_2, NOx, PM, VOCs, Air Toxics

Table 5. Top Three States by Refining Capacity in the U.S. (EIA 2010)

	Total Refineries	Percent of U.S. Refineries	Capacity (Barrels per day)	Percent of U.S. Capacity
Texas	27	18%	4,740,019	27%
Louisiana	19	13%	3,171,923	18%
California	20	14%	2,047,218	12%
Other States	82	55%	7,624,630	43%
U.S. Total	148	100%	17,583,790	100%

Transport and Storage

From the refinery, the majority of petroleum products are transported by pipeline to storage facilities. From there, tanker trucks distribute gasoline and other products to consumers. The transport and storage of petroleum products can lead to emissions of volatile organic compounds (VOCs). These emissions are broadly categorized as loading losses and breathing losses. Loading losses occur as the product is transferred from one container to another and organic vapors from an empty tank are displaced by the liquid being loaded in the tank (e.g., from pipeline to storage, from storage to tanker, from gas pump to vehicle). Breathing losses occur as tank vapor space expands and contracts in response to daily changes in temperature and barometric pressure. Breathing losses occur in the absence of any liquid level change in the tank.

The gasoline distribution system is a source of VOC emissions, and is listed as an area source that contributes to urban emissions of hazardous air pollutants in EPA's Integrated Urban Air Toxics Strategy Assessment. EPA found that gasoline vapors contain two hazardous air pollutants: benzene and ethylene dichloride. The benzene contributions from the gasoline distribution system are about 36 percent of national urban emissions, and the ethylene dichloride are about two percent of national urban emissions. EPA subsequently concluded that ethylene dichloride emissions had been eliminated from this source category through the removal of lead from gasoline. EDC had been added to leaded gasoline to serve as a lead scavenger and prevent the unwanted buildup of lead deposits in engines (Federal Register 2008a).

In January 2008, EPA finalized a rule to reduce emissions of air toxics emissions for area source gasoline distribution facilities that include the pipelines and terminals that distribute gasoline to the end user, but also include end users such as service stations, farms, rental car agencies, and automobile manufactures. The rules require best available seals on storage tanks and pipelines, use of submerged fill pipes, leak testing, and best practices to prevent evaporative emissions (Federal Register 2008a). Separately, EPA finalized a rule to reduce emissions from gasoline dispensing facilities that requires installation of vapor detection and reduction systems (Federal Register 2008b).

U.S. Production versus Imports

In 2009, the U.S. imported roughly 52 percent of the crude oil and refined petroleum products that it consumed. The top five source countries of U.S. petroleum imports are Canada, Mexico, Venezuela, Saudi Arabia, and Nigeria. As shown in Figure 11, in 2009, 21 percent of petroleum used in the U.S. was imported from Canada, and 11 percent was imported from Mexico. The category listed as "Other" includes Russia (5 percent) and Iraq (4 percent), as well as Bahrain, Iran, Kuwait, Qatar, United Arab Emirates, and the Neutral Zone (between Kuwait and Saudi Arabia). In 2009, the U.S. imported about 12 million barrels of petroleum products a day, and exported about 2 million barrels per day (EIA 2010d).

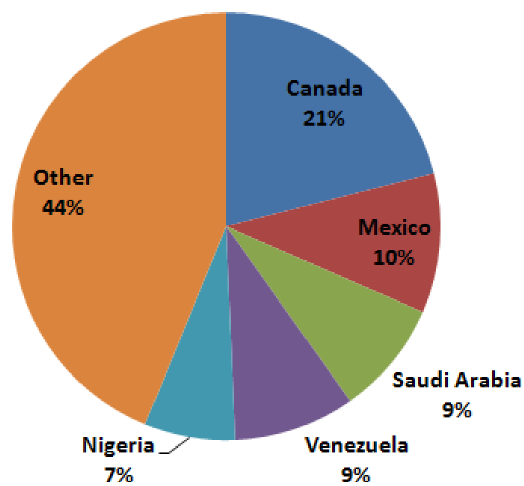


Figure 11. Percentage of Gross U.S. Petroleum Imports by Country

Transportation Funding System

The United States has adhered to the "user fee principle" in financing its transportation infrastructure for more than 50 years. Under this principle, users of highways pay for the construction and maintenance of roads. The federal government relies heavily on a fuel tax to support the cost of its highway system, and revenues from the tax go into the federal Highway Trust Fund (Huang et al. 2010).

The Highway Trust Fund holds taxes collected on motor fuels and truck-related taxes, including taxes on gasoline, diesel fuel, gasohol, and other fuels; truck tires and truck sales; and heavy vehicle use. In 1983, the fund was divided into the Highway Account and the Mass Transit Account. More than 80 percent of the total fund is directed to the Highway Account, including a majority of the fuel taxes as well as all truck-related taxes (GAO 2010). Table 6 summarizes the various taxes and the distribution of each.

Periodically, Congress enacts multiyear legislation that authorizes funding for the nation's surface transportation programs. In 2005, the Safe, Accountable, Flexible, and Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) authorized over $190 billion for a "Federal-Aid Highway Program" for fiscal years 2005 through 2009. The Highway Trust Fund is the principal source of funding for this authorization.

Because the Federal-Aid Highway Program operates on a user-pay system, wherein users contribute to the building and upkeep of the system, states have taken a strong interest in the rate of return on contributions. How funding has been distributed among states has been contentious. States that receive less than the estimated contributions of their highway users are known as "donor" states. States that receive more than the estimated contributions of their highway users are known as "donee" states (GAO 2010).

Table 6. Federal Highway Excise Tax Rates and Related Allocations to the Accounts of the Highway Trust Fund (Source: GAO 2010)

Motor Fuel Taxes				
Type of Excise Tax	Tax Rate (cents)	Distribution of tax		
		Highway Account, Highway Trust Fund (percent)	Mass Transit Account, Highway Trust Fund (percent)	Leaking Underground Storage Tank Trust Fund (percent)
Gasoline	18.4 per gallon	83. 9	15.5	0.5
Diesel	24.4 per gallon	87.9	11.7	0.4
Gasohol	18.4 per gallon	83.9	15.5	0.5
Liquefied petroleum gas	18.3 per gallon	88.4	11.6	0.0
Liquefied natural gas	24.3 per gallon	92.3	7.7	0.0
M85 (from natural gas)	9.25 per gallon	83.5	15.5	1.1
Compressed natural gas	144.47 per thousand cubic feet	93.3	6.7	0.0
Truck-related taxes- all proceeds to Highway Account				
Tires	9.45 cents for each 10 pounds of the maximum rated load capacity over 3,500 pounds			
Truck and trailer sales	12 percent of retailers sales price for tractors and trucks over 33,000 pounds gross vehicle weight (GVW) and trailers over 26,000 pounds GVW			
Heavy-vehicle use	Annual Tax for trucks 55,000 pounds and over GVW: $100 plus $22 for each 1,000 pounds (or fraction thereof) in excess of 55,000 pounds. Maximum tax: $550.			

The Federal Highway Administration within the Department of Transportation administers the Federal-Aid Highway Program and distributes most funds to the states through annual apportionments established by statutory formulas. Once the Federal Highway Administration apportions these funds, the money is available for states to allocate for construction, reconstruction, and improvement of highways and bridges on eligible federal-aid highway routes, as well as for other purposes authorized in law. The amount of federal funding made available through the Federal-Aid Highway Program ranged from $34.4 to $43.0 billion per year for fiscal years 2005 through 2009 (GAO 2010).

The demand for new roads and the cost of expanding and maintaining the transportation system have increased with population and economic growth. However, the current "user- fee" funding mechanism fails to meet the nation's current demands. In recent years, tax revenues have been unable to cover the costs of maintaining and improving the existing system. In addition, the increased fuel efficiency of motor vehicles has resulted in less fuel consumption per mile, and thus fewer tax dollars for the same amount of road use.

Policymakers have dealt with funding gaps in various ways, though rarely by raising federal gasoline taxes and other user fees. Some states have issued bonds or raised sales taxes through local referenda approved by voters. Despite growing budgetary problems, state and federal governments have reached into their general funds to fill this gap. The federal Highway Trust Fund, after being financially independent for more than fifty years, now relies on transfers from the general funds to stay solvent (Huang et al. 2010).

From fiscal years 2008 through 2010, Congress transferred a total of $34.5 billion in additional general revenues into the Highway Trust Fund. This means that, to a large extent, funding has shifted away from the contributions of highway users, breaking the link between highway taxes paid and benefits received by users. For many states, the share of Highway Trust Fund contributions and general revenue contributions are different, therefore state-based contributions to all the funding in the Trust Fund have become complicated. In addition, since March 2009, the American Recovery and Reinvestment Act of 2009 apportioned an additional $26.7 billion to the states for highways—a significant augmentation of federal highway spending that was funded with general revenues (GAO 2010).

Passed in 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) attempted to integrate public transit into the federal transportation policy framework. However, some modes of surface transportation remain outside these federal policies. Intercity passenger rail, for example, continues to be addressed in separate authorization bills, despite many parallels to the federal role with respect to highways (BPC 2009).

Public Transit

The total budget for all of the nation's public transportation systems was $55.5 billion in 2008, with $17.5 billion for capital investment and $38.0 billion for operating expenses. Total fares collected for public transit service and other agency earnings only covered 37.7 percent of annual operating expenses. The Federal government, through the Federal Transit Administration, provided 7 percent of operating funds and 39.9 percent of capital funds required to purchase or renew rolling stock and other infrastructure. Federal funding for public transportation comes from the Mass Transit Account of the Highway Trust Fund (see above), and is appropriated under multi-year omnibus transportation bills (currently SAFETU-LU). The remaining 55.3 percent of annual operating funds, and 60.1 percent of capital funds, were provided by city and state governments, generally via some type of sales tax (APTA 2010).

A survey released in April 2010 by the American Public Transportation Association indicates that U.S. transit systems currently face severe economic pressures due to declining state and local tax revenues precipitated by the recession of 2008 and 2009. The survey indicates that since January 2009, 59 percent of public transit systems have cut service or raised fares in response to falling subsidies. An additional 25 percent of agencies are considering cutting service or raising fares in the future. Of those agencies that have made cuts, 56 percent have cut rush hour service, 62 percent have cut off-peak service, and 40 percent have reduced their geographic coverage (APTA 2010).

Intercity Passenger Rail

As part of a strategy to prevent the collapse of the nation's railroads, the federal government took over passenger operations with the creation of Amtrak in 1971, allowing the remaining railroads to focus on shipping freight. However, it has proved difficult for Amtrak to provide financially viable national passenger rail service or to attract sufficient resources to maintain and operate their existing system. Amtrak has been forced to incur debt and defer maintenance on its own infrastructure, and has resulted in a dependence on Congressional appropriations.

Despite several attempts, no effort had successfully reformed the nation's passenger rail policy or integrated it with broader transportation policies and objectives (BPC 2009). However, using the Passenger Rail Investment and Improvement Act passed in 2008 and the American Reinvestment and Recovery Act in 2009, the Obama Administration used the economic recession to begin funding increased passenger rail. In January 2010, $8 billion in ARRA funding was allocated to the first projects, including high-speed rail between Orlando and Tampa, Florida. On October 28, the Secretary of Transportation announced a second phase, totaling $2.4 billion.

Airports

Every two years the Federal Aviation Administration (FAA) is required to provide the U.S. Congress with the National Plan of Integrated Airport Systems (NPIAS) which includes a five-year estimate of funding needed to support airport development and improvement. The NPIAS identifies nearly 3,400 existing and proposed airports that are significant to national air transportation and thus eligible to receive Federal grants under the Airport Improvement Program. It also includes estimates of the amount of money needed to fund infrastructure development projects that will bring these airports up to current design standards and add capacity to congested airports.

Through the Airport Improvement Program, FAA awards grants to public agencies (and, in some cases, to private owners and entities) for the planning and development of public-use airports. Large and medium primary hub airports can receive funding for 75 percent of eligible costs (or 80 percent for noise program implementation). Small primary, reliever, and general aviation airports can receive funding for 95 percent of eligible costs. Eligible projects include those improvements related to enhancing airport safety, capacity, security, and environmental concerns. Any professional services that are necessary for eligible projects — such as planning, surveying, and design — are eligible. Aviation demand at the airport must justify the projects, which must also meet Federal environmental and procurement requirements. Projects related to airport operations and revenue-generating improvements are typically not eligible for funding. Operational costs — such as salaries, equipment, and supplies — are also not eligible for AIP grants (FAA 2010).

The Airport Improvement Program was established by the Airport and Airway Improvement Act of 1982. Funds obligated for the program are drawn from the Airport and Airway Trust fund which is supported by collections related to passenger tickets, passenger flight segments, international arrivals/departures, cargo waybills, aviation fuels, and frequent flyer mile awards from non-airline sources like credit cards (FAA 2009).

Marine

The Maritime Administration within the U.S. Department of Transportation manages federal programs designed to promote the use of waterborne transportation and its integration with other segments of the transportation system. Among its programs are the Federal Ship Financing Program which provides loan guarantees to ship owners and shipyards to modernize the U.S. marine fleet. Vessels eligible for assistance generally include commercial vessels such as ferries; bulk, container, and cargo vessels; tankers; tugs; towboats; barges; dredges; oceanographic research vessels; floating power barges; offshore oil rigs and support vessels; and floating dry-docks. Additionally, the Maritime Administration manages a construction reserve fund, capital construction fund, and small shipyard grant program that provide resources to expand and improve U.S. maritime operations. Under the small shipyard grant programs, the federal government provides funding for 75 percent of a project with 25 percent matching funds from the shipyard. The American Recovery and Reinvestment Act included $100 million for the program, up from $10 million in 2008 (Maritime 2009).

This year, the Department of Transportation initiated America's Marine Highway Program, an initiative to move more cargo on the water rather than on highways. On August 11, 2010, the Transportation Secretary identified 18 marine corridors, 8 projects, and 6 initiatives for further development. The goal of the program is to identify routes where water transportation presents an opportunity to offer relief to landside corridors that suffer from traffic congestion, excessive air emissions or other environmental concerns and other challenges. The Maritime Administration made available $7 million for this program. Projects will be able to compete for this funding through a Notice of Funding Availability (DOT 2010b).

Recent Trends in Onroad Vehicles

The vast majority of light-duty vehicles on the road today, as well as new vehicles being purchased, are powered by conventional gasoline engines and operate on petroleum-derived gasoline fuel. Over the past twenty years, various alternative fuels and engine/drive train technologies have been developed and promoted for both light-duty and heavy-duty vehicles.

Some of these alternative fuels and technologies have the potential to reduce emissions of NOx, PM, and VOCs from transportation sources, but many are more specifically targeted toward reducing CO_2 emissions, and reducing petroleum use. Efforts to reduce petroleum use in the transportation sector are intended to enhance energy security by using locally produced energy sources rather than imported petroleum.

This section discusses the current status and potential benefits of the most significant of these alterative fuels and technologies, including natural gas, bio-derived fuels, electric vehicles, and hydrogen fuel cell vehicles.

Alternative Fuels

With relatively minor modifications, a gasoline engine (i.e. a spark-ignited, homogenous charge internal combustion engine) can operate on a range of volatile fuels, including natural gas, an alcohol such as ethanol or methanol, or a blend of petroleum-derived gasoline plus an alcohol.

Despite laws and incentives to encourage their use (see the discussion in the Policy Issues section) alternative transportation fuels, including natural gas and bio-derived fuels such as biodiesel and E85 ethanol are in limited use today. In 2008 they accounted for less than 0.5 percent of the fuel used for transportation; all alternative fuels together totaled only 750 million gasoline-equivalent gallons[9], compared to 132 billion gallons of gasoline consumed (DOE 2010d).

Natural Gas

Natural gas engines can be used to power both light-duty vehicles and heavy-duty trucks. For light-duty vehicles natural gas engines are virtually identical to gasoline engines. A number of companies convert gasoline cars to natural gas or bi-fuel operation by adding a natural gas fuel system and making minor modifications to the engine (NGV 2010). Bi-fuel vehicles have both a natural gas fuel system and a gasoline tank and can operate on either fuel.

Diesel engines are less easily converted to natural gas because the ignition systems differ. Natural gas requires a spark ignition system, while diesel engines use compression ignition, with no spark plug. Purpose-built heavy-duty natural gas engines are typically based on diesel engine designs, but with a spark ignition system designed in by the manufacturer.

Natural gas vehicles (NGV) require a fuel storage/delivery system composed of high-pressure gas storage cylinders, a gas pressure regulator(s), and gas shut-off solenoid(s). Currently, there are two different standards used in the U.S. for maximum fuel system pressure: 3,000 pounds per square inch (psi) and 3,600 psi. The most significant difference between NGVs and gasoline or diesel vehicles is the equipment and process required to fill the fuel tank. A natural gas fuel station is usually supplied with fuel from a utility pipeline, and includes a compressor to raise the pressure of the gas from distribution pressure to either 3,000 psi or 3,600 psi.

The Department of Energy estimates that there were 82,705 natural gas cars, pickups, and vans on the road in 2008 (EIA 2010c). Of these vehicles, only 36 percent were dedicated natural gas vehicles, and the rest were bi-fuel vehicles. The vast majority of these vehicles are owned by federal, state, and local governments and by natural gas fuel providers; 59 percent of these vehicles are operated in California, Arizona, Texas, and New York.

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[9] A gasoline-equivalent gallon is an amount of fuel that contains the same amount of energy as one gallon of gasoline (approximately 115,000 Btu).

Refueling natural gas-powered vehicles requires access to a retail natural gas fueling station. In 2008, there were 162,000 U.S. retail outlets selling gasoline, but only approximately 827 locations in the U.S. sold fuel for natural gas vehicles (0.5 percent). Many of those sites are private fleet fueling locations and not available to the public. The highest concentrations of natural gas fueling stations are in California (201) and New York (99).

Eight years ago there were eighteen models of light-duty dedicated natural gas and bi-fuel (gasoline/natural gas) vehicles available from major auto manufacturers for sale in the U.S., including a number from the Ford Motor Company (DOE 2007). In August 2004, Ford announced that it would discontinue production of all natural gas vehicles (NYT 2004), and other manufacturers have since followed suit.

Currently, the only production light-duty NGV available from a major auto manufacturer is the Honda Civic GX. The Civic GX uses a 110 hp natural gas engine with a compact five-speed automatic transmission. Other than the fuel being used, the Civic operates much like any other conventional gasoline vehicle.

The Civic GX NGV is certified to meet California SULEV (super ultra-low emission vehicle) emissions standards, but is also considered by CARB to be an advanced technology partial zero-emission vehicle (AT PZEV) because there are zero evaporative emissions from the fuel system. All natural gas vehicles have zero evaporative emissions because the high pressure fuel system is sealed to the atmosphere.[10]

While the Civic GX NGV is a very clean vehicle, it has lots of company. For model year 2010 there are 120 models of gasoline-fueled vehicles also certified to SULEV emission standards, as well as six gasoline hybrid models also certified as AT PZEV vehicles (EPA 2010d)[11].

Natural gas engines have approximately the same efficiency as gasoline engines, but due to the lower carbon content of natural gas they produce approximately 25 percent lower CO_2 emissions per mile.

Today there are only two companies making and selling dedicated heavy-duty natural gas engines into the U.S. market, Cummins and Doosan Infracore. A third company, Emissions Solutions, remanufactures Navistar DT466 diesel engines to operate on natural gas (NGVC 2010). Most truck manufacturers offer the Cummins natural gas engine as an option in various types of new trucks, including transit buses, refuse trucks, and work trucks. The other engines are primarily used in re-powers and conversions of existing diesel trucks.

The Department of Energy estimates that there were 14,266 natural gas trucks and 16,982 natural gas buses in service in 2008 (EIA 2010c). Of these vehicles, 64 percent were dedicated natural gas vehicles and the rest were bi-fuel vehicles.

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[10] Gasoline vehicles must have a fuel system that is "open" to the atmosphere or fuel could not be drawn from the tank. Modern cars use filters to capture and re-use gasoline vapors that evaporate from the fuel tank, but some vapors do escape, which contributes to total VOC emissions from transportation.

[11] Ford Fusion, Honda CRz, Honda Civic, Honda Insight, Toyota Prius, and Nissan Altima hybrids.

New model year 2010 and later heavy-duty natural gas engines are certified to the same emission standard as new heavy-duty diesel engines (0.01 g/bhp-hr PM and 0.02 g/bhp-hr NOx) and have approximately the same emissions per mile. New heavy-duty natural gas engines are no cleaner than new diesel engines – both have very low emissions - but they get there in a very different way. New diesel engines achieve these low levels of emissions by employing two types of "after-treatment" – a diesel particulate filter (DPF) to remove and destroy PM and selective catalytic reduction (SCR) to reduce NOx. New heavy-duty natural gas engines have inherently low PM emissions, and they use an automotive three-way catalyst (similar to those used on gasoline cars) to achieve low NOx emissions.

Heavy-duty natural gas engines are not as efficient as diesel engines, and natural gas trucks and buses typically use more fuel energy per mile than diesel trucks and buses. Testing has shown that per-mile CO_2 emissions from natural gas buses range from 6 percent to 30 percent lower than CO_2 emissions from diesel buses (SAE 2004).

Ethanol

The U.S. is the largest producer and user of ethanol fuel in the world. Most ethanol in the U.S. today is produced from corn. Other countries, such as Brazil, use sugarcane to produce ethanol. A starchy biomass such as corn requires enzymes to convert the starch to simple sugars and yeast to ferment the sugars to produce ethanol (NREL 2007).[12] There are also many companies working to perfect processes to produce "cellulosic ethanol" from fibrous sources such as grass or wood chips. Cellulosic biomass also contains sugars, but they are much harder to release and ferment. Cellulosic biomass requires more pre-treatment than starchy biomass, to allow for effective fermentation (NREL 2007).

Much of the gasoline sold in the U.S. today has up to 10 percent ethanol blended into it. This is done for one of two reasons: 1) the ethanol acts as an oxygenate in reformulated gasoline (RFG), or 2) the ethanol allows refiners to comply with renewable fuel mandates.

The addition of fuel-borne oxygen in gasoline helps cars to run cleaner, reducing NOx, VOC, and CO (EPA 2010b). The Clean Air Act requires counties in fourteen states plus the District of Columbia to burn "reformulated gasoline" (RFG) because they are in noncompliance with ambient air quality standards for ozone. Five additional states have opted into the program.[13] By law RFG must include 2 percent or 2.7 percent oxygen by weight (depending on location); since the use of MTBE was outlawed in 2007 ethanol has become the primary oxygenate used in RFG. To achieve the 2 percent oxygen requirement approximately 5.7 percent ethanol is required; to achieve the 2.7 percent oxygen requirement approximately 7.7 percent ethanol is required.

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[12] Ethanol is the alcohol that exists in alcoholic beverages. The production process for ethanol fuel is similar to the production of distilled spirits.

[13] Mandatory: California, Connecticut, Delaware, DC, Georgia, Illinois, Indianan, Louisiana, Maryland, New Jersey, New York, Pennsylvania, Texas, Virginia, and Wisconsin; Opt-in: Kentucky, Missouri, Massachusetts, New Hampshire, and Rhode Island

The Energy Policy Act of 2005 mandated that U.S. refiners use increasing amounts of "renewable fuels" in motor gasoline and diesel between 2006 and 2012 in order to enhance U.S. energy security. Refiners were required to sell 4 billion gallons of renewables in 2006, with the mandate increasing to 7.5 billion annual gallons in 2012 (Holt 2006). This mandate has increased the use of ethanol in gasoline, even in areas not required to use RFG.

In 1997, some manufacturers began selling "flex fuel" vehicles designed to operate on either gasoline or an E85 blend of 85 percent ethanol and 15 percent gasoline. In the 2010 model year there were 34 models of flex fuel E85 vehicles available from major auto manufacturers, mostly large sedans, pickups, SUVs, and mini-vans (DOE 2010c). The DOE Energy Information Administration estimates that in 2007 there were 7.1 million E85 vehicles on the road, but only about 6 percent of them routinely operated on E85, with the remainder being fueled primarily by gasoline (DOE 2010d). In 2008, there were 162,000 U.S. retail outlets selling gasoline, but there were only 1,980 locations in the country where one could get E85 fuel (1.2 percent), and some of these sites are fleet fueling locations that are not available to the public (DOE 2010d).

The use of ethanol as a transportation fuel increased from 1.95 billion gallons in 2003 to 7.26 billion gallons in 2008. In 2008, less than 1 percent of this ethanol was used in E85 blends – more than 99 percent was blended into standard gasoline and RFG (DOE 2010d).

Most of the E85 flex fuel vehicles on the market in 2010 were certified by EPA to achieve EPA Tier2/Bin 5 emission standards (fleet average). Virtually all these vehicle models come with various engine options, including both larger and smaller engines, and both flex fuel and gasoline-only engines. In comparing the flex fuel and gasoline only options for these vehicles it is clear that the flex fuel engines do not provide significant reductions in NOx, PM, and tail pipe VOC emissions compared to gasoline engines, when operated on E85. However, E85 is less volatile than gasoline, which results in fewer evaporative emissions (VOC) from the vehicle fuel system. According to EPA, using E85 also reduces carbon monoxide emissions and provides significant reductions in emissions of many harmful toxics, including benzene, but increases emissions of acetaldehyde--another toxic pollutant. EPA is conducting additional analysis to expand understanding of the emissions impacts of E85 (EPA 2009e).

In many cases the flex fuel version of the vehicle and the version with the same sized (displacement) gasoline engine are certified as having equivalent emissions. In many cases there are gasoline versions of the vehicle certified to be cleaner than the flex fuel version – i.e. meeting ULEV or SULEV standards – though the cleaner version may have a slightly smaller engine (EPA 2010d).

As discussed above, the push in the U.S. toward alternative vehicle fuels has been billed as both a way to reduce greenhouse gas emissions and improve energy security. On the greenhouse gas emissions side, there has been increasing attention from the environmental community on the lifecycle impacts associated with using corn as the primary feedstock for ethanol in the U.S. Skeptics of the benefits of corn-based ethanol point to the significant greenhouse gas emissions that are released as corn is farmed, harvested and processed into ethanol.

As a way to capture the impact of these upstream emissions, California is finalizing a Low Carbon Fuel Standard for vehicle fuels that mandates a 10-percent reduction in the lifecycle carbon intensity of vehicle fuels by 2020. (A group of Northeast and Mid-Atlantic states is currently considering a similar standard.) The standard measures carbon intensity in grams of CO_2 equivalent per megajoule of energy contained in the fuel.

Using data developed in support of the California Low Carbon Fuel Standard, M.J. Bradley & Associates estimated total lifecycle emissions on a per mile basis for a variety of different fuels/propulsion systems for this report. The analysis used a modeled Chevrolet Tahoe Sport Utility Vehicle to determine the amount of energy used per mile. The results of this analysis are shown in Figure 12. While an E85 blend of ethanol and gasoline yields low greenhouse gas emissions from the vehicle tail pipe[14], the upstream emissions associated with farming and land use significantly impact the benefits of E85 relative to other alternatives. For the modeled scenario shown in Figure 12 the per-mile lifecycle GHG emissions of an SUV burning E85 produced from corn are almost as high as emissions from the same SUV burning conventional gasoline. GHG emissions from a hybrid-electric version of the same vehicle burning conventional gasoline, or a diesel version, would be lower than from corn-based E85.

As noted in Figure 12, the intensity of greenhouse gas emissions of corn-based ethanol can vary significantly depending on the assumptions used in the estimates; the California standard lists 13 different values for ethanol depending on where the corn is grown, the type of fuel used to mill the corn and whether the milling process is wet or dry. These variables result in carbon intensity values ranging from 47 grams of CO_2 equivalent per megajoule to over 90 grams of CO_2 equivalent per megajoule.[15] Currently, California is deliberating over how to incorporate land use change into the emissions analyses of ethanol. The adjusted land use value is set to take effect in mid-2011.

To reflect the variability in potential carbon intensity values for corn-based ethanol, Figure 12 includes the lowest estimate in the California rule with the revised carbon intensity value for land use and the highest estimate in the California rule with the original carbon intensity value for land use. As shown, the assumptions used in estimating the emissions intensity of ethanol can have a dramatic impact on its consideration as a low carbon fuel.

Figure 12 also shows that alternate forms of ethanol have the potential to improve the fuel's greenhouse gas profile. Sugarcane-based ethanol has lower carbon intensity in the CA Low Carbon Fuel Standard despite the fact that it is almost exclusively produced and imported from Brazil, thus increasing emissions from transport and distribution. The primary driver of this difference is the much less intensive fuel production process.

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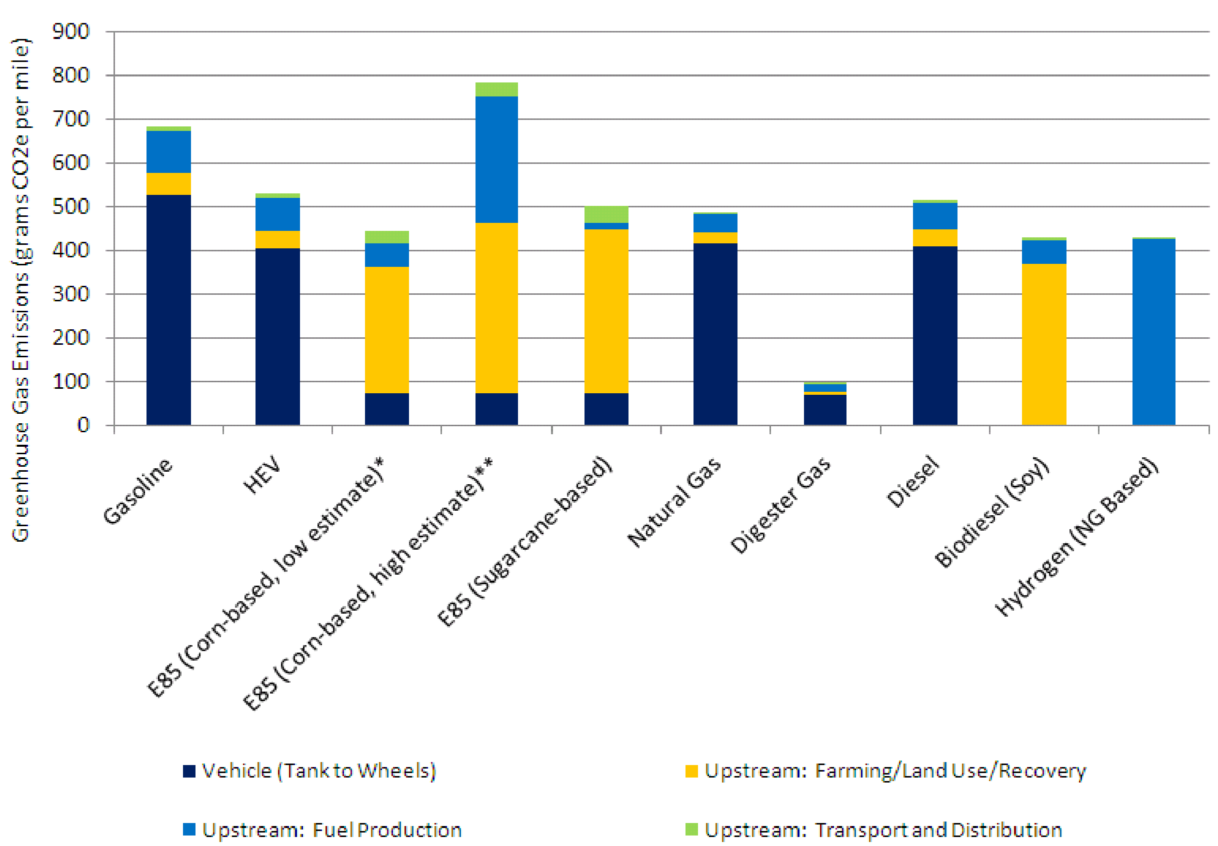
[14] A vehicle burning E85 would, in fact, emit significant CO_2 emissions from the tail pipe. However, it is the convention to treat tail-pipe CO_2 emissions from bio fuels as zero, because this CO_2 is recycled back into biomass as more plants are grown to produce the bio fuel. The tail-pipe emissions shown in Figure 12 for E85 come from the 15 percent petroleum gasoline in the blend.

[15] The California Low Carbon Fuel Standard Carbon Intensity Lookup Table for Gasoline and Fuels that Substitute for Gasoline is available at: http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf



*There is significant variability in estimates of the carbon intensity of corn-based ethanol. The low estimate is based on the CA LCFS look-up table for ethanol dry milled from CA-sourced corn powered by 20% biomass and 80% natural gas. It also uses revised land use impacts estimate of 13.9 grams of CO_2e per MJ.
**The high estimate is based on the CA LCFS look-up table for ethanol wet milled from midwest-sourced corn powered by 100% coal. It also uses the original land use impacts estimate of 30 grams of CO2e per MJ.
The CA LCFS look-up table is available at: http://www.arb.ca.gov/fuels/lcfs/121409lcfs_lutables.pdf

Figure 12. Average Life-cycle Greenhouse Gas Emissions Using Various Fuels in a Modeled Vehicle (grams CO_2e per mile)

Not shown in Figure 12 are more advanced forms of ethanol such as cellulosic ethanol that are still in the demonstration stages, but which hold promise to produce ethanol with fewer life-cycle greenhouse gas emissions. The lifecycle greenhouse gas impacts of the other fuels in Figure 12 are discussed below.

Biodiesel

Biodiesel is a transportation fuel produced from vegetable oils or animal fats. During production of biodiesel glycerin is removed from the oil, leaving behind methyl esters, which are used for fuel. Biodiesel has very similar chemical and physical properties as petroleum diesel, though it has higher oxygen content and virtually no sulfur. In the U.S., biodiesel is usually produced from soy bean oil, but it can also be produced from a range of vegetable oils including rapeseed oil, palm oil, and jatropha. There is ongoing research into using algae as a potential biodiesel feedstock because it is expected to produce high yields from a smaller area of land than vegetable oils (DOE 2010a).

Biodiesel can be used by itself to power a diesel engine, but is typically used as a blend with petroleum diesel. In the U.S. the most common blends are B5 (5 percent biodiesel and 95 percent petroleum diesel) and B20 (20 percent biodiesel and 80 percent petroleum diesel).

Between 2003 and 2008, annual use of biodiesel in the U.S. increased from 18 million gallons to 324 million gallons, but in 2008 biodiesel still accounted for less than one percent of all diesel fuel used by highway trucks (DOE 2010d). In 2008, total U.S. biodiesel production totaled 678 million gallons. More biodiesel was exported that year than was used domestically, with most exports going to Europe (DOE 2010a).

B20 and lower blends of biodiesel can be used in virtually any diesel engine without modification. In older trucks not equipped with a diesel particulate filter the use of B20 biodiesel has been shown to reduce direct PM emissions by approximately 10 percent (EPA2002a). Higher level blends can reduce PM emissions even more, but can also increase NOx emissions. Testing has shown that the use of biodiesel does not materially reduce PM emissions from diesel engines equipped with diesel particulate filter, as are all model year 2007 and later highway trucks (SAE 2004).

Figure 12 includes the lifecycle greenhouse gas emissions, on a per-mile basis, of soy-based biodiesel. Soy-based biodiesel produces approximately 17 percent lower life-cycle GHG emissions per mile than petroleum-based diesel fuel. Advanced forms of soy-based biodiesel show promise of being even less greenhouse gas intensive, and are being marketed as “renewable” biodiesel.

Electric Vehicles

In the early 1990s, the California Air Resources Board (CARB) introduced a Zero Emission Vehicle (ZEV) Mandate. This mandate originally required that the six largest automobile manufacturers ensure that 10% of the products they sold in California were “zero emission vehicles” by 2003. At the time the only way to achieve this goal was to create and sell battery electric vehicles (EV). This mandate led to the creation of such EVs as the Geo Metro EV, Ford Ranger EV, Toyota RAV4 EV, and the GM EV1. The GM EV1 was the only electric car produced which met all of the EV America performance goals of the United States Department of Energy (INL 2007). While only sold in limited numbers, primarily in California, the EV1 was generally considered to be a technical success, and gained a loyal following.

CARB has relaxed the original mandated 2003 introduction date for ZEVs several times, and has made other changes to the program which has changed the focus of manufacturer efforts from battery vehicles to fuel cell vehicles. In response all major manufacturers cancelled their EV development programs and discontinued the sale of the EV models they had produced.

The commercial success of the Toyota Prius, introduced to the U.S. market in 1999 (along with the Honda Insight hybrid), caused auto manufacturers to focus on gasoline hybrid-electric cars. Hybrids combine a gasoline engine with a small battery to significantly improve fuel economy. Hybrids are not truly EVs because they get all of the energy required to drive the vehicle from an on-board gasoline engine. Hybrids do take advantage of drive train electrification to improve over-all driving efficiency, which also reduces tail pipe emissions. With the addition of a larger battery and a charging port, a hybrid car can also be turned into a “plug-in” (i.e. charge-depleting) hybrid, which can pull some of the energy required to drive the vehicle from the electric grid.

In the last few years some major auto manufacturers have also turned their attention back to pure EVs, which will, in limited volume, again be available for purchase in 2011.

Hybrids

In the 2010 model year there were 20 models of hybrid electric vehicles available on the U.S. market; virtually all major auto manufacturers offer at least one hybrid model. For the 2011 model year an additional nine hybrid models from six different manufacturers will be introduced (DOE 2010b).

Approximately 300,000 hybrids were sold in the U.S. in 2009, and there may be as many as 1.5 million hybrids on the road. J.D. Powers and Associates estimates that annual hybrid sales may increase to 1.4 million by 2015 (Hybrid 2010).

Many of the early hybrids were small cars (Toyota Prius, Honda Insight, Honda Civic), but now the market includes hybrid versions of popular mid-size and large cars (Nissan Altima, Toyota Camry), as well as luxury cars (BMW, Lexus, Mercedes), and sport utility vehicles (Cadillac Escalade, Chevy Tahoe, GMC Yukon). The top ten model year 2010 vehicle models with the highest EPA fuel economy ratings are all hybrids (EPA 2010d). Model year 2010 hybrids get between 16 percent and 56 percent better fuel economy (MPG) than gasoline versions of the same car, based on EPA combined (city and highway) test results (EPA 2010d). Based on their combined fuel economy ratings, CO_2 emissions from model year 2010 hybrids will be 14 percent to 36 percent lower than CO_2 emissions from gasoline versions of the same car.

Hybrids have a reputation as being “cleaner” than conventional gasoline cars, but not all of them are. Many, but not all, model year 2010 HEVs are certified to SULEV emission standards, while the gasoline version of the same model is certified to ULEV standards (i.e. these hybrids are cleaner than equivalent gasoline cars). However, in some cases the hybrid and gasoline version are both certified to have the same emissions, and both are certified to be equivalent to fleet average emissions, known as LEV or EPA Tier 2 Bin 5. Six hybrid models are certified as AT PZEV vehicles, which are the cleanest cars on the road, other than EVs or fuel cell vehicles (discussed below).

Hybrid technology has also been deployed on heavy trucks, most notably on transit buses and medium-duty work trucks. Heavy-duty hybrids typically use a diesel engine, but there are some gasoline-hybrid transit buses operating in California. Every major North American transit bus manufacturer offers a diesel hybrid version of their buses. Over 4,000 hybrid transit buses are in service or on order today.

The largest fleet of hybrid transit buses is in New York City (over 1,600 hybrid buses), but there are also large fleets in Seattle, Toronto, Washington DC, Philadelphia, San Francisco, and Houston. Depending on where they are deployed, hybrid buses get 20 percent to 36 percent better fuel economy than diesel buses; The benefits of a hybrid compared to a standard diesel bus are greater in cities, like New York City, that have lower average in service speeds (NREL 2007).

Hybrid propulsion systems are also available from several different manufacturers for various types of medium and heavy-duty trucks such as shuttle buses, school buses, delivery vans, refuse trucks, truck tractors, and utility trucks (HTUF 2010). More than 1,000 or these vehicles are in service today.

Plug-in Hybrids

Plug-in, or charge-depleting, hybrids are intended to fill the gap between regular (charge-sustaining) hybrids and EVs. Plug-in hybrids have a larger battery pack than a regular hybrid, and also have a charging port. They are designed to be able to travel a certain distance – say 20 miles - using only energy from the battery, without turning on the gasoline engine (EV mode). After the energy in the battery pack is depleted the gasoline engine turns on and the vehicle acts like a regular hybrid. The driver can plug the car into a wall socket to re-charge the battery from the electric grid.

Plug-in hybrids work best for people who have relatively short daily commutes or trips. Most days they can commute to and from work either mostly or wholly on battery power, and recharge the battery pack at night. Yet, if they need to go on a longer trip they can do so without limiting the amount of time they can drive between charges, or needing to find places to plug in along the way.

There are currently no plug-in hybrids commercially available from any of the major auto manufacturers, but there are three companies that will convert various models of hybrids to plug-in hybrids by installing a larger battery pack and charging port, along with necessary control software (DOE 2010b).

Chevrolet has announced that they will start to sell the plug-in hybrid Chevy Volt, with an all-electric range of 40 miles, later this year. Five other major auto companies have announced plans to start production of U.S. plug-in models in 2011 or 2012. These vehicles have announced all-electric range of between 12 and 60 miles (Plug 2010).

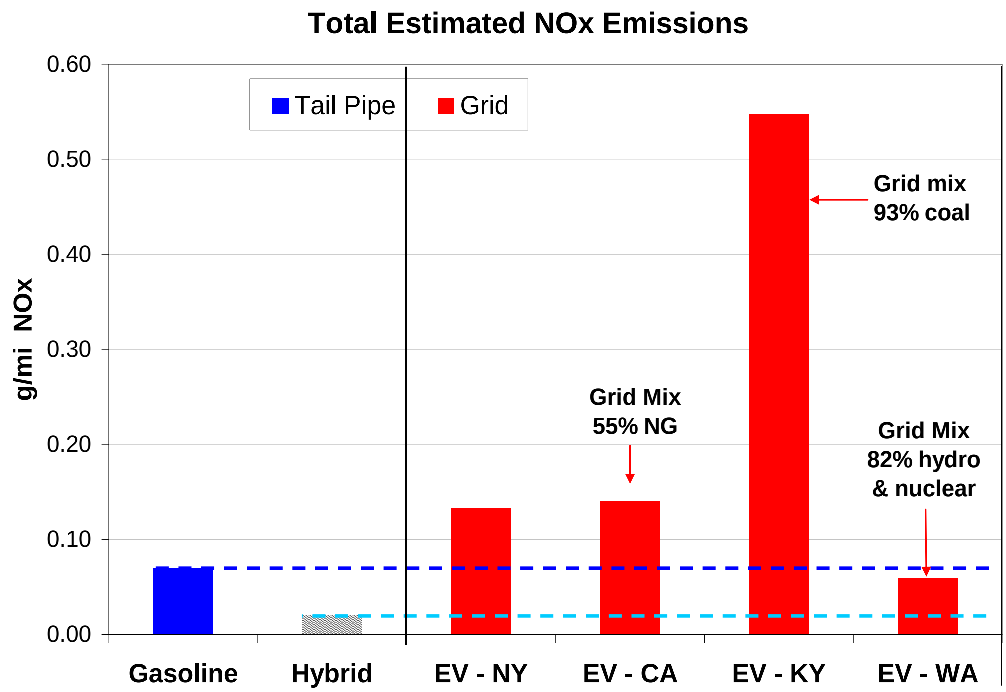
Electric Vehicles (EVs)

The Department of Energy estimates that there were 57,000 vehicles in use in 2008 that operate solely on electricity, not including hybrids and plug-in hybrid vehicles (DOE 2010d). However, only one model year 2010 EV was available for sale commercially to the public, the Tesla two-seat Roadster, which is priced at over $100,000 (DOE 2010b).

For model year 2011, Tesla will introduce an updated Roadster 2.5 with an advertised range of 245 highway miles between charges. Nissan will also introduce limited numbers of the Leaf, which has an advertised range of 100 city miles between charges (DOE 2010b).

Ford, BMW, Hyundai, Mitsubishi, and others have announced that they will introduce at least seven additional EV models in the U.S. in 2011 and 2012. Other companies will introduce EV models to Europe but not the U.S. (Plug 2010).

While EVs are advertised as zero emission vehicles that is not strictly true. While these vehicles have no tailpipe emissions, the power plants that produce the electricity used to charge them do emit a wide range of harmful air pollutants, including SO_2, PM, NOx, mercury and other air toxics, as well as CO_2. The net air quality benefit of an electric vehicle or a plug-in hybrid depends on the method used to produce electricity where they are used. See Figure 13 which compares total NOx emissions, and Figure 14 which compares total CO_2 emissions from a gasoline car, hybrid, and electric vehicle (EV).[16] As shown in this comparison, total g/mi NOx emissions from an EV would be higher than those from a new gasoline car in virtually all states other than Washington. NOx emissions from electricity production are lower in Washington than in any other state due to the high percentage of power produced from nuclear and hydro sources. EVs have significantly lower total CO_2 emissions than gasoline cars in many states. The exceptions are states like Kentucky which produce a large percentage of their power using coal. In these states CO_2 emissions from an EV would be marginally lower than those from a conventional gasoline car, but higher than those from an HEV.[17]

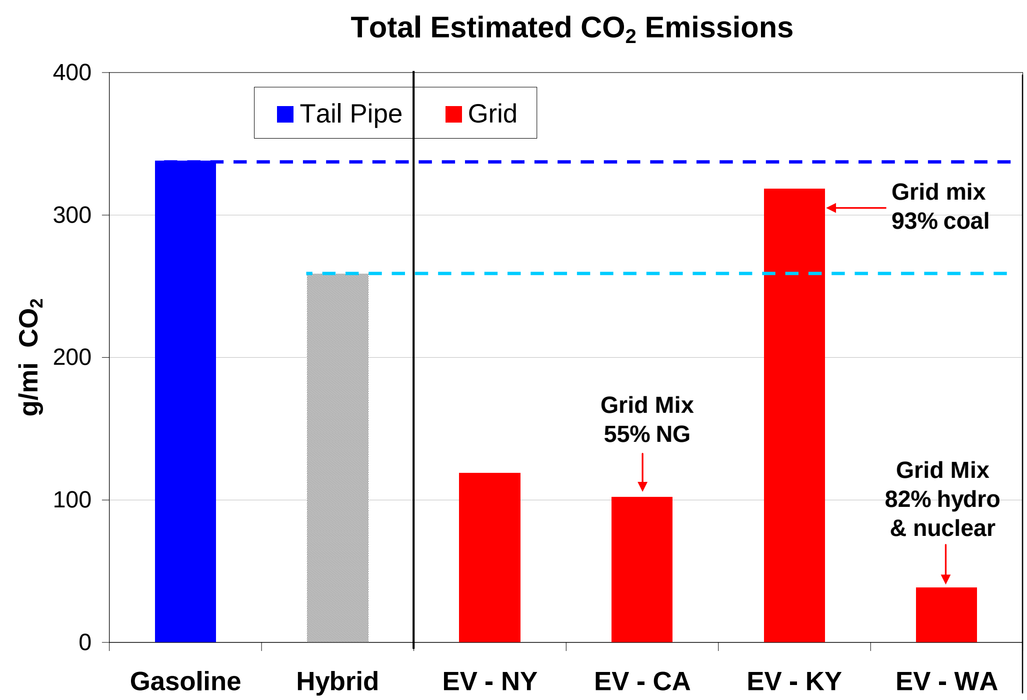


Source: M.J. Bradley & Associates

Figure 13. Estimated NOx Emissions (g/mi) from Gasoline Car, Hybrid, and EV Operating in Different States

[16] This analysis summarized in Figures 13 and 14 is by M.J. Bradley & Associates for this report. In Figures 13 and 14, CO_2 and NOx emissions for gasoline car and HEV are based on EPA combined MPG and emissions certification level for MY2010 Toyota Camry and MY 2010 Toyota Camry Hybrid. Calculations for EV assume the same driveline efficiency as the HEV (248 Whr/mi), assume 80 percent round-trip charging efficiency, and use EIA data on average grid emissions by state.

[17] Not all power produced in a given state is used in that state, nor is all the power used in a state necessarily produced there. The emissions rates for EVs shown in Figures 13 and 14 are approximate for each state. In general, a greater percentage of the electricity used in Southeast and Midwest is produced with coal than the electricity used in the Northeast, Northwest, and California.



Source: M.J. Bradley & Associates

Figure 14. Estimated CO_2 Emissions (g/mi) from Gasoline Car, Hybrid, and EV Operating in Different States

Hydrogen Fuel Cell Vehicles

A fuel cell vehicle uses a "fuel cell engine" which directly creates electricity that powers an electric motor to drive the vehicle's wheels. A fuel cell vehicle is therefore an electric vehicle, but one that creates its own electricity and does not need to be plugged in to recharge batteries. Many fuel cell vehicles actually incorporate a hybrid electric drive system – and include a battery pack – to improve overall efficiency.

Fuel cells are powered by pure hydrogen, which is the lightest of all gases. The necessary hydrogen is typically carried on the vehicle in high pressure tanks, similar to the way compressed natural gas vehicles carry their fuel.

Currently fuel cell vehicles are in the early stages of commercialization. All of the major auto companies have fielded concept, prototype or demonstration fuel cell sedans and sport utility vehicles in the last seven years – with at least fifteen different models introduced since 2000. Most of these vehicles have been operated by the companies themselves or have been fielded to government agencies and fleet customers as part of technology development or demonstration programs.

The Department of Energy estimates that there were 313 hydrogen-fueled vehicles on the road in 2008 (DOE 2010d). Most of these vehicles use fuel cells for power[18]. Honda has leased 50 of their fuel cell vehicle, the FCX Clarity, in California as part of a public demonstration project (DOE 2010b), but there are no other fuel cell vehicles available for purchase by the general public today.

Fuel cell vehicles fueled with pure hydrogen emit virtually no harmful tailpipe emissions of CO, NOx, VOC, or PM, and they also emit no CO_2 from the vehicle. Depending on the method used, production of the hydrogen fuel can produce significant CO_2 emissions, as well as other air pollutants such as NOx, PM, and SO_2.

Hydrogen is the most abundant element in our universe, but there is virtually no "free" hydrogen on earth – all of it is combined with other elements (mostly oxygen or carbon) in other substances. Hydrogen must be separated from these other elements to fuel a fuel cell vehicle. The hydrogen fuel used in vehicles is either derived from water (by electrolysis) or from a gaseous or liquid hydrocarbon fuel, usually natural gas, by reforming. The method of obtaining the fuel can have dramatic impacts on the lifecycle emissions associated with a fuel cell vehicle.

While either method results in a clean *vehicle*, the upstream emissions associated with reforming hydrocarbons to produce hydrogen fuel are significant. The net reduction in air emissions, relative to other options, from a fuel cell vehicle fueled by hydrogen produced via electrolysis will depend on the method used to produce the electricity used (similar to the discussion of air benefits of electric vehicles). Even considering only GHG emissions, as shown in Figure 12, a fuel cell vehicle fueled by hydrogen varies in lifecycle GHG emissions depending on the fuel used to produce the hydrogen.

[18] It is also possible to burn hydrogen in an internal combustion (IC) engine similar to a gasoline engine. Over the past few years there have been several demonstration programs of vehicles powered by hydrogen IC engines.

Major Policy Issues Associated with Transportation

The discussion of policy issues below is divided into two groups of policy options: those that would directly address the reduction of major pollutant emissions (NOx, PM, SO_2, VOC) from transportation sources; and those that are more directly targeted toward reducing greenhouse gas emissions (mostly CO_2) from transportation sources, or reducing the use of petroleum fuels to enhance energy security.

NOx, VOC, SO_2 and PM Reduction from Transportation

There are three main ways to reduce pollutant emissions from transportation sources: 1) set more stringent emission standards for various kinds of new vehicles, 2) regulate or control emissions from in-use vehicles, and 3) reduce the total number of vehicle miles traveled (VMT). A number of policy approaches in each of these categories are discussed below.

More Stringent Regulation of New Vehicles

The discussion below focuses of two categories of vehicles that could be targeted for further emissions reduction: light-duty cars and trucks and ocean-going marine vessels.

Light-duty Vehicle (Tier 3) Regulations

The Clean Air Act Amendments of 1990 defined two sets of standards for light-duty vehicles. The first, called Tier 1 standards were phased-in progressively between model years 1994 and 1997. The second, called Tier 2 standards were adopted in 1999 and phased-in from model year 2004 to 2009.

The staff of California Air Resources Board (CARB) is developing a proposal to amend California's Low-Emission Vehicle (LEV) regulations. The proposed amendments, to be known as LEV III, ask for more stringent tailpipe and greenhouse gas emission standards for new passenger vehicles. Combining the control of smog-causing pollutants and greenhouse gas emissions into a single coordinated package of standards is a new approach to ARB's motor vehicle standards. The new approach also includes efforts to support and accelerate the numbers of plug-in hybrids and zero-emission vehicles in California. CARB hosted a public workshop in May 2010 to discuss the proposed LEV III amendments (CARB 2010a).

Work is now beginning to further strengthen the federal limits on emissions from light-duty motor vehicles, called a “Tier 3” standard. EPA and the National Highway Traffic Safety Administration (NHTSA) are taking steps outlined by President Obama in a memorandum on May 21, 2010.The President called for EPA and the Department of Transportation to work with California on the next round of fuel efficiency and greenhouse gas standards for light-duty vehicles, to cover the 2017-2025 model years. On September 30, 2010, EPA and NHTSA issued a Notice of Intent to begin developing these standards (EPA 2010b). The memorandum also requests EPA to review current non-greenhouse gas emissions regulations and to develop new standards as part of a comprehensive regulatory program. This will allow EPA to develop a Tier 3 light-duty emissions program that could be modeled on California’s LEV-III proposal (AECC 2010).

Reducing Emissions from Marine and Ocean-going Vessels

Coastal marine vessels (ferries, tugs, fishing vessels, work boats) typically have large diesel engines that are very similar to diesel engines used in locomotives or large pieces of construction equipment, and these engines burn "distillate" fuel – i.e. standard diesel. EPA has defined "Tier 4" emissions standards for new engines used in these vessels (Category 1 and 2 marine engines), to be phased in between model years 2014 and 2017 depending on engine size. These Tier 4 regulations will reduce allowable NOx emissions by 64 percent and allowable PM emissions by 80 percent or more compared to Tier 2 standards now in effect. The Tier 4 marine engine standards are almost as stringent as current standards for diesel highway trucks.

Large ocean-going vessels (OGV) - cruise ships, tankers, and container ships - have extremely large and unique engines (Category 3 marine engines). These large-displacement, slow-speed engines - sized up to 100,000 horsepower - are unlike any land-based diesel engines. These engines also burn "residual fuel", which is literally from the bottom of the barrel of petroleum and contains high levels of sulfur and heavy metals. Residual fuels typically contain more than 1 percent sulfur - over 600 times more sulfur than the diesel fuel burned by highway trucks.

EPA regulation of ocean-going vessel engines follows international standards negotiated under the auspices of the International Maritime Organization (IMO), and codified in IMO Marpol Annex VI. Prior to 2004 these engines were unregulated. Engines in U.S. flagged vessels built beginning in 2004 were subject to Tier 1 limits for NOx only – PM and VOC remained unregulated. Tier 1 limits were weak, allowing at least twice as much NOx as was allowed from a highway truck engine built in 2004.

New regulations adopted in 2008 tightened emission limits for U.S.-flagged OGVs. Beginning in model year 2011, Tier 2 limits require NOx emissions 15 - 25 percent lower than Tier 1 limits. Beginning with engines built in model year 2016, Tier 3 limits require NOx emissions 80 percent lower than Tier 1 limits. Still, these standards will not result in "clean" engines: Tier 3 NOx limits for these vessels are more than seven times higher than NOx limits for new highway trucks. Tier 3 standards will also limit carbon monoxide and VOC emission for the first time, but PM remains unregulated.

Under IMO rules, EPA has also requested designation of U.S. coastal waters[19] as an Emissions Control Zone (ECA) for NOx and SO_2 (see Figure 15). If granted by IMO, this designation will mean that beginning in 2015 U.S. and foreign-flagged vessels will be required to comply with Tier 3 NOx limits while in these waters. Beginning in 2015 all ocean-going vessels will also be required to burn lower sulfur fuel while operating in U.S. coastal waters. EPA has established a fuel sulfur limit of 1,000 parts per million (ppm) within the North American ECA. This is more than a 90 percent reduction in sulfur compared to typical marine residual fuel, but it is still more than 60 times as much sulfur as is allowed in highway diesel fuel.

[19] All areas within 200 nautical miles of the U.S. coast line.

Source: EPA 2009a

Figure 15. Proposed North American IMO Emission Control Area

Regulation/Control of In-Use Vehicles

More stringent limits on emissions from new vehicles can dramatically reduce fleet-wide emissions over time. However, they do not achieve their full potential until the fleet has completely turned over to new vehicles, which could be many years. There are policies that can help to reduce emissions from in-use vehicles, without needing to wait for fleet turnover; these polices are addressed here.

The Clean Air Act severely restricts the ability of EPA to regulate in-use vehicles, though the Agency can develop and administer voluntary programs. Many of the policies discussed below must, of necessity, be left to the individual states to initiate and implement.

California Fleet Rules

In December 2008, the California Air Resources Board (CARB) adopted regulations to control emissions from all medium and heavy-duty trucks (Class 5-8) that operate in California, regardless of where the trucks are registered.

As originally adopted, the rules were to take effect in two stages. First, between 2011 and 2014 fleets would be required to phase-in on all of their trucks the "best available control technology" (BACT) for reducing particulate matter. This means that all medium and heavy trucks operating on California roads would need to be equipped with a DPF by the end of 2014 (CARB 2008).[20] Fleets could comply with this

[20] The phase-in schedule would have required a minimum of 25 percent of any fleet's trucks to comply by the end of 2011, 50 percent by the end of 2012, 75 percent by the end of 2013, and 100 percent by the end of 2014.

requirement either by retrofitting existing trucks with DPF, or by retiring older trucks and replacing them with new post-model year 2007 trucks that meet the most stringent EPA emission standards for PM. For some fleets, retiring would have meant that they no longer use the trucks in California, but continue to use them in other states.

The second stage of the rules was designed to further reduce NOx emissions from medium and heavy trucks. Between 2013 and 2022, this part of the regulation would have required fleet owners to accelerate the retirement of engines older than 12 years old, and replace them with engines built after model year 2010, which is when EPA's most stringent standard for allowable NOx emissions from new engines takes effect.[21] Fleets could theoretically comply with this requirement by replacing the old engines in their trucks with new engines, but most would likely retire (from use in California) their existing trucks and replace them with new trucks.

CARB staff estimated that the rules would apply to 220,000 medium-duty trucks (Class 5-6) and 720,000 heavy-duty trucks (Class 7-8). While 96 percent of medium-duty trucks affected by the rules are registered in California, 68 percent of heavy trucks affected by the rule are registered in other states (CARB 2010c). The heavy trucks potentially affected by the rules represent approximately 12 percent of the U.S. heavy truck fleet.

In September 2010, CARB staff proposed amendments to the onroad truck and bus regulation, which were approved by the Board in December 2010 (CARB 2010f). The amendments were proposed and approved because "the recession has negatively affected employment and revenue for most fleets affected by the regulations and has resulted in lower emissions" and the proposed update offered an opportunity to "simplify and streamline the regulation while providing fleets more flexibility in how they reduce their emissions" (CARB 2010c).

Major proposed changes to the rules include:

> ***Phase 1 (PM BACT):*** Only heavy vehicles (Class 7 and 8) with 1998-2006 model year engines will be subject to PM BACT requirements. Smaller trucks (Class 5 – 6) and heavy trucks with older engines will be exempt. This exempts approximately 130,000 trucks, virtually all of them registered in California.
>
> Fleets with vehicles subject to the amended rules will be required to phase in installation of PM BACT between January 2012 and 2014, although additional flexibility and credit provisions could allow a fleet to postpone achievement of full BACT until 2017. All fleets have been given one additional year to start their retrofits and replacement but most fleets will still be required to finish (100 percent PM BACT) at the same time mandated in the original rule, by the end of 2014.
>
> ***Phase 2 (NOx BACT):*** Owners will be required to reduce NOx emissions from the fleet by accelerating heavy-duty engine or vehicle replacement between January 1, 2015 and the end of

[21] The EPA2007 new engine standards reduced both allowable PM and allowable NOx emissions from new engines. The PM standard applied beginning with the 2007 engine model year, but the NOx standard was phased-in between model year 2007 and model year 2010. While model year 2007 – 2009 engines have lower NOx emissions than engines built earlier, NOx emissions from model year 2010 and later engines will be up to 80 percent lower.

2019 for 20-year or older engines, and by January 1, 2023, for all other engines. By the end of 2023, all medium and heavy truck engines (Class 5 – 8) in use in California will be required either to have been manufactured in 2010 or later, or be retrofitted to achieve equivalent NOx emission reductions.

As with the PM BACT rules, the proposed amendments delay the start date of accelerated fleet turnover (from 2013 to 2015) but keep the same end date (2023).

Voluntary Diesel Retrofit/Replacement Programs (DERA)

The Energy Policy Act of 2005 created the Diesel Emission Reduction Program (DERA) which gave EPA authority to make grants and loans to promote reductions in diesel emissions, and authorized up to $200 million in funding each year for fiscal years 2007 through 2011. In fiscal year 2008, Congress appropriated $49.2 million in funds for this program. In fiscal year 2009, the American Recovery and Reinvestment Act (ARRA) added $293 million in funding for DERA. In addition, Congress appropriated $60 million for retrofits for fiscal years 2009 and 2010.

The law specifies that 70 percent of the funds be used for national competitive grants and 30 percent be allocated to the states. Under DERA, EPA has created four different programs:

- *National Clean Diesel Funding Assistance Program* – to provide grants for projects that implement EPA- or ARB-verified diesel emission reduction technologies or strategies
- *The National Clean Diesel Emerging Technologies Program* – to award competitive grants for projects that spur innovation in reducing diesel emissions through the use, development and commercialization of emerging technologies.
- *SmartWay Clean Diesel Finance Program*- to issue competitive grants to establish national low-cost revolving loans or other innovative financing programs that help fleets reduce diesel emissions.
- *State Clean Diesel Grant Program* – to allocate funds to participating states to implement grant and loan programs for clean diesel projects.

Since 2008, EPA has awarded over 500 grants for diesel reduction projects; funded projects have included retrofits with diesel oxidation catalysts and diesel particulate filters, engine repowers, vehicle replacements, retrofits with idle reduction equipment, and retrofits with aerodynamic aids for highway trucks, locomotives, marine vessels, and construction equipment (EPA 2010a).

Many states also operate grant programs to provide funding for the clean up of diesel engines. Two of the largest are the Carl Moyer Memorial Air Quality Standards Attainment Program in California (Carl Moyer), and the Texas Emissions Reduction Plan (TERP). The Carl Moyer program started in 1998 and in its early years it was funded with appropriations in the state budget. Since 2005, it has been funded by a portion of fees charged for California's Smog Check program, as well as fees assessed on the sale of tires (STAPPA 2006). For fiscal year 2010/2011, California Air Resources Board estimates that $67.9 million will be available for the program (CARB 2010d).

TERP is funded by surcharges on the sale or lease of new and used highway and nonroad diesel vehicles, as well as fees charged for commercial motor vehicle inspections and a portion of fees for certificates of vehicle title (STAPPA 2006). TERP currently operates a competitive Emission Reduction Incentive Grants Program, a first-come first-served rebate program for upgrade or replacement of diesel equipment, the Texas Clean Fleet Program, and several grant programs to encourage development of new technologies to reduce vehicle emissions (TERP 2010). To date, TERP has provided $786 million in funding to reduce emissions from over 12,600 diesel vehicles operating in Texas (TERP 2010).

Mandatory Retrofits for Government Contracting

In 2003, New York City adopted Local Law 77 to clean up diesel exhaust from equipment used in City construction projects. Local Law 77 mandates retrofits on all diesel equipment greater than 50 hp, used on all publicly funded construction projects in New York City. On large construction projects, equipment impacted by this requirement would include most earth moving machines (i.e., loaders, backhoes, graders, bull-dozers, and off-road dump trucks), as well as large portable generators. In general, only small portable equipment such as small generators, light sets, welders, and air compressors, as well as some personnel lifts, have engines smaller than 50 hp (MJB&A 2009). The requirements under the law were phased in between 2004 and 2005 depending on the location and size of the project.

Local Law 77 requires the use of "best available technology" (BAT) to reduce PM emissions. Contractors must install an EPA- or ARB-verified diesel particulate filter, unless they can prove that these devices are not technically feasible to use on their specific piece of equipment. If so, they can install a verified diesel oxidation catalyst[22].

Other localities have taken a similar approach, but generally on a project-by-project basis. For example the Illinois Department of Transportation required some retrofits on equipment used for the rebuilding of the Dan Ryan Expressway, as did the Port of Seattle for construction of a new runway at Seattle's Sea-Tac airport (STAPPA 2006).

Light-duty Vehicle Inspection and Maintenance

Vehicle inspection and maintenance (I & M) programs help improve air quality by identifying high-emitting vehicles in need of repair and requiring them to be fixed as a prerequisite to vehicle registration. The 1990 Clean Air Act Amendments made I & M programs mandatory for several areas across the country, based upon air quality classification (i.e., attainment status), population, and geographic location. Thirty states have I & M programs at the state level, another three states and the District of Columbia have programs in specific cities or counties (EPA 2003).

The specifics of these programs vary, for example some require annual tests and others require biennial tests. Most programs started with actual exhaust emissions testing to identify high emitters, but most programs are moving away from instrument-based testing and toward the use of on-board diagnostics (OBD).

[22] Diesel particulate filters are verified to reduce PM emissions by 85 percent or more. Diesel oxidation catalysts are verified to reduce PM by 20 – 25 percent.

Since 1990, EPA new vehicle emission standards have required engine manufacturers to program OBD capability into all new engines. OBD uses on-board sensors and control logic to determine whether the different components of the engine's emissions control system are working properly. If a problem is detected the engine control module sets a "check engine" light on the vehicle dash and logs a fault code. Using standardized hardware and software a maintenance technician can download the fault codes to determine what the problem is, so that it can be fixed. Compared to tailpipe emissions tests OBD makes the identification of potential high emitters easier and less expensive. In addition, because the "check engine" light signals problems as soon as they occur, vehicle owners may be motivated to address the problem early, rather than having to wait for an annual or biennial emissions test to detect the problem.

Under an OBD-based I & M program, registration would be denied to a vehicle with an active check engine light because the identified emission control system fault could make the vehicle a high emitter. Once the problem has been fixed the vehicle would be allowed to be registered.

Vehicle inspection programs have been the target of budget cuts and political challenges over the past five years. Since inspection programs are included in state implementation programs associated with ozone standard attainment, EPA can prevent states from stopping a program if alterative measures do not maintain attainment. In 2005, EPA approved termination of vehicle emissions testing programs in northern Kentucky. Kentucky successfully argued that new regulations to require auto body repair shops to switch to high-efficiency paint sprayers, and to require the use of solvents with low vapor pressure for cleaning grease from industrial metal parts, would allow the counties in question to stay in attainment (Kentucky 2005). In 2009, EPA rejected Ohio's attempt to end its vehicle inspection program, despite recently re-designating 14 Ohio counties to attainment, because of concerns over backsliding and meeting future standards (EPA 2009c).

Heavy-duty Vehicle Inspection and Maintenance

Inspection and maintenance programs for heavy-duty diesel vehicles are currently less common than those for light-duty vehicles. However, these programs are becoming increasingly important as manufacturers rely more heavily on after-treatment devices (i.e., cleaning exhaust as opposed to reducing exhaust) to comply with more stringent new engine emission standards. After-treatment failures can result in a significant increase in emissions, and effective inspection and maintenance programs can detect after-treatment failures and ensure that they are fixed.

Eighteen states have heavy-duty vehicle testing programs (EEA 2004). As in the case of light-duty vehicles, the testing requirements vary from state to state. As an example of one of the more advanced programs, California's program has three components (CARB 2010b):

- Heavy-Duty Vehicle Inspection Program: Requires heavy-duty trucks and buses to be inspected for excessive smoke and tampering, and engine certification label compliance. Any heavy-duty vehicle traveling in California, including vehicles registered in other states and foreign countries, may be tested. Tests are performed by inspection teams at border crossings, weigh stations, fleet facilities, and randomly selected roadside locations.

- Periodic Smoke Inspection Program: Requires that diesel and bus fleet owners conduct annual smoke opacity inspections of their vehicles and repair those with excessive smoke emissions to ensure compliance. State officials randomly audits fleets, maintenance and inspection records and tests a representative sample of vehicles. All vehicles that do not pass the test must be repaired and retested.
- Emission Control Label: Requires that each vehicle operating in California - including those in transit from Mexico, Canada, or any other state - must be equipped with engines that meet California emission standards and be labeled as such.

As in California, virtually all current programs rely on the snap opacity test as the main method to identify high emitting heavy-duty diesel vehicles. Engines with low opacity are considered to be in good condition, while measured opacity levels above some specific threshold denote a high emitter. These opacity tests have limited value for three reasons: 1) they do not truly represent all vehicle operating conditions that could produce high PM, 2) it is relatively easy to cheat the test by not pushing the accelerator down quickly enough, and 3) the cut points defined for most test programs are too high to be of use for modern engines.

EPA required on-board diagnostic (OBD) systems on 2005 and later heavy-duty vehicles with gross vehicle weight less than 14,000 pounds. In February 2009, EPA finalized regulations requiring OBD systems on 2010 and later heavy-duty engines used in highway vehicles over 14,000 pounds GVWR. As with light-duty I&M, some time in the future heavy-duty I&M can migrate away from opacity testing and begin to rely on OBD as the main method to detect high emitters.

Reducing Driving

In the U.S., the use of cars has grown faster than the population. Between 1970 and 2008 the number or vehicles on U.S. roads increased at an average annual rate of 3.2 percent, and the number of miles those vehicles traveled annually increased at an average rate of 4.4 percent. Over that same time period the U.S. population grew at an average annual rate of only 1.3 percent.

The growth in driving is projected to continue out of proportion to population growth. At current rates, the Department of Energy projects an increase in VMT of 48 percent from 2005 to 2030 (EIA 2008). Looking solely at CO_2 emissions, an Urban Land Institute report estimated that the nation will offset the available reductions in emissions from cleaner vehicles by 2050 unless changes are made that reduce that reduce the growth in VMT (ULI 2007).

There are a number of policies that propose to get people out of their cars and onto less polluting modes for necessary trips - walking, biking, and pubic transportation.

Smart Growth Policies

According to data from the 2001 National Household Travel Survey, 87 percent of all trips made by Americans were made by personal auto, while only 9 percent were made by walking and only 1 percent were made using public transit. In addition, this survey shows that only 18 percent of trips are work-related, with almost three quarters of trips related to recreation and social activities or personal and family business.

Obviously, the character of community development and land use in the U.S. has a major impact on the transportation options available and the mode choices that people make. However, historically U.S. transportation policy decisions have encouraged driving and limited the availability of options for alternative transportation.

For decades, the top priority for federal investment has been highways. As Transportation for America describes it, the personal automobile has been the "priority mode for public support" leading to an "expansion of surface roads and streets to provide increased capacity for motor vehicle travel, with an emphasis on suburban and rural routes." The result has been sprawl:

> Although never explicitly stated, a tacit feature of this emphasis has been federal subsidization of suburban and exurban settlement patterns (Transportation 2009).

One result of those policies is decentralized communities, where access to work, shopping, health care, even food, is built around access to a car.

Compact Development vs. Typical Suburban Development: Evidence from the Three Reports

Study	Method	Conclusions
Moving Cooler	Analyzes the VMT generated by Americans living at different densities.	In comparison to low-density suburban development, compact suburban development reduces VMT by 20 percent and urban development reduces VMT by up to 60 percent.
Growing Cooler	Analyzes past studies of the connection between VMT and the characteristics of compact development.	In comparison to outer-edge suburban development patterns, compact development reduces VMT by 20 to 40 percent.
Driving and the Built Environment	Extensive review of published research.	Doubling residential density reduces VMT by 5 to 12 percent. If doubling density is combined with other changes, such as an increase in mixed-use development and transit improvements, the study estimates an upper limit of 25 percent for VMT reductions from compact development.

At a Glance: VMT and GHG Reduction Estimates from Compact Development (vs. Typical Suburban Development)

Study	VMT Reductions	GHG Reductions
Moving Cooler	20–60 percent	20–60 percent
Growing Cooler	20–40 percent	18–36 percent
Driving and the Built Environment	5–12 to 25 percent	5–12 to 25 percent

Figure 16. Effects of Land Use Patterns on VMT (ULI 2010)

In 2009, 50 percent of all U.S. housing units were located in the suburbs and 21 percent were located in rural areas, with only 29 percent in central cities (Census 2009).

As an Urban Land Institute analysis characterizes the situation:

> From World War II until very recently, nearly all new development has been planned and built on the assumption that people will use cars every time they travel. As a larger and larger share of our built environment has become automobile dependent, car trips and distances have increased, and walking and public transit use have declined (ULI 2007).

The Urban Land Institute recently published a summary of three major studies that evaluate the effect of land use on driving (ULI 2010). The major conclusions from these studies include:

- Compared to sprawling land use patterns, compact land use patterns result in fewer VMT. Compact patterns reduce the number of trips and their length.
- The VMT reduction from compact land use appears incrementally over time, but it is permanent
- As the amount and quality of compact development increases, the reduction in VMT accelerates.

In the context of these studies, "compact development" is a land use pattern that features:

- Medium to high density – concentrations of housing and employment;
- A mix of uses (residential, retail, office, manufacturing);
- Interconnected streets (i.e. fewer cul-de-sacs);
- Pedestrian, bicycle, and transit-friendly design; and
- Access and proximity to public transit options.

See Figure 16 for a summary of the effects of land use patterns on VMT from these studies. As shown, in comparison to suburban sprawl, compact development can reduce VMT by up to 60 percent.

More compact or densely developed communities have lower average daily VMT. Residents in sprawling cities, like Atlanta, drive roughly 25 percent more miles each day on average than residents of more compact cities, like Boston. A meta-analysis of studies found that people who live in cities with twice the density (and the accompanying diverse land use, interconnected streets and greater access) drove one third less than similar residents of cities with greater sprawl (ULI 2007).

The policies that create sprawl can also impact lung health in ways not just associated with air pollution emissions. With improved access and funding, better-off residents left the cities and moved to the suburbs, as did many of the services they needed, including health care. Researchers have argued that the increased sprawl left low income families with limited access to better paying jobs, adequate schools or protection from crime, as well as to health care, factors that made it more difficult for them to move out of poverty and put them a higher risk for health problems (Funders' Network 1999).

Many cities and some states are adopting policies, sometimes called "smart growth" or "compact development," to counter the unhealthy attributes of sprawl, including extended driving. For example, New York adopted a state law in August 2010 requiring infrastructure investments to be examined against "smart growth" principles (NY 2010). Others adopting similar principles that encourage greater density in development include San Diego, northern Virginia, and Orlando (ULI 2007).

Transportation Funding Authorization

Congress is due to take up the next formal authorization for funding the nation's transportation system. As noted earlier, federal funding for transportation has been based on "user fees," which have failed to keep pace with transportation needs. Since 1991, transportation authorization legislation has also moved toward integrating transportation planning and funding with meeting air quality goals, as well as expanding funding for transit and other alternatives to driving. The most recent authorizations legislation, the SAFETEA-LU, expired in September 2009, so new authorization is under discussion. Congress routinely extends the expired programs for short stretches until a new formal authorization is enacted.

The federal authorization funds not only highways but transit programs, allocating 20 percent or less of the total funding to transit. Under the SAFTEA-LU, highway programs received about $40 billion annually, while transit programs received about $9 billion. Since 1991, the authorization has also included funding for "Congestion Mitigation and Air Quality" programs, which funds air pollution control efforts and alternative transportation projects, such as pedestrian and bike paths.

In the 111th Congress, House Transportation Committee Chair James Oberstar and Ranking Member John Mica sought to bring a bill for consideration, the Surface Transportation Authorization Act of 2009. They were not successful. However, their proposal recognized the need for a national plan for transportation, a step that could better direct a funding system described by the General Accounting Office as a "cash transfer, a general purpose grant program" (U.S. House 2009). With the 112th Congress, the debate over the transportation bill is expected to resume. Mica will become committee chair, while Oberstar lost his reelection bid.

Meanwhile other groups have urged a national transportation strategy that would encourage more dense development, greater integration of public transportation and alternative transportation. Groups like Transportation for America have enlisted many public health groups, including the American Public Health Association, in their coalitions. These groups seek greater funding for public transportation and alternative transportation. Transportation for America supports increasing transit funding to 30 percent of total funding, as well as increased support for pedestrian and bicycle-friendly street design (Transportation2009). The Urban Land Institute has proposed a similar set of recommendations for the federal legislation, including steps that would encourage or require states, regional and local governments to use approaches to reduce VMT (ULI 2007).

Another question to be resolved is how the money is raised. The user-fee approach, in particular, the 18.3 cent per gallon gasoline tax, no longer provides adequate resources. Keeping adequate funding requires increased gasoline use to grow, unless the fees are increased, which has not happened since 1993. With higher mileage requirements and increased use of vehicles that do not solely depend on gasoline, the funds from a per -gallon tax will remain behind, even if VMT grows.

Increasing the gasoline tax could reduce VMT as well. There is some evidence that higher gasoline prices can reduce VMT. In 2008, a sharp spike in gasoline prices was accompanied by the first substantial drop in VMT in some time.

An alternative is a VMT-based system. Such a system would charge a fee based on the miles driven, not the fuel consumed. Vehicles and fueling stations would need specific equipment to assess the VMT and pay the fees. More research would be needed to put such a system in place, but Transportation for America and others urge that it be explored as a long-term funding mechanism.

In addition, public-private partnerships are growing, as governments look to alternatives for funding needed transportation projects. Private companies now own and operate toll roads and public transportation, as well as other transportation infrastructure. No clear guidance exists for structuring the relationship between the private companies and government entities to ensure that the projects meet requirements to reduce emissions and provide access.

High Speed Intercity Rail

The Obama Administration announced on October 28, 2010 additional $2.4 billion in funding for planning for a high speed intercity passenger rail system (DOT 2010a). The plan for this rail service includes new and improved rail service intended to reach speeds from 150 to 220 mph, as well as upgrades to existing lines. Supporters urge the expansion of a high speed intercity rail network as the current equivalent of the interstate highway system begun in the 1950s (FRA 2010). Groups including the Transportation for America and Urban Land Institute are supporting the expansion of intercity rail as part of an interconnected public transportation system and one way to supply future transportation needs outside of adding highway and air transportation capacity. The state of California approved $9.95 billion in bonds for 800 miles of high-speed rail in 2008 (SDUT 2010).

However, the cost of these projects makes them strong targets for budget cuts, as seen with the decision by New Jersey Governor Chris Christie to cut funding for a $9 billion railroad tunnel connecting his state with New York City. The question of “taxpayer subsidies” for rail has raised opposition in California, Wisconsin and other locations (IBT 2010). Supporters argue that other nations’ experience with high-speed rail systems show that they can succeed, and that both the federal highway system and the air transportation systems are currently heavily subsidized by federal funding.

Figure 17. Plan for High-Speed Rail Corridor Development, U.S. Department of Transportation

CO_2 Reduction from Transportation

The policies discussed below target reducing greenhouse gases and improving U.S. energy security rather than reducing traditional air pollutants. These policies fall into two categories: 1) regulation of fuel economy from new vehicles, and 2) mandating or creating incentives to switch to non-petroleum fuels for transportation

Fuel Economy Regulation of New Vehicles

As discussed, regulations are already in place through model year 2016 for light-duty vehicles, but EPA is currently in the process of developing a proposal for light-duty vehicle fuel economy applicable to model years 2017 through 2025. EPA is also in the process of developing a proposal for heavy-duty vehicle fuel economy applicable to model years 2014 through 2020. As these proposals are still in development, it is not clear how stringent these new rules will be, or what the total fuel and CO_2 reduction benefits will be.

Switch to Non-petroleum Fuels

Six federal laws mandate various government agencies to purchase alternative fuel vehicles, and all but three states have similar laws which usually apply to state and/or local government fleets (DOE 2010b). Twelve states also have laws or regulations that provide a renewable fuels mandate or requirement. The federal government has 22 different grant programs, and twelve different tax incentives that subsidize the purchase of alternative fuel or advanced technology vehicles, the purchase of alternative fuel infrastructure, or the purchase and use of alternative fuels by fleets and individual consumers. Thirty-three different states also operate grant programs and 39 states have state tax incentives. These laws and incentive programs typically cover one or more of the following fuels and technologies: natural gas, propane, ethanol, biodiesel, electric vehicles, hybrid-electric vehicles, plug-in hybrid vehicles, and hydrogen fuel cell vehicles and infrastructure.

In addition, the Energy Policy Act of 2005 mandated that U.S. refiners use increasing amounts of “renewable fuels” in motor gasoline and diesel between 2006 and 2012 in order to enhance U.S. energy security. Refiners were required to sell 4 billion gallons of renewables in 2006, with the mandate increasing to 7.5 billion annual gallons in 2012 (Holt 2006). This mandate has increased the use of ethanol in gasoline, even in areas not required to use reformulated gasoline, or RFG.

The current limit of 10 percent ethanol in standard gasoline and RFG is set by EPA, which has determined that this level of ethanol will not harm in-use engines. In separate decisions announced in October 2010 and January 2011, EPA granted a waiver request sought by several major ethanol producers to increase the allowable limit of ethanol in gasoline to 15 percent, but only for model year 2001 and newer cars (EPA 2011). These decisions have been controversial, and have been opposed by refiners, auto manufacturers, and some environmental groups, including the American Lung Association. Auto manufacturers have raised a concern that higher levels of ethanol may damage the three-way catalysts (i.e. catalytic converters) used on older cars. The American Lung Association has testified about concerns that the air quality and public health may be harmed by the increased use of mid-range blends of ethanol and urged more research.

Past approaches to moving transportation energy use away from petroleum and toward these alternative fuels have relied heavily on voluntary incentives for private consumers, including grants and direct subsidies, as well as tax rebates. Current mandatory requirements apply mostly to federal and state government fleets, and generally focus more on the purchase of alternative-fuel capable vehicles, including dual-fuel vehicles, than on purchase of the fuel itself. For example, to comply with the alternative fuel vehicle purchase requirements of the Energy Policy Act, it is enough that a fleet purchase flex-fuel E85 vehicles (able to operate on E85 or gasoline) or dual-fuel natural gas vehicles (able to operate on natural gas or gasoline): there is no requirement that once purchased the vehicles actually operate on an alternative fuel. As noted above, many of the flex-fuel and dual-fuel vehicles on the road operate almost exclusively on gasoline.

Some states are beginning to experiment with low carbon fuel standards and mandates, which will shift responsibility for decision making relative to alternative fuel use away from consumers and fleets and toward fuel producers and suppliers. Other policy approaches which have not yet been implemented in the U.S. include the inclusion of vehicles and/or transportation fuel suppliers in an economy-wide cap and trade scheme, and the imposition of higher user fees or taxes on petroleum-based fuels, specifically to provide an economic advantage for non-petroleum alternatives.

Transportation Recommended Reading

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