RESEARCH AND DEVELOPMENT OPPORTUNITIES FOR HEAVY TRUCKS

US DEPARTMENT OF ENERGY

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Introduction

Heavy-duty long-haul trucks are critical to the movement of the Nation's freight. These vehicles, which currently consume about 10 percent of the Nation's oil, are characterized by high fuel consumption, fast market turnover, and rapid uptake of new technologies. Improving the fuel economy of Class 8 trucks will dramatically impact both fuel and cost savings. This paper describes the importance of heavy trucks to the Nation's economy, and its potential for fuel efficiency gains.

Why Focus on Heavy Trucks?

Large and Immediate Impact

Investments in improving the fuel economy of heavy Class 8 trucks will result in large reduction in petroleum consumption within a short timeframe. While heavy-duty vehicles make up only 4% of the vehicles on the road, they account for more than 20% of the fuel consumed in the U.S. Because Class 8 heavy trucks have a high per-vehicle fuel use, rapid fleet turnovers and strong market incentives to implement new efficiency technologies, RD&D activities have very high return on investments for both the truck operator and the Federal Government. History has demonstrated that the industry is ready and willing to accept new technologies that provide fuel economy benefits, as these can translate into competitive advantages in the market. Finally, because much of the research, development, and production of these Class 8 trucks is done here in the United States, improvements in fuel efficiency will enable additional sales of these trucks and have direct job benefits.

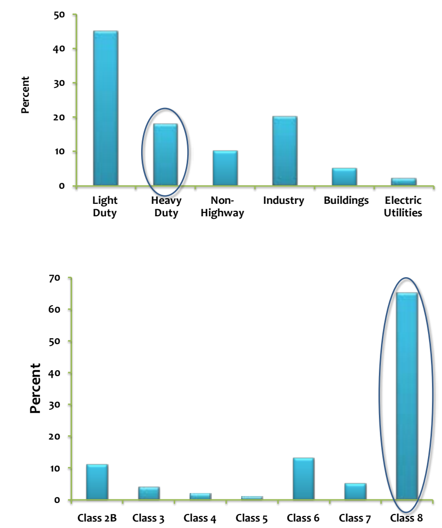

Figure 1. Petroleum Use by Sector in 2007 (top) and Petroleum Use by Truck Class (bottom)

Figure 2. Distribution of Truck Fleet Annual Average Miles of Travel (Data Source: 2002 Vehicle Inventory and Use Survey, EC97TV-US U.S. Bureau of the Census, Washington, D.C., 2002.)

Fleet Use Characteristics

The heavy-duty truck fleet turns over twice as fast as the light-duty automotive fleet, with the trucks with the highest annual use (Class 8 long-haul) turning over in about three years. These newest trucks travel between 150,000 and 200,000 miles per year, making their energy demand a significant portion of the total commercial truck fuel use. In fact, 50 percent of the trucks in the Class 8 segment use 80 percent of the fuel.

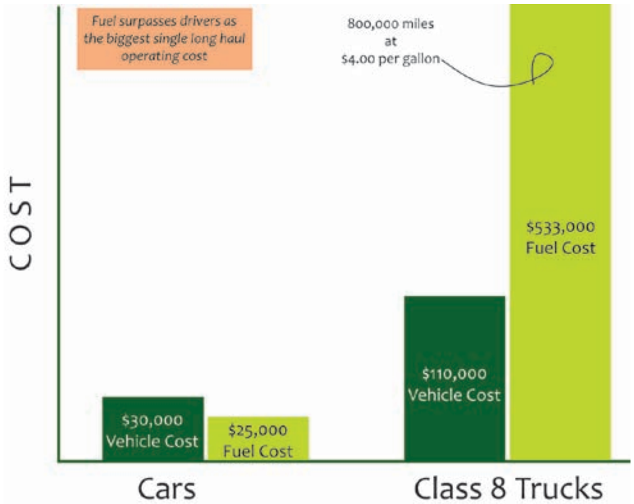

Figure 3. Relative Fuel and Vehicle Costs for Cars and Heavy Trucks.

Truck fuel cost is a key driver for adopting new technology. As Figure 3 shows, the lifetime fuel cost for an average passenger car is similar to the vehicle's original purchase price. This is in great contrast to the Class 8 truck, where lifetime fuel costs are around five times that of the original purchase price for the vehicle.

Operator Return on Investment

As described above, fuel is often the number one expense for truck fleets: annual fuel cost for Class 8 long-haul trucks can be in the range of $70,000 to $125,000. Because fleets operate on razor thin 1-2% profit margins, increased truck fuel economy increases the company's profits, and dramatically improves their chances of survival in tough business climates. For example, a 20 percent improvement in fuel economy can save $14,000 to $25,000 per year. With these large annual savings, paybacks for energy efficient technologies in Class 8 trucks can often be less than a single year – which is five to ten times shorter than new technologies in passenger vehicles.

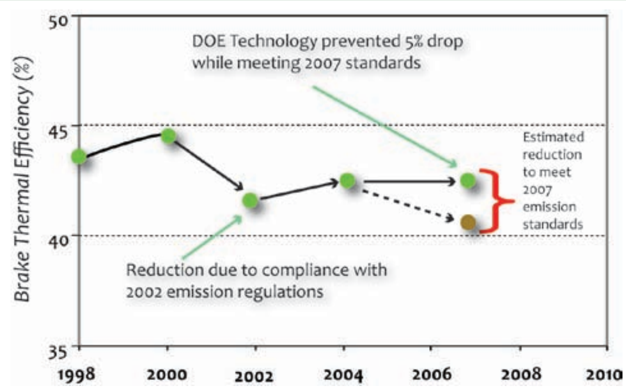

Figure 4. Recent History in Truck Engine Efficiency

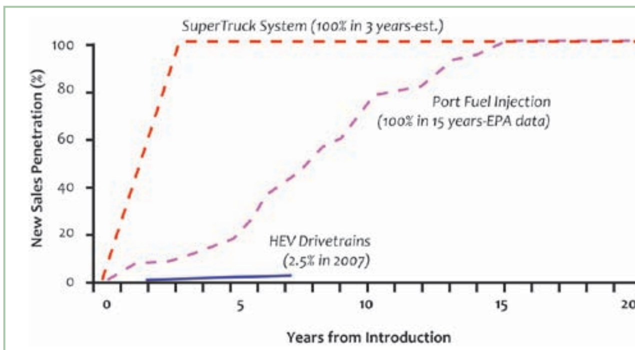

Figure 5. New Technology Can Penetrate Class 8 Truck Market in Three Years

Federal Return on Investment

The return on investment on the Federal government's funding of heavy vehicle research has been excellent. The Federal return on investment is greater than 60 to 1 ($7.7 billion in fuel savings from $125 million in research funding) for technologies developed from Federal research between 1999 and 2007 (benefits were calculated for model years 2004 to 2008). This dramatic return on Federal investment resulted in a national payback of approximately two months. In addition, because of the direct relationship between fuel saved and greenhouse gases avoided, these investments result in significant GHG emissions reductions of 25 million metric tons of CO_2. Vehicle operators have a negative cost of avoiding greenhouse gases: they save about $256 for each ton of CO_2 reduced.

Industry Willing to Adopt New Technology

Historic data have shown that DOE-sponsored technologies have been quickly adopted within the heavy truck fleet. The graphic in Figure 4 shows the effects of engine and emissions technologies developed in joint DOE/industry research efforts: these technologies were adopted by all major engine manufacturers and mitigated potential efficiency reductions that could have resulted from meeting the 2007 emissions standards. At a company level, technologies can typically be implemented across a range of engine models within the first year. Nationally, technologies developed for the Class 8 market are typically implemented in three years or less, and quickly penetrate into the Class 6 and 7 markets because of the similarity of these vehicle classes (see Figure 5).

Domestic and International Markets

Implementing energy efficient technologies for heavy vehicles will have a significant impact on the nation's petroleum consumption. According to the DOE Energy Information Administration's Annual Energy Outlook (AEO) 2009, U.S. heavy truck fuel consumption will increase 23 percent between 2009 and 2020 (because of economic growth drivers for freight transportation), while fuel use of light-duty vehicles will increase only 1 percent over the same period (because of corporate average fuel economy regulations and other factors driving light-duty vehicle fuel efficiency gains). This will make heavy trucks a more significant portion of the total transportation fuel use picture, and will mean that heavy truck fuel efficiency will be even more important in the future.

Truck fuel efficiency research can have an effect on the world market as well. First, a portion of the used trucks from the U.S. market are sold into secondary markets in foreign countries, so if these used trucks contain advanced fuel efficiency technologies, they will provide benefits to these countries as well. In addition, worldwide energy demand continues to grow, especially in non-OECD countries like China and India. These countries can benefit from the technologies developed and produced here in the U.S.

Figure 6. Illustration of Truck and Engine Manufacturing in North America

Domestic Jobs

Trucking is critical to the domestic economy. Trucks haul 69 percent of all freight tonnage, and collect 84 cents of every dollar spent on domestic freight transportation. There are almost 9 million people in trucking-related jobs, including over 3 million truck drivers. Many of these drivers are not part of large fleets, but are independent owner-operators (87 percent of fleets operate less than 6 trucks).

About 15 percent of trucking jobs are in manufacturing, in plants across North America. The market for the products resulting from this manufacturing effort is changing, as Caterpillar announced its withdrawal from the on-highway engine market effective in 2010, but PACCAR is entering the engine market with its own engines to be produced at a new plant in Mississippi. Also, Navistar is expanding its own engine offerings to sizes up to 15 liters (appropriate for Class 8 over-the-road trucks).

Lastly, it should be noted that most trucks used in the U.S. are designed for the North American market, in contrast to the light-duty market. At present, there is very little competition from imported vehicles because of differing regulations and customer needs.

A New Metric for Truck Fuel Efficiency

A critical issue with regard to truck fuel efficiency is the metric used to measure it. Miles per gallon is the most common measure for fuel economy: it is very common for light-duty vehicles, and is shown on vehicle window stickers, corporate advertising, and fuel economy websites. It is used in the light-duty market for compliance with corporate average fuel economy regulations, as well.

When measuring the fuel economy of heavy duty trucks it is a more meaningful measure to consider how much freight is moved per gallon of fuel. This fuel efficiency metric is known as "freight efficiency" and is most commonly expressed on a weight basis (ton miles per gallon). Freight efficiency is a superior metric because it recognizes the contribution of "avoided trips" to fuel savings (more freight per vehicle means fewer vehicles overall, typically resulting in fuel saved).

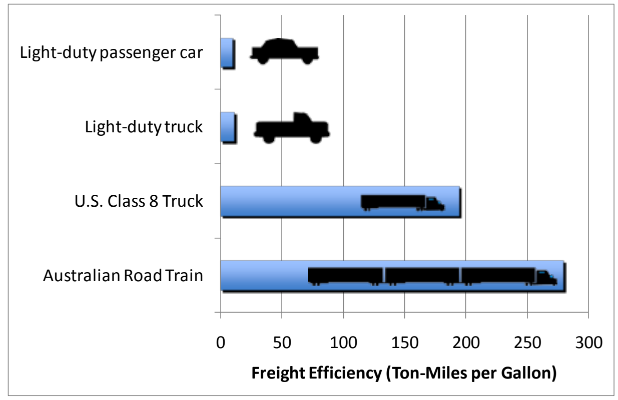

Figure 7. Sample Freight Efficiencies. (NOTE: The Road Train is a trucking concept used in Australia, similar to U.S. turnpike doubles. This concept uses a single Class 8 tractor to pull two or three standard semitrailers to increase the total cargo capacity pulled by each tractor.)

Some sample freight efficiencies (in ton miles per gallon) are shown in Figure 7. Note that a light-duty truck, despite its significantly higher miles per gallon than a Class 8 truck, achieves much lower freight efficiency because of its limited cargo capacity relative to the Class 8 truck.

R&D Opportunities for Heavy Trucks

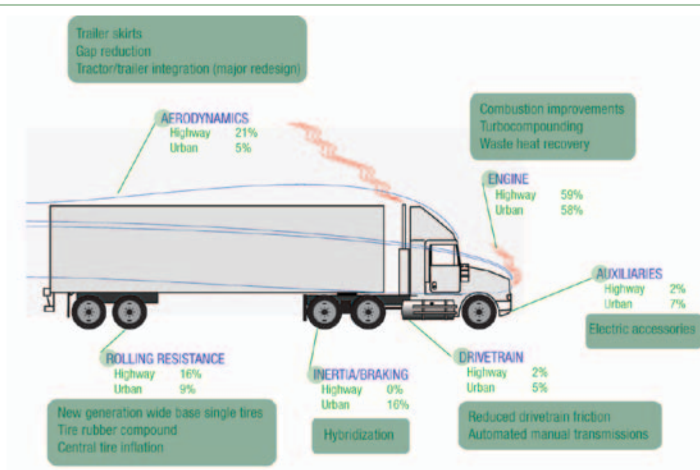

Figure 8. Energy Balance of Typical Class 8 Tractor/Semitrailer Combination Unit

Overview

Opportunities for increasing the freight efficiency of heavy trucks could entail improving the energy efficiency of Class 8 trucks, implementing new logistics technology to minimize empty or partly-loaded trucks and revisiting regulations that unnecessarily limit the size, shape and configurations of long-haul Class 8 trucks. Areas to be considered for technology R&D include improving engine systems, aerodynamics, tire rolling resistance, idle reduction, and drivetrain optimization (including hybridization).

A transformed truck system is required to realize significant savings, and requires that the truck and trailer be considered as a complete system, addressing all the significant areas of energy use as shown in Figure 8. As this figure illustrates, there are potential technology solutions for each of the truck's major components. Some specific technology opportunities for truck systems are listed below:

- Engine: advanced combustion, waste heat recovery (bottoming cycles, turbocompounding, thermoelectrics, etc.), friction and wear reduction, optimized aftertreatment
- Aerodynamic drag: trailer gap reduction (on tractor or trailer), trailer wake treatments, trailer side skirts
- Drivetrain optimization: friction and wear reduction, hybridization (even for Class 8 long haul)
- Accessory load reduction: electrification of accessory loads like power steering and air conditioning (synergistic with electric hybrid technology

Barriers to Success

There are several barriers of a technology or market nature that would hinder the success of future efficiency improvement efforts. These barriers will need to be addressed through technology R&D.

Engine/advanced combustion

A solid fundamental knowledge of engine combustion is needed to enable additional engine efficiency improvements and minimize risk in developing these improvements, especially with more advanced combustion techniques like homogeneous-charge compression ignition (HCCI). Robust and effective emission control devices that enable compliance with prevailing emission standards with minimal impact on fuel efficiency are needed. More advanced and sophisticated engine control strategies and equipment are needed to enable use of low-temperature combustion for high efficiency and low emissions.

Advanced energy storage

For hybrid or idle reduction systems, efficient and durable energy storage is needed. Advanced battery chemistries will need to be explored: truck duty cycles and power requirements are very different from those experienced with light-duty vehicles.

Advanced materials

For lightweight and durable tractors and trailers, advanced lightweighting materials will be needed, like low-cost carbon fiber.

Truck systems

Trucks are already efficient at freight movement, so making transformational strides in efficiency will require a radical rethinking of all aspects of truck design (integration of truck and trailer designs for aerodynamics, rethinking of truck structure, etc.) Truck manufacturing, while more integrated than in the past, still involves many separate manufacturing entities (truck OEMs, engine manufacturers, Tier 1 suppliers, trailer manufacturers, truck body manufacturers). Trucks, especially Class 8 trucks, are almost custom-made: systems integration is a complex issue that might involve multiple engines, multiple drivelines, multiple aero configurations, etc. For Class 8 long-haul trucks, analysis has shown there is much opportunity in trailer aerodynamics: however, there is much less incentive for trailer energy efficiency technologies (inexpensive trailers, mismatch of benefits and investor – the trailer owner who pays for the technology and the truck owner who benefits from the fuel savings). Regulatory changes may be required:

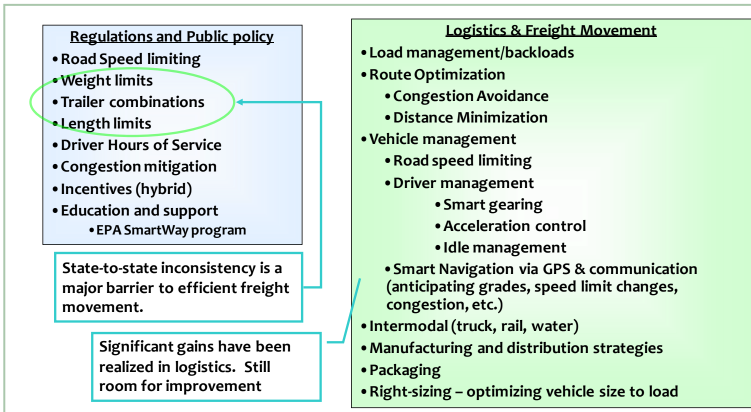

Figure 9. Key Factors in HD Truck Efficiency Regulation and Logistics

increased size and weight for Class 8 trucks (for improved freight efficiency), national speed limit regulations for trucks, consistent idling reduction regulations, etc. (see Figure 9).

Potential Benefits

The chart in Figure 10 shows the potential benefits to the Nation of one possible set of R&D efforts. The benefits are composed of three major components, also shown in the Figure: engine-related benefits (direct engine efficiency, waste heat recovery, and so forth); non-engine related benefits (aerodynamics, rolling resistance, etc.); and logistics/regulatory/behavioral benefits (changes in truck size and weight regulations, load management, speed limiters, etc.)

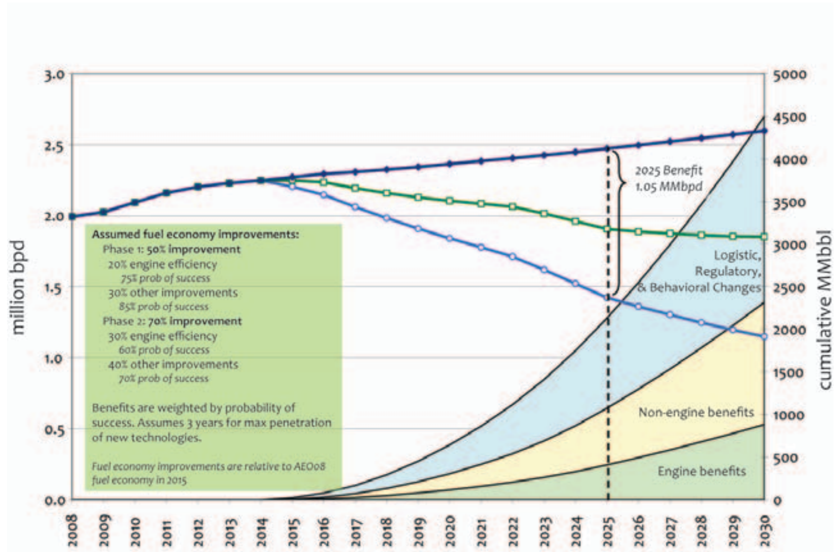

Figure 10. SuperTruck Potential Benefits – DOE's View