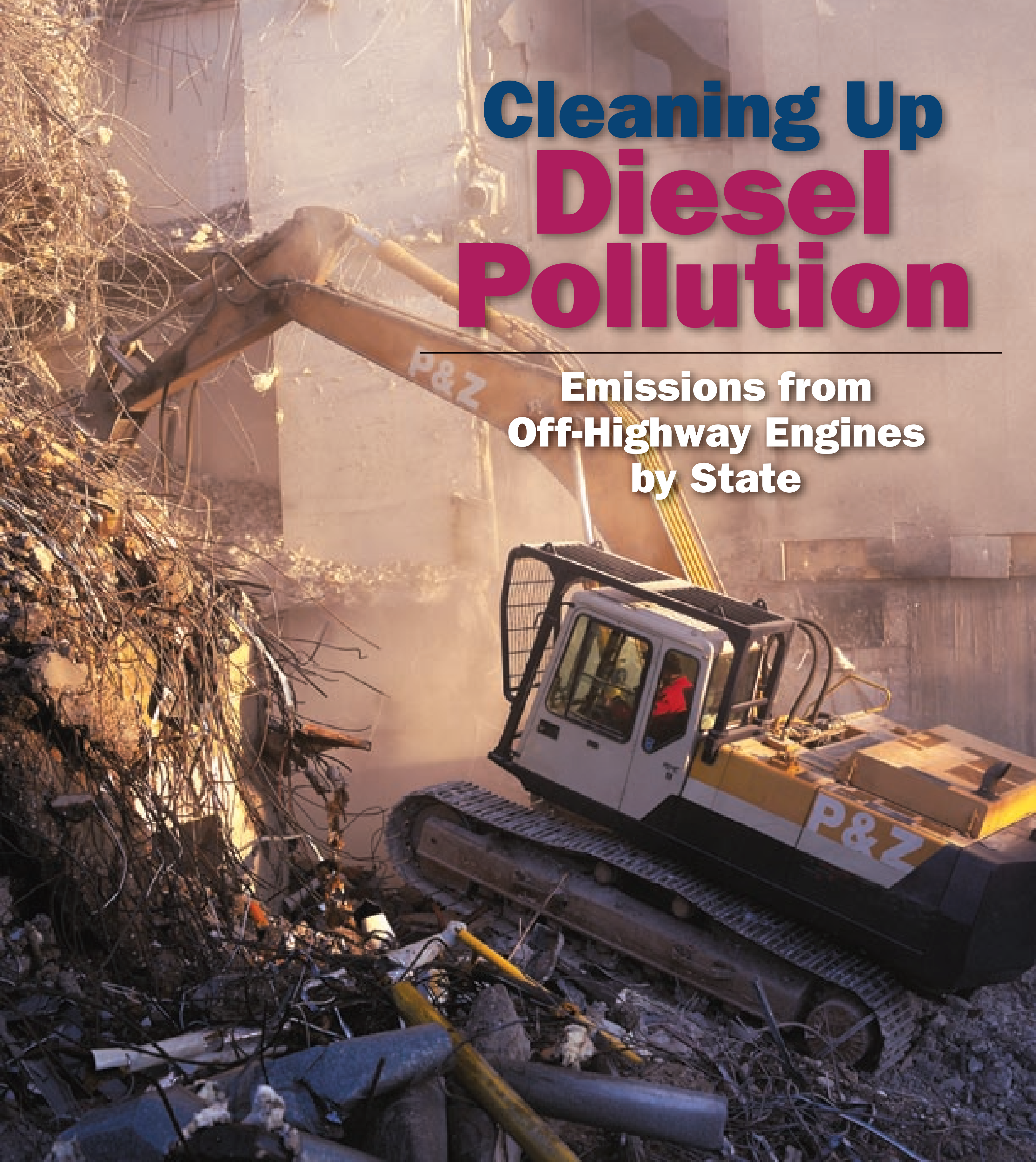
# Cleaning Up Diesel Pollution

## Emissions from Off-Highway Engines by State




Union of Concerned Scientists

Citizens and Scientists for Environmental Solutions

# Cleaning Up Diesel Pollution

## Emissions from Off-Highway Engines by State


by

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Union of Concerned Scientists
June 2003

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The Union of Concerned Scientists is a nonprofit partnership of scientists and citizens combining rigorous scientific analysis, innovative policy development, and effective citizen advocacy to achieve practical environmental solutions.

The UCS Clean Vehicles Program develops and promotes strategies to reduce the adverse environmental impact of the U.S. transportation system.

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# Executive Summary

Diesel engines provide the muscle power to tackle many of society's most strenuous tasks. For applications that demand power, fuel efficiency, and long engine life, diesel compression-ignition engines are tough to beat. This is why diesel engines currently power more than three million highway trucks and buses and well over twice that many off-highway engines (in trains, ships, and heavy equipment such as tractors, bulldozers, and excavators). However, while highway trucks and buses have been forced to reduce their pollution significantly, off-highway diesel engines are allowed to release large quantities of toxic soot and smog-forming pollutants into the air we breathe—and public health pays the price.

**PUBLIC HEALTH RISKS**

Diesel exhaust is a mixture of smog-forming pollutants, particulate matter (or soot), and other toxic constituents such as arsenic, cadmium, dioxin, and mercury (CARB, 1998). Small enough to be inhaled deep into the lungs, diesel exhaust particles can cause or exacerbate a wide variety of health problems, including asthma and other respiratory ailments, and have been linked to cancer and premature death. While scientists must often conduct animal testing to extrapolate the potential impact of pollutants on humans, our urban air has unfortunately allowed researchers to measure the effects of air pollution directly. We thus have overwhelming evidence that air pollution, particularly diesel exhaust, is harmful to human health, posing even higher risks for children and other vulnerable populations.

According to more than 30 epidemiological studies, people routinely exposed to diesel exhaust through their work on railroads, docks, trucks, or buses have a greater risk of lung cancer (CARB, 1998). A study by air pollution control officials and administrators estimates that diesel may be responsible for 125,000 additional cancers in the United States over a lifetime of exposure (STAPPA/ALAPCO, 2000). And the California Air Resources Board estimates that diesel pollution is responsible for 70 percent of that state's cancer risk due to airborne pollution (CARB, 2000).

Children may be especially susceptible to the harmful effects of diesel exhaust. Because they are outdoors more often and breathing at faster rates than adults, children and their developing lungs experience greater exposure to air pollutants (Wiley et al., 1993). This exposure has been shown to increase the severity of asthma attacks and possibly even cause asthma in otherwise healthy children (McConnell et al., 2002). Asthma, which afflicted one in 20 children in 1998 (Federal Interagency Forum on Child and Family Statistics, 2001), is not only the most common chronic disease of childhood, but also a leading cause of childhood disability.

**POLLUTION BURDEN**

In every state and major metropolitan area, off-highway diesel engines are a major source of air pollution. On average, these engines contribute about 45 percent of the particulate matter from all mobile sources—equivalent to the emissions of more than 17 million new urban transit

Table ES-1
**Soot and Smog-Forming Pollution from Off-Highway Diesel Engines**

| | Particulate Matter (Soot) | | | Smog-Forming Nitrogen Oxides | | |
|---|---|---|---|---|---|---|
| | Tons Released in 1999 | New Transit Bus Equivalent | Share of Mobile Source Pollution | Tons Released in 1999 | New Transit Bus Equivalent | Share of Mobile Source Pollution |
| **U.S. Totals** | **255,286** | **17,053,747** | **45%** | **3,709,556** | **10,545,027** | **29%** |
| Alabama | 3,475 | 232,122 | 36% | 173,093 | 492,045 | 50% |
| Alaska | 1,231 | 82,261 | 58% | 24,037 | 68,330 | 57% |
| Arizona | 3,121 | 208,474 | 36% | 52,399 | 148,953 | 25% |
| Arkansas | 4,169 | 278,524 | 53% | 62,292 | 177,075 | 37% |
| California | 18,835 | 1,258,254 | 41% | 313,172 | 890,243 | 29% |
| Colorado | 3,717 | 248,277 | 49% | 45,597 | 129,618 | 26% |
| Connecticut | 1,448 | 96,720 | 29% | 16,223 | 46,117 | 15% |
| Delaware | 731 | 48,847 | 38% | 10,535 | 29,947 | 27% |
| District of Columbia | 213 | 14,224 | 42% | 2,254 | 6,408 | 19% |
| Florida | 8,985 | 600,206 | 32% | 119,625 | 340,053 | 21% |
| Georgia | 5,142 | 343,487 | 32% | 72,771 | 206,863 | 18% |
| Hawaii | 861 | 57,507 | 47% | 13,244 | 37,648 | 33% |
| Idaho | 1,835 | 122,568 | 49% | 22,936 | 65,198 | 31% |
| Illinois | 12,384 | 827,271 | 52% | 159,952 | 454,689 | 32% |
| Indiana | 7,331 | 489,714 | 48% | 96,423 | 274,097 | 28% |
| Iowa | 7,976 | 532,815 | 68% | 84,218 | 239,402 | 44% |
| Kansas | 6,852 | 457,700 | 68% | 77,493 | 220,288 | 44% |
| Kentucky | 4,870 | 325,296 | 46% | 82,135 | 233,483 | 33% |
| Louisiana | 11,387 | 760,673 | 67% | 229,006 | 650,989 | 61% |
| Maine | 911 | 60,862 | 33% | 12,809 | 36,412 | 23% |
| Maryland | 2,626 | 175,388 | 31% | 35,367 | 100,537 | 18% |
| Massachusetts | 4,949 | 330,616 | 45% | 55,260 | 157,085 | 24% |
| Michigan | 6,735 | 449,916 | 34% | 89,027 | 253,073 | 21% |
| Minnesota | 8,522 | 569,285 | 53% | 105,385 | 299,574 | 36% |
| Mississippi | 4,186 | 279,641 | 47% | 71,618 | 203,587 | 35% |
| Missouri | 7,184 | 479,893 | 48% | 108,234 | 307,672 | 32% |
| Montana | 3,076 | 205,486 | 70% | 44,138 | 125,469 | 54% |
| Nebraska | 6,031 | 402,867 | 74% | 84,933 | 241,436 | 56% |
| Nevada | 1,737 | 116,016 | 46% | 24,645 | 70,058 | 30% |
| New Hampshire | 528 | 35,279 | 23% | 5,923 | 16,836 | 12% |
| New Jersey | 3,516 | 234,900 | 31% | 40,308 | 114,583 | 16% |
| New Mexico | 1,755 | 117,239 | 40% | 41,924 | 119,177 | 35% |
| New York | 9,613 | 642,158 | 39% | 132,308 | 376,106 | 24% |
| North Carolina | 5,012 | 334,810 | 32% | 58,703 | 166,873 | 16% |
| North Dakota | 5,691 | 380,165 | 85% | 55,679 | 158,277 | 67% |
| Ohio | 10,208 | 681,931 | 45% | 146,365 | 416,068 | 29% |

Table ES-1 **continued**

| | Particulate Matter (Soot) | | | Smog-Forming Nitrogen Oxides | | |
|---|---|---|---|---|---|---|
| | **Tons Released in 1999** | **New Transit Bus Equivalent** | **Share of Mobile Source Pollution** | **Tons Released in 1999** | **New Transit Bus Equivalent** | **Share of Mobile Source Pollution** |
| **U.S. Totals** | **255,286** | **17,053,747** | **45%** | **3,709,556** | **10,545,027** | **29%** |
| Oklahoma | 3,831 | 255,891 | 43% | 46,957 | 133,482 | 25% |
| Oregon | 3,286 | 219,500 | 42% | 44,342 | 126,050 | 27% |
| Pennsylvania | 7,057 | 471,403 | 37% | 104,717 | 297,675 | 23% |
| Rhode Island | 381 | 25,465 | 30% | 5,203 | 14,790 | 16% |
| South Carolina | 2,545 | 170,009 | 30% | 36,284 | 103,143 | 18% |
| South Dakota | 3,854 | 257,484 | 78% | 30,440 | 86,529 | 49% |
| Tennessee | 4,947 | 330,485 | 40% | 76,725 | 218,102 | 26% |
| Texas | 20,889 | 1,395,461 | 48% | 269,583 | 766,334 | 29% |
| Utah | 2,558 | 170,886 | 49% | 36,759 | 104,495 | 34% |
| Vermont | 331 | 22,110 | 26% | 2,872 | 8,165 | 10% |
| Virginia | 4,918 | 328,509 | 36% | 79,620 | 226,332 | 24% |
| Washington | 5,624 | 375,665 | 47% | 87,398 | 248,443 | 33% |
| West Virginia | 2,000 | 133,571 | 46% | 39,137 | 111,253 | 36% |
| Wisconsin | 4,963 | 331,511 | 39% | 52,361 | 148,843 | 48% |
| Wyoming | 1,264 | 84,408 | 55% | 27,131 | 77,123 | 48% |

NOTE: Off-highway diesel engines include heavy equipment, marine vessels, and locomotives. Particulate matter emissions are for particles 10 microns in diameter and less ($PM_{10}$). To calculate new transit bus equivalent emissions, we assumed a model year 2004 transit bus would release 0.44 grams per mile of particulate matter and 10.34 grams per mile of nitrogen oxides, and that the bus would travel 30,861 miles per year. See Appendix A for more details on UCS's compilation of the 1999 emission inventory and the calculation of new transit bus equivalent emissions.

SOURCE: All the mobile source emission data except California's off-highway pollution are based on the final 1999 emission inventory compiled by the U.S. EPA. The data are located at: ftp://ftp.epa.gov/EmisInventory/finalnei99ver2/criteria. California's off-highway emissions were provided by the California Air Resources Board. New transit bus grams-per-mile emissions are from Mark and Morey, 2000. Transit bus annual miles traveled are from U.S. DOE, 2002.

buses. These engines also release about one-quarter of the smog-forming nitrogen oxides from all mobile sources—equal to the emissions of about 10.5 million new urban transit buses.

California and Texas are the nation's biggest polluters in terms of particulate matter and nitrogen oxide emissions from off-highway engines (Table ES-1). In seven other states (Iowa, Kansas, Louisiana, Montana, Nebraska, North Dakota, and South Dakota), these engines contribute more than 60 percent of the particulate matter released by mobile sources.

New York and Los Angeles top the list of metropolitan areas with the most particulate matter and nitrogen oxide emissions from off-highway engines, followed by Houston, Boston, and Chicago (Table ES-2, p.4). In the Houston and Pittsburgh areas, off-highway engines are responsible for at least half of all particulate matter emitted by mobile sources.

### PLAYING BY UNFAIR RULES

Growing awareness of the public health dangers of diesel exhaust has led to stricter emissions standards for highway engines, but standards for off-highway engines continue to lag behind. Heavy diesel equipment, for example, was not required to meet any emissions standards until 1996—a

Table ES-2 **Pollution Impact on Major Metropolitan Areas from Off-Highway Diesel Engines**

| | Particulate Matter (Soot) | | | Smog-Forming Nitrogen Oxides | | |
|---|---|---|---|---|---|---|
| **Metropolitan Area** | **Tons Released in 1999** | **New Transit Bus Equivalent** | **Share of Mobile Source Pollution** | **Tons Released in 1999** | **New Transit Bus Equivalent** | **Share of Mobile Source Pollution** |
| New York | 7,623 | 509,211 | 36% | 76,738 | 218,139 | 16% |
| Los Angeles | 6,864 | 458,533 | 38% | 117,834 | 334,963 | 26% |
| Houston | 5,538 | 369,978 | 54% | 50,456 | 143,431 | 28% |
| Boston | 5,166 | 345,066 | 46% | 57,427 | 163,245 | 23% |
| Chicago | 5,050 | 337,379 | 41% | 70,175 | 199,485 | 25% |
| San Francisco | 3,610 | 241,158 | 42% | 55,662 | 158,228 | 30% |
| Philadelphia | 3,488 | 233,023 | 40% | 54,050 | 153,647 | 28% |
| Washington, D.C./ Baltimore | 3,478 | 232,329 | 34% | 46,551 | 132,329 | 19% |
| Dallas/Fort Worth | 2,828 | 188,899 | 35% | 34,249 | 97,358 | 17% |
| Detroit | 2,599 | 173,633 | 35% | 33,210 | 94,406 | 17% |
| Seattle | 2,332 | 155,795 | 42% | 35,374 | 100,557 | 26% |
| Cleveland | 2,308 | 154,201 | 40% | 38,378 | 109,095 | 31% |
| St. Louis | 2,057 | 137,422 | 41% | 33,162 | 94,269 | 26% |
| Atlanta | 1,921 | 128,341 | 28% | 23,424 | 66,587 | 13% |
| Pittsburgh | 1,866 | 124,640 | 50% | 33,847 | 96,214 | 36% |
| Miami/Fort Lauderdale | 1,811 | 120,980 | 39% | 22,606 | 64,261 | 21% |
| Phoenix | 1,788 | 119,428 | 40% | 21,591 | 61,377 | 22% |
| Denver | 1,675 | 111,884 | 47% | 19,596 | 55,704 | 22% |
| Minneapolis | 1,642 | 109,661 | 40% | 20,810 | 59,157 | 20% |
| San Diego | 1,466 | 97,933 | 35% | 19,069 | 54,207 | 24% |

NOTE: Off-highway diesel engines include heavy equipment, marine vessels, and locomotives. Particulate matter emissions are for particles 10 microns in diameter and less ($PM_{10}$). To calculate new transit bus equivalent emissions, we assumed a model year 2004 transit bus would release 0.44 grams per mile of particulate matter and 10.34 grams per mile of nitrogen oxides, and that the bus would travel 30,861 miles per year. See Appendix A for more details on UCS's compilation of the 1999 emission inventory and the calculation of new transit bus equivalent emissions.

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full three decades after the first regulations for highway diesel trucks and buses. As a result, highway trucks and buses have released lower amounts of particulate matter over time, but EPA data indicate that particulate matter and nitrogen oxide emissions from off-highway engines have increased during the last several decades.

Heavy diesel equipment is currently held to a complex, three-tiered set of emissions standards. The standards are based on engine power and are being phased in over a 10-year period ending in 2006. The current standards allow very small engines and large engines to release more pollution than mid-size engines. By 2007, heavy diesel equipment rated 50 horsepower or higher will be allowed to release 15 to 30 times more particulate matter than a new highway truck or bus, and about 15 times more nitrogen oxides. Small diesel engines (below 50 hp) will be allowed to release 45 to 60 times more particulate matter in 2007.

Average emissions from new heavy diesel equipment have fallen as stronger emissions standards have taken effect. An excavator built in 2003, for example, releases about half the emissions of a pre-1996 model (Figure ES-1). If future emissions standards for off-highway vehicles are harmonized with existing standards for highway trucks and buses, pollution could be reduced to approximately four percent the level emitted by pre-1996 engines.

### COST-EFFECTIVE CONTROLS EXIST

Cost-effective pollution controls under development for highway trucks and buses can be applied to off-highway engines as well. The unique operating conditions of off-highway engines will require some system modifications, but the overall costs should be modest, particularly for engines rated 75 hp and higher.

UCS evaluated the cost of installing state-of-the-art pollution controls on four different types of heavy diesel equipment: a tractor (75 hp), an excavator (180 hp), a combine (285 hp), and an articulated hauler, or large dump truck (420 hp). Our analysis indicates these pollution controls increase equipment costs only one to three percent, while reducing emissions 90 percent or more.

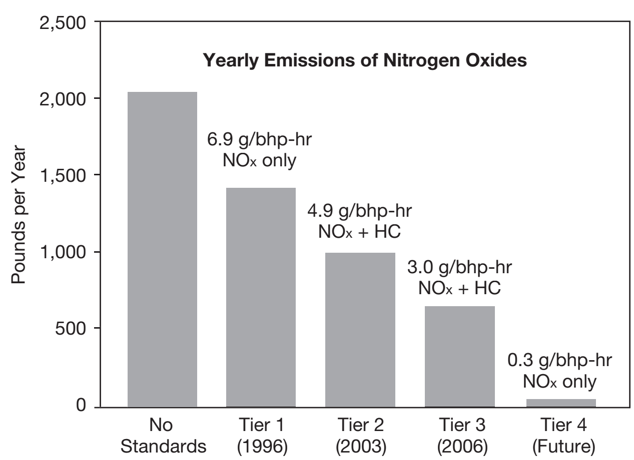
### A COMPREHENSIVE CLEANUP PLAN

Cleaning up both new heavy diesel equipment and the more than six million heavy diesel engines already in use will require a combination of federal, state, and local action. The most critical need is holding off-highway diesel engines accountable to the same standards highway trucks and buses must meet. Specifically, the EPA needs to:

- Reduce the sulfur level in diesel fuels 99 percent or more for all off-highway vehicles, including heavy equipment, locomotives, and marine vessels. Sophisticated emission controls require low-sulfur diesel fuel (15 parts per million) compared with today's level of 3,000 ppm or more.
- Harmonize emissions standards for heavy diesel equipment with existing standards for highway trucks and buses.
- Develop appropriate standards for locomotives and all types of marine engines, including commercial marine engines and large oceangoing ships.
- Develop an effective, enforceable inspection and maintenance program to ensure emission controls are functioning at their full potential and prevent tampering of exhaust controls.

At the state level, a combination of regulations, policies, and incentives can promote the installation of cleanup technologies on older engines, as well as the purchase of new, cleaner technologies. Local efforts to reduce heavy diesel emissions in sensitive communities provide models that can be replicated across the country.

Figure ES-1 **Pollution from an Excavator: Impact of Progressively Stronger Standards**




NOTE: g/bhp-hr stands for grams per brake horsepower hour, which is a measure for expressing the amount of pollution released per unit of power.

SOURCE: UCS calculation is based on the U.S. EPA's NONROAD model and background support documents located at: www.epa.gov/otaq/nonrdmdl.htm.

*Chapter 1*
# Today's Off-Highway Diesel Engines

Diesel engines provide the muscle power to tackle many of society's most strenuous tasks. For applications that demand power, fuel efficiency, and long engine life, diesel compression-ignition engines are hard to beat. Diesel engines power more than three million highway trucks and buses and well over twice that many pieces of off-highway heavy equipment. But these workhorses have been allowed to run wild, leaving a trail of toxic soot and smog-forming pollutants in the air we breathe, and public health has paid a price.

Growing awareness of the public health dangers of diesel exhaust has led to stricter emissions standards for highway diesel engines, but standards for off-highway engines continue to lag behind. As a result, off-highway diesel engines are major sources of air pollution, contributing about 45 percent of the particulate matter (or soot) and more than one-quarter of the smog-forming nitrogen oxides (NOx) from mobile sources. This pollution affects every state in the country, urban and rural areas alike.

This report evaluates the potential to clean up off-highway diesel engines, focusing particularly on the single largest source of pollution from this category: heavy equipment. Chapter One provides information on pollution from off-highway diesel engines, which are installed in trains, marine vessels, and heavy equipment. Chapter Two discusses the public health consequences of diesel pollution, highlighting its impact on children and other sensitive populations. In Chapter Three, we provide information on the cleanup technologies that could potentially reduce diesel pollution to very low levels. Chapter Four presents the results of our case study analysis of the costs and emissions benefits of installing state-of-the-art pollution controls on four types of heavy diesel equipment: tractors, excavators, combines, and articulated haulers, or large dump trucks. In Chapter Five, we discuss alternatives to diesel—electricity, alternative fuels, and fuel cells—that can reduce pollution and help diversify our energy choices. Finally, Chapter Six suggests how local governments, states, and the federal government should work together to build a comprehensive program for reducing public exposure to dangerous diesel exhaust.

## SOCIETY'S HEAVY LIFTERS

We rely on off-highway diesel engines to construct our homes, provide food for our families, build our streets and highways, and carry us long distances from home. These engines are found in every nook and cranny of the country, from our nation's farmlands to our cities and remote wilderness areas. Like highway diesel trucks and buses, off-highway engines capitalize on the advantages of compression ignition, providing more power at a wider range of speeds than conventional gasoline-powered engines.

Off-highway diesel engines are installed in marine vessels, locomotives, and heavy equiment. Heavy diesel equipment is used for construction (bulldozers and excavators), farming (tractors and combines), industrial and commercial usage (portable generators), recreation (snowmobiles), logging, and airport support (Table 1). These machines, which vary in horsepower from less than 10 to 3,000 horsepower (hp), must operate under a wide variety of engine cycles, speeds, and environmental conditions. In short, diesel engines provide the versatility, durability, and power to take care of society's heavy moving and lifting.

The advantages of compression ignition, however, come at the cost of public health. These machines are major sources of air pollution, releasing toxic particulates and smog-forming pollutants into the air we breathe.

**POLLUTION BURDEN**

While highway trucks and buses have released lower amounts of particulate matter over time, the limited data available on off-highway engines indicate that both particulate and nitrogen oxide emissions have increased during the last several decades (Figure 1, p.8). The amount of smog-forming nitrogen oxides from off-highway engines has climbed steadily since 1980, while highway engines have cut their emissions by one-third during the same period. Particulate matter emissions from off-highway engines surpassed emissions from highway vehicles in the mid-1990s, and unless action is taken soon, the gap will widen during the next several decades.

Table 1 **Types of Heavy Diesel Equipment**

| Construction and Mining | Agricultural |
|---|---|
| Bulldozers | Agricultural tractors |
| Excavators | Combines |
| Cranes | Irrigation sets |
| Graders | **Commercial/Industrial** |
| Backhoes | Generator sets |
| Tractors | Pumps |
| Skid steer loaders | Air compressors |
| Off-highway trucks | Welders |
| Rubber tire loaders | AC/refrigeration |
| **Recreational** | Terminal tractors |
| Snowmobiles | Forklifts |
| All-terrain vehicles | **Lawn & Garden** |
| **Logging** | Mowers |
| Shredders | Rotary tillers |
| **Airport** | Stump grinders |
| Ground support equipment | Commercial turf equipment |

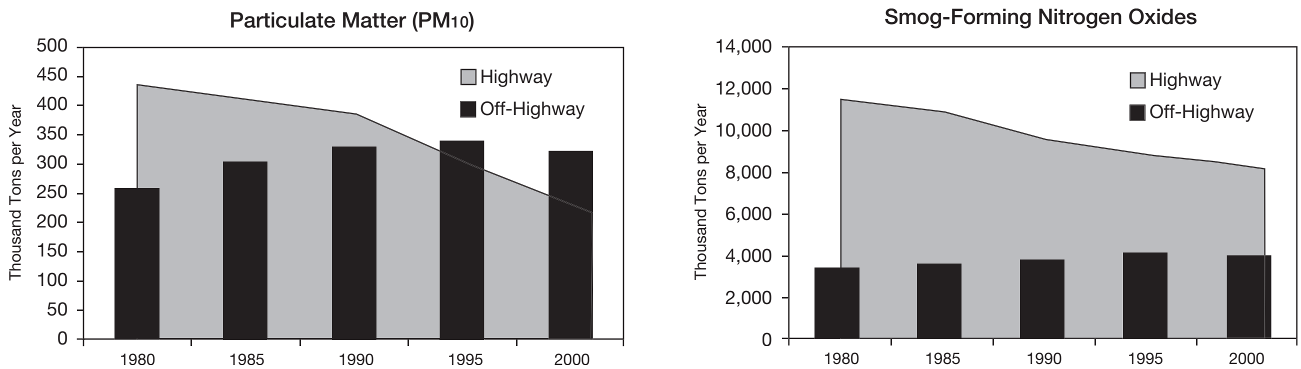
Off-highway engines are installed in heavy diesel and gasoline equipment, aircraft, marine vessels, and trains. Of these categories, heavy diesel equipment is the biggest source of particulate and nitrogen oxide pollution (Figure 2, p.9). In 2001, these engines released more than half of the par-

## The Diesel Trade-off: Power vs. Pollution

**Power:** Compared with standard spark-ignited engines, diesel compression-ignition engines typically operate more efficiently over a wider range of operating conditions, particularly at lower speeds. Instead of using a throttle and sacrificing efficiency as a result, diesel engines reduce their energy output by reducing fuel input. In addition, diesel engines operate at higher pressures, generate more horsepower output, and can thus haul heavier loads.

**Pollution:** Diesel's enhanced efficiencies come at the cost of toxic particulate matter and smog-forming pollution. As diesel fuel is compressed with air in the combustion chambers, pockets of excess fuel cause particulates to form. Sulfur in the diesel fuel and certain additives in lubricating oils can also lead to particulate formation. In addition, high engine temperatures promote the formation of smog-forming nitrogen oxides. Engineers are therefore faced with a trade-off between particulate matter and smog-forming pollutants: Lowering the engine temperature decreases nitrogen oxide emissions but increases the amount of unburned fuel, which is released in the form of particulates.

Figure 1 **Pollution Trends for Mobile Sources: Comparing Highway and Off-Highway Engines**




SOURCE: U.S. EPA, National Emissions Inventory, Average Annual Emissions, All Criteria Pollutants, for 1980, 1985, 1990–2001. Available online at: www.epa.gov/ttn/chief/trends/trends01/trends2001.pdf.

ticulates and nearly 40 percent of the nitrogen oxides from off-highway engines overall.

Heavy equipment is used for a wide variety of purposes, including construction, farming, industry, logging, recreation, and mining. Of the many sectors relying on this equipment, the construction and agricultural trades contribute the bulk of the pollution. These two sectors alone release more than 80 percent of the particulate matter and nitrogen oxide pollution from heavy diesel equipment (Figure 3).

Every state in the country bears the burden of pollution from off-highway diesel engines. For a detailed analysis of the pollution impact on each state from both off-highway diesel and mobile sources in general, see Appendix B.

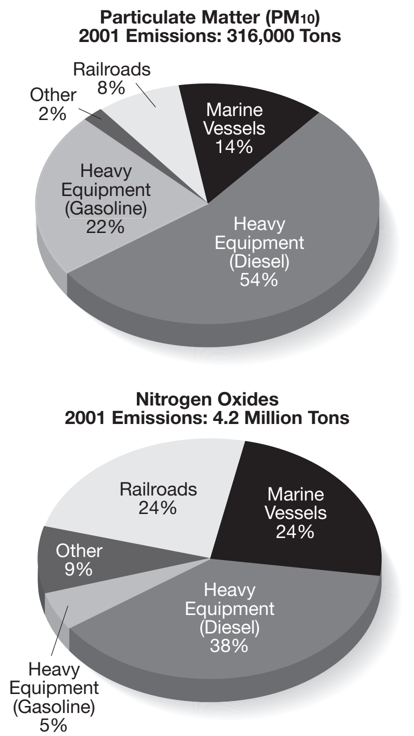
## PLAYING BY UNFAIR RULES

Off-highway diesel engines have not faced the regulatory scrutiny that highway diesel vehicles have. While emissions standards for highway vehicles, such as large trucks and buses, have grown increasingly tight, off-highway engines have been allowed to release much higher levels of toxic particulate matter and smog-forming pollution. For example, heavy diesel equipment was not required to meet any emissions standards until 1996, a full three decades after the first regulations for highway diesel trucks and buses. Compared with a new highway truck or bus, heavy diesel equipment (50 hp or greater) manufactured in 2007 will be allowed to release 15 to 30 times more particulate matter and about 15 times more nitrogen oxides (Figure 4, p.10). Small diesel engines (below 50 hp) will be allowed to release 45 to 60 times more particulate matter in 2007.

Heavy diesel equipment is currently held to a complex, three-tiered set of emissions standards (Table 2, p.11).[1] The standards are based on engine power and are being phased in over a 10-year period ending in 2006. The current standards allow very small engines (less than 50 hp) and

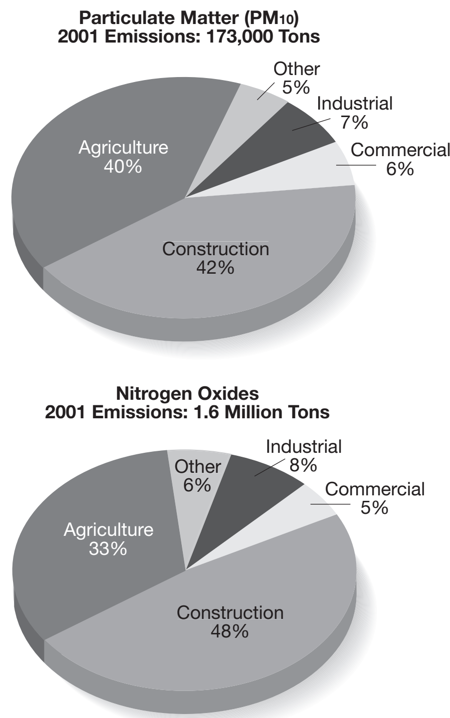
1 In 1994, the U.S. Environmental Protection Agency (EPA) issued its first set of emissions standards (called Tier 1) for off-highway diesel engines, except those used in locomotives, marine vessels, and underground mining equipment. The Tier 1 standards were phased in for different engine sizes between 1996 and 2000, reducing nitrogen oxide emissions from these engines by about 30 percent. The EPA then adopted Tier 2 standards, with more stringent emission standards for nitrogen oxides, hydrocarbons (HC), and particulate matter (PM) released by new off-highway diesel engines. For the first time, engines smaller than 50 hp had to meet emissions standards. The new rule phased in Tier 2 emissions standards from 2001 to 2006 for all engine sizes, and added even more stringent Tier 3 standards for engines between 50 and 750 hp from 2006 to 2008. The EPA estimates these standards will further reduce heavy diesel equipment emissions by 60 percent for nitrogen oxides and 40 percent for particulate matter relative to Tier 1 levels.

Figure 2 **Pollution from Off-Highway Vehicles, 2001**




SOURCE: U.S. EPA, National Emissions Inventory, Average Annual Emissions, All Criteria Pollutants, for 1980, 1985, 1990–2001. Available online at: www.epa.gov/ttn/chief/trends/trends01/trends2001.pdf.

Figure 3 **Pollution from Heavy Diesel Equipment, 2001**




SOURCE: U.S. EPA, National Emissions Inventory, Average Annual Emissions, All Criteria Pollutants, for 1980, 1985, 1990–2001. Available online at: www.epa.gov/ttn/chief/trends/trends01/trends2001.pdf.

large engines (greater than 750 hp) to release more pollution than mid-size engines.

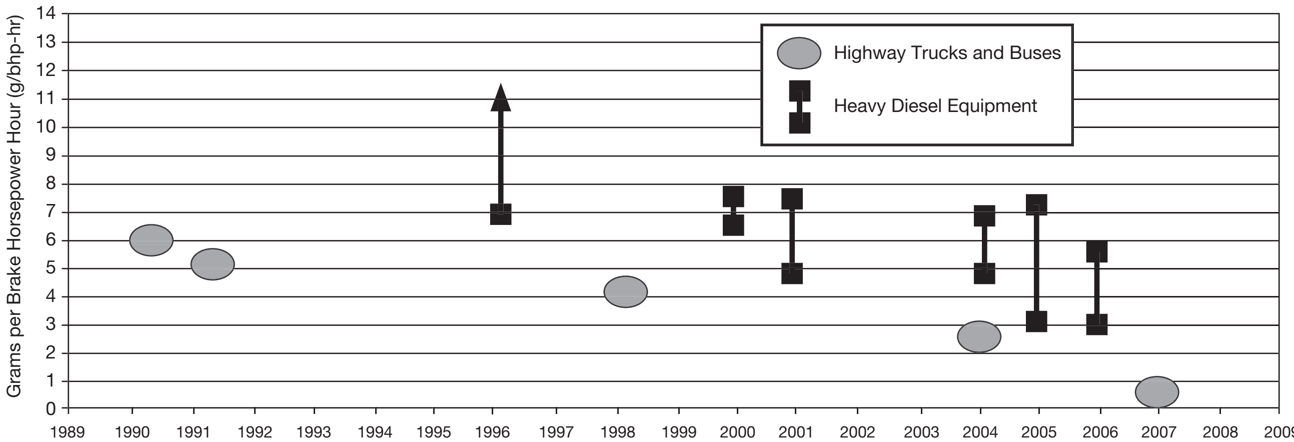
Emissions standards are based on test cycles that evaluate the amount of pollution released under certain operating conditions. Most heavy diesel equipment operates under stop-and-go or transient cycles, but the current test cycle for heavy diesel equipment only requires that engines meet the standard under steady-state conditions. Ideally, engines should have to meet emissions standards under transient test cycles tailored to their unique operating cycles.

According to the EPA's NONROAD model, emissions from new heavy diesel equipment have fallen steadily as stricter standards have come

## Real-World Pollution vs. Modeling

Unfortunately, we have very limited information about in-use emissions from heavy diesel equipment. If our experience with highway trucks and buses is a guide, heavy diesel vehicles may release more particulate matter and nitrogen oxides than certification standards would indicate. The rugged environmental conditions under which some heavy equipment operates could translate into even higher pollutant loads.

Figure 4 **Comparing Nitrogen Oxide (NOx) Emissions Standards for Diesel Engines: Highway vs. Heavy Equipment**

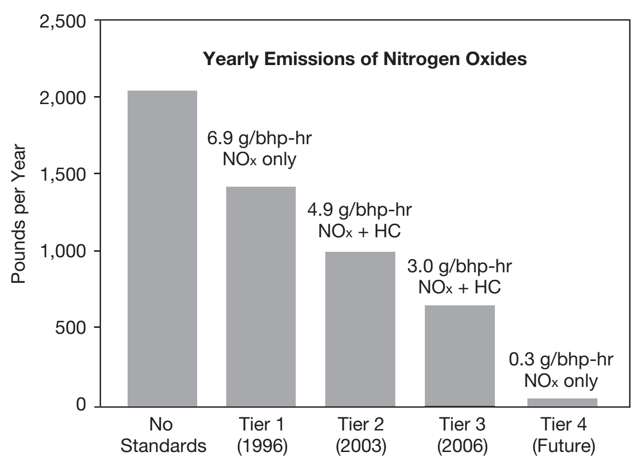



NOTE: Standards for heavy diesel equipment are for 25 horsepower and greater. Some of the standards include nonmethane hydrocarbons.

SOURCE: Heavy diesel equipment standards from U.S. EPA, 2002C; highway truck and bus standards for 2004 and earlier from U.S. EPA, 1997; highway standards for 2007 from U.S. EPA, 2000.

into effect (Figure 5). The model indicates that a 180 hp excavator built in 2006 will release one-third as many nitrogen oxides as a 1995 model. The Tier 3 standards, however, do not go far enough in protecting the public from the dangers of diesel exhaust. Stronger standards that more closely mirror the standards for highway trucks and buses could further reduce nitrogen oxide emissions by 90 percent relative to Tier 3 standards.

Figure 5 **Pollution from an Excavator: Impact of Progressively Stronger Standards**




NOTE: g/bhp-hr stands for grams per brake horsepower hour, which is a measure for expressing the amount of pollution released per unit of power.

SOURCE: UCS calculation is based on the U.S. EPA's NONROAD model and background support documents located at: www.epa.gov/otaq/nonrdmdl.htm.

**Table 2** **Today's Emissions Standards for Heavy Diesel Equipment**

Standards: grams per kilowatt hour, g/kW-hr (grams per brake horsepower hour, g/bhp-hr)

| Engine Power | No Limits | Tier 1 | Tier 2 | Tier 3 Pull Ahead | Tier 3 |
|---|---|---|---|---|---|
| > 560 kW (750 hp) | 1996–1999 | 2000–2005: NOx: 9.2 (6.9)<br>PM: 0.54 (0.4) | 2006–2010: NOx + HC: 6.4 (4.8)<br>PM: 0.2 (0.15) | | |
| 450 kW (600 hp) to < 560 kW (750 hp) | | 1996–2001: NOx: 9.2 (6.9)<br>PM: 0.54 (0.4) | 2002–2004: NOx + HC: 6.4 (4.8)<br>PM: 0.2 (0.15) | 2005 | 2006–2010: NOx + HC: 4.0 (3.0)<br>PM: 0.2 (0.15) |
| 225 kW (300 hp) to < 450 kW (600 hp) | | 1996–2000: NOx: 9.2 (6.9)<br>PM: 0.54 (0.4) | 2001–2004: NOx + HC: 6.4 (4.8)<br>PM: 0.2 (0.15) | 2005 | 2006–2010: NOx + HC: 4.0 (3.0)<br>PM: 0.2 (0.15) |
| 130 kW (175 hp) to < 225 kW (300 hp) | | 1996–2002: NOx: 9.2 (6.9)<br>PM: 0.54 (0.4) | 2003–2005: NOx + HC: 6.6 (4.9)<br>PM: 0.2 (0.15) | | 2006–2010: NOx + HC: 4.0 (3.0)<br>PM: 0.2 (0.15) |
| 75 kW (100 hp) to <130 kW (175 hp) | 1996 | 1997–2002: NOx: 9.2 (6.9)<br>PM: None | 2003–2006: NOx + HC: 6.6 (4.9)<br>PM: 0.3 (0.2) | | 2007–2010: NOx + HC: 4.0 (3.0)<br>PM: 0.3 (0.2) |
| 37 kW (50 hp) to < 75 kW (100 hp) | 1996–1997 | 1998–2003: NOx: 9.2 (6.9)<br>PM: None | 2004–2007: NOx + HC: 7.5 (5.6)<br>PM: 0.4 (0.3) | | 2008–2010: NOx + HC: 4.7 (3.5)<br>PM: 0.4 (0.3) |
| 19 kW (25 hp) to < 37 kW (50 hp) | 1996–1998 | 1999–2003: NOx + HC: 9.5 (7.1)<br>PM: 0.8 (0.6) | 2004–2010: NOx + HC: 7.5 (5.6)<br>PM: 0.6 (0.45) | | |
| 8 kW (11 hp) to < 19 kW (25 hp) | 1996–1999 | 2000–2004: NOx + HC: 9.5 (7.1)<br>PM: 0.8 (0.6) | 2005–2010: NOx + HC: 7.5 (5.6)<br>PM: 0.8 (0.6) | | |
| < 8 kW (11 hp) | 1996–1999 | 2000–2004: NOx + HC: 10.5 (7.8)<br>PM: 1.0 (0.75) | 2005–2010: NOx + HC: 7.5 (5.6)<br>PM: 0.8 (0.6) | | |

NOTE: "Tier 3 Pull Ahead" standards must be met by seven of the largest engine manufacturers. The U.S. EPA and Department of Justice charged these manufacturers in 1998 with using "defeat devices" that allowed their engines to release more nitrogen oxides in real-world driving than emissions standards permit. As part of a legal settlement, these manufacturers agreed to meet Tier 3 emissions standards for 300 to 750 hp heavy diesel engines by 2005 (one year earlier than the regulations specify).

SOURCE: U.S. EPA, 2002C.

*Chapter 2*
# Public Health Threats

Diesel exhaust is a mixture of smog-forming pollutants, soot particles, and toxic constituents. Exhaust from conventional diesel engines is small enough to be inhaled deep into the lungs, where it can cause or exacerbate a wide variety of public health problems. While scientists must often conduct animal testing to extrapolate the potential impact of pollutants on humans, our urban air has unfortunately allowed researchers to measure the effects of air pollution directly. We thus have overwhelming evidence that air pollution, particularly diesel exhaust, is harmful to human health, posing even higher risks for children and other vulnerable populations.

Table 3 **Public Health Impacts of Soot Reduction Due to Stronger Emissions Standards (EPA Proposed Rule, April 2003)**

| | Age Range | Avoided Incidence in 2030 |
|---|---|---|
| **Adults** | | |
| Premature mortality | 30 and older | 9,600 |
| Chronic bronchitis | 26 and older | 5,700 |
| Nonfatal myocardial infarctions | 18 and older | 16,000 |
| Hospital admissions (respiratory) | 20 and older | 4,500 |
| Hospital admissions (cardiovascular) | 20 and older | 3,800 |
| Work-loss days | 18-65 | 960,000 |
| Minor restricted-activity days | 18-65 | 57,000,000 |
| **Children** | | |
| Emergency room visits for asthma | 18 and younger | 5,700 |
| Acute bronchitis | 8 to 12 | 14,000 |
| Lower respiratory symptoms | 7 to 14 | 150,000 |
| Upper respiratory symptoms (asthmatic children) | 9 to 11 | 110,000 |
| **Total Monetized Benefits: $81 Billion per Year in 2030** | | |

SOURCE: U.S. EPA, 2003B.

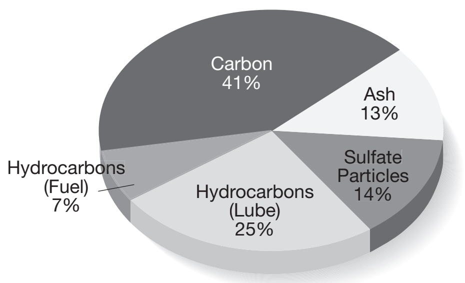
Reducing public exposure to diesel pollution—with its particulate matter, air toxics, and smog-forming pollutants—will help prevent children's asthma, reduce respiratory ailments, and save lives. The EPA estimates that strengthening emissions standards for heavy diesel equipment will prevent 9,600 premature deaths each year by 2030 (EPA, 2003B), save America $81 billion per year in 2030, and deliver a variety of other health and societal benefits (Table 3).

## PARTICULATE MATTER (SOOT)

Soot is released directly from the exhaust stream or it may form as a secondary particle when nitrogen oxides, hydrocarbons, and sulfur oxides released from the tailpipe react in the atmosphere.[2] Diesel particles released directly from the tailpipe are composed of a carbon core with an array of toxic compounds including metals, polycyclic aromatic hydrocarbons (PAHs), and dioxins adsorbed to the particle's surface (Cuddihy et al., 1984). The exact composition of diesel particulate matter varies depending on the engine technology, test conditions, and sulfur

2 The EPA has not attempted to quantify the role nitrogen oxides and hydrocarbons released from heavy equipment play in the formation of secondary particles (EPA, 2000). However, the agency believes the contribution from nitrogen oxides is "substantial," particularly in areas with high ammonia levels (nitrogen oxides react with ammonia to form ammonium nitrate particles).

Figure 6 **Composition of Diesel Particulate Matter**




NOTE: Represents diesel exhaust from a heavy-duty diesel vehicle manufactured after 1994, using the federal test procedure transient cycle.

*Definitions*
Carbon: Not bound with other elements; responsible for the black smoke in diesel exaust.

Hydrocarbons: Derived from lubricating oil and unburned fuel adsorbed onto the surface of carbon particles or present in the form of fine droplets.

Sulfate Particles: Derived from sulfur in diesel fuel and formed when sulfuric acid and water react.

Ash: Composed of metals formed from lubricating oil and engine wear.

SOURCE: Kittelson, 1998.

content of the fuel. Figure 6 presents an example of the mix of particulate pollutants emitted from a standard heavy diesel engine built after 1994.

Inhaling particulate matter can cause or exacerbate a variety of respiratory conditions and even lead to premature death. Sensitive populations including children, the elderly, asthmatics, and individuals with pre-existing respiratory or cardiovascular diseases are at the greatest risk from exposure to particulates (EPA, 2000).

### Respiratory impact of particulate matter

Diesel soot particles are tiny—98 percent are smaller than one micron in diameter—and virtually all can travel deep into the lungs and lodge in the alveoli, the delicate sites where oxygen exchange normally occurs (Bagley, 1996). Particulate matter is associated with adverse respiratory effects such as asthma, reduced lung function, reduced respiratory defense mechanisms, and acute respiratory illness (EPA, 2002). Numerous studies have reported an association between short-term exposure to particulates and hospital admissions for respiratory-related and cardiac diseases. [3]

### Premature death from particulate matter

Particulate matter has also been directly linked with premature death. A study of more than one million adults in 151 U.S. cities found that higher concentrations of fine particles (2.5 microns or less, called $PM_{2.5}$) were associated with a 17 percent increase in total mortality between cities with the least and most polluted air (Pope et al., 1995). In another study of more than 8,000 people living in six cities in the eastern United States, $PM_{2.5}$ was associated with even higher rates of mortality (Dockery et al., 1993). This study found a 26 percent increase in mortality between the cities with the highest and lowest levels of air pollution. Based on these studies and other research, the EPA estimates that new standards regulating $PM_{2.5}$ emissions will save 15,000 lives per year (EPA, 1997).

### Particle size and regulatory gaps

Historically, the EPA has only regulated particles 10 microns in diameter and smaller, known as $PM_{10}$;[4] current particulate emissions standards for heavy equipment are based on the weight of

3 For a list of these studies and a table of results, see EPA 2002.

4 For comparison, a human hair is about 70 microns in diameter.

$PM_{10}$ released directly from tailpipes. Recent EPA rulemaking establishing National Ambient Air Quality Standards for $PM_{2.5}$ has not yet resulted in changes to vehicle emissions standards.

Evidence that particle size plays a key role in potential health effects is increasing. Fine particles, for example, may contain more of the reactive substances linked to health impacts than coarse particles (EPA, 2000). These particles are small enough to bypass respiratory defenses and lodge deep in the lungs. Between 80 and 95 percent of diesel particles fall within the ultrafine size range of 0.05 to 1.0 micron (EPA, 2000).

Current regulations for particulates do not address growing concerns about the health effects of ultrafine particles and nanoparticles, which are difficult to measure with today's technology. These smaller particles may penetrate even more deeply into the respiratory tract, and their large surface-to-volume ratio could allow for more biological interaction. Because no accepted testing method exists to ensure these particles are measured accurately and consistently, comparisons between different studies are problematic (Andersson and Wedekind, 2001). In addition, different transient cycles, operating conditions, and exhaust temperatures may affect the generation of these very small particles. Since the EPA's current regulations governing particulates from heavy equipment are based on particle mass and not size distribution, stricter regulations may not reduce public health risks proportionally.

## AIR TOXICS

The health risks of air toxics vary from pollutant to pollutant, but all are serious, including cancer, immune system disorders, and reproductive problems. The California Air Resources Board (CARB) has listed diesel exhaust and its 41 constituent chemicals as "toxic air contaminants" that may cause or contribute to serious illness and even death (CARB, 1998). Of the many potential health risks from exposure to air toxics, cancer is the most studied and best understood.

### Cancer risks

According to more than 30 epidemiological studies, people who are routinely exposed to diesel exhaust through their work on railroads, docks, trucks, or buses have a greater risk of lung cancer (CARB, 1998). On average, these studies found long-term occupational exposure to diesel exhaust was associated with a 40 percent increase in the relative risk of lung cancer.

Numerous scientific bodies and agencies have linked exposure to diesel exhaust with cancer risk (Table 4). CARB (2000) estimates that diesel exhaust is responsible for 70 percent of California's cancer risk from airborne toxic pollution, which translates to 540 additional cancers per million people exposed to current outdoor levels of diesel pollution over a 70-year lifetime. These estimates

Table 4
**Cancer Risk Assessments of Diesel Exhaust**

| Year | Organization | Conclusion |
|---|---|---|
| 2002 | U.S. Environmental Protection Agency | Likely human carcinogen |
| 2001 | Americal Council of Government Industrial Hygienists (proposal) | Suspected human carcinogen |
| 2001 | U.S. Department of Health and Human Services | Reasonably anticipated to be a human carcinogen |
| 1998 | California Air Resources Board | Toxic air contaminant |
| 1996 | World Heath Organization International Programme on Chemical Safety | Probable human carcinogen |
| 1995 | Health Effects Institute | Potential to cause cancer |
| 1990 | State of California | Known to cause cancer |
| 1989 | International Agency for Research on Cancer (IARC) | Probable human carcinogen |
| 1988 | National Institute for Occupational Safety and Health (NIOSH) | Potential occupational carcinogen |

raised concerns about the danger diesel pollution poses to the entire nation.

The State and Territorial Air Pollution Program Administrators (STAPPA) and the Association of Local Air Pollution Control Officials (ALAPCO) conducted an analysis of the national risks from diesel, applying methodology and risk factors similar to California. Their study found that diesel pollution may be responsible for more than 125,000 additional cancers in the United States over a 70-year lifetime (STAPPA/ALAPCO, 2000).

## SMOG-FORMING POLLUTANTS

In the presence of sunlight, nitrogen oxides and hydrocarbons can react to form urban ozone, or smog. Smog can irritate the respiratory system, reduce lung function, exacerbate asthma, damage the lining of the lungs, and aggravate chronic lung diseases (EPA, 2000).

Approximately 116 million Americans—40 percent of the nation's population—currently live in areas that exceed the federal ozone standard (EPA, 2003C). Urban ozone pollution is linked to increased hospital admissions for respiratory problems such as asthma (Koren, 1995; White et al., 1994) and higher death rates on smoggy days, even at levels below the current federal standard (ATS, 1996). In addition, ozone air pollution has been associated with as many as 10 to 20 percent of all summertime respiratory hospital visits and admissions (EPA, 2000), and more than 1.5 million cases of significant respiratory problems in children and adults every year (EPA, 2000).

## HIGHER-RISK POPULATIONS

### Urban and low-income communities

Eighty percent of Hispanics, 65 percent of African-Americans, and 57 percent of Caucasians live in communities that fail to meet EPA air quality standards (ALA, 2002). Low-income communities in particular face higher exposure levels to diesel exhaust because they may be situated closer to freeways, distribution centers, or industrialized areas with increased truck traffic. Construction and migrant farm workers also face exposure to diesel exhaust if they operate or work near heavy diesel equipment.

### Children

Children may be particularly vulnerable to the harmful effects of air pollution (Ostro et al., 1995). Outdoors more often and breathing at faster rates than adults, children and their developing lungs may experience greater exposure to harmful air pollutants (Wiley et al., 1993), which appears to increase the severity of asthma attacks and even cause asthma in otherwise healthy children (McConnell et al., 2002). In communities with the highest ozone levels, children who participate in three or more team sports are more than three times as likely to become asthmatic compared with less active children.

Children raised in heavily polluted areas have reduced lung capacity, prematurely aged lungs, and increased risk of bronchitis and asthma compared with peers living in less urbanized areas (Dockery et al., 1989; Peters et al., 1999). In fact, the proximity of a child's school to major roads has been linked to asthma, and the severity of the child's symptoms increases with proximity to truck traffic (Pekkanen et al., 1997). The link between pollution and asthma is of particular concern because asthma is the most common chronic disease of childhood and a leading cause of disability among children. Approximately one in 20 children suffered from asthma in 1998 (Federal Interagency Forum on Child and Family Statistics, 2001), costing $2.4 billion in additional health care (Lozano et al., 1999).

Researchers at the University of Southern California (Gauderman et al., 2000) found that children exposed to ambient levels of particulates, nitrogen dioxide, and other air pollutants experienced more than four times as much lung damage as children exposed to secondhand smoke. Children who spent more time outdoors had even greater lung damage.

Because it is difficult to distinguish between the specific effects of diesel exhaust and those of other air pollutants on children's health, few studies have focused on the impact of diesel truck traffic. One, however, found that children living near busy diesel trucking routes had decreased lung function compared with children living near roads traveled mostly by automobiles (Brunekreef et al., 1997). A population-based survey of more than 39,000 children living in Italy found that those living on streets with heavy truck traffic were 60 to 90 percent more likely to report symptoms such as wheezing and coughing, and to have diagnoses such as bronchitis and pneumonia (Ciccone et al., 1998).

## GLOBAL WARMING POLLUTION

Diesel pollution not only harms public health directly, it also contributes to global warming, which carries longer-term public health and societal consequences. All fossil fuels, including diesel, gasoline, natural gas, and propane, contribute global warming pollution to Earth's atmosphere. Since the Industrial Revolution, levels of atmospheric carbon dioxide—a primary global warming gas—have increased by more than 30 percent, reaching concentrations higher than any observed in the last 420,000 years (Petit et al., 1999). The global average surface temperature has increased by one degree Fahrenheit since 1860, and scientific evidence suggests this is largely due to human activities (IPCC, 2001) that release heat-trapping gases from factories, power plants, and automobiles. Unless emissions of global warming pollution are drastically reduced, the average temperature could rise 2.5 to 10.4°F by the end of the 21st century (IPCC, 2001).

Some of the projected consequences of global warming, such as rising sea levels, increased frequency and intensity of extreme weather, vegetation shifts, and altered ranges of plant and animal species around the world, would have drastic effects on the global ecosystem (UCS, 1999, 2001, and 2003). Localized hazards would include increased chances of floods along coastlines and flood plains, wildfires in forest regions and grasslands, and landslides and avalanches in mountainous regions.

In addition to carbon dioxide, diesel exhaust in the form of carbon soot may also be contributing to global warming. One study estimates that black carbon may be responsible for 15 to 30 percent of global warming, second only to carbon dioxide (Jacobson, 2001). These data, though preliminary, suggest that the power and higher fuel economy of conventional diesel engines are not a panacea for global warming. In addition, some diesel cleanup technologies involve a fuel economy penalty, resulting in higher levels of carbon dioxide emissions.

# Chapter 3
# Cleanup Opportunities

Reducing pollution from heavy diesel equipment can be technically challenging due to the variation in engine use, power range, operating conditions, and size.

Unlike highway trucks and buses, which generally range from 150 to 600 hp, heavy diesel engines range from less than 10 to 3,000 hp. Some are used under steady-state conditions, while others operate under start-and-go or highly transient duty cycles. Emission controls for heavy diesel equipment must be tailored to the unique operating conditions and packaging constraints of each type of equipment. In addition, because emission controls can sometimes produce unwanted pollution (for example, nitrogen oxide controls often produce an increase in particulate emissions and vice versa), systems must be optimized to ensure all key pollutants are simultaneously controlled.

Luckily, many of the strategies for cleaning up highway trucks and buses can be easily applied to heavy diesel equipment, particularly for mid-size and large engines (Table 5). Off-the-shelf technologies are available today to meet current emissions standards for new heavy diesel equipment and reduce emissions from older equipment. More advanced controls to cut pollutant loads are under development, and manufacturers are already showcasing these technologies in demonstration vehicles (Table 6, p.18).

Table 5 **Diesel Emission Control Opportunities for Particulate Matter (PM) and Nitrogen Oxides (NOx)**

| Engine Improvements | Pollutants Controlled |
|---|---|
| Fuel injection systems | NOx & PM |
| Exhaust gas recirculation | NOx |
| Combustion chamber | NOx & PM |
| Charge air cooling | NOx |
| Homogenous charge compression ignition | PM |
| In-cylinder coatings | PM |
| **Fuel and Oil Specifications** | |
| Fuel formulation | NOx & PM |
| Lubrication oil | PM |
| **Exhaust Control Equipment** | |
| Oxidation catalyst | PM |
| Particulate traps | PM |
| NOx adsorbers | NOx |
| Lean NOx catalysts | NOx |
| Selective catalytic reduction | NOx & PM |
| Plasma-assisted catalysts | NOx |

## CLEANING UP OLDER EQUIPMENT

The majority of the heavy equipment in use today was built before any emissions standards existed. For equipment that cannot be retired and replaced with newer, cleaner alternatives, retrofit technologies are available to reduce emissions of particulates and smog-forming nitrogen oxides. Oxidation catalysts, for example, have been available for years, while lean nitrogen oxide catalysts are just entering the market today. These technologies are being applied to both highway and off-highway diesel equipment.

### Oxidation catalysts

*What are they?* Oxidation catalysts reduce the amount of particulates by transforming carbon particles into carbon dioxide. As exhaust passes through an oxidation catalyst, the precious metal catalyst oxidizes carbon monoxide, gaseous hydro-

Table 6 **Pollution Reduction Potential from Emission Control Technologies**

| Technology or Fuel | Pollution Reduction Potential: Particulates | Pollution Reduction Potential: Nitrogen Oxides | Fuel Economy Penalty | Issues | Stage of Development |
|---|---|---|---|---|---|
| Continuously regenerating (“passive”) particulate filter (1) | 85% or more | | Up to 2% | More smog-forming nitrous oxide ($NO_2$) emissions | Currently available |
| Active particulate filter | 85% or more | | 5% or more | | Available in Europe |
| Oxidation catalyst (2) | 20% to 50% | | None | | Currently available |
| Exhaust gas recirculation (3) | | Up to 50% | Up to 5% | | Available, but needs improvement to reach potential |
| Selective catalytic reduction (4) | 25% or more | 55% to 90% | 5% to 7% using urea | Secondary emissions | Under development |
| Lean NOx catalyst (5) | | 10% to 20% today<br>50% to 70% emerging | 2% to 6% | Potential for hydrocarbon slip | Under development |
| NOx adsorber or “trap” (6) | | 80% to 95% | 2% to 6% | Durability concerns | Under development |

NOTE: All of these technologies require low-sulfur fuel at or below 15 ppm for optimal performance.

SOURCES:
(1) Certification data from the California Air Resources Board for Johnson Matthey and Engelhard continuously regenerating passive systems.
(2) U.S. EPA certification data (EPA, 2001).
(3) DieselNet, 2000.
(4) Miller, 2000; MECA, 2003.
(5) Majewski, 2001; MECA, 2003.
(6) Brogan, 1998.

carbons, and liquid hydrocarbons adsorbed onto carbon particles. According to EPA tests, oxidation catalysts can reduce particulates by 20 to 50 percent on older engines (EPA, 2001). A key factor influencing their effectiveness is the level of sulfur in the diesel fuel. Because oxidation catalysts also oxidize sulfur dioxide, forming particulate sulfate emissions, they are most effective at reducing particulate emissions when the sulfur content of the diesel fuel is low. This technology is most appropriate for older engines that cannot be retrofitted with particulate filters (see below).

***Current use and outlook:*** Oxidation catalysts have been used for decades to reduce particulates from a variety of highway vehicles and heavy diesel equipment. More than 250,000 have been installed on a wide range of heavy diesel equipment including underground mining equipment, skid steer loaders, forklifts, and construction vehicles (MECA, 2003). For example, construction equipment used to clean debris from New York’s World Trade Center disaster and Boston’s “Big Dig” has utilized oxidation catalysts to help protect residents and workers from additional pollution exposure. Some 35 million diesel passenger cars also rely on oxidation catalysts to reduce particulate emissions.

### Diesel particulate filters

***What are they?*** Diesel particulate filters, also known as PM traps, capture particulates in the engine’s exhaust stream. Early evidence indicates that well-functioning filters can reduce particulate levels more than 90 percent, to the point where they are below detectable limits (LeTavec, 2000). In addition to reducing the mass of particulate emissions, filters also appear to reduce the number and toxicity of particles.

Diesel particulate filters will trap both combustible particles such as carbon soot and noncombustible materials such as the metals resulting from engine wear or the ash from lubricating oils. To clean the filter, the combustible particles must be oxidized (burned) through either passive or active ignition. Passive systems, which are being used on some new highway school and transit buses, use a catalyst to lower the oxidation temperature of the exhaust stream. Active systems use sparks or a heating device such as a microwave to heat the particles to the temperature needed for ignition (around 500° Celsius). Since they require additional energy to fuel the heating device, active systems carry a small fuel economy penalty. They are also slightly more expensive than passive systems.

The performance of passive systems, on the other hand, can be impaired by sulfur in the exhaust. Sulfur oxides compete for the catalyst sites required for the critical conversion of nitrogen oxide to nitrogen dioxide, increasing the temperature required for successful regeneration and making regeneration less effective. In addition, sulfur can be oxidized on the filter itself, clogging the device. The Department of Energy (DOE) found that sulfur in diesel fuel significantly harmed filter performance and could even cause emissions to increase relative to an uncontrolled engine (DOE, 2001). Higher-sulfur fuel will not necessarily damage active filters, but because the sulfur can be oxidized into particulate sulfate compounds, the amount of particulates released into the atmosphere increases.

Diesel particulate filters generally replace traditional muffler equipment, eliminating the need for two separate devices. Although this technology is typically larger than a muffler in both size (1.5 to 4 times the volume of engine displacement) and weight (two times the average muffler weight), most heavy diesel equipment has sufficient space and weight capacity for filter installation.

***Current use and outlook:*** Active particulate filters have been used on heavy diesel equipment in Europe and are now entering the U.S. market. Most heavy diesel equipment, because of its considerable idle time, varying operational speeds, and significant transient loads, does not have the duty cycles necessary to reach the temperature threshold for passive regeneration and will therefore require active filters (Starr, 2001). Manufacturers of passive filters are attempting to compensate by (1) using catalyst washcoats, (2) improving the oxidation capacity of the exhaust gas, and (3) increasing the engine exhaust temperature.

### Lean nitrogen oxide catalysts

***What are they?*** Lean nitrogen oxide catalysts, which reduce nitrogen oxide emissions in the presence of the oxygen-rich exhaust stream typical of diesel engines, have the potential to reduce nitrogen oxide emissions up to 30 percent. This technology typically uses hydrocarbons to convert nitrogen oxides into nitrogen gas, carbon dioxide, and water. Because hydrocarbons are not concentrated sufficiently in the exhaust stream, they (or diesel fuel) are injected directly into the exhaust, providing the environment necessary for nitrogen oxide reduction. This strategy does, however, carry a fuel economy penalty.

***Current use and outlook:*** In 2003, CARB verified the first combination lean nitrogen oxide catalyst and particulate filter for retrofitting certain highway diesel engines built in 1994 or later. The Longview system, designed by Cleaire Advanced Emission Controls as a muffler replacement unit, is the first retrofit equipment available for nitrogen oxide control and has been verified to reduce nitrogen oxides by 25 percent and particulates by 85 percent, with a fuel economy penalty between three and seven percent depending on the application (CARB, 2003). As yet, no lean nitrogen oxide catalysts or particulate filters are approved for use on off-highway diesel engines, though Cleaire is seeking to extend its verification to include certain off-highway engines.

## Fuel formulation changes

### LOW-SULFUR FUEL

***What is it?*** Low-sulfur fuel contains no more than 15 parts per million (ppm) of sulfur. Because the EPA currently has no controls on the sulfur level in heavy diesel equipment fuel, sulfur levels may exceed 3,000 ppm—more than six times higher than the level in highway diesel fuel, which is held to a maximum sulfur content of 500 ppm (dropping down to 15 ppm in mid-2006).

The EPA anticipates that reducing the amount of sulfur from 500 to 15 ppm will reduce sulfate particulates and sulfur oxide emissions by 97 percent (EPA, 1995). Perhaps more significantly for public health, many advanced emission controls require the use of low-sulfur fuel in order to function properly. Sulfur either impairs or totally compromises the performance of control technologies such as oxidation catalysts, particulate filters, lean nitrogen oxide catalysts, and exhaust gas recirculation.

***Current use and outlook:*** Low-sulfur diesel fuel is currently available in limited geographic pockets across the country, but will be widely available for use in highway vehicles starting in 2007. In order to harmonize emissions standards between the highway and off-highway sectors, the allowable sulfur level in heavy diesel equipment must also fall to 15 ppm. The EPA has considered an interim step of dropping the sulfur level to 500 ppm, but this tiered approach could compromise the 2007 highway standards.

One of the key problems with maintaining different sulfur levels in fuels is the risk of cross-contamination. There may be a magnitude difference between the sulfur levels of highway vehicles (15 ppm), heavy diesel equipment (500 to 3,000 or more ppm), and home heating oil (3,000 or more ppm). While refineries can take steps to ensure that high- and low-sulfur diesel fuel supplies remain separate, distribution and marketing networks may have difficulty maintaining strict separation. Low-sulfur diesel, for example, can be easily contaminated if stored in tanks that previously housed higher-sulfur fuels. Such contamination could lead to serious performance problems in emission control for both highway vehicles and heavy diesel equipment. The surest method for protecting emission controls from sulfur contamination is to hold all diesel fuels—whether for highway vehicles, heavy equipment, marine vessels, locomotives, or home heating—to a maximum sulfur level of 15 ppm.

### BIODIESEL

***What is it?*** Biodiesel is an alternative diesel fuel commonly composed of 20 percent pure biodiesel (derived from biological material such as plants or animal fats) and 80 percent conventional diesel fuel. Emissions of particulates, air toxics, carbon monoxide, and hydrocarbons are all reduced in biodiesel relative to conventional diesel fuels. However, nitrogen oxide emissions are increased. According to the EPA, soybean-based pure biodiesel produces a 45 percent reduction in particulates and a 10 percent increase in nitrogen oxides relative to diesel (EPA, 2002B). The greater the amount of pure biodiesel in the fuel, the lower the level of toxic particulates released. In addition, biodiesel has very low sulfur levels, typically below 15 ppm.

***Current use and outlook:*** Biodiesel is gaining appeal in certain applications such as school buses, refuse haulers, and passenger vehicles. However, because it costs significantly more than conventional diesel, biodiesel is commonly blended with conventional diesel, reducing its emissions benefits.

#### LUBRICATING OILS

***What are they?*** Oils used to lubricate heavy diesel engines can generate particulate emissions in two ways. First, the metallic portion of the oil, which cannot be burned, produces ash. Second, oil that evaporates in the crankcase and diffuses into the combustion chamber produces soot (DieselNet, 1998). Replacing metal additives with nonmetallic compounds should thus reduce the amount of ash generated, and using synthetic oils, which can be formulated to evaporate only within a narrow, high-temperature range, may also reduce particulate matter.

***Current use and outlook:*** Lubricating oils are not currently regulated by the EPA. Filling this regulatory gap could prove a sound strategy for reducing particulate emissions, particularly from older vehicles that do not have to meet more stringent emissions standards.

## CLEANING UP NEW ENGINES

A number of technologies for cleaning up new heavy diesel equipment are currently available or under development. New systems combining exhaust gas recirculation, advanced turbochargers, and advanced fuel injection are already being used in today's highway vehicles, while technologies to reduce nitrogen oxides, such as nitrogen oxide adsorbers and selective catalytic reduction, are in the development phase.

### Engine modifications

#### EXHAUST GAS RECIRCULATION

***What is it?*** Exhaust gas recirculation (EGR) returns a portion of the engine's exhaust to the combustion chamber. In the process, nitrogen oxide emissions are reduced because inert gases displace some of the oxygen that would otherwise enter the engine. Cooling the exhaust gas before it enters the combustion chamber can reduce emissions even further. However, EGR may increase particulates and engine wear while lowering fuel economy (DieselNet, 2000). Sulfur in the diesel fuel also poses a corrosive threat to the system.

***Current use and outlook:*** EGR has been a key strategy for manufacturers attempting to comply with the EPA's stricter nitrogen oxide standards for highway trucks and buses (which most manufacturers had to meet by October 2002). Cooled EGR will also be a likely necessity for manufacturers of heavy diesel equipment between 100 and 750 hp in order to meet Tier 3 standards starting in 2005.

#### ADVANCED TURBOCHARGERS

***What are they?*** Turbochargers are compressors used in many types of diesel engines to increase air pressure. Utilizing the engine's exhaust gas and a turbine, turbochargers increase engine power by increasing the amount of air inducted into the engine. Unfortunately, in rapid acceleration or stop-and-go conditions, diesel engines are often fuel-rich (too much fuel and not enough air), resulting in unburned emissions of hydrocarbons, carbon monoxide, particulates, and smoke. In turbocharged engines, this fuel-rich period, called turbolag, also wastes fuel and lowers fuel economy. Advanced turbochargers (e.g., variable

### Special Requirements of Smaller Engines

Engines rated below 75 hp will require adjustments in the form of electronic controls, turbochargers, or advanced fuel injection systems in order to employ advanced emission controls for nitrogen oxides and particulate matter. Nitrogen oxide adsorber catalysts, for example, require engines to modulate between lean and rich operation. Packaging these systems to ensure that functionality is not compromised will also require special engineering.

geometry turbochargers) rely on electronic controls to optimize combustion by controlling the air-to-fuel ratio and prevent over-enrichment during stop-and-go conditions. Cooling the exhaust gas after compression can further reduce nitrogen oxide emissions and increase system durability.

***Current use and outlook:*** Electronic superchargers have demonstrated pollution reductions of 20 to 40 percent for particulates and 30 to 65 percent for carbon monoxide (MECA, 2000), improving engine performance without penalizing fuel economy.

#### ADVANCED FUEL INJECTION

***What is it?*** With electronic controls to optimize fuel injection pressure, fuel spray pattern, injection rate, and timing, advanced fuel injection systems have been demonstrated to reduce nitrogen oxide emissions by 50 percent with no significant increase in particulates (Pierpont, 1995). Technology such as common-rail fuel injection limits nitrogen oxide formation by varying the rate of fuel injection over the duration of the injection period, ensuring the majority of fuel is burned at lower peak temperatures.

***Current use and outlook:*** Heavy diesel equipment over 100 hp will likely use common-rail fuel injection systems to meet Tier 3 standards starting in 2005, while engines under 100 hp can use less effective rotary injection systems.

## TOMORROW'S TECHNOLOGIES

To reduce nitrogen oxide emissions 90 percent or more from the Tier 3 level, technologies that have not yet appeared on the market will be needed. Prototype emission controls such as nitrogen oxide adsorbers and selective catalytic reduction are being tested for use on highway vehicles, and one of these technologies will likely emerge as the dominant nitrogen oxide-reducing strategy in the next few years.

### Nitrogen oxide adsorbers

***What are they?*** By trapping nitrogen oxides in a catalyst washcoat during oxygen-rich driving conditions, and releasing the nitrogen later in lean conditions, nitrogen oxide adsorbers, or traps, can potentially reduce nitrogen oxides 80 percent or more. Before this technology can be marketed, however, certain technical hurdles must be overcome. Current systems have not proved durable over the exhaust temperature profile typical of diesel engines (Duo and Bailey, 1998), or able to tolerate sulfur contamination.

Nitrogen oxide adsorbers require the periodic injection of a reducing agent such as hydrocarbons in order to regenerate the catalyst washcoat. This can be accomplished by either injecting fuel into the engine on the exhaust stroke (in single-path systems) or by switching the exhaust (in dual-path systems) and injecting fuel to regenerate one catalyst bed while the parallel catalyst bed is adsorbing nitrogen oxides. Single-path systems require less capital, but at the cost of a fuel economy penalty. Dual-path systems have a lower fuel economy penalty since less fuel is necessary in the closed catalyst bed, but the capital costs are higher. The complex exhaust configurations and valves necessary for exhaust flow management and catalyst regeneration make this technology an expensive option.

Further engineering considerations include the fact that nitrogen oxide adsorbers must be able to manage higher exhaust temperatures both in the engine (at the exhaust manifold) and within the exhaust components and catalysts. Adsorbers also require a good deal of space, with volumes ranging from as low as 1.5 times engine displacement for a single-path system to five times for a dual-path system.

***Current use and outlook:*** This technology offers the greatest promise for meeting the 90 percent control level established by forthcoming highway emissions standards for nitrogen oxides. Adsorbers have been successfully demonstrated in commercial use with lean-burning gasoline engines, but they have not been tested in diesel engines, which raises concerns about fuel contaminants that might reduce the catalyst's effectiveness. Unlike selective catalytic reduction (see below), nitrogen oxide adsorbers are self-contained and do not require the continual replenishment of a reagent. Opportunities to defeat this type of system are more limited than with selective catalytic reduction.

### Selective catalytic reduction

***What is it?*** Selective catalytic reduction (SCR) reduces nitrogen oxide emissions by using a chemical reagent (typically ammonia or urea) to convert nitrogen oxides to gaseous nitrogen and water vapor. This process can theoretically reduce nitrogen oxides more than 90 percent, and also control hydrocarbon and particulate matter emissions. However, SCR is sensitive to the timing and amount of reagent, variations in exhaust temperature, exhaust gas flow, and concentration of nitrogen oxides in the exhaust.

Toxic pollution in the form of ammonium nitrate particulates and ammonia can result if the reagent is injected at the wrong time or in the wrong amount (DieselNet, 2000B). If not enough urea is injected, for example, the catalyst stops working and nitrogen oxides are no longer reduced. If too much urea is injected, it passes through the catalyst (termed "slip") and is emitted into the atmosphere as ammonia. Increasing the catalyst volume can alleviate this issue, but at the cost of money and space. The catalyst may also be susceptible to poisoning from diesel exhaust constituents such as lube oil additives.

Because SCR requires sufficient exhaust temperatures to operate correctly, cold-start operation and excess idle are problematic. The catalyst also requires a larger amount of space than other emission control technologies (potentially two to three times engine displacement), but it is relatively inexpensive and the materials are widely available.

***Current use and outlook:*** SCR has been used for years on stationary engines and some marine applications, but its use on vehicles is still in the development phase. The technology has drawn significant interest because it may offer the highest level of nitrogen oxide control, and is being applied in demonstration vehicles such as the Ford Focus and some of the larger Class 8 heavy-duty trucks. However, shifting the technology from the steady-state conditions of stationary sources to the transient cycles of heavy diesel equipment poses significant challenges. SCR is more complex relative to other catalyst systems, larger in size, and more costly. In addition, users must periodically replenish the reagent, and there is currently neither an established distribution network for the reagent nor any incentive for vehicle operators to pay the additional cost.

Europeans consider SCR one of the front-running technologies for meeting future emissions standards, but it is unclear whether the technology will pass verification tests in the United States. Concerns about secondary pollution from the accidental release of urea or ammonia, as well as the durability and real-world performance of SCR, continue to plague its development.

## ENSURING LONG-TERM POLLUTION REDUCTION

Emerging exhaust control technologies such as selective catalytic reduction and particulate filters are new and relatively untested, and how they will perform under real-world conditions remains to be seen. Our experience with automotive emission controls indicates that it may take decades for the technology to realize its potential. The eventual success of such controls is predicated on two key factors: The equipment must be effective over a vehicle's lifetime, and emissions must be periodically inspected through an inspection and maintenance program.

Unlike passenger cars and trucks, off-highway diesel engines and heavy trucks and buses are not tested for real-world emissions. Heavy diesel engines must undergo a dynamometer test that measures the total mass of particles emitted per unit of energy (grams of pollutant per brake horsepower hour), but this test does not measure "in-use" emissions, which vary based on actual driving conditions, engine deterioration, and vehicle maintenance. An in-use test would more closely approximate the actual levels of air pollution released from heavy diesel vehicles, and provide a more accurate picture of the resulting human exposure to pollution.

The limited data available from real-world tests suggest that diesel engines may release more pollutants than certification standards indicate, especially particulate matter. Diesel trucks and buses, for example, may have released two to six times more particulate pollution than indicated by certification standards, while natural gas vehicles have maintained their emissions performance (Turner et al., 2000; West Virginia University, 1997). If historical experience is a guide, real-world emissions from aftertreatment technologies may also be higher than certification tests indicate. Some of the more complicated systems, such as active particulate filters or selective catalytic reduction, may even have higher rates of degradation and failure.

Furthermore, aftertreatment technologies that require upkeep or reduce a vehicle's fuel economy may suffer from tampering or misuse. Manufacturers responsible for the majority of heavy diesel engine sales, for example, allegedly used "defeat devices" in the 1990s to bypass air pollution regulations covering nitrogen oxides. Trucks and buses using these devices released up to 70 percent more pollution than "legal" vehicles (Mark and Morey, 2000). In 1998, the manufacturers agreed to stop using defeat devices in a settlement with the EPA and CARB.

Diesel cleanup technologies may struggle to stay clean over the 20, 30, and even 40 years that diesel engines can remain in operation. A variety of factors such as engine design, fuel sulfur content, vehicle maintenance, and certification determine whether a new aftertreatment technology will be effective over the useful life of a heavy diesel engine. To ensure that exhaust control technologies deliver on their environmental promise, an effective and enforceable in-use inspection and maintenance program including onboard diagnostic systems designed to detect malfunctions, chassis-based testing, and fuel auditing and special nozzle applicators to prevent misfueling is needed. In addition, aftertreatment devices should last the useful life of the vehicle. Without these safeguards in place, there is no guarantee that the technology will continue providing emissions benefits for a meaningful amount of time.

*Chapter 4*
# Case Studies

In evaluating the cost and emissions impact of installing state-of-the-art pollution controls on four types of heavy diesel equipment, UCS found that the most sophisticated controls (particulate filters and nitrogen oxide adsorbers) increased equipment costs by only one to three percent, while reducing pollutants by about 90 percent. The cost of adding these controls easily met EPA cost-effectiveness criteria for all four types of equipment. Furthermore, our analysis may actually overestimate the long-term costs of these controls, which should become less expensive as economies of scale, materials recycling, and engineering expertise push prices down.

## TYPES OF EQUIPMENT

The equipment in our case studies ranged in power from 75 to more than 400 hp, and varied in purpose from farming to construction and industrial projects (Table 7, p.26). The first type of equipment we evaluated is used to till soil (tractor), the second to excavate (hydraulic excavator), the third to thresh grain (agricultural combine), and the fourth to haul heavy loads (articulated hauler).

### Tractor

Tractors are a familiar symbol of American farms, and are considered one of the most essential pieces of agricultural equipment. Most tractors sold in the United States—more than 125,000 annually—are small (less than 99 hp). Engines of this size are commonly used in European light-duty vehicles, which may allow for some technology carry-over.

### Excavator

Common to most construction sites, hydraulic excavators are used to dig into the earth and move heavy materials. About 15,000 to 20,000 of these engines are sold in the United States every year; the 180 hp engine we evaluated represents the mid-size range.

**Tractor**

**Excavator**

Combine


Articulated hauler

### Combine

Agricultural combines cut and thresh grain. Because they are costly, only about 6,000 are sold every year, mostly to large-scale farming operations, and despite generally being used on a seasonal basis only, they have high utilization factors. The 285 hp engine we evaluated is subject to the Consent Decree pull-ahead standards, and must meet Tier 3 levels starting in 2006.

### Articulated hauler (dump truck)

Articulated haulers move large volumes of material, allowing other site machinery such as loaders and excavators to operate more efficiently. Only 2,000 of these vehicles are sold every year; our case study examines a large hauler (just over 400 hp).

## TECHNICAL ASSUMPTIONS

### Emissions analysis

To establish an emissions baseline, we assumed all four engines meet the emissions standards currently in place (Table 8). All of the engines will need to meet the more stringent Tier 3 emissions standards coming into effect in the next several years, which will likely require variable geometry turbochargers and exhaust gas recirculation. These technologies are already being used in new highway trucks and buses.

Table 7 **Assumed Power and Operating Characteristics of Four Types of Diesel Equpment**

| | Units | Tractor | Hydraulic Excavator | Combine | Articulated Hauler |
|---|---|---|---|---|---|
| Power | horsepower | 75 | 180 | 285 | 420 |
| Engine displacement | liters | 4.5 | 7.2 | 8.3 | 12.0 |
| Engine output | kilowatt hours/year | 15,680 | 86,514 | 18,816 | 303,353 |
| Annual operation | hours/year | 475 | 1,092 | 150 | 1,641 |
| Load factor | percent | 59% | 59% | 59% | 59% |
| Equipment lifetime | years | 17 | 7 | 25 | 7 |
| Annual fuel usage | gallons/year | 1,274 | 7,030 | 1,529 | 24,651 |

SOURCE: U.S. EPA NONROAD model and background support documents, located online at: www.epa.gov/otaq/nonrdmdl.htm.

Table 8 **Baseline vs. New Stronger Emissions Standards**

| | Nitrogen Oxide Standards (grams per horsepower hour, g/hp-hr) | | | Particulate Matter Standards (grams per horsepower hour, g/hp-hr) | | |
|---|---|---|---|---|---|---|
| **Vehicle** | **Today's Standards (Tier 3)** | **Stronger Standards** | **Emission Reduction** | **Today's Standards (Tier 3)** | **Stronger Standards** | **Emission Reduction** |
| Tractor | 3.2 | 0.30 | 91% | 0.3 | 0.01 | 97% |
| Hydraulic Excavator | 2.7 | 0.30 | 89% | 0.1 | 0.01 | 93% |
| Combine | 2.7 | 0.30 | 89% | 0.1 | 0.01 | 93% |
| Articulated Hauler | 2.7 | 0.30 | 89% | 0.1 | 0.01 | 93% |

### Pollution controls

We evaluated the costs of installing nitrogen oxide adsorbers and particulate filters, which can reduce nitrogen oxide and particulate matter emissions 90 percent or more, on all four engines. While particulate filters have proven to be the dominant strategy for soot control, no clear winner in the race to control nitrogen oxides has yet emerged. We chose to model the costs of nitrogen oxide adsorbers rather than their main competition, selective catalytic reduction (SCR), even though SCR appears to be less expensive. SCR needs to overcome significant hurdles before it can be considered a foolproof nitrogen oxide control strategy: lack of a dual-fuel infrastructure, vulnerability of the system to tampering and misuse, potential for a toxic release of ammonia into the environment, and difficulties of modifying a technology originally designed for steady-state engines to perform across transient vehicle cycles.

## TECHNICAL ISSUES

Two key technical issues must be addressed when installing pollution controls in heavy diesel equipment: emission control packaging and exhaust temperature. Since heavy diesel engines are designed for specific functions, emission controls (which are scaled in size to engine displacement, or the size of the compression chambers), need to be packaged appropriately to ensure engine functionality is preserved. Exhaust temperature needs to be controlled to ensure that emission controls function properly.

### Cost

Our analysis takes into account the costs of installation, labor, catalyst, materials, active engine controls, and packaging. Since heavy diesel equip-

## Should Gasoline Replace Diesel?

For engines under 75 hp, additional equipment is needed to ensure that pollution controls function properly. Conventional smaller engines with nitrogen oxide adsorbers, for example, require either in-cylinder post-fuel injection or supplemental in-exhaust fuel addition (MECA, 2003). Electronic controls may also be necessary to ensure filter regeneration.

Gasoline-powered, spark-ignited engines with three-way catalysts may offer the most cost-effective emissions reductions for smaller engines. New technologies such as variable valve actuation could improve the efficiency of spark-ignited gasoline engines, allowing them to compete with diesel for power, torque, durability, and fuel economy. One recent study, in fact, concluded that low particulate and nitrogen oxide emission levels could be achieved more cost-effectively in spark-ignited gasoline engines than diesel engines (SRI, 2003). The EPA has considered allowing smaller diesel engines to pollute at higher levels, but this kind of exemption could retard the development of cleaner, more cost-effective gasoline engines.

ment can adopt technologies currently being developed for highway trucks and buses, some economies of scale should be readily achieved. Therefore, our case studies assume a medium to high range of production.

Because particulate filters only entered the U.S. market in 2000, costs are anticipated to fall significantly once mass production achieves economies of scale, reduced labor investment, and precious metal optimization. We assume that particulate filters range in cost from about $835 for the smallest engine in our analysis (the 75 hp tractor) to nearly $2,100 for the largest engine (the articulated hauler).

Although nitrogen oxide control devices have less expensive catalyst materials than particulate filters, nitrogen oxide adsorbers must be coupled with active engine management to ensure catalyst regeneration. We assume the costs for such nitrogen oxide controls range from about $670 to $1,440.

### Cost-Effectiveness

The EPA classifies cost-effective emission reductions as $13,000 per ton of nitrogen oxides reduced and $40,000 per ton of particulate matter reduced (EPA, 2000).

## RESULTS

Adding state-of-the-art pollution controls to the engines in our case studies increases equipment costs one to three percent—an investment easily justified under EPA cost-effectiveness criteria. Nitrogen oxide controls are particularly cost-effective, ranging from $187 to $645 per ton (Table 9).

While our cost estimates reflect today's best engineering judgment, it is possible that our estimates will exceed the actual costs of compliance with stronger emissions standards. Implementation of the highway diesel rule will generate a large market for emission control technologies, and stronger standards for heavy diesel equipment will fuel market growth. The high cost of catalysts for particulate filters and nitrogen oxide adsorbers will drop as materials recycling and optimization reduce demand. Historically, analysts have overestimated the price of pollution controls and cleaner air, but even if our estimates were to double, emission controls for nitrogen oxides and particulates would still qualify for investment under the EPA's cost-effectiveness guidelines.

Table 9 **Cost-Effectiveness of Stonger Emissions Standards**

| | Units | Tractor | Hydraulic Excavator | Combine | Articulated Hauler |
|---|---|---|---|---|---|
| NOx emissions reduced | pounds/lifetime | 2,186 | 4,280 | 3,212 | 14,978 |
| NOx control cost | $/NOx controls | $669 | $948 | $1,071 | $1,443 |
| NOx cost-effectiveness | $/ton | $607 | $429 | $645 | $187 |
| PM emissions reduced | pounds/lifetime | 281 | 487 | 365 | 1,703 |
| PM control cost | $/PM controls | $835 | $1,287 | $1,471 | $2,090 |
| PM cost-effectiveness | $/ton | $7,496 | $9,959 | $15,165 | $4,621 |
| Today's equipment costs | $/equipment | $50,000 | $90,000 | $120,000 | $275,000 |
| Cost of pollution controls | $/control equipment | $1,504 | $2,235 | $2,542 | $3,533 |
| Increase in equipment cost | percentage | 3% | 3% | 2% | 1% |

SOURCE: UCS estimated the amount of emissions reduced by applying the U.S. EPA NONROAD model and its background support documents, located online at: www.epa.gov/otaq/nonrdmdl.htm. Control and equipment costs were estimated by M.J. Bradley and Associates, 2003.

*Chapter 5*
# Beyond Diesel

There are alternatives to diesel compression-ignition engines that can reduce pollution, increase our energy independence, and put us on a path toward the longer-term development of zero-emission engines. Alternative fuels such as electricity, natural gas, and ethanol allow us to diversify our energy sources while reducing toxic pollution. Hybrid technologies provide improved fuel economy, lower emissions, and a better understanding of how electric drives function. Ultimately, we need to move beyond both diesel and the internal combustion engine and turn instead to hydrogen-powered fuel cells, which offer the potential for pollution-free transportation.

## ALTERNATIVE FUELS

Alternative-fuel engines, which can be powered by natural gas, liquefied petroleum gas (propane), ethanol, methanol, electricity, liquefied natural gas, and hydrogen, are widely used in highway vehicles, particularly in transit and refuse fleets. Although few of these engines are currently available for use in the heavy equipment sector, alternative fuels such as electricity and natural gas power a growing number of agricultural pumps and airport support vehicles.

The cleanest alternative fuel currently used in the United States is natural gas, most often in its compressed form.[5] Natural gas is a fossil fuel like gasoline or diesel, but because it is inherently cleaner than oil, it does not need significant refinement to remove contaminants. Natural gas engines do have toxic emissions, but the trace amount of toxic particulates is generally attributed to crankcase lubricating oil and not the fuel itself (DOE, 2000). Decreasing the metallic portion of the lubricating oil, using synthetic oils that offer improved performance, and ensuring the engine is properly sealed to prevent leaks could reduce these emissions.

Like gasoline engines, natural gas engines are generally spark-ignited and use a throttle to control fuel input, resulting in lower fuel economy relative to diesel.[6] Next-generation natural gas engines using high-pressure direct injection can approach the high efficiency, lower heat loss, and high energy output of diesel engines, potentially reducing nitrogen oxides 37 percent and particulate matter 70 percent relative to diesel (Oueliette, 2000). However, these engines do not perform as well as spark-ignited natural gas engines in reducing particulate matter.

Studies comparing particulate matter and smog-forming emissions from natural gas and diesel engines have, until recently, consistently found natural gas to be the cleaner fuel. The advent of emission control technologies, especially particulate filters, gives diesel the opportunity to compete more closely with natural gas for the lowest emissions, both in mass and toxicity (Ahlvik and Brandberg, 2000; LeTavec, 2000). While concern about the long-term performance of diesel exhaust controls remains, alternative-fuel engines can become even cleaner by adopting

5 Compared with a conventional diesel fuel tank, a compressed natural gas tank (which stores the gas at pressures of 3,000 to 3,600 pounds per square inch) requires three to four times the space and weighs two to three times more (Cannon et al., 2000).

6 Natural gas engines can achieve 10 percent higher fuel economy or better compared with gasoline engines because their compression ratios are adjusted to take advantage of the higher octane rating of natural gas. Regular unleaded gasoline has an octane rating of 87, while the octane rating of natural gas is 130.

particulate filters, oxidation catalysts, and nitrogen oxide catalysts. As long as similar technologies are applied to both natural gas and diesel engines, natural gas, which is inherently cleaner than diesel and does not suffer from sulfur contamination, should retain its emissions advantage and prove cleaner over a vehicle's lifetime.

Natural gas also serves as a stepping-stone to another gaseous fuel, hydrogen, and the eventual market penetration of hydrogen-powered fuel cells. Since most of today's commercial hydrogen is reformed from natural gas—the least costly source of hydrogen fuel at the moment—building an infrastructure for natural gas should support longer-term development of zero-emission vehicles powered by hydrogen fuel cells.

## HYBRIDS

Hybrid engines combine the advantages of internal combustion and electricity, and can run on either diesel or alternative fuels. While a conventional internal combustion engine is mechanically attached to the vehicle's wheels through the transmission and driveshaft, hybrid vehicles use an electric motor to turn the wheels. Through a process called regenerative braking, hybrids also recover part of the braking energy that would otherwise be lost as heat, storing it for use during rapid acceleration. And, by turning the engine off while at rest, hybrids reduce both tailpipe emissions and noise.

This technology offers several advantages over a standard internal combustion engine. First, the engine's increased efficiency translates into higher fuel economy (as long as power is not diverted to vehicle amenities). Second, electric energy contributes no tailpipe emissions. Third, like natural gas vehicles, hybrid technology moves us closer to fuel cells, which generate electricity to drive the vehicle.

## FUEL CELLS

Fuel cells produce electricity through a chemical reaction between hydrogen and oxygen, a process that is both more efficient than internal combustion and much cleaner, since it creates no tailpipe emissions. The hydrogen needed to power a fuel cell can be derived from renewable sources such as solar energy or from traditional sources such as gasoline, methanol, and natural gas. For now, natural gas is the least costly source of hydrogen.

Fuel cell vehicles are in the prototype phase of development, and it may be several years before they are a reliable and cost-effective commercial product. Every automaker is engaged in research and development on these vehicles, and several U.S. transit agencies are experimenting with prototype buses. The promise of pollution-free, cost-effective transportation may ultimately make the internal combustion engine obsolete and revolutionize vehicle technology.

*Chapter 6*
# Paving the Way: Smart Public Policies

Cleaning up both new diesel equipment and the more than six million diesel engines already in use will require a combination of federal, state, and local action. Only federal action can ensure new engines are held to the same strict standards that existing trucks and buses must meet, and federal in-use testing protocols are needed to ensure engines and retrofit equipment remain clean throughout a vehicle's useful life. However, states, local governments, and communities must shoulder the responsibility of cleaning up the pollution from older engines. A combination of state regulations, policies, and incentives can promote retrofits and the purchase of cleaner technologies, while local efforts to reduce diesel emissions in vulnerable communities can be replicated across the country.

## FEDERAL ACTION

Without strong federal regulations, it will be difficult to reduce pollution from new off-highway diesel vehicles and engines. The federal Clean Air Act does not allow states to regulate new construction and farm equipment below 175 hp, new locomotives and locomotive engines, and commercial marine engines.

### Step one: Require low-sulfur fuel

Low-sulfur diesel fuel (15 ppm sulfur) must be mandated for all diesel vehicles. The performance of advanced emission controls can be impaired or completely compromised by sulfur contamination from standard off-highway diesel fuel, which contains at least 200 times more sulfur than necessary. Since highway diesel vehicles will be required to use low-sulfur fuel starting in late 2006, refineries are already investing in the technology required to reduce sulfur levels. Requiring *all* diesel fuels—whether intended for highway trucks and buses, heavy diesel equipment, commercial marine vessels, or locomotives—to use low-sulfur fuel will prevent misfueling and help protect sensitive emission controls from contamination.

### Step two: Pass stronger standards for heavy equipment

The EPA needs to harmonize its emission standards for heavy diesel equipment with the stronger standards already faced by highway diesel trucks and buses. In addition to ensuring regulatory parity, stronger standards will create economies of scale that push down the price of cleanup equipment. The cost of reducing pollution from heavy diesel vehicles can be kept relatively modest by capitalizing on emission control technologies under development for highway vehicles.

### Step three: Regulate trains and ships

The EPA also needs to turn its attention to other "off-highway" equipment such as locomotives and commercial marine vessels. Trains and ships currently contribute about 12 percent of all emissions from mobile sources, and their share will grow as other highway and off-highway engines become cleaner.

### Step four: Implement an in-use testing program

Finally, the EPA must ensure that new engines held to stricter emissions standards remain clean over their useful lifetime. The limited data available from real-world tests suggest that diesel engines may release two to six times more pollutants than certification standards indicate, especially for particulate matter. If historical experience is a guide, real-world emissions from new aftertreatment technologies may spike in the first few years, and systems that require more maintenance, such as active particulate filters and selective catalytic reduction, may have higher rates of degradation and failure. In-use testing, onboard diagnostics, and enforcement are necessary to translate stronger standards into public health gains.

## STATE AND LOCAL ACTION

States, local governments, and communities must work together to develop and implement innovative programs for retrofitting diesel equipment. Here are a few examples that not only attest to the power of a concerted effort to reduce public exposure to diesel pollution, but can also serve as models for the rest of the country.

### California incentives

The Golden State's Carl Moyer Program (CMP) is one of the nation's most creative means for encouraging the retirement of older diesel engines and their replacement with newer, cleaner alternatives. By funding the extra capital cost of vehicles and equipment that reduce smog-forming nitrogen oxides, this grant program allows diesel highway and off-highway engines to be replaced with cleaner natural gas, electric, and diesel engines, helping California meet its air quality obligations with critical near-term emission reductions.

The CMP successfully reduced smog-forming nitrogen oxide emissions by about 14 tons per day between 1999 and 2002—the equivalent of approximately one percent of the state's total nitrogen oxide emissions from highway vehicles. As of April 2002, the CMP had also replaced nearly 2,000 older diesel engines with new, cleaner diesel engines (primarily in marine vessels, off-highway equipment, and irrigation pumps), and funded more than 1,900 alternative-fuel vehicles (mainly transit buses and refuse trucks). The average cost-effectiveness of these projects was about $3,500 per ton of nitrogen oxides reduced—well below the $13,000 per ton program limit.

### Port of Los Angeles

Environmental and community groups, including the Natural Resources Defense Council and San Pedro and Peninsula Homeowners United, initiated a legal action against the City and Port of Los Angeles over a planned port expansion that would have increased pollution (NRDC, 2003). The city admitted that a single cargo vessel can emit as much as a ton of smog-forming nitrogen oxides and nearly 100 pounds of small particles or soot during a single day in its berth.

In March 2003, the parties agreed to a legal settlement with three key components. First, the settlement established a $50 million cleanup fund for air quality and aesthetic mitigation in the port area. Second, it required the port and city to prepare an environmental impact report on the new terminal. And third, it mandated that the port implement specific steps to reduce pollution, such as using alternative-fuel trucks instead of diesel vehicles at the site and providing ships with electric power so they do not have to idle their diesel engines while docked.

### Boston's "Big Dig"

In the late 1990s, a plan to build more than 160 lane miles of freeway through the middle of downtown Boston raised community concerns about pollution from construction vehicles in a densely populated and already polluted area. The "Big Dig"—the largest federal construction project in the country—is one of the first efforts to retrofit a large number of construction vehicles with oxidation catalysts and particulate filters. A coalition of federal, state, and local officials, environmental organizations, and community groups worked together to develop the Clean Air Construction

Initiative, which resulted in the installation of 120 oxidation catalysts on construction vehicles and another 100 planned for the future (ALA & ED, 2003). These retrofits should reduce particulate matter by some 200 tons over the project's remaining four or five years.

### New York's World Trade Center

One of the largest cleanup and rebuilding efforts in recent history is taking place at the lower Manhattan site of the former World Trade Center. Air pollution has been a serious concern since September 11, 2001, with cleanup crews still struggling to remove toxic soot and debris from buildings and ventilation systems. After the state and city governments, environmental groups, and community members raised concerns about the added pollution from diesel construction and cleanup equipment, Governor Pataki and the New York State Department of Environmental Conservation responded in September 2002 by requiring construction vehicles working downtown to use low-sulfur fuel and be retrofitted with the "best available" pollution control technology. These modest steps to mitigate the impact of the rebuilding process offer a "green construction" path that should be replicated throughout the country.

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*Appendix A*
# Calculating Emissions

## NEW TRANSIT BUS EQUIVALENT EMISSIONS

To calculate new transit bus equivalent emissions, we assume a model year 2004 diesel-powered urban transit bus will release 10.34 grams per mile of nitrogen oxides and 0.44 grams per mile of particulate matter. These emissions estimates are from Mark and Morey, 2000. We also assume transit buses will average 30,861 miles per year, based on the Department of Energy's *Transportation Energy Data Book* (DOE, 2002).

## 1999 EMISSION INVENTORY

To develop county-level emissions data for mobile sources, we relied on the EPA's final emission inventory, available online at: ftp://ftp.epa.gov/EmisInventory/finalnei99ver2. However, we could not reconcile the EPA's data for off-highway emissions in California with data published by the California Air Resources Board (CARB). Since the EPA considers CARB's data to be the most accurate, that is what we used. However, CARB provides information on reactive organic gases rather than volatile organic compounds, and does not provide information on $PM_{2.5}$ emissions, which we assume make up 99 percent of $PM_{10}$ emissions.

## CASE STUDIES

To develop our emissions and cost estimates for the four types of equipment evaluated in our case studies, we relied on technical information provided by M.J. Bradley and Associates. We also used technical support documents associated with the EPA's NONROAD model, located at: www.epa.gov/otaq/nonrdmdl.htm.

To calculate the emission factor for each type of equipment, we applied the following formula:

EF (adjusted) = EF (steady state) * TAF * DF
Where
EF (adjusted) = Final emission factor, adjusted for transient operation and deterioration, g/hp-hr
EF (steady state) = Steady-state emission factor, g/hp-hr
TAF = Transient adjustment factor, unitless
DF = Deterioration factor, unitless
= 1 + A * (cumulative hours * load factor)/median life at full load, in hours
A = Relative deterioration factor, unitless

# *Appendix B*
# State Fact Sheets: Air Pollution from Mobile Sources

### Definitions

| | |
|---|---|
| $PM_{10}$ | Particulate matter less than or equal to 10 microns in diameter |
| $PM_{2.5}$ | Particulate matter less than or equal to 2.5 microns in diameter |
| NOx | Nitrogen oxides |
| $SO_2$ | Sulfur dioxide |
| VOC | Volatile organic compounds (for all states except California) |
| ROG | Reactive organic compounds (for California only) |
| CO | Carbon monoxide |
| LNG | Liquefied natural gas |
| CNG | Compressed natural gas |

SOURCE: All mobile source emission data except California's off-highway pollution are based on the final 1999 emission inventory compiled by the U.S. EPA. The data are located online at: ftp://ftp.epa.gov/EmisInventory/finalnei99ver2/criteria. California's off-highway emissions were provided by the California Air Resources Board.

| U.S. TOTAL | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **571,878** | **489,125** | **12,617,563** | **741,785** | **8,066,635** | **90,357,081** |
| **Highway Vehicles** | **241,671** | **184,820** | **8,368,821** | **300,912** | **5,581,249** | **68,317,145** |
| **Off-Highway Equipment and Vehicles** | **330,206** | **304,305** | **4,248,742** | **440,873** | **2,485,386** | **22,039,935** |
| Heavy Equipment (Diesel) | 187,634 | 173,627 | 1,726,304 | 219,815 | 223,992 | 1,012,094 |
| Heavy Equipment (Gasoline) | 67,294 | 62,164 | 178,163 | 9,403 | 2,141,901 | 19,464,538 |
| Heavy Equipment (LNG & CNG) | 1,164 | 1,164 | 254,268 | 246 | 3,191 | 986,834 |
| Marine Vessels (Diesel) | 44,335 | 40,836 | 904,313 | 174,705 | 30,201 | 120,560 |
| Railroads (Diesel) | 23,317 | 21,265 | 1,078,939 | 28,444 | 41,569 | 111,593 |
| Aircraft | 6,463 | 5,250 | 106,755 | 8,259 | 44,533 | 344,316 |
| **Off-Highway Diesel** | **255,286** | **235,728** | **3,709,556** | **422,965** | **295,761** | **1,244,247** |
| **Off-Highway (Other Fuels)** | **74,921** | **68,577** | **539,185** | **17,909** | **2,189,625** | **20,795,688** |
| **Off-Highway Share of Mobile Source Pollution** | **58%** | **62%** | **34%** | **59%** | **31%** | **24%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **45%** | **48%** | **29%** | **57%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **33%** | **36%** | **14%** | **30%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **187,634** | **173,627** | **1,726,304** | **219,815** | **223,992** | **1,012,094** |
| Agriculture | 76,774 | 70,884 | 577,012 | 65,875 | 78,227 | 353,724 |
| Airport Ground Support | 770 | 716 | 10,582 | 1,015 | 1,569 | 9,431 |
| Commercial | 9,655 | 8,938 | 72,490 | 10,061 | 13,568 | 49,592 |
| Construction | 77,143 | 71,510 | 832,888 | 109,528 | 100,093 | 479,928 |
| Industrial | 14,581 | 13,538 | 139,425 | 20,571 | 18,252 | 72,642 |
| Lawn and Garden | 4,657 | 4,296 | 38,501 | 5,405 | 6,980 | 23,084 |
| Logging | 2,083 | 1,934 | 26,860 | 3,651 | 2,360 | 12,253 |
| Recreational | 379 | 346 | 1,661 | 218 | 580 | 2,339 |
| Underground Mining | 513 | 472 | 3,402 | 354 | 747 | 2,855 |
| Pleasure Craft | 607 | 560 | 20,646 | 2,796 | 1,024 | 3,673 |
| Railroad Equipment | 472 | 434 | 2,838 | 342 | 591 | 2,573 |

| ALABAMA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | $NO_x$ | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **9,613** | **8,071** | **344,927** | **12,528** | **170,558** | **1,780,821** |
| **Highway Vehicles** | **4,718** | **3,600** | **163,482** | **6,297** | **121,546** | **1,415,935** |
| **Off-Highway Equipment and Vehicles** | **4,895** | **4,470** | **181,445** | **6,230** | **49,012** | **364,886** |
| Heavy Equipment (Diesel) | 2,252 | 2,071 | 20,878 | 2,790 | 2,630 | 12,153 |
| Heavy Equipment (Gasoline) | 1,287 | 1,184 | 2,631 | 152 | 39,048 | 306,535 |
| Heavy Equipment (LNG & CNG) | 24 | 24 | 5,332 | 5 | 12 | 21,069 |
| Marine Vessels (Diesel) | 743 | 684 | 7,449 | 2,688 | 596 | 970 |
| Railroads (Diesel) | 480 | 432 | 144,766 | 558 | 6,398 | 18,497 |
| Aircraft | 109 | 75 | 389 | 38 | 326 | 5,661 |
| **Off-Highway Diesel** | **3,475** | **3,187** | **173,093** | **6,036** | **9,625** | **31,621** |
| **Off-Highway (Other Fuels)** | **1,420** | **1,283** | **8,352** | **195** | **39,387** | **333,265** |
| **Off-Highway Share of Mobile Source Pollution** | **51%** | **55%** | **53%** | **50%** | **29%** | **21%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **36%** | **40%** | **50%** | **48%** | **6%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **23%** | **26%** | **6%** | **22%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **2,252** | **2,071** | **20,878** | **2,790** | **2,630** | **12,153** |
| Agriculture | 535 | 492 | 3,809 | 431 | 521 | 2,398 |
| Airport Ground Support | 2 | 2 | 23 | 3 | 2 | 12 |
| Commercial | 143 | 132 | 1,001 | 142 | 195 | 712 |
| Construction | 1,022 | 940 | 10,271 | 1,390 | 1,246 | 6,160 |
| Industrial | 254 | 234 | 2,372 | 360 | 303 | 1,230 |
| Lawn and Garden | 58 | 54 | 468 | 70 | 87 | 281 |
| Logging | 167 | 154 | 2,069 | 283 | 178 | 970 |
| Recreational | 4 | 4 | 19 | 3 | 7 | 27 |
| Underground Mining | 42 | 38 | 276 | 29 | 61 | 231 |
| Pleasure Craft | 15 | 14 | 517 | 73 | 21 | 85 |
| Railroad Equipment | 9 | 8 | 52 | 6 | 11 | 47 |

| ALASKA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | $NO_x$ | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **2,116** | **1,861** | **42,184** | **4,232** | **26,284** | **236,556** |
| **Highway Vehicles** | **441** | **342** | **16,277** | **565** | **10,854** | **170,330** |
| **Off-Highway Equipment and Vehicles** | **1,674** | **1,519** | **25,907** | **3,668** | **15,430** | **66,226** |
| Heavy Equipment (Diesel) | 369 | 339 | 3,689 | 499 | 449 | 2,161 |
| Heavy Equipment (Gasoline) | 349 | 321 | 403 | 44 | 13,830 | 54,822 |
| Heavy Equipment (LNG & CNG) | 1 | 1 | 198 | 0 | 1 | 766 |
| Marine Vessels (Diesel) | 863 | 794 | 20,348 | 3,010 | 636 | 2,682 |
| Railroads (Diesel) | - | - | - | - | - | - |
| Aircraft | 93 | 64 | 1,269 | 115 | 514 | 5,795 |
| **Off-Highway Diesel** | **1,231** | **1,133** | **24,037** | **3,509** | **1,085** | **4,843** |
| **Off-Highway (Other Fuels)** | **443** | **386** | **1,870** | **159** | **14,344** | **61,383** |
| **Off-Highway Share of Mobile Source Pollution** | **79%** | **82%** | **61%** | **87%** | **59%** | **28%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **58%** | **61%** | **57%** | **83%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **17%** | **18%** | **9%** | **12%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **369** | **339** | **3,689** | **499** | **449** | **2,161** |
| Agriculture | 6 | 5 | 41 | 5 | 6 | 26 |
| Airport Ground Support | 8 | 7 | 85 | 11 | 8 | 43 |
| Commercial | 19 | 17 | 132 | 19 | 26 | 94 |
| Construction | 284 | 261 | 2,851 | 382 | 346 | 1,710 |
| Industrial | 17 | 16 | 150 | 23 | 22 | 81 |
| Lawn and Garden | 1 | 1 | 7 | 1 | 1 | 4 |
| Logging | 26 | 24 | 320 | 44 | 27 | 150 |
| Recreational | 6 | 5 | 26 | 3 | 9 | 36 |
| Underground Mining | | | | | | |
| Pleasure Craft | 2 | 2 | 71 | 10 | 3 | 12 |
| Railroad Equipment | 1 | 1 | 7 | 1 | 1 | 6 |

| ARIZONA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **8,683** | **7,294** | **206,193** | **9,954** | **135,691** | **1,479,089** |
| **Highway Vehicles** | **4,244** | **3,251** | **145,022** | **5,612** | **90,977** | **1,001,371** |
| **Off-Highway Equipment and Vehicles** | **4,438** | **4,043** | **61,171** | **4,342** | **44,715** | **477,717** |
| Heavy Equipment (Diesel) | 2,372 | 2,182 | 22,255 | 3,035 | 2,902 | 13,299 |
| Heavy Equipment (Gasoline) | 1,189 | 1,094 | 3,247 | 192 | 39,723 | 440,973 |
| Heavy Equipment (LNG & CNG) | 14 | 14 | 3,073 | 3 | 8 | 12,063 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | 749 | 674 | 30,144 | 878 | 1,163 | 2,983 |
| Aircraft | 115 | 79 | 2,452 | 234 | 919 | 8,400 |
| **Off-Highway Diesel** | **3,121** | **2,856** | **52,399** | **3,913** | **4,065** | **16,281** |
| **Off-Highway (Other Fuels)** | **1,318** | **1,187** | **8,772** | **429** | **40,650** | **461,436** |
| **Off-Highway Share of Mobile Source Pollution** | **51%** | **55%** | **30%** | **44%** | **33%** | **32%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **36%** | **39%** | **25%** | **39%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **27%** | **30%** | **11%** | **31%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **2,372** | **2,182** | **22,255** | **3,035** | **2,902** | **13,299** |
| Agriculture | 232 | 213 | 1,650 | 187 | 226 | 1,039 |
| Airport Ground Support | 32 | 29 | 350 | 46 | 33 | 175 |
| Commercial | 149 | 137 | 1,039 | 148 | 202 | 739 |
| Construction | 1,565 | 1,440 | 15,707 | 2,127 | 1,908 | 9,422 |
| Industrial | 178 | 163 | 1,585 | 245 | 217 | 844 |
| Lawn and Garden | 179 | 165 | 1,436 | 216 | 266 | 858 |
| Logging | 10 | 9 | 122 | 17 | 10 | 57 |
| Recreational | 12 | 11 | 51 | 7 | 18 | 71 |
| Underground Mining | | | | | | |
| Pleasure Craft | 8 | 7 | 261 | 37 | 11 | 43 |
| Railroad Equipment | 9 | 9 | 55 | 7 | 12 | 50 |

| ARKANSAS | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **7,908** | **6,837** | **168,731** | **9,891** | **92,451** | **1,007,424** |
| **Highway Vehicles** | **3,012** | **2,353** | **101,325** | **3,745** | **64,895** | **800,279** |
| **Off-Highway Equipment and Vehicles** | **4,897** | **4,484** | **67,405** | **6,146** | **27,556** | **207,145** |
| Heavy Equipment (Diesel) | 3,005 | 2,765 | 24,622 | 3,069 | 3,215 | 14,931 |
| Heavy Equipment (Gasoline) | 670 | 616 | 1,498 | 85 | 22,835 | 172,316 |
| Heavy Equipment (LNG & CNG) | 15 | 15 | 3,413 | 3 | 8 | 13,499 |
| Marine Vessels (Diesel) | 512 | 472 | 11,431 | 2,202 | 357 | 1,502 |
| Railroads (Diesel) | 652 | 587 | 26,239 | 767 | 1,004 | 2,594 |
| Aircraft | 43 | 29 | 203 | 20 | 137 | 2,302 |
| **Off-Highway Diesel** | **4,169** | **3,823** | **62,292** | **6,038** | **4,576** | **19,027** |
| **Off-Highway (Other Fuels)** | **727** | **660** | **5,114** | **108** | **22,980** | **188,118** |
| **Off-Highway Share of Mobile Source Pollution** | **62%** | **66%** | **40%** | **62%** | **30%** | **21%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **53%** | **56%** | **37%** | **61%** | **5%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **38%** | **40%** | **15%** | **31%** | **4%** | **2%** |
| **Heavy Equipment (Diesel)** | **3,005** | **2,765** | **24,622** | **3,069** | **3,215** | **14,931** |
| Agriculture | 1,856 | 1,708 | 13,208 | 1,494 | 1,806 | 8,314 |
| Airport Ground Support | 3 | 3 | 34 | 5 | 3 | 17 |
| Commercial | 85 | 79 | 598 | 85 | 116 | 426 |
| Construction | 828 | 762 | 8,328 | 1,127 | 1,010 | 4,995 |
| Industrial | 158 | 145 | 1,489 | 225 | 188 | 768 |
| Lawn and Garden | 18 | 16 | 145 | 21 | 26 | 85 |
| Logging | 40 | 37 | 491 | 67 | 42 | 230 |
| Recreational | 3 | 3 | 15 | 2 | 5 | 21 |
| Underground Mining | | | | | | |
| Pleasure Craft | 8 | 8 | 282 | 40 | 12 | 47 |
| Railroad Equipment | 5 | 5 | 32 | 4 | 7 | 29 |

| CALIFORNIA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | ROG | CO |
| **Mobile Sources - TOTAL** | **46,394** | **39,662** | **1,070,842** | **63,880** | **650,214** | **6,615,291** |
| **Highway Vehicles** | **20,524** | **14,293** | **703,556** | **11,305** | **521,940** | **5,701,038** |
| **Off-Highway Equipment and Vehicles** | **25,869** | **25,369** | **367,287** | **52,574** | **128,274** | **914,253** |
| Heavy Equipment (Diesel) | 14,426 | 14,282 | 218,929 | 26,861 | 25,982 | 101,107 |
| Heavy Equipment (Gasoline) | 3,804 | 3,766 | 20,954 | 384 | 80,831 | 680,726 |
| Heavy Equipment (LNG & CNG) | 66 | 65 | 12,184 | 6 | 2,549 | 28,625 |
| Marine Vessels (Diesel) | 3,238 | 3,026 | 39,457 | 21,827 | 2,824 | 6,406 |
| Railroads (Diesel) | 1,172 | 1,091 | 54,787 | 2,548 | 2,243 | 8,592 |
| Aircraft | 3,165 | 3,139 | 20,977 | 949 | 13,845 | 88,797 |
| **Off-Highway Diesel** | **18,835** | **18,399** | **313,172** | **51,236** | **31,049** | **116,105** |
| **Off-Highway (Other Fuels)** | **7,034** | **6,970** | **54,115** | **1,339** | **97,225** | **798,148** |
| **Off-Highway Share of Mobile Source Pollution** | **56%** | **64%** | **34%** | **82%** | **20%** | **14%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **41%** | **46%** | **29%** | **80%** | **5%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **31%** | **36%** | **20%** | **42%** | **4%** | **2%** |
| **Heavy Equipment (Diesel)** | **14,426** | **14,282** | **218,929** | **26,861** | **25,982** | **101,107** |
| Agriculture | 3,609 | 3,573 | 56,235 | 7,037 | 7,028 | 25,912 |
| Airport Ground Support | 110 | 109 | 1,483 | 47 | 127 | 681 |
| Commercial | 746 | 738 | 10,151 | 1,210 | 1,436 | 5,232 |
| Construction | 7,721 | 7,644 | 122,109 | 15,614 | 13,258 | 53,542 |
| Industrial | 1,777 | 1,759 | 21,250 | 2,357 | 3,160 | 12,043 |
| Lawn and Garden | 180 | 178 | 2,485 | 35 | 339 | 1,619 |
| Logging | 258 | 256 | 4,267 | 556 | 422 | 1,660 |
| Recreational | | | | | | |
| Underground Mining | | | | | | |
| Pleasure Craft (includes Recreational) | 25 | 25 | 949 | 5 | 213 | 419 |
| Railroad Equipment | | | | | | |

| COLORADO | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **7,522** | **6,886** | **178,437** | **9,409** | **121,652** | **1,570,526** |
| **Highway Vehicles** | **2,927** | **2,682** | **124,557** | **4,807** | **85,303** | **1,188,935** |
| **Off-Highway Equipment and Vehicles** | **4,594** | **4,204** | **53,880** | **4,602** | **36,350** | **381,592** |
| Heavy Equipment (Diesel) | 3,303 | 3,038 | 28,961 | 3,746 | 3,790 | 17,518 |
| Heavy Equipment (Gasoline) | 800 | 736 | 2,896 | 151 | 31,135 | 344,493 |
| Heavy Equipment (LNG & CNG) | 14 | 14 | 3,095 | 3 | 10 | 12,165 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | 414 | 372 | 16,636 | 483 | 646 | 1,648 |
| Aircraft | 63 | 44 | 2,292 | 218 | 768 | 5,768 |
| **Off-Highway Diesel** | **3,717** | **3,411** | **45,597** | **4,229** | **4,436** | **19,165** |
| **Off-Highway (Other Fuels)** | **878** | **794** | **8,283** | **373** | **31,914** | **362,427** |
| **Off-Highway Share of Mobile Source Pollution** | **61%** | **61%** | **30%** | **49%** | **30%** | **24%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **49%** | **50%** | **26%** | **45%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **44%** | **44%** | **16%** | **40%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **3,303** | **3,038** | **28,961** | **3,746** | **3,790** | **17,518** |
| Agriculture | 1,189 | 1,094 | 8,466 | 956 | 1,157 | 5,329 |
| Airport Ground Support | 20 | 18 | 219 | 29 | 21 | 109 |
| Commercial | 165 | 152 | 1,154 | 164 | 225 | 821 |
| Construction | 1,599 | 1,471 | 16,073 | 2,155 | 1,952 | 9,642 |
| Industrial | 197 | 182 | 1,946 | 282 | 242 | 956 |
| Lawn and Garden | 107 | 99 | 862 | 128 | 159 | 514 |
| Logging | 2 | 2 | 26 | 4 | 2 | 12 |
| Recreational | 12 | 11 | 51 | 7 | 18 | 72 |
| Underground Mining | | | | | | |
| Pleasure Craft | 3 | 3 | 116 | 16 | 5 | 19 |
| Railroad Equipment | 8 | 7 | 48 | 6 | 10 | 44 |

| CONNECTICUT | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **4,963** | **4,147** | **111,700** | **5,943** | **82,877** | **1,019,070** |
| **Highway Vehicles** | **2,565** | **1,945** | **88,629** | **3,496** | **54,017** | **729,230** |
| **Off-Highway Equipment and Vehicles** | **2,398** | **2,202** | **23,071** | **2,447** | **28,860** | **289,840** |
| Heavy Equipment (Diesel) | 1,279 | 1,177 | 12,248 | 1,692 | 1,585 | 7,195 |
| Heavy Equipment (Gasoline) | 909 | 836 | 2,431 | 124 | 26,987 | 264,687 |
| Heavy Equipment (LNG & CNG) | 19 | 19 | 4,020 | 4 | 9 | 15,860 |
| Marine Vessels (Diesel) | 169 | 155 | 3,975 | 587 | 124 | 524 |
| Railroads (Diesel) | - | - | - | - | - | - |
| Aircraft | 23 | 16 | 397 | 38 | 154 | 1,574 |
| **Off-Highway Diesel** | **1,448** | **1,332** | **16,223** | **2,280** | **1,710** | **7,719** |
| **Off-Highway (Other Fuels)** | **950** | **870** | **6,848** | **167** | **27,150** | **282,121** |
| **Off-Highway Share of Mobile Source Pollution** | **48%** | **53%** | **21%** | **41%** | **35%** | **28%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **29%** | **32%** | **15%** | **38%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **26%** | **28%** | **11%** | **29%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **1,279** | **1,177** | **12,248** | **1,692** | **1,585** | **7,195** |
| Agriculture | 36 | 34 | 260 | 29 | 36 | 164 |
| Airport Ground Support | 3 | 3 | 33 | 4 | 3 | 16 |
| Commercial | 121 | 111 | 844 | 120 | 164 | 601 |
| Construction | 833 | 766 | 8,363 | 1,127 | 1,016 | 5,017 |
| Industrial | 189 | 174 | 1,753 | 268 | 225 | 914 |
| Lawn and Garden | 78 | 72 | 631 | 94 | 116 | 375 |
| Logging | 1 | 1 | 10 | 1 | 1 | 5 |
| Recreational | 3 | 3 | 14 | 2 | 5 | 19 |
| Underground Mining | | | | | | |
| Pleasure Craft | 9 | 8 | 301 | 42 | 12 | 50 |
| Railroad Equipment | 7 | 6 | 39 | 5 | 8 | 36 |

| DELAWARE | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **1,920** | **1,641** | **38,701** | **2,667** | **26,205** | **271,130** |
| **Highway Vehicles** | **794** | **611** | **26,577** | **1,037** | **16,041** | **192,931** |
| **Off-Highway Equipment and Vehicles** | **1,126** | **1,030** | **12,124** | **1,630** | **10,164** | **78,199** |
| Heavy Equipment (Diesel) | 463 | 426 | 4,259 | 566 | 542 | 2,501 |
| Heavy Equipment (Gasoline) | 365 | 336 | 680 | 38 | 9,364 | 70,111 |
| Heavy Equipment (LNG & CNG) | 4 | 4 | 900 | 1 | 2 | 3,552 |
| Marine Vessels (Diesel) | 262 | 241 | 6,029 | 1,017 | 189 | 794 |
| Railroads (Diesel) | 6 | 6 | 247 | 7 | 10 | 25 |
| Aircraft | 26 | 18 | 10 | 1 | 57 | 1,218 |
| **Off-Highway Diesel** | **731** | **673** | **10,535** | **1,590** | **740** | **3,319** |
| **Off-Highway (Other Fuels)** | **395** | **358** | **1,590** | **40** | **9,423** | **74,880** |
| **Off-Highway Share of Mobile Source Pollution** | **59%** | **63%** | **31%** | **61%** | **39%** | **29%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **38%** | **41%** | **27%** | **60%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **24%** | **26%** | **11%** | **21%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **463** | **426** | **4,259** | **566** | **542** | **2,501** |
| Agriculture | 120 | 110 | 852 | 96 | 116 | 536 |
| Airport Ground Support | 1 | 1 | 7 | 1 | 1 | 3 |
| Commercial | 23 | 21 | 159 | 23 | 31 | 113 |
| Construction | 251 | 231 | 2,522 | 340 | 306 | 1,513 |
| Industrial | 43 | 39 | 395 | 60 | 51 | 206 |
| Lawn and Garden | 18 | 17 | 149 | 22 | 26 | 87 |
| Logging | 1 | 1 | 7 | 1 | 1 | 3 |
| Recreational | 1 | 1 | 4 | 1 | 1 | 6 |
| Underground Mining | | | | | | |
| Pleasure Craft | 5 | 4 | 156 | 22 | 6 | 26 |
| Railroad Equipment | 2 | 1 | 9 | 1 | 2 | 8 |

| DISTRICT OF COLUMBIA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **506** | **418** | **12,062** | **671** | **8,869** | **98,819** |
| **Highway Vehicles** | **260** | **193** | **9,529** | **380** | **7,521** | **83,615** |
| **Off-Highway Equipment and Vehicles** | **245** | **226** | **2,533** | **291** | **1,347** | **15,204** |
| Heavy Equipment (Diesel) | 207 | 191 | 2,036 | 278 | 255 | 1,219 |
| Heavy Equipment (Gasoline) | 32 | 29 | 103 | 6 | 1,083 | 13,277 |
| Heavy Equipment (LNG & CNG) | 1 | 1 | 175 | 0 | 0 | 686 |
| Marine Vessels (Diesel) | 0 | 0 | 4 | 1 | 0 | 1 |
| Railroads (Diesel) | 5 | 5 | 214 | 6 | 9 | 21 |
| Aircraft | - | - | - | - | - | - |
| **Off-Highway Diesel** | **213** | **196** | **2,254** | **285** | **264** | **1,241** |
| **Off-Highway (Other Fuels)** | **33** | **30** | **278** | **6** | **1,084** | **13,963** |
| **Off-Highway Share of Mobile Source Pollution** | **49%** | **54%** | **21%** | **43%** | **15%** | **15%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **42%** | **47%** | **19%** | **43%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **41%** | **46%** | **17%** | **41%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **207** | **191** | **2,036** | **278** | **255** | **1,219** |
| Agriculture | | | | | | |
| Airport Ground Support | 1 | 1 | 14 | 2 | 1 | 7 |
| Commercial | 9 | 8 | 60 | 9 | 12 | 43 |
| Construction | 181 | 166 | 1,815 | 245 | 221 | 1,089 |
| Industrial | 16 | 14 | 133 | 21 | 20 | 73 |
| Lawn and Garden | | | | | | |
| Logging | | | | | | |
| Recreational | 0 | 0 | 0 | 0 | 0 | 1 |
| Underground Mining | | | | | | |
| Pleasure Craft | 0 | 0 | 9 | 1 | 0 | 2 |
| Railroad Equipment | 1 | 1 | 5 | 1 | 1 | 5 |

| FLORIDA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **28,086** | **23,812** | **572,858** | **33,129** | **523,950** | **5,062,191** |
| **Highway Vehicles** | **12,286** | **9,335** | **426,164** | **16,628** | **329,310** | **3,388,594** |
| **Off-Highway Equipment and Vehicles** | **15,800** | **14,477** | **146,694** | **16,501** | **194,640** | **1,673,598** |
| Heavy Equipment (Diesel) | 7,012 | 6,451 | 66,579 | 9,108 | 8,643 | 39,225 |
| Heavy Equipment (Gasoline) | 6,545 | 6,021 | 12,092 | 759 | 181,886 | 1,577,622 |
| Heavy Equipment (LNG & CNG) | 36 | 36 | 7,972 | 8 | 23 | 30,968 |
| Marine Vessels (Diesel) | 1,581 | 1,454 | 37,264 | 5,528 | 1,165 | 4,911 |
| Railroads (Diesel) | 393 | 353 | 15,782 | 455 | 621 | 1,565 |
| Aircraft | 235 | 162 | 7,005 | 643 | 2,302 | 19,307 |
| **Off-Highway Diesel** | **8,985** | **8,258** | **119,625** | **15,092** | **10,429** | **45,701** |
| **Off-Highway (Other Fuels)** | **6,816** | **6,219** | **27,069** | **1,409** | **184,211** | **1,627,897** |
| **Off-Highway Share of Mobile Source Pollution** | **56%** | **61%** | **26%** | **50%** | **37%** | **33%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **32%** | **35%** | **21%** | **46%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **25%** | **27%** | **12%** | **28%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **7,012** | **6,451** | **66,579** | **9,108** | **8,643** | **39,225** |
| Agriculture | 610 | 562 | 4,346 | 491 | 594 | 2,736 |
| Airport Ground Support | 55 | 51 | 613 | 81 | 58 | 306 |
| Commercial | 672 | 618 | 4,699 | 668 | 915 | 3,343 |
| Construction | 4,481 | 4,123 | 44,972 | 6,090 | 5,462 | 26,980 |
| Industrial | 495 | 455 | 4,340 | 676 | 613 | 2,336 |
| Lawn and Garden | 510 | 469 | 4,093 | 614 | 758 | 2,444 |
| Logging | 58 | 53 | 718 | 98 | 62 | 337 |
| Recreational | 27 | 25 | 120 | 16 | 42 | 169 |
| Underground Mining | | | | | | |
| Pleasure Craft | 74 | 68 | 2,502 | 352 | 103 | 413 |
| Railroad Equipment | 29 | 27 | 176 | 21 | 37 | 160 |

| GEORGIA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **16,211** | **13,496** | **404,279** | **19,604** | **272,348** | **3,208,610** |
| **Highway Vehicles** | **9,271** | **7,140** | **314,439** | **12,061** | **208,127** | **2,532,843** |
| **Off-Highway Equipment and Vehicles** | **6,940** | **6,355** | **89,840** | **7,543** | **64,221** | **675,767** |
| Heavy Equipment (Diesel) | 4,172 | 3,838 | 38,276 | 5,148 | 4,946 | 22,753 |
| Heavy Equipment (Gasoline) | 1,680 | 1,545 | 4,700 | 262 | 56,699 | 607,475 |
| Heavy Equipment (LNG & CNG) | 38 | 38 | 8,475 | 8 | 20 | 33,405 |
| Marine Vessels (Diesel) | 271 | 249 | 6,384 | 945 | 200 | 841 |
| Railroads (Diesel) | 699 | 629 | 28,111 | 811 | 1,106 | 2,789 |
| Aircraft | 81 | 56 | 3,895 | 369 | 1,249 | 8,504 |
| **Off-Highway Diesel** | **5,142** | **4,716** | **72,771** | **6,903** | **6,252** | **26,383** |
| **Off-Highway (Other Fuels)** | **1,799** | **1,639** | **17,070** | **639** | **57,968** | **649,383** |
| **Off-Highway Share of Mobile Source Pollution** | **43%** | **47%** | **22%** | **39%** | **24%** | **21%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **32%** | **35%** | **18%** | **35%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **26%** | **28%** | **10%** | **26%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **4,172** | **3,838** | **38,276** | **5,148** | **4,946** | **22,753** |
| Agriculture | 848 | 780 | 6,034 | 682 | 825 | 3,798 |
| Airport Ground Support | 35 | 32 | 389 | 52 | 36 | 194 |
| Commercial | 313 | 288 | 2,190 | 311 | 426 | 1,558 |
| Construction | 2,277 | 2,095 | 22,869 | 3,095 | 2,776 | 13,720 |
| Industrial | 402 | 370 | 3,715 | 568 | 482 | 1,943 |
| Lawn and Garden | 177 | 163 | 1,419 | 213 | 264 | 849 |
| Logging | 85 | 79 | 1,057 | 145 | 91 | 496 |
| Recreational | 5 | 5 | 23 | 3 | 8 | 32 |
| Underground Mining | | | | | | |
| Pleasure Craft | 14 | 13 | 490 | 69 | 20 | 81 |
| Railroad Equipment | 15 | 14 | 91 | 11 | 19 | 82 |

| HAWAII | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **1,852** | **1,580** | **40,585** | **3,097** | **28,128** | **295,751** |
| **Highway Vehicles** | **714** | **544** | **24,417** | **960** | **19,340** | **201,070** |
| **Off-Highway Equipment and Vehicles** | **1,138** | **1,036** | **16,168** | **2,137** | **8,788** | **94,681** |
| Heavy Equipment (Diesel) | 499 | 459 | 4,717 | 649 | 614 | 2,824 |
| Heavy Equipment (Gasoline) | 227 | 209 | 554 | 35 | 7,241 | 84,901 |
| Heavy Equipment (LNG & CNG) | 1 | 1 | 310 | 0 | 1 | 1,175 |
| Marine Vessels (Diesel) | 361 | 333 | 8,527 | 1,260 | 267 | 1,124 |
| Railroads (Diesel) | - | - | - | - | - | - |
| Aircraft | 48 | 33 | 2,060 | 192 | 665 | 4,658 |
| **Off-Highway Diesel** | **861** | **792** | **13,244** | **1,909** | **881** | **3,948** |
| **Off-Highway (Other Fuels)** | **277** | **244** | **2,924** | **228** | **7,907** | **90,734** |
| **Off-Highway Share of Mobile Source Pollution** | **61%** | **66%** | **40%** | **69%** | **31%** | **32%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **47%** | **50%** | **33%** | **62%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **27%** | **29%** | **12%** | **21%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **499** | **459** | **4,717** | **649** | **614** | **2,824** |
| Agriculture | 35 | 32 | 247 | 28 | 34 | 156 |
| Airport Ground Support | 12 | 11 | 129 | 17 | 12 | 64 |
| Commercial | 42 | 39 | 295 | 42 | 58 | 210 |
| Construction | 348 | 321 | 3,492 | 476 | 425 | 2,096 |
| Industrial | 30 | 28 | 255 | 40 | 39 | 141 |
| Lawn and Garden | 28 | 26 | 221 | 35 | 42 | 133 |
| Logging | | | | | | |
| Recreational | 0 | 0 | 1 | 0 | 0 | 1 |
| Underground Mining | | | | | | |
| Pleasure Craft | 2 | 2 | 64 | 9 | 3 | 11 |
| Railroad Equipment | 2 | 2 | 14 | 2 | 3 | 13 |

| IDAHO | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **3,786** | **3,272** | **74,357** | **3,733** | **48,631** | **524,665** |
| **Highway Vehicles** | **1,437** | **1,123** | **49,148** | **1,786** | **29,047** | **391,997** |
| **Off-Highway Equipment and Vehicles** | **2,349** | **2,149** | **25,209** | **1,947** | **19,584** | **132,668** |
| Heavy Equipment (Diesel) | 1,580 | 1,453 | 12,681 | 1,554 | 1,665 | 7,698 |
| Heavy Equipment (Gasoline) | 480 | 442 | 958 | 65 | 17,411 | 118,025 |
| Heavy Equipment (LNG & CNG) | 5 | 5 | 1,088 | 1 | 3 | 4,281 |
| Marine Vessels (Diesel) | 1 | 1 | 22 | 4 | 1 | 3 |
| Railroads (Diesel) | 254 | 229 | 10,233 | 301 | 387 | 1,010 |
| Aircraft | 29 | 20 | 228 | 22 | 117 | 1,652 |
| **Off-Highway Diesel** | **1,835** | **1,683** | **22,936** | **1,859** | **2,053** | **8,711** |
| **Off-Highway (Other Fuels)** | **514** | **466** | **2,273** | **88** | **17,531** | **123,958** |
| **Off-Highway Share of Mobile Source Pollution** | **62%** | **66%** | **34%** | **52%** | **40%** | **25%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **49%** | **51%** | **31%** | **50%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **42%** | **44%** | **17%** | **42%** | **3%** | **2%** |
| **Heavy Equipment (Diesel)** | **1,580** | **1,453** | **12,681** | **1,554** | **1,665** | **7,698** |
| Agriculture | 1,077 | 991 | 7,669 | 866 | 1,048 | 4,827 |
| Airport Ground Support | 2 | 2 | 20 | 3 | 2 | 10 |
| Commercial | 49 | 45 | 341 | 48 | 66 | 243 |
| Construction | 308 | 283 | 3,095 | 415 | 376 | 1,858 |
| Industrial | 55 | 51 | 504 | 77 | 67 | 265 |
| Lawn and Garden | 20 | 18 | 160 | 23 | 28 | 93 |
| Logging | 59 | 54 | 730 | 100 | 63 | 342 |
| Recreational | 4 | 4 | 19 | 2 | 7 | 26 |
| Underground Mining | | | | | | |
| Pleasure Craft | 4 | 4 | 131 | 18 | 5 | 22 |
| Railroad Equipment | 2 | 2 | 14 | 2 | 3 | 13 |

| ILLINOIS | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **23,851** | **20,475** | **507,123** | **30,207** | **310,250** | **3,684,134** |
| **Highway Vehicles** | **9,039** | **6,891** | **320,189** | **12,119** | **214,996** | **2,686,845** |
| **Off-Highway Equipment and Vehicles** | **14,812** | **13,584** | **186,934** | **18,088** | **95,254** | **997,289** |
| Heavy Equipment (Diesel) | 9,780 | 8,997 | 79,765 | 10,017 | 10,663 | 48,696 |
| Heavy Equipment (Gasoline) | 2,260 | 2,079 | 7,355 | 393 | 79,970 | 872,294 |
| Heavy Equipment (LNG & CNG) | 65 | 65 | 14,183 | 14 | 36 | 55,956 |
| Marine Vessels (Diesel) | 1,391 | 1,280 | 31,419 | 5,737 | 982 | 4,132 |
| Railroads (Diesel) | 1,212 | 1,091 | 48,768 | 1,415 | 1,896 | 4,830 |
| Aircraft | 104 | 72 | 5,444 | 511 | 1,707 | 11,380 |
| **Off-Highway Diesel** | **12,384** | **11,368** | **159,952** | **17,169** | **13,541** | **57,658** |
| **Off-Highway (Other Fuels)** | **2,429** | **2,215** | **26,982** | **919** | **81,713** | **939,630** |
| **Off-Highway Share of Mobile Source Pollution** | **62%** | **66%** | **37%** | **60%** | **31%** | **27%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **52%** | **56%** | **32%** | **57%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **41%** | **44%** | **16%** | **33%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **9,780** | **8,997** | **79,765** | **10,017** | **10,663** | **48,696** |
| Agriculture | 5,576 | 5,130 | 39,690 | 4,483 | 5,427 | 24,984 |
| Airport Ground Support | 54 | 50 | 598 | 79 | 56 | 299 |
| Commercial | 487 | 448 | 3,404 | 483 | 663 | 2,422 |
| Construction | 2,718 | 2,500 | 27,306 | 3,661 | 3,315 | 16,380 |
| Industrial | 670 | 616 | 6,228 | 948 | 801 | 3,239 |
| Lawn and Garden | 215 | 198 | 1,729 | 256 | 318 | 1,030 |
| Logging | 0 | 0 | 3 | 0 | 0 | 1 |
| Recreational | 9 | 8 | 38 | 5 | 13 | 54 |
| Underground Mining | 12 | 11 | 82 | 9 | 18 | 69 |
| Pleasure Craft | 16 | 15 | 546 | 76 | 22 | 90 |
| Railroad Equipment | 24 | 22 | 142 | 17 | 30 | 129 |

| INDIANA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **15,292** | **13,057** | **345,663** | **19,811** | **199,269** | **2,451,125** |
| **Highway Vehicles** | **6,813** | **5,279** | **235,316** | **8,702** | **151,170** | **1,921,750** |
| **Off-Highway Equipment and Vehicles** | **8,478** | **7,778** | **110,347** | **11,109** | **48,099** | **529,376** |
| Heavy Equipment (Diesel) | 5,639 | 5,187 | 46,775 | 5,905 | 6,181 | 28,484 |
| Heavy Equipment (Gasoline) | 1,054 | 969 | 3,826 | 197 | 39,800 | 455,043 |
| Heavy Equipment (LNG & CNG) | 42 | 42 | 9,256 | 9 | 22 | 36,650 |
| Marine Vessels (Diesel) | 1,059 | 974 | 24,196 | 4,184 | 756 | 3,184 |
| Railroads (Diesel) | 633 | 570 | 25,451 | 734 | 1,003 | 2,525 |
| Aircraft | 52 | 36 | 842 | 81 | 337 | 3,490 |
| **Off-Highway Diesel** | **7,331** | **6,731** | **96,423** | **10,822** | **7,940** | **34,193** |
| **Off-Highway (Other Fuels)** | **1,148** | **1,047** | **13,925** | **287** | **40,159** | **495,183** |
| **Off-Highway Share of Mobile Source Pollution** | **55%** | **60%** | **32%** | **56%** | **24%** | **22%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **48%** | **52%** | **28%** | **55%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **37%** | **40%** | **14%** | **30%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **5,639** | **5,187** | **46,775** | **5,905** | **6,181** | **28,484** |
| Agriculture | 3,018 | 2,776 | 21,481 | 2,426 | 2,937 | 13,521 |
| Airport Ground Support | 13 | 12 | 149 | 20 | 14 | 74 |
| Commercial | 206 | 190 | 1,443 | 205 | 281 | 1,026 |
| Construction | 1,848 | 1,700 | 18,572 | 2,490 | 2,255 | 11,141 |
| Industrial | 404 | 372 | 3,802 | 577 | 478 | 1,967 |
| Lawn and Garden | 108 | 100 | 875 | 130 | 161 | 520 |
| Logging | 4 | 3 | 43 | 6 | 4 | 20 |
| Recreational | 7 | 7 | 32 | 4 | 11 | 45 |
| Underground Mining | 12 | 11 | 80 | 8 | 18 | 67 |
| Pleasure Craft | 7 | 6 | 230 | 32 | 9 | 38 |
| Railroad Equipment | 12 | 11 | 70 | 8 | 15 | 63 |

| IOWA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **11,755** | **10,380** | **193,523** | **11,814** | **97,908** | **1,168,000** |
| **Highway Vehicles** | **2,992** | **2,337** | **102,974** | **3,724** | **62,625** | **857,152** |
| **Off-Highway Equipment and Vehicles** | **8,763** | **8,043** | **90,549** | **8,090** | **35,283** | **310,848** |
| Heavy Equipment (Diesel) | 7,166 | 6,593 | 54,444 | 6,464 | 7,334 | 33,800 |
| Heavy Equipment (Gasoline) | 740 | 680 | 2,291 | 123 | 26,694 | 257,492 |
| Heavy Equipment (LNG & CNG) | 16 | 16 | 3,702 | 3 | 11 | 14,619 |
| Marine Vessels (Diesel) | 160 | 147 | 3,554 | 693 | 111 | 467 |
| Railroads (Diesel) | 651 | 586 | 26,219 | 774 | 982 | 2,585 |
| Aircraft | 31 | 21 | 339 | 33 | 152 | 1,885 |
| **Off-Highway Diesel** | **7,976** | **7,325** | **84,218** | **7,932** | **8,426** | **36,852** |
| **Off-Highway (Other Fuels)** | **787** | **718** | **6,331** | **159** | **26,857** | **273,996** |
| **Off-Highway Share of Mobile Source Pollution** | **75%** | **78%** | **47%** | **69%** | **36%** | **27%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **68%** | **71%** | **44%** | **67%** | **9%** | **3%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **61%** | **64%** | **28%** | **55%** | **8%** | **3%** |
| **Heavy Equipment (Diesel)** | **7,166** | **6,593** | **54,444** | **6,464** | **7,334** | **33,800** |
| Agriculture | 5,820 | 5,355 | 41,429 | 4,679 | 5,665 | 26,078 |
| Airport Ground Support | 1 | 1 | 16 | 2 | 2 | 8 |
| Commercial | 132 | 122 | 926 | 131 | 180 | 659 |
| Construction | 988 | 909 | 9,936 | 1,332 | 1,206 | 5,960 |
| Industrial | 163 | 151 | 1,520 | 232 | 195 | 792 |
| Lawn and Garden | 43 | 40 | 346 | 51 | 65 | 208 |
| Logging | 1 | 1 | 13 | 2 | 1 | 6 |
| Recreational | 4 | 3 | 15 | 2 | 5 | 21 |
| Underground Mining | | | | | | |
| Pleasure Craft | 6 | 6 | 208 | 29 | 9 | 34 |
| Railroad Equipment | 6 | 5 | 35 | 4 | 7 | 32 |

| KANSAS | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **10,031** | **8,814** | **175,924** | **10,063** | **83,068** | **1,034,258** |
| **Highway Vehicles** | **2,702** | **2,094** | **93,382** | **3,449** | **58,759** | **770,765** |
| **Off-Highway Equipment and Vehicles** | **7,328** | **6,720** | **82,542** | **6,614** | **24,310** | **263,493** |
| Heavy Equipment (Diesel) | 6,080 | 5,593 | 46,645 | 5,572 | 6,264 | 28,881 |
| Heavy Equipment (Gasoline) | 434 | 398 | 1,853 | 90 | 16,736 | 217,949 |
| Heavy Equipment (LNG & CNG) | 13 | 13 | 3,015 | 3 | 10 | 11,909 |
| Marine Vessels (Diesel) | 10 | 9 | 215 | 42 | 7 | 28 |
| Railroads (Diesel) | 762 | 685 | 30,633 | 890 | 1,189 | 3,034 |
| Aircraft | 30 | 21 | 181 | 18 | 103 | 1,693 |
| **Off-Highway Diesel** | **6,852** | **6,287** | **77,493** | **6,504** | **7,460** | **31,942** |
| **Off-Highway (Other Fuels)** | **477** | **432** | **5,049** | **110** | **16,849** | **231,551** |
| **Off-Highway Share of Mobile Source Pollution** | **73%** | **76%** | **47%** | **66%** | **29%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **68%** | **71%** | **44%** | **65%** | **9%** | **3%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **61%** | **64%** | **27%** | **55%** | **8%** | **3%** |
| **Heavy Equipment (Diesel)** | **6,080** | **5,593** | **46,645** | **5,572** | **6,264** | **28,881** |
| Agriculture | 4,786 | 4,403 | 34,062 | 3,850 | 4,657 | 21,441 |
| Airport Ground Support | 1 | 1 | 8 | 1 | 1 | 4 |
| Commercial | 116 | 107 | 812 | 115 | 158 | 578 |
| Construction | 961 | 883 | 9,656 | 1,300 | 1,171 | 5,792 |
| Industrial | 162 | 149 | 1,605 | 233 | 196 | 789 |
| Lawn and Garden | 44 | 41 | 357 | 53 | 66 | 214 |
| Logging | | | | | | |
| Recreational | 3 | 3 | 13 | 2 | 5 | 18 |
| Underground Mining | | | | | | |
| Pleasure Craft | 3 | 3 | 100 | 14 | 4 | 17 |
| Railroad Equipment | 5 | 5 | 32 | 4 | 7 | 29 |

| KENTUCKY | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **10,545** | **8,999** | **252,526** | **17,193** | **130,064** | **1,503,220** |
| **Highway Vehicles** | **4,772** | **3,712** | **162,610** | **6,022** | **97,581** | **1,228,501** |
| **Off-Highway Equipment and Vehicles** | **5,773** | **5,287** | **89,916** | **11,171** | **32,484** | **274,719** |
| Heavy Equipment (Diesel) | 2,599 | 2,392 | 22,077 | 2,830 | 2,940 | 13,454 |
| Heavy Equipment (Gasoline) | 816 | 751 | 2,071 | 109 | 26,915 | 232,457 |
| Heavy Equipment (LNG & CNG) | 18 | 18 | 4,187 | 4 | 10 | 16,538 |
| Marine Vessels (Diesel) | 1,747 | 1,607 | 39,008 | 7,477 | 1,218 | 5,127 |
| Railroads (Diesel) | 524 | 471 | 21,050 | 606 | 833 | 2,090 |
| Aircraft | 68 | 47 | 1,524 | 146 | 568 | 5,053 |
| **Off-Highway Diesel** | **4,870** | **4,470** | **82,135** | **10,912** | **4,991** | **20,671** |
| **Off-Highway (Other Fuels)** | **903** | **817** | **7,781** | **259** | **27,493** | **254,048** |
| **Off-Highway Share of Mobile Source Pollution** | **55%** | **59%** | **36%** | **65%** | **25%** | **18%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **46%** | **50%** | **33%** | **64%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **25%** | **27%** | **9%** | **17%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **2,599** | **2,392** | **22,077** | **2,830** | **2,940** | **13,454** |
| Agriculture | 1,124 | 1,034 | 7,998 | 904 | 1,093 | 5,035 |
| Airport Ground Support | 6 | 5 | 64 | 8 | 6 | 32 |
| Commercial | 120 | 110 | 838 | 119 | 163 | 596 |
| Construction | 973 | 896 | 9,784 | 1,324 | 1,187 | 5,869 |
| Industrial | 207 | 191 | 1,914 | 292 | 249 | 1,000 |
| Lawn and Garden | 34 | 32 | 278 | 41 | 50 | 163 |
| Logging | 10 | 9 | 122 | 17 | 10 | 57 |
| Recreational | 4 | 3 | 17 | 2 | 6 | 23 |
| Underground Mining | 105 | 96 | 695 | 72 | 153 | 584 |
| Pleasure Craft | 9 | 8 | 320 | 45 | 13 | 53 |
| Railroad Equipment | 8 | 7 | 48 | 6 | 10 | 43 |

| LOUISIANA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **17,061** | **15,095** | **374,139** | **39,006** | **146,534** | **1,453,923** |
| **Highway Vehicles** | **4,074** | **3,164** | **138,092** | **5,162** | **91,796** | **1,080,056** |
| **Off-Highway Equipment and Vehicles** | **12,988** | **11,931** | **236,046** | **33,843** | **54,738** | **373,867** |
| Heavy Equipment (Diesel) | 2,937 | 2,702 | 27,242 | 3,534 | 3,378 | 15,602 |
| Heavy Equipment (Gasoline) | 1,535 | 1,412 | 2,714 | 166 | 44,598 | 314,578 |
| Heavy Equipment (LNG & CNG) | 16 | 16 | 3,547 | 3 | 21 | 14,096 |
| Marine Vessels (Diesel) | 8,061 | 7,417 | 187,775 | 29,618 | 5,870 | 24,734 |
| Railroads (Diesel) | 388 | 350 | 13,989 | 448 | 552 | 1,550 |
| Aircraft | 50 | 35 | 779 | 74 | 319 | 3,307 |
| **Off-Highway Diesel** | **11,387** | **10,468** | **229,006** | **33,600** | **9,799** | **41,885** |
| **Off-Highway (Other Fuels)** | **1,601** | **1,462** | **7,040** | **244** | **44,939** | **331,981** |
| **Off-Highway Share of Mobile Source Pollution** | **76%** | **79%** | **63%** | **87%** | **37%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **67%** | **69%** | **61%** | **86%** | **7%** | **3%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **17%** | **18%** | **7%** | **9%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **2,937** | **2,702** | **27,242** | **3,534** | **3,378** | **15,602** |
| Agriculture | 970 | 892 | 6,900 | 780 | 943 | 4,344 |
| Airport Ground Support | 5 | 5 | 58 | 8 | 5 | 29 |
| Commercial | 145 | 133 | 1,015 | 144 | 198 | 722 |
| Construction | 1,339 | 1,232 | 13,452 | 1,821 | 1,632 | 8,067 |
| Industrial | 365 | 336 | 4,184 | 552 | 455 | 1,820 |
| Lawn and Garden | 32 | 30 | 259 | 39 | 47 | 153 |
| Logging | 49 | 45 | 608 | 83 | 52 | 285 |
| Recreational | 3 | 3 | 13 | 2 | 5 | 18 |
| Underground Mining | | | | | | |
| Pleasure Craft | 21 | 19 | 702 | 99 | 29 | 116 |
| Railroad Equipment | 9 | 8 | 52 | 6 | 11 | 48 |

| MAINE | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **2,776** | **2,357** | **54,896** | **3,436** | **53,382** | **546,917** |
| **Highway Vehicles** | **1,104** | **826** | **39,778** | **1,520** | **27,618** | **405,381** |
| **Off-Highway Equipment and Vehicles** | **1,672** | **1,531** | **15,119** | **1,916** | **25,763** | **141,537** |
| Heavy Equipment (Diesel) | 626 | 576 | 6,093 | 820 | 736 | 3,459 |
| Heavy Equipment (Gasoline) | 727 | 668 | 1,040 | 89 | 24,724 | 131,198 |
| Heavy Equipment (LNG & CNG) | 5 | 5 | 1,137 | 1 | 2 | 4,471 |
| Marine Vessels (Diesel) | 285 | 262 | 6,716 | 993 | 210 | 885 |
| Railroads (Diesel) | - | - | - | - | - | - |
| Aircraft | 29 | 20 | 133 | 13 | 91 | 1,524 |
| **Off-Highway Diesel** | **911** | **838** | **12,809** | **1,813** | **946** | **4,344** |
| **Off-Highway (Other Fuels)** | **761** | **693** | **2,309** | **103** | **24,818** | **137,193** |
| **Off-Highway Share of Mobile Source Pollution** | **60%** | **65%** | **28%** | **56%** | **48%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **33%** | **36%** | **23%** | **53%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **23%** | **24%** | **11%** | **24%** | **1%** | **1%** |
| **Heavy Equipment (Diesel)** | **626** | **576** | **6,093** | **820** | **736** | **3,459** |
| Agriculture | 102 | 94 | 726 | 82 | 99 | 457 |
| Airport Ground Support | 1 | 1 | 11 | 1 | 1 | 5 |
| Commercial | 40 | 37 | 282 | 40 | 55 | 201 |
| Construction | 278 | 256 | 2,795 | 375 | 339 | 1,676 |
| Industrial | 59 | 55 | 542 | 83 | 72 | 285 |
| Lawn and Garden | 16 | 15 | 130 | 19 | 24 | 77 |
| Logging | 110 | 101 | 1,359 | 186 | 117 | 637 |
| Recreational | 13 | 12 | 55 | 7 | 19 | 78 |
| Underground Mining | | | | | | |
| Pleasure Craft | 5 | 5 | 180 | 25 | 7 | 30 |
| Railroad Equipment | 2 | 2 | 14 | 2 | 3 | 13 |

| MARYLAND | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | $NO_x$ | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **8,421** | **7,055** | **193,501** | **10,500** | **137,387** | **1,638,697** |
| **Highway Vehicles** | **4,355** | **3,322** | **150,739** | **5,831** | **92,168** | **1,196,646** |
| **Off-Highway Equipment and Vehicles** | **4,067** | **3,733** | **42,762** | **4,669** | **45,218** | **442,051** |
| Heavy Equipment (Diesel) | 1,990 | 1,831 | 18,217 | 2,459 | 2,405 | 10,847 |
| Heavy Equipment (Gasoline) | 1,400 | 1,288 | 3,512 | 188 | 41,867 | 415,446 |
| Heavy Equipment (LNG & CNG) | 13 | 13 | 2,820 | 3 | 7 | 11,052 |
| Marine Vessels (Diesel) | 504 | 463 | 11,860 | 1,768 | 371 | 1,563 |
| Railroads (Diesel) | 132 | 119 | 5,291 | 150 | 216 | 527 |
| Aircraft | 28 | 19 | 1,062 | 101 | 353 | 2,616 |
| **Off-Highway Diesel** | **2,626** | **2,413** | **35,367** | **4,377** | **2,992** | **12,937** |
| **Off-Highway (Other Fuels)** | **1,441** | **1,320** | **7,395** | **292** | **42,227** | **429,114** |
| **Off-Highway Share of Mobile Source Pollution** | **48%** | **53%** | **22%** | **45%** | **33%** | **27%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **31%** | **34%** | **18%** | **42%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **24%** | **26%** | **9%** | **23%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **1,990** | **1,831** | **18,217** | **2,459** | **2,405** | **10,847** |
| Agriculture | 356 | 327 | 2,532 | 286 | 346 | 1,594 |
| Airport Ground Support | 7 | 7 | 81 | 11 | 8 | 41 |
| Commercial | 148 | 136 | 1,037 | 147 | 202 | 738 |
| Construction | 1,113 | 1,024 | 11,172 | 1,506 | 1,357 | 6,703 |
| Industrial | 181 | 166 | 1,595 | 248 | 223 | 855 |
| Lawn and Garden | 154 | 142 | 1,240 | 185 | 228 | 738 |
| Logging | 4 | 4 | 53 | 7 | 5 | 25 |
| Recreational | 4 | 4 | 19 | 3 | 7 | 27 |
| Underground Mining | | | | | | |
| Pleasure Craft | 13 | 11 | 427 | 60 | 18 | 71 |
| Railroad Equipment | 10 | 9 | 62 | 7 | 13 | 56 |

| MASSACHUSETTS | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | $NO_x$ | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **10,956** | **9,341** | **227,008** | **13,750** | **157,161** | **1,895,468** |
| **Highway Vehicles** | **4,371** | **3,302** | **159,461** | **6,013** | **104,954** | **1,374,477** |
| **Off-Highway Equipment and Vehicles** | **6,585** | **6,039** | **67,548** | **7,737** | **52,208** | **520,992** |
| Heavy Equipment (Diesel) | 4,534 | 4,171 | 44,503 | 6,043 | 5,575 | 26,476 |
| Heavy Equipment (Gasoline) | 1,514 | 1,393 | 4,040 | 215 | 45,637 | 460,893 |
| Heavy Equipment (LNG & CNG) | 31 | 31 | 6,603 | 7 | 16 | 26,050 |
| Marine Vessels (Diesel) | 358 | 329 | 8,441 | 1,252 | 264 | 1,113 |
| Railroads (Diesel) | 58 | 52 | 2,316 | 66 | 93 | 230 |
| Aircraft | 91 | 63 | 1,646 | 154 | 624 | 6,230 |
| **Off-Highway Diesel** | **4,949** | **4,552** | **55,260** | **7,361** | **5,931** | **27,819** |
| **Off-Highway (Other Fuels)** | **1,636** | **1,487** | **12,288** | **376** | **46,276** | **493,173** |
| **Off-Highway Share of Mobile Source Pollution** | **60%** | **65%** | **30%** | **56%** | **33%** | **28%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **45%** | **49%** | **24%** | **54%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **41%** | **45%** | **20%** | **44%** | **4%** | **1%** |
| **Heavy Equipment (Diesel)** | **4,534** | **4,171** | **44,503** | **6,043** | **5,575** | **26,476** |
| Agriculture | 44 | 40 | 312 | 35 | 43 | 197 |
| Airport Ground Support | 16 | 15 | 181 | 24 | 17 | 90 |
| Commercial | 221 | 204 | 1,549 | 220 | 302 | 1,102 |
| Construction | 3,789 | 3,486 | 38,058 | 5,105 | 4,622 | 22,830 |
| Industrial | 318 | 292 | 2,928 | 448 | 381 | 1,532 |
| Lawn and Garden | 110 | 101 | 887 | 131 | 163 | 527 |
| Logging | 0 | 0 | 5 | 1 | 0 | 2 |
| Recreational | 9 | 8 | 38 | 5 | 13 | 54 |
| Underground Mining | | | | | | |
| Pleasure Craft | 14 | 13 | 473 | 66 | 20 | 78 |
| Railroad Equipment | 12 | 11 | 72 | 9 | 15 | 65 |

| MICHIGAN | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **19,628** | **16,693** | **424,467** | **24,151** | **351,062** | **3,813,742** |
| **Highway Vehicles** | **8,784** | **6,742** | **312,462** | **11,543** | **213,526** | **2,852,143** |
| **Off-Highway Equipment and Vehicles** | **10,844** | **9,951** | **112,005** | **12,607** | **137,536** | **961,599** |
| Heavy Equipment (Diesel) | 4,954 | 4,557 | 43,921 | 5,781 | 5,700 | 25,974 |
| Heavy Equipment (Gasoline) | 3,936 | 3,621 | 7,451 | 507 | 129,416 | 869,727 |
| Heavy Equipment (LNG & CNG) | 60 | 60 | 13,133 | 14 | 31 | 51,961 |
| Marine Vessels (Diesel) | 1,557 | 1,433 | 36,115 | 5,823 | 1,129 | 4,756 |
| Railroads (Diesel) | 224 | 202 | 8,991 | 254 | 370 | 897 |
| Aircraft | 113 | 78 | 2,394 | 229 | 890 | 8,284 |
| **Off-Highway Diesel** | **6,735** | **6,192** | **89,027** | **11,858** | **7,199** | **31,627** |
| **Off-Highway (Other Fuels)** | **4,109** | **3,759** | **22,978** | **750** | **130,337** | **929,972** |
| **Off-Highway Share of Mobile Source Pollution** | **55%** | **60%** | **26%** | **52%** | **39%** | **25%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **34%** | **37%** | **21%** | **49%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **25%** | **27%** | **10%** | **24%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **4,954** | **4,557** | **43,921** | **5,781** | **5,700** | **25,974** |
| Agriculture | 1,678 | 1,544 | 11,948 | 1,349 | 1,633 | 7,521 |
| Airport Ground Support | 24 | 22 | 265 | 35 | 25 | 132 |
| Commercial | 314 | 289 | 2,199 | 312 | 428 | 1,565 |
| Construction | 2,047 | 1,883 | 20,566 | 2,758 | 2,498 | 12,339 |
| Industrial | 605 | 556 | 5,648 | 859 | 719 | 2,933 |
| Lawn and Garden | 167 | 154 | 1,343 | 199 | 248 | 801 |
| Logging | 48 | 44 | 597 | 82 | 51 | 280 |
| Recreational | 17 | 15 | 73 | 10 | 26 | 104 |
| Underground Mining | | | | | | |
| Pleasure Craft | 34 | 31 | 1,165 | 162 | 48 | 192 |
| Railroad Equipment | 20 | 18 | 118 | 14 | 25 | 107 |

| MINNESOTA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **16,206** | **14,161** | **289,957** | **18,614** | **205,436** | **2,038,359** |
| **Highway Vehicles** | **4,937** | **3,817** | **172,090** | **6,350** | **106,904** | **1,487,075** |
| **Off-Highway Equipment and Vehicles** | **11,268** | **10,344** | **117,867** | **12,264** | **98,531** | **551,284** |
| Heavy Equipment (Diesel) | 6,700 | 6,164 | 53,261 | 6,511 | 7,068 | 32,560 |
| Heavy Equipment (Gasoline) | 2,660 | 2,447 | 4,658 | 330 | 89,077 | 483,409 |
| Heavy Equipment (LNG & CNG) | 28 | 28 | 6,186 | 6 | 16 | 24,421 |
| Marine Vessels (Diesel) | 1,250 | 1,150 | 29,127 | 4,589 | 911 | 3,837 |
| Railroads (Diesel) | 572 | 514 | 22,997 | 671 | 885 | 2,275 |
| Aircraft | 58 | 40 | 1,639 | 157 | 574 | 4,783 |
| **Off-Highway Diesel** | **8,522** | **7,829** | **105,385** | **11,771** | **8,863** | **38,671** |
| **Off-Highway (Other Fuels)** | **2,746** | **2,515** | **12,482** | **494** | **89,668** | **512,612** |
| **Off-Highway Share of Mobile Source Pollution** | **70%** | **73%** | **41%** | **66%** | **48%** | **27%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **53%** | **55%** | **36%** | **63%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **41%** | **44%** | **18%** | **35%** | **3%** | **2%** |
| **Heavy Equipment (Diesel)** | **6,700** | **6,164** | **53,261** | **6,511** | **7,068** | **32,560** |
| Agriculture | 4,641 | 4,269 | 33,030 | 3,731 | 4,516 | 20,791 |
| Airport Ground Support | 26 | 24 | 286 | 38 | 27 | 143 |
| Commercial | 211 | 194 | 1,473 | 209 | 287 | 1,048 |
| Construction | 1,422 | 1,308 | 14,291 | 1,916 | 1,734 | 8,572 |
| Industrial | 278 | 256 | 2,585 | 394 | 331 | 1,345 |
| Lawn and Garden | 59 | 54 | 470 | 70 | 87 | 282 |
| Logging | 19 | 18 | 239 | 33 | 20 | 112 |
| Recreational | 14 | 13 | 63 | 8 | 22 | 89 |
| Underground Mining | | | | | | |
| Pleasure Craft | 22 | 21 | 769 | 107 | 32 | 127 |
| Railroad Equipment | 9 | 9 | 56 | 7 | 12 | 51 |

| MISSISSIPPI | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **8,958** | **7,732** | **203,281** | **13,747** | **103,982** | **1,032,862** |
| **Highway Vehicles** | **3,908** | **3,103** | **126,699** | **4,490** | **74,786** | **832,570** |
| **Off-Highway Equipment and Vehicles** | **5,049** | **4,629** | **76,582** | **9,258** | **29,197** | **200,292** |
| Heavy Equipment (Diesel) | 2,212 | 2,035 | 19,079 | 2,438 | 2,415 | 11,282 |
| Heavy Equipment (Gasoline) | 810 | 745 | 1,489 | 87 | 24,879 | 167,584 |
| Heavy Equipment (LNG & CNG) | 14 | 14 | 3,278 | 3 | 8 | 12,971 |
| Marine Vessels (Diesel) | 1,537 | 1,414 | 34,925 | 6,196 | 1,091 | 4,595 |
| Railroads (Diesel) | 438 | 394 | 17,615 | 516 | 673 | 1,741 |
| Aircraft | 39 | 27 | 197 | 19 | 131 | 2,120 |
| **Off-Highway Diesel** | **4,186** | **3,843** | **71,618** | **9,149** | **4,179** | **17,617** |
| **Off-Highway (Other Fuels)** | **863** | **786** | **4,964** | **109** | **25,017** | **182,675** |
| **Off-Highway Share of Mobile Source Pollution** | **56%** | **60%** | **38%** | **67%** | **28%** | **19%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **47%** | **50%** | **35%** | **67%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **25%** | **26%** | **9%** | **18%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **2,212** | **2,035** | **19,079** | **2,438** | **2,415** | **11,282** |
| Agriculture | 1,120 | 1,031 | 7,974 | 902 | 1,090 | 5,020 |
| Airport Ground Support | 1 | 1 | 9 | 1 | 1 | 5 |
| Commercial | 76 | 70 | 533 | 76 | 104 | 379 |
| Construction | 696 | 641 | 6,999 | 947 | 849 | 4,198 |
| Industrial | 157 | 145 | 1,465 | 223 | 188 | 761 |
| Lawn and Garden | 16 | 15 | 127 | 19 | 23 | 76 |
| Logging | 127 | 117 | 1,569 | 215 | 135 | 736 |
| Recreational | 3 | 3 | 13 | 2 | 5 | 18 |
| Underground Mining | | | | | | |
| Pleasure Craft | 10 | 10 | 355 | 50 | 15 | 59 |
| Railroad Equipment | 6 | 5 | 34 | 4 | 7 | 31 |

| MISSOURI | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **15,008** | **12,836** | **337,338** | **19,323** | **192,614** | **2,150,960** |
| **Highway Vehicles** | **6,307** | **4,864** | **216,585** | **8,177** | **138,576** | **1,674,267** |
| **Off-Highway Equipment and Vehicles** | **8,701** | **7,973** | **120,753** | **11,146** | **54,039** | **476,694** |
| Heavy Equipment (Diesel) | 5,026 | 4,624 | 40,676 | 5,058 | 5,414 | 24,805 |
| Heavy Equipment (Gasoline) | 1,436 | 1,321 | 3,635 | 196 | 45,260 | 414,490 |
| Heavy Equipment (LNG & CNG) | 27 | 27 | 6,057 | 6 | 16 | 23,886 |
| Marine Vessels (Diesel) | 1,106 | 1,017 | 25,239 | 4,387 | 789 | 3,321 |
| Railroads (Diesel) | 1,052 | 947 | 42,319 | 1,228 | 1,645 | 4,192 |
| Aircraft | 54 | 37 | 2,827 | 272 | 915 | 5,999 |
| **Off-Highway Diesel** | **7,184** | **6,588** | **108,234** | **10,673** | **7,847** | **32,318** |
| **Off-Highway (Other Fuels)** | **1,517** | **1,385** | **12,519** | **473** | **46,191** | **444,376** |
| **Off-Highway Share of Mobile Source Pollution** | **58%** | **62%** | **36%** | **58%** | **28%** | **22%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **48%** | **51%** | **32%** | **55%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **34%** | **36%** | **12%** | **26%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **5,026** | **4,624** | **40,676** | **5,058** | **5,414** | **24,805** |
| Agriculture | 3,100 | 2,852 | 22,069 | 2,492 | 3,017 | 13,891 |
| Airport Ground Support | 21 | 19 | 232 | 31 | 22 | 116 |
| Commercial | 223 | 205 | 1,561 | 222 | 304 | 1,110 |
| Construction | 1,277 | 1,175 | 12,837 | 1,720 | 1,558 | 7,701 |
| Industrial | 288 | 265 | 2,655 | 405 | 345 | 1,389 |
| Lawn and Garden | 79 | 72 | 634 | 94 | 116 | 376 |
| Logging | 3 | 3 | 41 | 6 | 4 | 19 |
| Recreational | 9 | 8 | 38 | 5 | 14 | 54 |
| Underground Mining | | | | | | |
| Pleasure Craft | 16 | 15 | 544 | 76 | 22 | 90 |
| Railroad Equipment | 11 | 10 | 65 | 8 | 14 | 59 |

| MONTANA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **4,376** | **3,865** | **81,871** | **4,258** | **32,600** | **378,636** |
| **Highway Vehicles** | **1,064** | **837** | **36,421** | **1,293** | **20,492** | **291,257** |
| **Off-Highway Equipment and Vehicles** | **3,311** | **3,028** | **45,450** | **2,965** | **12,109** | **87,379** |
| Heavy Equipment (Diesel) | 2,434 | 2,239 | 18,248 | 2,138 | 2,459 | 11,350 |
| Heavy Equipment (Gasoline) | 209 | 192 | 615 | 35 | 8,563 | 70,297 |
| Heavy Equipment (LNG & CNG) | 2 | 2 | 434 | 0 | 2 | 1,694 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | 643 | 578 | 25,890 | 767 | 964 | 2,551 |
| Aircraft | 25 | 17 | 263 | 25 | 122 | 1,487 |
| **Off-Highway Diesel** | **3,076** | **2,817** | **44,138** | **2,905** | **3,423** | **13,901** |
| **Off-Highway (Other Fuels)** | **235** | **211** | **1,312** | **61** | **8,686** | **73,478** |
| **Off-Highway Share of Mobile Source Pollution** | **76%** | **78%** | **56%** | **70%** | **37%** | **23%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **70%** | **73%** | **54%** | **68%** | **11%** | **4%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **56%** | **58%** | **22%** | **50%** | **8%** | **3%** |
| **Heavy Equipment (Diesel)** | **2,434** | **2,239** | **18,248** | **2,138** | **2,459** | **11,350** |
| Agriculture | 2,090 | 1,923 | 14,881 | 1,681 | 2,035 | 9,367 |
| Airport Ground Support | 1 | 1 | 15 | 2 | 1 | 7 |
| Commercial | 37 | 34 | 258 | 37 | 50 | 184 |
| Construction | 241 | 222 | 2,429 | 325 | 294 | 1,456 |
| Industrial | 33 | 30 | 313 | 46 | 41 | 157 |
| Lawn and Garden | 3 | 3 | 29 | 4 | 4 | 15 |
| Logging | 18 | 17 | 228 | 31 | 20 | 107 |
| Recreational | 6 | 6 | 28 | 4 | 10 | 39 |
| Underground Mining | | | | | | |
| Pleasure Craft | 2 | 2 | 58 | 8 | 2 | 9 |
| Railroad Equipment | 2 | 2 | 10 | 1 | 2 | 10 |

| NEBRASKA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **8,198** | **7,290** | **151,748** | **8,089** | **57,274** | **702,677** |
| **Highway Vehicles** | **1,832** | **1,429** | **63,234** | **2,291** | **38,448** | **520,981** |
| **Off-Highway Equipment and Vehicles** | **6,366** | **5,861** | **88,514** | **5,798** | **18,826** | **181,696** |
| Heavy Equipment (Diesel) | 4,815 | 4,430 | 36,021 | 4,238 | 4,878 | 22,452 |
| Heavy Equipment (Gasoline) | 304 | 280 | 1,280 | 60 | 11,910 | 142,657 |
| Heavy Equipment (LNG & CNG) | 8 | 8 | 1,743 | 2 | 6 | 6,873 |
| Marine Vessels (Diesel) | 4 | 3 | 79 | 15 | 2 | 10 |
| Railroads (Diesel) | 1,212 | 1,128 | 48,833 | 1,441 | 1,832 | 4,815 |
| Aircraft | 24 | 12 | 557 | 41 | 199 | 4,889 |
| **Off-Highway Diesel** | **6,031** | **5,562** | **84,933** | **5,695** | **6,712** | **27,278** |
| **Off-Highway (Other Fuels)** | **335** | **299** | **3,581** | **103** | **12,114** | **154,418** |
| **Off-Highway Share of Mobile Source Pollution** | **78%** | **80%** | **58%** | **72%** | **33%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **74%** | **76%** | **56%** | **70%** | **12%** | **4%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **59%** | **61%** | **24%** | **52%** | **9%** | **3%** |
| **Heavy Equipment (Diesel)** | **4,815** | **4,430** | **36,021** | **4,238** | **4,878** | **22,452** |
| Agriculture | 4,112 | 3,783 | 29,263 | 3,308 | 4,001 | 18,420 |
| Airport Ground Support | 2 | 2 | 26 | 3 | 2 | 13 |
| Commercial | 77 | 71 | 536 | 76 | 104 | 381 |
| Construction | 508 | 467 | 5,111 | 688 | 620 | 3,066 |
| Industrial | 82 | 76 | 758 | 116 | 99 | 396 |
| Lawn and Garden | 27 | 25 | 217 | 33 | 41 | 132 |
| Logging | | | | | | |
| Recreational | 2 | 2 | 9 | 1 | 3 | 13 |
| Underground Mining | | | | | | |
| Pleasure Craft | 2 | 2 | 83 | 12 | 3 | 14 |
| Railroad Equipment | 3 | 3 | 19 | 2 | 4 | 18 |

| NEVADA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **3,773** | **3,218** | **82,528** | **4,583** | **57,274** | **619,228** |
| **Highway Vehicles** | **1,573** | **1,204** | **53,840** | **2,082** | **40,267** | **457,332** |
| **Off-Highway Equipment and Vehicles** | **2,201** | **2,014** | **28,687** | **2,502** | **17,007** | **161,897** |
| Heavy Equipment (Diesel) | 1,479 | 1,360 | 14,255 | 1,924 | 1,802 | 8,549 |
| Heavy Equipment (Gasoline) | 435 | 400 | 1,216 | 65 | 14,128 | 145,958 |
| Heavy Equipment (LNG & CNG) | 3 | 3 | 639 | 1 | 2 | 2,486 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | 258 | 232 | 10,390 | 303 | 400 | 1,028 |
| Aircraft | 26 | 18 | 2,188 | 209 | 675 | 3,875 |
| **Off-Highway Diesel** | **1,737** | **1,593** | **24,645** | **2,227** | **2,202** | **9,577** |
| **Off-Highway (Other Fuels)** | **464** | **421** | **4,042** | **274** | **14,804** | **152,319** |
| **Off-Highway Share of Mobile Source Pollution** | **58%** | **63%** | **35%** | **55%** | **30%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **46%** | **50%** | **30%** | **49%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **39%** | **42%** | **17%** | **42%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **1,479** | **1,360** | **14,255** | **1,924** | **1,802** | **8,549** |
| Agriculture | 104 | 95 | 738 | 83 | 101 | 464 |
| Airport Ground Support | 7 | 7 | 79 | 11 | 7 | 40 |
| Commercial | 48 | 44 | 338 | 48 | 66 | 240 |
| Construction | 1,202 | 1,106 | 12,069 | 1,627 | 1,466 | 7,241 |
| Industrial | 49 | 45 | 416 | 65 | 61 | 227 |
| Lawn and Garden | 60 | 55 | 483 | 72 | 89 | 288 |
| Logging | | | | | | |
| Recreational | 2 | 2 | 11 | 1 | 4 | 15 |
| Underground Mining | | | | | | |
| Pleasure Craft | 3 | 3 | 104 | 15 | 4 | 17 |
| Railroad Equipment | 3 | 3 | 19 | 2 | 4 | 18 |

| NEW HAMPSHIRE | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **2,298** | **1,942** | **50,552** | **2,417** | **42,636** | **467,944** |
| **Highway Vehicles** | **1,197** | **932** | **41,986** | **1,503** | **24,579** | **346,172** |
| **Off-Highway Equipment and Vehicles** | **1,101** | **1,010** | **8,566** | **914** | **18,057** | **121,772** |
| Heavy Equipment (Diesel) | 468 | 431 | 4,513 | 618 | 575 | 2,624 |
| Heavy Equipment (Gasoline) | 552 | 507 | 1,002 | 67 | 17,350 | 112,302 |
| Heavy Equipment (LNG & CNG) | 7 | 7 | 1,443 | 1 | 3 | 5,691 |
| Marine Vessels (Diesel) | 60 | 55 | 1,409 | 208 | 44 | 186 |
| Railroads (Diesel) | - | - | - | - | - | - |
| Aircraft | 15 | 11 | 198 | 19 | 85 | 970 |
| **Off-Highway Diesel** | **528** | **486** | **5,923** | **827** | **619** | **2,810** |
| **Off-Highway (Other Fuels)** | **573** | **524** | **2,643** | **87** | **17,438** | **118,962** |
| **Off-Highway Share of Mobile Source Pollution** | **48%** | **52%** | **17%** | **38%** | **42%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **23%** | **25%** | **12%** | **34%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **20%** | **22%** | **9%** | **26%** | **1%** | **1%** |
| **Heavy Equipment (Diesel)** | **468** | **431** | **4,513** | **618** | **575** | **2,624** |
| Agriculture | 26 | 24 | 183 | 21 | 25 | 115 |
| Airport Ground Support | 1 | 1 | 9 | 1 | 1 | 5 |
| Commercial | 46 | 43 | 324 | 46 | 63 | 231 |
| Construction | 279 | 256 | 2,801 | 376 | 340 | 1,681 |
| Industrial | 68 | 62 | 628 | 96 | 81 | 327 |
| Lawn and Garden | 19 | 18 | 155 | 23 | 27 | 90 |
| Logging | 15 | 14 | 188 | 26 | 16 | 88 |
| Recreational | 8 | 7 | 33 | 4 | 12 | 46 |
| Underground Mining | | | | | | |
| Pleasure Craft | 5 | 5 | 179 | 25 | 7 | 30 |
| Railroad Equipment | 2 | 2 | 14 | 2 | 3 | 13 |

| NEW JERSEY | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | PM10 | PM2.5 | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **11,270** | **9,451** | **249,716** | **13,725** | **195,596** | **2,193,023** |
| **Highway Vehicles** | **5,476** | **4,132** | **193,295** | **7,557** | **125,827** | **1,495,174** |
| **Off-Highway Equipment and Vehicles** | **5,795** | **5,319** | **56,421** | **6,168** | **69,768** | **697,850** |
| Heavy Equipment (Diesel) | 3,027 | 2,785 | 28,578 | 3,941 | 3,760 | 16,915 |
| Heavy Equipment (Gasoline) | 2,182 | 2,007 | 5,897 | 304 | 64,867 | 642,876 |
| Heavy Equipment (LNG & CNG) | 36 | 36 | 7,870 | 8 | 20 | 30,888 |
| Marine Vessels (Diesel) | 475 | 437 | 11,172 | 1,680 | 349 | 1,472 |
| Railroads (Diesel) | 14 | 13 | 559 | 16 | 23 | 56 |
| Aircraft | 60 | 42 | 2,346 | 218 | 749 | 5,643 |
| **Off-Highway Diesel** | **3,516** | **3,235** | **40,308** | **5,637** | **4,132** | **18,443** |
| **Off-Highway (Other Fuels)** | **2,278** | **2,085** | **16,113** | **531** | **65,636** | **679,407** |
| **Off-Highway Share of Mobile Source Pollution** | **51%** | **56%** | **23%** | **45%** | **36%** | **32%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **31%** | **34%** | **16%** | **41%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **27%** | **30%** | **11%** | **29%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **3,027** | **2,785** | **28,578** | **3,941** | **3,760** | **16,915** |
| Agriculture | 125 | 115 | 891 | 101 | 122 | 561 |
| Airport Ground Support | 23 | 21 | 256 | 34 | 24 | 128 |
| Commercial | 384 | 353 | 2,684 | 381 | 523 | 1,910 |
| Construction | 1,879 | 1,728 | 18,863 | 2,542 | 2,291 | 11,317 |
| Industrial | 391 | 359 | 3,571 | 548 | 471 | 1,877 |
| Lawn and Garden | 180 | 166 | 1,444 | 216 | 267 | 863 |
| Logging | | | | | | |
| Recreational | 8 | 7 | 34 | 5 | 12 | 48 |
| Underground Mining | | | | | | |
| Pleasure Craft | 22 | 20 | 736 | 103 | 30 | 122 |
| Railroad Equipment | 16 | 15 | 99 | 12 | 21 | 90 |

| NEW MEXICO | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | PM10 | PM2.5 | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **4,347** | **3,657** | **121,396** | **5,022** | **63,794** | **791,382** |
| **Highway Vehicles** | **2,288** | **1,787** | **77,416** | **2,850** | **51,445** | **675,261** |
| **Off-Highway Equipment and Vehicles** | **2,059** | **1,870** | **43,980** | **2,172** | **12,349** | **116,121** |
| Heavy Equipment (Diesel) | 920 | 846 | 8,284 | 1,094 | 1,078 | 4,982 |
| Heavy Equipment (Gasoline) | 268 | 246 | 826 | 45 | 9,800 | 102,685 |
| Heavy Equipment (LNG & CNG) | 3 | 3 | 769 | 1 | 3 | 3,012 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | 835 | 752 | 33,640 | 989 | 1,274 | 3,321 |
| Aircraft | 33 | 23 | 462 | 44 | 195 | 2,121 |
| **Off-Highway Diesel** | **1,755** | **1,598** | **41,924** | **2,082** | **2,352** | **8,303** |
| **Off-Highway (Other Fuels)** | **304** | **272** | **2,056** | **90** | **9,997** | **107,818** |
| **Off-Highway Share of Mobile Source Pollution** | **47%** | **51%** | **36%** | **43%** | **19%** | **15%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **40%** | **44%** | **35%** | **42%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **21%** | **23%** | **7%** | **22%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **920** | **846** | **8,284** | **1,094** | **1,078** | **4,982** |
| Agriculture | 251 | 231 | 1,784 | 202 | 244 | 1,123 |
| Airport Ground Support | 2 | 2 | 23 | 3 | 2 | 12 |
| Commercial | 51 | 47 | 355 | 50 | 69 | 253 |
| Construction | 511 | 470 | 5,126 | 694 | 623 | 3,077 |
| Industrial | 68 | 62 | 656 | 96 | 85 | 325 |
| Lawn and Garden | 27 | 25 | 217 | 33 | 41 | 131 |
| Logging | 1 | 1 | 13 | 2 | 1 | 6 |
| Recreational | 4 | 4 | 19 | 3 | 7 | 27 |
| Underground Mining | | | | | | |
| Pleasure Craft | 2 | 2 | 72 | 10 | 3 | 12 |
| Railroad Equipment | 3 | 3 | 20 | 2 | 4 | 18 |

| NEW YORK | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | $NO_x$ | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **24,651** | **20,886** | **549,803** | **32,460** | **393,618** | **4,594,262** |
| **Highway Vehicles** | **11,080** | **8,436** | **389,468** | **14,917** | **261,037** | **3,380,067** |
| **Off-Highway Equipment and Vehicles** | **13,571** | **12,451** | **160,335** | **17,543** | **132,581** | **1,214,195** |
| Heavy Equipment (Diesel) | 7,133 | 6,562 | 66,079 | 8,932 | 8,641 | 39,488 |
| Heavy Equipment (Gasoline) | 3,765 | 3,463 | 9,601 | 551 | 120,182 | 1,101,190 |
| Heavy Equipment (LNG & CNG) | 63 | 63 | 13,792 | 14 | 37 | 53,971 |
| Marine Vessels (Diesel) | 2,006 | 1,846 | 47,192 | 7,082 | 1,475 | 6,219 |
| Railroads (Diesel) | 474 | 427 | 19,038 | 543 | 767 | 1,894 |
| Aircraft | 131 | 90 | 4,635 | 423 | 1,479 | 11,433 |
| **Off-Highway Diesel** | **9,613** | **8,834** | **132,308** | **16,556** | **10,883** | **47,601** |
| **Off-Highway (Other Fuels)** | **3,959** | **3,617** | **28,027** | **987** | **121,698** | **1,166,594** |
| **Off-Highway Share of Mobile Source Pollution** | **55%** | **60%** | **29%** | **54%** | **34%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **39%** | **42%** | **24%** | **51%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **29%** | **31%** | **12%** | **28%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **7,133** | **6,562** | **66,079** | **8,932** | **8,641** | **39,488** |
| Agriculture | 901 | 829 | 6,414 | 724 | 877 | 4,037 |
| Airport Ground Support | 68 | 62 | 748 | 99 | 70 | 373 |
| Commercial | 814 | 749 | 5,695 | 809 | 1,109 | 4,052 |
| Construction | 4,293 | 3,950 | 43,122 | 5,784 | 5,237 | 25,868 |
| Industrial | 754 | 694 | 6,795 | 1,047 | 919 | 3,602 |
| Lawn and Garden | 187 | 172 | 1,510 | 224 | 277 | 897 |
| Logging | 19 | 18 | 241 | 33 | 21 | 113 |
| Recreational | 23 | 21 | 101 | 13 | 35 | 142 |
| Underground Mining | | | | | | |
| Pleasure Craft | 36 | 33 | 1,233 | 172 | 51 | 204 |
| Railroad Equipment | 37 | 34 | 220 | 27 | 46 | 199 |

| NORTH CAROLINA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | $NO_x$ | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **15,610** | **13,098** | **364,410** | **17,894** | **257,354** | **2,958,978** |
| **Highway Vehicles** | **8,475** | **6,558** | **286,170** | **10,860** | **187,870** | **2,258,091** |
| **Off-Highway Equipment and Vehicles** | **7,134** | **6,540** | **78,240** | **7,035** | **69,484** | **700,887** |
| Heavy Equipment (Diesel) | 4,520 | 4,158 | 41,547 | 5,561 | 5,312 | 24,527 |
| Heavy Equipment (Gasoline) | 1,981 | 1,822 | 5,258 | 283 | 62,640 | 620,582 |
| Heavy Equipment (LNG & CNG) | 54 | 54 | 11,843 | 12 | 27 | 46,864 |
| Marine Vessels (Diesel) | 157 | 144 | 3,686 | 556 | 115 | 486 |
| Railroads (Diesel) | 335 | 301 | 13,470 | 390 | 526 | 1,335 |
| Aircraft | 88 | 61 | 2,436 | 233 | 864 | 7,094 |
| **Off-Highway Diesel** | **5,012** | **4,604** | **58,703** | **6,507** | **5,953** | **26,348** |
| **Off-Highway (Other Fuels)** | **2,123** | **1,936** | **19,537** | **528** | **63,531** | **674,539** |
| **Off-Highway Share of Mobile Source Pollution** | **46%** | **50%** | **22%** | **39%** | **27%** | **24%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **32%** | **35%** | **16%** | **36%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **29%** | **32%** | **11%** | **31%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **4,520** | **4,158** | **41,547** | **5,561** | **5,312** | **24,527** |
| Agriculture | 1,018 | 937 | 7,246 | 819 | 991 | 4,561 |
| Airport Ground Support | 18 | 17 | 200 | 27 | 19 | 100 |
| Commercial | 277 | 255 | 1,941 | 275 | 378 | 1,381 |
| Construction | 2,368 | 2,179 | 23,791 | 3,205 | 2,888 | 14,269 |
| Industrial | 516 | 475 | 4,858 | 738 | 610 | 2,515 |
| Lawn and Garden | 165 | 151 | 1,325 | 198 | 245 | 791 |
| Logging | 112 | 103 | 1,385 | 190 | 119 | 649 |
| Recreational | 11 | 10 | 49 | 7 | 17 | 69 |
| Underground Mining | | | | | | |
| Pleasure Craft | 19 | 18 | 662 | 93 | 27 | 109 |
| Railroad Equipment | 15 | 14 | 90 | 11 | 19 | 82 |

| NORTH DAKOTA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **6,681** | **6,030** | **83,781** | **5,924** | **29,454** | **331,724** |
| **Highway Vehicles** | **778** | **612** | **26,828** | **950** | **15,635** | **230,051** |
| **Off-Highway Equipment and Vehicles** | **5,903** | **5,419** | **56,953** | **4,974** | **13,819** | **101,673** |
| Heavy Equipment (Diesel) | 5,262 | 4,840 | 38,393 | 4,416 | 5,217 | 24,062 |
| Heavy Equipment (Gasoline) | 198 | 182 | 725 | 37 | 7,906 | 73,376 |
| Heavy Equipment (LNG & CNG) | 2 | 2 | 456 | 0 | 3 | 1,792 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | 429 | 386 | 17,286 | 512 | 643 | 1,703 |
| Aircraft | 13 | 9 | 93 | 9 | 50 | 740 |
| **Off-Highway Diesel** | **5,691** | **5,227** | **55,679** | **4,928** | **5,860** | **25,765** |
| **Off-Highway (Other Fuels)** | **212** | **192** | **1,274** | **46** | **7,959** | **75,908** |
| **Off-Highway Share of Mobile Source Pollution** | **88%** | **90%** | **68%** | **84%** | **47%** | **31%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **85%** | **87%** | **67%** | **83%** | **20%** | **8%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **79%** | **80%** | **46%** | **75%** | **18%** | **7%** |
| **Heavy Equipment (Diesel)** | **5,262** | **4,840** | **38,393** | **4,416** | **5,217** | **24,062** |
| Agriculture | 4,901 | 4,508 | 34,878 | 3,939 | 4,769 | 21,955 |
| Airport Ground Support | 1 | 1 | 7 | 1 | 1 | 3 |
| Commercial | 38 | 35 | 267 | 38 | 52 | 190 |
| Construction | 295 | 271 | 2,965 | 397 | 360 | 1,779 |
| Industrial | 21 | 20 | 188 | 29 | 26 | 101 |
| Lawn and Garden | 3 | 3 | 24 | 3 | 4 | 13 |
| Logging | | | | | | |
| Recreational | 1 | 1 | 5 | 1 | 2 | 7 |
| Underground Mining | | | | | | |
| Pleasure Craft | 2 | 1 | 52 | 7 | 2 | 9 |
| Railroad Equipment | 1 | 1 | 7 | 1 | 2 | 6 |

| OHIO | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **22,663** | **19,332** | **507,177** | **30,225** | **319,081** | **3,946,969** |
| **Highway Vehicles** | **9,712** | **7,456** | **336,407** | **12,751** | **220,451** | **2,923,447** |
| **Off-Highway Equipment and Vehicles** | **12,951** | **11,876** | **170,770** | **17,475** | **98,630** | **1,023,522** |
| Heavy Equipment (Diesel) | 7,363 | 6,774 | 64,885 | 8,485 | 8,475 | 38,948 |
| Heavy Equipment (Gasoline) | 2,560 | 2,355 | 7,735 | 407 | 86,594 | 907,991 |
| Heavy Equipment (LNG & CNG) | 69 | 69 | 15,112 | 15 | 37 | 59,774 |
| Marine Vessels (Diesel) | 1,916 | 1,763 | 44,141 | 7,346 | 1,380 | 5,811 |
| Railroads (Diesel) | 929 | 836 | 37,339 | 1,071 | 1,486 | 3,709 |
| Aircraft | 114 | 79 | 1,557 | 150 | 659 | 7,289 |
| **Off-Highway Diesel** | **10,208** | **9,373** | **146,365** | **16,903** | **11,340** | **48,468** |
| **Off-Highway (Other Fuels)** | **2,743** | **2,503** | **24,404** | **572** | **87,290** | **975,054** |
| **Off-Highway Share of Mobile Source Pollution** | **57%** | **61%** | **34%** | **58%** | **31%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **45%** | **49%** | **29%** | **56%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **33%** | **35%** | **13%** | **28%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **7,363** | **6,774** | **64,885** | **8,485** | **8,475** | **38,948** |
| Agriculture | 2,496 | 2,296 | 17,768 | 2,007 | 2,429 | 11,184 |
| Airport Ground Support | 15 | 14 | 163 | 22 | 15 | 81 |
| Commercial | 391 | 360 | 2,739 | 389 | 533 | 1,949 |
| Construction | 3,425 | 3,152 | 34,414 | 4,615 | 4,179 | 20,645 |
| Industrial | 708 | 651 | 6,694 | 1,010 | 843 | 3,440 |
| Lawn and Garden | 243 | 223 | 1,954 | 290 | 361 | 1,165 |
| Logging | 10 | 10 | 127 | 18 | 11 | 60 |
| Recreational | 15 | 14 | 67 | 9 | 23 | 95 |
| Underground Mining | 16 | 15 | 104 | 11 | 23 | 88 |
| Pleasure Craft | 21 | 19 | 721 | 101 | 30 | 119 |
| Railroad Equipment | 22 | 21 | 134 | 16 | 28 | 122 |

| OKLAHOMA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **8,825** | **7,496** | **191,900** | **9,457** | **126,016** | **1,406,441** |
| **Highway Vehicles** | **4,115** | **3,184** | **139,506** | **5,272** | **95,622** | **1,125,754** |
| **Off-Highway Equipment and Vehicles** | **4,711** | **4,311** | **52,394** | **4,185** | **30,393** | **280,688** |
| Heavy Equipment (Diesel) | 3,327 | 3,061 | 27,197 | 3,361 | 3,574 | 16,357 |
| Heavy Equipment (Gasoline) | 807 | 742 | 2,058 | 114 | 25,789 | 247,494 |
| Heavy Equipment (LNG & CNG) | 13 | 13 | 2,867 | 3 | 13 | 11,349 |
| Marine Vessels (Diesel) | 29 | 27 | 694 | 103 | 22 | 92 |
| Railroads (Diesel) | 474 | 426 | 19,066 | 556 | 734 | 1,886 |
| Aircraft | 60 | 42 | 512 | 50 | 261 | 3,510 |
| **Off-Highway Diesel** | **3,831** | **3,515** | **46,957** | **4,019** | **4,330** | **18,335** |
| **Off-Highway (Other Fuels)** | **880** | **796** | **5,437** | **166** | **26,064** | **262,353** |
| **Off-Highway Share of Mobile Source Pollution** | **53%** | **58%** | **27%** | **44%** | **24%** | **20%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **43%** | **47%** | **25%** | **43%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **38%** | **41%** | **14%** | **36%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **3,327** | **3,061** | **27,197** | **3,361** | **3,574** | **16,357** |
| Agriculture | 2,105 | 1,937 | 14,979 | 1,694 | 2,048 | 9,429 |
| Airport Ground Support | 5 | 5 | 60 | 8 | 6 | 30 |
| Commercial | 118 | 108 | 823 | 117 | 160 | 586 |
| Construction | 802 | 737 | 8,056 | 1,090 | 977 | 4,831 |
| Industrial | 235 | 217 | 2,566 | 350 | 291 | 1,163 |
| Lawn and Garden | 43 | 40 | 346 | 52 | 65 | 208 |
| Logging | | | | | | |
| Recreational | 4 | 3 | 16 | 2 | 6 | 23 |
| Underground Mining | | | | | | |
| Pleasure Craft | 9 | 8 | 312 | 44 | 13 | 51 |
| Railroad Equipment | 7 | 6 | 40 | 5 | 8 | 36 |

| OREGON | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **7,748** | **6,621** | **166,652** | **9,638** | **105,127** | **1,254,980** |
| **Highway Vehicles** | **3,402** | **2,638** | **115,556** | **4,326** | **69,127** | **932,069** |
| **Off-Highway Equipment and Vehicles** | **4,346** | **3,983** | **51,097** | **5,312** | **36,000** | **322,912** |
| Heavy Equipment (Diesel) | 2,579 | 2,373 | 23,781 | 3,134 | 2,972 | 13,940 |
| Heavy Equipment (Gasoline) | 993 | 914 | 2,578 | 137 | 31,974 | 289,913 |
| Heavy Equipment (LNG & CNG) | 15 | 15 | 3,340 | 3 | 8 | 13,148 |
| Marine Vessels (Diesel) | 469 | 432 | 11,001 | 1,678 | 344 | 1,450 |
| Railroads (Diesel) | 238 | 214 | 9,561 | 279 | 367 | 945 |
| Aircraft | 52 | 36 | 835 | 80 | 335 | 3,516 |
| **Off-Highway Diesel** | **3,286** | **3,018** | **44,342** | **5,091** | **3,682** | **16,335** |
| **Off-Highway (Other Fuels)** | **1,061** | **965** | **6,754** | **221** | **32,318** | **306,577** |
| **Off-Highway Share of Mobile Source Pollution** | **56%** | **60%** | **31%** | **55%** | **34%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **42%** | **46%** | **27%** | **53%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **33%** | **36%** | **14%** | **33%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **2,579** | **2,373** | **23,781** | **3,134** | **2,972** | **13,940** |
| Agriculture | 720 | 662 | 5,124 | 579 | 701 | 3,226 |
| Airport Ground Support | 7 | 6 | 74 | 10 | 7 | 37 |
| Commercial | 135 | 124 | 945 | 134 | 184 | 673 |
| Construction | 1,219 | 1,122 | 12,254 | 1,643 | 1,487 | 7,350 |
| Industrial | 163 | 150 | 1,496 | 229 | 196 | 785 |
| Lawn and Garden | 76 | 70 | 611 | 91 | 113 | 364 |
| Logging | 235 | 216 | 2,911 | 399 | 250 | 1,365 |
| Recreational | 9 | 9 | 41 | 5 | 14 | 58 |
| Underground Mining | | | | | | |
| Pleasure Craft | 8 | 8 | 286 | 40 | 12 | 47 |
| Railroad Equipment | 7 | 6 | 39 | 5 | 8 | 36 |

| PENNSYLVANIA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | PM$_{10}$ | PM$_{2.5}$ | NOx | SO$_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **18,893** | **15,910** | **460,461** | **25,440** | **297,147** | **3,672,357** |
| **Highway Vehicles** | **9,639** | **7,432** | **333,057** | **12,484** | **211,627** | **2,761,299** |
| **Off-Highway Equipment and Vehicles** | **9,253** | **8,478** | **127,404** | **12,956** | **85,520** | **911,058** |
| Heavy Equipment (Diesel) | 4,858 | 4,469 | 43,689 | 5,863 | 5,803 | 26,271 |
| Heavy Equipment (Gasoline) | 2,027 | 1,861 | 6,680 | 364 | 76,498 | 817,532 |
| Heavy Equipment (LNG & CNG) | 59 | 59 | 12,926 | 13 | 31 | 51,042 |
| Marine Vessels (Diesel) | 1,632 | 1,502 | 38,331 | 5,769 | 1,200 | 5,051 |
| Railroads (Diesel) | 566 | 510 | 22,697 | 652 | 905 | 2,255 |
| Aircraft | 110 | 76 | 3,081 | 294 | 1,084 | 8,907 |
| **Off-Highway Diesel** | **7,057** | **6,481** | **104,717** | **12,285** | **7,908** | **33,578** |
| **Off-Highway (Other Fuels)** | **2,197** | **1,997** | **22,687** | **671** | **77,613** | **877,480** |
| **Off-Highway Share of Mobile Source Pollution** | **49%** | **53%** | **28%** | **51%** | **29%** | **25%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **37%** | **41%** | **23%** | **48%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **26%** | **28%** | **10%** | **23%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **4,858** | **4,469** | **43,689** | **5,863** | **5,803** | **26,271** |
| Agriculture | 983 | 904 | 6,994 | 790 | 956 | 4,402 |
| Airport Ground Support | | | | | | |
| Commercial | 396 | 364 | 2,768 | 393 | 539 | 1,969 |
| Construction | 2,471 | 2,273 | 24,811 | 3,343 | 3,013 | 14,884 |
| Industrial | 640 | 589 | 5,926 | 904 | 768 | 3,090 |
| Lawn and Garden | 186 | 172 | 1,502 | 224 | 276 | 893 |
| Logging | 26 | 24 | 327 | 45 | 28 | 153 |
| Recreational | 19 | 18 | 85 | 11 | 30 | 120 |
| Underground Mining | 99 | 91 | 654 | 68 | 144 | 549 |
| Pleasure Craft | 14 | 13 | 477 | 67 | 20 | 79 |
| Railroad Equipment | 24 | 22 | 146 | 18 | 30 | 132 |

| RHODE ISLAND | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | PM$_{10}$ | PM$_{2.5}$ | NOx | SO$_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **1,277** | **1,058** | **31,751** | **1,742** | **23,026** | **275,757** |
| **Highway Vehicles** | **669** | **502** | **24,568** | **941** | **16,155** | **200,877** |
| **Off-Highway Equipment and Vehicles** | **608** | **557** | **7,183** | **802** | **6,871** | **74,880** |
| Heavy Equipment (Diesel) | 268 | 247 | 2,531 | 353 | 334 | 1,483 |
| Heavy Equipment (Gasoline) | 208 | 191 | 604 | 31 | 6,360 | 67,609 |
| Heavy Equipment (LNG & CNG) | 5 | 5 | 1,150 | 1 | 3 | 4,531 |
| Marine Vessels (Diesel) | 113 | 104 | 2,671 | 395 | 84 | 352 |
| Railroads (Diesel) | 0 | 0 | 1 | 0 | 0 | 0 |
| Aircraft | 13 | 9 | 227 | 22 | 91 | 905 |
| **Off-Highway Diesel** | **381** | **351** | **5,203** | **748** | **418** | **1,835** |
| **Off-Highway (Other Fuels)** | **227** | **206** | **1,980** | **54** | **6,453** | **73,044** |
| **Off-Highway Share of Mobile Source Pollution** | **48%** | **53%** | **23%** | **46%** | **30%** | **27%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **30%** | **33%** | **16%** | **43%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **21%** | **23%** | **8%** | **20%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **268** | **247** | **2,531** | **353** | **334** | **1,483** |
| Agriculture | 5 | 4 | 33 | 4 | 5 | 21 |
| Airport Ground Support | 1 | 1 | 9 | 1 | 1 | 4 |
| Commercial | 36 | 33 | 249 | 35 | 49 | 177 |
| Construction | 150 | 138 | 1,509 | 203 | 183 | 905 |
| Industrial | 55 | 51 | 514 | 79 | 66 | 268 |
| Lawn and Garden | 16 | 15 | 130 | 19 | 24 | 77 |
| Logging | | | | | | |
| Recreational | 1 | 1 | 6 | 1 | 2 | 8 |
| Underground Mining | | | | | | |
| Pleasure Craft | 2 | 2 | 69 | 10 | 3 | 11 |
| Railroad Equipment | 2 | 2 | 12 | 2 | 3 | 11 |

| SOUTH CAROLINA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOX | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **8,359** | **7,050** | **199,280** | **9,877** | **139,698** | **1,571,400** |
| **Highway Vehicles** | **4,521** | **3,531** | **153,775** | **5,631** | **98,286** | **1,210,372** |
| **Off-Highway Equipment and Vehicles** | **3,838** | **3,519** | **45,505** | **4,246** | **41,412** | **361,028** |
| Heavy Equipment (Diesel) | 1,991 | 1,831 | 18,617 | 2,512 | 2,349 | 10,837 |
| Heavy Equipment (Gasoline) | 1,234 | 1,135 | 2,652 | 151 | 36,537 | 316,832 |
| Heavy Equipment (LNG & CNG) | 23 | 23 | 5,037 | 5 | 11 | 19,922 |
| Marine Vessels (Diesel) | 278 | 256 | 6,567 | 971 | 205 | 866 |
| Railroads (Diesel) | 276 | 248 | 11,100 | 321 | 433 | 1,100 |
| Aircraft | 37 | 25 | 1,532 | 286 | 1,876 | 11,471 |
| **Off-Highway Diesel** | **2,545** | **2,336** | **36,284** | **3,804** | **2,987** | **12,803** |
| **Off-Highway (Other Fuels)** | **1,293** | **1,183** | **9,221** | **442** | **38,425** | **348,225** |
| **Off-Highway Share of Mobile Source Pollution** | **46%** | **50%** | **23%** | **43%** | **30%** | **23%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **30%** | **33%** | **18%** | **39%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **24%** | **26%** | **9%** | **25%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **1,991** | **1,831** | **18,617** | **2,512** | **2,349** | **10,837** |
| Agriculture | 405 | 372 | 2,880 | 326 | 394 | 1,813 |
| Airport Ground Support | 6 | 6 | 66 | 9 | 6 | 33 |
| Commercial | 114 | 105 | 798 | 113 | 155 | 568 |
| Construction | 1,029 | 947 | 10,335 | 1,399 | 1,255 | 6,199 |
| Industrial | 232 | 213 | 2,164 | 330 | 276 | 1,125 |
| Lawn and Garden | 88 | 81 | 702 | 106 | 131 | 421 |
| Logging | 93 | 85 | 1,148 | 157 | 99 | 538 |
| Recreational | 4 | 3 | 16 | 2 | 6 | 22 |
| Underground Mining | | | | | | |
| Pleasure Craft | 14 | 12 | 462 | 65 | 19 | 76 |
| Railroad Equipment | 8 | 7 | 47 | 6 | 10 | 42 |

| SOUTH DAKOTA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **4,964** | **4,443** | **62,544** | **4,414** | **28,649** | **333,383** |
| **Highway Vehicles** | **890** | **700** | **30,633** | **1,083** | **17,097** | **243,873** |
| **Off-Highway Equipment and Vehicles** | **4,075** | **3,743** | **31,911** | **3,331** | **11,552** | **89,510** |
| Heavy Equipment (Diesel) | 3,788 | 3,485 | 27,781 | 3,209 | 3,770 | 17,382 |
| Heavy Equipment (Gasoline) | 199 | 183 | 651 | 34 | 7,621 | 68,011 |
| Heavy Equipment (LNG & CNG) | 3 | 3 | 730 | 1 | 3 | 2,881 |
| Marine Vessels (Diesel) | 0 | 0 | 2 | 0 | 0 | 0 |
| Railroads (Diesel) | 66 | 59 | 2,657 | 79 | 99 | 262 |
| Aircraft | 18 | 13 | 90 | 9 | 59 | 973 |
| **Off-Highway Diesel** | **3,854** | **3,545** | **30,440** | **3,288** | **3,869** | **17,644** |
| **Off-Highway (Other Fuels)** | **220** | **199** | **1,472** | **43** | **7,682** | **71,866** |
| **Off-Highway Share of Mobile Source Pollution** | **82%** | **84%** | **51%** | **76%** | **40%** | **27%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **78%** | **80%** | **49%** | **75%** | **14%** | **5%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **76%** | **78%** | **44%** | **73%** | **13%** | **5%** |
| **Heavy Equipment (Diesel)** | **3,788** | **3,485** | **27,781** | **3,209** | **3,770** | **17,382** |
| Agriculture | 3,474 | 3,196 | 24,728 | 2,793 | 3,381 | 15,566 |
| Airport Ground Support | 1 | 1 | 7 | 1 | 1 | 3 |
| Commercial | 35 | 32 | 243 | 34 | 47 | 173 |
| Construction | 234 | 215 | 2,358 | 315 | 285 | 1,413 |
| Industrial | 33 | 31 | 305 | 47 | 41 | 161 |
| Lawn and Garden | 3 | 3 | 26 | 4 | 4 | 14 |
| Logging | 2 | 2 | 28 | 4 | 2 | 13 |
| Recreational | 3 | 3 | 15 | 2 | 5 | 21 |
| Underground Mining | | | | | | |
| Pleasure Craft | 2 | 2 | 61 | 9 | 2 | 10 |
| Railroad Equipment | 2 | 1 | 9 | 1 | 2 | 8 |

| TENNESSEE | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOX | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **12,433** | **10,508** | **300,769** | **17,469** | **186,488** | **2,129,990** |
| **Highway Vehicles** | **6,113** | **4,716** | **211,719** | **7,898** | **139,020** | **1,701,910** |
| **Off-Highway Equipment and Vehicles** | **6,320** | **5,791** | **89,050** | **9,571** | **47,467** | **428,081** |
| Heavy Equipment (Diesel) | 3,278 | 3,015 | 29,455 | 3,904 | 3,792 | 17,556 |
| Heavy Equipment (Gasoline) | 1,276 | 1,174 | 3,202 | 174 | 41,311 | 371,289 |
| Heavy Equipment (LNG & CNG) | 32 | 32 | 7,153 | 7 | 16 | 28,281 |
| Marine Vessels (Diesel) | 1,146 | 1,054 | 25,904 | 4,698 | 809 | 3,407 |
| Railroads (Diesel) | 524 | 472 | 21,366 | 599 | 855 | 2,148 |
| Aircraft | 65 | 45 | 1,970 | 188 | 684 | 5,399 |
| **Off-Highway Diesel** | **4,947** | **4,541** | **76,725** | **9,201** | **5,456** | **23,111** |
| **Off-Highway (Other Fuels)** | **1,373** | **1,251** | **12,325** | **370** | **42,011** | **404,969** |
| **Off-Highway Share of Mobile Source Pollution** | **51%** | **55%** | **30%** | **55%** | **26%** | **20%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **40%** | **43%** | **26%** | **53%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **26%** | **29%** | **10%** | **22%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **3,278** | **3,015** | **29,455** | **3,904** | **3,792** | **17,556** |
| Agriculture | 971 | 893 | 6,913 | 782 | 945 | 4,351 |
| Airport Ground Support | 14 | 13 | 152 | 20 | 14 | 76 |
| Commercial | 185 | 170 | 1,293 | 184 | 252 | 920 |
| Construction | 1,654 | 1,522 | 16,610 | 2,249 | 2,016 | 9,964 |
| Industrial | 328 | 302 | 3,062 | 467 | 390 | 1,593 |
| Lawn and Garden | 74 | 69 | 598 | 90 | 111 | 357 |
| Logging | 21 | 19 | 262 | 36 | 22 | 123 |
| Recreational | 6 | 5 | 25 | 3 | 9 | 35 |
| Underground Mining | | | | | | |
| Pleasure Craft | 14 | 13 | 477 | 67 | 20 | 79 |
| Railroad Equipment | 11 | 10 | 65 | 8 | 13 | 59 |

| TEXAS | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **43,910** | **37,363** | **956,097** | **64,423** | **619,425** | **6,691,570** |
| **Highway Vehicles** | **18,856** | **14,407** | **648,850** | **25,132** | **466,475** | **4,967,626** |
| **Off-Highway Equipment and Vehicles** | **25,054** | **22,956** | **307,247** | **39,291** | **152,950** | **1,723,945** |
| Heavy Equipment (Diesel) | 12,972 | 11,934 | 126,745 | 15,018 | 17,451 | 79,900 |
| Heavy Equipment (Gasoline) | 3,843 | 3,534 | 11,094 | 643 | 127,454 | 1,530,294 |
| Heavy Equipment (LNG & CNG) | 80 | 80 | 16,766 | 17 | 57 | 69,734 |
| Marine Vessels (Diesel) | 5,798 | 5,334 | 57,085 | 20,352 | 1,764 | 7,796 |
| Railroads (Diesel) | 2,119 | 1,907 | 85,752 | 2,479 | 2,664 | 6,923 |
| Aircraft | 243 | 168 | 9,805 | 783 | 3,561 | 29,298 |
| **Off-Highway Diesel** | **20,889** | **19,175** | **269,583** | **37,849** | **21,878** | **94,619** |
| **Off-Highway (Other Fuels)** | **4,165** | **3,781** | **37,664** | **1,442** | **131,072** | **1,629,325** |
| **Off-Highway Share of Mobile Source Pollution** | **57%** | **61%** | **31%** | **61%** | **25%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **48%** | **51%** | **27%** | **59%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **30%** | **32%** | **14%** | **23%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **12,972** | **11,934** | **126,745** | **15,018** | **17,451** | **79,900** |
| Agriculture | 4,599 | 4,230 | 32,728 | 3,701 | 4,474 | 20,601 |
| Airport Ground Support | 80 | 74 | 2,688 | 118 | 842 | 5,550 |
| Commercial | 739 | 680 | 5,168 | 734 | 1,006 | 3,677 |
| Construction | 5,636 | 5,185 | 70,000 | 7,661 | 9,038 | 41,995 |
| Industrial | 1,367 | 1,257 | 11,012 | 2,025 | 1,319 | 5,325 |
| Lawn and Garden | 394 | 363 | 3,169 | 475 | 585 | 1,889 |
| Logging | 64 | 59 | 792 | 108 | 68 | 371 |
| Recreational | 22 | 20 | 96 | 13 | 34 | 136 |
| Underground Mining | | | | | | |
| Pleasure Craft | 32 | 29 | 858 | 154 | 36 | 143 |
| Railroad Equipment | 39 | 36 | 236 | 28 | 49 | 213 |

| UTAH | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOX | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **5,247** | **4,510** | **108,432** | **5,966** | **70,923** | **813,868** |
| **Highway Vehicles** | **1,881** | **1,427** | **67,105** | **2,556** | **47,382** | **628,719** |
| **Off-Highway Equipment and Vehicles** | **3,367** | **3,083** | **41,328** | **3,410** | **23,541** | **185,149** |
| Heavy Equipment (Diesel) | 2,548 | 2,345 | 24,552 | 3,289 | 3,061 | 14,696 |
| Heavy Equipment (Gasoline) | 540 | 497 | 1,316 | 79 | 19,775 | 159,717 |
| Heavy Equipment (LNG & CNG) | 9 | 9 | 1,862 | 2 | 5 | 7,339 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | 10 | 214 | 12,207 | 12 | 15 | 39 |
| Aircraft | 260 | 19 | 1,391 | 29 | 685 | 3,358 |
| **Off-Highway Diesel** | **2,558** | **2,559** | **36,759** | **3,301** | **3,075** | **14,734** |
| **Off-Highway (Other Fuels)** | **809** | **525** | **4,568** | **110** | **20,466** | **170,414** |
| **Off-Highway Share of Mobile Source Pollution** | **64%** | **68%** | **38%** | **57%** | **33%** | **23%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **49%** | **57%** | **34%** | **55%** | **4%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **49%** | **52%** | **23%** | **55%** | **4%** | **2%** |
| **Heavy Equipment (Diesel)** | **2,548** | **2,345** | **24,552** | **3,289** | **3,061** | **14,696** |
| Agriculture | 266 | 244 | 1,891 | 214 | 258 | 1,190 |
| Airport Ground Support | 10 | 10 | 115 | 15 | 11 | 57 |
| Commercial | 71 | 66 | 498 | 71 | 97 | 355 |
| Construction | 2,054 | 1,890 | 20,622 | 2,779 | 2,505 | 12,373 |
| Industrial | 104 | 96 | 995 | 148 | 127 | 504 |
| Lawn and Garden | 31 | 29 | 253 | 38 | 46 | 150 |
| Logging | | | | | | |
| Recreational | 4 | 3 | 16 | 2 | 6 | 22 |
| Underground Mining | | | | | | |
| Pleasure Craft | 4 | 4 | 140 | 20 | 6 | 23 |
| Railroad Equipment | 4 | 4 | 24 | 3 | 5 | 21 |

| VERMONT | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **1,283** | **1,080** | **28,409** | **1,295** | **23,550** | **276,805** |
| **Highway Vehicles** | **714** | **558** | **24,437** | **883** | **14,681** | **218,149** |
| **Off-Highway Equipment and Vehicles** | **570** | **522** | **3,973** | **412** | **8,870** | **58,656** |
| Heavy Equipment (Diesel) | 331 | 304 | 2,872 | 375 | 381 | 1,732 |
| Heavy Equipment (Gasoline) | 226 | 208 | 426 | 32 | 8,457 | 53,913 |
| Heavy Equipment (LNG & CNG) | 3 | 3 | 634 | 1 | 1 | 2,495 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | - | - | - | - | - | - |
| Aircraft | 10 | 7 | 40 | 4 | 30 | 515 |
| **Off-Highway Diesel** | **331** | **304** | **2,872** | **375** | **381** | **1,732** |
| **Off-Highway (Other Fuels)** | **239** | **217** | **1,100** | **37** | **8,489** | **56,923** |
| **Off-Highway Share of Mobile Source Pollution** | **44%** | **48%** | **14%** | **32%** | **38%** | **21%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **26%** | **28%** | **10%** | **29%** | **2%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **26%** | **28%** | **10%** | **29%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **331** | **304** | **2,872** | **375** | **381** | **1,732** |
| Agriculture | 122 | 112 | 865 | 98 | 118 | 544 |
| Airport Ground Support | 1 | 1 | 8 | 1 | 1 | 4 |
| Commercial | 23 | 21 | 161 | 23 | 31 | 115 |
| Construction | 132 | 121 | 1,326 | 178 | 161 | 796 |
| Industrial | 31 | 29 | 286 | 44 | 37 | 150 |
| Lawn and Garden | 12 | 11 | 90 | 14 | 18 | 56 |
| Logging | 5 | 5 | 66 | 9 | 6 | 31 |
| Recreational | 4 | 4 | 17 | 2 | 6 | 24 |
| Underground Mining | | | | | | |
| Pleasure Craft | 1 | 1 | 48 | 7 | 2 | 8 |
| Railroad Equipment | 1 | 1 | 7 | 1 | 1 | 6 |

| VIRGINIA | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOX | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **13,582** | **11,419** | **330,965** | **17,182** | **208,422** | **2,440,849** |
| **Highway Vehicles** | **6,899** | **5,309** | **239,174** | **8,996** | **150,953** | **1,865,989** |
| **Off-Highway Equipment and Vehicles** | **6,683** | **6,111** | **91,791** | **8,186** | **57,468** | **574,860** |
| Heavy Equipment (Diesel) | 3,400 | 3,127 | 31,264 | 4,182 | 4,074 | 18,682 |
| Heavy Equipment (Gasoline) | 1,639 | 1,508 | 4,269 | 230 | 50,786 | 521,164 |
| Heavy Equipment (LNG & CNG) | 25 | 25 | 5,600 | 5 | 13 | 22,085 |
| Marine Vessels (Diesel) | 761 | 700 | 17,925 | 2,670 | 561 | 2,362 |
| Railroads (Diesel) | 757 | 681 | 30,431 | 880 | 1,190 | 3,016 |
| Aircraft | 102 | 70 | 2,303 | 219 | 845 | 7,550 |
| **Off-Highway Diesel** | **4,918** | **4,508** | **79,620** | **7,732** | **5,825** | **24,061** |
| **Off-Highway (Other Fuels)** | **1,765** | **1,603** | **12,171** | **454** | **51,644** | **550,799** |
| **Off-Highway Share of Mobile Source Pollution** | **49%** | **54%** | **28%** | **48%** | **28%** | **24%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **36%** | **40%** | **24%** | **45%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **25%** | **27%** | **9%** | **24%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **3,400** | **3,127** | **31,264** | **4,182** | **4,074** | **18,682** |
| Agriculture | 623 | 573 | 4,436 | 501 | 606 | 2,792 |
| Airport Ground Support | 21 | 19 | 227 | 30 | 21 | 114 |
| Commercial | 189 | 174 | 1,320 | 187 | 257 | 939 |
| Construction | 1,924 | 1,769 | 19,330 | 2,604 | 2,346 | 11,595 |
| Industrial | 302 | 278 | 2,745 | 422 | 366 | 1,448 |
| Lawn and Garden | 167 | 154 | 1,346 | 201 | 248 | 802 |
| Logging | 58 | 53 | 714 | 98 | 61 | 335 |
| Recreational | 9 | 8 | 40 | 5 | 14 | 57 |
| Underground Mining | 80 | 74 | 532 | 55 | 117 | 446 |
| Pleasure Craft | 14 | 13 | 493 | 69 | 20 | 81 |
| Railroad Equipment | 14 | 12 | 81 | 10 | 17 | 73 |

| WASHINGTON | | | | | | |
|---|---|---|---|---|---|---|
| | 1999 Emissions in Tons per Year | | | | | |
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **12,068** | **10,337** | **261,539** | **16,230** | **160,906** | **1,886,820** |
| **Highway Vehicles** | **4,685** | **3,575** | **162,770** | **6,264** | **102,915** | **1,379,135** |
| **Off-Highway Equipment and Vehicles** | **7,383** | **6,763** | **98,770** | **9,966** | **57,991** | **507,685** |
| Heavy Equipment (Diesel) | 3,787 | 3,484 | 34,229 | 4,491 | 4,342 | 20,182 |
| Heavy Equipment (Gasoline) | 1,652 | 1,519 | 4,179 | 223 | 51,076 | 454,399 |
| Heavy Equipment (LNG & CNG) | 24 | 24 | 5,201 | 5 | 14 | 20,471 |
| Marine Vessels (Diesel) | 1,242 | 1,142 | 29,244 | 4,360 | 914 | 3,854 |
| Railroads (Diesel) | 595 | 535 | 23,925 | 697 | 923 | 2,367 |
| Aircraft | 84 | 58 | 1,991 | 190 | 723 | 6,411 |
| **Off-Highway Diesel** | **5,624** | **5,162** | **87,398** | **9,548** | **6,179** | **26,404** |
| **Off-Highway (Other Fuels)** | **1,760** | **1,601** | **11,372** | **419** | **51,813** | **481,281** |
| **Off-Highway Share of Mobile Source Pollution** | **61%** | **65%** | **38%** | **61%** | **36%** | **27%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **47%** | **50%** | **33%** | **59%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **31%** | **34%** | **13%** | **28%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **3,787** | **3,484** | **34,229** | **4,491** | **4,342** | **20,182** |
| Agriculture | 1,207 | 1,111 | 8,593 | 971 | 1,175 | 5,409 |
| Airport Ground Support | 21 | 19 | 227 | 30 | 21 | 113 |
| Commercial | 225 | 207 | 1,575 | 224 | 306 | 1,120 |
| Construction | 1,660 | 1,528 | 16,682 | 2,237 | 2,026 | 10,006 |
| Industrial | 263 | 242 | 2,400 | 368 | 318 | 1,264 |
| Lawn and Garden | 111 | 102 | 897 | 133 | 164 | 532 |
| Logging | 260 | 239 | 3,215 | 440 | 276 | 1,507 |
| Recreational | 14 | 13 | 60 | 8 | 21 | 85 |
| Underground Mining | | | | | | |
| Pleasure Craft | 15 | 14 | 513 | 72 | 21 | 85 |
| Railroad Equipment | 11 | 10 | 68 | 8 | 14 | 61 |

| WEST VIRGINIA | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOX | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **4,308** | **3,679** | **109,933** | **7,256** | **53,335** | **648,285** |
| **Highway Vehicles** | **2,022** | **1,587** | **68,770** | **2,477** | **40,179** | **540,910** |
| **Off-Highway Equipment and Vehicles** | **2,286** | **2,092** | **41,163** | **4,779** | **13,156** | **107,376** |
| Heavy Equipment (Diesel) | 854 | 786 | 7,646 | 999 | 1,046 | 4,721 |
| Heavy Equipment (Gasoline) | 259 | 238 | 765 | 41 | 10,955 | 93,185 |
| Heavy Equipment (LNG & CNG) | 5 | 5 | 1,153 | 1 | 3 | 4,547 |
| Marine Vessels (Diesel) | 833 | 766 | 18,914 | 3,362 | 591 | 2,488 |
| Railroads (Diesel) | 313 | 281 | 12,577 | 365 | 488 | 1,245 |
| Aircraft | 22 | 15 | 108 | 10 | 73 | 1,189 |
| **Off-Highway Diesel** | **2,000** | **1,833** | **39,137** | **4,726** | **2,125** | **8,455** |
| **Off-Highway (Other Fuels)** | **286** | **259** | **2,026** | **53** | **11,031** | **98,921** |
| **Off-Highway Share of Mobile Source Pollution** | **53%** | **57%** | **37%** | **66%** | **25%** | **17%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **46%** | **50%** | **36%** | **65%** | **4%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **20%** | **21%** | **7%** | **14%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **854** | **786** | **7,646** | **999** | **1,046** | **4,721** |
| Agriculture | 141 | 130 | 1,007 | 114 | 138 | 634 |
| Airport Ground Support | 1 | 1 | 14 | 2 | 1 | 7 |
| Commercial | 47 | 43 | 328 | 47 | 64 | 234 |
| Construction | 442 | 407 | 4,452 | 599 | 540 | 2,671 |
| Industrial | 79 | 72 | 749 | 111 | 97 | 379 |
| Lawn and Garden | 12 | 11 | 96 | 15 | 19 | 60 |
| Logging | 11 | 10 | 133 | 18 | 11 | 62 |
| Recreational | 3 | 2 | 11 | 1 | 4 | 15 |
| Underground Mining | 113 | 104 | 747 | 78 | 164 | 627 |
| Pleasure Craft | 3 | 2 | 88 | 12 | 4 | 15 |
| Railroad Equipment | 3 | 3 | 21 | 3 | 4 | 19 |

| WISCONSIN | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOx | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **12,780** | **10,934** | **263,600** | **14,007** | **194,226** | **2,094,097** |
| **Highway Vehicles** | **5,607** | **4,352** | **191,146** | **7,118** | **114,898** | **1,556,635** |
| **Off-Highway Equipment and Vehicles** | **7,174** | **6,582** | **72,455** | **6,890** | **79,329** | **537,461** |
| Heavy Equipment (Diesel) | 4,307 | 3,962 | 36,095 | 4,581 | 4,731 | 21,749 |
| Heavy Equipment (Gasoline) | 2,106 | 1,937 | 4,085 | 286 | 72,738 | 478,599 |
| Heavy Equipment (LNG & CNG) | 37 | 37 | 8,136 | 8 | 19 | 32,181 |
| Marine Vessels (Diesel) | 392 | 360 | 8,815 | 1,633 | 275 | 1,159 |
| Railroads (Diesel) | 264 | 238 | 7,451 | 311 | 281 | 735 |
| Aircraft | 69 | 47 | 7,873 | 71 | 1,284 | 3,038 |
| **Off-Highway Diesel** | **4,963** | **4,560** | **52,361** | **6,525** | **5,288** | **23,644** |
| **Off-Highway (Other Fuels)** | **2,211** | **2,021** | **20,094** | **365** | **74,041** | **513,818** |
| **Off-Highway Share of Mobile Source Pollution** | **56%** | **60%** | **28%** | **49%** | **41%** | **26%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **39%** | **42%** | **20%** | **47%** | **3%** | **1%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **34%** | **36%** | **14%** | **33%** | **2%** | **1%** |
| **Heavy Equipment (Diesel)** | **4,307** | **3,962** | **36,095** | **4,581** | **4,731** | **21,749** |
| Agriculture | 2,255 | 2,074 | 16,050 | 1,813 | 2,194 | 10,103 |
| Airport Ground Support | 5 | 4 | 51 | 7 | 5 | 25 |
| Commercial | 189 | 174 | 1,319 | 187 | 257 | 939 |
| Construction | 1,341 | 1,234 | 13,484 | 1,808 | 1,636 | 8,087 |
| Industrial | 357 | 328 | 3,353 | 509 | 421 | 1,736 |
| Lawn and Garden | 75 | 69 | 602 | 89 | 111 | 360 |
| Logging | 45 | 41 | 552 | 76 | 47 | 259 |
| Recreational | 15 | 14 | 65 | 8 | 23 | 92 |
| Underground Mining | | | | | | |
| Pleasure Craft | 16 | 15 | 555 | 77 | 23 | 92 |
| Railroad Equipment | 11 | 10 | 63 | 8 | 13 | 57 |

| WYOMING | 1999 Emissions in Tons per Year | | | | | |
|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | NOX | $SO_2$ | VOC | CO |
| **Mobile Sources - TOTAL** | **2,288** | **1,980** | **57,047** | **2,438** | **25,044** | **294,048** |
| **Highway Vehicles** | **833** | **655** | **29,194** | **1,018** | **16,406** | **240,204** |
| **Off-Highway Equipment and Vehicles** | **1,455** | **1,325** | **27,854** | **1,420** | **8,637** | **53,845** |
| Heavy Equipment (Diesel) | 745 | 685 | 6,221 | 768 | 826 | 3,807 |
| Heavy Equipment (Gasoline) | 177 | 163 | 369 | 26 | 6,984 | 46,149 |
| Heavy Equipment (LNG & CNG) | 1 | 1 | 276 | 0 | 2 | 1,093 |
| Marine Vessels (Diesel) | - | - | - | - | - | - |
| Railroads (Diesel) | 519 | 467 | 20,910 | 619 | 778 | 2,060 |
| Aircraft | 14 | 9 | 77 | 7 | 47 | 736 |
| **Off-Highway Diesel** | **1,264** | **1,152** | **27,131** | **1,387** | **1,605** | **5,867** |
| **Off-Highway (Other Fuels)** | **191** | **173** | **723** | **33** | **7,033** | **47,978** |
| **Off-Highway Share of Mobile Source Pollution** | **64%** | **67%** | **49%** | **58%** | **35%** | **18%** |
| **Off-Highway Diesel Share of Mobile Source Pollution** | **55%** | **58%** | **48%** | **57%** | **6%** | **2%** |
| **Off-Highway Heavy Diesel Equipment Share of Mobile Source Pollution** | **33%** | **35%** | **11%** | **32%** | **3%** | **1%** |
| **Heavy Equipment (Diesel)** | **745** | **685** | **6,221** | **768** | **826** | **3,807** |
| Agriculture | 391 | 359 | 2,781 | 314 | 380 | 1,751 |
| Airport Ground Support | 1 | 0 | 5 | 1 | 1 | 3 |
| Commercial | 19 | 18 | 134 | 19 | 26 | 95 |
| Construction | 247 | 227 | 2,483 | 333 | 301 | 1,490 |
| Industrial | 36 | 33 | 420 | 55 | 46 | 180 |
| Lawn and Garden | 3 | 3 | 27 | 4 | 4 | 14 |
| Logging | 5 | 5 | 64 | 9 | 6 | 30 |
| Recreational | 6 | 6 | 28 | 4 | 10 | 39 |
| Underground Mining | 35 | 32 | 232 | 24 | 51 | 194 |
| Pleasure Craft | 1 | 1 | 42 | 6 | 2 | 7 |
| Railroad Equipment | 1 | 1 | 5 | 1 | 1 | 4 |

# Cleaning Up Diesel Pollution

## EMISSIONS FROM OFF-HIGHWAY ENGINES BY STATE


From tractors to trains to cruise ships, "off-highway" diesel engines are found in every part of the country. We rely on these workhorses to do our heavy moving and lifting, but unlike highway trucks and buses that have to meet strict pollution standards, off-highway engines have been allowed to run wild, leaving a trail of toxic soot and smog-forming pollutants in the air we breathe.

This report's analysis of pollution from off-highway diesel engines in all 50 states and 20 major metropolitan areas shows the significant impact these engines have on air quality both locally and nationally. For just a slight increase in equipment costs, existing cleanup technologies could be installed on off-highway diesel engines, cutting pollution significantly and allowing us all to breathe a little easier.

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