Delivering the Green

Reducing Trucks' Climate Impacts While Saving at the Pump

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

EXECUTIVE SUMMARY

Most of the products we buy today have at some point been transported by a heavy-duty truck—a critical part of our freight-transportation system. But this reliable service comes at a price. Nearly all modern heavy-duty trucks run on petroleum-based diesel fuel, and as with other forms of fossil-fueled transportation their tailpipe emissions contribute to poor local air quality and rising global temperatures. Meanwhile, the high costs of diesel and gasoline are busting the budgets of truckers and consumers alike.

A win-win solution is possible, however. The technologies that reduce global warming emissions from trucks also reduce fuel use and smog-forming pollutants while lowering truckers' operating costs. Considering only products that are commercially available today, tractor-trailers can be equipped with aerodynamic devices and high-performance tires and wheels yielding a greater-than-12-percent reduction in fuel consumption. For a typical long-range truck traveling over 100,000 miles per year, this would translate to an annual savings of 2,000 gallons of diesel fuel. The initial cost of the upgrades could be recovered by fuel savings in as short a time as one year, and over $30,000 in net gain could be realized over the lifetime of the truck. Retrofitting existing tractor-trailers offers significant fuel and cost savings for all but the oldest and lowest-mileage trucks, while choosing the most efficient tractor-trailers when buying new allows for the greatest savings overall.

Improving truck efficiency is not only good for the bottom line but also can help California meet its global warming, air quality, and petroleum dependence goals. Installing available retrofit technology both on new and in-use trucks and trailers could reduce global warming pollution emissions by 17 million metric tons (MMT) of CO_2eq (carbon dioxide equivalent) by 2020—the same effect as taking 2.5 million cars off the road.[1]

Compared with other regulatory strategies that California is considering in order to meet its global warming emissions-reduction targets, requiring cost-effective retrofits on trucks is one of the most powerful. (Only three other proposed strategies promise greater reductions.[2]) Moreover, 470 tons of smog-forming nitrogen oxides could be reduced nationwide by 2020, with 60 tons eliminated in California—which would help in attaining national air quality standards in the San Joaquin Valley and Los Angeles area, two of the country's most polluted areas. Implementing these basic truck-efficiency improvements would reduce diesel consumption in California by 5 percent over business as usual, or 200 million gallons annually, by 2020.

Some truck fleets have already invested in these cost-saving technologies. But the vast majority have not, as there continue to be barriers to their widespread adoption even in the face of rising fuel prices. One reason is that trucks go through many owners over their lifetimes; a current owner may choose not to invest in improving the truck's efficiency if it will be sold in a couple of years. Split ownership of tractors and trailers presents similar challenges. And the absence of standardized fuel-economy testing data for new trucks and retrofit components has slowed adoption as well.

These and other market barriers can be overcome through policies initiated by California lawmakers and regulators. Requiring the use of low-rolling-resistance tires on all heavy-duty trucks and trailers, the retrofitting of trailers with aerodynamic improvements, and fleets' use of the most efficient new trucks is just a start. California could further reduce emissions over the long term by creating new-truck performance-based standards on global warming pollution. Truck and trailer manufacturers could meet these standards, which currently do not exist, through numerous strategies that employ advances in engine technology, drivetrain efficiency, hybridization, aerodynamics, and rolling resistance.

Well-designed climate policies targeting both today's and tomorrow's trucks can help California meet its climate change and air quality goals, reduce the state's dependence on petroleum, save truckers money at the pump, and ease pressures to raise shipping costs.

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Reducing Trucks' Climate Impacts While Saving at the Pump

By Don Anair

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California stands out as a leader in combating climate change, having set statewide targets for reducing global warming pollution; emissions are to be back to 1990 levels by 2020 and at 80 percent below 1990 levels by 2050. These reduction targets are on the order of what scientists tell us is needed throughout the developed world to avoid the most severe impacts of climate change. Otherwise, high levels of warming in California would be expected to reduce the Sierra snowpack—an important source of water for drinking and irrigation throughout the state—by 70–90 percent. And increased temperatures in the already heavily polluted San Joaquin Valley and Los Angeles areas could raise the number of days conducive to forming ozone, a major ingredient of smog, by 75–80 percent.[3]

Globally, the rise in temperature would be expected to cause serious, even catastrophic, problems. They include food and water shortages for hundreds of millions of people, a loss of some 30 percent of the world's species, and the potential onset of the disintegration of the Greenland ice sheet—which would in turn raise sea levels worldwide by 20 feet or more and thus result in the inundation of low-lying coastal areas, including parts of many of the world's major cities.[4]

To prevent the most calamitous effects of climate change, it is especially important that we meet the reduction target of 2050, and just as critical is the path we choose in getting there. Because global warming pollutants persist in the atmosphere for decades, we have to consider our cumulative emissions from now through 2050. Essentially, the United States has a global warming pollution budget for the next 40 years, and the more global warming pollution we emit in the beginning, the greater the reductions must be in later years. For example, if we begin cutting our emissions by 4 percent per year starting in 2010, we can reach the 2050 target. But if we wait until 2020, we will have to begin making much sharper cuts—approximately 8 percent per year—to achieve the same goal.[5] The more reductions we make now, in other words, the more flexibility we will have later on, and the less costly the overall effort will be. A major element of such near-term actions should be the curtailing of truck emissions through efficiency improvements on new and used trucks.

Trucks are responsible for 20 percent of all transportation-related global warming pollution in California.

TRUCK POLLUTION AND FUEL CONSUMPTION

California heavy-duty trucks each year consume some 3 billion gallons of diesel fuel—their primary sources of energy—and are responsible for 20 percent of all transportation-sector global warming pollutant emissions, second only to passenger cars.[6,7] The transportation sector is the largest producer of global warming pollution in California, accounting for more than 40 percent of total emissions. As the movement of goods in California continues to grow through the next decade, trucks are expected to increase the

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Reducing NO_x Emissions along the Way

Nitrogen oxides (NO_x) emitted from the tailpipes of heavy-duty trucks contribute to the formation of ground-level ozone (or "smog") when they react in the atmosphere with hydrocarbons in the presence of sunlight. Ozone is a lung irritant that can damage the respiratory track, compromise lung function, and aggravate chronic lung diseases. In addition, NO_x emissions also react with ammonia in the atmosphere to create nitrates—fine particulates that can penetrate deep into the lungs and cause or aggravate a variety of respiratory illnesses and cardiovascular disease. Both ozone and particulate pollution have been linked to increased risk of premature death.[8,9]

Diesel-fueled trucks are California's largest source of NO_x emissions, responsible for 30 percent of the state total (which also includes contributions from passenger cars, power plants, and refineries).[10] Testing of trucks retrofitted with technologies that reduce global warming pollution and improve fuel economy has also shown reductions in tailpipe NO_x emissions ranging from 10 percent to as much as 40 percent.[11] New-engine standards adopted by the U.S. Environmental Protection Agency (EPA) will reduce new-truck NO_x emissions by more than 90 percent beginning in 2010, and rules proposed by the California Air Resources Board aim for all trucks operating in California to meet similar standards by 2020. Applying global warming pollution retrofits to new and used trucks will widen those future benefits as well as provide some relief in the interim.

number of miles they travel on the state's highways from 15.9 billion miles in 2005 to 21.3 billion miles in 2020, a 33 percent increase. Along with traveling more miles, heavy-duty trucks will also consume more fuel, with diesel consumption and global warming emissions expected to increase a similar 30 percent between 2005 and 2020.

The primary global warming pollutant produced by combusting diesel fuel in heavy-duty trucks, and by refining it from crude oil in the first place, is carbon dioxide (CO_2). Thus reducing the diesel fuel consumption of trucks also eliminates global warming pollution both from combusting and producing the fuel.

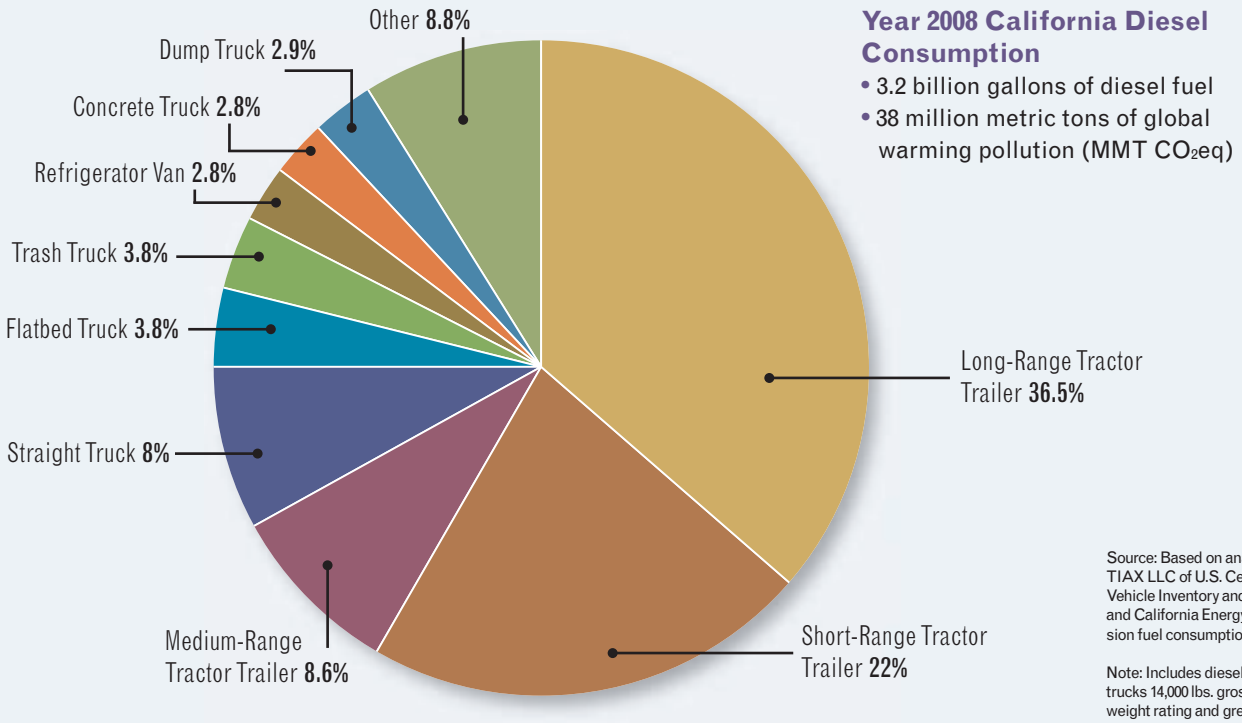
The breakdown of diesel fuel consumption in California, shown in Figure 1 by truck type, is proportional to the global warming pollution emitted by these vehicles. About two-thirds of trucks' diesel consumption is from tractor-trailers, commonly called "big rigs," which are categorized according to the miles they travel.

Long-range tractor-trailers, trucks whose primary trip length is greater than 200 miles, account for more than 35 percent of the diesel fuel consumed in California. Trucks doing long-range work can top 130,000 miles annually and burn a gallon of diesel fuel every 6 to 6.5 miles.[12] This high annual mileage and low number of miles per gallon mean that even small improvements in fuel efficiency can add up to thousands of dollars in annual savings in fuel costs while cutting global warming pollution.

Medium-range tractor-trailers, those with primary trip lengths between 100 and 200 miles, consume about 9 percent of the diesel fuel in California. These trucks can average as much as 80,000 miles per year and operate over a mix of highway and suburban routes.[13] Tractor-trailers in such regional distribution service can also realize cost and pollution savings from efficiency improvements.

Short-range tractor-trailers, those with primary trip lengths of less than 100 miles, consume more than 20 percent of California's diesel fuel. While these

FIGURE 1: Diesel Fuel Use of Trucks Operating in Caliornia



trucks generally do not log as many miles per year as medium- and long-range tractor-trailers, many still travel more than 50,000 miles in a mix of highway, suburban, and urban driving.

The largest non-tractor-trailer consumer of diesel fuel in California is the straight box truck. These vehicles, accounting for 8 percent of diesel consumption, vary in application from urban delivery to regional distribution and come in a variety of sizes and carrying capacities.

Together, tractor-trailers and straight box trucks represent over three-fourths of the diesel fuel consumption and global warming pollution from all trucks operating in California. Fuel consumption translates directly into operating costs for truck owners, whether of single vehicles or fleets. The 3 billion gallons of diesel fuel used in California alone translates into a yearly expense of $10 billion.[14] A tractor-trailer doing long-range travel can consume 20,000 gallons of diesel fuel in a single year, pushing the fuel bill for a single truck to $65,000 per year (at a diesel price of $3.24 per gallon).

Often, increased fuel prices are passed on to consumers through the use of fuel surcharges, which have grown significantly in the past year. At diesel fuel prices of around $4 per gallon, shippers such as UPS and FedEx tack on charges for their parcel deliveries of more than 8 percent. Truckload shipment costs are generally seeing surcharges in the range of 30–60 percent when diesel prices are at $4 per gallon,[15] and these increases in shipping rates can translate directly into higher costs for consumer goods.

TECHNOLOGY IMPROVEMENTS

Commercially available aerodynamic and rolling-resistance improvements can be applied today, both to new trucks and in-use trucks, to reduce fuel consumption and global warming pollution. Other technologies, including advanced combustion techniques, drivetrain efficiency improvements, and hybridization, offer even greater reductions in emissions but are most suitable for integration into new trucks.

FIGURE 2: Classic Trucks

Typical **classic-styled truck** with long nose, flat bumper, low roof, and exposed air cleaners, exhaust stacks, and fuel tanks. Photo courtesy of Don Anair.

Aerodynamic-style tractor with low-profile front, aerodynamic bumper, full-height roof fairing, hidden exhaust stacks, and fuel tank side fairings. Photo courtesy of Don Anair.

Tractor Design

Most heavy-truck manufacturers offer tractors with aerodynamic designs that include rounded bumpers, high roof fairings (which direct air over the trailer), fuel tank fairings, and cab side extenders (which partially cover the gap between the tractor and the trailer). The best designs can reduce fuel consumption by as much as 15 percent over non-aerodynamic models. Some aerodynamic components, such as fuel tank fairings and bumpers, can be installed on existing tractors, but these vehicles' basic profiles are more difficult to modify. In any case, the maximum benefit will occur when choosing a fully equipped aerodynamic model, whether new or used.

While most large fleets purchase more fuel-efficient aerodynamically designed tractors, not all big rigs traveling America's highways incorporate the best designs. In fact, many of them have the "classic" look reminiscent of the 1970s big rig (Figure 2).[16] These trucks feature long-nose fronts, large flat bumpers, exposed side-exhaust pipes, and other accessories protruding from the vehicle that increase aerodynamic drag. Manufacturers continue to sell these tractors—detrimental to fuel economy and global warming emissions—while admitting that they may be 15 percent less efficient than aerodynamically styled counterparts.[17] This difference could add up to 2,500 extra gallons of diesel fuel burned per year at an additional cost of more than $8,000 to the truck operator.[18] Truck buyers may start to shy away from purchasing such vehicles, given today's fuel prices, but others may be stuck with a $130,000 investment that they cannot afford to operate competitively. Without standardized fuel-economy testing and labeling of heavy-duty trucks, buyers may not be aware of the significant economic impacts of the decision they are making when purchasing a classic-styled tractor.

Trailer Design

More than 60 percent of the time, a tractor pulls a rectangular box-van trailer behind it. When a tractor-trailer combination is traveling at highway speeds, more than half of the power produced by the engine is used to overcome aerodynamic drag. Reducing this drag by 20 percent can result in a 10 percent fuel economy improvement.[19] The three primary areas where the trailer affects aerodynamic drag are the front gap between the tractor and the trailer, the open area under the trailer, and directly behind the trailer. But wind tunnel testing and over-the-road testing have shown that numerous retrofit designs help reduce drag and thus improve the fuel economy of trailers. These retrofits include side skirts, front fairings, and rear flaps or "boat tails" (Figure 3). A few fleets have adopted these technologies and some trailer manufacturers have started offering the components on

new trailers.[20] Spotting one on the highway, however, is still a challenge.

Tires

Tires are also important to a truck's fuel economy; a 15 percent decrease in tires' rolling resistance can lower diesel consumption by 5 percent.[21] Among the tires available today, the best-performing products show fuel-economy improvements of 3 percent or more over the average tire.[22] Even greater savings can be gained by switching from steel to lightweight aluminum wheels and from dual (side-by-side) to single-wide-based tires, as the latter offer lower rolling resistance, lighter weight, and slight aerodynamic improvement. Together, wide-base tires and aluminum wheel sets can improve fuel economy by about 5 percent.[23]

Straight Trucks

Straight trucks (Figure 4) equipped with box-shaped cargo areas can also benefit from tire and aerodynamic improvements. While these trucks may not travel as far as long-range tractor-trailers, many spend significant amounts of time at highway speeds. Often these trucks do not come equipped with front fairings, which deflect air over the box behind the cab. Installing such an aerodynamic fairing on a box truck and using tires with low rolling resistance can improve fuel efficiency and provide significant cost savings over the life of the vehicle.

Low-rolling-resistance tires, wide-base wheels, and aerodynamic trailer fairings do not come as standard equipment on new tractor-trailers and straight trucks. These components must either be specified at the time of purchase or acquired separately from different technology providers. In the analysis that follows, we examine the economic and emissions benefits of

FIGURE 3: Aerodynamic Retrofit Technologies

Trailer Side Skirts These are body panels installed on trailers which cover the gap between the rear wheels of the tractor and the wheels of the trailer. Photo courtesy of Laydon Composites Ltd.

Front Fairing These devices are attached to the front side of the trailer to reduce drag and improve handling.
Photo courtesy of Nose Cone Mfg. Co., Inc.

Rear Tail Fairing These devices are designed to reduce the drag created at the back of the trailer.
Photo courtesy of ATDynamics, Inc.

FIGURE 4: Straight Truck Retrofits

The owner of a **straight truck** can install an aerodynamic fairing on the front of the vehicle to improve aerodynamic drag. Straight trucks with longer box trailers could also benefit from the installation of side skirts. Photo courtesy of Nose Cone Mfg. Co., Inc.

TABLE 1: Tractor-Trailer Technology Packages and Fuel Economy Improvements

Fuel Economy Improvement Technology Package	Package Description	% Fuel Economy Improvement for In-Use Retrofits (and New Vehicles*)		
		Long Range**	Medium Range	Short Range
Partial Technology Package***	• Trailer side skirts • Trailer front fairing • Low-rolling-resistance tires • Full aerodynamic tractor package for new trucks only	8% (10%)	6.8% (8.1%)	6.1% (7.1%)
Full Technology Package	Includes partial package plus: • Trailer rear fairing • Aluminum wheels (wide base or dual)	10.8% (12.8%)	10% (11.3%)	9.1% (10.1%)

Notes:
*Fuel economy improvement estimates for new vehicles includes benefits from fully equipped aerodynamic tractor.

**Long range represents trucks with primary trip lengths of greater than 200 miles, medium range between 100 and 200 miles, and short range fewer than 100 miles.

***Different combinations of technologies that achieve similar savings are possible. For example, a trailer rear fairing used in the partial technology package in place of the trailer side skirt would result in similar fuel economy improvements.

TABLE 2: Straight-Truck Technology Packages and Fuel Economy Improvements

Fuel Economy Improvement Technology Package	Partial Technology Package	% Fuel Economy Improvement for In-Use Retrofits
Partial Technology Package	• Front fairing • Low-rolling-resistance tires	6.8%
Full Technology Package	Includes partial package plus: • Aluminum wheels	8.1%

equipping new trucks with these technologies as well as of retrofitting trucks already in use.

ECONOMIC BENEFITS FOR NEW AND IN-USE TRUCKS

Equipping a truck with efficient tires and aerodynamics gives the biggest payoff when it is new, as new trucks travel the greatest number of miles afterward. But significant cost savings and emissions reductions are also obtainable by retrofitting used trucks. Benefits can be realized by single-truck and trailer owners as well as large trucking fleets operating in long-, medium-, and short-range applications.

To estimate potential costs and benefits, two technology packages are evaluated for tractor-trailers and straight trucks (Tables 1 and 2). For tractor-trailers, the partial technology package includes front and side trailer fairings and low-rolling-resistance tires on the trailer and tractor; the full technology package adds a rear fairing and wide-base or dual aluminum wheels to the partial-technology-package upgrades. For newly purchased tractor-trailers, it is assumed that the selection of an aerodynamic tractor provides a 1 to 2 percent fuel economy benefit (depending on the package) compared with the in-use tractor. Comparison with a classic tractor would result in even higher benefits. Lower fuel economy benefits for medium- and short-range tractor-trailers are a result of lower average speeds, which reduce the effects of aerodynamic improvements.

The technology upgrades for straight trucks consist of a front aerodynamic fairing and low-rolling-resistance tires under the partial technology package and the addition of aluminum wheels in the full technology package.

New Trucks

Equipping new trucks with the full technology package offers the greatest overall fuel savings and emissions reductions (about 30 percent greater than the partial technology package) while providing a positive economic payback over the life of the vehicle. This superiority holds across nearly all combinations of tractor-trailer ratios, operating ranges, and fuel prices.

Tables 3 and 4 (p. 10) show the potential benefits of equipping new trucks with aerodynamic and tire improvements for a specific service category (long, medium, or short range) and technology package (partial or full). Results are presented for each type of service, assuming that the vehicle remains in that service for its entire life. Net lifetime fuel-cost savings (after the initial capital investment is recovered) are indicated, along with payback period (months until initial investment is recovered), gallons of fuel saved, and global warming pollution reductions. Trucking fleets often own more than one trailer per truck, while single-truck owners may own only one trailer or be hired to pull a trailer owned by someone else. The two scenarios described below consider (1) trucks and trailers with a single owner and (2) large-fleet ownership, with an average of 2.5 trailers per truck.

Single truck and trailer owner (one trailer per tractor)

The full technology package offers the greatest fuel reductions, cost savings, and global warming pollution reductions for long-range, medium-range, and short-range tractor-trailers.

Owners of a truck and trailer combination using the full technology package in long-range service can save as much as $31,700 over the life of the truck, reduce fuel consumption by more than 17,000 gallons and global warming pollution by 200 metric tons, and recoup their initial investment in less than two years. Using the lower-cost partial technology package provides a shorter payback period but results in more modest cost savings and smaller reductions in overall fuel consumption and global warming emissions. The partial technology package saves 3,400 fewer gallons of fuel and yields $2,200 less in net (cost) savings relative to the full technology package. Trucks operating in medium- and short-range applications have longer payback periods but still achieve lifetime cost savings of $15,000–$27,300. Payback periods range from approximately a year and a half (19 months) to just over three years (40 months)—far shorter than the median lifetimes of medium-range (13 years) and short-range (19 years) tractor-trailers.

Using the full technology package on new trucks maximizes global warming pollution reductions while maintaining net cost savings across all truck types.

Large trucking fleet (2.5 trailers per tractor)

In spite of the higher cost of upgrading 2.5 trailers per tractor, fleets can still maximize global warming pollution reductions and fuel savings with the full technology package, while achieving net dollar savings. For long-range trucks, the partial technology package offers the shortest payback period (27 months), and the full technology package costs can be recovered in just over four and a half years (56 months). At $3.24 per gallon of diesel fuel, net dollar savings are about 25 percent lower for the full technology package than for the partial technology package, but fuel consumption and global warming emissions reductions are 25 percent greater. Additional benefits to fleets could accrue, as trailers will likely last longer than the tractors pulling them, given that they are traveling only 2.5 times fewer annual miles.

Similar results are shown for medium- and short-range tractor-trailers; net positive lifetime savings are realized both for the partial and full technology packages. The full technology package offers global warming pollution reductions and fuel savings that are more than 30 percent greater than those of the partial

TABLE 3: Full Technology Packages on New Trucks

Truck Type	% Fuel Economy Improvement	Lifetime Fuel Savings (gallons of diesel fuel)	Global Warming Pollution Savings (metric tons of CO_2 equivalent)	Large Fleet (2.5 trailers per tractor)		Single Tractor-Trailer	
				Payback (months)	Net Savings	Payback (months)	Net Savings
Long-Range Tractor-Trailer	12.8%	17,100	208	56	$17,600	23	$31,700
Medium-Range Tractor-Trailer	11.3%	17,100	208	87	$14,000	34	$27,300
Short-Range Tractor-Trailer	10.1%	13,600	166	101	$5,400	40	$17,900
Straight Trucks	8.1%	2,100	26	N/A	N/A	114	$1,300

Notes: a) Net savings include future fuel savings minus the intial capital cost with a fuel price of $3.24 per gallon of diesel and a discount rate of 7 percent. b) Capital costs for the full technology package are $11,245 for a single tractor-trailer, $24,590 for 2.5 trailers per tractor, and $3,255 for straight trucks. c) Lifetime benefits are accrued over nine years for long-range tractor-trailers, 14 years for medium-range tractor-trailers, and 20 years for short-range tractor-trailers and straight trucks. d) Benefits for fleets and single tractor-trailer owners are calculated over the lifetime of the tractor. Each trailer in a fleet is assumed to travel one mile for every 2.5 miles traveled by a tractor. Because trailers in fleets are traveling fewer annual miles than tractors, they will likely survive longer and accrue benefits over longer periods of time. These additional benefits are not included.

TABLE 4: Partial Technology Packages on New Trucks

Truck Type	% Fuel Economy Improvement	Lifetime Fuel Savings (gallons of diesel fuel)	Global Warming Pollution Savings (metric tons of CO_2 equivalent)	Large Fleet (2.5 trailers per tractor)		Single Tractor-Trailer	
				Payback (months)	Net Savings	Payback (months)	Net Savings
Long-Range Tractor-Trailer	10.0%	13,700	167	27	$23,200	12	$29,500
Medium-Range Tractor-Trailer	8.1%	12,700	155	43	$16,900	19	$23,200
Short-Range Tractor-Trailer	7.1%	9,900	121	60	$9,000	26	$15,300
Straight Trucks	6.8%	1,800	22	N/A	N/A	40	$2,400

Notes: a) Net savings include future fuel savings minus the intial capital cost with a fuel price of $3.24 per gallon of diesel and a discount rate of 7 percent. b) Capital costs for the partial technology package are $5,380 for a single tractor-trailer, $11,680 for 2.5 trailers per tractor, and $1,530 for straight trucks. c) Lifetime benefits are accrued over nine years for long-range tractor-trailers, 14 years for medium-range tractor-trailers, and 20 years for short-range tractor-trailers and straight trucks. d) Benefits for fleets and single tractor-trailer owners are calculated over the lifetime of the tractor. Each trailer in a fleet is assumed to travel one mile for every 2.5 miles traveled by a tractor. Because trailers in fleets are traveling fewer annual miles than tractors, they will likely survive longer and accrue benefits over longer periods of time. These additional benefits are not included.

technology package, with payback periods within the useful life of the tractor-trailer.

At higher fuel prices, payback periods will shorten and lifetime net savings will increase substantially. At $5 per gallon—a level reached in California in July 2008—net savings for either the full technology or partial technology package top $40,000. In addition, fleets with 2.5 or more trailers per tractor can expect to see greater lifetime cost savings with the full technology package compared with the partial technology package.[24]

Straight trucks

There are also cost and fuel savings benefits to retrofitting straight trucks with aerodynamic improvements and better-performing tires. The partial technology package of an aerodynamic add-on in the front of the box above the cab and low-rolling-resistance tires can pay for itself in just over three years (40 months) and save $2,400. Reducing the global warming emissions by another 17 percent with the full technology package achieves $1,300 in savings but has a significantly longer payback period.

In-Use Tractor-Trailers and Straight Trucks

Retrofitting in-use tractor-trailers and straight trucks also offers cost and fuel savings as well as reductions of global warming emissions. For single-truck and trailer owners, the full technology package offers the greatest emissions benefits and positive economic payback for trucks less than 13 years of age, while the partial technology package offers positive savings for trucks and trailers as old as 15 years. Based on fleets with 2.5 trailers per truck, the full technology package offers the greatest emissions benefits and positive economic payback for trucks less than seven years of age, while the partial technology package offers positive savings for trucks and trailers as old as nine years.

As trucks and trailers age, the annual mileages they log decreases, maintenance requirements increase, and reliability declines. Often, after some five to eight years, the trucks move from long-range to medium- or short-range regional operations, in which they typically operate for another 10 years or more. As a result, retrofitting used tractors and trailers can result in fuel-cost savings over the remaining life of the tractor-trailer.

Single truck and trailer (one trailer per tractor)

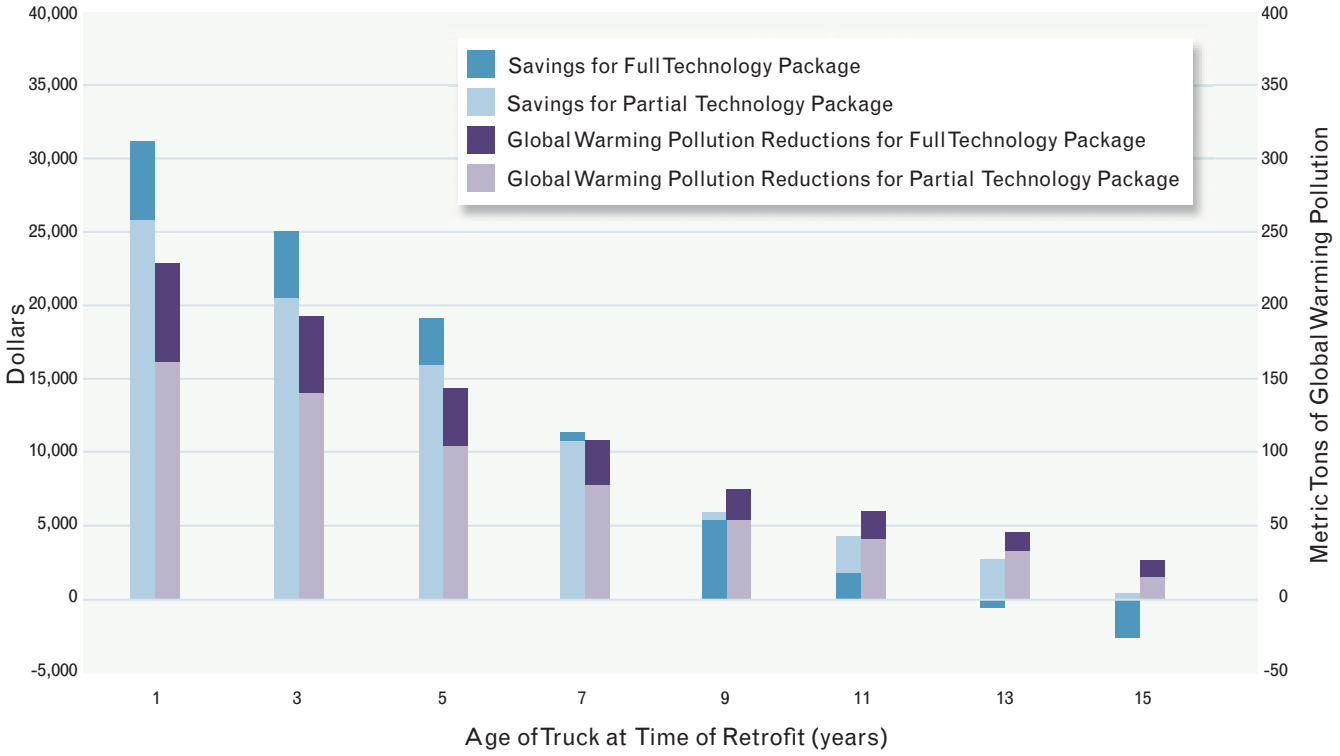
Figure 5 (p. 12) illustrates the expected lifetime fuel-cost savings as a function of the age at which the tractor-trailer is retrofitted. For tractor-trailers under 13 years old, retrofitting with the full technology package offers net cost savings and the greatest global warming pollution reductions over the remaining life of the truck. Even older vehicles between 13 and 15 years old can be retrofitted with the partial technology package and achieve cost savings and additional global warming pollution benefits.

Large trucking fleet (2.5 trailers per tractor)

Figure 6 (p. 12) illustrates the expected lifetime fuel-cost savings as a function of the age at which the tractor-trailer is retrofitted. For tractor-trailers less than seven years old, retrofitting with the full technology package offers net cost savings and the greatest global warming pollution reductions over the remaining life of the truck. Even older vehicles between seven and nine years old can be retrofitted with the partial technology package and achieve cost savings and additional emissions benefits.

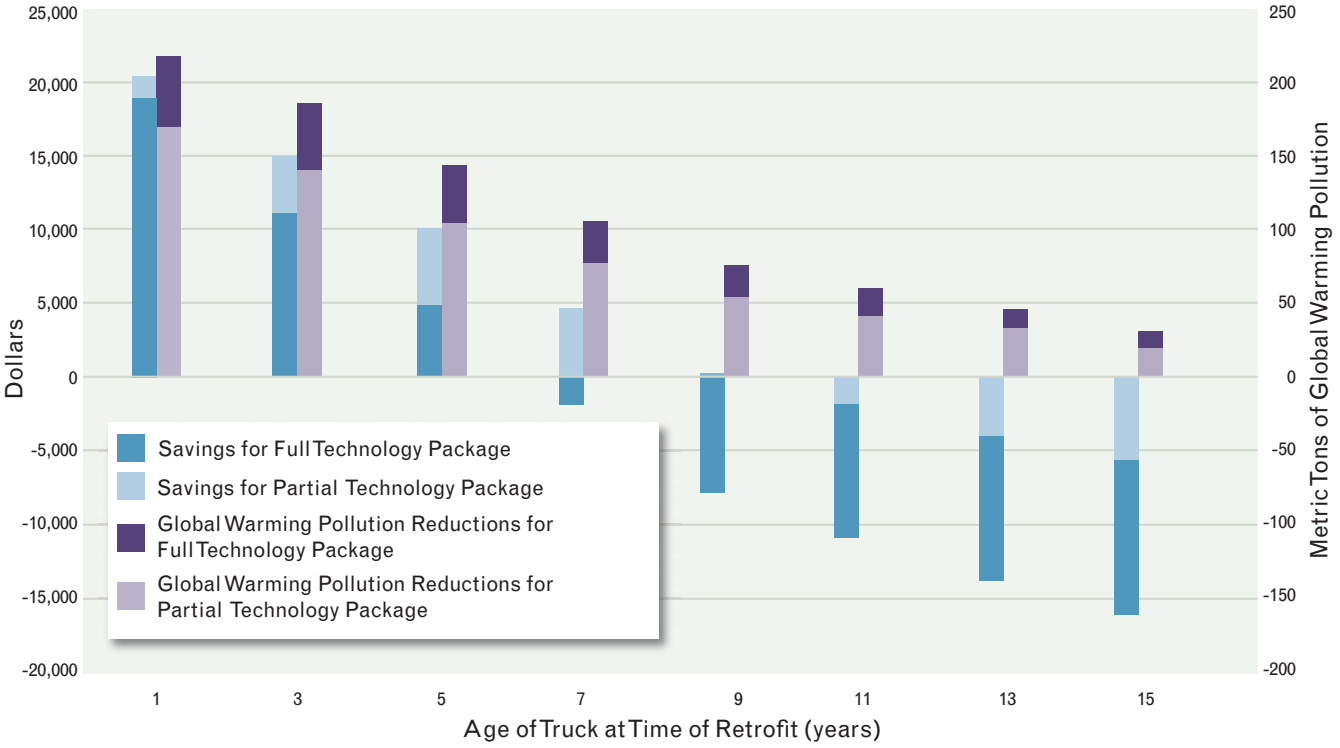
Fleets that operate with fewer than 2.5 trailers, travel more miles than average, or use trailers for longer periods than tractors stand to achieve even greater cost savings and emissions benefits than estimated here.

FIGURE 5: Single Tractor-Trailer In-Use Retrofit Benefits



Notes: a) Assumes a $3.24 diesel fuel price. b) Tractor-trailer moves to regional operation at age 8 and remains in service through age 19. c) Net lifetime savings are expressed in 2008 dollars.
Source: Based on TIAX LLC, September 2008, *Heavy-duty truck retrofit technology: Assessment and regulatory approach*, final report.

FIGURE 6: Trucking Fleet In-Use Retrofit Benefits



Notes: a) Assumes a $3.24 diesel fuel price. b) Tractor-trailer moves to regional operation at age 8 and remains in service through age 19. c) Net lifetime savings are expressed in 2008 dollars.
Source: Based on TIAX LLC, September 2008, *Heavy-duty truck retrofit technology: Assessment and regulatory approach*, final report.

TACKLING CLIMATE CHANGE WITH CALIFORNIA'S TRUCK FLEET

Implementing efficiency improvements in new and in-use trucks and trailers operating in the state will help California meet its 2020 climate goals while saving truck owners money at the pump. Moreover, the co-benefits of NO_x and petroleum reductions will help California meets its air quality and energy security goals.

To estimate the potential in-state and out-of-state benefits of fleet-wide adoption of these technologies, we assume the following:

- The full technology package is used on new tractor-trailers and straight trucks and the partial technology package is applied to in-use trucks.
- Trucks that do not pull box trailers (such as flatbed and tanker trucks) are assumed to benefit from improved tires, wheels, and new aerodynamic tractors but not to benefit from aerodynamic trailer improvements.
- Used tractor-trailers and straight trucks that were put into service before 2010 and travel more than 50,000 miles per year (15,000 miles for straight trucks) are retrofitted between 2010 and 2014.
- Tractor-trailers traveling less than 50,000 miles per year (the average mileage of trucks older than 11 years) are not equipped with retrofits.[25]

California Benefits

In 2020, 2.6 million metric tons (MMT) of global warming pollution would be prevented and 211 million gallons of diesel saved in California by tractor-trailers and straight trucks equipped with efficiency upgrades (Table 5). These reductions represent a 5.5 percent reduction in statewide diesel fuel use in 2020, by which an additional 61 tons of smog-forming NO_x emissions would be eliminated.

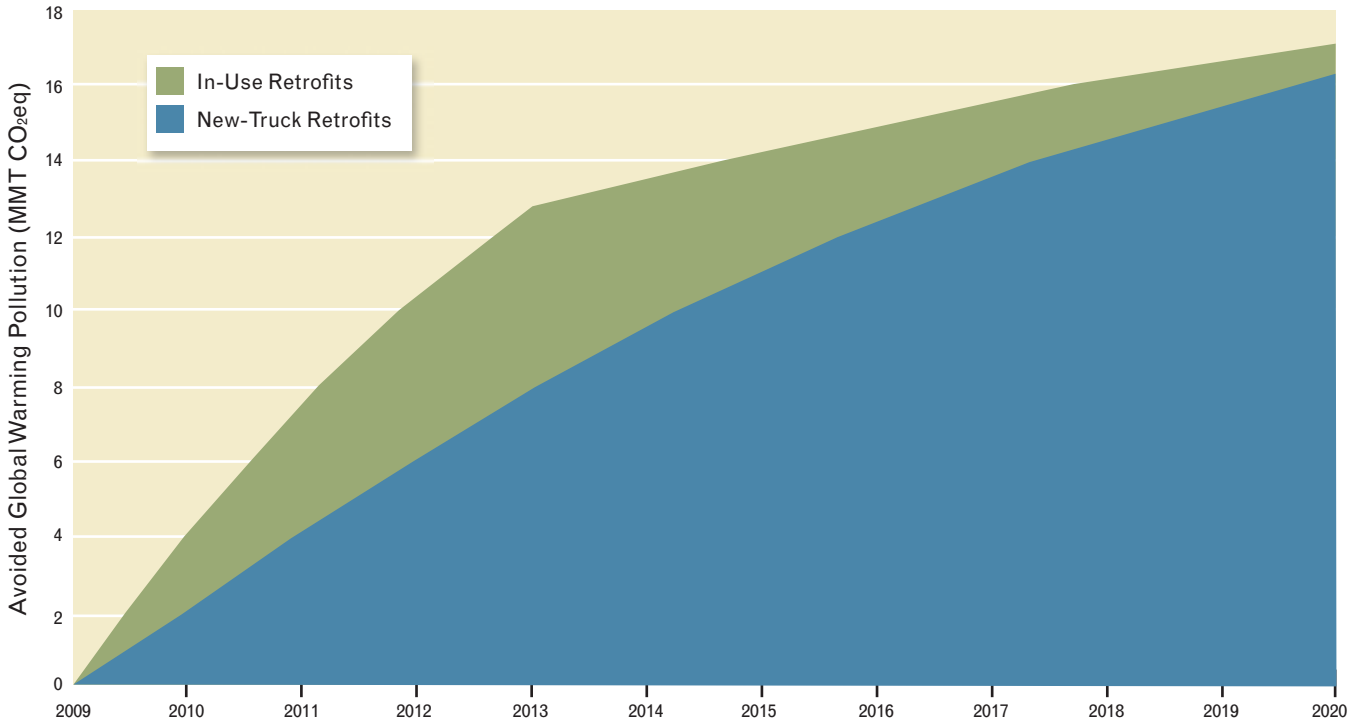
Between 2010 and 2020, a total of 1.7 billion gallons of diesel fuel would be saved and global warming pollution would be reduced by more than 20 MMT.

TABLE 5: Reductions of Global Warming Pollution, Petroleum, and Nitrogen Oxides in California and Nationally

	2020 Diesel Fuel Savings (million gallons/year)	2020 Global Warming Pollution (MMT CO_2eq/year)	2020 NO_x (tons/year)	2010–2020 Fuel Savings (billion gallons)	2010–2020 Cumulative Global Warming Pollution Reductions (MMT CO_2 eq)
In-State California Benefits	211	2.6	61	1.7	20.6
Out-of-State National Benefits	1,210	14.7	412	10.7	123
Total Benefits	1,421	17.3	473	11.8	144

Notes: Global warming emissions estimates include tailpipe and upstream emissions from diesel fuel production.
Source: TIAX LLC, September 2008, *Heavy-duty truck retrofit technology: Assessment and regulatory approach*, final report.

FIGURE 7: Global Warming Pollution Benefits from In-Use and New-Truck Retrofits between 2010–2020



Notes: Global warming emissions estimates include tailpipe and upstream emission from diesel fuel production.
Source: TIAX LLC, September 2008, *Heavy-duty truck retrofit technology: Assessment and regulatory approach*, final report.

National Benefits

Additional emissions reductions would occur from retrofitted vehicles operating outside California, as many of them are driven throughout the country and spend only a fraction of their time in the state. The global warming pollution and fuel benefits occurring outside California are more than five times greater than the in-state benefits alone. In 2020, both in-state and out-of-state benefits would total 17.3 MMT of global warming pollution and 473 tons of NO_x reductions from trucks equipped with efficiency retrofits. Diesel fuel savings would top 1.4 billion gallons annually by 2020, with cumulative savings between 2010 and 2020 reaching nearly 12 billion gallons. At $3.24 per gallon, fuel savings by truck owners and operators during those years would approach $40 billion (undiscounted).

Figure 7 shows the total in-state and out-of-state global warming pollution benefits from truck retrofits and new purchases between 2010 and 2020. While in-use retrofits make up about 10 percent of the annual reductions in 2020, they account for a full 25 percent of the cumulative benefits between 2010 and 2020. The remaining benefits result from equipping new tractor-trailers and straight trucks with the full technology package.

These results show that there is opportunity for the California truck fleet to do its part to meet our climate change challenge, achieve air quality benefits, and reduce petroleum demand while saving money on fuel.

Additional Practices for Reducing Fuel Consumption and Global Warming Pollution

Improvements in aerodynamics and tire rolling-resistance technologies will help to make California's fleet of trucks more fuel-efficient. In addition to these vehicle performance improvements, truck owners and operators can take other steps to reduce their fuel consumption:

Slowing down. The California highway speed limit for tractor-trailers is 55 miles per hour, yet trucks often exceed it. A truck traveling at 70 mph can consume

15 percent more fuel than one traveling at 60.[26] Installing road-speed governors, which restrict a truck's speed, can help ensure that speed limits are being observed.

Keeping tires properly inflated. The use of automatic tire-inflation devices can provide a 0.5 percent or greater improvement in fuel economy.[27] Some fleets, which do not habitually check and maintain tire pressure, may see a more substantial benefit.

Proper maintenance and use of low-friction lubes and oils. Repairing damaged body parts and ensuring proper wheel alignment and tire wear can also reduce fuel consumption. And using low-viscosity synthetic lubes and oils in engines, transmissions, and axles can improve engine and drivetrain efficiency up to 3 percent.[28,29]

Driver training. Fuel-efficient driving, including competent shifting, smooth acceleration, coasting, and adherence to lower speeds are skills that can be developed through proper training. According to the U.S. Environmental Protection Agency (EPA), fleets that invest in driver training can improve overall efficiency by an average of 4 percent, with potential savings up to 20 percent being possible. Implementing driver-incentive programs such as cash bonuses as well as equipping trucks with fuel-economy displays can also decrease fuel use and help maintain driver performance.[30]

Elimination of idling. California has adopted a five-minute idling limit for diesel trucks. Making a habit of turning off the engine when exiting the cab can save fuel, and eliminating overnight idling by using alternative cab heating and cooling devices can save up to a gallon of diesel fuel per hour.

New-truck specifications. When establishing specifications for a new truck, it is important to select components that will maximize fuel economy. EPA SmartWay certification will ensure that the truck or trailer being purchased meets, at a minimum, the SmartWay efficiency requirements.[31] However, additional considerations such as engine size, transmission type, and axle gearing are also important. Minimizing the gap between the tractor cab and the trailer also improves efficiency.

BARRIERS TO CLEANER TRUCKS

Fuel prices directly affect trucks' operating costs, but these expenses do not always translate into adoption of fuel-saving technologies, many of which have been around for decades but are yet to become standard equipment on trucks and trailers. Bad experiences with unproven technology and operating on tight margins can make owners averse to the risk of trying new products, despite data showing that the adoption of more fuel-efficient technology will save money. Standard fuel-economy metrics for heavy-duty trucks do not exist as yet, and certification of efficient retrofit technologies has only begun relatively recently under the EPA's SmartWay program.

Equipping trucks operating in California with today's technology could reduce diesel fuel consumption by 1.4 billion gallons in 2020 and eliminate global warming pollution equivalent to taking 2.5 million cars off the road.

Tractors pulling different trailers on a daily basis, short-term ownership, and split ownership of the tractor and trailer have also created mixed economic incentives. Moreover, while the current price of diesel fuel has spurred interest in fuel efficiency, fluctuating diesel prices and the uncertainty of future prices can stall investments. And access to financing can present a challenge to small fleets and single-truck owner-operators.

Lack of Standards and Testing

When purchasing a passenger vehicle, buyers can compare it with other vehicles in terms of EPA rating (derived from results of government-administered tests) for fuel economy. While the rating may not exactly reflect the exact number of miles per gallon that the new owner will achieve—given variations in driving habits, terrain, and other factors—it does allow for choice based on general performance. Heavy-duty trucks do not have to go through similar testing and are not required to meet an efficiency standard. To overcome this lack of information, large fleets may do their own truck testing with different retrofit devices, but not all trucking fleets or truck owners have the ability to do this type of testing.

Fuel economy standards and testing requirements do not exist for today's heavy-duty trucks, leaving truck buyers without a means for comparison.

Lack of Information and Resistance to Change

Without standards for new trucks, maximizing a truck's fuel economy relies heavily on the knowledge of the purchaser, who must decide which features will be included in the new vehicle and which retrofits may be installed after it is in use. Evaluating the fuel-economy improvement claims of product manufacturers can be challenging, time-consuming, and frustrating. And poor experiences with substandard products can lead to greater skepticism and slower adoption of fuel-saving technology. The EPA's voluntary SmartWay program, which offers certification of tractors and trailers meeting minimum fuel-efficiency requirements, is starting to fill the information gap.

Slow acceptance of certain technologies, such as those that require driver interaction once installed, can be attributed to resistance to changing behavior. For example, rear trailer fairings may need to be stowed before backing to a loading dock, a task that can be completed in well under one minute. Nevertheless, the seemingly small change in operations can deter adoption of this proven fuel-saving technology.

Truck Turnover and Fluctuating Fuel Prices

Investing in fuel efficiency may seem like a sure bet for a truck that could be on the road for over 19 years and travel well over a million miles, but it will likely go through many owners. The short ownership periods relative to trucks' useful lives, coupled with uncertainty in fuel prices, may prevent businesses from considering efficiency upgrades. However, as shown by the results presented in this report, payback periods of 1–2 years are possible with retrofits available today. So even with ownership periods of only a few years, retrofitting can make good business sense. Owners who retrofit their trucks may also recoup some costs at the time of resale.

Trailer Ownership

Often, the tractor and the trailer are owned by different entities. This means that the driver does not have the ability to improve the trailer performance and that the trailer owner may not get the direct benefit of trailer retrofits.

Multiple Trailers per Tractor

While a new long-haul truck might accrue over 130,000 miles per year, a typical trailer may travel only half that distance. Less annual mileage can mean a longer useful life for trailers than tractors, but it also means that it may take longer to recoup an investment in fuel-saving technology. Overall, there are some 2.5 trailers for every tractor on the road today in the United States, based on data from the largest trucking fleets.[32]

Financial Barriers

Upgrading tractors, trailers, and straight trucks requires capital investments that must be paid up front. Some small operators may not have the funds available or may find it difficult to obtain loans with favor-

able terms. Better access to financing for efficiency upgrades could help overcome some of the barriers to installing truck retrofits.

POLICY RECOMMENDATIONS FOR CLEANER TRUCKS

State and federal regulators can play useful roles in helping to overcome barriers and make trucking a more fuel-efficient industry.

In-Use Retrofit Requirements

California can immediately begin to tackle global warming emissions from heavy-duty trucks by getting the most efficient new trucks on the road and retrofitting existing trucks and trailers with proven technologies. Requiring such upgrades can help overcome the barriers of short-term and sometimes split ownership of tractors and trailers and spur greater investment in cost-effective fuel-saving innovations.

Testing and Labeling for Fuel Efficiency and Global Warming Pollution

Large fleets may have the resources to carry out their own fuel-economy testing, but many small fleets and owner-operators do not have that luxury. Universal measures of trucks' fuel efficiency and global warming pollution would allow apples-to-apples comparisons of different manufacturers' vehicles used in similar applications. As part of the SmartWay program, the EPA is currently developing procedures that could be a basis for implementing a testing and labeling program. Similarly, testing and labeling should be required for truck tires and retrofits. Under such circumstances, truckers will have access to the information needed for choosing the most efficient options.

New-Truck Standards

Unlike new passenger vehicles in California, new trucks have no standards for global warming emissions or fuel economy. Modest improvements have been made over the past 30 years and additional ones are likely, but today's fleets largely fail to take advantage of proven technology to reduce fuel consumption. Thus truck manufacturers sell SmartWay-certified truck models alongside classically styled and inefficient trucks, unnecessarily increasing our country's reliance on petroleum and contributing to climate change. Global warming pollution standards for new trucks would help move the entire U.S. truck fleet toward lower emissions and greater efficiency.

The 2007 energy bill (the Energy Independence and Security Act) authorizes the establishment of federal fuel-economy standards, but implementation of such standards will not likely occur until 2016 or later. In the meantime, California should take the lead by developing global warming pollution standards for trucks, as it has for passenger cars, thereby ensuring that technologies for trucks evolve and enter the marketplace as quickly as possible. These standards should also include energy-efficiency requirements for insulated/refrigerated trailers, which rely on small diesel engines to provide climate-controlled cargo areas.

Improved Accessibility to Financing

Many small-fleet and independent owners realize that upgrading their vehicles will yield savings in the long run, but they may not have access to the needed capital. The EPA's SmartWay program and the nonprofit Cascade Sierra Solutions are working to address this financing gap through programs to increase truckers' access to loans with favorable terms. California should expand current diesel-cleanup grants and incentive programs to include loan components that accelerate adoption of fuel-efficient technologies. Loans designed to match retrofits' monthly fuel savings to loan payments could minimize out-of-pocket expenses for trucker owners.

California can help overcome barriers to cleaner trucks by setting in-use and new-truck global warming pollution standards.

Because trucks contribute to the problems of air quality degradation, global warming, and petroleum consumption, they must be part of the solutions. That would be morally just, but there are also some practical incentives. As shown in this report, tackling global warming emissions and excess petroleum consumption will provide overall economic benefits to the operators of heavy-duty trucks. With appropriate policies in place to maximize global warming pollution reductions, California's truck fleet can become a model for the rest of the world in establishing clean and efficient freight transportation.

Endnotes

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This report was written by Don Anair, a senior analyst in the UCS Clean Vehicles Program.

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Delivering the Green

Reducing Trucks' Climate Impacts While Saving at the Pump

Installing available retrofit technology on new and in-use trucks and trailers operating in California could reduce 17 million metric tons of global warming pollution annually by 2020–the same effect as taking 2.5 million cars off the road. Overcoming the barriers to more efficient trucks could save thousands of dollars on fuel costs while helping California meet its petroleum reduction, air quality, and climate change goals.

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