Fuel Efficiency and Greenhouse Gas Emissions Standards for Heavy-Duty Pickups and Vans: Phase 2

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Acronyms and Abbreviations

ACEEE	American Council for an Energy-Efficient Economy
BMEP	Brake mean effective pressure
CO_2	Carbon dioxide
EGR	Exhaust gas recirculation
EPA	Environmental Protection Agency
FTP	Federal Test Procedure
g/bhp-hr	Grams per brake horsepower-hour
gal/100 miles	Fuel consumption in gallons per 100 miles
GCWR	Gross combined weight rating
GEM	Greenhouse gas emissions model
GHG	Greenhouse gas
GM	General Motors
GVWR	Gross vehicle weight rating
HD	Heavy-duty
HFET	Highway Fuel Economy Test
L	Liter
lbs	Pounds
LD	Light-duty
mpg	Miles per gallon
NAS	National Academy of Sciences
NRC	National Research Council
NHTSA	National Highway Traffic Safety Administration
NOx	Nitrogen oxides
ORNL	Oak Ridge National Laboratory
RR	Rolling resistance
SAE	Society of Automotive Engineers
SCR	Selective catalytic reduction
S-GDI	Stoichiometric gasoline direct injection
SwRI	Southwest Research Institute
THUD	Transportation, Housing and Urban Development, and Related Agencies
VIUS	Vehicle inventory and use survey
VMT	Vehicles miles traveled
VVA	Variable valve actuation

Executive Summary

In 2011, the US Environmental Protection Agency (EPA) and the Department of Transportation (DOT) adopted the first fuel efficiency and greenhouse gas standards for heavy-duty vehicles in the United States. The program divides heavy-duty vehicles into three categories, one of which is heavy-duty pickups and vans, the subject of this paper. The standards require these vehicles to lower fuel consumption on average by 12% in the 2018 model year, relative to 2010 levels.

EPA and DOT are now developing a second phase of the standards, which will apply to later-model-year vehicles. In this report we evaluate and make recommendations concerning the technologies available to reduce fuel consumption of heavy-duty pickups and vans. We also address the combined fuel consumption reduction those technologies could achieve and several issues relating to the structure of the standards. The inadequacy of current data on real-world duty cycles of heavy-duty pickups and vans is a recurring theme in this discussion.

Our assessment of available fuel efficiency technologies draws from agency documents, the 2010 National Academy of Sciences report on heavy-duty-vehicle fuel efficiency, and recent work from the Southwest Research Institute. The agencies' light-duty fuel economy and greenhouse gas rule for model years 2017–2025 is a key source of information, because the technologies that can be used to improve heavy-duty pickups and van fuel efficiency are by and large the same as those that are applicable to their light-duty counterparts. Moreover, a gap between the levels of fuel efficiency required of these two groups of vehicles could distort the market for pickups and vans.

Fuel savings are available from improvements both to the powertrain and to the remainder of the vehicle. Different technology opportunities are available to gasoline- and diesel-fueled vehicles, which are of equal importance in the heavy-duty pickup and van market. For gasoline engines, the technologies delivering greatest fuel savings are turbocharging and downsizing, cylinder deactivation, and variable valve actuation. For diesel engines, downsizing, combustion and fuel optimization, friction reduction, and high-efficiency after-treatment give the largest reductions. Among non-engine technologies, some of the largest savings would result from upgrading from a 6-speed to an 8-speed automatic transmission while improving transmission efficiency, adding start–stop capability, reducing vehicle weight, and electrifying accessories.

Combining the various technologies we considered into packages yielded the results shown in table ES1. We initially used a multiplicative approach to calculate savings, which we then adjusted to reflect overlap in the technologies' fuel savings benefits. We conclude that, including the adjustment for overlapping benefits, the Phase 1 and Phase 2 standards together could reduce fuel consumption of gasoline vehicles by 31% and of diesel vehicles by 28% relative to 2010 levels.

Table ES1. Overall fuel consumption reduction for HD diesel and gasoline pickups and vans from 2010 levels

Reduction	% fuel consumption and CO_2 reduction from 2010 levels	
	Gasoline	Diesel
Total reduction from engine technologies	18.7%	14.1%
Total reduction from vehicle and transmission technologies	19.8%	19.0%
Overall reduction from 2010 baseline	34.8%	30.5%
Loss from the overlapping of benefits in engine and transmission technologies	5.1%	3.6%
Adjusted overall reduction from 2010 baseline	**31.3%**	**27.9%**
Reduction to be achieved in Phase 1 (2014–2018)	10.2%	15.3%
Overall reduction beyond Phase 1	**23.4%**	**14.9%**

There are also several ways the agencies could improve on the structure of the program in Phase 2. First, they should define more carefully the work-factor attribute upon which the standards are based. Manufacturers do not uniformly calculate the parameters of payload capacity and towing capacity included in the work factor. The agencies could correct this problem by moving to parameter definitions based on a vehicle's demonstrated capabilities. Also, the work factor as currently defined does not adequately capture the relationship between a vehicle's utility and its fuel consumption or CO_2 emissions. In particular, it does not reflect the differences between gasoline and diesel vehicles, which could lead to the standards' having unintended adverse consequences.

Second, the option offered in Phase 1 to certify diesel pickups and vans as vocational vehicles may allow manufacturers to meet a less demanding standard. The result could be a weakening of both the pickup and van standard and the vocational vehicle standard. The most recent criteria pollutant emissions programs for vehicles, i.e., the federal Tier 3 and California LEV III standards, will for the first time require heavy-duty diesel pickups and vans to be certified through chassis testing. This eliminates the rationale for the optional certification these vehicles as vocational vehicles, so the option should be eliminated in Phase 2.

Finally, there is currently no fuel economy window sticker for heavy-duty pickups and vans. Such a sticker should be added in Phase 2 to allow vehicle buyers to compare vehicles based on both fuel efficiency and work capabilities.

In view of the findings of this report, we recommend that policymakers and relevant agencies take the following actions:

- Put in place a data collection program for HD pickups and vans, for example by reinstating the Vehicle Inventory and Use Survey (VIUS). Data collected should permit statistically valid analysis and should include sales, configurations, fuel consumption, loading and towing behavior, and miles traveled. The data should be made available to the public.

- If HD pickup and van duty cycles are found to be substantially different from those of LD pickups and vans, revise HD test cycles and protocols accordingly.

- Establish strong fuel efficiency targets for HD pickups and vans in Phase 2, based on consideration of all available technology. The standards should achieve at least a 31% fuel consumption reduction for gasoline vehicles and a 28% reduction for diesel vehicles in Phase 1 and Phase 2 combined.

- Minimize any fuel efficiency gap between similar LD and HD pickups and vans in order to avoid market distortion.

- Carefully define the work factor parameters of payload capacity and towing capacity to ensure uniform practice across vehicles and manufacturers. Manufacturers' advertised values should not be accepted for certification purposes.

- Using compliance data from the Phase 1 program and other data that may become available, conduct a new analysis of the relationship between CO_2 emissions and work factor, and determine whether revisions to the work factor are needed.

- If an attribute can be found to capture adequately the utility of both gasoline- and diesel-fueled HD pickups and vans, apply a single, fuel-neutral standard to all vehicles. Otherwise, set standards to reflect the differing functions and differing relationships between work factor and fuel consumption for gasoline and diesel vehicles

- Consider expressing fuel in units of gasoline gallon equivalent, diesel gallon equivalent, or Btu per 100 miles in order to increase comparability across fuels and facilitate harmonization of CO_2 standards and fuel efficiency standards.

- Require that all complete pickups and vans, irrespective of fuel type, be certified on a chassis dynamometer.

- Establish a consumer-oriented fuel efficiency label for HD pickups and vans similar to the label for light-duty vehicles.

Introduction

In 2011, the US Environmental Protection Agency (EPA) and the National Highway Traffic Safety Administration (NHTSA) adopted the first US standards for fuel efficiency and greenhouse gas (GHG) emissions for heavy-duty (HD) vehicles, including HD pickups and vans (EPA and NHTSA 2011a). These standards ("Phase 1") are expected to reduce the fuel consumption of new HD pickups and vans by an average of 12% in 2018 from 2010 levels (EPA and NHTSA 2011b). A second phase of the HD fuel efficiency and GHG emissions standards ("Phase 2") is now under development and will be adopted in early 2016 (White House 2014). While the Phase 1 rule was a milestone in addressing vehicle fuel consumption and GHG emissions, Phase 2 offers major opportunities for further progress on fuel efficiency and improvements in the structure of the standards. This report identifies such opportunities specifically for HD pickups and vans.

Our intent is to inform policymakers and others interested in vehicle fuel efficiency and GHG emissions about technologies that can contribute to significant fuel consumption reductions in Phase 2. We also explore regulatory issues critical to achieving a real-world reduction in fuel use. From our analyses we develop recommendations for the upcoming Phase 2 rulemaking. These recommendations are meant to maximize the benefits of the program and improve upon certain features of the Phase 1 rule.

HEAVY-DUTY PICKUPS AND VANS

Heavy-duty (HD) pickups and vans are those with a gross vehicle weight rating (GVWR) of 8,500 to 14,000 lbs. HD pickups and vans have the highest sales volume of all HD vehicle types, with about 790,000 sold in the United States in 2008 (EPA 2008). The agencies projected sales to continue at approximately this level for the few years following (EPA and NHTSA 2011b).

HD pickups and vans accounted for 12% of all HD GHG emissions in 2005, compared with 22% of GHG emissions from vocational vehicles and 66% from tractor-trailers (EPA and NHTSA 2011b), as shown in figure 1.[1] Up-to-date sales data and, as discussed below, performance and operational data for these vehicles are hard to obtain, and this has made it difficult to design policies to improve their fuel efficiency.

[1] Vehicles' fuel consumption and GHG emissions are closely related. While this report focuses on fuel efficiency, data and discussion relating to some issues may be stated in terms of GHG emissions for convenience.

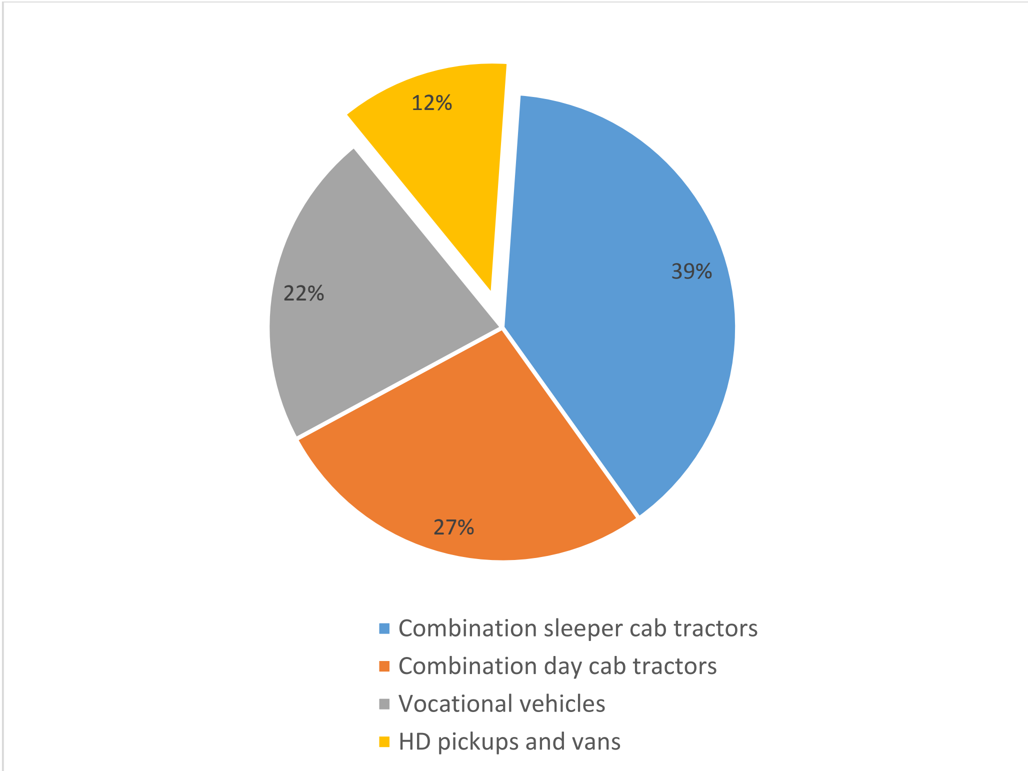

Figure 1. CO_2 emissions from heavy-duty vehicle categories. *Source:* EPA and NHTSA 2011b.

HD pickups and vans have many commercial uses, including carrying passengers and equipment and moving goods. They are also used as shuttle buses and ambulances (EPA and NHTSA 2011b). About 90% of HD pickups and vans are ¾-ton and 1-ton pickup trucks, 12- and 15-passenger vans, and large work vans that are sold by vehicle manufacturers as cab-complete pickups (EPA and NHTSA 2011b). General Motors (GM), Ford, and Chrysler account for more than 95% of HD pickup and van sales in the United States (EPA and NHTSA 2011a). Other manufacturers including Isuzu, Daimler, Mitsubishi, and Nissan have also stepped into this market.

Of the 790,000 HD pickups and vans sold in 2008 (EPA 2008), 79% were pickup trucks. A breakdown by fuel, type, and weight is shown in figure 2. Class 2b pickups (8,500–10,000 lbs. GVWR) dominated this sector, with 55% of sales. Overall, diesel and gasoline had equal share, although vans were overwhelmingly Class 2b gasoline vans, which captured nearly 81% of van share. Class 2b diesel vans had 9% of the van market, and Class 3 diesel and gasoline vans constituted the remaining 10% of the van market.

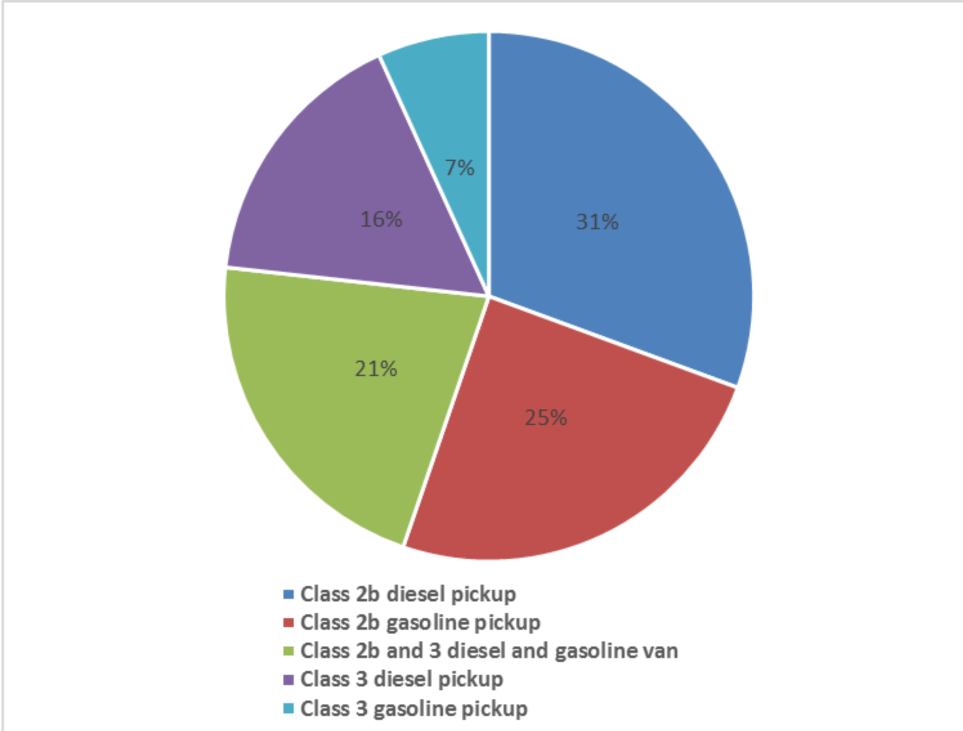

Figure 2. HD pickup and van sales breakdown in 2008. *Source:* EPA 2008.

PHASE 1 STANDARDS

The Phase 1 standards, which apply to model years 2014 to 2018, are expected to reduce the average fuel consumption of gasoline pickups and vans by 10% and diesel pickups and vans by 15% by 2018, relative to 2010 levels (EPA and NHTSA 2011a; EPA and NHTSA 2011b). The standards vary with vehicle attributes since they are based on a "work factor" that combines payload and towing capacities with a fixed adjustment for four-wheel drive. It should be noted that vehicles do not have to meet their targets individually. Rather, each manufacturer must meet a standard calculated as the production-weighted average of the targets for its diesel and gasoline fleets of HD pickups and vans produced in each model year. This means in particular that the average fuel efficiency required under the standards is not fixed in advance, but will depend on the mix of vehicles sold in future model years.

Fuel Efficiency Technologies for HD Pickups and Vans

The main determinant of the potential for fuel efficiency gains is the availability of cost-effective technology improvements. This section discusses available technologies and their effectiveness, alone and in packages.

COMPARISON WITH LARGE LIGHT-DUTY PICKUPS

Much of the analysis of fuel efficiency potential for HD pickups and vans is drawn from analysis of these vehicles' light-duty (LD) counterparts, with which they share many features. Manufacture of LD pickups (i.e., those with GVWR below 8,500 lbs.) is also dominated by GM, Ford, and Chrysler, who together had a market share of almost 86% in 2011 (AN 2012). These manufacturers often use the same engine for their LD and HD classes, with or without small differences in size and power.

About 2 million LD pickups were sold in the United States in 2008 (Pickuptrucks.com 2009). Large pickups (at least 6,000 lbs. GVWR) dominated the LD pickup market, with 1.6 million units sold (Pickuptrucks.com 2009). Because LD pickups are sold in greater numbers than HD pickups and vans, they likely drive the development of technology to a greater degree than HD pickups and vans do. This is true for gasoline vehicles only, however; diesel's penetration into LD is still very small.

The duty cycle of a work truck can be quite different from that of a personal vehicle, and this may have implications for the applicability of fuel efficiency technologies. However duty cycle data are not readily available. The US Census Bureau's Vehicle Inventory and Use Survey (VIUS) collected data on truck operation but did not clearly distinguish between LD and HD pickups. Moreover, the VIUS was discontinued after the 2002 survey. The Phase 1 HD rule mentioned differences in duty cycle and towing capacity between LD and HD trucks but did not quantify them. The 2010 National Academy of Sciences (NAS) report provided some information on fuel economy, annual vehicle miles traveled (VMT), and annual mileage range, but the data represented HD pickups and vans and vocational vehicles together, making it difficult to distinguish information specific to HD pickups and vans (NRC 2010).

For purposes of compliance with the HD standards, HD pickups and vans are tested on a chassis dynamometer using the same test cycles that are used for LD fuel economy vehicle testing. The HD rule applies the same cycle weighting as well: the Federal Test Procedure (FTP) city and highway cycles are weighted 55% and 45%, respectively (EPA and NHTSA 2011b). However HD pickup and van certification testing is conducted at half payload, while LD vehicles are tested at curb weight plus 300 lbs. The use of half payload for HD vehicles is intended to produce certification values that better reflect the fuel efficiency of the vehicle during work function. However the towing function is not represented in HD testing, so certification values provide no insight into how towing may affect fuel efficiency in operation. Thus, as a consequence of inadequate data on HD pickup and van duty cycle and incomplete representation of work function in the HD rule test protocols, there may be substantial discrepancies between technologies' effects on fuel efficiency as certified and the real-world fuel savings those technologies provide.

Notwithstanding these issues, the status of fuel efficiency in the LD sector is an essential starting point for a discussion of the HD case. Under LD fuel economy standards adopted in 2012, the average fuel economy of large LD pickups will reach about 25 miles per gallon (mpg) in 2018 (EPA and NHTSA 2012). This is almost 47% higher than the average fuel economy expected for HD gasoline pickups and vans in 2018, as shown in table 1. Furthermore, large LD pickups are expected to reach 36 mpg in 2025.

Table 1. Average fuel economy (mpg) for LD and HD pickups and vans under existing standards

Vehicle type	Current	2014	2016	2018	2025
Class 2b and 3 HD gasoline pickups and vans	15.4 (MY2010)	15.6	16.1	17.2	NA
Class 2a large LD trucks (footprint 66 sq. ft.)*	20.5 (MY2009)	23.1	24.7	25.2	36.0

MY is model year. *Tested at different test weight than HD vehicles.

LD vehicles weigh less than their HD counterparts, and HD vehicles are tested at half payload, as noted above. However differences in curb weight and payload explain less than half of the difference in fuel efficiency requirements for the two classes of trucks (Khan and Langer 2012). The remaining gap between the fuel efficiency requirements for LD and HD pickups with similar specifications warrants further investigation, as the relationship between the performance needs of work trucks and the fuel economy levels that these vehicles could achieve has not been thoroughly explored from an engineering perspective. Any gap between fuel economy requirements for LD and HD pickups for which there is no such engineering rationale could produce distortions in the pickup market, shifting sales toward the heavier vehicles.

Fuel Efficiency Technologies for Pickups and Vans

Several recent technology assessments are available for HD pickups and vans: the agencies' analysis for Phase 1, the 2010 NAS HD vehicle study (NRC 2010), and a recent technology evaluation by the Southwest Research Institute (SwRI) for NHTSA (SwRI 2014). In addition, there is much applicable information in the agencies' analysis for the LD 2017–2025 rule (EPA and NHTSA 2012). The effectiveness numbers for individual technologies estimated in these studies in some cases differ greatly. While the NAS study was extensive, the SwRI evaluation is more relevant for Phase 2, considering its timing and scope, which included evaluating technologies on numerous test cycles, including the FTP city and highway cycles used for certification for both LD and HD pickups and vans. The SwRI study assessed the fuel consumption reduction potential of some, though not all, of the latest technologies.

We used information from the sources mentioned above to determine the effectiveness and applicability of multiple technologies in four categories: engine, transmission, electrification and accessories, and the remainder of the vehicle. We then created packages of technologies to reduce the fuel consumption of gasoline and diesel vehicles. Numbers from the SwRI study provided the backbone for our packages, followed by numbers from the Phase 1 rule. All SwRI study effectiveness numbers used in this report are weighted 55% city cycle/45% highway cycle. In some cases we have included technology effectiveness results from the NAS study or other sources. All numbers shown reflect fuel efficiency improvement relative to 2010 model year vehicles. While we expect that our technology packages are quite cost effective, that analysis is not within the scope of this report.

Engine Technologies

The above studies included comprehensive technology evaluations for gasoline engines. For diesel engines, the technology evaluations other than the SwRI study either were limited to a few technologies or evaluated an integrated package. Our packages adopt the fuel savings potential values from the SwRI study when available, except when there were major discrepancies between the SwRI estimate and the other data sources.

TURBOCHARGING AND DOWNSIZING

Downsized, turbocharged engines offer a major opportunity to improve gasoline vehicle fuel efficiency. SwRI compared a 6.2-liter V-8 gasoline engine to a simulated downsized 3.5-liter V-6 and found 16% fuel savings. The NAS study found turbocharged downsizing benefits in the range of 10–14%. Downsized, turbocharged engines played a major role in the agencies' compliance scenario for the light-duty fuel efficiency standards for model years 2017–2025; the LD rule found 12.3% savings for 33% downsizing with turbocharging (EPA and NHTSA 2012). A gasoline engine largely can retain its performance when downsized and turbocharged, but fuel savings benefits may be reduced or eliminated at high load operation, including towing. This technology is therefore especially suitable for vehicles not regularly employed in heavy towing.

Most current diesel engines are already turbocharged, as turbocharging enables the higher power levels that are expected of diesel vehicles. Some of these vehicles in fact may be overpowered as a result, and in those cases engine downsizing is a means to reduce fuel consumption while still meeting vehicle performance requirements. SwRI found that downsizing an 8-cylinder diesel engine to a 4-cylinder engine provided a 12% reduction in fuel consumption.

The agencies did not include turbocharging and downsizing in Phase 1 for gasoline vehicles, arguing that "although these technologies made penetration in large light-duty pickups, they did not demonstrate those benefits in the heavy-duty fleet[,] likely due to concerns with durability of this technology in the sustained high-load duty cycles frequently encountered on heavy-duty pickups" (EPA and NHTSA 2011a). Downsizing was not considered for diesel vehicles either, presumably because it reduces the performance parameters of diesel. While such concerns limit the applicability of downsized engines, some HD pickups and vans have duty cycles that can accommodate the technology. In particular, vans are not typically engaged in towing, and some HD pickups with relatively low payload and towing capacities may also be good candidates for downsized engines.

We examined the work factor of pickups and vans to determine their potential market size. Work factor varied from below 3,000 lbs. to almost 8,300 lbs. Only 17% of diesel pickups and vans had a work factor of less than 5,000 lbs. but for gasoline pickups and vans, the proportion increased to 67% (EPA 2008). In light of these findings, we assumed that 17% of diesel pickups and vans and 67% of gasoline pickups and vans do not engage in sustained high load operation and hence are candidates for engine downsizing.

OTHER ENGINE TECHNOLOGIES

Apart from turbocharging and downsizing, cylinder deactivation and variable valve actuation (VVA) provide major fuel savings for gasoline engines. Cylinder deactivation saves fuel at light load operation. It deactivates intake and exhaust valves to prevent fuel injection into some cylinders at light loads, thereby enabling an 8- or 6-cylinder engine to operate like a 4-cylinder engine (EPA and NHTSA 2011a). VVA, on the other hand, controls the flow of air and fuel at intake and exhaust, valve timing, and valve lift. It adds flexibility to the engine valve trains and enables adaptive timing for various engine operating conditions. The SwRI study demonstrated significant fuel savings from cylinder deactivation and VVA for gasoline vehicles in all applicable duty cycles. When evaluated independently on a 6-liter V-8 engine, cylinder deactivation and VVA resulted in almost 8% and 7% fuel savings, respectively. However, when cylinder deactivation was evaluated on a downsized engine (3.5-liter V-6), its fuel savings benefit was reduced to 2%. This was not surprising, since the engine operated at optimum load after downsizing and the role of cylinder deactivation had been minimized. Hence our package does not include cylinder deactivation for turbocharged and downsized gasoline engines. We assume full fuel savings for non-downsized engines. Similarly, we applied VVA only in engines that had not been downsized.

It should be noted that other engine technologies considered here may have overlapping benefits as well. For example, cylinder deactivation and VVA address some of the same efficiency losses; therefore, when employed together, they will not achieve the same fuel savings as when applied separately. This issue is addressed in the section Overlapping Benefits and Phase 2 Potential, below, where we apply a correction factor to account for the overlapping of benefits.

Engine friction reduction provides significant fuel savings, especially for diesel pickups. Diesel engines operate at higher cylinder pressure than do gasoline engines and experience greater friction as a result (Stanton 2013). Diesel engine designers have made great strides over the last decade to reduce friction by using lighter oil and low-tension rings. Nonetheless, improvement opportunities remain, for example through an efficient injection system, smooth piston–cylinder operation, an efficient cooling system, reduced viscosity of engine oil, and better mechanical efficiency of pumps. The SwRI study found more than 4% overall fuel savings by reducing friction by 17% at high load operation and by 5% at light load operation. The study also found almost 8% fuel savings by doubling these values of friction reduction, but we adopted the lower estimates in calculating the effectiveness of our package, because the doubled values would necessitate almost 30% reduction in engine and accessory friction, which might not be cost effective or even achievable in the near term.

Gasoline engines can benefit from using cooled exhaust gas recirculation (EGR). Cooled EGR can reduce the fuel consumption of both direct-injected and port-injected gasoline engines by reducing pumping losses, mitigating knock, cooling the exhaust, and eliminating the need for fuel enrichment (Alger 2010). SwRI found 3.7% savings from cooled EGR. By contrast, diesel engines, which already use EGR for nitrogen oxide (NOx) control, could be made more fuel efficient by the elimination of EGR. The use of selective catalytic reduction (SCR) to comply with the stringent 2010 EPA NOx standards of 0.2 grams per brake horsepower-hour (g/bhp-hr) has considerably reduced the necessity of using EGR technology in diesel engines. However the use of on-board diagnostics and the expectation that California will further increase the stringency of NOx standards may keep manufacturers from eliminating EGR for diesel engines. Hence we do not include this option in the diesel package.

Overall, our engine technology packages reduce fuel consumption by 19% and 14% for gasoline and diesel vehicles, respectively, from 2010 levels, as shown in table 2 and table 3.

Total benefits shown in the tables were calculated using a multiplicative method; corrections for potential overlaps in technology benefits are discussed below.

Table 2. Engine technology effectiveness for gasoline pickups and vans from 2010 baseline

Engine technologies	Percentage fuel consumption and CO_2 reduction from 2010 baseline				
	HD Phase 1 rule	LD 2017–2025 rule	SwRI 2014	ACEEE estimate	Market penetration assumed
Engine friction reduction	2.0%	2.4%	1.5%	2.0%	100%
Variable valve actuation	2.5%	4.9%	6.7%	6.7%	33%
Stoichiometric GDI	1.5%	1.5%	0.2%	1.5%	100%
Downsizing from 6.2L V-8 to 3.5L V-6 with turbocharging	4.0%	12.3%*	15.3%	12.3%	67%
Cylinder deactivation	3.0%	5.7%	7.7%	7.7%	33%
Cooled EGR	NE**	3.5%	3.7%	3.7%	100%
Total reduction potential from engine technologies at assumed penetration				18.7%	

*18 bar brake mean effective pressure (BMEP). **Not examined.

Table 3. Engine technology effectiveness for diesel pickups and vans from 2010 baseline

Engine technologies	Percentage fuel consumption and CO_2 reduction from 2010 baseline				
	HD Phase 1 rule	NRC 2010 (TIAX 2009)	SwRI 2014	ACEEE estimate	Market penetration assumed
Engine friction reduction	5%	2.5%	4.4%	4.4%	100%
Combustion and fuel optimization		4.9%	NE*	4.9%	100%
Turbo efficiency improvement	NE	2%	2.5%	2.5%	100%
Engine downsizing/rightsizing	NE	NE	11.0%	11.0%	17%
Low back pressure	NE	NE	0.8%	0.8%	100%
High-efficiency after-treatment	4.0%	4.0%	NE	4.0%	100%
Total reduction potential from engine technologies at assumed penetration				14.1%	

* Not examined

Transmission Technologies, Start–Stop Systems, and Accessory Electrification

HD pickups and vans have already made the transition to 6 speed automatic transmission, so we consider the benefits of going beyond 6 speeds. We have adopted SwRI's estimate of 4.4% fuel savings as a result of moving from 6-speed to 8-speed transmissions and improving mechanical efficiency, as shown in table 4. We have used this estimate rather than the higher estimates given in the other studies, because we did not find recent data to support the higher numbers.

Start–stop systems save fuel by shutting off the engine when the vehicle is at rest and restarting it when the driver presses the acceleration pedal. We take the agencies' Phase 1 estimate of 4% benefit for gasoline pickups and vans from a 42-volt system with limited regeneration (EPA 2010). A 42-volt system offers high enough power to run air conditioning. It is more efficient than a 12-volt start–stop system, provides limited power assist, and gives much more freedom in placing the air-conditioning unit. In the absence of agency evaluation for start–stop technology in HD diesel pickups and vans, we take the 2.2% effectiveness number from a 12-volt start–stop system for diesel pickups and vans from the LD 2017–25 rule (EPA and NHTSA 2011c), although this estimate is lower than the value estimated by the NAS study. This is reasonable, since diesel vehicles are relatively efficient when idling; therefore, start–stop savings would be lower for diesels than for gasoline vehicles. We assumed 50% penetration of this technology in the Phase 2 time frame.

Electric steering and improved alternator and pumps would provide 2.8% fuel savings, consistent with the agencies' findings for both HD and LD pickups and vans (EPA and NHTSA 2011a; EPA and NHTSA 2012).

Vehicle Technologies

Heavy-duty pickups and vans can achieve modest fuel savings from aerodynamic improvements and larger savings from tire improvements. SwRI estimated that rolling resistance (RR) could be reduced by 30%, which would yield a 3.2% reduction in fuel consumption. However pickups that offer off-road capability are not candidates for these low-RR tires. To estimate how many vehicles are eligible for low-RR tires, we took 4WD vehicles as a surrogate for those that might be engaged in off-road work, although consumers choose 4WD for many other applications as well. The 2008 EPA data set showed that 40% of gasoline pickups and vans and 82% of diesel pickups and vans were equipped with 4WD. Therefore, we assumed 30% RR reduction for 60% of gasoline and 18% of diesel vehicles, and 10% RR reduction for the remaining vehicles. We used the same data to determine the applicability of secondary axle disconnect, since vehicles without 4WD cannot benefit from this technology.

The agencies considered a 5% mass reduction in Phase 1, resulting in 1.6% fuel savings. However more weight reduction is possible, especially with the increasing use of aluminum in vehicles. Ford recently announced that it would eliminate 700 lbs., more than 10%, from its next-generation Super-Duty pickups (Martinez 2014). We used the SwRI results for weight reduction, which found 3.5% fuel savings from 900 lbs. of weight reduction. Table 4 shows the effectiveness of various transmission and vehicle technologies.

Table 4. Transmission and vehicle technology effectiveness for diesel and gasoline pickups and vans from 2010 baseline

Vehicle/ transmission technology	Percentage fuel consumption and CO_2 reduction from 2010 baseline						
	HD Phase 1 rule	LD 2017–2025 rule for light trucks and vans	NRC 2010	SwRI 2014	ACEEE estimate for gasoline	ACEEE estimate for diesel	Market penetration assumed
8-speed automatic transmission (from 6-speed)	3.5%	5.8%	7.5%	4.4%	4.4%		100%
High-efficiency gearbox		4.3%					100%
Start-stop 42V or 12V/hybrid*	4.0%	2.2%	18%	NE**	4.0%	2.2%	50% penetration for start-stop
Electric power steering, improved alternator, and accessories	2.8%	2.9%		NE	2.8%		100%
10% aero drag reduction	2.1%	2.3%	3%	1.4%	2.1%		100%
Rolling resistance reduction	1.5% (10% RR)	2.9% (15% RR)	2%	3.2% (30% RR)	2.5%	1.8%	10% improvement across all tires plus 30% improvement for vehicles without 4WD
Reduced A/C power	NE	NE	NE	1.9%	1.9%		100%
Low-friction lubricants/Reduced chassis friction	0.5%	N/A	NE	1.0%	1.0%		100%
Low-drag brakes	NE	0.8%	NE	NE	0.8%		100%
Secondary axle disconnect	NE	1.6%	NE	NE	0.6%	1.3%	4WD vehicles only
Mass reduction	3.2%	5.2%	1.8%	3.6%	3.6%		100%
Total fuel consumption reduction from vehicle technologies					19.8%	19.0%	

* The NRC study did not estimate effectiveness for start-stop systems, but it considered full hybrid systems in its package for HD pickups and vans, giving rise to estimated fuel savings of 18%. ** Not examined.

OVERALL FUEL CONSUMPTION REDUCTION IN PHASE 2

Using a multiplicative approach to combining technology benefits, but without applying any correction factor for overlapping of benefits, we conclude that the technologies considered above, when applied at the penetration rates shown, provide a 35% average reduction in fuel consumption for gasoline vehicles and 31% for diesels relative to 2010 levels. Table 5 shows these results. All technologies considered in this analysis are already in the market, and manufacturers will gain further experience in applying most of them to meet the LD 2012–2016 and 2017–2025 standards.

Table 5. Overall fuel consumption reduction for HD diesel and gasoline pickups and vans from 2010 levels

Reduction	% fuel consumption and CO_2 reduction from 2010	
	Gasoline	Diesel
Total reduction from engine technologies (tables 2 and 3)	18.7%	14.1%
Total reduction from vehicle and transmission technologies (table 4)	19.8%	19.0%
Overall reduction from 2010 baseline	34.8%	30.5%

The overall fuel consumption reductions shown in table 5 are based on the effectiveness of individual technologies and do not account for possible overlaps in benefits. For engine and transmission technologies, there is a risk of double-counting benefits when more than one technology in a package addresses the same efficiency losses. The problem is illustrated by VVA and cylinder deactivation in gasoline engines. Cylinder deactivation prevents fuel injection into some cylinders in light load operation by deactivating the intake and exhaust valves, while VVA changes the timing of intake or exhaust valves (or both) to reduce pumping losses. Both of these technologies alter the functioning of the intake and exhaust valves, and their fuel savings benefits may consequently overlap.

We used EPA's Lumped Parameter Model (EPA 2011) and the SwRI analysis of gasoline engines to understand the adjustments employed to account for such overlaps in benefits. Combining engine friction reduction, VVA, stoichiometric gasoline direct injection (S-GDI),[2] cylinder deactivation, turbocharging and downsizing, and transmission improvement on a gasoline vehicle would result in a 17.0% reduction in fuel consumption using the multiplicative approach that we applied above, while the Lumped Parameter Model resulted in only a 12.8% reduction. Similarly, a package consisting of GDI, VVA, EGR, cylinder deactivation, and friction reduction on a 6.2-liter V-8 gasoline engine would give a total reduction of 18.4% based on SwRI's individual technology effectiveness values and using the multiplicative method, while the SwRI simulation for this package found only a 13.6% fuel consumption reduction. Based on these examples showing reductions of 20% and 26% in combined benefits due to overlap, we apply a 23% correction to the overall fuel consumption reductions for gasoline vehicles.

Applying the same method for diesel vehicles, we found a correction factor of 8% from LD Lumped Parameter Model findings and correction factors ranging from 20% to 37% in SwRI findings. We applied a 20% correction to diesel engine technologies and transmission benefits.

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[2] Stoichiometric GDI in gasoline engines enables direct fuel injection at high pressure into the combustion chamber, like diesel engine fuel injection. Direct fuel injection allows higher compression ratios in gasoline engines and achieves increased thermodynamic efficiency.

Thus, after applying the correction factor for overlapping benefits, we would expect the fuel savings of the gasoline and diesel packages to be approximately 31% and 28%, respectively, relative to 2010 levels, as shown in table 6.

An earlier analysis, which drew primarily from the 2010 NRC report and Phase 1 rule documents, concluded that it was possible to achieve 29% and 26% fuel consumption reductions in gasoline and diesel vehicles, respectively, relative to the 2010 baseline, though with very limited consideration of technology overlap and penetration issues (ACEEE et al. 2014). With the addition of the SwRI results, we find that it is possible to achieve greater fuel consumption reductions than found by the earlier analysis.

The agencies estimated that Phase 1 standards would result in 10% and 15% average reductions in fuel consumption for gasoline and diesel vehicles, respectively. Dividing out the reductions from Phase 1, we conclude that gasoline and diesel vehicles can reduce their fuel consumption by a further 23% and 15%, respectively, in Phase 2. Table 6 shows the net fuel consumption reduction.

Table 6. Net fuel consumption reduction for HD diesel and gasoline pickups and vans

Reduction	% fuel consumption and CO_2 reduction from 2010 levels	
	Gasoline	Diesel
Overall reduction from 2010 baseline (table 5)	34.8%	30.5%
Loss from the overlapping of benefits in engine and transmission technologies	5.1%	3.6%
Adjusted overall benefits from 2010 baseline	31.3%	27.9%
Reduction to be achieved in Phase 1 (2014–2018)	10.2%	15.3%
Overall reduction beyond Phase 1	23.4%	14.9%

Structural Considerations for Phase 2

While the levels set for fuel efficiency and greenhouse gas standards are clearly central to the program's benefits, success hinges on structural aspects as well. The program must be equitable and transparent and should not distort the market for the vehicles it regulates. In this regard, several features of the Phase 1 program warrant a fresh look for the next round of standards. First, the work factor attribute, which determines the fuel efficiency target for individual vehicles, raises several issues that were not fully resolved in Phase 1. Second, the Phase 1 standards set separate targets for gasoline vehicles and diesel vehicles, thus falling short of setting performance-based standards. Third, diesels under Phase 1 have an additional certification option that may invite misuse. Finally, a consumer label for HD pickups and vans has yet to be created. This section discusses these issues in order and suggests next steps for each.

WORK FACTOR

Under the Phase 1 standards, fuel efficiency and GHG targets are "attribute-based," meaning that the targets vary with vehicle properties. The rationale for attribute-based standards is that they can reflect any increase in fuel consumption necessitated by vehicle utility requirements and thus ensure that the standards do not discourage buyers from purchasing vehicles with the capabilities that they need.

The agencies considered vehicle payload and towing capacities and four-wheel-drive capability to be the primary determinants of functionality for HD pickups and vans, and these features tend to increase fuel consumption. For example, higher payload capacity may require more power or greater braking capability; higher towing capacity may require higher axle ratios, larger tires, or a larger radiator. The agencies used these three features to define the attribute "work factor" as follows:

$$Work\ Factor = [0.75 \times (Payload\ Capacity + xwd)] + [0.25 \times Towing\ Capacity]$$

Here, xwd is 500 lbs. if the vehicle is equipped with four-wheel drive and 0 lbs. otherwise. Payload capacity and towing capacity are expressed in pounds.

The CO_2 emissions and fuel consumption targets under the standards are linear functions of work factor, as shown in the following equations. A vehicle with a higher work factor is assigned higher fuel consumption and CO_2 emissions targets.

$$CO2\ Emissions\ Target\ \left(\frac{grams}{mile}\right) = [a * Work\ Factor + b]$$

$$Fuel\ Consumption\ Target\ \left(\frac{gallons}{100\ miles}\right) = [c * Work\ Factor + d]$$

Coefficients a, b, c, and d are different for each year of the standards and are different for gasoline and diesel vehicles. The 2018 CO_2 emissions targets are shown in figure 3.

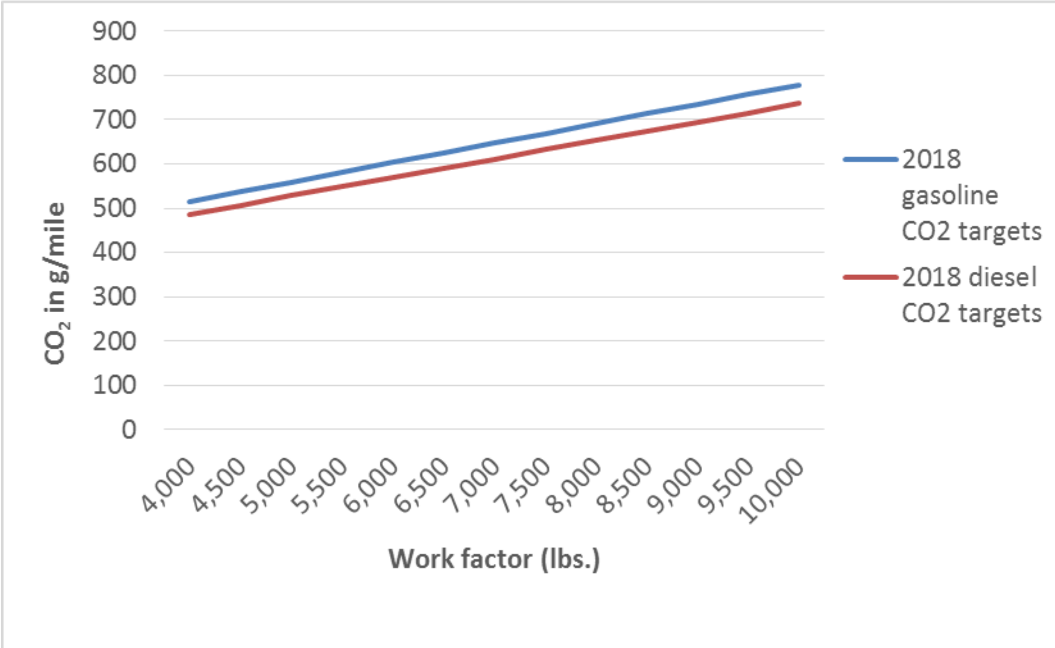

Figure 3. CO_2 emissions/fuel efficiency targets for diesel and gasoline pickups and vans

Gasoline vehicle targets are 6% less stringent than those for diesel vehicles with the same work factor. The 2018 fuel consumption targets for gasoline and diesel differ by a greater amount: 18% across all work factors. This is because fuel efficiency, for the purposes of the standards, is expressed in volumetric terms (gallons per 100 miles), and diesel has a substantially higher energy density than gasoline has. While this report focuses on fuel efficiency, figure 3 compares the targets in CO_2 terms, because that provides a more realistic picture of the relative stringencies of the standards for gasoline and diesel.

Using a volumetric measure of fuel efficiency presents an obstacle to harmonizing CO_2 and fuel consumption standards. This problem could be eliminated by using gallons gasoline equivalent (in energy terms) per 100 miles, or gallons diesel equivalent or British thermal unit (Btu), as the fuel efficiency metric.

Payload and Towing Capacities

Basing standards for HD pickups and vans on payload and towing capacities is consistent with accommodating the work requirements of these vehicles. However the specifications entering into the work factor as defined in Phase 1 raise concerns. The Phase 1 rule defines payload and towing capacities as follows:

$$Payload\ Capacity = GVWR - Curb\ Weight$$

$$Towing\ Capacity = GCWR - GVWR$$

The rule defines the three weight parameters involved in payload and towing capacities as follows:

- *GVWR* is "the value specified by the vehicle manufacturer as the maximum design loaded weight of a single vehicle, consistent with good engineering judgment."
- *Curb weight* "has the meaning given in 40 CFR 86.1803, consistent with the provisions of § 1037.140. 9." According to the referenced section of the Code of Federal Regulations, "Curb weight means the actual or the manufacturer's estimated weight of the vehicle in operational status with all standard equipment, and weight of fuel at nominal tank capacity, and the weight of optional equipment computed in accordance with §86.1832-01; incomplete light-duty trucks shall have the curb weight specified by the manufacturer" (40 CFR 86.1803-1).
- *GCWR* is "the value specified by the vehicle manufacturer as the maximum weight of a loaded vehicle and trailer, consistent with good engineering judgment. For example, compliance with SAE J2807 is generally considered to be consistent with good engineering judgment, especially for Class 3 and smaller vehicles."

All three definitions involve manufacturer discretion. This leeway could weaken the standards, in effect. For example, two manufacturers recently claimed 150 to 250 lbs. additional payload in model year 2015 pickups by lowering vehicle curb weight (Vellequette 2014). These manufacturers did not count the weight of some equipment, such as spare tire and rear bumper, in determining the curb weight. Adding 250 lbs. to the payload would increase a vehicle's work factor by 188 lbs. This in turn would lessen the CO_2 emissions reduction required in 2018 by 8.3 grams per mile, or 11 to 20%, depending on the work factor of the vehicle. Furthermore, our inspection of vehicle specifications on manufacturer websites suggested that a modest increase in towing capacity may not require any changes in engine or vehicle specs.

It should also be noted that the Phase 1 rule may have inadvertently given still greater discretion to manufacturers. The rule states: "The payload and towing capacity inputs used to determine manufacturer compliance will be the advertised values" (EPA and NHTSA 2011a). The advertised values for maximum payload and towing are determined entirely by the manufacturers and may differ greatly from the values calculated using the definitions above. One investigation of this issue found that certain manufacturers overstated the towing capacity by almost 1,000 lbs. to counter competitors' marketed towing capacities (Pickuptrucks.com 2012). We understand that the "advertised values" were intended in the rule to refer to the weight parameters defining payload and towing capacities, not to the payload and towing capacities themselves, but this should be clarified in the rule.

Hence it is important that the agencies better define payload and towing capacities in the rule. Over the past several years, the Society of Automotive Engineers has been developing a standard (SAE J2807) that defines protocols for testing and calculating maximum towing ratings. Some manufacturers, though not all, have pledged to use the SAE standard (cars.overstock.com 2015). Given the performance-based approach taken by the SAE, it is likely that the Phase 2 rule could benefit from the incorporation of the SAE standard into the definition of towing capacity used in the work factor.

Validity of Work Factor Attribute

In the Phase 1 rulemaking, the agencies developed the work factor attribute using the specifications of HD pickups and vans of model year 2008. Neither fuel consumption nor

CO_2 emissions data exist for most of these vehicles, so EPA derived emissions values from CO_2 test data that were available for a small number of vehicles of model years 2008–2010 (EPA 2010). EPA extrapolated emissions values from the test data using the test weights, axle ratios, and 2/4-wheel-drive corrections for the full 2008 vehicle set. The agencies used the resulting synthetic data set to perform regression analyses of CO_2 emissions against various possible attributes and chose the work factor defined above as the attribute on which to base the standard.

This approach to defining work factor raises several questions. First, the specifics of the extrapolation of CO_2 emissions data differed by manufacturer and varied greatly among them. The agencies did not offer an engineering-based explanation for the methodology, and it is not clear why such variation should occur. Second, the correlation between work factor and the derived CO_2 emissions values is weak (R^2 value of 0.32); moreover, we found that other linear combinations of payload and towing capacities yielded better correlations than did the chosen work factor. Third, in their regression analyses the agencies did not weight the data by sales, so the results may not properly capture the dominant characteristics of the HD pickup and van market. A more detailed investigation of the relationship is called for, especially given the diversity of HD pickups and vans. Fortunately, the agencies should now have CO_2 emissions data for all model year 2014 HD pickups and vans and therefore should have a much sounder basis for setting the Phase 2 standards.

FUEL TYPE

Fuel type is one aspect of the relationship between work factor and CO_2 emissions that warrants further evaluation. Separating the EPA data set discussed above by fuel type, one notes that while gasoline vehicle emissions are highly correlated with work factor (R^2 value of 0.71), there is little correlation for diesel vehicles (R^2 value of 0.12), as shown in figure 4. Moreover, the slope of the regression line for diesel vehicle CO_2 is distinctly different from that for gasoline vehicles. A 1,000-pound increase in the work factor of a diesel vehicle is correlated with an emissions increase only one-third as large as the emissions increase for a gasoline vehicle. While these results should be viewed with caution, given the issues raised above concerning the data set and the analysis on which they are based, the marked difference between gasoline and diesel vehicles' CO_2 emissions as a function of work factor is evident from the original test data as well.

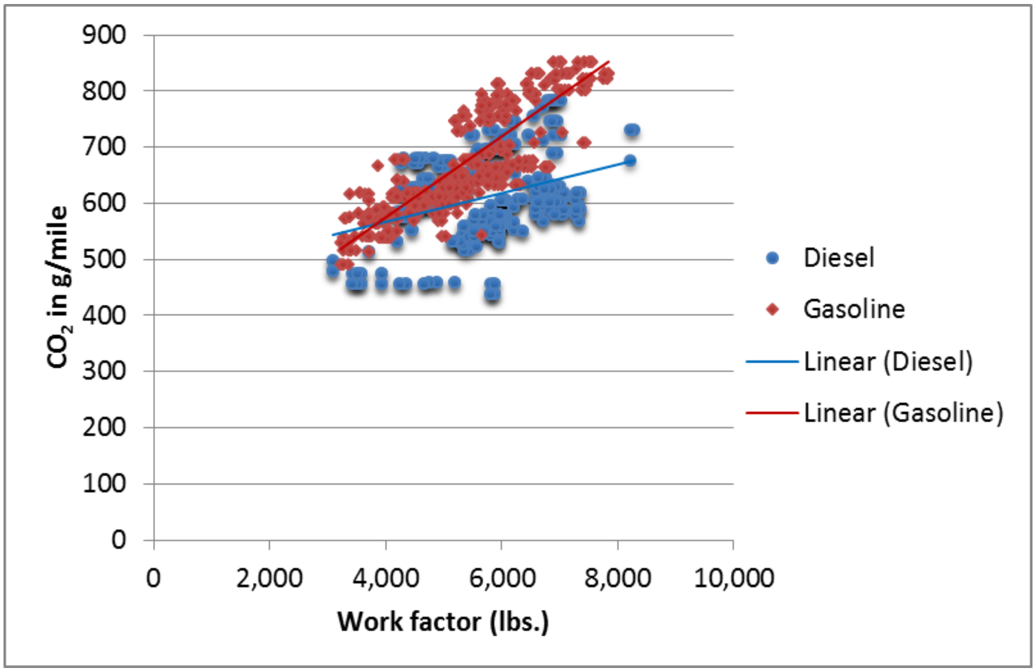

Figure 4. CO_2 emissions versus work factor for HD pickups and vans by fuel

The agencies did set different standards for gasoline vehicles and diesel vehicles in Phase 1, but the lines defining the standards have almost equal slopes, as shown in figure 3. Hence, given the very different slopes of the lines showing the relationship between emissions and work factor for gasoline and diesel, as shown in figure 4, the standards may incentivize increasing work factor for diesel vehicles and decreasing work factor for gasoline vehicles, potentially distorting the market. This mismatch should be addressed in Phase 2.

The best solution may not be as simple as changing the slopes of the lines defining the standards, however, because that approach reinforces the Phase 1 decision to set separate CO_2 emissions standards for gasoline and diesel vehicles. As a general matter, performance-based standards are preferable to technology- and fuel-specific standards because they typically provide the greatest benefit at the lowest cost. Hence, in other regulatory contexts, gasoline and diesel vehicles are often required to meet the same standards. For example, in the case of LD vehicle emissions, gasoline and diesel vehicles are subject to the same greenhouse gas and criteria pollutant standards. Such requirements have been adopted despite the substantially greater difficulty that one vehicle type may face in meeting the standard.

In the case of the Phase 1 rule, the agencies' rationale for setting different fuel efficiency targets for diesel and gasoline vehicles was based in part on the different specifications for these vehicles and differences in available technologies. However, if work factor is in fact an adequate measure of utility for these vehicles, then having the fuel efficiency target vary with work factor should address the utility concern. Furthermore, to the extent that diesel and gasoline vehicles compete in the same market, standards should be set at the best fuel efficiency level available to either vehicle type. However it should be recognized that fuel-neutral standards may meet with more resistance in the HD pickup market, where both fuel types have large shares, than in the LD market, where diesels make up only a small percentage of sales.

CERTIFICATION PROTOCOLS FOR DIESEL PICKUPS AND VANS

In Phase 1, manufacturers of diesel HD pickups and vans have the option to certify their vehicles as vocational trucks, rather than use the chassis dynamometer test procedure discussed above (EPA 2011). Vocational vehicle engines are subject to a separate engine standard and certified on an engine dynamometer, while the remainder of the vehicle is subject to the vocational vehicle standard and certified through EPA's Greenhouse Gas Emissions Model (GEM).

The Phase 1 standards require an 8% reduction in fuel consumption for Class 2b–5 vocational diesel vehicles (EPA and NHTSA 2011b). The improvement will come almost entirely from the engine, with a small contribution from lower tire rolling resistance. In comparison, diesel pickups and vans will be required to reduce fuel consumption by 15% in Phase 1, according to the agencies. This raises the concern that manufacturers might choose to certify diesel pickups and vans as vocational vehicles to avoid a somewhat more demanding standard.

If manufacturers of HD diesel pickups and vans were to choose to certify them as vocational vehicles, the fuel efficiency gains of these vehicles could be substantially diminished. Moreover, any extra savings achieved through this alternative test protocol could be used to offset shortfalls in efficiency improvements of the manufacturer's other vocational vehicles and their engines. Indeed, given the high volume of HD diesel pickup and van sales (about 400,000 in 2008) relative to those of vocational vehicles (less than 200,000 combined for Class 3–8 vocational vehicles in 2010), modest improvements in HD pickup and van efficiency could not only fully meet the program's requirements for these vehicles but also eliminate the need for manufacturers to make any improvements to their vocational vehicles or engines.

Fortunately, manufacturers are not likely to use this option extensively. Recently adopted criteria pollutant standards for vehicles, California's LEV III and the federal Tier 3 Motor Vehicle Emission and Fuel Standards (EPA 2014), require HD pickups and vans to be chassis certified. That is, these standards will apply to the entire vehicle, not to the engine alone. Given the need for these vehicles to undergo chassis testing for criteria emissions beginning in model year 2017, manufacturers may prefer to simplify the testing process by certifying for fuel efficiency and GHG emissions at the same time. In any case, the agencies have the opportunity to align protocols for the fuel efficiency and GHG program with those of the criteria pollutant programs in Phase 2. This would eliminate the concern raised by the alternative certification pathway for diesel vehicles. In any case, the agencies should ensure that the vocational standards are not so weak as to make this alternative pathway an invitation for manufacturers to migrate their HD diesel pickups and vans, especially Class 3 pickups, into the vocational segment.

LABELING

At present, HD pickups and vans carry no window sticker enabling buyers to compare vehicles' fuel efficiency at the time of purchase. Providing information for buyers is an important aspect of the effort to improve fuel efficiency, as several parties have noted. The 2010 NRC heavy-duty report stressed the need for accurate consumer information, stating, "Given the high fuel consumption sensitivity of some medium- and heavy-duty vehicle purchasers, it appears that one priority should be to ensure that accurate information on the fuel consumption characteristics of a completed vehicle is available to the purchaser. Having such information would help drive the selection of vehicles with the lowest fuel consumption for the task performed" (NRC 2010). The Phase 1 rule itself stated, "We do intend to consider this issue as we begin work on the next phase of regulations, as we recognize that a consumer label can play an important role in reducing fuel consumption and GHG emissions" (EPA and NHTSA 2011a). In 2011, 17 US senators wrote to the agencies requesting, among other things, that the rule require window stickers for heavy-duty pickups. They stated: "The label would be especially helpful to the farmers, contractors, landscapers, and other small business owners who purchase approximately 785,000 of these pick-up trucks each year, but who currently cannot compare the fuel economy of large pick-up truck models" (US Senate 2011). The Senate Subcommittee on Transportation, Housing, and Urban Development and Related Agencies (THUD) report for FY2012 stated:

> The Committee commends the Department of Transportation for expressing its intent to create fuel economy labels for large pickup trucks and commercial vans, and it directs the Department to prioritize this rulemaking in order to label vehicles within 3 model years. The Committee also encourages the Department to provide information on the fuel economy of large pickup trucks and commercial vans on fueleconomy.gov while the labeling regulation is being drafted. (THUD 2012).

The Phase 2 rule provides the opportunity to act on these recommendations and commitments and address the need for buyer information. The long-standing LD fuel economy labeling program could be expanded to cover these vehicles. Given that the HD fuel efficiency certification values reflect testing at half payload, translating these values to miles per gallon would yield lower numbers than the fuel economy of a comparable vehicle tested as an LD vehicle. Thus the label would need to clearly convey the distinct testing requirements for HD vehicles. However this need can be met in multiple ways and should not be accepted as a reason to further delay HD vehicle labeling. Using the original units of the HD standard (gallons per hundred miles), for instance, or changing the background color of the label may suffice to distinguish the HD label from an LD label. It may also be beneficial to include on the label the fuel economy (in miles per gallon) of the HD pickup or van when tested as an LD vehicle, so that the buyer can compare the performance of LD and HD vehicles when they are used as personal transport, i.e., lightly loaded.

Conclusions and Recommendations

The Phase 1 fuel efficiency and greenhouse gas emissions standards for model year 2014–2018 HD pickups and vans represent a milestone in addressing the fuel consumption and GHG emissions of these vehicles. However, due in part to a shortage of information about the duty cycles and other operating characteristics of these vehicles, the agencies did not consider, or discounted the benefits of, many important fuel efficiency technologies in determining the stringency of the standards. In the next phase of the program, there are opportunities to achieve greater fuel consumption reductions from these vehicles and to improve other features of the standards.

In view of the findings presented in the report, we recommend the following actions by policymakers and relevant agencies:

- Put in place a data collection program for HD pickups and vans, for example by reinstating the Vehicle Inventory and Use Survey (VIUS). Data collected should permit statistically valid analysis and should include sales, configurations, fuel consumption, loading and towing behavior, and miles traveled. The data should be made available to the public.

- If HD pickup and van duty cycles are found to be substantially different from those of LD pickups and vans, revise HD test cycles and protocols accordingly.

- Establish strong fuel efficiency targets for HD pickups and vans in Phase 2, based on consideration of all available technology. The standards should achieve at least a 31% fuel consumption reduction for gasoline vehicles and a 28% reduction for diesel vehicles in Phase 1 and Phase 2 combined.

- Minimize any fuel efficiency gap between similar LD and HD pickups and vans, in order to avoid market distortion.

- Carefully define the work factor parameters payload capacity and towing capacity to ensure uniform practice across vehicles and manufacturers. Manufacturers' advertised values should not be accepted for certification purposes.

- Using compliance data from the Phase 1 program and other data that may become available, conduct a new analysis of the relationship between CO_2 emissions and work factor, and determine whether revisions to the work factor are needed.

- If an attribute can be found to capture adequately the utility of both gasoline- and diesel-fueled HD pickups and vans, apply a single, fuel-neutral standard to all vehicles. Otherwise, set standards to reflect the differing functions and differing relationships between work factor and fuel consumption for gasoline and diesel vehicles.

- Consider expressing fuel in units of gasoline gallon equivalent, diesel gallon equivalent, or Btu per 100 miles, in order to increase comparability across fuels and facilitate harmonization of CO_2 standards and fuel efficiency standards.

- Require that all complete pickups and vans, regardless of fuel type, be certified on a chassis dynamometer.

- Establish a consumer-oriented fuel efficiency label for HD pickups and vans similar to the label for light-duty vehicles.

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