Abstract

Many strategies have been identified to improve trucking fuel efficiency and reduce air emissions, including emissions of greenhouse gases (GHGs). Strategies can be broadly categorized as either technological (changing the physical characteristics of a truck) or operational (changing the ways trucks are utilized). To date, EPA’s SmartWay Transport Partnership has focused primarily on increasing the market penetration of technological strategies for long-haul combination trucks. This paper examines the potential for GHG emission reductions and fuel savings from trucking-sector strategies that are not currently a central focus of the SmartWay program. In particular, the paper examines the potential GHG emissions reductions from operational strategies across the trucking industry and from strategies (both technological and operational) for short-haul trucks engaged primarily in urban operation.

Diesel-electric hybrid trucks have by far the greatest potential emissions benefit among the strategies analyzed. This strategy results in large efficiency gains and could be applied to large segments of the truck population. Other technological strategies with the greatest emission reduction potential are transmission adjustment for single-unit van body and utility trucks, and automatic engine shutdown for nearly all single-unit trucks. Among operational strategies, those with the greatest potential emissions benefit are improved pallet loading for long-haul, van-trailer combination trucks and speed reduction for long-haul owner-operators.
**Introduction**

Freight trucks are a large and growing source of U.S. greenhouse gas (GHG) emissions. They account for only about 7% of U.S. vehicle miles traveled (VMT) but produce 26% of total on-road carbon dioxide (CO₂) emissions. GHG emissions from freight trucks have increased at a significantly faster rate than emissions from light-duty vehicles and most other freight modes. As a result, freight trucks’ share of total on-road GHGs has grown substantially since 1990. Figure 1 illustrates the relative change in transportation GHG emissions by mode from 1990 to 2008.

Figure 1: Relative Change in Transportation GHG Emissions by Mode, 1990-2008

![Graph showing relative change in transportation GHG emissions by mode from 1990 to 2008.](chart.png)


Part of this increase in truck emissions during this period was due to robust growth in freight demand. However, the other major factor was the notable lack of improvement in fuel efficiency in the trucking sector. At least some analyses suggest that between 1990 and 2005, trucking GHG emissions per ton-mile actually increased by 10% (1). The reasons for this increase are not well understood, but are likely related to the following: market demand for more powerful engines, requirements for advanced emission control devices that may have compromised fuel efficiency, a decline in operational efficiency, and the elimination of mandatory highway speed limits. There are many factors (e.g., widening of the Panama Canal) that could affect total VMT and GHG emissions of U.S. trucks in the future.
Many strategies to improve trucking fuel efficiency and reduce GHG emissions have been identified. They can be broadly categorized as technological strategies (which change the physical characteristics of a truck) or operational strategies (which change the way trucks are utilized). To date, EPA’s SmartWay Transport Partnership has focused primarily on increasing the use of technological strategies for long-haul combination trucks. Thus far, the SmartWay program has evaluated and verified the fuel-savings and emissions reduction benefits of the following types of technologies: idle reduction (e.g., auxiliary power units), aerodynamics (e.g., trailer gap reducers), and low-rolling-resistance tires.

Due at least in part to SmartWay, the market penetration of those technologies has increased in the long-haul combination segment of the trucking industry. This paper examines the potential for fuel savings and GHG emission reductions from strategies that are not currently a central focus of the SmartWay program and that could be adopted voluntarily by individual carriers. To identify the strategies analyzed in this paper, we reviewed the literature to develop a master list and then winnowed this list to those strategies that had potentially large national benefits and for which information was available. If the potential for GHG emissions from these strategies is significant, then new approaches may be needed to promote them and make them financially attractive to carriers.

**Literature Review**

Over the last decade, there has been significant interest by policy makers and other stakeholders in reducing the fuel consumption and air emissions of freight trucks. This interest has generated a large research literature on technological and operational strategies to reduce emissions. Some of this research was conducted under the auspices of EPA’s SmartWay Transport Partnership to encourage the voluntary adoption of new technologies and business practices. (2) (3) (4) U.S. DOE has also conducted studies as part of its 21st Century Truck Program and other energy efficiency programs. (5) (6) (7) (8) U.S. DOT has an active research program as well. (9) In the last several years, as EPA has considered the creation of GHG regulations for freight trucks, there has been an increased focus on estimating the costs and benefits of heavy-duty vehicle technologies to improve aerodynamics, reduce rolling resistance, and improve engine efficiency. (10) (11) (12) (13)

Among operational strategies, long-haul truck idling has received substantial attention (14) (15), but other operational strategies have been less thoroughly considered. Although opportunities to reduce GHG emissions from the medium-duty truck fleet have been examined in existing studies (16) (17) (18), there is still a significant research need to quantify the opportunities in this sector.

This paper presents the results of research on a number of technological and operational strategies that have received less attention to date, specifically those heavy-duty operational practices that have not been heavily promoted by SmartWay and technological and operational strategies for medium-duty trucks that have not had a high profile in existing research. The results will be of interest to policy makers, academics, business managers and other stakeholders who seek to reduce the environmental footprint of freight transportation. Our research provides not only estimates of the effectiveness of these technologies in specific applications, but a quantification of their promise for contributing to reductions in U.S. freight-sector GHG emissions. This paper does not examine the implementation costs of the strategies; rather, it provides a “bottom-up” analysis of strategies that have not yet fully penetrated the trucking sector and that have potential for GHG emissions benefits.

Life-cycle assessment research has found that strategies that increase the weight of trucks could result in increased air emissions from pavement construction and maintenance. (19) Although such impacts are worth considering, they are beyond the scope of this paper.
Methodology

To begin this study, we conducted a literature review of both academic research and trade press to identify potential strategies and their impacts on fuel efficiency and GHG emissions. We developed estimates of the VMT and fuel use associated with various segments of the U.S. freight truck population, using information from the Vehicle Inventory and Use Survey (VIUS), Highway Statistics, and commercial motor carrier fleet directories. We also reviewed available data on the current utilization levels of the strategies and their potential applicability, including surveys conducted by the American Transport Research Institute (ATRI), National Private Truck Council (NPTC), and other industry groups.

Next we conducted approximately 14 interviews of trucking industry managers and related industry experts to verify and supplement the information gathered in the literature review. Companies interviewed included:

- 3 large truckload carriers
- 3 small truckload
- 1 large less-than-truckload carrier
- 1 large expedited delivery carrier
- 3 private trucking fleets
- 2 trucking industry independent consultants
- 1 aftermarket parts manufacturer

A major challenge in this research is estimating current levels of market penetration for fuel-saving strategies. The 2002 VIUS (the last conducted) is now somewhat dated and did not collect information about most of the fuel-saving strategies of interest. Truck and equipment manufacturers and vendors are generally unwilling to share their estimates of market penetration, which they consider confidential business information. Therefore, we relied on a combination of public data sources, industry group surveys, and industry interviews to estimate the current and maximum potential market penetration of the identified strategies and the associated fuel savings and GHG reductions.

Profile of U.S. Truck Fleet

Trucks perform the bulk of freight movement in the U.S. They include tractor-trailer combination trucks as well as single-unit trucks used in applications like urban pick-up and delivery, waste hauling, and construction. There is no universally accepted definition of what differentiates a “freight truck” or a “heavy-duty truck” from a truck used for personal travel (e.g., pick-ups and SUVs). Typically the distinction is made based on weight or number of tires, with most studies assuming that trucks with six or more tires are freight trucks used for commercial purposes, and four-tire trucks are for personal use. This boundary generally corresponds to a gross vehicle weight rating (GVWR) of 10,000 lbs. In this paper, we consider only trucks with GVWR of 10,000 lbs or more, which corresponds to U.S. DOT vehicle Class 3 and above.

According to vehicle registration data, there were 2.2 million truck tractors and 6.8 million single-unit trucks in the U.S. in 2007. Table 1 shows estimates of how these trucks and their associated vehicle miles traveled (VMT) are distributed between long-haul and short-haul operations. We define vehicles with an average daily length of haul less than 200 miles to be short-haul and trucks with an average trip distance longer than this to be long-haul. Short-haul trucks outnumber long-haul trucks by roughly three to one.
With regard to emissions, an important segment of the short-haul truck fleet is the drayage fleet operating to and from marine ports and other intermodal facilities. In many regions, drayage trucks are among the oldest and highest-emitting trucks in operation, and they can contribute significantly to localized air pollution including diesel PM hotspots. However, drayage trucks contribute a relatively small share of national-level GHG emissions. Based on a recent national-scale port emission inventory developed for the U.S. EPA (covering 88 ports), we estimate that GHG emissions from trucks serving ports make up approximately one percent of total U.S. heavy-duty truck GHG emissions. Therefore, this research does not focus on specific GHG reduction strategies for drayage trucks.

Table 1: Estimated U.S. Truck Population by Vehicle Type and Operating Range

<table>
<thead>
<tr>
<th>Truck Type</th>
<th>Area of Operation</th>
<th>Trucks</th>
<th>VMT (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Unit</td>
<td>Short-haul (&lt; 200 miles)</td>
<td>6,058,000</td>
<td>72,939</td>
</tr>
<tr>
<td></td>
<td>Long-haul (&gt; 200 miles)</td>
<td>749,000</td>
<td>9,015</td>
</tr>
<tr>
<td></td>
<td>Sub-Total</td>
<td>6,807,000</td>
<td>81,954</td>
</tr>
<tr>
<td>Combination</td>
<td>Short-haul (&lt; 200 miles)</td>
<td>888,000</td>
<td>58,003</td>
</tr>
<tr>
<td></td>
<td>Long-haul (&gt; 200 miles)</td>
<td>1,333,000</td>
<td>87,005</td>
</tr>
<tr>
<td></td>
<td>Sub-Total</td>
<td>2,221,000</td>
<td>145,008</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>9,028,000</td>
<td>226,962</td>
</tr>
</tbody>
</table>

Source: Truck and VMT sub-totals from FHWA, Highway Statistics; range distribution based on U.S. Census, 2002 VIUS.

To assess the applicability and potential uptake of fuel-saving strategies, another relevant characteristic is the type of carrier. **For-hire** trucking refers to all carriers who haul freight for another company under contract. Most for-hire carriers can be classified as either:

- **Truckload** (TL) carriers, which provide direct point-to-point service to shippers that can fill an entire trailer with cargo, or
- **Less-than-truckload** (LTL) carriers, which are used by shippers that do not require a whole trailer. LTL carriers provide local pick-ups, consolidate shipments into full truckloads at a terminal, carry shipments to a destination terminal, and then provide local delivery from there.

**Private** trucking is comprised of shippers that carry their own cargo. Private carriage is often used by major retailers with large and elaborate supply-chain networks. Note that some private carriers have authority to provide for-hire service, a strategy they use to help reduce empty miles when not carrying their own cargo.

In November 2006, there were more than 290,000 for-hire motor carriers and an additional 504,000 private fleets on file with U.S. DOT. There were also nearly 235,000 “other” interstate motor carriers according to the U.S. DOT.¹ Most for-hire trucking companies are small businesses, with almost 96% operating 20 or fewer trucks and 89% operating six trucks or less. (20) Many for-hire truckers are owner-operators who operate as sole proprietors and contract themselves out to other firms. In some cases, these individuals may have multiple customers and make independent decisions for themselves regarding equipment and operational issues. In other cases, owner-operators work for a single company as contractors and have less leeway to make independent business decisions.

¹ Other carriers were those that did not specify their segment or checked multiple segments. It should be noted that the FMCSA motor carrier database has historically been slow in purging defunct carriers, so their estimated number of motor carriers may overestimate the total population of firms.
GHG Reduction Strategies

This section describes eight promising GHG reduction strategies for trucking. We have organized strategies into two major categories, as follows:

- Operational Strategies – those that change the way trucks are utilized, and
- Technological Strategies – those involving a physical change to trucks and/or trailers.

We describe each strategy and the segment(s) of the trucking industry for which it is relevant. As above, we define long-haul trucks as those that operate primarily more than 200 miles from home base; nearly 65% of these trucks are Class 8b combination trucks. We define as short-haul trucks those that operate primarily within 200 miles of home base; these include both combination and single-unit trucks in all weight classes 3 to 8.

Speed Reduction

Speed reduction is one of the most effective strategies for improving truck fuel efficiency. Truck power requirements and fuel use tend to increase in a non-linear manner above 40 mph, so limiting top highway speeds is a particularly effective way to save fuel. For this reason, and for safety benefits, nearly all large carriers limit the top speed of their trucks using engine governors. Limits are typically in the range of 60 to 68 mph. The American Trucking Association (ATA) estimated that 77% of its members have speed limiters set at 68 mph or lower. (21)

Our discussions with trucking companies suggest that speed reduction offers very little opportunity for additional GHG reduction among long-haul trucking companies, with the exception of owner-operators. While the ATA survey suggests that 23% of larger long-haul fleets do not govern truck speed, achieving speed reductions among this segment of the industry is probably quite difficult. Some of these carriers likely operate in Western states where highway speed limits of 75 mph are common. Among the 77% of ATA members that do govern truck speed, there are opportunities for additional fuel savings and GHG reductions by further restriction of speed. However, because there is little information to evaluate this potential, we focused our analysis on the owner-operator population. The potential effect of speed reduction on the entire trucking industry is a topic that warrants further research.

Owner-operators have typically resisted using speed governors, so there are potential GHG benefits from increasing usage among this segment of the fleet. The challenge is finding ways to encourage owner-operators to limit their maximum highway speed by working through shippers, third-party logistics providers (3PLs), or the truckload carriers that contract with owner-operators.

Among short-haul trucks, opportunities for GHG reduction from speed governors are more limited, because these trucks typically spend less time at highway speeds. Exceptions are short-haul trucks that serve warehouses or other facilities located on the perimeter of metropolitan areas. However, based on our interviews, we believe that, like long-haul fleets, most large short-haul fleets already have speed governors.

To estimate fuel savings from limiting maximum truck speed, many in the trucking industry rely on a simple rule of thumb that each 1 mph reduction results in an increase of 0.1 mpg. Determining the actual impact of speed reduction on fuel economy is more complex, and depends on factors such as the truck gross vehicle weight, road grade, and the vehicle’s aerodynamic drag.
To estimate the potential benefits of this strategy, we assume that among long-haul combination trucks, owner-operators and other very small fleets (five trucks or less) operating in long-haul service are the only major industry segments that do not currently make significant use of speed governors. According to VIUS, these fleets represent 11% of all combination truck VMT. Among single-unit truck fleets, we believe the opportunities for speed reduction are primarily in mid-size fleets (25-100 trucks), since we believe most large fleets already use governors, and small fleets of single-unit trucks would be very difficult to influence. Mid-size fleets make up 15% of all single-unit truck VMT, according to VIUS.

Reducing Empty Miles

Reducing empty miles traveled is a key concern for trucking companies because it can increase revenue and profits without increasing fuel consumption or other operating costs. Truck empty mileage varies by the type of service (truckload, LTL, private) and by the range of operation. As shown in Table 2, the portion of empty miles tends to decline as operating range increases. Carriers making long-distance trips simply cannot afford many empty backhauls.

Table 2: Empty Mileage by Area of Operation and Service Type

<table>
<thead>
<tr>
<th>Area of Operation</th>
<th>Truckload</th>
<th>LTL</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 Miles or Less</td>
<td>35%</td>
<td>16%</td>
</tr>
<tr>
<td>51 - 100 Miles</td>
<td>34%</td>
<td>10%</td>
</tr>
<tr>
<td>101 - 200 Miles</td>
<td>29%</td>
<td>6%</td>
</tr>
<tr>
<td>201 - 500 Miles</td>
<td>18%</td>
<td>11%</td>
</tr>
<tr>
<td>501 or More Miles</td>
<td>11%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Source: 2002 VIUS

A variety of load-matching services are available that allow vehicles delivering goods to fill empty backhauls by identifying loads available for pickup close by. Based on our interviews with carriers, we believe the potential additional benefits of this strategy are very minimal among for-hire (both TL and LTL) carriers because the existing incentives to reduce empty miles are so great and there are no major barriers to maximizing loaded miles. However, we believe there may be potential benefits for reducing empty miles among private carriers. According to a survey by NPTC, 28% of all private fleet miles are empty, a higher percentage than for-hire fleets. (22)

Private fleets have three basic strategies to reduce empty hauls:

- First, by using intra-corporate hauling, private carriers can try to fill empty backhauls with freight from their associated business operations. For instance, trucks delivering finished products could seek to ship supplies for manufacturing operations on their return trip.

- Another approach is to obtain for-hire operating authority and to fill empty backhauls with outside freight shipments from third parties.

- Finally, companies can use trip leasing to operate their vehicles under the authority of another carrier to fill empty backhauls.

Approximately 53% of private fleets already have for-hire operating authority. (23) Assuming that most of the opportunity for this strategy lies with those firms engaged in long-haul operations without for-hire authority, we conservatively estimate that this strategy is applicable to approximately half of long-haul truck tractors operating in private fleets, or about 250,000 tractors.
One can benchmark private fleets against the for-hire industry, where the empty mileage rate ranges between 10% and 20%, depending on the typical average haul. However, it is unlikely private carriers on average could achieve this level of efficiency. To estimate the fuel savings from this strategy, we assume that half of the private fleet (the half currently lacking for-hire authority) can reduce empty miles from 33% to 28%.

**Increase Truck Loading**

If trucks can increase loading of their cargo space, more freight can be moved with fewer trips. For long-haul trucks, strong incentives already exist to fill payload space to the federal/state volume or weight limits (whichever comes first). For trucks that “weigh-out” (i.e., limited by weight restrictions) there are no opportunities to increase loading unless the empty (tare) weight of the truck is reduced. For trucks that “cube-out” (i.e., limited by size/volume restrictions), more efficient loading can produce fuel savings and a reduction in GHG emissions.

Among long-haul trucks, those pulling van trailers cube-out for approximately 80% of loaded miles, according to VIUS. For short-haul trucks, loading is commonly dictated more by delivery schedules than payload capacity, so opportunities to increase loading are limited. Thus, the GHG opportunities for this strategy are primarily among van trailer trucks, which account for two-thirds of total VMT by combination trucks.

The specific strategies to increase loading depend on the freight being transported, including the dimensions of the parcel units, the type of packaging, and its strength/fragility. For trucks that use “floor loading” (cargo stacked directly on the floor without use of pallets), maximizing load volume may require use of software tools or loading consultants. Many van trailers are loaded with pallets, stacked as high as possible and then wrapped in plastic or other binding materials. Some carriers have found opportunities to increase the number of pallets loaded in a truck trailer. The most common pallet conforms to standards set by the Grocery Manufacturers Association (GMA): 40 inches wide by 48 inches long. The standard combination truck van trailer is 48 or 53 feet long (exterior length) and roughly 98 inches wide (interior width). In conventional loading, a trailer can hold 24 to 26 GMA pallets (see Figure 2 below).

Loading can be slightly increased with the use of “pin-wheeling” – turning every other pallet by 90 degrees. With this approach, a standard trailer can hold 26 to 28 GMA pallets. The pallets used must be special “double-entry” pallets, which can be accessed by a forklift from all four sides. Loading can be further increased through the use of aluminum "plate wall" trailers, which have thinner walls and a few more inches of interior width (101 inches wide). Using “turned loading,” these trailers can hold up to 30 GMA pallets.

*Figure 2. Methods of Loading Pallets*
A leading national office products retailer now uses turned loading for all the long-haul loads carried by its private fleet. This private fleet also transports heavier and smaller pallets of paper, which are only 36 inches wide. By mixing in a few of these paper pallets on a GMA truck load, the retailer can achieve 32 pallets per trailer. Thus, compared to conventional loading, the retailer can carry 23% more freight per truckload. This translates into roughly 20% fewer truck trips and fuel use to move a given volume of freight.

Alternative pallet loading strategies apply only to trucks hauling pallets. According to VIUS, van trailer trucks make up 67% of all VMT by combination trucks. Based on analysis of the Product Carried variable in VIUS, we estimate that roughly half of these van trailer loads are on pallets. Many large carriers hauling pallets already use pin-wheeling and turned loading, provided that the shippers employ the right types of pallets and loading equipment (e.g., forklifts and hand lifts). Plate wall trailers are becoming the industry norm. Thus, the opportunities for additional gains come from carriers using older trailers and shippers using conventional pallets. Based on our discussions with private and for-hire carriers, we estimate this to be roughly one-third of long-haul trucks moving palletized loads, or one-sixth of all van-trailer combination trucks. Thus, we estimate that for long-haul trucks carrying pallets, use of “turned loading” could reduce VMT and fuel use by 15%, compared to conventional loading.

**Improved Routing**

Carriers use vehicle tracking and routing software to monitor the operation of their fleets and to ensure that vehicles use the most efficient routes and maintain schedules. Use of this type of software can result in a reduction in empty mileage and VMT, although route optimization is constrained to some extent by truck route restrictions and weight limits for bridges. Based on the interviews we conducted, we assume that all large trucking companies use routing programs, so the potential benefits of this strategy are likely negligible among these fleets. However, based on our interviews with carriers, we believe there may be benefits among smaller carriers and owner-operators. Even companies that are using software or vehicle tracking systems may not be holding their drivers accountable for the actual routes driven.

Firms with a dense, multi-stop delivery network are the ones that can see the greatest benefit from using software solutions to improve routing. Routing software solutions tend to have the highest payoff for private fleets in regional or short-haul operations, where the software is best able to optimize routing among a significant number of customer pickup and delivery sites. Industry experts and contacts with private fleets suggest that the use of routing software can reduce vehicle mileage between 7% and 25%. Our estimate of the average opportunity is 10%. While market penetration of routing systems is widespread among large fleets, approximately half of the private fleet market has 10 or fewer trucks. (24)
Many of these firms are potential targets for these solutions. Among small private fleets, those engaged in local operations (70% of these fleets) are likely to see the greatest benefits.

In addition to optimizing route plans, carriers can improve fuel efficiency by reducing vehicle miles driven that do not conform to planned routes. Carriers using on-board GPS and communications equipment can monitor the location and routes traveled by their vehicles. “Geofencing” software alerts dispatchers when trucks depart significantly from a planned route. Carriers without such capabilities can reduce out-of-route miles simply by comparing “hub miles” (i.e., actual miles driven) to the trip reports submitted by drivers. The level of fuel and emissions savings from this strategy will vary greatly depending on a carrier’s operating characteristics. One small carrier noted that the annual fuel savings are in the low single-digit percentages after the first year of implementing this strategy. Our interviews suggest the benefits of improving route adherence are applicable to long-haul carriers with mid-size fleets (i.e., 25 to 100 trucks).

In summary, this strategy involves two components focused on different market segments. One strategy uses technology to select optimized routes. We assume this strategy applies to small private fleets in local operations. To calculate benefits, we assume small private fleets operate 250,000 combination trucks and 70% of these are involved in local operation. We calculate a CO₂ benefit by assuming this segment of the industry has an average annual truck mileage of 40,000 and average fuel economy of 6 mpg; the strategy is assumed to reduce VMT by 10% among this segment.

The second strategy involves use of GPS tools to reduce out-of-route miles. We assume this strategy applies to mid-size (25-100 trucks) combination truck fleets in long-haul operation. Based on VIUS, we estimate that these fleets account for 8.6% of all combination truck VMT. We assume that the strategy will reduce VMT by 4% among the applicable fleet.

**Aerodynamic Improvements (Single-Unit Trucks)**

Single-unit trucks are primarily used in a short-haul or pickup-and-delivery operation. Compared to long-haul combination trucks, single-unit trucks experience fewer efficiency gains from the use of aerodynamics. This is due to their lower drag coefficient and the smaller percentage of operating hours spent at highway speeds. All vehicles can benefit from more aerodynamic cab design, which can include the design of the front bumper, grill, hood, and mirrors. These components are incorporated by the truck manufacturer with little opportunity for beneficial after-market add-ons. For single-unit trucks with van-style bodies, there are additional potential benefits from improving the aerodynamics of the cargo space. There are aftermarket air deflectors and other devices designed for these trucks.

Using Detroit Diesel’s Spec Manager software, we estimated the fuel-efficiency improvements of a roof deflector and a full aerodynamic package for a three-axle, 25,000 GVW box van. Spec Manager is a software program for use by fleet managers to compare the effects of truck configurations on operating performance, including fuel economy. Users can select among a large number of drive cycles. While we were not able to review the relationships embedded in Spec Manager, our experience with the program suggests that it predicts fuel economy impacts on par with those of publications from ATA, DOE, and other sources. Operation of the three-axle box van was simulated using a short-haul urban driving cycle with 30% of vehicle time at highway speeds and 70% in urban driving conditions.

The simulation estimated the fuel-economy benefits of a roof deflector to be 3.2 percent and the benefits of a full aerodynamic package to be 4.8 percent. We believe these figures somewhat overstate the actual fuel efficiency benefits, because they reflect truck models that are 5 to 10 years old. Newer single-unit trucks have better aerodynamics. Thus, we estimate that the addition of aerodynamic features to box vans...
(both two- and three-axle) will improve fuel efficiency by 3% on average. This is consistent with other recent studies. (10)

EPA’s SmartWay program promotes aerodynamic improvements for combination trucks, so we did not consider benefits among this segment of the trucking industry. Fuel savings for single-unit trucks are primarily limited to those with van-style bodies, which account for 25% of single-unit VMT (and 8.4% of all truck VMT). Only about 10% of these trucks have currently have full aerodynamic devices.

**Diesel-Electric Hybrids**

Diesel-electric hybrids, hydraulic hybrids, and battery-electric vehicles all hold the potential to increase the fuel efficiency of trucks and reduce air emissions. However, because hydraulic hybrids and battery-electric trucks are not yet commercially available for a significant segment of the truck market, we analyzed only the potential emissions savings from wider use of diesel-electric hybrids. Diesel-electric hybrid vehicles achieve their greatest fuel savings in stop-and-go traffic. Therefore, the best markets for them are urban pickup-and-delivery and short-haul markets. Trucking operations with frequent starts and stops, significant idle time, and a need for exportable power are likely to be early adopters. These would include food and beverage, delivery, and refrigerated trucks. In October 2010, a large parcel carrier announced the purchase of 130 diesel-electric hybrid delivery trucks, adding to its existing fleet of 250 of the vehicles. (25)

Diesel-electric hybrid vehicles are likely to achieve fuel efficiency improvements of 15% to 35%. (7) (8) The fuel-efficiency benefits modeled depend on the type of hybrid engine and drive cycle that is assumed, the grade of the route, and how much cargo the vehicle is carrying, among other factors, Drive cycles with longer and flatter routes that don’t involve as much braking show lower benefits for hybrid vehicles. More heavily loaded vehicles will also tend to increase the benefits of hybrids because the technology can allow the engine to operate at a more optimal load if fully loaded. The benefits assumed in this analysis are in the mid-range of those estimated for hybrid vehicles under different scenarios. These benefits are consistent with vehicles operating on shorter routes in stop-and-go traffic, but with lighter cargo that does not require the engine to operate close to full load. For this analysis, we assume average GHG emissions reductions of around 25% for short-haul fleets overall, including both combination and single-unit trucks.

As part of this research, we talked with several private fleets who have been experimenting with diesel-electric hybrid trucks. All of these interviewees reported fuel savings and generally acceptable performance characteristics. However, they noted that the operating cost savings does not presently offset the significant price premium of hybrid trucks.

**Transmission Adjustment**

The fuel efficiency of a given truck is heavily influenced by the transmission and engine throttle operation. Training programs that teach drivers how to operate vehicles more efficiently focus heavily on: (1) upshifting sooner, and (2) minimizing full throttle application (i.e., not flooring the gas pedal). Drivers who follow these rules, and also minimize idling, can often improve their fuel efficiency by 10% to 15%. However, it is difficult to make drivers comply with operating guidelines.

An alternative to driver training is to electronically program trucks to operate in a more fuel-efficient manner. One strategy is to reprogram the automatic transmission control module so that trucks up-shift at lower speeds. Factory settings for automatic transmissions are often based on maximizing power rather than fuel economy. In some cases, these adjustments can be made by truck manufacturers; alternatively, there are add-on engine tuning devices that do this.
A major office products retailer has reprogrammed the transmissions on all the single-unit trucks in its private fleet, which consist primarily of Class 5 and 6 trucks. The net effect of this strategy, in combination with implementing speed governing, was a fleet-wide increase in fuel economy from 8.5 to 9.6 mpg. This transition occurred at the same time that as the fleet switched to ultra-low sulfur diesel, which the company estimates reduced fuel economy by about 0.3 mpg. The net effect has been a fuel economy gain of 12% to 16%. The company estimates the mpg gain from transmission adjustment alone was approximately 10%.

For this analysis, we focus on transmission adjustment for single-unit trucks, because more combination trucks are manual transmission. Among single-unit trucks, the significant fuel benefits would come from trucks engaged in urban stop-and-go operation that do not have high power demands. Using VIUS, we estimate that these trucks (primarily van body and service trucks) account for 69% of all VMT by single-unit trucks. Among this subset, we estimate 40% of VMT is attributable to trucks with automatic transmissions. Thus, the maximum market share is about 28% of single-unit truck VMT (69% * 40%). Current market share is small – we assume 5%. Based on the experience of one of the private fleet owners interviewed, we assume an average improvement in fuel economy of 10%.

**Automatic Engine Shutdown for Single-Unit Trucks**

Reducing engine idling is an opportunity for all truck fleets, not just long-haul fleets in which drivers sleep in their cabs. Any fleets with drivers who make frequent stops or wait in their vehicles for periods of time may benefit from the use of idling-control technologies. One industry observer noted that among private fleets, it is not unusual for idling to account for as much as 35% of engine operating time. Research by Argonne National Laboratory suggests that approximately 7% of all single-unit truck fuel use is associated with idling, and this percentage is much higher for some types of trucks. (14)

Owners of newer trucks Class 6 or higher can take advantage of the capabilities of the engine’s electronic control module (ECM) to implement automatic engine shutdown. These trucks have engines that can be programmed to shut down automatically after a pre-determined length of idling time. This technology is not fool-proof, however. For at least some engines, this shutdown feature can be circumvented if the driver revs the engine high enough to reset the idling timer. Fleet managers can monitor driver behavior of this type by downloading data from the engine’s ECM. For other trucks that do not have an ECM-based shutdown capability, there are retrofit technologies available.

Automatic engine shutdown can be implemented in nearly all trucks to reduce idling. For trucks with sleeper cabs (combination trucks in long-haul service), idling reduction is a major thrust of the SmartWay program, so we have not considered those vehicles as an opportunity. According to Gaines et al., among single-unit trucks, the largest portion of idling occurs with service trucks, van-body trucks, and dump trucks. (14)

With the recent volatility in fuel prices, it is likely that some owners of trucks with built-in engine shutdown capability (i.e., newer Class 6 and higher trucks) have already activated the shutdown feature. It may be possible to encourage these fleet owners to shorten the allowed amount of idling time (e.g., from 15 minutes to 3 minutes). A greater opportunity exists to reduce idling in fleets of vehicles without the ECM-based engine shutdown capability. To calculate benefits, we assume that the current market share of this strategy among Class 3 to 5 trucks is essentially zero, and the market share among Class 6 to 7 trucks is 25%. We calculated total idling fuel use based on the methodology used by Gaines et al. (14), and assumed that 75% of idling could be eliminated. Some engine idling will need to continue to provide
driver comfort during extremely cold or hot weather. The net effect is a 5.8% reduction in fuel use among applicable single-unit trucks.

**Conclusion: Potential Reduction in GHG Emissions**

To calculate the potential reduction in GHG emissions associated with each strategy described in this paper, we first identified the segment of the truck fleet to which the strategy applies, as well as the VMT and fuel use associated with that segment. We estimated current and maximum potential market penetration of each strategy in terms of VMT. We then calculated the potential fuel savings that would be achieved with the maximum market penetration, and calculated the associated CO₂ emissions. Because CO₂ makes up more than 95% of freight truck GHG emissions, we did not calculate emissions of other GHGs (e.g., nitrous oxide and methane).

Table 3 below summarizes the potential GHG reductions from the strategies discussed in this paper. Diesel-electric hybrid trucks have by far the greatest potential emissions benefit among the strategies analyzed, because this strategy results in large efficiency gains and could be applied to large segments of the truck population. Besides diesel-electric hybrids, the technological strategies with the greatest emission reduction potential are:

- Transmission adjustment for single-unit van body and utility trucks, and
- Automatic engine shutdown for nearly all single-unit trucks.

Among operational strategies, those with the greatest potential emissions benefit are:

- Improved trailer loading of pallets for long-haul, van-trailer combination trucks, and
- Speed reduction for long-haul owner-operators.

The CO₂ benefits in Table 3 are not fully additive, and we have not conducted an analysis of overlap in order to estimate a total maximum net benefit. However, based on our professional judgment, our conservative estimate is that their total net benefit is likely to be at least 10 million metric tons of GHGs.

For comparison, analyses done at the outset of the SmartWay program estimated a potential 2010 GHG reduction of approximately 20 million metric tons for strategies focused on long-haul combination truck fleets. (3) Thus, we believe this research shows there are significant potential GHG reduction opportunities in the trucking sector beyond the strategies currently being advanced by EPA’s SmartWay program.

This analysis is based on estimates of current and maximum market penetration that were, in some cases, derived from a limited number of interviews. Future research could develop more robust estimates through more extensive interviews or statistical sampling. Additional research could also examine the costs of adopting these strategies. Diesel-electric hybrid trucks clearly have large potential GHG benefits, but those benefits may come at significant cost. By comparison, most of the other strategies could be achieved at relatively low cost.

Finally, there are potential obstacles other than cost that could hinder wider adoption. The SmartWay program’s success to date is due in large part to the participation of many of the country’s largest truck carriers. It will be challenging to achieve widespread adoption of these strategies by the large number of owner-operators and small carriers.
### Table 3: Summary of Strategies Analyzed

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Improvement in Fuel Economy</th>
<th>Applicable Industry Segment</th>
<th>Market Penetration (% of VMT in Applicable Industry Segment)</th>
<th>Market Penetration (% of All Truck VMT)</th>
<th>2010 CO₂ Benefits (Thousand Metric Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational Strategies</strong></td>
<td></td>
<td></td>
<td>Current</td>
<td>Maximum</td>
<td>Current</td>
</tr>
<tr>
<td>Speed Reduction (70 to 65 mph)</td>
<td>8%</td>
<td>Combination trucks, owner-operators, long-haul</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>3%</td>
<td>Single-unit trucks, mid-size fleets</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Reduce Empty Mileage (by 5 percentage points)</td>
<td>5%</td>
<td>Combination trucks, private fleets, long-haul</td>
<td>50%</td>
<td>100%</td>
<td>6%</td>
</tr>
<tr>
<td>Improve Trailer Loading (pallets)</td>
<td>20%</td>
<td>Combination trucks, van trailer, long-haul</td>
<td>33%</td>
<td>50%</td>
<td>8%</td>
</tr>
<tr>
<td>Improve Truck Routing (optimization)</td>
<td>10%</td>
<td>All truck types, private, small fleets, short-haul</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Improve Truck Routing (route adherence)</td>
<td>4%</td>
<td>Combination trucks, mid-size fleets, long-haul</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Technological Strategies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerodynamic Improvements</td>
<td>3%</td>
<td>Single-unit trucks, van body</td>
<td>10%</td>
<td>100%</td>
<td>1%</td>
</tr>
<tr>
<td>Diesel-electric hybrids</td>
<td>25%</td>
<td>Single-unit trucks, short-haul</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>Combination trucks, short-haul</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Transmission Adjustment</td>
<td>10%</td>
<td>Single-unit trucks, van body and utility trucks, automatic transmission</td>
<td>5%</td>
<td>100%</td>
<td>0.4%</td>
</tr>
<tr>
<td>Automatic Engine Shutdown</td>
<td>6%</td>
<td>All single-unit trucks</td>
<td>15%</td>
<td>100%</td>
<td>5%</td>
</tr>
</tbody>
</table>
Acknowledgement

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Works Cited


