Union of Concerned Scientists

FACT SHEET

HALF THE OIL SOLUTION: HEAVY-DUTY TRUCK EFFICIENCY

Big Rigs, Big Oil Savings

Technologies to reduce heavy-duty truck fuel use and emissions

HIGHLIGHTS

From local delivery vans to the 18-wheel tractor-trailers rumbling down the highway, heavy-duty vehicles are a vital part of our economy. But these vehicles are thirsty for fuel: they consume 25 percent of the fuel used on U.S. roadways even though they make up only 7 percent of the vehicle fleet on those roads.

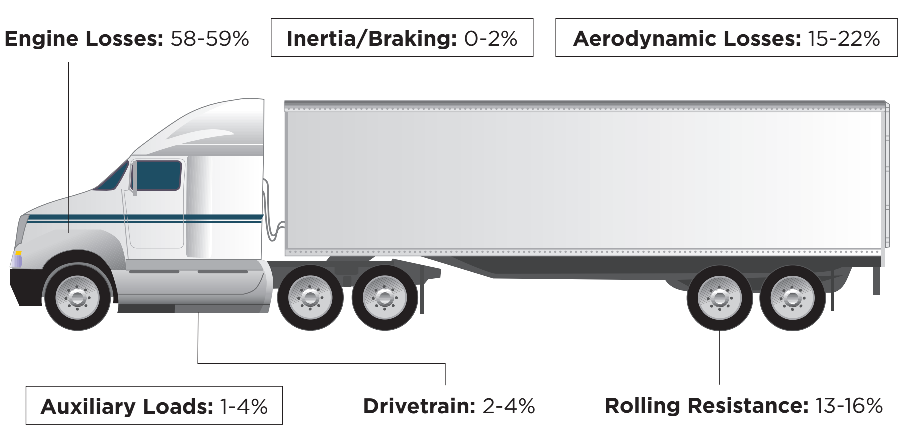
Using technologies available today, and those expected to come to the marketplace in the coming years, we can significantly improve the efficiency of our heavy-duty vehicle fleet and cut oil use by millions of barrels every year. These technologies will save truckers money and reduce global warming pollution while maintaining truck performance and reliability. Strong policies can help spur technological innovation in trucks and other vehicle fleets, getting us on the path to cut projected U.S. oil consumption in half in the next 20 years.

Heavy-duty vehicles—tractor-trailers, buses, and pickup trucks, to name a few—are a vital part of our national economy; they move goods, take our kids to school, and collect our trash. But while these truck and buses make up only 7 percent of vehicles on America's roads, they consume more than a quarter of all the fuel used to travel them.

Fuel economy and global warming standards adopted in 2011, which apply to new trucks sold between 2014 and 2018, will reduce oil consumption from the heavy-duty vehicle fleet by 390,000 barrels per day in 2030, roughly equivalent to the amount of oil we import each year from Iraq. The standards will also cut global warming emissions by 270 million metric tons in 2030, equivalent to the emissions from more than 4 million of today's passenger cars and trucks over their lifetimes. With technologies available in the marketplace today and those under development, we can bring even greater fuel savings and emission reductions to our nation's trucking fleet beyond 2018 and keep us on a path to cutting our nation's projected oil consumption in half in the next 20 years.

To determine the types of technologies that can improve fuel efficiency in heavy-duty vehicles, it's helpful to start by examining where these vehicles lose the most energy (see Figure 1 for an example). There are numerous technologies that can help minimize these losses and make a truck go farther on a gallon of

FIGURE 1. Energy Losses in Tractor-Trailers



At highway speeds, more than half of the energy contained in diesel fuel is lost to inefficiencies in the combustion process of the engine. The remaining energy is used to move the vehicle down the road and to operate auxiliary loads such as air conditioning, heating, and electronics.

SOURCE: NRC 2010

Despite the evolution of engine technology over the past 100 years, the diesel engines used in most of today's tractor-trailers convert less than half of the energy in the fuel to operating the vehicle.

fuel. Described below are some of these technologies, all of which would allow truck manufacturers to meet or exceed existing efficiency standards. Many of these technologies are either available on the market today but not yet deployed widely in truck fleets, or being developed and demonstrated as part of the Department of Energy's (DOE) SuperTruck program.[1]

Engine and Drivetrain Improvements

The internal combustion engine, whether gasoline-, diesel-, or natural gas-powered, converts the chemical energy in fuel into mechanical energy (which propels a vehicle down the road) and heat. Despite internal combustion engine technology having evolved over the past 100 years, the diesel engines used in most of today's tractor-trailers convert less than half of the energy in the fuel to operating the vehicle. Fortunately, engineers continue to find ways to make engines more efficient. The SuperTruck program, for example, has set a goal of increasing engine efficiency to 55 percent and is currently demonstrating many technologies in order to achieve such efficiency.

Engineers are also looking at ways to improve integration of the engine and the transmission, which transfers power from the engine through one or more axles to the wheels. Transmission-related losses can account for up to 6 percent of total heavy-duty vehicle energy losses.

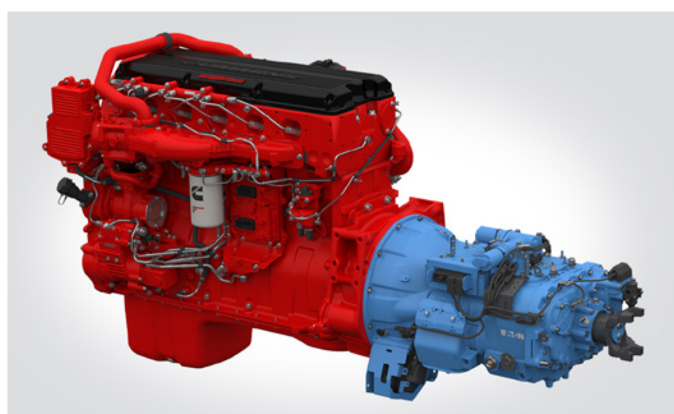
There are a number of potential strategies for improving the efficiency of engines and drivetrains for heavy-duty vehicles. Combining several of these technologies would maximize fuel efficiency gains while maintaining expected vehicle performance.

WASTE HEAT RECOVERY

About a quarter of the energy in a gallon of fuel ends up as heat in the exhaust. Recovering this waste heat and converting it into usable electrical or mechanical energy can help operate the vehicle more efficiently. One promising technology, currently being developed as part of the SuperTruck program, employs a Rankine, or bottoming, cycle (TIAX 2009). Similar to how large steam turbines at power plants work, this technology utilizes excess heat from engine exhaust or engine coolant to evaporate a fluid under pressure; the fluid is then passed through an expander, creating electrical or mechanical power. This technology delivers the most improvement when exhaust gas temperatures are high, which is typical for heavy-duty tractor-trailers traveling at highway speeds. This technology **could offer a 6 to 10 percent reduction in fuel consumption** by tractor-trailers (Koeberlein 2012; NESCCAF et al. 2009).

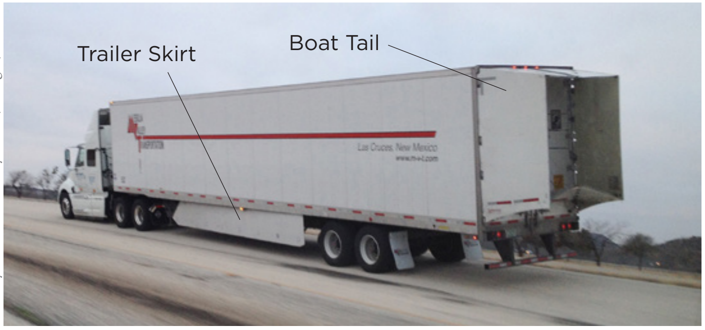
ENGINE DOWNSPEEDING

Another approach to improving efficiency is engine downspeeding, in which the engine is designed to provide more torque at lower revolutions per minute (RPMs), requiring less fuel to operate. Because lower engine speeds require more shifting, engine downspeeding is typically combined with an automated manual transmission (described below). Initial results from SuperTruck research show an estimated **4 percent improvement in fuel efficiency** for downspeeding of a tractor-trailer. Engine downspeeding in smaller trucks used in stop-and-go driving can bring even greater improvements, with one study finding up to a 14 percent improvement in fuel efficiency when advanced controls are combined with a supercharger to boost torque at lower engine RPMs (Keidel et al. 2012).



Courtesy of Cummins Inc. and Eaton

Better integration of the engine (red) and transmission (blue) in a truck's powertrain, along with other improvements such as automated shifting and engine downspeeding, can help improve heavy-duty truck fuel efficiency.



AERODYNAMIC DEVICES FOR TRAILERS

Devices that improve airflow on a tractor-trailer are designed for different areas of the trailer.

AUTOMATED MANUAL TRANSMISSIONS

Manual-shift transmissions have dominated the tractor-trailer segment, primarily because of superior fuel economy and performance compared with automatic-shift transmissions. However, automated manual transmissions (AMTs), which have been recently gaining market share, combine the fuel economy benefits of a manual gearbox with an electronically controlled gearshift, ensuring consistent, fuel-efficient shifting under all conditions (Berg 2012). Electronic sensors help the transmission determine the right gear under the given road conditions, vehicle speed, and load to make optimal shift decisions.[2] Use of AMTs also allows an increase in the number of gears, which would be more difficult to manage without automation,[3] and enables strategies like engine downspeeding and skip-shifting (skipping past gears when they are not needed) (Baxter 2013). This technology could **boost fuel efficiency for tractor-trailers by 4 to 8 percent** and can provide fuel savings in other heavy-duty vehicles as well (TIAX 2009).

Further efficiency improvements to AMTs are possible with improved shifting technology. When shifting gears on a manual or even an automated manual transmission, the engine must be disengaged during the shift. It takes time to return to full power after the shift is completed, which adversely affects fuel consumption. Dual-clutch automated transmissions can eliminate this inefficiency by applying the engine's power to one clutch at the same time as it is being disengaged from the other clutch (Green Car Congress 2012; NRC 2010).

6X2 DRIVE AXLE

Another strategy to reduce drivetrain inefficiencies for tractor-trailers is by using only one drive axle (known as 6x2) instead of the more common two-drive axle (6x4) configuration. The 6x2 axle configuration, which reduces vehicle weight and road friction, accounts for only about 4 percent of the new U.S. long-haul tractor market but is used widely in Europe. Lack of traction in adverse conditions has been noted as the primary concern for adopting this technology. However, load-shifting technologies, which can adjust the weight on the drive axle to provide extra traction when needed, have helped to mitigate this concern. The 6x2 drive axle configuration delivers about a **2.5 percent increase in fuel efficiency** compared with the 6x4 configuration (NACFE 2014).

Aerodynamic Improvements

Aerodynamic drag—the force that acts on an object as it moves through the air—has a significant impact on vehicle fuel efficiency. For a tractor-trailer operating on the highway, aerodynamic drag can account for between 15 and 22 percent of total energy loss (NRC 2010).

As a result of the implementation of model year (MY) 2014–2018 medium- and heavy-duty fuel economy standards, manufacturers are working to optimize the shape of tractors to reduce drag. Many of these new tractors are already making their way into the marketplace. A number of these aerodynamic features are being used on vocational vehicles such as delivery vans and box trucks as well.

Automated manual transmissions combine the fuel economy benefits of a manual gearbox with an electronically controlled gearshift, ensuring consistent, fuel-efficient shifting under all conditions.

TABLE 1. Tractor-Trailer Fuel Economy: Small Improvements Mean Big Savings

Average Fuel Economy	6.5 miles per gallon
Average Annual Mileage	120,000 miles
Annual Fuel Consumption	18,500 gallons
Annual Global Warming Emissions	241 metric tons
Annual Fuel Cost	$72,400

Annual Savings Improving Fuel Efficiency by:	Fuel Savings	Emissions Reductions	Fuel Cost Savings
1%	185 gallons	2.4 metric tons	$700
5%	925 gallons	12.1 metric tons	$3,600
10%	1,850 gallons	24.1 metric tons	$7,200

Long-haul tractor-trailers consume the most fuel of any vehicle on the road, averaging only about 6.5 miles per gallon and traveling more than 100,000 miles per year, and thus stand to gain the most from fuel-saving technologies. The annual emissions savings from just a 10 percent improvement in fuel efficiency for a typical tractor-trailer is equivalent to the annual emissions from nearly four passenger vehicles.

Note: Fuel economy, mileage, and fuel consumption estimates are based on the average new MY 2010 tractor-trailer, using diesel fuel at a cost of $3.90/gallon. Emissions estimates based on 29 pounds of carbon dioxide per gallon of diesel fuel, which includes upstream emissions from extraction and refining.

Improvements to trailers, however, were not included in MY 2014–2018 standards, presenting a significant opportunity for further gains. A number of aerodynamic devices are available for trailers:

- **Gap fairings** reduce turbulence by smoothing the airflow between the tractor and the trailer.
- **Trailer side skirts** (which push air around the wheels) and undertray fairings (which direct the airflow under the axles to the rear of the trailer) reduce turbulence between the trailer and the road.
- **Boat tails, vortex stabilizers**, and other end fairings help to smooth air flow at the rear of the trailer.

Applying a combination of these technologies to 53' box van trailers, which make up more than 70 percent of the trailers in today's fleet, **can reduce fuel consumption by up to 12 percent** (NRC 2010). Further advances in tractor-trailer aerodynamics through both technology refinement and innovation are being pursued to achieve even greater fuel savings and emission reductions.

Tire and Wheel Improvements

Tractor-trailers and other heavy vehicles lose a lot of energy to the friction of tires rolling on the road. Indeed, rolling resistance in tractor-trailers operating on the highway can account for between 13 and 16 percent of their total energy losses (NRC 2010), compared with 5 to 7 percent for the average passenger vehicle (NRC 2011). Low rolling resistance tires can improve vehicle fuel efficiency by minimizing the energy lost to friction and flexing of tires under load, ensuring that more energy is used to propel the vehicle down the road and **reducing fuel consumption by 3 percent or more** (EPA n.d.).

In addition to standard low rolling resistance tires, single-wide tires (also sometimes called wide-based single tires or "super singles") work in place of the two tires typically seen on each end of the axle. They provide the same performance as the two tires, but weigh about 100 pounds less (or 200 pounds per axle). Single-wide tires, which currently account for a small share of new tire sales (NACFE 2013a), can **improve fuel efficiency 5 percent** when used on either the tractor or the trailer and by 8 percent when used on both (Franzese, Knee, and Slezak 2009).

Just as with cars, maintaining proper tire inflation is crucial to optimizing truck fuel efficiency. Tire pressure monitoring systems and automatic tire-inflation systems not only help to reduce tire wear and improve the lifetime of the tire but also can **decrease fuel consumption by as much as 1.5 percent** (NACFE 2013b).

Courtesy of Michelin North America

Single-wide tires (left), which replace a traditional dual-tire configuration (right), not only weigh less but also can improve fuel efficiency by reducing the amount of energy lost to tires flexing during travel.

Courtesy of Daimler Trucks North America

Establishing strong standards can help move improvements like advanced aerodynamic design from the test tunnel to the roadway.

Hybridization

Hybrid-electric trucks combine a conventional internal combustion engine with an electric motor, batteries, and braking-energy capture (called regenerative braking). Braking energy stored in the batteries can be used by the electric motor to help propel the vehicle; the additional power provided by the motor may allow the internal combustion engine to be smaller than that of a standard truck. Hydraulic hybrids work in a similar manner, but braking energy is stored as a pressurized fluid rather than in batteries. Hybrid-electric trucks can travel farther than their conventional diesel counterparts before refueling, while the regenerative braking system can extend brake life.

Several truck manufacturers are now offering hybrid models, and thousands of hybrid systems are already being used in vehicles ranging from public-transit and school buses to package- and beverage-delivery trucks (for example, see Eaton 2012). A review by the National Academy of Sciences found that **fuel-consumption reductions of up to 50 percent** are possible with current hybrid truck technologies, depending on the type of truck, the application, and specific hybrid technology used (NRC 2010). Hybridization offers the largest fuel savings in vehicles that frequently stop and start such as garbage trucks, buses, and delivery vehicles; however, hybridization is also being considered for long-haul highway operations as well (TIAX 2009).

While hybrid-electric powertrains are the most mature electric-drive truck technology presently on the road, plug-in hybrid, battery-electric, and fully electric vehicle systems are all being pursued to improve efficiency and reduce emissions.[4]

Conclusion

Innovative fuel efficiency technologies, like the ones described above, are helping to make our nation's tractor-trailers, vocational trucks, and heavy-duty pickups and vans go farther using less oil, without sacrificing performance. Improved fuel efficiency reduces the environmental impacts associated with oil use as well as the fuel cost of transporting goods across the country. Standards adopted for MY 2014–2018 are helping to accelerate the deployment of more fuel efficient trucks; establishing standards for 2019 and beyond that support even greater improvements in fuel efficiency, and apply to trucks as well as the trailers they pull, can help continue to drive further innovation and gets us on track to cut our nation's projected oil use in half over the next 20 years.

ENDNOTES

1 *For further information on the SuperTruck program (also called the 21st Century Truck Partnership) visit* http://www1.eere.energy.gov/vehiclesand-fuels/about/partnerships/21centurytruck.

2 *For an example of an AMT with electronic sensor capability, see* http://www.volvotrucks.com/trucks/na/en-us/products/powertrain/ishift/pages/ishift_ILF.aspx

3 *Increasing the number of gears in a manual transmission can enable greater fuel efficiency but also increases the amount of shifting, leading to driver fatigue.*

4 *For further information on opportunities for truck electrification, see UCS 2012.*

> **The annual emissions savings from a 10 percent improvement in fuel efficiency for a typical tractor-trailer is equal to the annual emissions from nearly four passenger vehicles.**

REFERENCES

Baxter, J. 2013. Acceptance of AMTs grows, makers say. *Transport Topics*. Online at *http://www.ttnews.com/articles/petemplate.aspx?storyid=31574*, accessed February 18, 2014.

Berg, T. 2012. Automated mechanical transmissions gaining steadily in Class 8 trucks. *Trucking Info*, March. Online at *http://www.truckinginfo.com/channel/equipment/article/story/2012/03/automated-mechanical-transmissions-gaining-steadily-in-class-8-trucks.aspx*, accessed February 18, 2014.

Eaton Corporation. 2012. Eaton hybrid power expert to speak on the benefits of system integration at Alternative Clean Technologies Expo. Online at *http://www.eaton.com/rr/OurCompany/NewsEvents/NewsReleases/PCT_359416*, accessed September 11, 2012.

Environmental Protection Agency (EPA). No date. About the SmartWay Technology Program. Online at *http://www.epa.gov/smartway/forpartners/technology.htm*, accessed January 28, 2014.

Franzese, O., E. Knee, and L. Slezak. 2009. Effect of wide-based single tires on Class-8 combination truck fuel efficiency. Washington, DC: Department of Energy. Online at *http://cta.ornl.gov/cta/Publications/Reports/Effect%20of%20Wide-Based%20Single%20Tires%20on%20Class-8%20Combination%20Truck%20Fuel%20Efficiency.pdf*, accessed January 28, 2014.

Green Car Congress. 2012. Volvo Trucks launches new FH heavy-duty truck; I-Torque and I-See cut fuel consumption by up to 10%. Online at *http://www.greencarcongress.com/2012/09/fh-20120906.html*, accessed February 18, 2014.

Keidel, S., P. Wetzel, B. Biller, K. Bevan, and A. Birckett. 2012. Diesel engine fuel economy improvement enabled by supercharging and downspeeding. *SAE International Journal of Commercial Vehicles* 5(2):483-493, doi:10.4271/2012-01-1941. Online at *http://papers.sae.org/2012-01-1941*, accessed February 18, 2014.

Koeberlein, D. 2012. Cummins SuperTruck Program: Technology and system level demonstration of highly efficient and clean, diesel powered Class 8 trucks. Online at *http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2012/adv_combustion/ace057_koeberlein_2012_o.pdf*, accessed February 18, 2014.

National Research Council (NRC). 2010. *Technologies and approaches to reducing the fuel consumption of medium- and heavy-duty vehicles*. Washington, DC. Online at *http://www.nap.edu/catalog.php?record_id=12845*, accessed February 18, 2014.

National Research Council (NRC). 2011. *Assessment of fuel economy technologies for light-duty vehicles*. Washington, DC. Online at *http://www.nap.edu/catalog.php?record_id=12924*, accessed February 21, 2014.

North American Council for Freight Efficiency (NACFE). 2013a. Fleet fuel efficiency benchmark study. Online at *http://nacfe.org/wp-content/uploads/2014/01/NACFE-2013-Study-Report-FINAL-March.pdf*, accessed February 18, 2014.

North American Council for Freight Efficiency (NACFE). 2013b. Tire pressure systems – Confidence report. Online at *http://nacfe.org/wp-content/uploads/2014/01/TPS-Detailed-Confidence-Report1.pdf*, accessed February 18, 2014.

North American Council for Freight Efficiency (NACFE). 2014. Trucking efficiency: Confidence findings on the potential of 6x2 axles. Executive summary. Online at *http://nacfe.org/wp-content/uploads/2014/01/Trucking-Efficiency-6x2-Confidence-Report-FINAL-011314.pdf*, accessed February 13, 2014.

Northeast States Center for a Clean Air Future (NESCCAF), International Council for Clean Transportation (ICCT), Southwest Research Institute (SwRI), and TIAX, LLC (TIAX). 2009. Reducing heavy-duty long haul combination truck fuel consumption and CO_2 emissions. Online at *http://www.theicct.org/sites/default/files/publications/HDVemissions_oct09.pdf*, accessed March 14, 2014.

TIAX, LLC (TIAX). 2009. *Assessment of fuel economy technologies for medium- and heavy-duty vehicles*. Report to the National Academy of Sciences. Cambridge, MA.

Union of Concerned Scientists (UCS). 2012. Truck electrification: Reducing emissions and cutting oil use. Fact sheet. Online at *http://www.ucsusa.org/assets/documents/clean_vehicles/Truck-Electrification-Cutting-Oil-Consumption-and-Reducing-Pollution.pdf*, accessed February 18, 2014.

NATIONAL HEADQUARTERS
Two Brattle Square
Cambridge, MA 02138-3780
Phone: (617) 547-5552
Fax: (617) 864-9405

WASHINGTON, DC, OFFICE
1825 K St. NW, Suite 800
Washington, DC 20006-1232
Phone: (202) 223-6133
Fax: (202) 223-6162

WEST COAST OFFICE
2397 Shattuck Ave., Suite 203
Berkeley, CA 94704-1567
Phone: (510) 843-1872
Fax: (510) 843-3785

MIDWEST OFFICE
One N. LaSalle St., Suite 1904
Chicago, IL 60602-4064
Phone: (312) 578-1750
Fax: (312) 578-1751