chapter five

Transportation, Energy, and the Environment

Without energy, vehicles and other forms of transportation cannot move. The U.S. transportation sector requires great quantities of energy, about a quarter of the national total. Petroleum supplies about 97 percent of the energy used in transportation in the form of gasoline, diesel fuel, or other light oils (USDOE 1998b). For more than a century, no other fuel has been able to compete successfully with petroleum for motorized transportation. Were it not for its environmental impacts, petroleum's portability (light weight and high energy content) and ease of control make it a nearly ideal transportation fuel. The only other significant sources are natural gas, used to drive compressors on pipelines, electricity for rails and subways, and alcohol for blending into gasoline.

Energy supply is not a problem at this time. Petroleum production capability worldwide is so much greater than demand that prices in 1998 reached virtually all-time lows (in real terms). Resource constraints that could lead to rising prices are thought to be at least a decade away, and possibly much further. Even U.S. production, which had been in a seemingly inexorable decline since 1970, has almost leveled out, despite low prices. The supply system works so effectively that even local disruptions are rare except for occasional weather problems or natural disasters.

Nevertheless, serious energy and environmental issues are associated with transportation. The current abundance of petroleum cannot be assured in the future. Over half the petroleum used in the United States must now be imported. Most U.S. imports are from suppliers who have been reliable, but political instability in any of the major producer regions could disrupt world supplies, leading to steep price increases, as has occurred several times since the early 1970s. Economic damage could be serious. The Strategic Petroleum Reserve was established to provide additional supplies when imports are disrupted, but, as discussed below, its ability to do so is diminishing. The transportation sector uses over 65 percent of all the petroleum consumed in this country (up from 60 percent in 1975) (USDOE 1998b). The lack of significant alternatives leaves transportation particularly vulnerable should a disruption occur in the supply system.

Furthermore, heavy dependence on petroleum is the root of most environmental problems caused by transportation. Despite major improvements in emission rates over the last two decades, transportation continues to be the primary source of pollutants that affect air quality: carbon monoxide, nitrogen oxides, and volatile organic compounds. Fuel consumption by mobile sources also results in a large percentage of the key hazardous air pollutants released in urban and rural areas of the nation. Moreover, the transportation sector contributes to other environmental impacts such as oil spills and hazardous waste. Upcoming federal efforts to reduce these impacts will influence technology and operational changes across the sector.

In addition, the carbon dioxide (CO_2) created by combustion of petroleum in the transportation sector is responsible for about 26 percent of all greenhouse gases emitted in the United States, which in turn accounts for about one-quarter of all anthropogenic emissions of greenhouse gases in the world (USDOE 1998e). Mounting evidence shows that global climate change is potentially a very serious problem. If efforts to control greenhouse gas emissions are undertaken, overall costs will be minimized if the lowest cost options are implemented. Each economic sector, including transportation, has potential low-cost reductions.

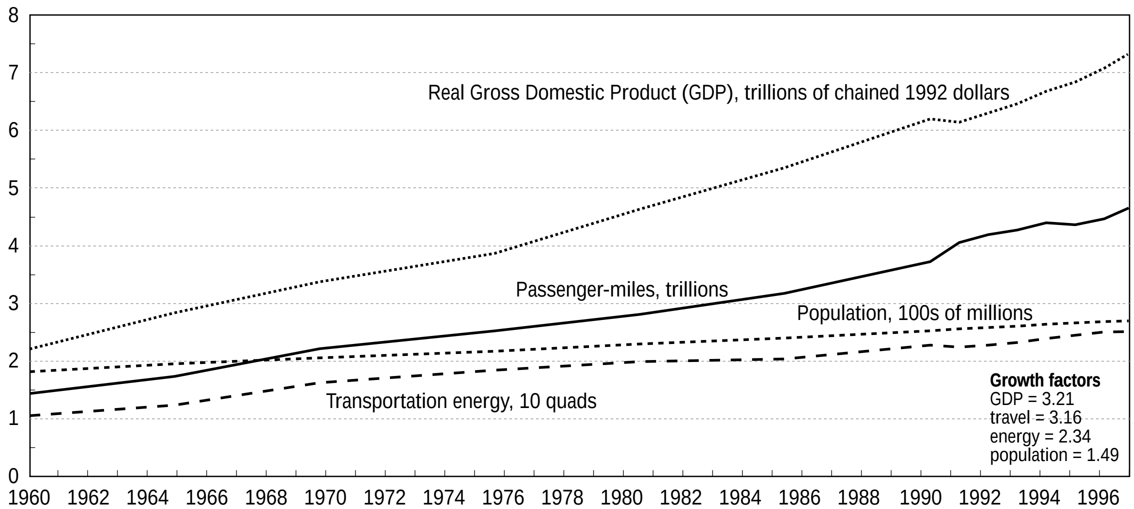
This chapter describes the current status of energy and environmental issues. It also reviews various technologies that could alleviate the problems.

ENERGY[1]

As the economy has grown, so has transportation and the use of energy. There are, however, marked differences in the growth rates, as shown in figure 5-1. Energy use in the transportation sector has grown by a factor of about 2.34 since 1960, less than passenger-miles, despite the increased size of cars and engines now. Improved vehicular efficiency is largely responsible for this difference, as discussed in the next section. Figure 5-2 shows energy consumption by mode for 1997. Total energy for transportation was 24.8 quadrillion (quads) British thermal units (Btu). Highway vehicles account for about 80 percent of total transportation energy use and 84 percent of transportation petroleum consumption (USDOE 1998b and USDOT BTS Forthcoming).

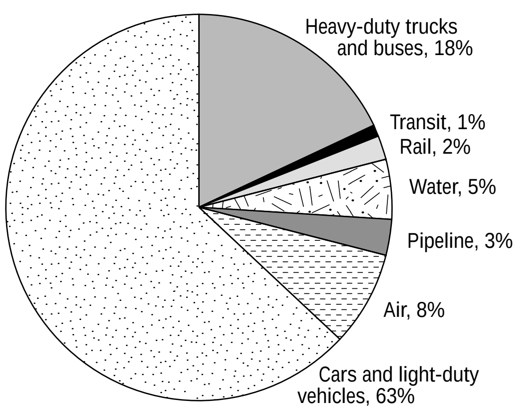
[1] Energy Information Administration (EIA) data are used throughout this chapter. EIA relies on surveys to collect its energy data and models to forecast energy supply and demand. For information about survey methodology and statistical reliability, the reader is referred to EIA references cited in this chapter or the EIA website at www.eia.doe.gov. For information about EIA's modeling standards, please see www.eia.doe.gov/oss/standard.html.

Figure 5-1
Transportation Energy and Economic Activity: 1960–97



SOURCES: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1999* (Washington, DC: Forthcoming); U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, December 1998.

Figure 5-2
Transportation Energy Use by Mode: 1997



SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1999* (Washington, DC: Forthcoming).

Vehicle Economy

Automobiles and other vehicles are far more efficient today than at the start of the energy crisis in 1973, and improvements are still being implemented. Manufacturers have reduced vehicle weight, improved the rolling resistance of tires, and added lockup torque conversion to transmissions to eliminate slippage at highway speeds. Engines have been improved by switching from carburetors to fuel injection, improving combustion control, and adding valves to improve engine breathing. Trucks as well as cars have benefited from these improvements, but heavier frames and poorer aerodynamics mean that trucks are necessarily less efficient.

Since 1988, however, essentially all the gain in new motor vehicle efficiency has been offset by increases in weight and power within classes, and by consumer shifts to lower economy vehicles, especially light-duty trucks (sport utility vehicles, minivans, and pickup trucks). The sales-weighted average weight of new cars rose from 2,805 pounds in 1988 to 3,071 pounds in 1997 (average weight was 3,349 pounds at the start of fuel economy standards in 1978). Also, engines gained about 35 horsepower during this period (USDOT NHTSA 1998).

Figure 5-3 shows the trends in fuel consumption for highway vehicles. It is clear from the figure that fuel mileage has leveled off, mirroring the leveling off of new car mileage. Average fuel economy for the new passenger car fleet has been in the range of 27.9 to 28.8 miles per gallon (mpg) since 1988 and is now slightly below the peak. The Corporate Average Fuel Economy (CAFE) standard has been constant at 27.5 mpg since 1990 (USDOT NHTSA 1998).

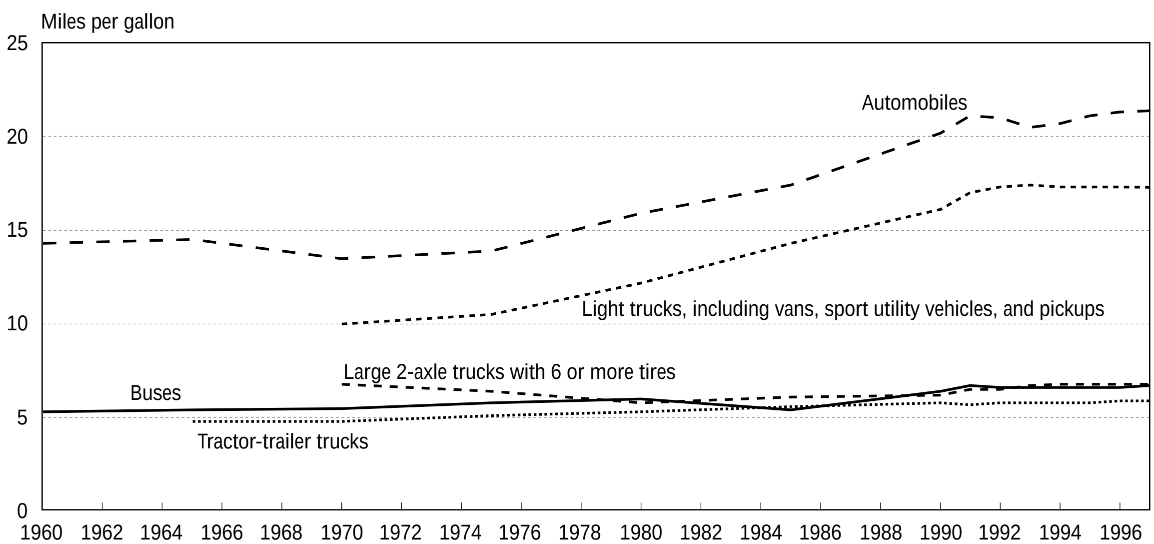
On average, foreign and domestic cars meet the CAFE standard, but Ford Motor Company and several high-end imported cars were below it in model year 1997. All domestic light trucks and several imported ones are below CAFE standards (20.7 mpg) and have been for several years (USDOT NHTSA 1998).

Manufacturers are liable for civil penalties for noncompliance with the standard unless they have accumulated credits from the previous three years for exceeding the standard. They may also borrow ahead if they can demonstrate expected future performance above the standard. Penalties are assessed at $5.50 for each tenth of an mpg multiplied by the number of cars sold by the manufacturer. Thus, a company selling a million cars averaging 26.5 mpg (one mpg below the standard) could be penalized $55 million if the company had no credits accumulated and/or borrowing rights (USDOT NHTSA 1998).

Manufacturers who meet the standard and expect to continue to do so have little regulatory incentive to further raise mileage. The only exception is for those who have to heavily promote their smaller cars to stay above the standard. In those cases, raising their average fuel economy would permit them to sell more heavy, powerful cars, which are generally more profitable.

Light-duty trucks have become quite popular in recent years. Sales of minivans grew rapidly in the 1980s and early 1990s but have declined slightly since 1994. Sales of sport utility vehicles have continued growing, and they are now the fourth most popular vehicle class. More cars than

Figure 5-3
Highway Vehicle Average Fuel Consumption: 1960–97



NOTE: This figure shows the results for the entire fleet of operating vehicles, not just new ones, and is derived from estimates of vehicle travel and total fuel consumed.

SOURCE: U.S. Department of Transportation, Bureau of Transportation Statistics, *National Transportation Statistics 1999* (Washington, DC: Forthcoming).

trucks are sold in this country, but the difference is narrowing. In 1988, 10,370,000 cars and 4,740,000 light trucks were sold; in 1997, there were 8,260,000 cars and 6,530,000 trucks sold. Figure 5-4 shows sales of light vehicles by class (excluding classes of less than 100,000 sales). Sales of most light truck classes gained, while most automobile classes declined (Davis 1998).

Some of this trend may be short-term in duration, but, clearly, many buyers are finding what they want in light trucks rather than cars: interior spaciousness, carrying capacity, visibility, and a perception of safety (at least for themselves if not for occupants of other cars in a collision.) However, the trend does have implications for energy consumption because light trucks average about 5 mpg less than cars. Figure 5-5 shows the sales-weighted CAFE rating for the same classes of light vehicles, divided into those that increased sales and those that lost sales from 1990 to 1997. Only midsize cars gained in sales, and that was very slight. The biggest sales loser among trucks was the one with the highest mileage, small pickups. Overall, figure 5-5 shows a marked shift from high mileage to lower mileage vehicles.

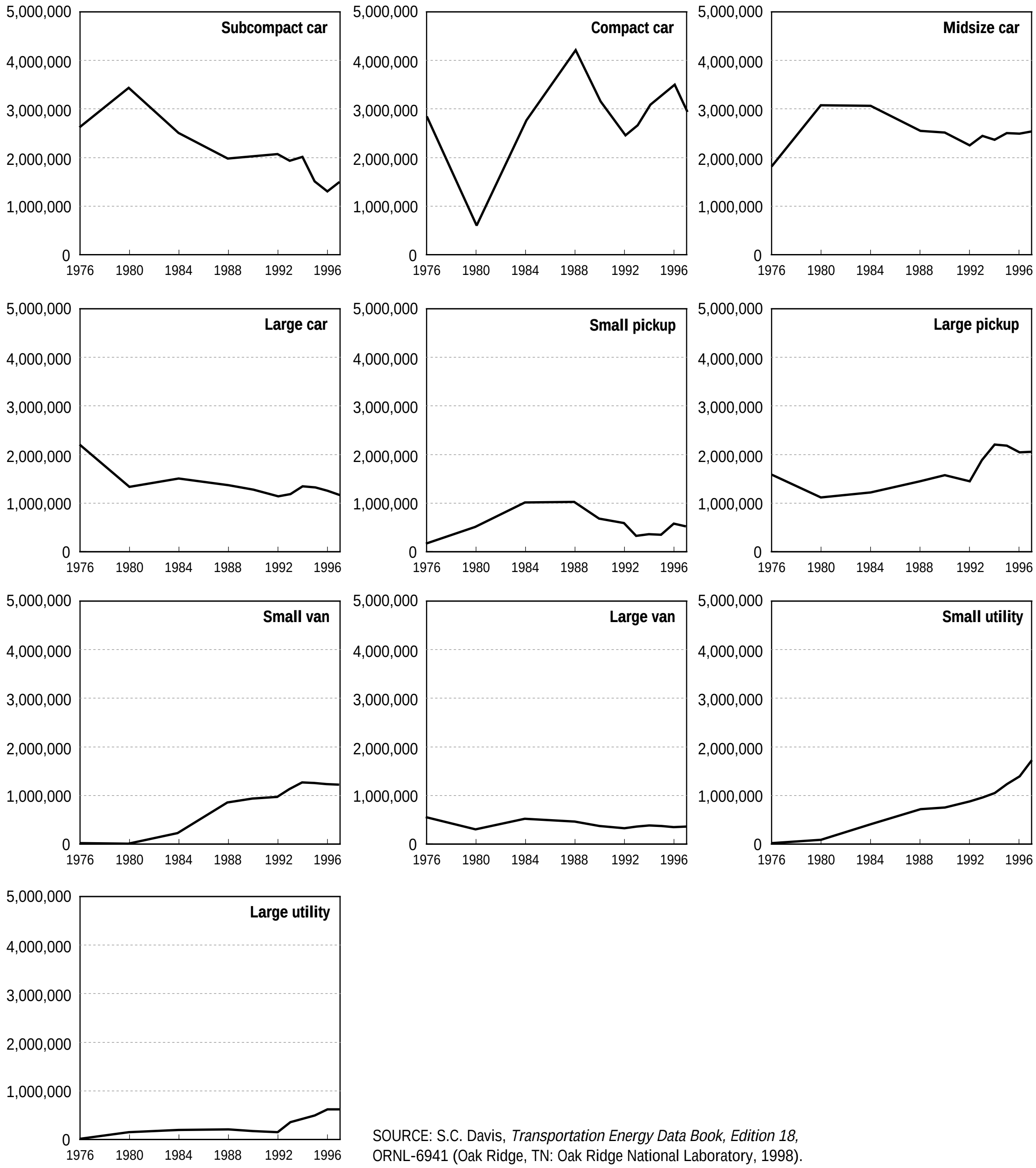
A variety of technologies for further raising efficiency are available or are emerging from the laboratory. Improving aerodynamics to reduce drag is one of the most important in the near term. Internal engine improvements such as variable valve timing and lower rolling resistance tires can also be important. In the longer term, transmissions may have improved electronic controls to select the gear that will allow the engine to operate most efficiently for the given load. A continuously variable transmission would be even better, allowing the engine to operate at peak efficiency at all times. These improvements, and more radical technologies such as the diesel hybrid engine or fuel cells, could be introduced by automobile manufacturers if they saw sufficient demand or were induced by regulations.

Absent higher fuel prices or tightened regulations, however, these advances will be implemented slowly at best. Most manufacturers meet the current standards, and consumers are not demanding greatly increased economy. Therefore, petroleum consumption is likely to continue to increase in the transportation sector.

Energy consumption per passenger-mile (energy intensity) for some other means of travel differs surprisingly little from automobiles. However, intermodal comparisons should be considered approximations. Data for the different modes are collected in a variety of ways and are based on different assumptions. For example, airlines record passenger-miles, but data on occupancy of private automobiles are estimated from surveys. Even relatively hard data, such as state sales of gasoline, must be modified to resolve anomalies, and transit data, which cover light and heavy rail, are more difficult to reconcile.

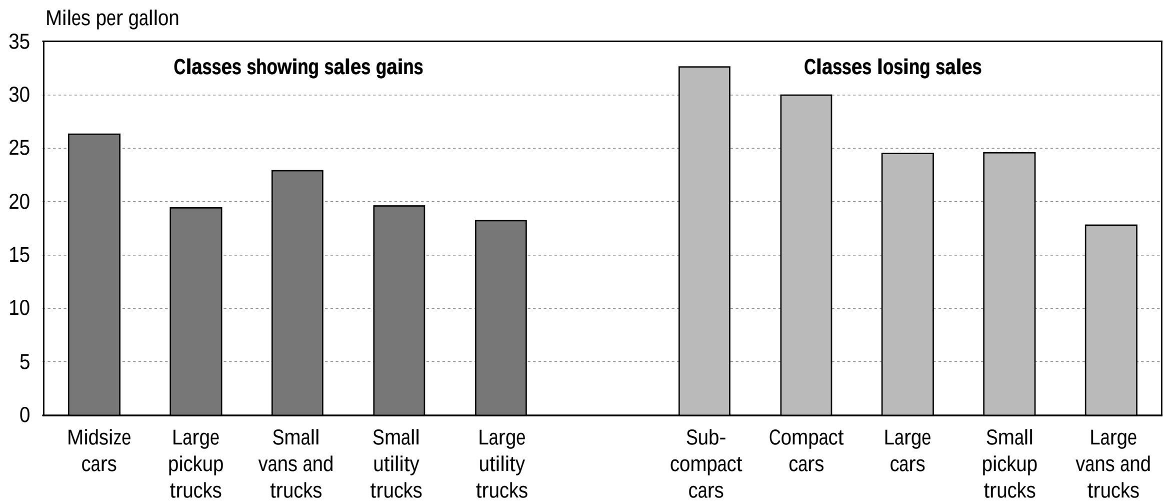
With these caveats in mind, in 1996 passenger car energy intensity was about 3,700 Btu per passenger-mile, down slightly from 3,900 in 1990 and 4,200 in 1980. (Even though new vehicle fuel economy has leveled off, the entire fleet is still more efficient today than years ago, which indicates why energy intensity has declined somewhat.) Light-truck energy intensity was 4,529 Btu per passenger-mile in 1996, down from 4,859 in 1990 and 5,384 in 1980 (assuming the same occupancy rates as automobiles). Air carrier energy intensity was 4,100 Btu per passenger-mile in 1996 (versus 4,800 in 1990 and 5,800 in 1980) (Davis 1998). The decline in energy intensity of air travel is due largely to higher occupancy. Flying a full plane requires considerably less than twice the fuel of a half-full one, but yields twice the passenger-miles. Airlines have been increasingly successful in filling their planes. Some have even reconfigured seating to

Figure 5-4
U.S. Sales of Domestic and Foreign Light-Duty Vehicles by Class



SOURCE: S.C. Davis, *Transportation Energy Data Book, Edition 18,* ORNL-6941 (Oak Ridge, TN: Oak Ridge National Laboratory, 1998).

Figure 5-5
Fuel Economy of Light Vehicles by Class and Sales Change: 1990–97



SOURCE: S.C. Davis, *Transportation Energy Data Book, Edition 18,* ORNL-6941 (Oak Ridge, TN: Oak Ridge National Laboratory, 1998).

fit in more passengers. Newer airplanes are more efficient, but that probably has less effect on energy intensity than the greater number of passengers sharing the fuel. If the economy declines, occupancy may drop and energy intensity rise (Davis 1998).

Energy intensity of Amtrak trains was about 2,400 Btu per passenger-mile in 1996, down from 2,600 in 1990 and 3,200 in 1980. By contrast, energy intensity of rail transit (commuter trains and subways) actually rose from 3,000 in 1980 to 3,500 in 1990. Intercity buses show the lowest energy intensity, about 1,000. Transit buses are higher, at about 4,500 Btu per passenger-mile, as might be expected from their stop-and-go duty cycles (but transit bus data are particularly weak since passenger-miles are not automatically recorded with ticket sales) (Davis 1998).

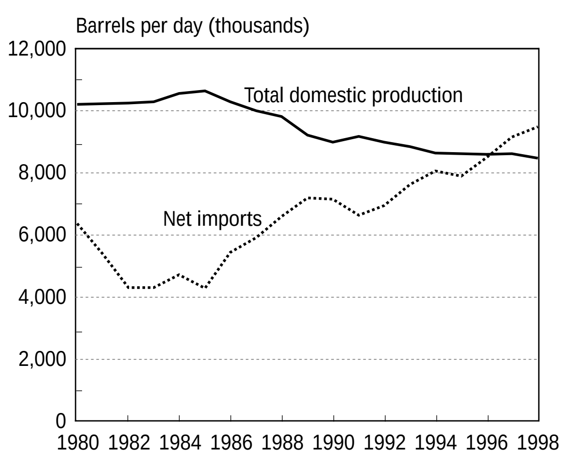
National Security Issues

Energy became a national security issue when imports of petroleum grew to a significant fraction of total consumption during the energy crises of the 1970s. Petroleum shortages can cause considerable economic damage and great inconvenience to many people. Future price and availability of oil are key uncertainties. Transportation is the sector most responsible for oil demand. It is also the sector most vulnerable to oil disruptions and price increases. In addition, the price of oil has a great impact on oil exporting countries, many of which are important allies of the United States.

For the most part, the current low prices are economically beneficial, but they encourage consumption, which generally means more imports. The oil import dependence issue was explored in *Transportation Statistics Annual Report 1998* (TSAR98) (USDOT BTS 1998b). The points made there, such as the potential future dominance of the Organization of Petroleum Exporting Countries (OPEC), potential price increases and their impact on the economy, and the inelasticity of the transportation sector's demand for oil, are still valid although some of the concerns seem far in the future. Moreover, some threats are difficult to foresee. Political problems can arise even with countries with which the United States currently has stable relations. For example, Venezuela is the largest supplier of oil to the United States, with 17 percent of all imports. The recently elected President of Venezuela has expressed concern over its high level of exports, especially when the price is so low. Persian Gulf nations supply another 18 percent of imports, and all members of OPEC supply 45 percent (USDOE 1998b).

The volume of imported oil and petroleum products surpassed that of U.S. production in 1997, as shown in figure 5-6. In terms of energy value, imported petroleum exceeded domestic production in 1994, and has taken an increased share every year since. In 1997, the United States produced 16.2 quadrillion Btu (quads) of petroleum, including crude oil, natural gas plant, and other liquids. Net imports of crude oil and petroleum products totaled 19.6 quads (USDOE 1999). The transportation sector required 24 quads of petroleum, equivalent to all U.S. production plus 40 percent of all imports (USDOE 1998b).

Figure 5-6
Petroleum Production and Imports: 1980–98



SOURCE: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* (Washington, DC: January 1999), tables 3.1a and b.

Never before in U.S. history, even at the height of concern over energy in the 1970s, have imports of petroleum exceeded production. U.S production may stay level for a period or even increase slightly, but growth in demand basically means growth in imports. When world oil supplies tighten, the United States could be more vulnerable to disruptions than ever before.

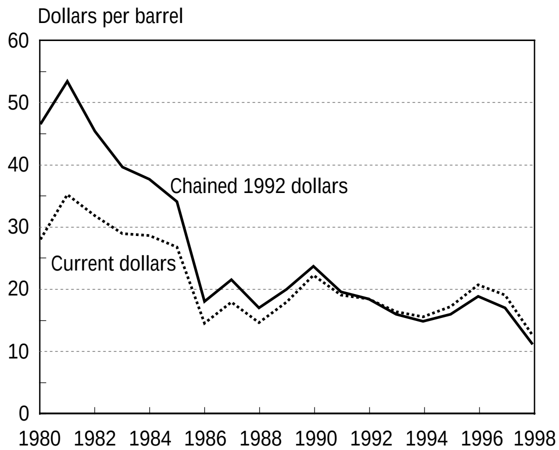
The Strategic Petroleum Reserve was created in 1977 to help the country ride out disruptions. The size of the storage has stayed roughly constant since 1988, but imports have risen significantly. Therefore, the protection provided has dropped steadily. In 1977, it held 563 million barrels, equivalent to 63 days of imports. The peak, in 1985, was 115 days (USDOE 1998b).

It is very unlikely that a high fraction of U.S. imports would be disrupted, but the Reserve is intended to protect against price shocks as well as physical shortages. The transportation sector, with its relatively inelastic demand, would not be able to quickly reduce consumption by more than a few percent without seriously inconveniencing many people. If just 20 percent of imports had to be replaced, the Reserve would last about 10.5 months at current levels. While that is more than supplied by any one country, petroleum exporting countries could well use any sizable disruption in world supplies to further restrict exports and raise prices.

The situation now is the exact opposite of this potential problem. Asian economic difficulties have reduced world oil demand appreciably, lowering prices and causing serious problems for oil producers. The Russian economy has been particularly hurt by the drop in revenues because oil is by far its most important export.

Oil prices are unlikely to rise very much until Asian economies improve. Figure 5-7 shows past oil price trends. Prior to the economic crises, oil

Figure 5-7
World Oil Price: 1980–98



SOURCE: U.S. Department of Energy, Energy Information Administration, *Annual Review of Energy 1998,* DOE/EIA-0384(98) (Washington, DC: July 1999), table 5.19.

demand for 10 East Asian countries (Indonesia, South Korea, Thailand, Malaysia, Philippines, Singapore, Taiwan, Japan, China, and India) had been growing at 5.6 percent per year, the fastest growth of any large region of the world. In 1998, East Asian oil demand was essentially unchanged, and world oil demand growth from 1997 to 1998 was about 300,000 barrels per day. This is 25 percent lower than the 1.2 million barrels per day that the Energy Information Administration (EIA) had forecast before the crisis, even with low prices encouraging consumption in other importing countries (USDOE 1998c).

It is unclear how quickly the East Asian economies will recover. Quite likely the recovery schedule will be different for the various countries, particularly since Japan's problems are different from the others. Japan is taking some important steps to stabilize its banks and restore economic growth, but some analysts are skeptical that its efforts will be adequate. Other Asian countries are showing signs of a turnaround, but it is too soon to tell if a recovery is underway. Asian problems could contribute to soft oil prices for several years. Recently, EIA lowered its projected price of oil by about $5 per barrel for the next several years (USDOE 1998c).

Alternative Fuels

Petroleum provides about 97 percent of all transportation energy as shown in table 5-1. In 1992, it provided about 98 percent. The use of alternative and replacement fuels doubled from 1992 to 1998 while the use of gasoline rose only 10 percent, but that 10 percent increase (11.3 billion gallons) was more than twice as large as the entire use of alternative fuels (about 4.3 billion gallons) in 1998 (USDOE 1998a).

Nevertheless, there is considerable interest in alternative fuels for two reasons—reducing air emissions and oil dependence. TSAR98 discussed the use of blending alternatives such as ethyl alcohol (ethanol) and methyl-tertiary-butyl-ether (MTBE) with gasoline to reduce emissions. MTBE and ethanol, which is mixed with gasoline to form gasohol, are oxygenates, which improve the combustion of gasoline. They are called replacement fuels because they directly replace some gasoline out of each gallon that consumers buy. This application accounts for most of the nonpetroleum fuel used. Replacement fuels also slightly reduce carbon emissions and oil consumption, as discussed elsewhere in this chapter, but the main incentive for using them is to reduce local air pollution.

In theory, alternative fuels have far greater potential than replacement fuels to reduce oil consumption, because they can replace all or almost all the petroleum-based fuel that a vehicle uses, rather than the few percent that oxygenates replace. There are a variety of options for alternative fuels. Of the 418,000 alternative-fueled vehicles (AFVs) operating in 1998, 274,000 (about two-thirds) used liquefied petroleum gas (LPG), primarily propane (USDOE 1998a). LPG

Table 5-1
Alternative Transportation Fuels
(Million gasoline-equivalent gallons per year)

	1992	1994	1996	1998[P]
Alternative fuels				
Liquified petroleum gas	208	249	239	253
Compressed natural gas	17	24	47	77
Liquefied natural gas	1	2	3	6
Methanol	4	6	2	3
Ethanol	—	—	3	2
Electricity	—	—	1	1
Total	**230**	**281**	**296**	**335**
Replacement fuels/oxygenates				
MTBE[a]	1,175	2,019	2,750	3,081
Ethanol in gasohol	701	846	660	857
Traditional fuels				
Gasoline[b]	110,135	113,144	117,783	121,465
Diesel	23,866	27,293	30,101	32,461
Total	**134,001**	**140,437**	**147,884**	**153,926**
Total fuel consumption[c]	**134,231**	**140,719**	**148,180**	**154,260**

[a] Includes a very small amount of other ethers, primarily tertiary-amyl-methyl-ether and ethyl-tertiary-butyl-ether.
[b] Gasoline consumption includes ethanol in gasohol and MTBE.
[c] Total fuel consumption is the sum of alternative fuels and traditional fuels. Oxygenate consumption is included in gasoline consumption.

KEY: MTBE = methyl-tertiary-buytl-ether; P = preliminary.

NOTE: Totals may not equal sum due to rounding.

SOURCE: U.S. Department of Energy, Energy Information Administration, *Alternatives to Traditional Transportation Fuels 1997* (Washington, DC: 1998).

has been popular because it is widely available, relatively inexpensive, about as portable as gasoline, and engines can be easily converted to burn it. While LPG burns more cleanly than gasoline or diesel, it is a petroleum-based fuel and thus offers little advantage for reducing petroleum dependence or carbon emissions.

The next most popular alternative fuel is natural gas; in 1998, 96,000 vehicles used compressed natural gas and another 1,500 used liquefied natural gas (USDOE 1998a). As with LPG, natural gas is widely available and engines can be converted easily to burn it very cleanly. However, storage is not as straightforward as for LPG or gasoline. Natural gas must be either compressed to very high pressures or cooled to very low temperatures to liquefy it. Then it must be stored that way in the vehicle until it is used. One or the other approach is necessary to reduce the volume sufficiently for the vehicle to carry enough fuel for a reasonable range. Both approaches entail elaborate and expensive vehicle fuel tanks and major changes to the fuel supply infrastructure. Natural gas vehicles directly reduce consumption of petroleum and greatly reduce emissions of urban air pollutants. They reduce emissions of carbon by at least 25 percent and more if the engine is modified to take advantage of the high octane value of natural gas.

AFVs that use ethanol or methyl alcohol (methanol) also are being tested. About 22,000 vehicles burn a mixture of 85 percent methanol and 15 percent gasoline. A few hundred more burn pure methanol, but these vehicles can be difficult to start, especially in cold weather. Another 18,000 burn ethanol, usually with 15 percent gasoline (USDOE 1998a).

Some vehicles are designed as flexible-fuel vehicles, capable of burning either alcohol or gasoline. Alcohol-fueled vehicles still use the basic automobile engine but require substantial modification to it. They will require radical changes to the fuel supply system if many of them are to operate. Methanol usually is produced from natural gas but is much more portable. Thus, it solves the storage problem for natural gas but entails much more difficult production and distribution problems. Ethanol usually is made from grain using an energy-intensive process. Currently, ethanol does not offer major petroleum-reduction or carbon dioxide-reduction advantages because fossil fuels are typically used to produce ethanol. Moreover, CO_2 is produced in the fermentation process.

Advanced technologies, however, could allow alcohol to be produced much less expensively from renewable, nonfood sources such as wood and plant wastes. If successful, alcohol-fueled vehicles could contribute significantly to reduced petroleum dependence, local air pollution, and carbon dioxide emissions. Raising crops for the production of alcohol could slow the conversion of marginal farmland to forest, which would be good for farmers but might create some negative environmental impacts, depending on the crops raised and the land used. In fact, a farming resurgence could reduce the credit the United States is expected to receive for sequestration of carbon in trees, which is discussed below.

Yet another option is electric vehicles (EVs), the ultimate in flexible-fuel vehicles, because electricity used to charge the batteries can be produced from almost any energy source. These are considered to be the only zero-emissions vehicles (ZEVs) because they do not burn any fuel themselves. Some pollution may be produced while generating power to charge the batteries, but net pollution from EVs frequently will be lower than from conventional vehicles. If the power is generated from renewable energy or nuclear powerplants, air pollution is negligible.

There are still many uncertainties over the full environmental impact of the entire fuel cycle for both conventional and electric vehicles. The relative advantage of each will vary in different parts of the country. At present, batteries are the only means of storage, and they hold much less energy than the same volume of liquid fuels. As a result, EV performance is distinctly inferior to conventional vehicles. They have a range of about 100 miles on today's battery technology and require lengthy recharging periods. Emerging technology (e.g., nickel-metal hydride) promises to be much better than lead-acid batteries. Several manufacturers now are offering EVs with nickel-metal batteries. EVs can offer major advantages in carbon reduction and oil independence as well as reduced urban air pollution if the technological problems can be solved.

Only about 6,000 EVs are currently operating in the United States (USDOE 1998a). However, this number could rise rapidly. California and New York have aggressively promoted the use of EVs because of severe urban air pollution problems. Both states were to have required automobile manufacturers to introduce ZEVs in 1998, but both programs have been postponed. California has reached an agreement with manufacturers that 10 percent of the new vehicles sold in the state in 2003 will be ZEVs. Manufacturers hope that by then the technology, particularly batteries, will have improved to the point that EVs will be sufficiently attractive that people will want them. New York's intended requirement of 2 percent of all cars sold in the state in 1998 to be ZEVs was overturned by the

Circuit U.S. Court of Appeals in August 1998 on the grounds that it was preempted by the federal Clean Air Act (*EV World* 1998).

GREENHOUSE GASES

Controlling the emissions of greenhouse gases, which most scientists believe could cause global climate change with a potentially disastrous impact, is a contentious and complex issue for the international community. Nevertheless, international agreements to lessen the risk exist:

- In 1992, the United Nations Framework Convention on Climate Change, in Rio de Janeiro, established the principle that nations should take voluntary steps to reduce emissions.
- In 1997, parties to the Convention met in Kyoto, and agreed to a Protocol setting targets for individual industrialized countries.
- The 1998 meeting of the parties in Buenos Aires adopted a plan of action to resolve by 2000 the numerous uncertainties of the Kyoto Protocol.

The United States signed the Kyoto Protocol, but the Clinton Administration has stated that it will not submit the Protocol to the Senate for its advice and consent until there is meaningful participation by developing countries. Many in Congress have expressed opposition to the Protocol for several reasons. Some say redirecting our natural resources to meet this goal could reduce the economic growth rate and hurt the competitiveness of the United States relative to countries that are not affected (especially developing countries). Others believe that climate change has not been adequately shown to be a problem. Proponents of control argue that it is essential to take steps now to avoid likely environmental catastrophes in coming years; that it is incumbent on the United States, by far the biggest emitter of greenhouse gases, to take the lead; and that, if approached intelligently, reductions in greenhouse gases will not be prohibitively expensive, and could create business opportunities for companies and countries selling energy efficient technologies. These issues are beyond the scope of this report, which will discuss transportation's role in greenhouse gas emissions and how those emissions might be reduced.

Table 5-2 shows carbon emissions from energy consumption in transportation and other sectors. Transportation emissions grew 9.5 percent from 1990 to 1997, which was less than in the residential and commercial sectors but more than in industry. In absolute numbers, however, transportation emissions grew the most—about 41 million metric tons of carbon (mmtc) during this period. The transportation sector's carbon emissions in 1997 were 473 mmtc, or about 32 percent of all energy-related carbon emissions. Other greenhouse gases covered by the Kyoto Protocol include methane, nitrous oxide (N_2O), halocarbons, and several others. Collectively, these are equivalent to less than 300 mmtc. The transportation sector is responsible for about 20 percent of the N_2O, which is equivalent to about 17 mmtc. Mobile sources emitted only a trivial amount of methane, but a substantial amount came from refineries producing transportation fuels. That, however, is usually counted under

Table 5-2
Carbon Emissions by Sector
(Million metric tons of carbon)

	1990	1995	1996	1997
Transportation	432	459	471	473
Industrial	454	465	478	483
Residential	253	270	286	287
Commercial	207	218	226	237
Total	**1,346**	**1,412**	**1,461**	**1,480**

SOURCE: U.S. Department of Energy, Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1997,* DOE/EIA 0673 (97) (Washington DC: October 1998).

the industry sector. Overall, these compounds are converted to carbon equivalents. In 1997, the transportation sector contributed about 26 percent of U.S. emissions covered by the Kyoto Protocol.

If the U.S. Congress consents to the Kyoto Protocol, the announced target for the United States will be 7 percent below the 1990 level for all greenhouse gases averaged over the 2008 to 2012 period. The actual reduction target, however, will be more difficult because of three factors that cannot yet be quantified.

First, the Kyoto Protocol accounts for net carbon sequestration in forests in meeting the target, but not in setting the target. Sequestration is substantial in the United States because of reforestation of former farmland. The Protocol also allows nations to purchase credits for reductions made in other countries. It is not yet clear how many credits can be purchased, but they could represent a substantial amount of the reduction required. Finally, the target is based on the collective impact of all greenhouse gases. Carbon dioxide is by far the most important, but other gases may be easier or more difficult to control, affecting the reduction that will be required from carbon. A realistic lower limit for the carbon target is the 1990 level, 1,346 mmtc, not 7 percent below it. Thus, emissions would have to be reduced 134 mmtc from the 1997 level of 1,480 mmtc (USDOE 1998f).

Of course, emissions will continue to climb if actions are not taken. A variety of projections have been made for the period 2008 to 2012. In October 1998, EIA released a report analyzing some of the economic consequences of implementing the Kyoto Protocol. This report projects that without government actions, carbon emissions from energy will rise to 1,791 mmtc by 2010. The transportation sector is responsible for 617 mmtc of that total. If emissions are held to the 1990 level in 2010, transportation's share of the 1990 level of emissions would be 550 mmtc. Thus, while total carbon emissions are reduced, those from the transportation sector would still grow from current levels, though at a reduced rate from the business-as-usual scenario (USDOE 1998f).

Each nation committed to the Kyoto Protocol determines how to meet its target and would have several implementation options (see, e.g., Heinz Center 1998). Each sector could be affected differently by the various options. It is possible, as in the EIA scenario, that U.S. transportation would not have to make any actual reduction from current levels of emissions, but if it does not at least limit growth of emissions, other sectors will have to make deeper reductions and implement more expensive options.

Carbon emissions from automobiles can be limited by: 1) improving efficiency, 2) a shift in consumer purchases to favor more efficient cars, 3) the use of nonfossil fuels, or 4) driving less.

In the transportation sector, reducing carbon emissions is almost the same as saving oil. Measures to raise vehicle efficiency, such as the Partnership for a New Generation of Vehicles, could produce substantial reductions, as discussed above. These measures could be applied to all classes of vehicles.

A consumer shift to more fuel-efficient vehicles would be a reversal of a long-term trend toward larger, more powerful cars and light trucks, including sport utility vehicles. As noted earlier, that trend has balanced improvements in efficiency, and average new vehicle fuel economy has remained essentially flat since 1988. Furthermore, that shift would have to be massive to make much difference.

Alternative fuels have been discussed above. Cars and conventional fuels incorporating alternative components are being developed by manufacturers largely to meet urban air pollution regulations. The impact AFVs could have on carbon emissions depends on the particular alternative fuel. Natural gas has some advantage, but not as much as fuel derived from renewable energy sources. Ethanol produced from conventional grain may have little advantage, but fuels made from cellulosic ethanol would be more advantageous. Emissions from electric vehicles depend on how the power is produced. If the electric sector switches much of its coal-fired generation to natural gas and increases its use of renewable sources, carbon emissions should be significantly lower than for conventionally fueled cars. In any case, an entirely new energy distribution system would need to be developed along with the vehicle technology.

Mass transit and carpooling are two ways to reduce driving without curtailing activities. Both are important in urban areas, but people would have to greatly increase their use of these options to make a large contribution to carbon emissions reduction. U.S. development patterns are diffuse, making it difficult for many people to permanently shift to mass transit or to carpooling. More compact development patterns could evolve or be encouraged, but would take many years to have much of an impact on people's transportation choices. Passenger-miles are likely to continue to climb, albeit perhaps at a slower rate if carbon emissions controls are initiated.

Emissions from the transportation sector will continue to grow unless new technology is introduced at an unusually rapid pace, or people make major changes in their buying patterns. All of the four options for achieving reductions discussed above are likely to play a role, but efficiency improvements will be the most important.

ENVIRONMENT [2]

As with most activities that contribute to the nation's economic growth, transportation has adverse impacts on the environment. This section begins by discussing pollution generated during the use of transportation vehicles, vessels, and aircraft. It then discusses transportation infrastructure (such as airports and highways) and the impacts from the manufacture of transportation equipment. Finally, the section examines impacts arising from vehicle maintenance and the disposal of the equipment and infrastructure when their useful life ends. At each of these phases in the life cycle of the transportation system, a range of impacts occurs. Such analysis provides a more complete appraisal of the system, but the available data are limited.

Pollutant emissions estimates generally are used as a surrogate for impacts in this section. For the vehicle use (or travel) phase, the Environmental Protection Agency's (EPA's) national estimates of emissions trends for six categories of air pollutants, called "criteria and related pollutants" extend back to 1970 and cover all transportation modes. (The term reflects their regulatory status under the Clean Air Act (CAA) of 1970). EPA is now building an air toxics database that in the future may provide emissions estimates for over 100 pollutants. This database will also contribute to a better understanding of emissions impacts during other transportation-related phases, such as infrastructure development and vehicle maintenance and disposal.

Data on transportation-related water pollution, solid and hazardous waste generation,

[2] Environmental Protection Agency (EPA) data are used throughout this section. EPA relies on various models and calculation techniques to estimate emissions. For information about models, the reader is referred to the EPA references cited in this chapter or the EPA website at www.epa.gov.

noise, and the physical disruption of habitat are collected or estimated too infrequently to provide reliable national trend data for all modes and phases. An exception is the vehicle manufacturing phase, where many kinds of trend data are available by equipment type. Overall, however, data are inadequate to confidently make comparisons across modes. Also, data are inadequate to generalize about the complex relationship between the transportation network, diffuse development patterns, and environmental quality; the secondary effects of transportation for land use are not addressed in this report.

Vehicle Travel

Most analyses of transportation-related environmental impacts focus on air pollutants emitted during the travel phase. Cars, trucks, locomotives, planes, and boats emit a wide variety of air pollutants when they are operated: criteria and related pollutants, toxic pollutants, and chlorofluorocarbons (CFCs), among others. The constituents contribute to ill health, acid deposition, smog, stratospheric ozone depletion, and climate change.

With the exception of CFCs, air pollution from transportation is a consequence of the fuels consumed, which vary by mode. Passenger cars primarily use gasoline; freight trucks and freight locomotives, diesel. Commercial aircraft consume jet fuel, while general aviation aircraft use aviation gasoline or jet fuel. Marine vessels burn residual oil, diesel, gasoline, and coal. These different fuels and the way they are consumed (and regulated) result in differing mixes of pollutants. Diesel highway vehicles, for instance, were responsible for only 3 percent of the total estimated carbon monoxide (CO) emitted by onroad vehicles in 1997, but 61 percent of total emissions of particulate matter under 10 microns in diameter (PM-10).

Transportation emissions can and have been reduced in a number of ways, primarily by altering existing fuels, changing the way vehicles burn these fuels, or adding emissions control devices that absorb and alter pollutants before they are emitted. Another option is to switch to alternative fuels.

► Criteria and Related Pollutants

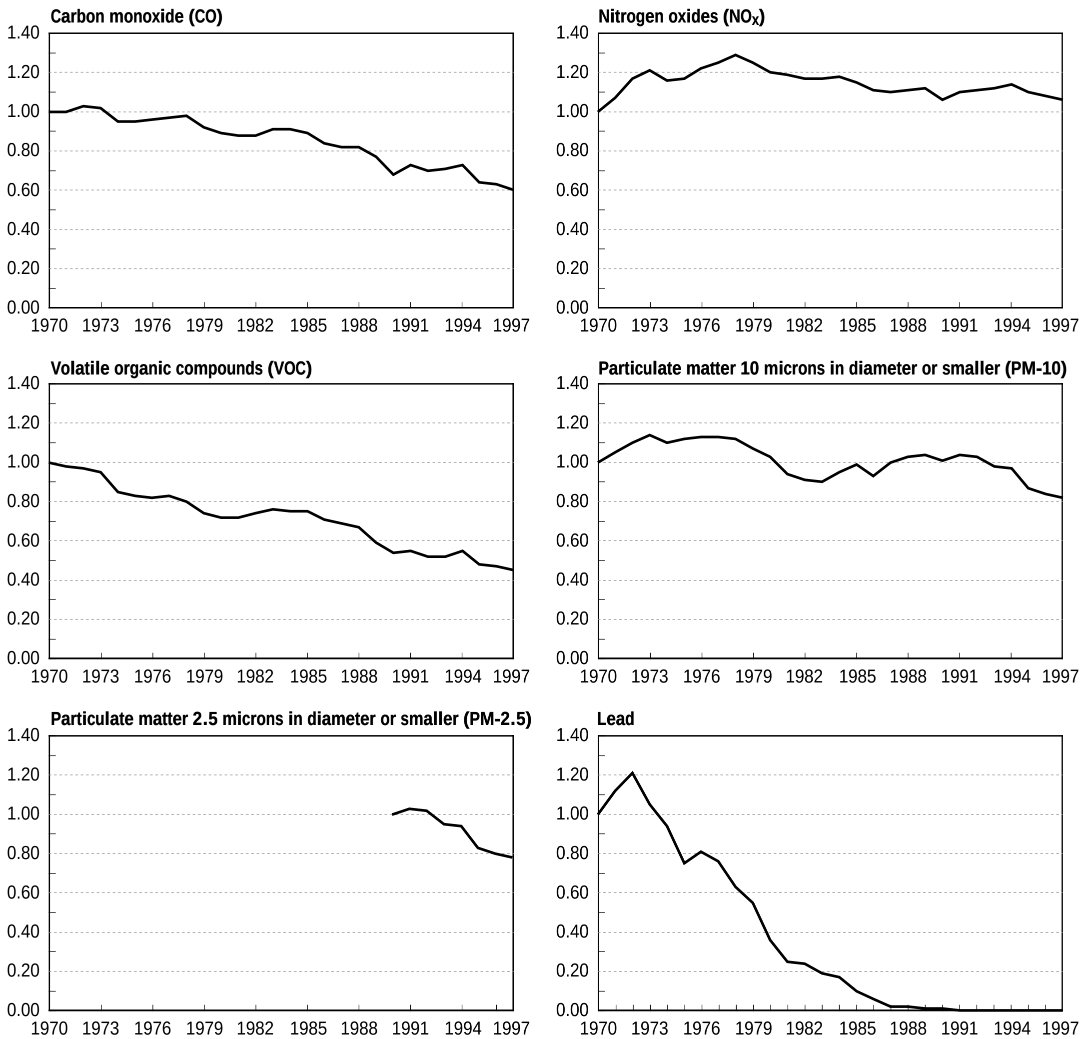
National estimates of emissions of the six criteria and related pollutants—CO, nitrogen oxides (NO_X), volatile organic compounds (VOC), sulfur dioxide (SO_2), PM, and lead—have been made since the early 1970s. These estimates, from EPA's National Emission Trends (NET) database, cover both mobile and stationary (onroad and nonroad) sources of air pollution. Onroad mobile sources include light-duty gasoline vehicles and motorcycles, light-duty gasoline trucks, heavy-duty gasoline vehicles, and diesel vehicles. Nonroad mobile sources cover aircraft, marine vessels, railroad locomotives and maintenance vehicles, and recreational and airport service gasoline and diesel vehicles.[3]

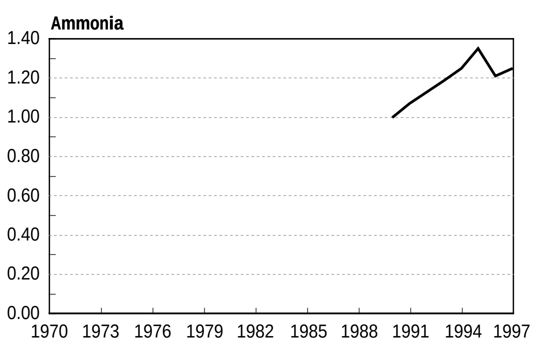
EPA national emissions estimates are modeled, not directly measured. EPA updates its estimates each year, often revising estimates for prior years as well. County-level vehicle-miles traveled (vmt) and emissions factors are used to estimate emissions from onroad vehicles. The emissions factors are derived from models that vary depending on the pollutant.

Figure 5-8 shows the trends in transportation emissions from 1970 to 1997. As shown, sizable reductions in most emissions categories since the early 1980s are apparent even though vmt has increased appreciably. For 1997, in comparison with all sources for which EPA estimates emissions,

[3] The NET database also includes construction, industrial, lawn and garden, farm, light commercial, and logging equipment in the nonroad category. These are not included here. (See USDOT BTS 1996 for a detailed discussion.)

Figure 5-8
National Transportation Emissions Trends Index: 1970–97
1970 = 1.0; 1990 = 1.0 for PM-2.5 and ammonia





NOTE: In estimating criteria and related pollutant emissions for 1997, the Environmental Protection Agency (EPA) made adjustments to prior years. For onroad mobile sources, EPA revised 1996 data. For nonroad mobile sources, EPA revised some estimates back to 1970. The figure reflects those changes and supercedes the similar figure 4-8 in *Transportation Statistics Annual Report 1998.*

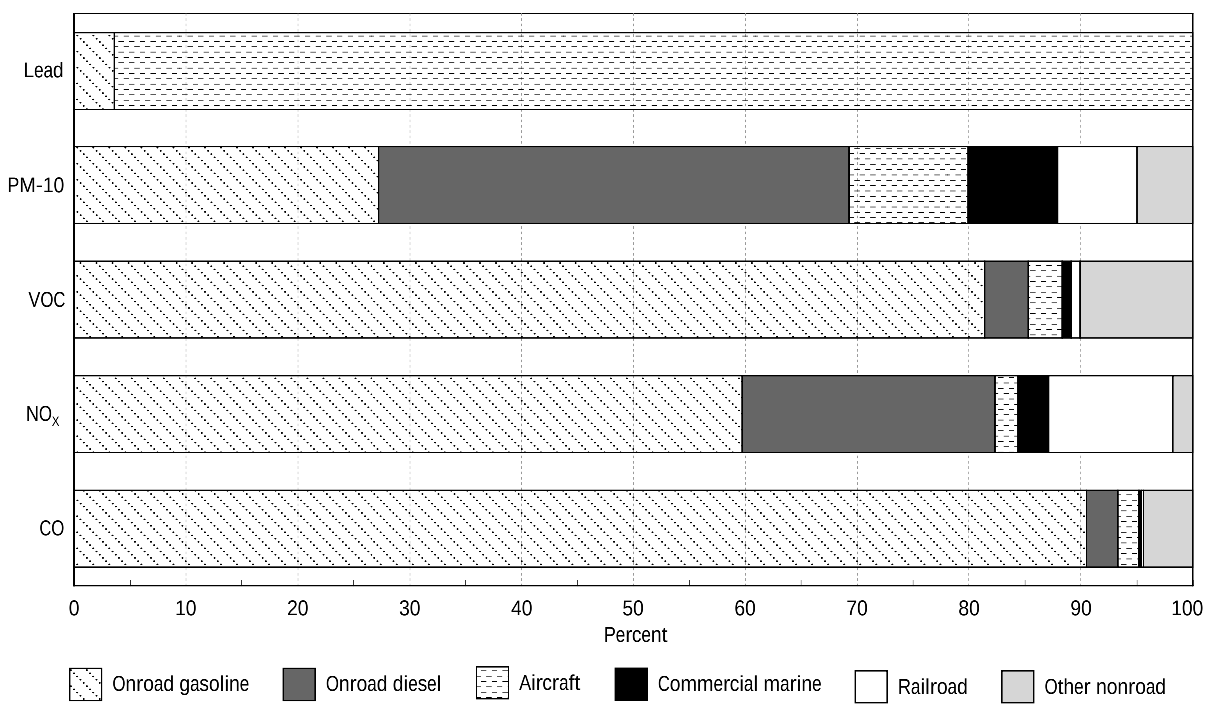
SOURCE: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality Planning and Standards, National Air Pollution Emission Trends, 1900–1997, available on the EPA website at www.epa.gov/ttn/chief/trends97/emtrnd.html.

mobile sources contributed 62 percent (53,842,000 short tons) of all CO, 36 percent (8,573,000 short tons) of NO_X, 32 percent (6,138,000 short tons) of VOC, and 13 percent (522 tons) of lead. Mobile source lead emissions have declined significantly since 1970 when they were 82 percent of all lead emissions. Today, vehicle-use lead emissions come primarily from general aviation, nonroad engines, marine vessels, and motor racing vehicles fuels (63 *Federal Register* 49240).

While mobile sources are only responsible for 1 percent (414,000 short tons) of PM-10 emissions, the contribution rises to 4 percent (324,000 short tons) for the smaller size PM-2.5 emissions (particulate matter of 2.5 microns or smaller). EPA has added a new pollutant for 1997—ammonia—with data estimated back to 1990. Mobile sources provided 8 percent (243 tons) of total ammonia emissions in 1997. Onroad gasoline vehicles generated 98 percent of mobile source emissions from ammonia; the balance came from highway diesel vehicles, railroads, and marine vessels. Gaseous ammonia reacts in the air with SO_2 and NO_X, resulting in ammonium sulfate and nitrate particles that are found in PM-2.5. As figure 5-8 shows, estimated annual mobile source ammonia emissions have been erratic but have risen sharply since 1990.

Modal shares of the 1997 emissions of five pollutants are shown in figure 5-9. When com-

Figure 5-9
Modal Shares of Key Criteria Pollutants from Transportation Sources: 1997



KEY: CO = carbon monoxide; NO_X = nitrogen oxides; PM-10 = particulate matter 10 microns in diameter or smaller; VOC = volatile organic compounds.

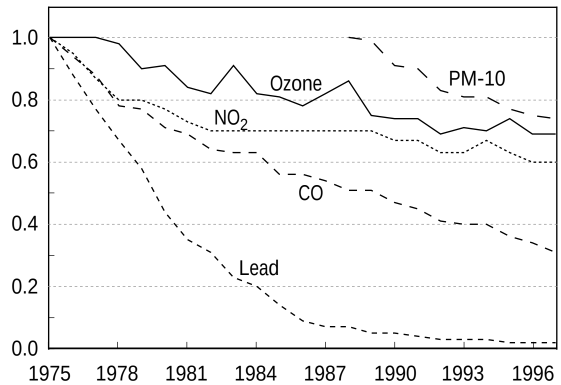
NOTES: Other nonroad includes recreational vehicles, recreational marine vessels, airport service vehicles, and railroad maintenance equipment. Does not include farm, construction, industrial, logging, light commercial, and lawn and garden equipment.

SOURCE: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality Planning and Standards, National Air Pollution Emission Trends, 1990–1997, available on the EPA website at www.epa/ttn/chief/trends97/emtrnd.html.

pared with revised 1996 data, it shows that, in general, minor shifts have occurred from onroad gasoline vehicles to onroad diesel and nonroad mobile sources.

The decline in emissions of criteria and related pollutants from transportation vehicles has played a major role in improving the nation's air quality over the last three decades. Figure 5-10 shows air quality trends from 1975 to 1997. During this 22-year period, CO concentrations declined 69 percent; nitrogen dioxide (NO_2), 40 percent; ozone, 31 percent; and lead, 98 percent. PM-10 has declined 26 percent since 1988, when monitoring began for this size particulate. (Since these data are directly measured by monitoring stations, they are not attributable to any particular source, such as transportation.) While the long-term downward trends are unmistakable, for 1996 and 1997 the concentration levels of NO_2, ozone, and lead remained the same with PM-10 declining only fractionally. Meanwhile, measured concentrations for CO continued to decline in 1997.

Figure 5-10
National Air Quality Trends Index for Criteria Pollutants: 1975–97
1975 = 1.0; 1988 = 1.0 for PM-10



KEY: CO = carbon monoxide; NO_2 = nitrogen dioxide; PM-10 = particulate matter 10 microns in diameter or smaller.

NOTES: Numbers of monitoring sites that provide raw data vary by pollutant and year. For 1975–77: CO (141 sites), lead (43 sites), NO_2 (40 sites), ozone (149 sites). For 1978–87: CO (208 sites), lead (160 sites), NO_2 (93 sites); ozone (320 sites). For 1988–97: CO (368 sites); lead (195 sites); NO_2 (224 sites), ozone (660 sites).

SOURCE: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality and Planning and Standards, National Air Quality and Emissions Trends Report, 1997, 454/R-98-016, December 1998, available at www.epa.gov/oar/aqtrnd971, table A-9.

► Air Toxic Pollutants

Knowledge about nationwide sources of hazardous air pollutants (HAPs), more commonly called air toxic pollutants, is improving. Air toxics have the potential to cause serious environmental or health effects (e.g., cancer, reproductive disorders, or developmental and neurological problems). EPA's National Toxics Inventory (NTI) now contains national estimates of toxic air emissions in 1990 and 1993. The agency plans to compile estimates for the NTI every third year; 1996 estimates are slated to become available in late 1999.

There is some overlap in coverage between the NTI's air toxics and the NET's criteria pollutants; for example, many air toxics are VOC or constituents of particulates, and lead is included in both databases. Because NTI is a relatively new database, EPA does not have the same level of confidence in the NTI data as it does in the NET.

For 1993, EPA estimated that 8.1 million tons of 166 HAPs[4] were released nationwide (USEPA OAR AQPS 1998). EPA attributed 21 percent (1.7 million tons) to mobile sources (onroad and nonroad), 61 percent to point sources (e.g., factories and powerplants), and 18 percent to area sources (e.g., dry cleaners and solvent cleaning industries).[5] The breakdown among sources varies widely by state, with mobile sources rang-

[4] The Clean Air Act requires EPA to study and potentially regulate 188 HAPs, but EPA only has 166 HAPs in its inventory to date.

[5] Both point and area sources are stationary sources. Point sources emit more than 10 tons per year of an individual HAP or 25 tons per year of aggregate HAPs. Area sources emit less than these amounts per year; however, because there can be more facilities in this category, area sources may generate more pollutants overall than point sources.

ing from 55 percent in Hawaii to 10 percent in Alabama. EPA estimated that in 1993 HAPs released by onroad gasoline vehicles (1.3 million tons) were 16 percent below its 1990 estimate due to use of reformulated fuels required to reduce urban ozone. These data also show that onroad gasoline vehicles emit 76 percent of all mobile source HAPs.[6]

[6] In this and other sections where data other than the NET are used, it has not been possible to eliminate subcategories of nonroad mobile sources mentioned in the criteria pollutant section.

In the 1990s, EPA regulated air toxics through maximum achievable control technology standards, directed primarily at stationary point sources. Because of a CAA mandate, EPA published a draft Integrated Urban Air Toxics Strategy in September 1998 (63 *Federal Register* 49240). The strategy provisionally identifies 33 air toxics as presenting the greatest health risks in urban areas. Mobile sources emitted almost 40 percent of these pollutants in the base year, 1990 (see table 5-3).

EPA expects to publish a final Integrated Urban Toxics Strategy by June 1999 and is con-

Table 5-3
Mobile Source Urban Hazardous Air Pollutants: 1990 Base Year
(Estimated tons per year)

Chemical	Onroad vehicles	% of total[a]	Nonroad aircraft	% of total[a]	Nonroad other	% of total[a]
1,3 butadiene	36,920	47.7	854	1.1	16,628	21.5
Acetaldehyde	28,163	27.5	2,090	2.0	6,394	6.2
Acrolein	8,152	11.6	989	1.4	5,376	7.7
Arsenic and compounds	2	0.1	—		—	
Benzene	208,740	47.6	1,106	0.3	89,998	20.5
Chromium and compounds	28	2	—		17	1.2
Dioxins/furans	9.5×10^{-5}	1.6	—		—	
Formaldehyde	97,506	35.6	6,791	2.5	26,864	9.8
Lead and compounds	1,690	35.8	384	8.1	197	4.2
Manganese and compounds	22	0.7	—		20	0.6
Nickel and compounds	16	0.9	—		9	0.5
Polycyclic organic matter as 16-PAH	76	0.3	5	<0.1	47	0.2
Subtotal	**381,314**		**12,219**		**145,551**	
Polycyclic organic matter as 7-PAH	*34*	*1.7*	*<0.1*	*<0.1*	*24*	*1.2*
Polycyclic organic matter as EOM	*56,157*	*13.9*	—		—	
Styrene	*17,200*	*38.8*	*194*	*0.4*	*4,657*	*10.5*
Total	**454,705**		**12,412**		**15,232**	

[a] Percentage of total emissions, all sources, both urban and rural.

KEY: EOM = extractable organic matter; PAH = polycyclic aromatic hydrocarbon; — = less than 0.01 or no estimate made.

NOTES: Chemicals in italics are those for which the Environmental Protection Agency estimated base-year emissions data; they are not included on the current list of 33 draft urban hazardous air pollutants (HAPs).

SOURCES:
For data: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality Strategies and Standards Division and Emissions, Monitoring, and Analysis Division, 1990 Emissions Inventory of Forty Section 112(k) Pollutants, Interim Final Report, available at www.epa.gov/ttn/uatw/112k/112kfac.html, January 1998.

List of 33 draft urban HAPs:
U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality Planning and Standards, National Air Quality and Emissions Trends Report, 1997, 454/R-98-016, December 1998, available at www.epa.gov/oar/aqtrnd97/, table 5-4.

currently updating a 1993 study on the cancer effects of several mobile source pollutants. Subsequently, EPA plans to promulgate national regulations to control HAP emissions from motor vehicles and fuels, as well as from point and area sources.

▶ Stratospheric Ozone Depletion

CFCs and other chemicals deplete the stratospheric ozone layer that protects the earth from harmful ultraviolet rays. Before production was halted at the end of 1995, CFC-12 was widely used as the refrigerant for mobile air conditioning (MAC) systems in cars, trucks, and other vehicles. In the late 1980s, MAC systems accounted for 37 percent of total CFC-12 use (Oldenburg and Hirschhorn 1991). The last new MAC units with CFC-12 were shipped in 1994. These units are expected to have a lifetime of 12 years, thus emissions—while declining—are expected to continue to 2006. Emissions of CFC-12 from pre-1995 units occur from leaks during use, while being serviced, and at disposal. Servicing is expected to consume 84 percent of the stocks of CFC-12 available in 1998 (USEPA OAR SPD 1998). An estimated 66 million MAC units were still in operation in 1998 in the United States.

The primary replacement chemical for MAC units has been HFC-134a, although EPA now lists nine other acceptable alternates. Department of Energy preliminary estimates of 1997 emissions from all sources, including transportation, list 24,000 metric tons of CFC-12 and 18,000 metric tons of HFC-134a. During the period 1990 to 1996, CFC-12 emissions declined by 68 percent, while HFC-134a emissions, which are not ozone-depleting, rose 13 percent (USDOE 1998e).

▶ Aircraft Cruise Emissions

Only criteria pollutant emissions during aircraft landing and takeoff (LTO) are included in EPA's NET data on aircraft emissions. Aircraft engines, however, also emit pollutants, such as CO_2, NO_X, and water vapor while cruising. The quantity of aircraft pollutants emitted is a function of the type of aircraft and engine, modes of operation—taxi/idle-out, takeoff, climb-out, cruise, approach, and taxi/idle-in—and how long engines are operated in each mode.

Cruise-level pollutants are a concern because of their potential impact on global atmospheric problems, such as stratospheric ozone depletion and climate change. However, the extent of these emissions and their impacts are not well known. A Special Report on Aviation and the Global Atmosphere by the Intergovernmental Panel on Climate Change (IPCC 1999) will be used by the International Civil Aviation Organization (ICAO) to consider potential reduction solutions in three categories: changes in technology, operational measures, and market-based options.

A Federal Aviation Administration (FAA) report suggests that air traffic control operational changes that reduce flight restrictions and result in improved aircraft fuel efficiencies could lower NO_X emissions by 10 percent, CO by 13 percent, and hydrocarbons by 18 percent. Over 90 percent of these reductions would occur during flight phases above 3,000 feet (USDOT FAA 1998a). Between 1975 and 1995, U.S. airlines improved fuel efficiency by about 44 percent through technical and operational changes (USDOT BTS 1998a).

▶ Pipeline Emissions

There are over 200,000 miles of petroleum and 1.3 million miles of natural gas pipeline in the United States (USDOT BTS 1998a, table 1-8). EPA's AIRS Facility Subsystem (AFS) provides insight into the type and magnitude of pipeline emissions. However, because of the physical differences between pipelines and other modes and the ways in which AFS data are collected, the data are difficult to use. Comparisons cannot be made using AFS facility-based and NET mobile source data.

According to the AFS, pipelines emit all of the criteria and related pollutants, as well as toxic pollutants as do other modes. Petroleum pipeline data systems (SIC 46) are more likely to emit more SO_2 and VOC than do natural gas pipeline systems (SIC 49). The latter emit more CO, PM-10, and NO_2. Pipelines also emit a variety of HAPs. For a natural gas distribution system (SIC 4924), one state estimated emissions at the county level of 77 pounds per year of total HAPs. In addition, the record shows emissions of nickel, phenol, toluene, xylenes, formaldehyde, mercury, manganese, and cadmium. The latter three are listed as constituents of total suspended particulate emissions (USEPA OAR AQPS 1999a).

Other Vehicle Travel Impacts

While far less quantitative information is available, it is known that transportation vehicles during use impact the environment in many other ways besides emitting air pollutants. Common to all modes is the problem of accidents and leaks that result in spills of hazardous materials, including crude oil and petroleum products. Noise pollution affects people who live or work along highways, railways, and near airports. Other impacts include fugitive dust emissions from roads, oil and coolant releases from locomotives, roadkill, habitat disruption, introduction of nonnative species, and dumping of solid waste and sewage from marine vessels.

► Noise

The transportation system creates pervasive noise, degrading the quality of life to those exposed. Primary sources are aircraft LTOs and traffic moving along highways and railways. Although there are no national trend data on noise, national standards have been developed by FAA for aircraft and by EPA for medium and heavy highway trucks, motorcycles, locomotives, and railcars.

Noise is measured in decibels (dB) that increase as amplitude doubles or in the A-weighted scale (dBA) that emphasizes sound frequencies people hear best. At 65 dBA noise becomes annoying; 128 dBA is the pain threshold (USDOT BTS 1996, 151). Highway trucks manufactured after January 1988 are subject to a maximum rating of 80 dBA. The standard for motorcycles varies from 70 to 82 dBA depending on the model year (1983 to 1989) and type and whether or not the purchaser is the federal government (49 CFR Part 205). Noise standards for locomotives manufactured after December 1979 range from 70 to 90 dBA depending on whether the locomotives are moving or stationary. Railcars moving more than 45 miles per hour have a limit of 93 dBA. Various standards also apply to railroad switching equipment used in railyards (49 CFR Part 210).

Aircraft LTO noise has come under the most recent scrutiny. Stage 3 noise-certified aircraft are being phased in according to regulations promulgated under the Aircraft Noise and Capacity Act of 1990. Stage 3 aircraft noise levels range from 95 to 105 dBA and differ depending on aircraft weight and LTO operations. By the end of December 1999, all aircraft weighing over 75,000 pounds using U.S. airports must be Stage 3 certified. In August 1998, FAA reported to Congress that 260 domestic and foreign operators had reached a combined fleet mix of 79.8 percent Stage 3 aircraft by the end of December 1997. This was an increase of 4.3 percent over the Stage 3 fleet mix a year earlier (USDOT FAA 1998b).

► Spills of Oils and Hazardous Materials

Mode operators are required by law to report spills of hazardous materials, such as oxidizers, combustible liquids and gases, and corrosive material. Three data sources provide information on the extent and cost of spills. The U.S. Department of Transportation's (DOT's) Hazardous Materials Information System (HMIS) records reported hazardous materials incidents by four modes: highway, rail, air, and water.[7] DOT's Integrated Pipeline Information System in the Office of Pipeline Safety aggregates incident data reported by hazardous liquid pipeline operators and natural gas pipeline distribution and transmission operators. These two databases contain the numbers, costs, and causes of incidents, the number of injuries and deaths caused by the incidents, and the type and volume of commodities spilled.

The U.S. Coast Guard's Modified Marine Safety Information System contains data on oil pollution incidents occurring in U.S. waters. Data released in 1999 show that in 1993 through 1998 there were approximately 9,000 spills on average each year. The yearly average over this time period for volume of oil spilled is approximately 2 million gallons. It should be noted that for 1997 and 1998 the volume of oil spilled fell below 1 million gallons (USDOT USCG 1999). While, historically, the amount spilled each year can vary greatly, these data show a continuation of an overall decline since the early 1970s (see USDOT BTS 1996).

HMIS data show that four modes (highway, air, water, and rail) together averaged 14,385 hazardous materials incidents per year between 1993 and 1997. Highway vehicles were the source of 86 percent of these incidents. This does not necessarily mean that highway vehicles are more prone to hazardous materials accidents, since the data are not normalized by, for instance, vmt, number of trips, or commodity flows by mode. Two classes of hazardous materials—flammable/combustible liquids and corrosive materials—are involved in almost 80 percent of each mode's incidents, a likely consequence of these substances being among the most widely shipped in the United States. Combustible liquids include gasoline, petroleum products, and solvents; and corrosive materials include cleaners and acids (USDOT OHMS 1998).

Hazardous liquid pipelines incurred an average of 200 incidents per year between 1988 and 1997 resulting in an average of 2 deaths, 16 injuries, $34 million in damages, and a net loss of 85,000 barrels of liquid per year. Outside damage and external corrosion were the primary cause of hazardous liquid pipeline incidents in 1997 (USDOT OPS 1998).

Natural gas transmission and distribution operators reported a 1988 to 1997 average of 215 incidents per year, resulting in 18 fatalities, 91 injuries, and $32 million in property damage. In 1997, the primary cause of natural gas pipeline incidents was damage from outside forces. For transmission pipelines alone, internal corrosion ranked second. At the conclusion of a 1996 liquid pipeline accident investigation, the National Transportation Safety Board recommended in late 1998 that the DOT Office of Pipeline Safety make several changes to federal regulations to improve the pipeline industry's ability to prevent accidental releases caused by corrosion (USDOT OPS 1998).

Infrastructure Development and Operation

All transportation vehicles require supporting infrastructure, such as highways and bridges, rail lines and terminals, airports, and marine ports and marinas. In a sense, pipelines could be viewed as stationary vehicles or infrastructure through which commodities pass. All modes require fueling stations or equipment, and servicing and repair facilities. Establishment (and enlargement)

[7] HMIS water data are limited to nonbulk shipments on vessels, and cover all U.S. waters and U.S. carriers wherever they may be at the time of the incident. Coverage does not include major incidents such as tanker spills, which are in the U.S. Coast Guards' Modified Marine Safety Information System.

of these facilities and infrastructure takes land, disrupting the habitats of people and wildlife who were prior users of the space, while their construction, maintenance, and operation generates air and water pollutants, wastes, and noise.

Repairs to roads and railways create wastes, such as railroad ties and rails, concrete, and asphalt pavement. Oil, soot, grease, and chemicals run off roads, airports, railyards, and maintenance facilities with the potential to pollute surface waters or seep into and contaminate underground water. Vehicles themselves do not contribute much to particulate emissions but fugitive dust from paved and unpaved roads generated 44 percent (14.8 million tons) of all PM-10 and 30 percent (2.5 million tons) of all PM-2.5 emissions in 1997 (USEPA OAR AQPS 1999b). The following sections highlight marine facilities and airports.

Marine Facilities

There are more than 1,900 major coastal seaports and Great Lakes terminals, nearly 3,200 berths in the United States, and over 1,800 river terminals are located in 21 states (USDOT BTS MARAD USCG 1999). During operation, ships generate garbage, sewage, and bilge and ballast waters. Bilge water consists of fuel, oil, onboard spills, and wash waters generated during daily operations, as well as solid wastes, such as rags, metal shavings, paint, glass, and cleaning agents. Ballast waters from tankers may contain cargo residues, such as petroleum products. The international Maritime Pollution Convention of 1978, to which the United States is a signatory, covers discharges of these and other substances from ships at sea. Raw sewage, for instance, can be discharged 12 miles from land (USEPA OECA 1997). If not dischargable at sea, ship wastes are supposed to be unloaded while in ports. Ports then become responsible for proper management of the wastes. Port facilities that maintain and repair marine vessels generate additional wastes.

Ports and navigation channels must be periodically dredged to maintain proper depth and for enlargement. From 1993 to 1997, the U.S. Army Corps of Engineers dredged an average of 273 million cubic yards of material per year from navigation channels at an annual average cost of $542 million (USACE 1998). Dredged materials, if classified as hazardous or toxic, may have to be disposed of in confined facilities rather than used beneficially, such as for beach nourishment or fill for industrial or urban development.

► Airport Infrastructure Operations

Airports are an example of transportation infrastructure where modes converge. Airplanes land and take off. Highway vehicles (automobiles, trucks, and buses) deliver and pick up goods and passengers. At some airports, transit rail and ferries may also transport passengers. Airport facilities operate, repair, and maintain aircraft and supporting vehicles. Airports also supply services to passengers and workers, such as food, shopping, and restrooms. All these activities have the potential to impact public health and the environment within the airport and surrounding areas.

There were 566 civil, certificated airports[8] in the United States in 1997 (USDOT BTS 1998a, table 1-2). These airports differ greatly in size and how they operate. In most cases, a local government owns the airport and leases the facilities to airlines, service businesses, and other operators. Chicago O'Hare International Airport, which is one of the largest in the world, handled approximately 38 million enplaned passengers in 1998 (USDOT BTS OAI 1999). It has 162 aircraft gates in 4 terminal buildings and in 1994 had more than 380,000 aircraft departures (USDOT

[8] Certificated airports serve air carrier operations with aircraft seating more than 30 passengers.

FAA n.d., table 4-8). Given the wide variety of activities and multiple operators, data on airport impacts must be aggregated or disaggregated from various sources. Still, a complete quantitative picture of environmental impacts does not emerge.

EPA's criteria pollutant data include airport service equipment in its nonroad mobile category, but there are no national data on emissions of onroad mobile sources specific to airports. The NET contains aircraft LTO data (see table 5-4). Aircraft emissions estimates for 1997 range from 4 percent of total NO_X nonroad 1997 emissions to 100 percent of lead emissions. The percentages increase somewhat when service equipment emissions are added, with NO_X rising to 6 percent, largely due to the use of diesel equipment. Worldwide LTO standards for NO_X, CO, and unburned hydrocarbons (such as VOC) are set by ICAO.[9]

EPA's inventory of 33 urban air toxics attributes emissions of more than 12,000 tons of these pollutants to aircraft LTO operations (see table 5-3 above) (USEPA OAR AQSSD/EMAD 1998). This represents 8 percent of the estimated total nonroad toxic air emissions and includes 1,3-butadiene, acetaldehyde, acrolein, benzene, formaldehyde, and lead. The use by general aviation aircraft of aviation gasoline results in lead emissions.

EPA's Biennial Reporting System on Hazardous Waste has data on Airports, Flying Fields, and Services (SIC 4581) for the years 1989, 1991, 1993, and 1995. EPA, however, does not aggregate and publish the data by SIC. Airport reporting appears to be inconsistent from one year to the next, which most likely results from reporting rules; a facility may have to report one year but not the next depending on the quantity of waste generated and changes in the way a facility manages these wastes. For instance, Buffalo Airport, New York, only reported in 1995. In Virginia, Dulles International Airport reported in 1991, 1993, and 1995; National Airport, only in 1995. Dulles reported that its shops and warehouse building activities generated an average of 53 tons of hazardous waste per

[9] Countries belonging to ICAO can accept the standards or petition ICAO to be exempted. In April 1997, the United States adopted ICAO NO_X and CO emissions standards for commercial aircraft engines.

Table 5-4
Aircraft-Related Criteria Pollutants Emitted at Airports: 1997
(Short tons)

Source	CO	NO_X	VOC	SO_2	PM-10	Lead
Aircraft, landing and takeoff	1,012,026	177,521	186,923	11,914	40,924	503
% of total (nonroad mobile sources)	6.0	3.9	7.7	1.1	8.8	100.0
Airport service equipment						
Gasoline	140,657	3,192	6,436	0	36	0
Diesel	42,995	93,242	10,757	0	11,343	0
Total aircraft and service equipment	**1,195,678**	**273,955**	**204,116**	**11,914**	**52,303**	**503**
% of total (nonroad mobile sources)	7.1	6.0	8.4	1.1	11.2	100.0

KEY: CO = carbon monoxide; NO_X = nitrogen oxides; PM-10 = particulate matter 10 microns in diameter or smaller; SO_2 = sulfur dioxide; VOC = volatile organic compounds.

SOURCE: U.S. Environmental Protection Agency, Office of Air and Radiation, Air Quality Strategies and Standards, National Air Pollutant Emission Trends, 1900–1997, forthcoming on the EPA website, 1999.

year. Among the listed items were degreasing parts cleaner, roof caulking, flammable and corrosive liquids, unused pesticides, mixed freons, and toluene. Some of the largest quantities and varieties of hazardous wastes are reported separately by airline company maintenance facilities. United Airlines' maintenance operations facility at San Francisco International Airport reported in all years except 1989. The facility generated an average of 2,285 tons of hazardous waste per year (USEPA OSW 1999).[10]

Hazardous materials spills occur primarily during aircraft cargo loading and unloading operations and from leaking storage tanks, mainly of petroleum products. According to HMIS data, the air mode averaged 864 spills per year, or 6 percent of all mode spills from 1993 to 1997 (USDOT OHMS 1998). Flammable/combustible liquids and corrosive materials constitute 78 percent of annual spills. Airports store aircraft fuel in aboveground and underground tanks that have the potential to leak. Federal regulations do not cover aboveground tanks of petroleum products unless they are part of a pipeline facility, and EPA has deferred action on underground tanks at airports. Thus, the EPA Corrective Action Measures database on underground tanks does not include airport tanks. Some states, such as Florida and Virginia, are moving toward addressing the issue of the leaks themselves. Virginia is working on a case-by-case basis with airport development plans to assure that storage technology upgrades and leak detection systems are included. The Aerospace Industries Association and the American Petroleum Institute are conducting a study on leak detection technologies for airport fuel storage systems.

An important airport environmental issue is runoff into surface waters and soil of deicing chemicals used during winter months. A summary of deicing and anti-icing of aircraft and airport runways was presented in TSAR98. Some regulatory measures are underway that could provide more information and may alter airport pollutant-generating activities. In early 1997, EPA's Toxics Release Inventory (TRI) office received a petition from environmental groups to add SIC 45 (Transportation by Air) to its annual reporting system. A decision will not be made until late 1999 or early 2000.[11] If the sector is added to the TRI, airports that meet threshold levels of emissions will have to report on certain toxic releases to air, water, and land.

In another effort, EPA's Office of Water is conducting a preliminary study on airport deicing that is scheduled for completion in late 1999 (63 *Federal Register* 29203). The study results could prompt development of a guidance document or regulations leading to effluent guidelines for airports.

Vehicle and Parts Manufacturing

Factories that manufacture transportation vehicles and parts generate air and water pollutants and solid wastes, some of which are classified as hazardous.[12] Many of these facilities are required to report annually to the TRI on their releases and transfers of toxic chemicals. This information will help determine the environmental impacts of vehicle and parts manufacturing. However, differences between TRI data and the NET criteria and related pollutant data that EPA estimates for mobile sources make comparisons

[10] The average was calculated using 1989, 1991, 1993, and 1995 data from U.S. Environmental Protection Agency (USEPA OSW 1993–97).

[11] An EPA working group must first report on the current TRI motor vehicle exemption.

[12] This section does not cover pipeline manufacturing and only reviews the final manufacturing and assembly stages related to highway, air, marine, and rail vehicles and parts. A more comprehensive review, such as during a life-cycle assessment, would also consider environmental impacts from primary stages, such as raw material extraction and refining.

with other phases of the transportation system difficult.

TRI data are estimated by facilities, but the facilities do not have to report emissions below a threshold.[13] The list of TRI chemicals has changed from year to year. Some have been removed because they were determined not to meet the criteria for listing; others have been added. The list started in 1987 (the first reporting year) with 308 chemicals; in 1995, it contained more than 600 chemicals and 28 chemical categories. The set of criteria pollutants has remained constant since the 1970s. Of the criteria pollutants, CO, NO_X, and SO_2 are not on the TRI list; lead is, however. In addition, some of the chemicals on the TRI qualify as VOC or constituents of particulates (PM-10 or PM-2.5). Chemicals in EPA's air toxics inventory (the NTI) are a subset of those in the TRI.

Analysis of the environmental impact of transportation equipment manufacturing is also complicated by the sizable international trade in this industry. Thus, the environmental impacts from manufacturing in the United States are not proportional to the numbers of vehicles American's use. For instance, over 12 million passenger cars, trucks, and buses were produced in the United States in 1994 (AAMA 1995). Many of the parts for these vehicles may be imported. Furthermore, while just over 1 million cars, trucks, and buses produced in the United States were exported in 1994, imports totaled almost 5 million vehicles. Data on the value of other modal vehicle trade show U.S. exports exceed imports, especially for civilian aircraft. One exception may be motorcycles and parts; 1997 data list only imports (USDOC 1998).

[13] Manufacturing facilities in SICs 20–39 report if they have 10 or more full-time employees and release/transfer from manufacturing or processing more than 25,000 pounds of a listed chemical or more than 10,000 pounds from "otherwise use." Methods of estimation used by facilities can vary.

► Toxic Pollutants[14]

Facilities in the transportation equipment manufacturing (TEM—SIC 37) sector report to EPA's TRI annually on environmental releases of toxic air and water pollutants and hazardous wastes. They also report on the transfers of these chemicals offsite of their facilities (for recycling, energy recovery, treatment, and disposal) and to publicly owned treatment works.[15]

Among the manufacturing sectors that reported 1996 data to the TRI, TEM is ranked fourth in total onsite releases and sixth in total transfers offsite (USEPA OPPT 1999). Table 5-5 compares the sector's releases and transfers by mode. It shows that highway vehicle and parts manufacturers were responsible for 65 percent of the sector's releases and 77 percent of the transfers in 1996. For all modes, air emissions were the most significant in terms of total pounds released onsite. Just 15 chemicals contributed 92 percent of all these releases. They include xylene, styrene, glycol ethers, toluene, methyl ethyl ketone, manganese, and others.

EPA has compared year-to-year SIC 37 TRI data, based on a core set of chemicals that have been consistently reported. Between 1988 and 1996, subsectors (by 4-digit SIC) have reduced onsite releases, ranging from 34 percent for motor vehicle and car bodies (SIC 3711) to 96 percent for aircraft engines (SIC 3724). Most of the reductions are due to lower air emissions. An exception is SIC 3751 (motorcycles, bicycles,

[14] The basis for this discussion is facilities that report to the TRI under SIC 37 (transportation equipment industry). However, many vehicle parts are manufactured by facilities that report under other SICs. They include tires (SIC 30), automotive glass (SIC 32), batteries and lighting systems (SIC 36), portions of engines (SIC 35), and automotive seats (SIC 25). In addition, the stamping process is represented in fabricated metals (SIC 34). In most of these categories, vehicle parts data are comingled with data on other products.

[15] Facilities must also report on the amount of and how they manage chemicals onsite. These data are not included in this discussion.

Table 5-5

Toxic Release Inventory Data for Transportation Equipment Manufacturing: 1996

(In pounds, except as noted)

		Onsite releases					Transfers offsite			
Sector by mode	**SIC**	**Air emissions**	**Surface water discharges**	**Under-ground injection**	**Land releases**	**Total onsite releases**	**For disposal**[a]	**For waste management**[b]	**Total offsite**	**Totals**
Motor vehicle and car bodies	3711	40,561,496	10,428	0	15,310	40,587,234	1,517,251	46,128,216	47,645,467	88,232,701
Truck and bus bodies	3713	4,719,018	3,257	0	47,986	4,770,261	133,698	4,308,171	4,441,869	9,212,130
Motor vehicle parts and accessories	3714	15,634,030	83,564	0	363,251	16,080,845	4,348,414	103,728,587	108,077,001	124,157,846
Truck trailers	3715	1,705,764	265	0	115,727	1,821,756	16,370	996,221	1,012,591	2,834,347
Motorcycles, bicycles, and parts	3751	721,200	0	0	0	721,200	9,050	679,411	688,461	1,409,661
Highway vehicles total		*63,341,508*	*97,514*	*0*	*542,274*	*63,981,296*	*6,024,783*	*155,840,606*	*161,865,389*	*225,846,685*
Aircraft	3721	4,247,896	16,719	0	15,866	4,280,481	62,547	2,283,762	2,346,309	6,626,790
Aircraft engines and engine parts	3724	484,200	86,909	0	73,773	644,882	430,432	11,984,305	12,414,737	13,059,619
Aircraft parts and equipment, nec	3728	2,396,026	324	0	15,949	2,412,299	120,680	2,504,350	2,625,030	5,037,329
Aircraft total		*7,128,122*	*103,952*	*0*	*105,588*	*7,337,662*	*613,659*	*16,772,417*	*17,386,076*	*24,723,738*
Ship building and repairing	3731	2,707,317	19,752	0	23,922	2,750,991	191,201	7,760,908	7,952,109	10,703,100
Boat building and repairing	3732	11,274,153	0	0	27,134	11,301,287	11,007	469,057	480,064	11,781,351
Marine vessels total		*13,981,470*	*19,752*	*0*	*51,056*	*14,052,278*	*202,208*	*8,229,965*	*8,432,173*	*22,484,451*
Railroad equipment	3743	1,328,150	1	0	1	1,328,152	210,868	1,983,439	2,194,307	3,522,459
Railroad total		*1,328,150*	*1*	*0*	*1*	*1,328,152*	*210,868*	*1,983,439*	*2,194,307*	*3,522,459*
Miscellaneous[c]		12,323,358	2,901	0	5,501	12,331,760	578,421	18,724,061	19,302,482	31,634,242
Total (pounds)		***98,102,608***	***224,120***	***0***	***704,420***	***99,031,148***	***7,629,939***	***201,550,488***	***209,180,427***	***308,211,575***
TOTAL (tons)		**49,051**	**112**	**0**	**352**	**49,516**	**3,815**	**100,775**	**104,590**	**154,106**

[a] Disposal is an environmental release that occurs offsite.
[b] Waste management categories include recycling, energy recovery, treatment, and publicly owned treatment works.
[c] Data for facilities that reported more than one Standard Industrial Classification (SIC) 37.

NOTES: This table does not include data for all facilities that report under SIC 37. Space vehicles, guided missiles, and parts (SIC 3761, 3764, and 3769), travel trailers and campers (SIC 3792), tanks and tank components (SIC 3795), and transportation equipment not elsewhere classified (nec) (SIC 3799) have been excluded.

SOURCE: U.S. Environmental Protection Agency, Office of Prevention, Pesticides, and Toxic Substances, 1996 Public Data Release: Ten Years of Right-To-Know, available at www.epa.gov/opptintr/tri/pdr96/2drhome.htm, 1999.

and parts), which increased total onsite releases by 125 percent between 1988 and 1996.

▶ Criteria and Related Air Pollutants

Current data sources do not provide data comparable to that of mobile sources on the emissions of criteria and related pollutants from TEM. AIRS AFS contains data for key SIC 37 categories, but not necessarily for all facilities nationwide (see above). For the NET, EPA makes national emissions estimates for stationary sources but does not necessarily align them with SICs.

The NET does not contain data for all stationary source categories across all pollutant categories. For the transportation equipment industry, EPA estimates CO, NO_X, and VOC emissions. For 1997 and prior years, CO and NO_X emissions estimates are zero, which means they are less than 1 ton. Using AIRS data, however, EPA's Office of Enforcement and Compliance Assurance estimated that just three TEM sectors—motor vehicles and bodies, motor vehicle parts and accessories, and shipbuilding and repair—emit over 15,000 tons of CO and 28,000 tons of NO_2 per year (USEPA OECA 1998). Under the NET's solvent utilization category, EPA shows VOC emissions for surface coating of autos and light trucks, large ships, aircraft, and railroad vehicles. EPA also estimates VOC emissions from rubber tire manufacturing. The combined VOC emissions for these source categories, as well as TEM, total 162 tons for 1997; surface coating of autos and light trucks are 81 percent of the total.

▶ Nonhazardous Wastes

Little is currently known about the nationwide amount of nonhazardous solid waste (called industrial wastes) generated by transportation (or any other) sector facilities. EPA's most recent industrial wastes estimate was for 1985. It found that the TEM sector generated 13 million tons in that year (US Congress OTA 1992). Since the estimate only included wastes managed in land-based units, such as landfills, it most likely covered only part of the sector's total generation. Of the 16 manufacturing sectors for which EPA estimated such wastes, the transportation equipment sector ranked 14th and generated less than 1 percent of the total.

▶ Regulation of Manufacturing Sectors

Manufacturers must comply with environmental regulations, chief among them are those related to air emissions, water discharges, and hazardous waste. Hazardous waste regulations are not industry-specific but apply broadly to any facility that generates, stores, or transports hazardous wastes above a threshold amount. EPA has not set specific water discharge standards for TEMs as a sector; however, TEM facilities that discharge wastewaters into surface waters must obtain permits (usually at the state or local level) to do so. Many TEM facilities could become subject to standards EPA expects to propose by late 2000 for facilities that manufacture, maintain, or rebuild finished metal parts, products, or machines.

In the 1970s and 1980s, EPA's regulatory concentration focused on VOC from stationary sources, such as TEM facilities, to help areas meet air quality standards. In the 1990s, EPA's focus on reducing HAP emissions affected several TEM categories. Since late 1996, shipbuilding manufacturers have been required to make use of maximum achievable control technology (MACT) standards to reduce emissions of HAPs. Targeted chemicals include xylene, toluene, ethylbenzene, methyl ethyl ketone, methyl isobutyl ketone, ethylene glycol, and glycol ethers. EPA expects the standards to reduce emissions by 350 tons per year from a base of nearly 1,500 tons per year (60 *Federal Register* 64330). Aerospace manufacturing and rework facilities became subject to new standards in late 1995. The standards apply to specific operations at over 2,800 facilities that are major sources of HAPs.[16] EPA expects the standards to reduce nationwide emissions of chromium, cadmium, methelyne chloride, toluene, xylene, methyl ethyl ketone, ethylene glycol, and glycol ethers by 124,000 tons (60 *Federal Register* 45948).

EPA is now developing MACT and VOC requirements for styrene emissions from boat manufacturing and, by late 1999, expects to propose standards for rubber tire production, auto and light-duty truck manufacturers (surface coating operations), asphalt concrete manufacturers, and engine testing facilities. EPA, operating under a consent decree, has a deadline to finalize most of these (and other) rules by the end of 2000.

Vehicle Maintenance and Support

The nation has a myriad of facilities that clean, maintain, repair, and fuel transportation equipment and vehicles. Servicing the vehicles and equipment generates air and water pollutants and hazardous and solid wastes. Little national data are available that would enable comparisons among modes nor with other areas of the transportation system.

Many of the troublesome wastes generated during maintenance of vehicles also pose problems during the disposal phase (see below). For many wastes, determining how they are disposed depends on their classification under state or local regulations. A hazardous or special waste classification may prohibit placing wastes in municipal landfills. For instance, 38 states had laws in 1995 that either banned rubber tires from landfills or required them to be shredded or cut prior to disposal in a landfill (RRI 1996). At the federal level, EPA identified the open burning of scrap tires in 1998 as a source of polycyclic organic matter, a HAP regulated under a special provision of the CAA. EPA issued a final rule in late 1998 to reduce VOC emissions from automobile refinishing operations by 31,900 tons per year (63 *Federal Register* 48806). Instead of setting emissions standards for refinishing shops, EPA required manufacturers of automobile refinish coatings to reduce the VOC content of their products.

The American Trucking Association's "Green Truck" website (www.trucking.org/greentruck/) lists 16 problematic wastes and cautions facilities to check with local landfill operators before throwing them away. The list includes various fluids, used antifreeze, used solvents (including those that are citrus-based), batteries, shop rags, oil spill absorbent material, catalytic converters, and so on. A special program at a U.S. Postal Service maintenance facility in New England demonstrated that the amounts of four types of waste can be reduced by implementing good operating procedures and making process modifications. From 1992 through 1995, the facility eliminated used parts solvent, used antifreeze, and brake cleaning solvent wastes, and reduced waste paint and solvent by 90 percent (USPS n.d.).

Small service stations and repair facilities have been a focus for many state pollution prevention and small business technical assistance programs. For instance, in 1992, Washington's Department of Ecology (WDE) initiated a campaign to help automotive repair shops better understand and voluntarily meet hazardous waste requirements. There are 10,000 of these shops that manage some 30 different wastes that are potentially hazardous. WDE visited over 1,700 shops, particularly those specializing in auto bodies, auto dealerships, auto repair, machine shops, radiator shops, service stations, tire dealers, and transmission shops. WDE estimated that, statewide, automotive repair shops

[16] A major source is a facility that emits more than 10 tons of a specific HAP per year or more than 25 tons of any combination of HAPs.

were responsible for 1.2 million gallons of used antifreeze, 1 million used fuel filters, 35 tons of used lead solder, 4,000 55-gallon drums of used paint thinner and solvent, and 1.3 million aerosol spray cans used for lubrication and degreasing per year (WDE 1994).

► Fueling

Air pollutants are emitted during the fueling of transportation vehicles. Because gasoline evaporates more readily than diesel fuels, gasoline vehicles contribute more to this problem. EPA separates fuel-related evaporative emissions into Stage I (distribution to markets) and Stage II (refueling of vehicles) categories. Service station Stages I and II and other operations emitted an estimated 825,000 short tons of VOC in 1997, with refueling responsible for 52 percent (427,000 short tons), according to EPA's NET. Total VOC emissions in the nonmobile source category of NET, called Storage and Transport (of which Stages I and II are part), were estimated at 1,377,000 short tons for 1997. As noted earlier, total mobile source VOC emissions in 1997 were 6,138,000 short tons; Storage and Transport are not part of this total. EPA has sought to control retail gasoline evaporative emissions through such measures as requiring dispensing facilities to install fuel pump devices to recover refueling emissions and requiring manufacturers to install vapor recovery systems in new light-duty vehicles.

EPA's NTI lists four Stages I and II gasoline toxic pollutants—benzene, polycyclic organic matter as 16-PAH, ethylene dichloride, and lead—and estimated total emissions of 11,575 tons in urban areas for the baseline year of 1990. EPA also estimated lead emissions for both stages of aircraft gasoline distribution at 0.15 tons in urban and rural areas. In 1998, EPA announced that it would consider the development of regulations to control lead emissions from evaporative losses associated with aviation gasoline transfer and storage, aircraft refueling, and spillage.

Data on emissions from the fueling of locomotives are not disaggregated by EPA; however, locomotive fueling's contribution to air pollution is most likely minor. First, freight locomotives are generally powered by diesel fuels. Second, passenger train locomotives are often powered by electricity. While this means that related emissions occur at powerplants and depend on the type of fuel used to generate the electricity, they are relatively minor. The Department of Energy reports that railroads and rail transit systems purchased less than an average of 3 percent per year from 1993 to 1997 of all kilowatt-hours sold in the United States (USDOE 1998d).

► Leaking Underground Storage Tanks

The need for fueling also creates the potential for underground water contamination. Most fuel storage tanks are buried underground, especially at retail gasoline stations. These tanks have a history of leaking due to corrosion, overflows, and spills. In response to legislation, EPA set up the Underground Storage Tank (UST) Program in the mid-1980s to remediate leaking tanks holding petroleum products and establish regulations on leak detection and tank standards. Data reported to EPA by states, as of September 1998, show that the country has almost 900,000 active regulated tanks and that 1.2 million tanks have been closed and over 300,000 cleanups initiated since 1990. This leaves 168,000 known releases not yet cleaned up (USEPA OSW OUST 1998).

To prevent leaks, detection rules became effective in the early 1990s, but EPA gave facilities subject to the tank standards 10 years (until December 22, 1998) to comply. Options for UST owners have been to close, upgrade, or replace tanks that do not meet the standards. In early December 1998, EPA estimated that 56 percent of the USTs then in operation met the federal standards and issued a guidance document on pending enforcement efforts (USEPA OECA/ OSWER 1998). EPA expects most enforcement efforts, especially those affecting small business and local government, to be conducted by states. In 22 states, for instance, distributors are not allowed to deliver gasoline to facilities that are not yet in compliance.

▶ Transportation Equipment Cleaning

EPA's Office of Water proposed effluent guidelines in mid-June 1998 for facilities that clean the interiors of tank trucks, rail tank cars, or barges that have been used to transport cargo. In general, these pending guidelines will affect independent operators because other facilities are part of industry sectors already covered by Clean Water Act effluent guidelines. Ninety-five percent of transportation equipment cleaning facilities that discharge wastewater do so to publicly owned treatment works. The majority of the barge facilities (77 percent), however, discharge directly to U.S. surface waters (63 *Federal Register* 34685).

In addition to the residual products from tanks being cleaned, wastewater generated by the transportation equipment cleaning industry includes water and steam used to clean the tank interiors, prerinse solutions, chemical cleaning solutions, final rinse solutions, tank exterior washing wastewater, boiler blowdown, tank hydrotesting wastewater, and safety equipment cleaning rinses. Aside from conventional pollution (e.g., oil and grease, elevated levels of suspended solids or biological oxygen demand, and Ph affects), these operations produce priority toxic and nonconventional pollutants, including chemicals listed in the TRI. Toxic and nonconventional pollutants differ depending on the type of cargo being washed out. EPA has done a pollutant reduction and cost analysis based on different technical options. Ultimate reductions will depend on the technologies chosen for the effluent guidelines, expected in mid-2000.

Disposal of Vehicles and Parts

Vehicles are generally disposed of when they reach the end of their useful lifetimes. While they are in service, old parts are discarded as repairs are made. Components of transportation infrastructure, such as railroad rails and ties and highway pavement, also must be disposed of or reused in some way. The disposal of vehicles, parts, and infrastructure results primarily in solid wastes, some of which are hazardous. As with the maintenance phase (see above), disposal data are limited.

The number of vehicles scrapped in the United States each year varies. Between 1992 and 1996, for instance, an annual average of 11 million passenger cars and 2.8 million trucks were scrapped (USDOT BTS 1998a, table 4-43). Similar data for other vehicle modes are not available. Some aircraft and ships are kept for possible future refurbishing and use. Rail locomotives are commonly remanufactured, prolonging their useful life. In addition, a portion of the nation's stock of used highway vehicles, locomotives and railcars, marine vessels, and aircraft are exported to other countries for continued use.

Prior to disposal, transportation vehicles are generally dismantled. For automobiles, much of the material generated can be recycled. For instance, almost three-quarters of the 12.8 million tons of material generated from retired automobiles was recycled in 1994. The remainder (3.5 million tons) was placed in landfills (USDOT BTS 1996). The process of dismantling vehicles, however, has the potential to generate many hazardous wastes if not done properly (see table 5-6). For instance, the commingling of different fluids during dismantling can reduce recycling options. EPA requires that mobile air conditioner fluids be extracted and handled separately. CFC-12 can be sold to certified handlers

Table 5-6
Wastes from Vehicle Dismantling Operations that may be Classified as Hazardous

Air bags
Antifreeze
Asbestos
Auto body shop waste
Auto fluff
Brake fluid
Fuel and fuel filters
Lead parts
Lead-acid batteries
Mercury switches
Refrigerant (CFCs)
Shop towels
Spray cans
Sump sludges
Transmission filters
Transmission fluid
Used oil
Used oil filters
Wastewater
Windshield washer fluid

SOURCE: Washington State Department of Ecology, Hazardous Waste and Toxics Reduction Program, *Vehicle Recycling Manual: A Guide for Vehicle Recyclers* (Olympia WA: October 1997).

and eventually is used by facilities that service old MAC units. An estimated 5 million pounds of CFC-12 is reclaimed each year from all sources (USEPA OAR SPD 1998).

► Batteries and Used Oils

Lead-acid batteries are used in highway vehicles, marine vessels, and aircraft. Mandatory recycling programs for lead-acid batteries now exist in some form in 30 states (EXIDE 1998). Between 1991 and 1996, an estimated annual average of 94.6 percent of the lead available from old batteries in the United States was recycled. Onroad and nonroad mobile sources batteries contributed 88 percent, 72 percent of which came from highway vehicles[17] (BCI 1998). Other types of batteries—such as alkaline, lithium, magnesium, nickel-cadmium, and nickel-mercury batteries—are now found in vehicles. Their disposal may be regulated and recycling encouraged at the state or local level.

Many states encourage the recycling of used oil. According to EPA, an estimated 380 million gallons of used oil are recycled each year (USEPA OSWER 1996). Vehicles contain a wide variety of oils that become contaminated with dirt, metal scrapings, water, or chemicals during use. Oils include motor oil, transmission fluid, lubricating oil, gear oil, cutting oil, hydraulic oil, differential oil, power-steering fluid, and transaxle fluid. Used motor oil can be refined and reused as motor oil or processed for furnace fuel oil.

► Marine Vessel Dismantling

In 1998, the General Accounting Office (GAO) released a report detailing problems involved in scrapping U.S. vessels. Ship scrapping is complicated by an extremely high level of environmental and worker safety risks. Ships can contain hazardous materials, such as asbestos, polychlorinated biphenyls (PCBs), lead, mercury, and cadmium. The materials can be released during the dismantling process, polluting land and water surrounding the site (US Congress GAO 1998).

DOT's Maritime Administration (MARAD) is the U.S. government's disposal agent for surplus merchant-type vessels of 1,500 gross tons or more.[18] The Merchant Marine Act of 1936 (as amended) authorizes MARAD to sell obsolete vessels for scrap in domestic and foreign markets.

In August 1999, MARAD had 111 vessels ready to be scrapped with 16 more awaiting transfer by the U.S. Navy. Many of these ships are in poor condition and most were built with polychlorinated biphenyls (PCBs), a hazardous material used in capacitors, transformers, electri-

[17] It is not possible to break out modes other than marine vessels from these data. Motorcycle and aircraft battery data are included in the totals but individually hidden for confidential reasons.

[18] Federal Property and Administrative Services Act of 1949.

cal equipment, cables, paint, gaskets, and adhesives.

In 1993, EPA advised MARAD of its position that the export for scrapping of a government ship containing regulated quantities of PCBs was prohibited under the Toxic Substances Control Act. On September 23, 1998, the Vice President issued a moratorium prohibiting overseas scrapping through October 1, 1999, with an exception provided for MARAD to request a waiver from the Council for Environmental Quality after January 1999.

Prior to 1994, MARAD sold most of its ships for scrapping overseas. Between 1987 and 1994, MARAD sold 130 ships, and then did not sell any more ships for scrapping until 1997, when 2 were sold to domestic scrappers in Brownsville, Texas. In 1998 and 1999, MARAD awarded 22 ships to domestic scrappers located in Brownsville, but to date the scrappers have only taken delivery on 6. Awards are based on a bidder's technical compliance plan and record relating to environmental and worker health and safety. MARAD will dispose of all unassigned vessels in the National Defense Reserve Fleet by September 30, 2001 ". . . in a manner that maximizes the return on the vessels to the United States."[19]

DATA NEEDS

Energy

Transportation energy data are good, but not as good as they should be. Deficiencies in data inhibit understanding of how well current policy is working and the differences changes might make. Much of the energy discussion in this report involves data that are based in part on estimates and extrapolations rather than directly measured values. Furthermore, some important details are missing. Areas where better data would allow more accurate analysis include: automobile efficiency, trends in petroleum consumption and imports, and growth of nonpetroleum fuels in the transportation sector. Better data on how and where people drive and the energy they consume doing so would also aid in understanding and controlling urban sprawl.

Of greatest concern is the uncertainty in the area of light-duty vehicle fuel use. This information is not measured directly but inferred from data supplied by the states that procure it in the process of collecting fuel tax revenues. While fairly accurate on a gross basis, it provides no detail on matters such as fuel consumption by make and model, vehicle occupancy, or vmt.

Estimates of the costs of reducing carbon emissions from the transportation sector are very uncertain because of the lack of this detail. There is only a general, largely theoretical, sense of how people would react to higher prices or stricter economy standards. Under changing conditions, such as carbon restrictions, vehicle selection and miles traveled, occupancy rate, and other factors, are likely to be different, but they are hard to predict unless sufficient detail on how people behave exists.

An extensive, accurate, and frequent survey of light-duty vehicle energy consumption by make, model, and year, coupled with odometer readings would go a long way toward filling this need. This survey could collect the same sort of data as the Truck Inventory and Use Survey (TIUS), as discussed in TSAR97 and TSAR98, but be directed at all vehicles. A Vehicle Inventory and Use Survey would have to be conducted somewhat differently from TIUS because it is unlikely to be mandatory, but the results should be valuable.

It is also important to improve data on nonpetroleum fuels, especially those used for blending with gasoline. As noted in TSAR98, some additives, especially ethers, are not accounted for, and

[19] National Maritime Heritage Act of 1994.

the components of imported reformulated gasoline often are not known exactly. Both these factors are of increasing importance. In addition, the production of grain alcohol requires a large amount of petroleum, both on the farm and at the distillery. Energy from petroleum may approach or even exceed the energy of the alcohol produced, yet it is assigned to the industrial sector. A better understanding of the entire system of alcohol production and use could provide a more accurate energy (and carbon) accounting. Blending is far more important than alternative fuels on their own, and it is important to understand just what is being used.

If electric and hybrid-electric vehicle production grows as rapidly in coming years as some analysts believe, it will be important to understand where the power is coming from and how it is used. The groundwork should be laid now to determine the data that must be collected and how to collect it.

Other areas of inadequate data include heavy-truck load factors and bus energy use. Trucks often are required to make return trips empty, but surveys do not usually distinguish between fuel consumption on loaded and unloaded trips. Very little energy data are collected on intracity and school buses. Overall energy consumption accuracy would be improved with better data on buses.

Environment

In general, environmental data are collected and aggregated in ways that are useful to those who oversee the separate air, water, and solid waste laws and regulations. Some of these data are collected regularly; others, only occasionally. Because of this, data provide some but not full understanding of the environmental consequences of transportation. To achieve a full understanding, trend data are needed on emissions of a range of pollutants for all modes and several phases in the life cycle of vehicles. In addition, information is needed on how emissions impact public health and the environment and how this changes over time.

Sufficient, equivalent data to enable comparisons among the phases—travel, infrastructure, manufacturing, maintenance, and disposal—are not available. Modal comparisons are only possible within the travel and manufacturing phases. Overall, transportation environmental data are particularly weak in showing the effects of pollutants emitted. Difficult questions such as how and to what extent they damage human health, agriculture, ecosystems, and so on remain unanswered.

► Travel Phase

From an environmental perspective, travel (or the use of vehicles and other transportation equipment) is the most often considered phase of the transportation system. This is also the phase for which data is most complete.

Data on six criteria air pollutants generated by highway vehicles, aircraft, marine vessels, and rail locomotives are the most comprehensive transportation environmental data available. The prime reason is that the Clean Air Act, unlike other environmental legislation, directs EPA to consider both stationary and mobile (i.e., transportation) sources of air pollution. In addition, EPA annually estimates emissions of these pollutants and has done so for over two decades. These National Emissions Trends data are complemented by data EPA aggregates annually from monitoring stations across the nation, providing long-term trends in the nation's air quality.

Air emissions data are improving. EPA is in the process of building the National Toxics Inventory database of estimated emissions of 188 hazardous air pollutants for both stationary and mobile sources on a biennial basis. There is, however, no monitoring system in place that will provide measurements of actual HAPs in the nation's air. Such data are collected only sporadically and usually for only one specific pollutant or set of pollutants.

Not all modes are thoroughly covered by the NET and the NTI air emissions data. EPA, for instance, only estimates aircraft criteria and toxic pollutant emissions occurring during landing and takeoff operations. However, aircraft produce most of their emissions while at altitudes above 3,000 feet, where their impact is more global than local.

In addition, EPA does not consider pipelines to be mobile sources. EPA's AIRS Facility Subsystem database provides insight into both criteria and toxic air pipeline emissions; however, the data are difficult to use. AFS data are estimated at the facility level and submitted to AFS by states. The data are not valid as national trend data. Only large sources are included, not all states report each year, and states may only submit data for areas that have not reached attainment status under the CAA. At best, AFS data can be normalized by the number of facilities included in the database for any given category to show average estimated emissions per facility type per year. Pipelines, however, do not fit the concept of a facility; AFS pipeline data show, in essence, emissions within a specific county of a particular pipeline.

Noise pollution and spills of hazardous materials are the other known, major environmental problems occurring during the travel phase. FAA produces data intermittently on population exposure to unacceptable levels of aircraft noises but, in the last decade, no national-level data have been available that quantify exposure to highway or railroad noise. Annual national data on the volume and types of hazardous materials spilled from all modes, including pipelines, are available. These data do not provide information about the residuals that are not cleaned up or whether they ultimately contaminate groundwater, nor do they enable modal comparisons.

► Infrastructure

Transportation depends on infrastructure that includes highways, marine ports and marinas, airports, and rail lines and terminals. With the exception of waterway dredging by the U.S. Army Corps of Engineers (USACE), there are no trend data on infrastructure impacts.

A major impact of infrastructure is the land it displaces from other uses. Yet, land use and habitat degradation are topics about which very little is known on a national scale. Construction, operation (or use of), and maintenance of infrastructure generates air and water pollution and solid wastes. Some of these data are available on a trend basis, but can be difficult to aggregate by facility type (e.g., airports, rail terminals) or modal source. Other data are estimated periodically. For instance, EPA is currently studying the amount of debris created by highway and bridge construction and renovation.

USACE annual data identify the amount of materials dredged from the nation's navigable waterways and the cost of doing so. There are only sporadic collections of similar data for dredging done by private port authorities. Other than on a case-by-case basis, little is known about impacts of contaminated dredged materials.

► Manufacturing Phase

Comprehensive data are available for U.S. manufacturing sectors for several pollutant categories. For the most part, it is possible to attribute these data to modes. The Toxics Release Inventory contains a decade of data reported annually by manufacturing facilities on hundreds of toxic chemicals released to air, surface water, and the land. These data are collected by SIC. Conveniently, one major grouping

(SIC 37) covers the transportation equipment industry and is subdivided by modes. It does not, however, include pipelines.

The transportation equipment industry group contains the bulk of vehicle manufacturing, especially the assembly stage. Many vehicle parts, however, are manufactured by facilities that report under other SICs, where vehicle parts data are comingled with data for other products. These parts include tires, automotive glass, batteries and lighting systems, portions of engines, and automotive seats. In addition, the vehicle stamping process is represented in fabricated metals.

In addition to TRI data, EPA biennially collects data on the amounts of hazardous waste generated by manufacturing facilities, but these are not aggregated by SIC. EPA's AIRS data contain criteria pollutant emissions by SIC, but the limitations of use described above for pipelines apply here as well. EPA made the most recent estimate of nonhazardous solid wastes generated by the transportation equipment industry in 1985.

► Vehicle and Parts Maintenance and Disposal

Vehicles and parts must be maintained and then disposed of when their useful life is ended. Data deficiencies for this phase make it the most difficult to understand on a national scale. Recent state-level actions taken to improve environmental performance of small businesses, such as auto repair shops, have resulted in improved knowledge about the types of hazardous and nonhazardous materials these facilities generate. While some states have made estimates of the amounts generated, there is little national-level data. Exceptions include national annual estimates of tire and lead-acid battery recycling and disposal.

The numbers of cars and trucks scrapped each year is known. An occasional study estimates the amount of end-of-life automobile solid wastes recycled and disposed of, but little is known about the ultimate fate of trucks, railway cars and locomotives, airplanes, and marine vessels. Furthermore, there are no data on the amount or consequences of parts disposal during the lifetime of vehicles, or on the host of liquids also disposed of as vehicles are repaired and scrapped. Because it is an ozone-depleting substance phased out under the Montreal Protocol, the amount of HC-134a used annually and recycled for mobile air conditioning units is available. EPA estimates the amount of motor oil recycled each year, but the amounts and fate of other liquids, such as transmission and power-steering fluids, are unknown.

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