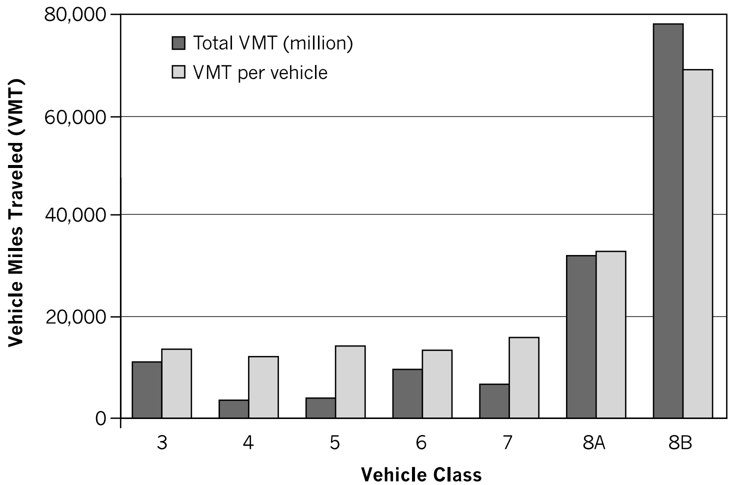
CHAPTER 4

BENEFITS OF GREENER TRUCKS AND BUSES

The truck market today is extremely diverse, ranging from garbage trucks that may travel less than 5,000 miles per year in dense cities to tractor-trailer trucks that travel over 100,000 miles in a year on the open road (Figure 6).

Figure 6. Mileage of Heavy Trucks



Source: DOC 2000

This creates opportunities for technology and fuel solutions tailored to the specific needs of the user, the truck's driving pattern, and the local environment. For example, cleaner alternative fuels are a priority for densely populated urban areas and applications where users, such as school children, are particularly sensitive to pollution. Hybrid and fuel cell trucks are likely to offer their largest benefits in stop-and-go driving. And conventional diesel improvements may make most sense for long-haul trucks operating at constant, high speeds over the open road.

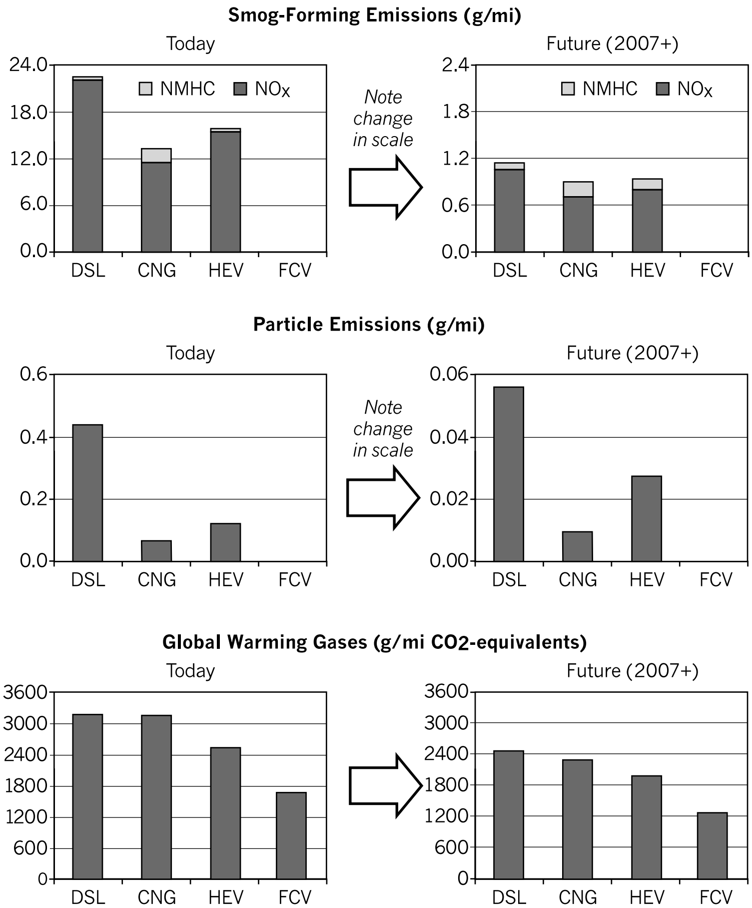
To illustrate the per-vehicle benefits that can accrue through cleaner and more efficient technologies and fuels, we constructed four case studies: a transit bus, school bus, parcel delivery truck, and long-haul truck.[32] For each

[32] See Table A-1 for detailed values.

of these, we determined what the emissions would be if it were powered by diesel, compressed natural gas, hybrid electric drive, or fuel cells. And we examined how emissions could change in the future as the industry adopts more advanced technologies in order to meet the proposed regulations discussed above. We also modeled the national benefits of reduced emissions brought about by conversion to cleaner technologies.

Figure 7. Urban Bus Emissions

Class 8, 33,000+ lb gross vehicle weight (GVW)



DSL= diesel bus; CNG = compressed natural gas bus;
HEV = hybrid electric bus *with particulate trap*; FCV = fuel cell bus.

Estimates based on UCS modeling (Mobile 6 analysis of NO_x and HC and real-world data for PM) and AFDC n.d.; CARB 2000b; EPA 1998b, EPA 1999a, EPA 2000; NAVC 2000. See text for discussion.

Case Study 1: Transit Bus

Because transit buses often operate in cities, where public exposure to smog and diesel particles is highest, transit agencies should purchase the cleanest buses possible. Buses fueled by natural gas are the best commercial choice today. Demonstration programs show that prototype diesel hybrid-electric buses have yet to match the low smog-forming emissions of compressed natural gas buses. Diesel hybrid buses can decrease emissions of particles (especially when using traps) and heat-trapping gases compared with conventional diesel buses, as Figure 7 shows, but more testing is needed to evaluate their ability to reduce toxic emissions.

Zero emissions make hydrogen fuel cells the natural choice for transit buses as soon as they become commercially available, which will be within the next few years. In addition, these offer the potential for large reductions in heat-trapping emissions. Even when the hydrogen is produced from fossil fuels, heat-trapping emissions decrease by half compared with future diesel and by 35 percent compared with diesel hybrids. Transit agencies that start down the natural gas path today are building an infrastructure for future fuel cell buses, because many of the changes in facilities necessary to accommodate natural gas fuel will be useful for hydrogen.

Case Study 2: School Bus

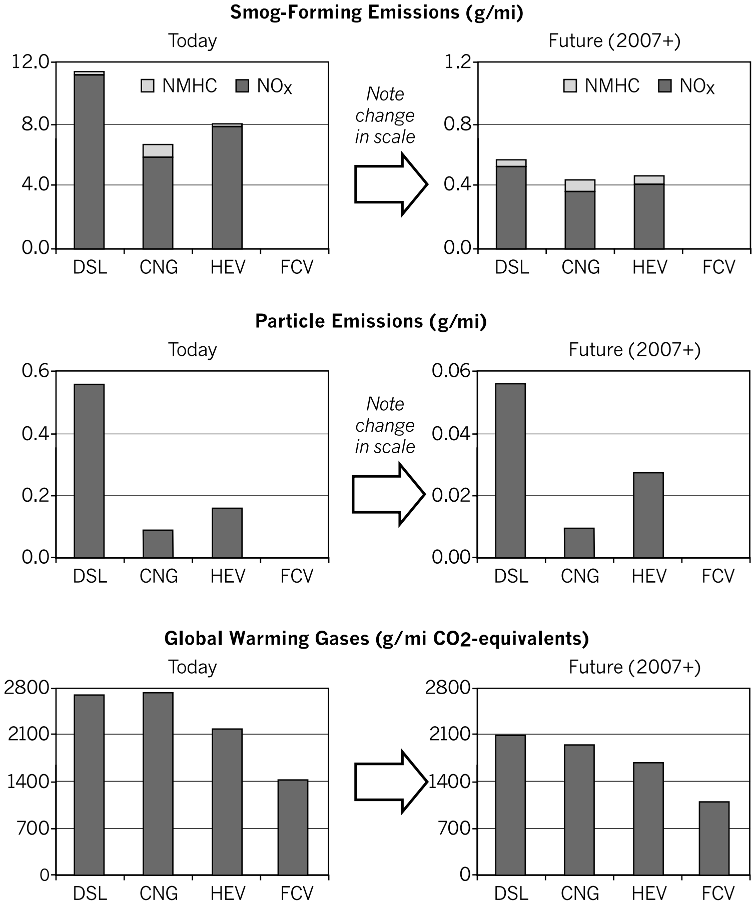
Children, and their sensitive lungs, deserve the absolute cleanest buses. Natural gas buses, with their dramatically low particle emissions (85 percent lower than conventional diesel and 46 percent lower than hybrids equipped with traps), are the safest choice for transporting children today. These buses also emit 42 percent less smog-forming pollutants than diesel buses, as Figure 8 (next page) illustrates.

While diesel hybrid buses are, from a global warming standpoint, slightly better than buses running on compressed natural gas, they do not provide the same level of protection from toxic diesel soot—and lessening children's exposure to toxic soot takes precedence in school bus applications. Future diesel hybrid school buses could eventually emit almost as few smog-forming pollutants as natural gas buses, but if their particle emissions are three times higher (as we projected), they will continue to be a less prudent choice for school buses.

Eventually, zero-pollution fuel cell buses will become the cleanest option for school buses, as well as the lowest contributors to global warming. Schools that invest in natural gas refueling infrastructure today will be well positioned to make the transition to fuel cell buses, because hydrogen refueling systems use many of the same components as are needed for compressed natural gas.

Figure 8. School Bus Emissions

Class 8, 33,000+ lb gross vehicle weight (GVW)



DSL= diesel bus; CNG = compressed natural gas bus;
HEV = hybrid electric bus *with particulate trap*; FCV = fuel cell bus.

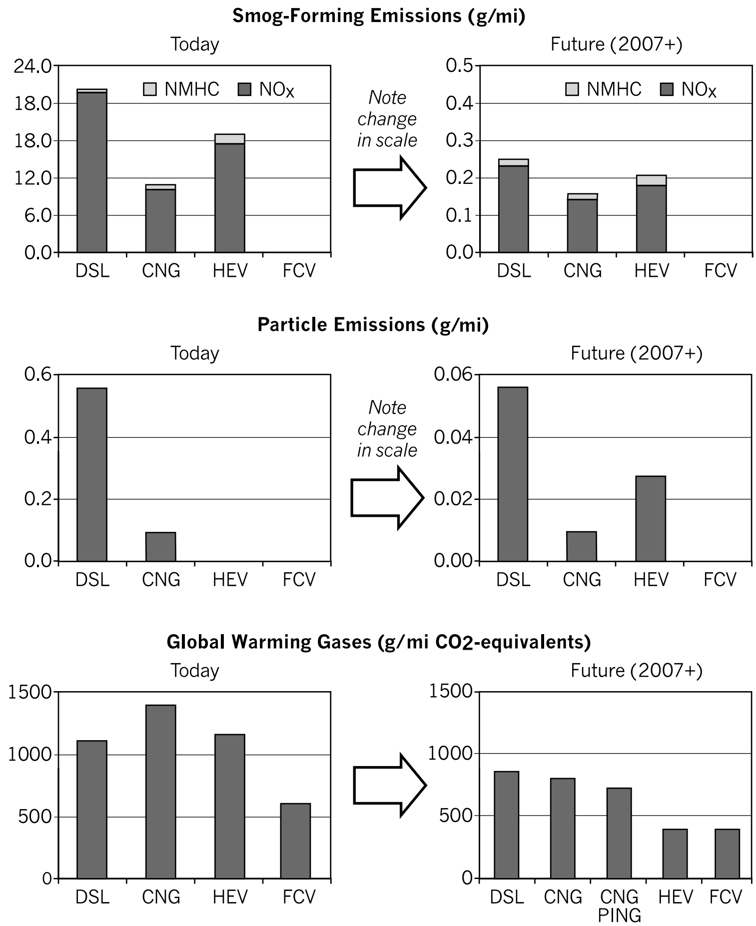
Estimates based on UCS modeling (Mobile 6 analysis of NO_X and HC and real-world data for PM) and AFDC n.d.; CARB 2000b; EPA 1998b, EPA 1999a, EPA 2000; NAVC 2000. See text for discussion.

Case Study 3: Parcel Delivery Truck

Parcel delivery trucks, such as those operated by UPS, FedEx, or the Postal Service, are an important target for cleanup, since they operate in densely populated urban centers and in residential neighborhoods. Zero-polluting hydrogen fuel cells are the best long-term option for such urban delivery vehicles. As Figure 9 (next page) shows, they will emit 50 percent less heat-trapping gases than delivery trucks powered by diesel or natural gas. While

Figure 9. Parcel Delivery Truck Emissions

Class 3, 10,001 – 14,000 lb gross vehicle weight (GVW)



DSL= diesel bus; CNG = compressed natural gas bus;
HEV = hybrid electric bus *with particulate trap*; FCV = fuel cell bus.

Estimates based on UCS modeling (Mobile 6 analysis of NO_X and HC and real-world data for PM) and AFDC n.d.; CARB 2000b; EPA 1998b, EPA 1999a, EPA 2000; NAVC 2000. See text for discussion.

hybrids may match the global warming benefit of fuel cells in the long term, they cannot compete on smog-forming or particle emissions.

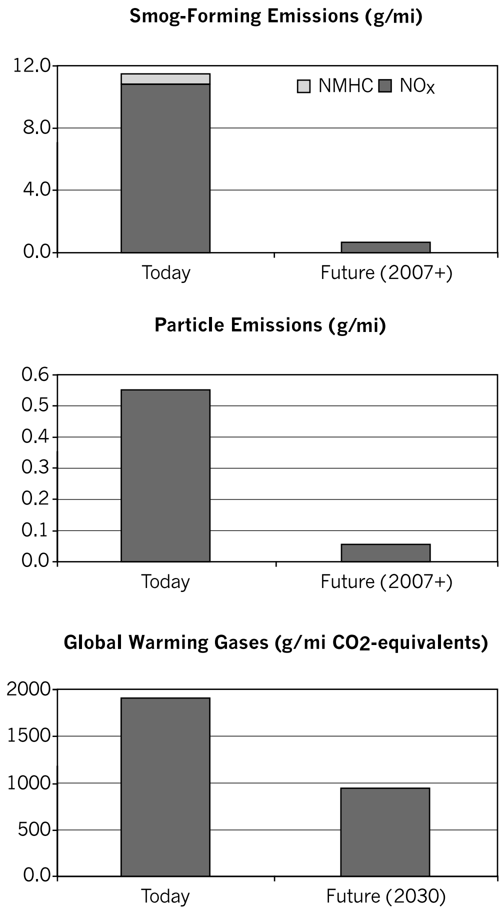
Until fuel cells become widely available, a mix of technologies can reduce the environmental impacts of urban delivery vehicles. Natural gas, which is available for centrally refueled vehicles, offers the greatest public health benefits, but may have a slight global warming penalty compared with diesel vehicles. Natural gas engines that use diesel fuel to initiate combustion (so-called pilot-injection natural gas engines) are more efficient and would reduce global warming emissions, but have yet to match the pollution performance of pure natural gas engines. Hybrid vehicles are not as clean as natural gas, but emit over 50 percent less heat-trapping gases.

Case Study 4: Long-Haul Tractor-Trailer

Forthcoming cleaner diesel technologies will substantially reduce emissions of smog-forming pollutants, particles, and heat-trapping gases from class 8 long-haul trucks. Long daily driving ranges makes natural gas less suitable for

Figure 10. Long-Haul Tractor-Trailer Emissions

Class 8B, 60,000+ lb gross vehicle weight (GVW)



Estimates based on UCS modeling (Mobile 6 analysis of NO_x and HC and real-world data for PM) and AFDC n.d; CARB 2000b; EPA 1998b, EPA 1999a, EPA 2000; NAVC 2000. See text for discussion.

these trucks (although this would be less of a problem for liquefied natural gas trucks). And the long periods of highway driving at high speeds means that hybrids or fuel cells may not significantly improve fuel economy or reduce pollutant emissions. However, using fuel cells for auxiliary power sources could eliminate idling emissions.

Pollution savings through new diesel technologies are well within reach, offering the potential to reduce smog-causing emissions by 95 percent over conventional diesel and particulates by 90 percent, as Figure 10 (opposite) indicates. Reducing heat-trapping emissions from diesel trucks is a greater challenge, since they are efficient vehicles today, but if technical targets can be achieved, these gases can be cut to half of today's levels from long-haul trucks.

National Benefits

To evaluate the benefits of greener trucks and buses, we constructed a model to estimate the national savings in energy, heat-trapping gases, and key air pollutants that might result from aggressive policies to improve or replace diesel truck technology and fuels. We developed a snapshot of what the diesel truck market could look like in 2030.

Base Case

We derived a baseline for comparison from the travel and fuel-economy projections collected in the EPA's draft rule for heavy-duty diesel engines and fuels (EPA 2000). These projections suggest that US diesel trucks will travel a total of 475 billion miles in 2030, more than double the total today. The EPA also assumes that, as in the past, truck fuel economy will continue to improve, slightly offsetting the impact of increased travel miles.[33] Nonetheless, under the EPA scenario total energy use by diesel trucks increases nearly 75 percent by 2030 compared with today's usage (Davis 1999).[34]

Green Scenario

In developing scenarios of future technology and fuel penetration, we considered a variety of factors, including commercial readiness, cost, and market characteristics (e.g., drive cycle, range, and power requirements). Our expectation is that successful research and development programs, coupled with aggressive policies, will deliver technologies and fuels that do

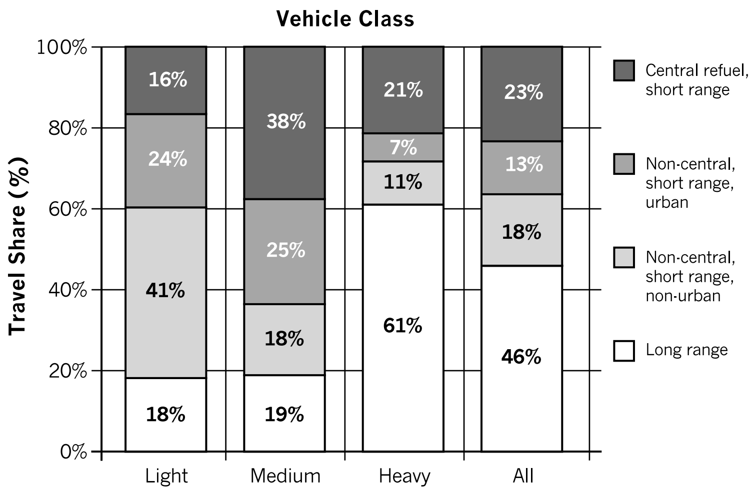
[33] The EPA assumes the following fuel-economy increases for new heavy-duty trucks by 2030 (vs. model year 2000): 28 percent (light heavy), 8 percent (medium heavy), 36 percent (heavy heavy), and 30 percent (urban bus). For our base case, we assume a lower increase in heavy-heavy fuel economy, only 28 percent, the increase projected by the recent Annual Energy Outlook forecast (EIA 2000). We also adjusted the EPA's base case by accounting for increasing sales of trucks as predicted by the Energy Information Administration (EIA). This adjustment increases the fraction of miles traveled by newer vehicles compared with the EPA's base case, which assumes static travel fractions regardless of calendar year.

[34] The EPA's estimate projects that trucks will consume slightly more than 25 percent more energy in 2030 than projections in the Annual Energy Outlook (EIA 2000). The EPA projects higher vehicle miles traveled but also higher fuel economy than the EIA.

not face substantial cost hurdles to entering the market.[35] Rather, we see the characteristics of individual vehicle use as determining the market potential of various technologies.

Figure 11 presents an overview of current travel data for the US truck fleet, based on data from the Vehicle Inventory and Use Survey (DOC 2000). Nationwide, over 20 percent of all truck miles are traveled by vehicles fueled in central locations that typically travel less than 200 miles from their home base.

Figure 11. Heavy Truck Mileage by Major Use



1. UCS analysis of Commerce Department's Vehicle Inventory and Use Survey (DOC 2000).
2. Short-range vehicles typically have a range of 200 miles or less.
3. Urban/nonurban fraction for noncentral, short-range vehicles based on the EPA's analysis of vehicle miles traveled for urban vs. rural roadways (EPA 1999a).
4. Long-range vehicles typically have a range of more than 200 miles.

Alternative fuels that rely on a unique fuel infrastructure are ideally suited to this market.[36] Nearly 15 percent of all miles are traveled by short-range trucks operating largely in urban areas that are not centrally refueled. Short driving range and urban travel suggests that average speeds are low and vehicles are operating in congested areas. Diesel hybrid vehicles might be

[35] This assumption is supported by recent analyses of potential future vehicle and fuel costs of alternative fuels, hybrids, and fuel cells for heavy-duty applications (DOE 2000; DeCicco and Mark 1998; An et al. 2000; Mark and Davis 1998).

[36] Clearly, technical advances that allow more fuel to be stored on board alternative fuel trucks could change this assumption. Such advances might include better compressed or liquefied gas storage or the widespread use of liquid alternative fuels.

good candidates for this type of driving pattern, since hybridization offers the greatest benefits in stop-and-go driving. Finally, over 45 percent of all miles are traveled by vehicles with a range greater than 200 miles. We assumed that these will largely be advanced diesel vehicles. Our assumptions about the market penetration of each technology are sketched out below, for each size class of trucks. In the appendix, Table A-2 summarizes these assumptions.

Light-Heavy Trucks Light-heavy trucks include vehicles such as super-duty pickups, urban delivery vans (e.g., UPS trucks), and smaller freight trucks that are rated at between 8,500 and 19,500 pounds gross vehicle weight.[37] For these vehicles, we assumed that technologies like alternative fuel engines, hybrids, and fuel cells that are envisioned for their smaller cousins—large pickups, sport-utility vehicles, and vans—will be available. Roughly 15 percent of the miles in this size category are traveled by short-range, centrally fueled vehicles. We assumed that natural gas delivery vehicles, such as those already being used by some fleets, will fully capture this portion of the market by 2030.

Another 20 percent of miles are driven by long-range vehicles; this category is likely to continue to consist of conventional diesel trucks. The remaining 65 percent of short-range vehicles that are not centrally fueled offer large opportunities for both diesel hybrids and fuel cells. We assumed that diesel hybrids will enter the market first, with their share of sales growing rapidly from introduction in the 2005–2010 timeframe. We assumed that fuel cells will begin to enter this size class around 2010, building off the market success of fuel cell passenger vehicles and the resulting infrastructure. Under our scenario, fuel cells would eventually eclipse diesel hybrids as the urban delivery vehicle of choice by 2030.

Medium-Heavy Trucks Trucks and buses between 19,500 and 33,000 pounds gross vehicle weight offer the largest market for short-range, centrally fueled vehicles, as they account for over 35 percent of miles traveled in this category. We assumed that natural gas vehicles will dominate in the early years, but that fuel cells will eventually work their way into this segment of the market. Hybrid vehicles will account for the majority of short-range trips for vehicles that are not centrally fueled, accounting for over 35 percent of miles by 2030.

Heavy-Heavy Trucks Trucks over 33,000 pounds gross vehicle weight account for the majority of miles traveled by all trucks. And nearly 75 percent of the miles in this weight category are traveled by vehicles with a range greater than 200 miles or in rural areas without central refueling. This is the target market for advanced diesels with improved fuel economy and emissions performance. The remainder of the market will be split, under our scenario, among alternative fuels, diesel hybrids, and fuel cells.

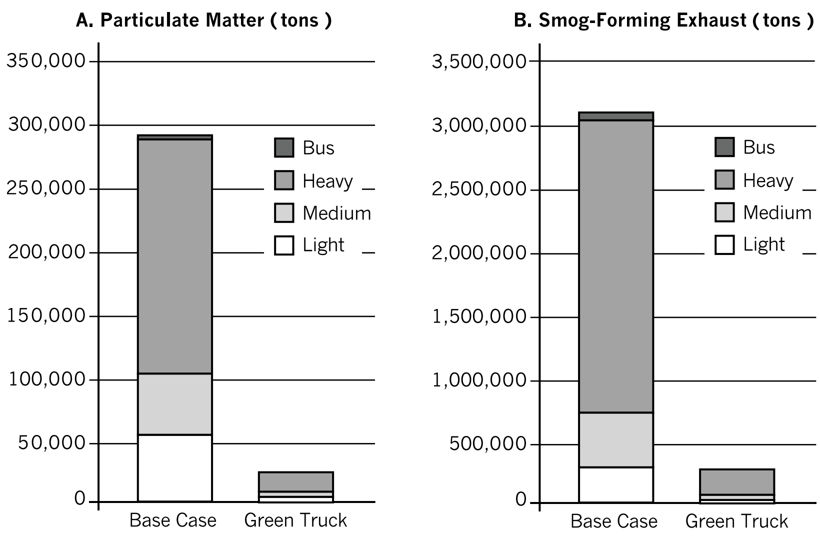
[37] Gross vehicle weight is the weight of a vehicle including its maximum payload.

Urban Buses Natural gas buses are already making their way into the urban bus market, and we assumed that this trend will continue until the fuel cell technology being demonstrated today begins to take over the bus market in the next decade. By 2030, we assumed that all new urban buses will be powered by fuel cell engines.

Results

The technologies and fuels available for heavy trucks could transform the transportation sector—protecting public health, the environment, and the economy even as truck miles double over the next 30 years. Nationwide, we estimated that pollutant emissions from diesel trucks can be cut by 91 to 92 percent in 2030 over the base case, if aggressive, real-world reductions in emissions are achieved (Figure 12 A & B). The smog-forming exhaust savings alone are equivalent to removing over 60 million of today's cars from the road.[38] Tighter standards for diesel trucks would form the backbone of the air pollution savings, but alternative fuels and advanced technologies such as hybrids and fuel cells offer additional emissions benefits—especially in urban areas where large populations are exposed to harmful diesel exhaust.

Figure 12. National Benefits of Greener Trucks and Buses in 2030



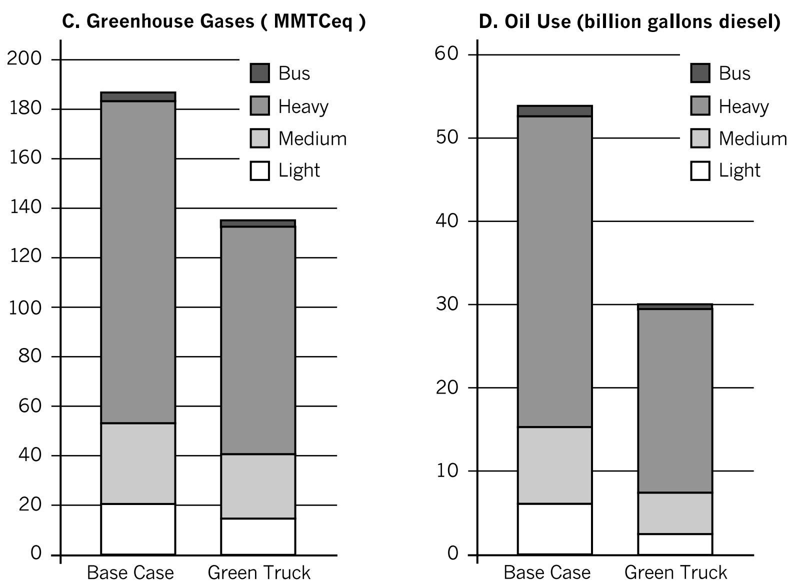
1. See Table A-3 for details.
2. Light = Class 2B–5; Medium = Class 6–7; Heavy = Class 8; Bus = Urban Bus.

[38] We estimated 3.69 grams/mile for the average passenger vehicle in calendar year 2000, based on total national emissions inventory (EPA 1997b), total national automobile travel, and annual average per-vehicle travel rate of 11,400 miles (Davis 1999).

We estimated that heat-trapping emissions from US diesel trucks can be cut 26 percent (Figure 12 C), a substantial reduction given that today's diesel engines are already relatively efficient. These benefits will grow if low-carbon fuels, such as hydrogen produced from solar energy or biomass-derived ethanol, are used. For this analysis, we assumed that all fuels are produced from fossil fuels, but renewable fuels can provide significant benefits beyond those estimated here. This is an important area for further study.

In addition to the gains in reducing air pollution and contributions to global warming, our green scenario has the added advantage of cutting petroleum use. We estimated that the amount of oil used by diesel trucks can be cut by 45 percent over the base case (Figure 12 D), keeping petroleum use for highway trucks in 2030 at about today's levels. These savings will help insulate truckers from the price volatility of oil, as well as protecting the US economy by reducing oil imports. Slightly over half of these oil savings accrue from gains in efficiency, while the remainder come from switching from diesel fuel to alternatives such as natural gas or hydrogen.

Figure 12 (continued).



1. See Table A-3 for details.
2. Light = Class 2B–5; Medium = Class 6–7; Heavy = Class 8; Bus = Urban Bus.

Our estimates suggest that fuel cells can virtually eliminate urban buses from the pollution picture. Fuel cells also play a major role in delivering large reductions in the light-heavy truck segment, as do diesel hybrids. Because these smaller delivery vehicles and large vans are close cousins to passenger vehicles (especially SUVs, pickups, and vans), fuel cells and hybrids developed for the passenger vehicle market will pay off for light-heavy trucks as well. But our results show that long-haul heavy trucks continue to be the dominant polluters in 2030, indicating that this market segment should be a priority for efforts to further reduce emissions, heat-trapping gases, and oil use.