Big Rigs, Big Oil Savings

Technologies to reduce heavy-duty truck fuel use and emissions

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 trucks 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

<table>
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<th>Engine Losses: 58-59%</th>
<th>Inertia/Braking: 0-2%</th>
<th>Aerodynamic Losses: 15-22%</th>
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<td>Auxilary Loads: 1-4%</td>
<td>Drivetrain: 2-4%</td>
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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.

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).

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.
**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. Use of AMTs also allows an increase in the number of gears, which would be more difficult to manage without automation, 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.

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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).

![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.](image-url)
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/vehiclesandfuels/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.