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EPA/NHTSA Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles

On October 25, 2010, the U.S. Environmental Protection Agency (EPA) and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) announced the world's first-ever program to reduce greenhouse gases (GHGs) and improve fuel efficiency of medium- and heavy-duty vehicles. While Japan deserves full credit for establishing the world's first fuel economy program for medium and heavy-duty vehicles in 2005 that will go into effect in 2015, the US rule proposal adds several important elements: (1) drives efficiency improvements in all aspects of the heavy-duty vehicle for the two highest fuel consumption classes: tractor trailers and pickups / vans (2) sets separate standards for engines and vehicles, and (3) establishes standards for four major greenhouse gases. The agencies are expecting to finalize the rule by July 30, 2011 after a notice and sixty-day comment period that ends on January 31, 2011.

In 2007, the Energy Independence and Security Act (EISA) instructed the EPA and NHTSA to work collaboratively to deliver regulations under their respective authorities: the EPA is proposing GHG emission standards under the Clean Air Act, and NHTSA is proposing fuel efficiency standards under the EISA. The emissions included in the EPA's program will be carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs).

Overall, the stringency of the program ranges from 7 to 20% reduction in fuel consumption in the model year (MY) 2018 timeframe. The stringency levels vary based on vehicle subcategories that are based on weight classes and vehicle attributes. The rule proposal is best understood as three separate regulatory designs as well as specific provisions for heavy-duty engines that power tractor trucks and vocational vehicles.

The EPA and NHTSA estimated the costs and benefits of the proposed regulations, and the per-vehicle figures are summarized in Table 1. In addition to additional capital costs and lifetime savings, the payback period—that is, the amount of time it takes for the expected fuel savings to outweigh the increased up-front costs—is an important factor of interest. For tractor trucks, given the high number of annual miles these ve-

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hicles typically travel, the agencies estimate that payback for each vehicle will generally occur within the first year of ownership. The case of heavy-duty pickup trucks and vans is different, as these vehicles average much less annual mileage on average, so the fuel savings take longer to accrue. For this group of vehicles, the agencies estimate a payback time of about of five years. For vocational vehicles, the estimated fuel savings of nearly $500 in year one is larger than the modest cost increase of roughly $360, thus making the payback time less than a year.

Table 1: Estimated Additional Costs and Fuel Savings Benefits for MY 2018 Vehicles

Vehicle Category	Additional Cost per Truck (MY 2018)	Lifetime Fuel Savings (3% Discount Rate)	Reference in Preamble and Regulations Document[1]
Tractor Trucks	$5,901	$79,699	Table VIII-11
HD Pickups and Vans	$1,411	$3,996	Table VIII-10
Vocational Vehicles	$359	$4,360	Table VIII-9

1 US EPA and NHTSA (2010) Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles. (http://www.gpo.gov/fdsys/pkg/FR-2010-11-30/pdf/2010-28120.pdf).

The agencies estimate total benefits from the proposed rule, which will affect vehicles beginning with model year 2014, of nearly 250 million metric tons of avoided GHGs and approximately 500 million barrels of oil saved over the lifetime of the vehicles sold during 2014 to 2018. This translates to total societal benefits of $49 billion, which is a net benefit of $41 billion after accounting for the estimated $7.7 billion in costs to industry. The rule builds on a Congressionally- mandated study by the National Academy of Sciences (NAS) and previous work developed by the ICCT[1]. The table below provides relevant statistics for each vehicle class within the medium and heavy-duty vehicle sector.

Table 2: From the NAS Study – Vehicle Population, Fuel Use, and Mileage

Vehicle Size	Population (M)	Annual Miles (M miles)	Annual Fuel Use (M gallons)	% of Population	% of Annual Miles	% of Fuel Use
Class 2B	5.800	76,700	5,500	52.8%	35.1%	19.3%
Class 3	0.691	9,744	928	6.3%	4.5%	3.3%
Class 4	0.291	4,493	529	2.6%	2.1%	1.9%
Class 5	0.166	1,939	245	1.5%	0.9%	0.9%
Class 6	1.710	21,662	3,095	15.6%	9.9%	10.9%
Class 7	0.180	5,521	863	1.6%	2.5%	3.0%
Class 8	2.154	98,522	17,284	19.6%	45.1%	60.8%
TOTAL	10.992	218,580	28,444	100%	100%	100%

1 In collaboration with the Northeast States Center for a Clean Air Future (NESCCAF), Southwest Research Institute, and TIAX, LLC, the ICCT released the report, Reduction Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO2 Emissions in October 2009 (http://www.theicct.org/2009/10/reducing-hdv-emissions/). ICCT-sponsored activities also include analyses of the heavy-duty fleet and industry characteristics, modeling fuel economy versus duty cycle, and a fuel efficiency metric evaluation.

Tractor Trucks (Class 7 and 8). Tractors trucks are vehicles that are typically used to haul goods over long distances. These trucks account for more than 60 percent of fuel consumption and GHG emissions from the heavy-duty sector and thus attract the greatest amount of regulatory attention in the rule proposal. There are nine separate standards for tractor trucks: three categories of vehicles (Class 7, Class 8 day cab, and Class 8 sleeper cab) and three roof height categories (low, medium, and high). Manufacturers would certify tractors using a newly developed computer simulation model called the Greenhouse gas Emissions Model (GEM). For tractors, inputs to the model include data on aerodynamics, tire rolling resistence, weight reduction, and extended idle reduction. In addition, as aforementioned, there is also a separate engine standard. Trailers used in combination trucks are not included in the proposal and are expected to be addressed in a future regulation.

Commercial Pickups and Vans (Class 2B and 3). This category of heavy-duty pickup trucks and vans accounts for about 20 percent of fuel use and GHG emissions, second after the tractor trucks. These vehicles are tested on a chassis dynamometer with the stringency of the standards scaled by a newly created "work factor" that reflects the vehicle's utility (i.e., hauling capacity, payload, and capacity for four-wheel drive). This aspect of the rule can be viewed as an extension of the light-duty passenger vehicle GHG and CAFE program. It is arguably the simplest regulatory regime in this multifaceted rulemaking.

Vocational Trucks (Class 2B – 8). This is a catchall category for rest of the medium- and heavy-duty vehicles. Together, these vehicles account for the remaining 20 percent of the fuel use in the sector. The Class 6 box trucks typically used in urban deliveries are the biggest single fuel users accounting for half the total or about 10 percent. The vast array of different configurations of these vehicles (bucket trucks, refuse vehicles, buses, etc.), duty cycles, and work loads, make this category particularly challenging to regulate. Similar to the tractor program, there is a separate engine standard for this this group of vehicles. Manufacturers would certify vocational vehicles using the GEM software by inputting tire specifications.

Heavy-duty Engines. Engine testing for compliance with GHG and fuel efficiency standards will occur simultaneously with testing for criteria pollutants using the same procedures and test cycles that are currently used. In effect, three more pollutants must measured and reported: CO_2, CH_4, and N_2O. The procedures to determine which engines must actually be tested will also remain the same as in current criteria pollutant testing. Engines will be categorized as light-heavy (Class 2B through 5), medium-heavy (Class 6 and 7) and heavy-heavy (Class 8) based on what vehicle class they are used in. Within each of these compliance categories, all engine models offered by each manufacturer will be grouped into engine families based on specific criteria that define engines with similar emission characteristics. Manufacturers must select at least one engine from each family for testing, consistent with selection procedures defined in 40 CFR Part 86.

Table 3 provides additional detail on the vehicle and engine categories included in the proposal. For each category the table also identifies the entity responsible for complying with the standards.

TABLE 3: SUMMARY OF INCLUDED VEHICLE AND ENGINE CATEGORIES

Rule category	Vehicle classes	Weight (GVWR[1])	Typical vehicles	Regulated entity	Requirement (metric)
Tractor trucks and engines	Class 7 and 8 tractors	• 27,000 – 33,000 lbs. (12 – 15 tons) • 33,001 lbs. and over (15 tons and over)	Tractor trucks	• Tractor manufacturer • Engine manufacturer	• Whole vehicle GHG and fuel consumption standard (g CO2/ton-mile, gallon/1,000 ton-mile) • Engine standard (g CO2/bhp-hr, gallon/100 bhp-hr)
Heavy-duty pickup trucks and vans	Selected class 2B and 3 vehicles	8,501 – 14,000 lbs. (3.9 – 6.4 tonnes[2])	• Full size pickups • Utility vans • Step vans	Vehicle manufacturer	Whole vehicle GHG and fuel consumption standard (g CO2/mile, gallon/100 mile)
Vocational vehicles and engines	• Light HDVs (Class 2B though 5) • Medium HDVs (Class 6 and 7) • Heavy HDVs (Class 8)	• 8,501 – 19,500 lbs. (3.9 – 8.8 tonnes) • 19,501 – 33,000 lbs. (8.8 – 15 tonnes) • 33,001 lbs and over (> 15 tonnes)	• City delivery • Bucket trucks • Beverage trucks • Large walk-in delivery trucks • School buses • Refuse trucks • Cement trucks	• Vehicle manufacturer (chassis) • Engine manufacturer	• Whole vehicle[3] GHG and fuel consumption standard (g CO2/ton-mile, gallon/1,000 ton-mile) • Engine standard (g CO2/bhp-hr, gallon/100 bhp-hr)

1 GVWR: The gross vehicle weight rating is the maximum loaded weight of a vehicle including fuel, passenger, and cargo.

2 Tonne: metric tonne (= 2,204.6 lbs)

3 While the regulation for vocational vehicles is technically a ‘vehicle’ standard, in its current form, the program would only require testing, reporting, and improvements in tire efficiency.

The following sections explore each of these three regulatory programs in more detail. Also, there is a section at the end of document that discusses the various elements of the proposed options for the test procedure of hybrid vehicles. It should be noted that the regulation is yet to be finalized, and the agencies are seeking comment on various open issues as well as many other aspects of the proposal.

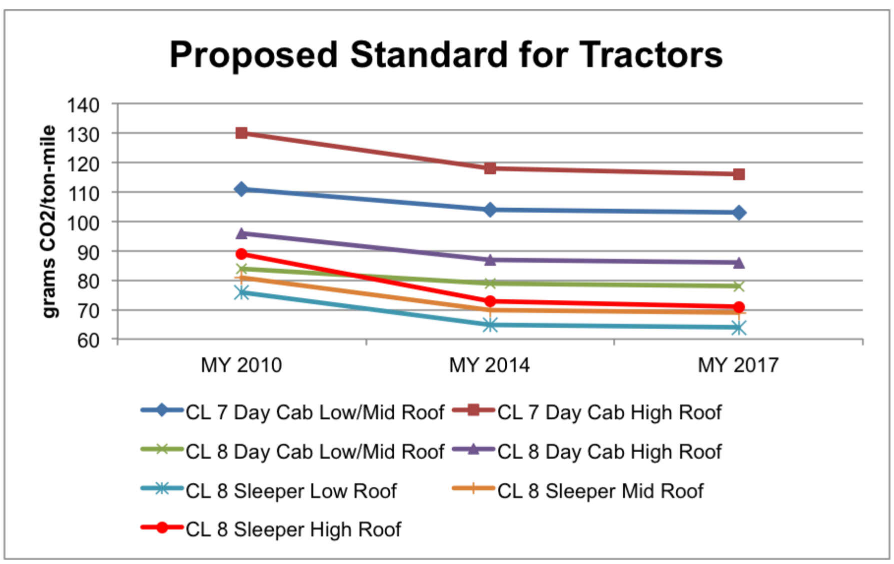
Class 7 and 8 Tractor Trucks

The EPA and NHTSA are proposing separate vehicle-based and engine standards for Class 7 and 8 tractor trucks. Engine manufacturers would be subject to the engine regulation, and vehicle manufacturers would be required to install certified engines in their tractors. In addition, tractor manufacturers would be required to certify compliance using a newly developed simulation model that evaluates design elements such as the tractor’s aerodynamic features and the rolling resistance values of its tires.

A. Vehicle-based Standard

For the vehicle-based part of the tractor regulation, the proposal outlines nine subcategories based on three dimensions: gross vehicle weight, cab configuration (day or sleeper cab), and roof height (low, medium, or high). The EPA is proposing standards for all subcategories starting in model year (MY) 2014, and the mandatory NHTSA program will begin in MY 2016 after two years of voluntary compliance. The respective metrics proposed for the EPA and NHTSA programs are grams of CO_2 per ton-mile and gallons of fuel per 1,000 ton-miles, where a ton-mile is defined as a ton of freight transported one mile. The standards in the EPA and NHTSA programs are identical, based on an emission factor of 10,180 grams of CO_2 per gallon of diesel fuel. However, as discussed below, the EPA proposed standard also includes limits on engine N_2O and CH_4, as well as limits on emissions of refrigerant from air conditioning systems. The EPA standards for all of vehicle subcategories are shown below in Figure 1. Note that there are only seven distinct stringency lines in Figure 1 based on the fact that the agencies are not aware of any mid roof day cab tractors, but any that might exist would be subject to the respective low roof standards. As compared to the baseline values, which are meant to represent average MY 2010 tractors, the values for MY 2014 are a 6 to 18% improvement, depending on the specific tractor subcategory. The tightening of the standard in MY 2017 represents a 7 to 20% improvement over the MY 2010 values. The increased stringency in the MY 2017 standard is predicated solely on engine improvements.

Figure 1: Proposed Tractor CO_2 Emission Standards



(Source: Values from Table II-1 in Section II.B.(1)(a) *US EPA and NHTSA (2010) Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles* (http://www.gpo.gov/fdsys/pkg/FR-2010-11-30/pdf/2010-28120.pdf).

B. Technology Assessment

The proposed stringency levels are based on the adoption of currently available technologies and include improvements in aerodynamic design, use of lower rolling resistance tires, vehicle weight reduction, and extended idle reduction technologies. In addition, in the targets for the engine standard, the agencies considered technologies such as friction reduction, aftertreatment optimization, and turbocompounding.

There is a wide range of aerodynamic configurations and features in the tractor market, and the agencies are proposing a technology bin approach to represent the variety of tractors are available—or, are expected to be available—in the near future. The aerodynamic technology bins are summarized below in Table 4.

TABLE 4: TRACTOR AERODYNAMICS BINS AND APPROXIMATE BASELINE (MY 2010) MARKET SHARES

Bin Name	Description	Baseline New Truck Fleet (%Market Share)
Classic	• Few if any aero features • Certain features detract from aero performance (bug deflectors, B-pillar exhaust stacks, etc.)	25%
Conventional	• Generally aerodynamic shape • No 'Classic' features that detract from aero performance	70%
SmartWay	• Added aero features such as fully enclosed roof fairings, side extending gap reducers, fuel tank fairings, and streamlined grill/hood/mirrors/bumpers	5%
Advanced SmartWay	• Additional aero features such as underbody airflow treatment, lowered ride height	0%
Advanced SmartWay II	• Features that are in prototype development such as advanced gap reduction, rearview cameras to replace mirrors, advanced body designs	0%

Source: Section II.B.(2)(c) and Section III.A.(1) in the Preamble and Regulations document

The right column of Table 4 shows the approximate market share of the aerodynamic bins for model year 2010 tractors. In their assessment for technology adoption for this rulemaking, the agencies assumed that a large percent of sales would migrate from the 'Classic' and 'Conventional' bins to the 'SmartWay' and 'Advanced SmartWay' bins. The adoption assumptions for each tractor subcategory are summarized below in Table 5.

In addition to aerodynamic improvements, the other technology categories that the agencies identified as viable options for the tractor market are low rolling resistance (LRR) tires, weight reduction, and extended idle reduction. As with aerodynamics, the agencies have employed a bin approach to assess tires, though three bins are used instead of five. The three bins are 'Baseline,' 'SmartWay,' and 'Advanced SmartWay,' and the adoption assumptions are given in

Table 5. Looking at tractor weight, the agencies estimate that, on average, 400 pounds of reduction can be achieved by using aluminum in place of steel wheels and single-wide tires as replacements for duals tires. Finally, currently available technologies such as auxiliary power units eliminate the extended (main engine) idling in sleeper cabs that is used to support hotel loads. As shown in Table 5, the proposal assumes a 100% adoption rate for this technology in Class 8 sleeper cabs (current levels are approximately 30%).

Table 5: Proposed Technology Adoption Percentages for Class 7 and 8 Tractors

	Class 7		***Class 8***				
	Day Cab		*Day Cab*		*Sleeper Cab*		
	Low/Mid Roof	*High Roof*	*Low/Mid Roof*	*High Roof*	*Low Roof*	*Mid Roof*	*High Roof*
Aerodynamics (Cd)							
Classic	0%	0%	0%	0%	0%	10%	0%
Conventional	40%	30%	40%	30%	30%	20%	10%
SmartWay	50%	60%	50%	60%	60%	60%	70%
Adv. SmartWay	10%	10%	10%	10%	10%	10%	20%
Adv. SmartWay II	0%	0%	0%	0%	0%	0%	0%
Steer Tires (CRR kg/metric ton)							
Baseline	40%	30%	40%	30%	30%	30%	10%
SmartWay	50%	60%	50%	60%	60%	60%	70%
Adv. SmartWay	10%	10%	10%	10%	10%	10%	20%
Drive Tires (CRR kg/metric ton)							
Baseline	40%	30%	40%	30%	30%	30%	10%
SmartWay	50%	60%	50%	60%	60%	60%	70%
Adv. SmartWay	10%	10%	10%	10%	10%	10%	20%
Weight Reduction (lb)							
Control	100%	100%	100%	100%	100%	100%	100%
Extended Idle Reduction (gram CO_2/ton-mile reduction)							
Control	N/A	N/A	N/A	N/A	100%	100%	100%
Vehicle Speed Limiter							
Control	0%	0%	0%	0%	0%	0%	0%

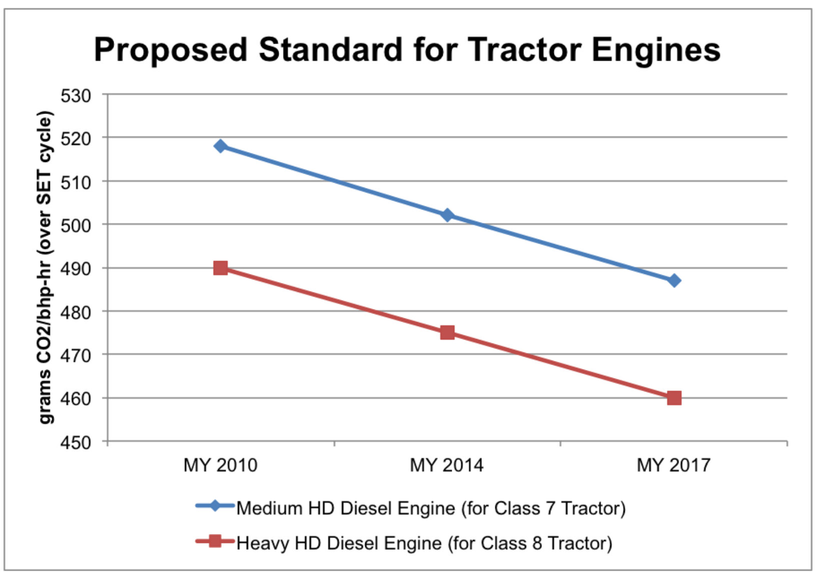
Source: Values from Table III-4 in Section III.A.(2)(a)(iv) in the Preamble and Regulations document.

C. Engine-based standard

The engine-only component of the tractor (and vocational vehicle) regulation is designed to compliment the EPA's criteria pollutant regulatory program. Engine testing for compliance with GHG and fuel efficiency standards will occur simultaneously with testing for criteria pollutants including oxides of nitrogen (NOx), particulate matter (PM), carbon monoxide (CO), and hydrocarbons (HC) using the same procedures and test cycles. In effect, three more pollutants must measured and reported: CO_2, CH_4, and N_2O.

An engine will be categorized as Light-Heavy if its intended use is in Class 2B through Class 5 vehicles, Medium-Heavy for use Classes 6 and 7 vehicles, and Heavy-Heavy for use in Class 8 vehicles. Within each of these compliance categories, all engine models offered by each manufacturer will be grouped into engine families based on specific criteria that define engines with similar emission characteristics. Manufacturers must select at least one engine from each family for testing, consistent with selection procedures defined in 40 CFR Part 86. The medium- and heavy-heavy engines installed in tractors would be required to the meet their respective standards based on the steady-state SET test cycle[2].

Figure 2: Tractor Engine CO2 Emission Standards.



(Source: Values from Table II-2 in Section II.B.(1)(b) in the Preamble and Regulations document)

As with the tractor proposal, the EPA engine CO_2 standard (grams per bhp-hr) is scheduled to begin in MY 2014, while NHTSA's fuel consumption standard (gallon per 100 bhp-hr) is voluntary in MYs 2014, 2015, and 2016 and mandatory starting in MY 2017, harmonized with the EPA's MY 2017 standards. For the MY 2014 standard, the proposed engine technology package

2 The SET test cycle is a series of 13 steady-state load points. For the SET cycle, average emissions at each load point are reported separately, and an over-all weighted average is reported based on pre-defined weighting factors.

includes engine friction reduction, improved aftertreatment devices, improved combustion processes, and low temperature exhaust gas recirculation (EGR) optimization. The technology package for the MY 2017 engine adds turbocompounding to the MY 2014 package. It should be noted that the more stringent tractor standards for MY 2017 (see Figure 1) reflect the CO_2 emissions reductions required through the MY 2017 engine standards. As aforementioned, the MY 2017 tractor standards are only premised on advances in engine technology—not improvements in vehicle technologies. Figure 2 shows the standards for medium- and heavy-heavy engines in MYs 2014 and 2017, as well as the MY 2010 baseline values.

In addition to these CO_2 standards, the limits for both N_2O and CH_4 are proposed at 0.05 grams/bhp-hr. These standards would go into effect in MY 2014 and would remain the same over the useful life of the engine, as the agencies report that test data shows N_2O and CH_4 emissions do not increase over the life of the engine.

D. Vehicle Certification

The agencies have developed a MATLAB/Simulink-based software program called the Greenhouse gas Emissions Model (GEM) to evaluate fuel use and CO_2 emissions through the simulation of whole-vehicle operation, which is consistent with NAS recommendation. This model will be used to certify vehicle compliance with GHG and fuel efficiency standards, based on model inputs specific to each vehicle. Conceptually, GEM is similar to many models that have been developed by other research institutions and commercial entities in that it uses various inputs to characterize a vehicle's properties (weight, aerodynamics, and rolling resistance) and predicts how the vehicle would behave on a second-by-second basis when following a specific drive cycle.

The inputs in the GEM are associated with many features of the vehicle that have a strongest impact on fuel consumption and CO_2 emissions. One potential shortfall of the software is that the GEM does not currently credit any gains that may be achieved in the driveline system. While, presumably, many of the improvements in engine technology will be motivated by the distinct engine regulation, no credit would be given to advances in transmission efficiency or better synergy between the engine and transmission. For tractors, manufacturers would provide five modeling inputs: 1) coefficient of drag (C_d), 2) rolling resistance (kg/metric ton) for both steer and drive tires, 3) weight reduction, 4) extended idle reduction technology, and 5) vehicle speed limiter.

It is proposed that tractor manufacturers determine the aerodynamic drag coefficient by using either the coast-down method (SAE J2263) or wind tunnel tests. However, it is not yet specified how the agencies will evaluate C_d results that may differ based on the fact that they were generated using different test methods. For rolling resistance, manufacturers will need to determine these values experimentally by using the ISO 28580 test method. In addition, tractor manufacturers can specify up to three other features that will be used in the GEM model to modify fuel use calculations:

Speed limiter – if top speed is limited to below 65 mph an alternate test cycle will be used to reflect this lower top speed.

Weight reduction – if manufacturers use single-wide tires or aluminum wheels they can increase the payload weight used for fuel use and CO_2 calculations by the amount that the actual truck weight is reduced as compared to the standard value.

Extended Idle Reduction Technology (Class 8 Sleeper cab only) – If equipped with this technology, the GEM model will credit the truck 5 g/ton-mile CO_2 emissions. For low-, mid-, and high-roof sleeper cabs, this 5 g/ton-mile credit is 6.6%, 6.2%, and 5.6% of total baseline emissions, which are 76, 81, and 89 g/ton-mile for the respective subcategories.

For compliance testing on the GEM, the agencies are proposing three drive cycles: 1) the California Air Resources Board (ARB) Transient cycle, 2) a 65 mph cruise cycle, and 3) a 55 mph cruise cycle. For each vehicle type (sleeper cab or day cab), these three cycles will be weighted to simulate actual driving profiles. The weighting factors for tractors are shown Table 6.

Table 6: Drive Cycle Weighting Factors for Tractors

	Day Cabs	**Sleeper Cabs**
Transient	19%	5%
55 mph cruise	17%	9%
65 mph cruise	64%	86%

The EPA and NHTSA are proposing that the vehicle standard is on a ton-mile basis, and, as such, have also proposed that tractors be modeled in GEM using standard 53 ft box trailers and fixed payload values. The agencies are proposing that the fixed payload for Class 7 and Class 8 tractors be 25,000 and 38,000 pounds of payload respectively. These payload amounts represent a heavily loaded trailer, but not maximum gross vehicle weight rating (GVWR), since most trailers "cube-out" (i.e. are volume limited) rather than "weigh-out."

In addition to the engine- and tractor-based standards for CO_2 and the engine limits on N_2O and CH_4, the EPA is proposing a separate standard to reduce leakage of hydrofluorocarbons (HFCs). Unlike the 'gram of refrigerant leakage per year' system in place in the light-duty vehicle sector, the EPA is proposing a 'percentage of refrigerant leakage per year' to reflect the variety of air conditioning designs and layouts in the heavy-duty sector. The EPA is proposing a standard of 1.5% leakage per year for Class 7 and 8 tractors. It is estimated the average percent leakage for a MY 2010 vehicle is roughly 2.7%.

E. Compliance Provisions

There are many provisions in the proposal detailing what tractor manufacturers must do to comply with the standards. Responsibilities include reporting, in-use testing and verification, labeling, and durability and warranty requirements. These various elements are summarized in Table 7 below.

Table 7: Summary of Compliance Provisions for Tractor and Tractor Engine Manufacturers

	Heavy-Duty Engines for Tractors	**Class 7 and 8 Tractors**
Demonstrating Compliance	Test engine results adjusted for deterioration factors would define the Family Certification Limit (FCL); engines in the family may not exceed this limit. A Family Emissions Limit, defined as 2% above FCL, would apply to enforcement audits and production line testing.	Compliance testing is done using the GEM software, as described above.
Durability	Manufacturers must develop testing-based deterioration factors for engines to reflect potential increases in CO_2 emissions due to aging aftertreatment devices or other engine wear.	Agencies believe that if vehicle remains in its original certified condition throughout its useful life, GHG emissions will not increase as a result of service accumulation.
In-use	In-use data collection from PEMS, but no in-use standard. "Not-to-exceed" (NTE) limit deemed inapplicable to CO_2.	Vehicles must remain in certified configuration throughout their lives; aerodynamic components, idle reduction equipment, speed-limiting devices would be checked. LRR tires verified at the point of initial sale; no requirement that replacement tires must be LRR (though agency savings calculations reflect continued use of LRR tires).
Labeling	Will use criteria pollutant label showing certified configuration; must show Family Certification Levels or Family Emissions Limits for GHGs if manufacturer participating in Averaging, Banking and Trading (ABT). Will show category of vehicle for which engine is certified.	Emissions control label lists all the CO_2 emission reduction equipment and features of the vehicle (e.g., aero fairings, idle reduction systems, vehicle speed limiters, etc.).
Other Certification Issues		Manufacturers must warrant for the useful life of the vehicle any component other than tires that is being relied upon to reduce GHG emissions.
Penalties	The EPA is able to provide for HD nonconformance penalties under Section 206(g) of Clean Air Act but does not believe they will be necessary, given the flexibility mechanisms and that the standards are "readily feasible."	

F. Flexibility Mechanisms

Averaging, Banking, and Trading (ABT). The ABT program for engines is based on existing the engine ABT program for criteria pollutants and uses the same subcategories: light-, medium-, and heavy- heavy-duty diesel. Gasoline or spark ignition (e.g., natural gas) engines for heavy-duty vehicles fall into their own regulatory subcategory. Vehicle credits or debits for tractors would be calculated in terms tons CO_2 (or gallons for the NHTSA regulation) based on the following equation:

Credit (or debit) = (Std – [GEM output]) x (Payload Tons) x (Volume) x (UL) x (10-6)

where

Std = the standard of the specific tractor regulatory class (grams/ton-mile)

GEM outputs = results from the GEM simulation (grams/ton-mile)

Payload tons = 12.5 tons for Class 7 and 19 tons for Class 8

Volume = (projected or actual) production volume of the tractor family

UL = useful life of the tractor (435,000 miles for Class 8 and 185,000 miles for Class 7)

In this regulatory scheme, final production values are needed to determine each manufacturer's compliance status. Manufacturers must make a "good faith" demonstration of their production estimates for a given model year, and then after production ends, the manufacturers' compliance credits (or debits) are calculated. Similar to the proposed Heavy-duty Engine ABT program, the agencies are proposing that tractor manufacturers would be able to carry forward deficits from their regulatory subcategories for three years before reconciling the shortfall.

Averaging—that is, using a credit for over-compliance to compensate for under-compliance debits—is permitted only within the nine tractor subcategories. Similarly, credits generated within a subcategory would be tradable between manufacturers in that specific subcategory only. Credits would not be transferrable between engine and vehicle regulatory categories. An exception is that certain advanced technologies (see below) can generate credits applicable to any category, including engines. For both engine and tractor manufacturers, the agencies propose that credit deficits could be carried forward a maximum of three years before reconciling the shortfall.

Early Credits. Manufacturers can generate credits by certifying vehicles to the applicable standard at least six months before the standard is effective. The value of these early credits is not affected by the year in which they are generated or applied, and the credits can be used only within the appropriate subcategory. The EPA and NHTSA are requesting comment on whether or not a credit multiplier—specifically, a factor of 1.5—should be applied to early credits as an incentive for early compliance.

Advanced Technology Credits. Rankine cycle (bottoming cycle) engines and hybrid, electric, and fuel cell vehicles can generate credits that can be applied across all vehicle and engine categories. The agencies are seeking comment on any conversion factors that may be needed to allow such cross-category applications. As with early credits, the agencies are seeking comment as to whether a multiplier of 1.5 would be appropriate to apply to advanced technology credits. In terms of analyzing the benefits of hybrid vehicles, the agencies have proposed using either an engine dynamometer or chassis dynamometer evaluation procedure. However, due to the complexity involved with properly valuating hybrid systems in a laboratory setting, the agencies are requesting comments on the most appropriate test procedures to accurately measure the fuel consumption and CO_2 benefits of hybrids. A more detailed discussion of hybrid test procedure in the proposal is summarized below in the *Hybrid Vehicle Test Procedure* section.

GHG substitution. For the engine regulatory program, CH_4 and N_2O emissions in excess of the limits the rule sets for these pollutants can be offset by additional CO_2 reductions. The required offset is computed using their global warming potentials (GWPs), as defined by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report in which N_2O has a 100-year GWP value of 298, and CH_4 has a 100-year GWP value of 25.

Class 2B and 3 Commercial Pickups and Vans

Unlike the tractor category, the EPA and NHTSA propose to use chassis dynamometers for certification of the Class 2B and 3 vehicles as complete vehicles, and there will be no separate regulation for their engines. The primary motivation behind this regulatory design is the fact these vehicles are often very similar to their variants in the Class 2 category, and their lighter weight allows for ease in chassis-based testing. Because of the similarities between the Class 2, 2B, and 3 categories, the agencies have proposed a regulatory design for these vehicles that is closely related to the program for light-duty vehicles.

A. Vehicle-based standard

The agencies are proposing fleet average targets for commercial pickups and vans based on a "work factor" attribute that combines vehicle payload capacity and vehicle towing capacity, in pounds, with an additional fixed adjustment for four-wheeled drive vehicles. The definition for work factor (WF) is as follows:

WF = [0.75 x (Payload Capacity + xwd)] + [0.25 x Towing Capacity]

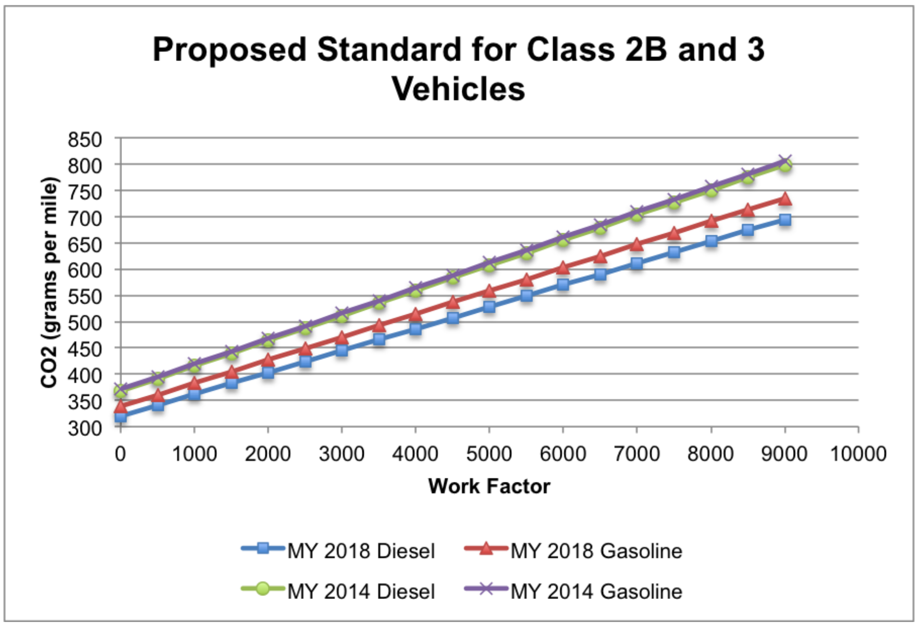
where

Payload Capacity = GVWR (lbs) – Curb Weight (lbs)

xwd = 500 if the vehicle is equipped with 4 wheel drive and 0 otherwise

In the proposal, the grams CO_2/mile (EPA) and gallons/100 miles (NHTSA) standards are a function of the work factor.[3] As shown in Figure 3 below, as the work factor value increases, the limit values for fuel use and CO_2 increase linearly. As proposed, the regulation will be implemented in phases from MY 2014 to 2018 and include separate standards for diesel and gasoline vehicles based on differing technology potential (discussed in more detail in the following section). In MY 2014 the performance standard for diesel and gasoline vehicles in terms of CO_2 (and fuel use) per mile are almost identical; however, by MY 2018 the limit line for diesels is roughly 6% lower. The agencies estimate that in MY 2018 the average CO_2 emissions as compared to a MY 2010 baseline will be 10% lower for gasoline vehicles and 15% lower for diesel vehicles.

FIGURE 3: PROPOSED EPA CO_2 STANDARDS FOR HEAVY-DUTY PICKUPS AND VANS



(Graphic created using the equations and Table II-7 in in Section II.C.(1)(c) in the Preamble and Regulations document)

3 As with the proposed tractor regulation, the standards in the EPA and NHTSA programs are identical, based on an emission factor of 10,180 grams of CO2 per gallon of diesel fuel. Also, for gasoline vehicles, the conversion factor is 8,887 grams of CO2 per gallon of gasoline.

B. Technology Assessment

The table below summarizes the technologies that the agencies believe can provide cost-effective reductions in fuel use and CO_2 emissions. The fuel consumption reduction estimates from the Draft Regulatory Impact Analysis[4] are shown in the middle column. In total[5], the fuel consumption reductions associated with these technologies are estimated at 12% as compared to a MY 2010 baseline for gasoline powered vehicles and 17% for diesels.

Table 8: Additional Costs (2008$) and Fuel Use/$CO_2$ Reduction Estimates for Class 2B and 3 Heavy-duty Pickups and Vans

Technology	Applicability	Fuel Consumption (CO_2) Reduction	2014	2018
Low friction lubricants	All	0 – 1%	$4	$4
8-speed automatic trans	All	1.7%	$231	$218
Low RR tires	All	1 – 2%	$6	$6
Aerodynamics	All	1 – 2%	$54	$51
Electric power steering	All	1 – 2%	$108	$101
AC refrigerant leakage reduction	All	2%	$21	$19
Engine friction reduction	Gasoline	1 – 3%	$108	$108
Coupled cam phasing	Gasoline	1 – 4%	$46	$43
Cylinder deactivation	Gasoline	3 – 4%	$193	$182
Stoichiometric GDI V8	Gasoline	1 – 2%	$395	$372
Mass reduction (5%)	Gasoline 2B	1.6%	$462	$435
Mass reduction (5%)	Gasoline 3	1.6%	$513	$483
Engine improvements	Diesel	4 – 6%	$172	$152
Aftertreatment improvements	Diesel	3 – 5%	$110	$104
Improved accessories	Diesel	1 – 2%	$88	$82
Mass reduction (5%)	Diesel 2B	1.6%	$544	$511
Mass reduction (5%)	Diesel 3	1.6%	$576	$542
Overall MY 2018 Package (2B)	**Gasoline**	**12 %**	**$1,628**	**$1,539**
Overall MY 2018 Package (2B)	**Diesel**	**17 %**	**$1,338**	**$1,248**

(Table created using values from Table 2-36 in the Draft Regulatory Impact Analysis document)
Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles (http://www.epa.gov/otaq/climate/regulations/420d10901.pdf).

4 US EPA and NHTSA (2010) Draft Regulatory Impact Analysis: Proposed Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles (http://www.epa.gov/otaq/climate/regulations/420d10901.pdf).

5 Note that the percentages are not directly additive because many of the technologies target the similar aspects of the engine, driveline, or vehicle systems. When used in combination with other technologies, the marginal contribution from each technology is less than if it were used by itself.

C. Certification

For heavy-duty pickups and vans, vehicle fuel efficiency and GHG emission standards will be tested on a chassis dynamometer, which closely mirrors the light-duty vehicle program. The agencies are proposing to use the Urban Dynamometer Driving Cycle (UDDS) and the Highway Fuel Economy Dynamometer Procedure (HFET). Both of these cycles are defined by a speed (miles per hour) time trace. The UDDS is a highly transient cycle with numerous stops and starts, while the HFET is a much less transient cycle with a maximum speed of 60 mph and an average speed of 48.6 mph. The complete UDDS test includes one "cold start" test followed after ten minutes by one "hot start" test. The HFET cycle is run with the vehicle already warmed up.

D. Compliance and Flexibility Provisions

Closely aligning the regulatory design for Class 2B and 3 heavy-duty pickups and vans with that of the light-duty program was a high priority for the agencies, and, as such, they have proposed a fleet averaging system for manufacturer compliance. Each manufacturer's fleet average will be based on final production volumes for the model year. Manufacturers must make a "good faith" demonstration of their production estimates for a given model year, and then after production ends, the manufacturers' compliance 'scores' are calculated. A manufacturer would generate credits if its fleet average CO_2 (EPA) or fuel consumption (NHTSA) level is lower than its standard and would generate debits if its fleet average CO_2 or fuel consumption level is above that standard. The following example is purely illustrative and helps to explain the fleet averaging calculation.

In the table below, a manufacturer is producing three models (A, B, and C) with different work factor values. Based on their WFs, each model is subject to different targets, given in the third column from the left. Subtracting each model's actual CO_2 result from their target value yields a score for each model—positive values for a model that has exceeded its target and negative values for those that have not. At the end of the production year, the manufacturer multiplies each model score with its production volume and a fixed useful life (miles) value to transform the scores into tons CO_2. Adding the CO_2 tons for all models yields a final balance for the manufacturer. In this example, the manufacturer has a 4,000 ton credit. If the total balance were negative, the manufacturer would have a debit. To align with the provisions of the light-duty GHG program, the agencies propose identical terms: a 5-year limit on credit carry-forward and a 3-year limit on debit carry-forward. In other words, a manufacturer would only be allowed to have a negative balance for a maximum three consecutive years before facing a penalty.

Table 9: Compliance Example for Class 2B and 3 Heavy-duty Pickup Truck and Vans

Vehicle Model	Actual CO_2 Chassis Test Result (g/mi)	Target CO_2 Value Based on WF Value (g/mi)	Score = Target – Actual	End of Model Year Production Volume	Score x Volume	Useful Life (mi)	Tons CO_2 (tons)
A	620	600	-20	3,000	-60,000	200,000	-12,000
B	700	710	10	2,000	20,000	200,000	4,000
C	635	650	15	4,000	60,000	200,000	12,000
						Total Balance =	**4,000**

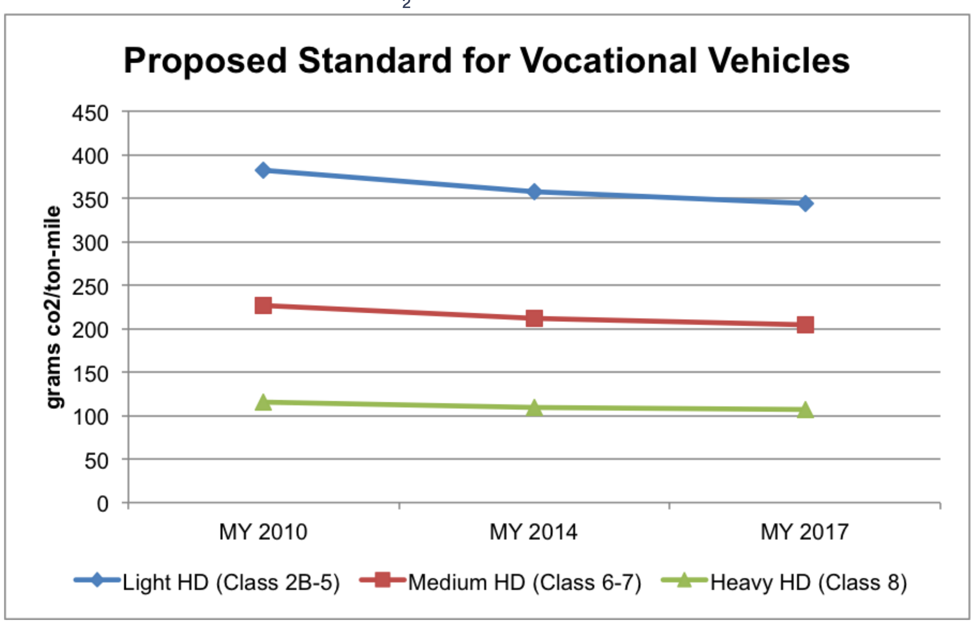
Class 2B through 8 Vocational Vehicles

The vocational category encompasses any heavy-duty vehicles that are not classified as a tractor or heavy-duty pickup or van. The diverse grouping includes vehicles such as bucket trucks, urban delivery vehicles, refuse trucks, and buses. As with the tractors, the EPA and NHTSA are proposing separate vehicle-based and engine standards for vocational vehicles. Engine manufacturers would be subject to the engine regulation, and chassis manufacturers would be required to install certified engines in their chassis. Similar to the tractor program, vocational vehicles would be certified using the GEM software. As discussed in the Vehicle Certification section below, the design input for manufacturers would be limited to tire specifications.

A. Vehicle-based Standard

Vocational trucks are divided into three sub-categories by weight: light heavy-duty (Class 2B through 5), medium heavy-duty (Class 6 and 7) and heavy heavy-duty (Class 8). Identical to the tractor provisions, the EPA is proposing standards for all subcategories starting in model year (MY) 2014, and the mandatory NHTSA program will begin in MY 2016 after two years of voluntary participation. Also, the respective metrics proposed for the EPA and NHTSA programs are grams of CO_2 per ton-mile and gallons of fuel per 1,000 ton-miles. The EPA standards for all of vehicle subcategories are shown below in Figure 4.

FIGURE 4: PROPOSED VOCATIONAL VEHICLE CO_2 EMISSION STANDARDS



(Graphic created using values from Table II-9 in Section II.D.(1)(a) in the Preamble and Regulations document)

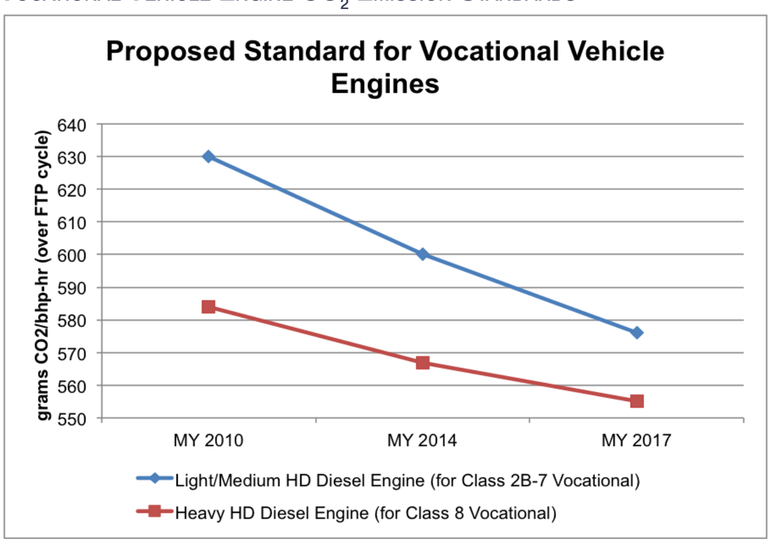
B. Technology Assessment

In determining the standard for vocational vehicles, the agencies choose to limit the stringency to what could be achieved with engine improvements and by using low rolling resistance tires. For non-engine systems, they acknowledge the potential in technology areas such as aerodynamics, weight reduction, and transmissions but have proposed to only focus on tires to avoid the challenges that are inherent when trying to regulate such a diverse vehicle category. Including aerodynamics, weight reduction, and transmissions in the program would require that the agencies regulate a wide range of small entities that are final bodybuilders, which is something they believe is not feasible at this time. Also, the agencies would need to develop a large number of unique standards to reflect the specific weight and aerodynamic differences and would need test procedures to evaluate these differences that would not be excessively burdensome.

C. Engine-based Standard

The engine regulation for vocational vehicles is virtually identical to the program for tractors engines, as described above. The only difference is that the light-, medium-, and heavy-heavy engines installed in tractors would be required to the meet their respective standards based on the Heavy-duty FTP rather than the steady-state SET test cycle. The Heavy-duty FTP cycle is more representative of the stop-and-go, urban driving conditions that are common to vocational vehicles. The proposed EPA standards for MY 2014 and MY 2017 diesel engines are shown below in Figure X. Also, the Heavy-duty gasoline engines used in the vocational space are subject to a separate standard of 627 grams CO_2/bhp-hr in MY 2016.[6] The agencies estimate a MY 2010 baseline for gasoline engines at 660 grams CO_2/bhp-hr.

FIGURE 5: VOCATIONAL VEHICLE ENGINE CO_2 EMISSION STANDARDS



(Graphic created using values from Table II-11 in Section II.D.(1)(b)(i) in the Preamble and Regulations document)

6 As with the entire proposal, the standards in the EPA and NHTSA programs are identical, based on an emission factor of 10,180 grams of CO2 per gallon of diesel fuel and 8.887 for gasoline.

D. Vehicle Certification

For the GEM model, the agencies have established predefined values including payload, vehicle frontal area, and aerodynamic drag, but the manufacturers will input tire rolling resistance coefficients (C_{RR}) for steer and drive tires. The C_{RR} values will be determined experimentally by the tire manufacturer using the ISO 28580 test method. For compliance, model results from the three different test cycles will be weighted as follows: 37% of 65 mph Cruise, 21% of 55 mph Cruise, and 42% of the Transient cycle. The test weight used in the GEM will be based on the vehicle class, as identified above. Light-heavy-duty vehicles will have a test weight of 16,000 pounds; 25,150 pounds for medium heavy-duty vehicles; and heavy heavy-duty vocational vehicles will use a test weight of 67,000 pounds.

The agencies acknowledge that the GEM may be overly detailed for certifying tires, but they believe that as technology advances, other features of vocational vehicles may warrant inclusion in future rulemakings. This certification process puts the framework in place to accommodate future additions.

E. Compliance and Flexibility Provisions

As with the proposal for the tractor program, final compliance would be determined using the end-of-model-year production counts. Vehicle credits or debits for vocational vehicles would be calculated in terms tons CO_2 (or gallons for the NHTSA regulation) based on the following equation:

Credit (or debit) = (Std – [GEM output]) x (Payload Tons) x (Volume) x (UL) x (10^{-6})

where

Std = the standard of the specific tractor regulatory class (grams/ton-mile)

GEM outputs = results from the GEM simulation (grams/ton-mile)

Payload tons = 2.85 tons for LHD, 5.6 tons for MHD, and 19 tons for HHD vehicles

Volume = (projected or actual) production volume of the tractor family

UL = useful life of the vehicle (110,000 miles for LHD, 185,000 miles for MHD, or 435,000 miles for HHD vehicles)

Similar to the proposed heavy-duty engine and tractor ABT programs, the vehicle credits generated within each regulatory subcategory would be allowed to be averaged, banked, or traded between chassis manufacturers within their existing subcategories. Also, the agencies are proposing that chassis manufacturers would be able to carry forward deficits from their regulatory subcategories for three years before reconciling these debits.

Hybrid Vehicle Test Procedure

The agencies are proposing two options for certification of heavy-duty hybrid vehicles for generation of compliance credits. The first option is to use a chassis dynamometer test procedure very similar to the one that will be used to certify Class 2B and 3 pickups and vans. This test procedure can be used to test both charge-sustaining and charge-depleting (plug-in) hybrid pickups and vans. For this testing option, the agencies propose to adopt the SAE J1711 test procedure. For charge-sustaining hybrids, in order for the test to be valid the agencies will require that the net energy change (NEC) in the vehicle energy storage system be less than 1 percent of total cycle energy over each complete test cycle.

For charge-depleting hybrids, the agencies are proposing to test them over the complete UDDS and HFET cycles, beginning with a fully charged energy storage system. Testing cannot be terminated until the end of a complete cycle, even if the energy storage system is fully depleted and the engine turns on in the middle of the test. After completion of testing on each cycle, manufacturers must re-charge the battery pack using normal procedures, and measure total energy required (AC watt-hours) from the wall, including any losses in the charger.

The agencies are also proposing an alternative option where an engine dynamometer will be used to conduct "hardware-in-the-loop" testing of a complete hybrid power train, including the engine and all hybrid system components, as discussed below.

Engine Testing of Pre-transmission Hybrids. The agencies are proposing to allow manufacturers to certify pre-transmission hybrids based on hardware-in-the-loop testing using a standard engine dynamometer and the FTP engine dynamometer test cycle. Under this scenario the measured brake-specific fuel consumption and CO_2 emissions of the tested hybrid system can be used directly to calculate the hybrid benefit (i.e. the percent reduction as compared to a conventional engine).

The current FTP test cycle only has positive torque values defined. Negative torque values will need to be defined for the "motoring" sections of the cycle for use in pre-transmission hybrid testing in order to define the maximum energy potentially available for capture and re-use by the hybrid system (i.e. regenerative braking). The agencies have yet to develop this aspect of the proposed test procedure.

Engine Testing of Post-transmission Hybrids. The agencies are considering allowing manufacturers to certify post-transmission hybrids based on hardware-in-the-loop testing using a powertrain test cell. A powertrain test cell would differ from a traditional engine test cell in that it would require an "electric, alternating current dynamometer" to accommodate the "additional rotational inertia and speeds associated with the inclusion of the vehicle/hybrid transmission" (RIA[7], page 3-32).

7 US EPA and NHTSA (2010) Draft Regulatory Impact Analysis: Proposed Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles (http://www.epa.gov/otaq/climate/regulations/420d10901.pdf).

For this type of test the FTP engine test cycle cannot be used. The agencies have yet to define an alternate vehicle-type test cycle (vehicle speed versus time or power and drive shaft speed versus time) for this purpose.

Chassis Testing of Hybrids. For chassis testing, the agencies are proposing to use four different test cycles and to calculate a weighted average value for measured CO_2 emissions based on the weighting factors shown in Table 10. With the exception of the Power Take Off (PTO) cycle, the proposed test cycles are the same as those that will be used in the GEM simulation model (discussed above).

The PTO cycle includes 30 different mode points with varying duration. At each mode point there is a defined pressure in each of two hydraulic circuits, represented as percentage of normalized peak pressure. These modes are intended to represent typical PTO operation to power hydraulic equipment on utility and refuse trucks. When testing on this cycle the vehicle will be stationary, and the PTO output will be connected to a test bench that can absorb the energy output of the system.

Table 10: Test Cycle Weighting Factors for Chassis Dynamometer Testing of Hybrid Vehicles

	Transient	55 mph	65 mph	PTO
Vehicles without PTO	42%	21%	37%	0%
Vehicles with PTO	30%	15%	27%	28%

(Table created using values from Table IV-2 and Table IV-3 in Section IV.B.(2)(b)(ii) in the Preamble and Regulations document)

Certification of a 'hybrid benefit' would be based on an "A-B" test of both a hybrid vehicle or drive train (A) and an "equivalent" conventional vehicle or drive train (B), using the following formula:

Hybrid Benefit [g CO_2/ton mile] = $((CO_{2A} - CO_{2B}) \div CO_{2A})$ x Applicable Standard [g CO_2/ton mile]

where the "A" vehicle is the hybrid version and the "B" vehicle is the conventional version

Next Steps

In the proposal, the agencies request comments on a wide range of topics from stringency levels to test procedure to flexibility provisions. It is expected that feedback received during the public workshops and throughout the comment period will results in changes reflected in the final rule to be published in July 30, 2011. Comments on all aspects of the proposal must be submitted by January 31, 2011. Instructions for submitting comments can be found on page 1 of the proposed rule, which has been published in the Federal Register (http://www.gpo.gov/fdsys/pkg/FR-2010-11-30/pdf/2010-28120.pdf).

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