Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles

Liquid fuel consumption by medium- and heavy-duty vehicles (MHDVs) represents 26 percent of all U.S. liquid transportation fuels and is increasing more rapidly than in other vehicle sectors. If the United States is to reduce its reliance on foreign sources of oil and decrease carbon dioxide emissions from the transportation sector, it is important to consider how to limit the fuel consumption of MHDVs. This report provides a survey of current approaches to fuel economy and regulations; a review and assessment of technologies to reduce fuel consumption; an assessment of costs and benefits of integrating fuel consumption reduction technologies into vehicles; a review of potential unintended consequences and the alternative nontechnology approaches to reducing fuel consumption; and a review of options for regulatory design.

Vehicles belonging to the medium- and heavy-duty class are used in every sector of the economy for a multitude of applications. While light-duty vehicles (such as cars and light trucks) are sold in a limited number of well-known configurations, there are literally thousands of different configurations for MDHVs, including bucket trucks, pickup trucks, garbage trucks, delivery vehicles, buses, and long-haul tractor trailers. These vehicles encompass a broad range of duty cycles, from high-speed operation on highways with few stops to lower speed urban operation with many stops per mile.

Because they serve a load-bearing function, the most meaningful metric of fuel efficiency in MHDVs is fuel consumption per payload carried, or load-specific fuel consumption (LSFC). Standards might include several different values of LSFC due to variables among vehicle classes.

Given the diversity of the features and use profiles in MDHVs, establishing standards such as those currently implemented for light-duty vehicles will be complicated, but not impossible. Regulations for fuel consumption in medium and heavy duty trucks already exist in Japan and are under development by the European Commission. In Japan, the complexity of MHDV configurations has even led to the use of computer simulation, rather than full-vehicle testing, as a cost-effective means to calculate fuel efficiency. The United States has already taken important steps toward regulation of MDHVs. Engine-based certification procedures have been applied to address emissions from heavy-duty vehicles and non-transportation engines. Safety and emission regulations are already in place, and the state of California is building on the Environmental Protection Agency's SmartWay Partnership to implement its own approach to regulating truck fuel consumption.

Technologies and Costs of Reducing Fuel Consumption

This report contains evaluations of a wide range of fuel saving technologies for medium- and heavy-duty vehicles. Some technologies, such as automated manual transmissions and wide-base single low-resistance rolling tires, are already in production, while others are in varying stages of development or have only been studied using simulation models. In today's market, purchasers must weigh the additional cost of fuel saving technologies against the fuel savings that will accrue. In most cases, market penetration is low at this time. As a result, many technologies may struggle to achieve market acceptance, despite sometimes substantial fuel savings, unless driven by regulation or by higher fuel prices.

In order to compare the effectiveness of the reviewed technologies, their applications were grouped and their potential fuel saving characteristics applied to seven types of MHDVs (results shown in Figure 1). Estimated costs of the technologies in dollars per percent of fuel saved, dollars per gallon saved each year, and by the "breakeven" price, at which the fuel savings would be equal to the total cost of the technology package applied to a vehicle in a given class, are shown in Table 1. Although the breakeven fuel prices in Table 1 do not reflect variation in length of vehicle ownership or operation and maintenance costs, they serve as a useful metric for considering the private and societal costs and benefits of regulation.

As shown in Figure 1 and Table 1, the fuel consumption reduction potential of the specific powertrain and vehicle technologies are extremely dependent on application and duty cycle. While some are economically viable at today's fuel prices, others examined require significantly higher fuel prices or increased concern for environmental and security externalities to justify their application. In addition to these considerations, cost measurements should be examined; the common metric of cost per percent fuel saved, used in Table 1, can be misleading because it fails to account for total annual fuel consumption. This is illustrated in the discrepancies between cost per percent fuel saved and dollars per gallon saved per year.

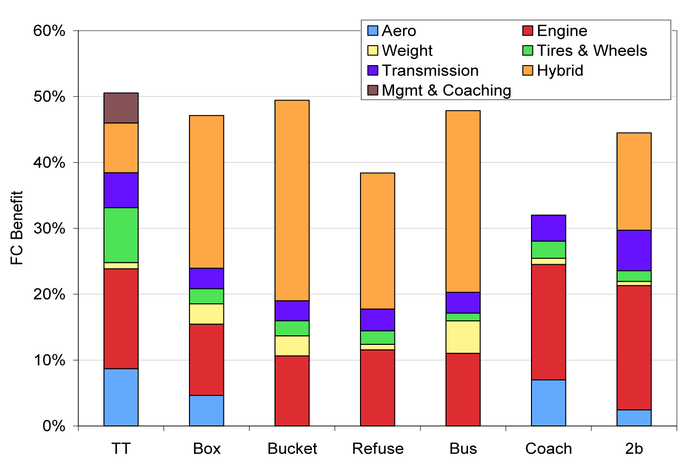

FIGURE 1. Comparison of 2015-2020 new vehicle potential fuel-saving technologies for seven vehicle types: tractor trailer (TT), Class 3-6 box (box), Class 3-6 bucket (bucket), Class 8 refuse (refuse), transit bus (bus), motor coach (coach), and Class 2b pickups and vans (2b). SOURCE: TIAX (2009) at ES-4.

TABLE 1. Fuel Consumption Reduction Potential for Typical New Vehicles in 2015–2020 and Effectiveness Comparisons for Seven Vehicle Configurations. SOURCE: Adapted from TIAX (2009).

Vehicle Class	Fuel Consumption Reduction, %	Capital Cost, $	Cost Effectiveness Metric		
			$/% Fuel Saved	Dollars per Gal. Saved per Year	Breakeven Fuel Price, $/Gal.
Tractor-trailer	51	84,600	1,670	7.70	1.10
Class 6 box truck	47	43,120	920	29.30	4.20
Class 6 bucket truck	50	49,870	1,010	37.80	5.40
Class 2b pickup	45	14,710	330	33.70	4.80
Refuse truck	38	50,800	1,320	18.90	2.70
Transit bus	48	250,400	5,230	48.00	6.80
Motor Coach	32	36,350	1,140	11.60	1.70

Indirect Effects and Externalities

The implementation of technologies and policies to spur greater fuel efficiency in MHDVs will produce a variety of indirect costs, benefits, and externalities, which must be assessed in order to produce effective policies. The following should be considered in order to help avoid or mitigate negative consequences:

- fleet turnover impacts
- increased ton-miles shipped due to reduction in costs
- shifts in the purchase of vehicle classes
- environmental costs
- congestion
- safety
- incremental weight impacts

Alternative Approaches

There may be approaches to reducing fuel consumption that are more effective and less costly than those mentioned previously. As the Department of Transportation (DOT) and National Highway Traffic Safety Administration (NHTSA) conduct further analyses of fuel conservation options, these alternative approaches should be considered:

- **Market-based instruments.** Fuel taxes operate to make fuel-saving technologies more attractive and provide incentives for saving fuel, while producing fewer unintended consequences than standards. Although politically difficult, it is stronly recommended that Congress consider fuel taxes as an alternative to mandating fuel efficiency standards for medium- and heavy-duty trucks.
- **Increases in vehicle size and weight limits.** Increasing vehicle size and weight limits offers potentially significant fuel savings for the entire tractor-trailer combination truck fleet. This would need to be weighed against increased costs of road repair. Congress should give serious consideration to liberalizing weight and size restrictions in a way that maintains safety and minimizes the cost of potential infrastructure changes.
- **Driver training.** There are significant opportunities for fuel savings when drivers are trained properly. Indications are that this could be one of the most cost-effective and best ways to reduce fuel consumption and improve productivity of the trucking sector. The federal government should encourage and provide incentives for the dissemination of information about the relationship between driving behavior and fuel savings.
- **Other methods.** Benefits and costs should also be weighed for a cap-and-trade system of emissions regulation, and for the implementation of intelligent vehicle and highway systems.

Approaches to Fuel Consumption Reduction and Regulations

Regulatory changes made in the coming years will establish the design for MHDV fuel consumption standards for the next few decades and possibly longer. Once established, regulated parties, certification procedures, and compliance methods will be difficult to modify. It is therefore important to implement a well-designed system that enhances and improves upon the commercial trucking industry's existing desire to maximize the fuel economy of its trucks and fleets. In particular, final-stage vehicle manufacturers should be the target of the regulations since they have the greatest control over the design of the vehicle and its major subsystems that affect fuel consumption. There is also a need for a standardized test protocol for components, and safeguards for the confidentiality of the data and information.

Fuel consumption metrics should be established that are tied to the task associated with a particular type of MHDV. Also, targets for fuel consumption should be set on the basis of potential improvements in vehicle efficiency and changes in cargo carrying capacity. To help set these targets, regulators should use simulation modeling that makes use of data from component and powertrain tests. Such modeling could achieve the required target accuracy while lowering administrative costs.

To initiate this process, Congress should appropriate funds for NHTSA to implement, as soon as possible, a major engineering contract to develop an approach for component testing and simulation modeling for vehicle types covering several applications. The purpose of this effort is to arrive at LSFC data for these vehicles. The actual vehicles should also be tested using appropriate procedures to confirm the actual LSFC values and validate the selected methods.

Finally, NHTSA should conduct a pilot program to "test drive" the certification process and validate the regulatory instruments. The pilot program should focus on gaining experience with certification testing, data gathering, compiling, and reporting to help determine the accuracy and repeatability of all the test methods and simulation strategies. It should also gather data on fuel consumption from several representative fleets of vehicles to help provide a check on the effectiveness of the regulatory design.

Committee to Assess Fuel Economy Technologies for Medium- and Heavy Duty Vehicles: Andrew Brown, Jr. (Chair), Delphi Corporation; **Dennis N. Assanis**, University of Michigan; **Roger Bezdek**, Management Information Services, Inc.; **Nigel N. Clark**, West Virginia University; **Thomas M. Corsi**, University Of Maryland, **Duke Drinkard**, Southeastern Freight Lines; **David E. Foster**, University Of Wisconsin; **Roger D. Fruechte**, Consultant; **Ron Graves**, Oak Ridge National Laboratory; **Garrick Hu**, Consultant; **John H. Johnson**, Michigan Technological University; **Drew Kodjak**, International Council On Clean Transportation; **David F. Merrion**, Detroit Diesel (Retired); **Thomas E. Reinhart**, Southwest Research Institute; **Aymeric P. Rousseau**, Argonne National Laboratory; **Charles K. Salter**, Consultant; **James J. Winebrake**, Rochester Institute Of Technology; **John Woodrooffe**, University Of Michigan Transportation Research Institute; **Martin B. Zimmerman**, University Of Michigan

Staff: Duncan Brown, Study Director; **Dana Caines,** Financial Associate; **Lanita Jones,** Administrative Coordinator; **Joseph Morris**; Senior Program Officer, Transportation Research Board; **Jason Ortego**, Senior Program Assistant (Until December 2009); **Madeline Woodruff**, Senior Program Officer; **E. Jonathan Yanger**, Senior Program Assistant; **James J. Zucchetto**, Director, Board On Energy And Environmental Systems

The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Congress through the National Highway Traffic Safety Administration. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the sponsor. This report brief was prepared by the National Research Council based on the Committee's Report. This report is a product of the National Academies' **Board on Energy and Environmental Systems**.

Copies of the full report can be purchased from the National Academies Press, 500 5th Street NW, Washington DC, 20001; (800) 624-6242; www.nap.edu

Report issued August 2010.