U.S. Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles

On August 9th 2011, the U.S. Environmental Protection Agency (EPA) and the Department of Transportation's National Highway Traffic Safety Administration (NHTSA) finalized the world's first-ever program to reduce greenhouse gases (GHGs) and improve fuel efficiency of medium- and heavy-duty vehicles.[1] 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 adds several important elements: (1) drives efficiency improvements in all aspects of the heavy-duty vehicle for the two highest fuel consumption classes: tractor trucks and pickup trucks, (2) sets separate standards for engines and vehicles, and (3) establishes standards for four major greenhouse gases in addition to fuel consumption limits.

The US EPA and NHTSA worked collaboratively to deliver regulations under their respective authorities: the EPA developed GHG emission standards under the Clean Air Act, and NHTSA developed fuel efficiency standards under the 2007 Energy Independence and Security Act. The emissions included in the EPA's program will be carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs). The EPA program will begin in model year (MY) 2014, while the NHTSA program will be voluntary in MYs 2014 and 2015 and will become mandatory starting in MY 2016. The reason for the difference in timelines is the EISA requires NHTSA to have four full years of lead-time following the finalization of the rule. The EPA has no such lead-time provision under the Clean Air Act.

Overall, the stringency of the program ranges from 6 to 23% reduction in fuel consumption in the MY 2017 timeframe as compared to a MY 2010 baseline. The stringency levels vary based on vehicle subcategories that are based on weight classes and vehicle attributes. The rule is best understood as three separate regulatory programs linked to specific provisions for heavy-duty engines that power tractor trucks and vocational vehicles.

The EPA and NHTSA (hereafter "the agencies") estimated the costs and benefits of the 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 that the agencies took into account when setting the standards for the various regulatory subcategories. For tractor trucks, given the high number of annual miles these

ICCT Policy Updates summarize regulatory and other developments related to clean transportation worldwide.

The International Council on Clean Transportation

www.theicct.org

info@theicct.org

1 US EPA and NHTSA (2011) Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles. (http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf).

vehicles typically travel, the agencies estimate that payback for each vehicle will generally occur within the first year of ownership. The payback period for heavy-duty pickup trucks and vans is slightly longer, as these vehicles average much less annual mileage, so the fuel savings take longer to accrue. For this group of vehicles, the agencies estimate a payback time of about of two years. For vocational vehicles, the estimated fuel savings of roughly $700 in year one is larger than the modest cost increase of $378, thus making the payback time less than a year.

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. There are nine separate standards for tractor trucks based on combinations of three categories of vehicles (Class 7, Class 8 day cab, and Class 8 sleeper cab) and three roof height categories (low, medium, and high).

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

Vehicle category	Additional cost per truck in 2009 Dollars (MY 2018)	Lifetime fuel savings (3% Discount Rate)	Reference in the regulation
Tractor trucks	$6,215	$79,089	Table VIII-11
HD pickups and vans	$1,048	$7,187	Table VIII-9
Vocational vehicles	$378	$5,872	Table VIII-10

The agencies estimate total benefits from the 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. Using estimates for climate, energy security, and air pollution externalities, the agencies estimate 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.[2] The rule builds on a Congressionally-mandated study by the National Academy of Sciences (NAS) and previous work developed by the ICCT.[3] Table 2 provides relevant statistics for each vehicle class in the commercial sector.

Manufacturers must 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 resistance, 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 this rulemaking but 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 roughly 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

2 Applying a 3% discount rate.

3 In collaboration with the Northeast States Center for a Clean Air Future (NESCCAF), Southwest Research Institute, and TIAX, LLC, the ICCT released the report, *Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions* in October 2009 (http://www.the-icct.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. See the www.theicct.org for more information.

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

Vehicle Size	GVWR (lbs)*	Population (millions)	Annual Miles (million miles)	Annual Fuel Use (mil gallons)	% of Population	% of Annual Miles	% of Fuel Use
Class 2B	8,501 – 10,000	5.800	76,700	5,500	52.8%	35.1%	19.3%
Class 3	10,001 – 14,000	0.691	9,744	928	6.3%	4.5%	3.3%
Class 4	14,001 – 16,000	0.291	4,493	529	2.6%	2.1%	1.9%
Class 5	16,001 – 19,500	0.166	1,939	245	1.5%	0.9%	0.9%
Class 6	19,501 – 26,000	1.710	21,662	3,095	15.6%	9.9%	10.9%
Class 7	26,001 – 33,000	0.180	5,521	863	1.6%	2.5%	3.0%
Class 8	> 33,000	2.154	98,522	17,284	19.6%	45.1%	60.8%
TOTAL		**10.992**	**218,580**	**28,444**	**100%**	**100%**	**100%**

* GVWR: Gross Vehicle Weight Rating of the vehicle, including fuel, passengers, and cargo

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 (Classes 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 rolling resistance test data.

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 be 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 ultimately 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 design 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 rule. For each category the table also identifies the entity responsible for complying with the standards. Table 4 summarizes the key changes in the regulation from the proposal, which was published in October 2010, to the final rule.

The following sections explore each of these three regulatory programs in more detail. Also, included at the end of document is a section that discusses the various elements of the options for quantifying the fuel savings and emissions benefits of advanced technologies such as hybrid vehicles.

Class 7 and 8 Tractor Trucks and Engines

The EPA and NHTSA have finalized separate vehicle 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 these vehicles 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.

Table 3: Summary of Included Vehicle and Engine Categories

Rule category	Vehicle classes	Weight (GVWR)*	Typical vehicles	Regulated entity**	Requirement (metric)
Tractor trucks and engines	Class 7 and 8 tractors	• 26,001 – 33,000 lbs. (11.8 – 15 tonnes) • 33,001 lbs. (15 tonnes) and over	• Tractor trucks	• Tractor manufacturer • Engine manufacturer	• Whole vehicle GHG and fuel consumption standard (g CO_2/ton-mile, gallon/1,000 ton-mile) • Engine standard (g CO_2/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)	• Full size pickups • Utility vans • Step vans	Vehicle manufacturer	Whole vehicle GHG and fuel consumption standard (g CO_2/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 • Transit buses • School buses • Refuse trucks • Cement trucks	• Chassis manufacturer • Engine manufacturer	• Whole vehicle GHG and fuel consumption standard (g CO_2/ton-mile, gallon/1,000 ton-mile) • Engine standard (g CO_2/bhp-hr, gallon/100 bhp-hr)

* Tonne = metric ton = 1,000 kg = 2,204.6 pounds
** Vehicles and engines must be certified every model year.

Table 4: Key Changes from the Proposal to the Final Rule

	Applicability	Proposal	Final Rule
Regulatory Subcategories	Class 7 and 8 Tractors	7 unique regulatory subcategories based on the assumption that there are no mid roof day cab configurations in existence	9 unique regulatory subcategories. For day cabs, there are standards for both low and mid roof tractors.
Stringency*	Class 7 Low Roof Tractors	8.2%	10.3%
	Class 7 Mid Roof Tractors	8.2%	10.2%
	Class 7 High Roof Tractors	10.9%	13.0%
	Class 8 Day Cab Low Roof Tractors	7.2%	9.1%
	Class 8 Day Cab Mid Roof Tractors	7.2%	9.5%
	Class 8 Day Cab High Roof Tractors	9.6%	13.6%
	Class 8 Sleeper Cab Low Roof Tractors	14.9%	17.5%
	Class 8 Sleeper Cab Mid Roof Tractors	15.0%	18.0%
	Class 8 Sleeper Cab High Roof Tractors	19.5%	23.4%
	Class 2B – 5 Vocational Vehicles	9.9%	8.6%
	Class 6 and 7 Vocational Vehicles	10.1%	8.9%
	Class 8 Vocational Vehicles	7.0%	5.9%
Greenhouse Gas Model (GEM)	Class 7 and 8 Tractors and Class 2B – 5 Vocational Vehicles	Version 1.0	Version 2.0 includes a new driver model, a simplified electrical system model, and revised engine fuel maps that better characterize the MY 2017 engine standards.
Aerodynamic Assessment	Class 7 and 8 Tractors	Manufacturers determine coefficient of drag (C_d) based on one of three test methods. This C_d value is entered directly into the GEM.	Tractors are assigned a bin number based on C_d * [frontal area], which is determined by coastdown testing. Each bin number has a unique, predefined C_d value that is entered into the GEM
Flexibility Provisions	Class 7 and 8 Tractors, Class 2B – 5 Vocational Vehicles and LHD, MHD, and HHD Engines	Averaging, banking, and trading (ABT) is only allowed within individual regulatory subcategories.	ABT is allowed between all tractors and vocational vehicles in the same weight category. The weight categories are light heavy-duty (Class 2B – 5), medium heavy-duty (Class 6 and 7), and heavy heavy-duty (Class 8). ABT is also allowed between tractor and vocational engines in the same weight category.

* The percentage shown are the difference between the MY 2017 standard and the MY 2010 baseline value

A. Vehicle Standard

For the vehicle-based part of the tractor program, the regulation outlines nine subcategories based on three dimensions: GVWR, cab configuration (day or sleeper cab), and roof height (low, medium, or high). The EPA standards for all subcategories start in model year (MY) 2014, and the mandatory NHTSA program will begin in MY 2016 after two years of voluntary compliance. The respective metrics for the EPA and NHTSA vehicle 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 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 the vehicle subcategories are shown below in Figure 1. As compared to the baseline values, which are meant to represent average MY 2010 tractors, the values for MY 2014 are a 7 to 20% improvement, depending on the specific tractor subcategory. The tightening of the standard in MY 2017 represents a 9 to 23% improvement over the MY 2010 values. The increased stringency in the MY 2017 standard is predicated solely on engine improvements.

B. Technology Assessment

The 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.

Figure 1: Tractor CO_2 Emission Standards

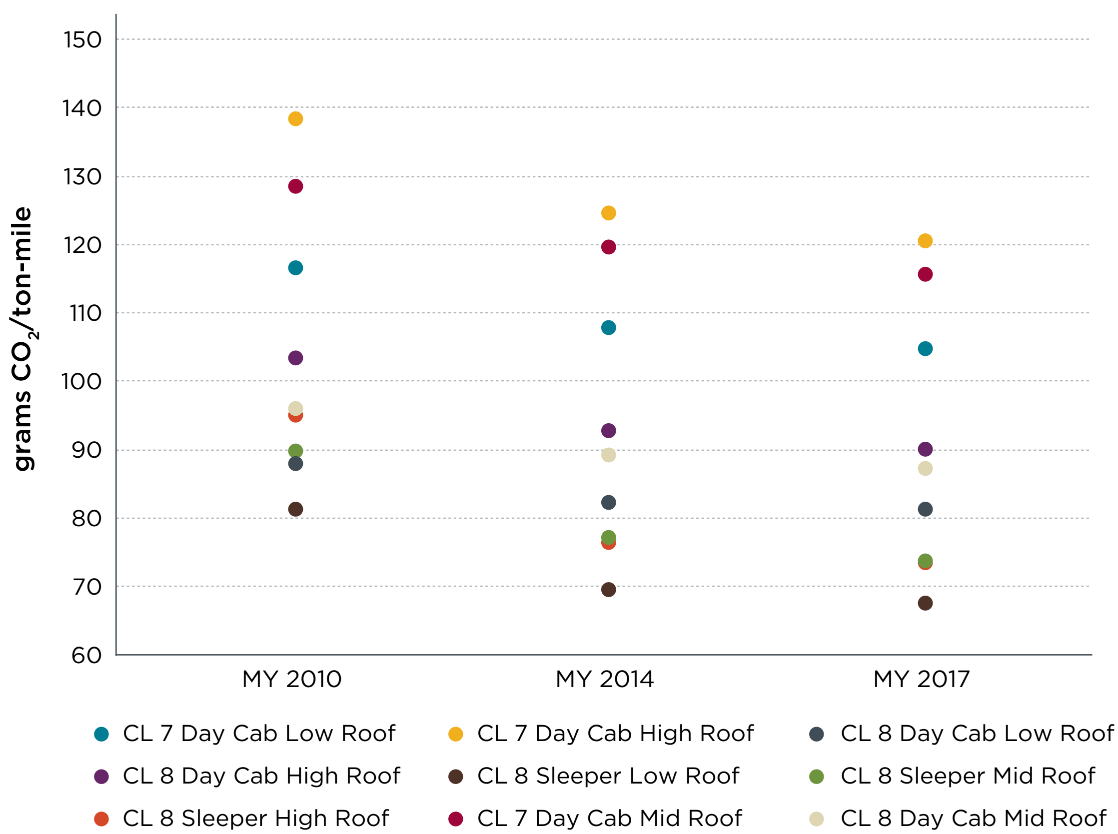


Table 5: Tractor Aerodynamics Bins and Approximate Baseline (MY 2010) Market Shares

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

There is a wide range of aerodynamic configurations and features in the tractor market, and the agencies have finalized 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 for high roof tractors are summarized in Table 5.[4]

The right column of Table 5 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 Bin I and Bin II to Bin III and Bin IV. The adoption assumptions for each tractor subcategory are summarized below in Table 6.

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, Bin I, and Bin II, 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 material substitution such as 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 regulation assumes a 100% adoption rate for this technology in Class 8 sleeper cabs (current levels are approximately 30%).

4 See Section II.B.(3)(c) and Section III.A.(1)(a) in the regulation.

C. Engine Standard

The engine component of the tractor (and vocational vehicle) regulation is designed as an extension of 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.

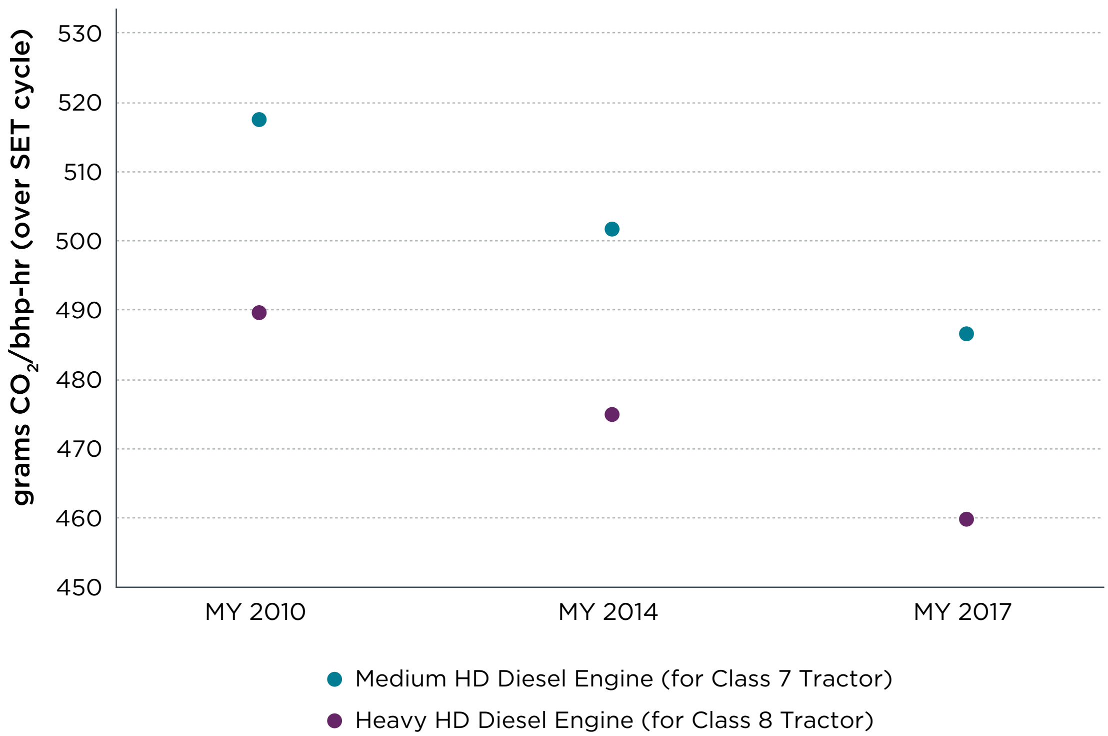
Table 6: Technology Adoption Percentages for Class 7 and 8 Tractors
(Table created using values from Table III-4 in the regulation)

	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 (C_d)							
Bin I	0%	0%	0%	0%	0%	10%	0%
Bin II	40%	30%	40%	30%	30%	20%	10%
Bin III	50%	60%	50%	60%	60%	60%	70%
Bin IV	10%	10%	10%	10%	10%	10%	20%
Bin V	0%	0%	0%	0%	0%	0%	0%
Steer Tires (C_{RR} kg/metric ton)							
Baseline	40%	30%	40%	30%	30%	30%	10%
Bin I	50%	60%	50%	60%	60%	60%	70%
Bin II	10%	10%	10%	10%	10%	10%	20%
Drive Tires (C_{RR} kg/metric ton)							
Baseline	40%	30%	40%	30%	30%	30%	10%
Bin I	50%	60%	50%	60%	60%	60%	70%
Bin II	10%	10%	10%	10%	10%	10%	20%
Weight Reduction (lb)							
400 lb. reduction	100%	100%	100%	100%	100%	100%	100%
Extended Idle Reduction (gram CO_2/ton-mile reduction)							
Automatic engine shutoff	N/A	N/A	N/A	N/A	100%	100%	100%
Vehicle Speed Limiter							
VSL	0%	0%	0%	0%	0%	0%	0%

A tractor engine will be categorized as Medium-heavy if its intended use is in 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.[5]

5 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.

Figure 2: Tractor Engine CO_2 Emission Standards



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 engine technology package 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 finalized at 0.10 grams/bhp-hr respectively as measured over the Composite Heavy-duty FTP cycle with a defined deterioration factor of 0.02 g/bhp-hr. These species will be measured over the FTP because the agencies cite that this cycle poses a higher risk for N_2O and CH_4 formation as compared to the SET cycle.

To date, engines powered by fuels such as natural gas and liquefied petroleum gas have primarily been used by vocational vehicles and, to a lesser extent, heavy-duty pickup trucks and vans. The provisions for alternative fuel engines are discussed below in part (c) of the Vocational Vehicles section. The rules governing alternative fuel tractor engines are identical to their vocational counterparts, except that the certification testing will be done over the SET cycle rather than the FTP cycle.

Flexibility Mechanisms for the Tractor Engine Standard

There are two flexibility provisions that are specific to the engine standard. The first provision was created in response to requests from manufacturers that new rules for fuel efficiency and GHGs be aligned in terms of timing with on-board diagnostics (OBD) requirements that go into effect in MY 2013 and MY 2016. Rather than delaying OBD requirements to model years 2014 and 2017, the agencies have created an optional phase-in standard that manufacturers can use for compliance. The two pathways are shown below in Table 6.

The second flexibility provision is based on the fact that not all manufacturers have chosen to employ SCR technology in their emissions control systems. SCR systems, which are assumed to be part of a baseline MY 2010 engine, allow engines to be tuned for greater fuel efficiency. Because any engine that does not utilize SCR is generally less efficient, the agencies have created an alternative compliance pathway for these manufacturers. Under this pathway, manufacturers would have an individual standard based on a 3% reduction from a MY 2011 baseline. This alternative will only be available for model years 2014 through 2016, and starting in MY 2017, these manufacturers would be subject to the same standard of 460 g/bhp-hr and 487 g/bhp-hr for heavy- and medium-duty tractor engines respectively. In order to prevent a manufacturer from setting an artificially high MY 2011 baseline, the agencies are requiring that this unique baseline value be an average over all engines in an engine family certified and sold for MY 2011.

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 recommendations. 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. After conducting a peer review of GEM version 1.0

Table 7: Comparison of Primary and Alternative Standards for MHD and HHD Tractor Engines
(Table created using values from Table II-4 in the regulation)

	HHD Tractor Engines		MHD Tractor Engines	
	Primary Standard	**Optional Standard**	**Primary Standard**	**Optional Standard**
Baseline	490	490	518	518
MY 2013	490	485	518	512
MY 2014	475	485	502	512
MY 2015	475	485	502	512
MY 2016	475	460	502	487
MY 2017	460	460	487	487

Table 8: Aerodynamic Input Definitions to GEM for High Roof Tractors
(Table created using values from Table II-7 in the regulation)

	Class 7	**Class 8**	
	Day Cab	Day Cab	Sleeper Cab
	High Roof	High Roof	High Roof
Aerodynamic Test Results (C_dA in m^2)			
Bin I	≥ 8.0	≥ 8.0	≥ 7.6
Bin II	7.1 – 7.9	7.1 – 7.9	6.7 – 7.5
Bin III	6.2 – 7.0	6.2 – 7.0	5.8 – 6.6
Bin IV	5.6 – 6.1	5.6 – 6.1	5.2 – 5.7
Bin V	≤ 5.5	≤ 5.5	≤ 5.1
Aerodynamic Input to GEM (C_d)			
Bin I	0.79	0.79	0.75
Bin II	0.72	0.72	0.68
Bin III	0.63	0.63	0.60
Bin IV	0.56	0.56	0.52
Bin V	0.51	0.51	0.47

(which was released in October 2010 with the Notice of Proposed Rulemaking) and incorporating additional test data, the agencies have released version 2.0 of the model. The new version includes a new driver model, a simplified electrical system model, and revised engine fuel maps that better characterize the MY 2017 engine standards.

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. In GEM the pre-defined parameters include the tractor-trailer combination curb weight, payload, engine characteristics, and drivetrain for each vehicle type. 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. However, manufacturers may opt to use the Innovative Technology Credit system (described in more detail below in Section F) to capture the credits of any technology whose benefits cannot be readily quantified in the GEM certification process.

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.

To determine the aerodynamic coefficient of drag, tractor manufacturers may use coastdown

Table 9: Aerodynamic Input Definitions to GEM for Low and Mid Roof Tractors
(Table created using values from Table II-8 in the regulation)

	Class 7		**Class 8**			
	Day Cab		Day Cab		Sleeper Cab	
	Low Roof	Mid Roof	Low Roof	Mid Roof	Low Roof	Mid Roof
Aerodynamic Test Results (C_dA in m²)						
Bin I	≥ 5.1	≥ 5.6	≥ 5.1	≥ 5.6	≥ 5.1	≥ 5.6
Bin II	≤ 5.0	≤ 5.5	≤ 5.0	≤ 5.5	≤ 5.0	≤ 5.5
Aerodynamic Input to GEM (C_d)						
Bin I	0.77	0.87	0.77	0.87	0.77	0.87
Bin II	0.71	0.82	0.71	0.82	0.71	0.82

testing (a modified SAE J1263 procedure[6] that is referred to in the rule as the "enhanced coastdown procedure"), wind tunnel testing, or computational fluid dynamics (CFD) simulation. However, to address consistency and level playing field concerns, the enhanced coastdown method has been set as the reference test method, and, as such, all C_d results developed using wind tunnel testing or CFD must be aligned against the reference method. Any alternative aerodynamic testing method must be correlated to the enhanced coastdown procedure using a reference vehicle. After determining a C_dA result from testing, the tractor will be assigned a bin number based on the values in Table 7 (or Table 8 in the case of low and mid roof tractors), and the corresponding C_d value in the lower portion on the table will be the actual input into the GEM.

For rolling resistance, manufacturers will need to determine these values experimentally by using the ISO 28580 test method. This test will be used to determine the rolling resistance coefficient (C_{RR}, measured in kilogram per metric ton) for both the steer and drive axle tires. In addition, tractor manufacturers can specify up to three other features that will be used in the GEM to modify fuel use and emissions 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, aluminum wheels, or substitute aluminum or high-strength steel for other vehicle components, 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. The complete list of weight reduction default values, which are based on material substitution, can be found in Table II-9 of the prepublication regulation.
- *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 6.3%, 5.6%, and 5.3% of total baseline emissions, which are 80, 89, and 94 g/ton-mile for the respective subcategories.

6 See Section 3.2.2.1 of the Regulatory Impact Analysis for more information about the Society of Automotive Engineers (SAE) 1263 test procedure and the modifications that have been adopted for this rulemaking. The most notable modification in the test procedure is that low and mid roof tractors will be tested in a bobtail (i.e., no trailer) configuration.

For compliance testing on the GEM, the agencies have adopted 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 below in Table 10.

The EPA and NHTSA have set the metric on a ton-mile basis, and, as such, tractors will be modeled in GEM using standard 53 ft box trailers and fixed payload values. The fixed payload for Class 7 and Class 8 tractors will be 25,000 and 38,000 pounds of payload respectively. These values are based on average payload data from the Federal Highway Administration. 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."

Table 10: Drive Cycle Weighting Factors for Tractors
(Table created using values from Table II-10 in the regulation)

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

In addition to the engine and vehicle standards for CO_2 and the engine limits on N_2O and CH_4, there is 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, this program will have a 'percentage of refrigerant leakage per year' to reflect the variety of air conditioning designs and layouts in the heavy-duty sector. The EPA has finalized a standard of 1.5% leakage per year for Class 7 and 8 tractors that have a refrigerant capacity of greater than 733 grams. It is estimated the average percent leakage for a MY 2010 vehicle is roughly 2.7%. For vehicles with air conditioning systems with a refrigerant capacity of 733 grams or lower, the EPA has defined the standard in terms of leakage rate, at 11.0 grams/year.

E. Compliance Provisions

There are many provisions in the regulation 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 10 below.

F. Flexibility Mechanisms

The following flexibility mechanisms are applicable to both tractors and all engine/vehicle subcategories covered in the program unless stated otherwise.

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. The final ABT rules are consistent with the ABT provisions for criteria pollutants with same weight engines treated as a single averaging set regardless of the vehicles in which they are installed.

With respect to tractors and vocational vehicles, these same weight categories—light (Class 2B-5), medium (Class 6 and 7), and heavy heavy-duty (Class 8)—will be used for averaging sets. Therefore, manufacturers will be able to average, bank, and trade across vocational vehicle and tractor subcategories with the same weight class groups.

Table 11: 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 after-treatment 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.”	

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 tractors and 19 tons for Class 8 tractors

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 Heavy-duty Engine ABT program, tractor manufacturers will 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 are 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 reconciliation.

Early Credits

Manufacturers can generate credits by demonstrating improvements in excess of the standards prior to the model year the standards become effective. For example, if a manufacturer's MY 2013 subcategory of heavy heavy-duty vocational vehicles exceeds the EPA MY 2014 standard for those same vehicles, then that manufacturer would earn MY 2013 credits to utilize in its ABT program starting in MY 2014. 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. Credits may only be earned if the manufacturer certifies their entire subcategory at GHG and fuel consumption levels below the standards. There is an exemption to this provision for tractors—manufacturers can obtain Early Credits for their additional sales of MY 2013 SmartWay certified tractors as compared to their MY 2012 sales. The EPA and NHTSA have finalized a credit multiplier of 1.5 as an incentive for early compliance.

Advanced Technology Credits

Rankine cycle (bottoming cycle) engines and hybrid, all-electric, and fuel cell vehicles can generate credits that can be applied across all vehicle and engine categories. As with Early Credits, the agencies are finalizing a multiplier of 1.5 for Advanced Technology Credits. However, the agencies are capping the amount of Advanced Technology Credits that can be used in any averaging set in a model year at 60,000 metric tons. The agencies have set the stringency for this first phase of the rule based on the belief that these advanced technologies will not gain significant share prior to 2020.

The GEM simulation tool is not suitable to certify hybrid, all-electric, or fuel cell vehicles because it only includes a single standard drivetrain model. A discussion of the test methods that can be used to quantify advanced technology credits for hybrid and advanced vehicles is provided below in the *Hybrid Vehicle Test Procedure* section.

Vehicles with zero tailpipe emissions such as all-electric or fuel cell vehicles can generate credits based on the diesel standards targets for their model year. In determining the value of the credits for both the EPA and NHTSA programs, these vehicles are given a GHG and fuel consumption score of zero. In other words, upstream fuel and electricity processes will not be taken into account.

Innovative Technology Credits

The EPA and NHTSA have finalized provisions by which manufacturers can earn credits for technologies whose fuel use and emissions benefits are not readily captured over the engine test cycles or in GEM simulations. The agencies have devised the Innovative Technology Credit system so that manufacturers can receive credit for these "off-cycle" benefits. Credits for these technologies must be based on real-world fuel consumption and/or GHG reductions that can be measured with verifiable test methods. Manufacturers seeking these credits have two options:

1. Evaluation of the baseline and control engine or vehicle over a pre-approved test procedure, which includes engine, powerpack, and chassis dynamometer testing as well as on-road testing, or
2. Submission of an alternative test method to the EPA and NHTSA, which must be approved[7] by the agencies prior to the demonstration program.

Unlike Advanced Technology Credits, Innovative Technology Credits can only be used in the regulatory engine or vehicle subcategory in which they are generated.

GHG Substitution

For the engine program, CH_4 and N_2O emissions in excess of the 0.10 g/bhp-hr limit 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. The converse—substituting overcompliance in the N_2O or CH_4 standards for CO_2 credits—will not be allowed because the N_2O and CH_4 cap standards represent levels that all but the worst vehicles should already be well below. However, there is an exception for engine manufacturers can certify useful life N_2O emissions to very low levels—defined in the rule as being below 0.04 g/bhp-hr. Manufacturers can earn 2.98 grams of CO_2 credit for every 0.01 grams N_2O reduced below 0.04 g/bhp-hr, which is consistent with the global warming potential value for N_2O as defined by the IPCC. This exception is only available in model years 2014 through 2016.

Class 2B and 3 Commercial Pickups and Vans

Unlike the tractor category, the EPA and NHTSA will use chassis dynamometers for certification of the Class 2B and 3 pick-up trucks and vans 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 chassis dynamometer testing. Because of the similarities between the Class 2, 2B, and 3 categories, the agencies have developed a regulatory design for these vehicles that is closely related to the program for light-duty vehicles.

7 Any alternative test method for generating Innovative Technology Credits would also be subject to public comment.

A. Vehicle Standard

The agencies have finalized 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:

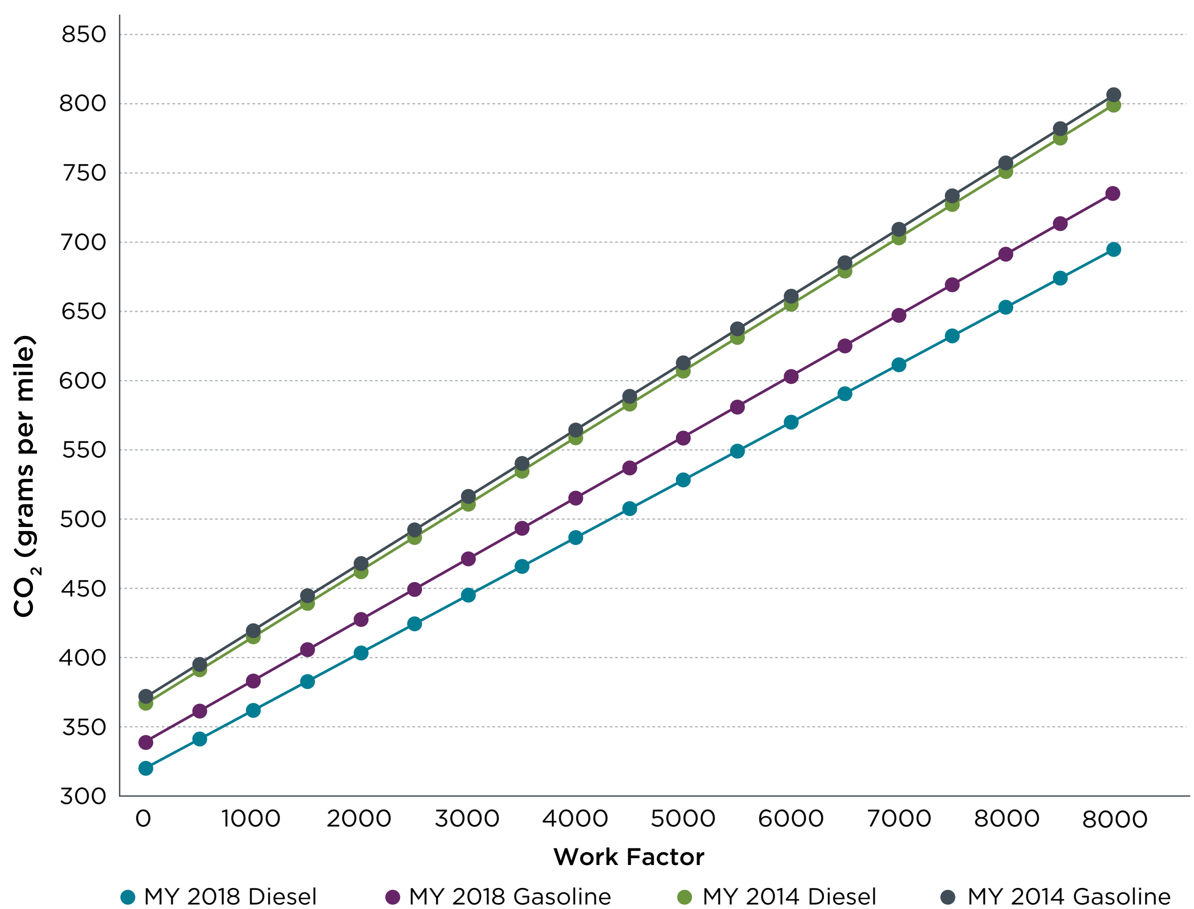
Payload Capacity = GVWR (lbs) – Curb Weight (lbs)

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

In the rule, the grams CO_2/mile (EPA) and gallons/100 miles (NHTSA) standards are a function of the work factor.[8] As shown in Figure 3 below, as the work factor value increases, the limit values for fuel use and CO_2 increase linearly. 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 12% lower for gasoline vehicles and 17% lower for diesel vehicles.

8 As with the tractor regulation, 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. For gasoline vehicles, the conversion factor is 8,887 grams of CO_2 per gallon of gasoline.

Figure 3: EPA CO_2 Standards for Heavy-Duty Pickups and Vans



In addition, EPA has adopted a per-vehicle N_2O and CH_4 emission standards of 0.05 g/mi to apply beginning in MY 2014 for HD pickup trucks and vans subject to the CO_2 standards. Also, as with tractors, the EPA has finalized a standard of 1.5% refrigerant leakage per year for heavy-duty pickup trucks and vans.

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 Regulatory Impact Analysis[9] are shown in the middle column. In total[10],

9 US EPA and NHTSA (2011) 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/documents/420r11901.pdf).

10 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.

Table 12: Additional Costs (2009 Dollars) and Fuel Use/CO_2 Reduction Estimates for Class 2B and 3 Heavy-duty Pickups and Vans

(Table created using values from Table 2-40 in the Regulatory Impact Analysis)

Technology	Applicability	Fuel Consumption (CO_2) Reduction	2014	2018
Low friction lubricants	All	0 – 1%	$4	$4
8-speed automatic transmission (relative to 6-speed automatic transmission)	All	1.7%	$281	$269
Low RR tires	All	1 – 2%	$7	$7
Aerodynamics	All	1 – 2%	$58	$55
Electric power steering	All	1 – 2%	$115	$109
AC refrigerant leakage reduction	All	2%	$21	$19
Engine friction reduction	Gasoline	1 – 3%	$116	$116
Stoichiometric GDI V8	Gasoline	1 – 2%	$481	$460
Mass reduction (5%)	Gasoline 2B	1.6%	$108	$103
Mass reduction (5%)	Gasoline 3	1.6%	$115	$109
Engine improvements	Diesel	4 – 6%	$184	$167
Aftertreatment improvements	Diesel	3 – 5%	$119	$114
Improved accessories	Diesel	1 – 2%	$93	$89
Mass reduction (5%)	Diesel 2B	1.6%	$121	$115
Mass reduction (5%)	Diesel 3	1.6%	$127	$121
Overall MY 2018 Package (2B)	**Gasoline**	**12 %**	**$1,191**	**$1,142**
Overall MY 2018 Package (2B)	**Diesel**	**17 %**	**$1,003**	**$948**

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.

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. Fuel consumption and GHGs will be measured using the same test procedures that are used in the criteria pollutant program. Results from the Light-duty FTP and the Highway Fuel Economy Test Cycle (HFET) will be weighted by 55 percent and 45 percent, respectively, and then averaged into a combined-cycle result. Both of these cycles are defined by a speed (miles per hour) time trace. The Light-duty FTP is a transient cycle that is representative of "city" driving, while the HFET is a much less transient cycle with a maximum speed of 60 mph and an average speed of 48.6 mph.

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 finalized 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 work factors, 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, there will be identical terms: a 5-year limit on credit carry-forward and a 3-year limit on debit carry-forward. In other

Table 13: Compliance Example for Class 2B and 3 Heavy-duty Pickup Trucks 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 * 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**

words, a manufacturer would only be allowed to have a negative balance for a maximum three consecutive years before facing a penalty.

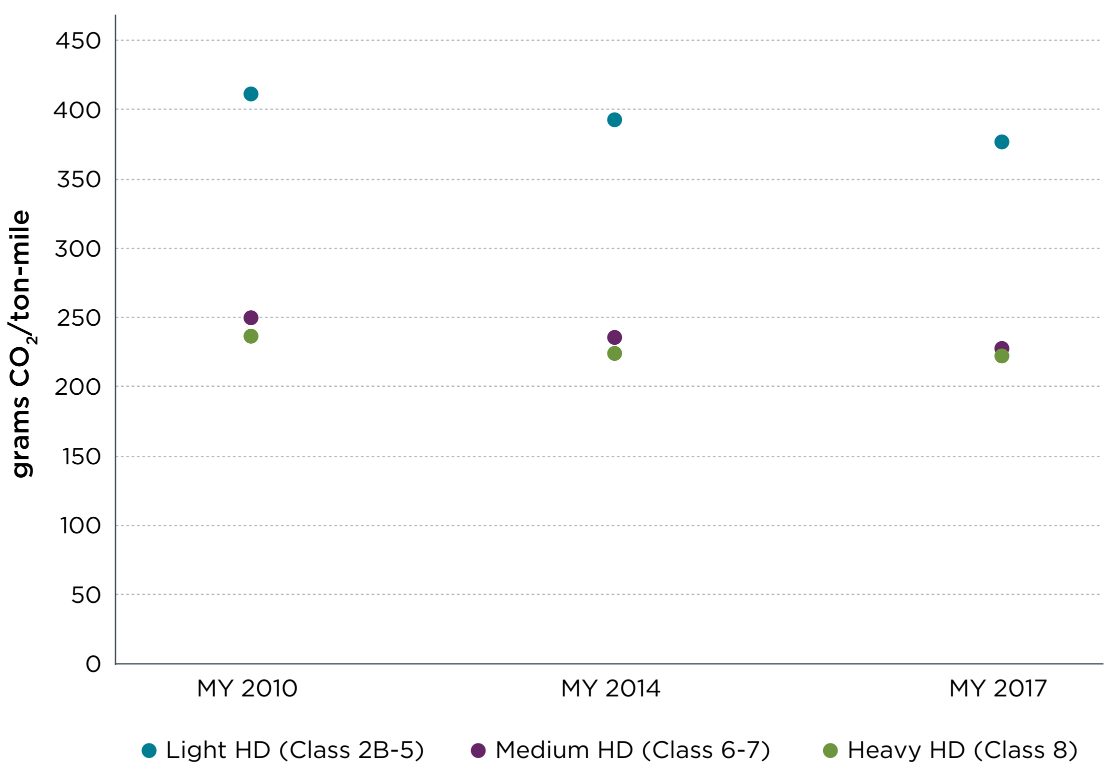
Class 2B through 8 Vocational Vehicles

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 have finalized separate vehicle and engine standards for vocational vehicles. Engine manufacturers are subject to the engine regulation, and chassis manufacturers are required to install certified engines in their chassis. Similar to the tractor program, vocational vehicles will 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 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 standards for all subcategories start 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 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. As compared to the baseline MY 2010 values, the standards for MY 2014 are a 4 to 5% improvement, depending on the specific subcategory. The tightening of the standard in MY 2017 represents a 6 to 9% improvement over the MY 2010 values. As with tractors, the increased stringency in the MY 2017

Figure 4: Vocational Vehicle CO_2 Emission Standards



standard is based solely on the MY 2017 engine improvements.

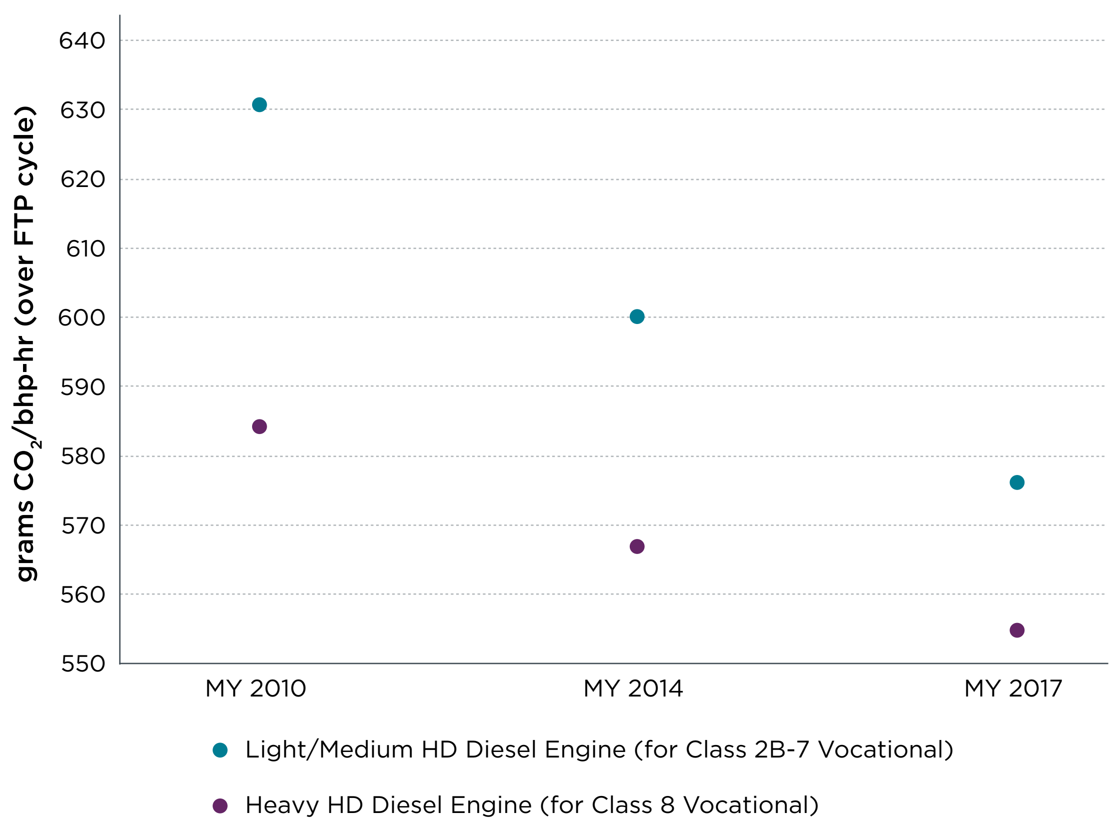
B. Technology Assessment

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 decided 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 Standard

The engine regulation for vocational vehicles is virtually identical to the program for tractors engines, as described above. An engine will be categorized as Light-Heavy if its intended use is in Class 2B through Class 5 vehicles, Medium-Heavy for use in Classes 6 and 7 vehicles and Heavy-Heavy for use in Class 8 vehicles. The only difference is that the light-, medium-, and heavy-heavy engines installed in vocational vehicles 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 EPA standards for MY 2014 and MY 2017 diesel engines are

Figure 5: Vocational Vehicle Engine CO_2 Emission Standards



shown below in Figure 5. 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.[11] The agencies estimate a MY 2010 baseline for gasoline engines at 660 grams CO_2/bhp-hr.

Alternative Fuels

For engines powered by alternative fuels, the agencies have finalized a provision that these engines will be evaluated by measuring CO_2 emissions for the EPA program and converting CO_2 emissions to fuel consumption for the NHTSA program. Natural gas and liquid petroleum gas engines, which are the most common alternative fuel engines in the heavy-duty sector, have roughly 20 to 30% lower CO_2 emissions than their conventional diesel and gasoline counterparts due to the fact that these fuels have a lower carbon content. So, these engines would meet the MY 2014 and MY 2017 standards without additional costs and generate credits for engine manufacturers. The agencies believe that this in itself is a substantial enough advantage for alternative fuels and are not including a credit multiplier for these engines.

For model years 2014 and 2015, flex-fuel gasoline/ethanol vehicles will be tested on both gasoline and E85, which is 85% ethanol by volume. Certified CO_2 emissions will be determined by weighting both the gasoline and E85 results by 50%. In model years 2016 and later, manufacturers will have to provide data as to the actual levels of E85 use in the real-world by their vehicles, else the default assumption will be 100% gasoline use. As with natural gas and LPG vehicles, fuel use will be calculated based on measured CO_2 emissions and CO_2 equivalency, not energy equivalency.

Flexibility Mechanisms for the Vocational Engine Standard

Flexibility provisions for vocational engines are similar to those of tractor engines. The first of these provisions is an alternative ("OBD phase-in") compliance pathway that, as with the optional pathway for tractor engines, requires reductions in model years 2013 and 2016 instead of model years 2014 and 2017. A comparison of the primary and alternative compliance pathways for vocational engine manufacturers is shown below in Table 14.

Table 14: Comparison of the Primary and Alternative Standards for LHD/MHD and HHD Vocational Engines (Table created using values from Table II-18 in the regulation)

	HHD Vocational Engines		LHD/MHD Tractor Engines	
	Primary Standard	**Optional Standard**	**Primary Standard**	**Optional Standard**
Baseline	584	584	630	630
MY 2013	584	577	630	618
MY 2014	567	577	600	618
MY 2015	567	577	600	618
MY 2016	567	555	600	576
MY 2017	555	555	576	576

11 As with the entire rule, 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 and 8,887 grams CO_2 for gasoline.

As with the tractor engine standard, the second flexibility provision gives manufacturers of vocational engines that have not used SCR in their emissions control systems the option to set an individual baseline and standard for model years 2014 through 2016. The standard is set at a 2.5% improvement for LHD and MHD engines and 3% for HHD engines. Starting in MY 2017, these manufacturers would be subject to the same standard of 555 g/bhp-hr and 576 g/bhp-hr for heavy and light/medium heavy-duty tractor engines respectively. Just as with tractor engines, in order to prevent a manufacturer from setting an artificially high MY 2011 baseline, the agencies are requiring that this unique baseline value be an average over all engines in an engine family certified and sold for MY 2011.

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 42,000 pounds. These weights represent vehicle empty (or "curb") weight plus payload. The payload values were developed based on US Federal Highway Administration statistics, but the payload value for heavy heavy-duty vehicles was adjusted from 38,000 lbs. in the proposal to 15,000 lbs. in the final rule after the agencies considered comments from industry about the actual curb weights and payloads of Class 8 vehicles.

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.

Unlike for tractors and heavy-duty pickup trucks and vans, the EPA is not adopting refrigerant leakage standards for vocational vehicles due to the complexity in the assembly process and the potential for different entities other than the chassis manufacturer (which is the regulated party) being involved in the air conditioning system production and installation.

E. Compliance, Flexibility Provisions, and Exemptions

As with the tractor program, final compliance will be determined using the end-of-model-year production counts. 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 vocational vehicle 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 7.5 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)

As aforementioned, these vocational vehicle credits may be averaged, banked, or traded within the weight category (light, medium, or heavy heavy-duty) in which they are generated, regardless of the vehicle type. Also, chassis manufacturers will be able to carry forward deficits from their regulatory subcategories for three years before reconciling these debits. Opportunities for Early, Advanced, and Innovative Technology Credits for vocational vehicles are identical to those of the tractor program, which are discussed above.

Certain vocational vehicles that operate primarily in off-road environments are not good candidates for low rolling resistance tires. The infrequent exposure to on-road environments greatly limits the fuel reduction benefits of low rolling resistance tires. The agencies have provided exemptions to vehicles that meet one or more of the following criteria:

- Any vehicle equipped with an axle that has a gross axle weight rating of 29,000 lbs;
- Any truck or bus that has a speed attainable in 2 miles of not more than 33 mph;
- Any truck that has a speed attainable in 2 miles of not more than 45 mph, an unloaded vehicle weight that is not less than 95% of its gross vehicle weight rating (GVWR), and no capacity to carry occupants other than the driver and operating crew;
- Any mixed service vehicle equipped with off-road tires that are speed restricted at 55 mph or less.

While these vehicles will be exempt from using low rolling resistance tires, standards for heavy-duty engines used in these vehicles will still apply.

Hybrid Vehicle Test Procedure

There are two options for certifying hybrid vehicles for generation of advanced technology 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 are adopting the SAE J2711 test procedure. The second option uses an engine dynamometer to conduct "hardware-in-the-loop" testing of a complete hybrid power train, including the engine and all hybrid system components.

Chassis Testing of Hybrids

For chassis testing, the manufacturer will have to test an advanced technology vehicle and an "equivalent" conventional baseline vehicle. There are four different test cycles that must be used to calculate a weighted average value for measured CO_2 emissions and fuel use based on the weighting factors shown in Table 14. Vehicles such as refuse or bucket trucks use

Table 15: Test Cycle Weighting Factors for Chassis Dynamometer Testing of Hybrid Vehicles
(Table created using values from Table IV-1 in the regulation and Equation 3-1 in the Regulatory Impact Analysis)

	Transient	55 mph	65 mph	PTO
Vocational vehicles without PTO	75%	9%	16%	0%
Day cab tractors without PTO	19%	17%	64%	0%
Sleeper cab tractors without PTO	5%	9%	86%	0%
Vehicles with PTO	30%	15%	27%	28%

Power Take Off (PTO) units to operate various accessory systems during parked idling. A PTO allows energy to be drawn from the vehicle's primary drive system and used to power an attachment of a separate machine. With the exception of the PTO cycle, the proposed test cycles for chassis dynamometer testing are the same as those that will be used in the GEM simulation model.

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.

Certification of a 'hybrid benefit' would be based on an "A-B" test of both a hybrid vehicle or advanced drive train (A) and an "equivalent" conventional vehicle or drive train (B), using the following formula[12]:

Hybrid Benefit [g CO_2/ton mile] = ((CO_2A – CO_2B) ÷ 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.

Engine Testing of Pre-transmission Hybrids

The agencies are also allowing 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 (gal/100 bhp-hr) and CO_2 emissions (g/bhp-hr) 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). This test method will not require an A-B test of both the advanced and baseline system.

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). To ensure that credits certified using engine testing are comparable to credits certified using A-B chassis testing, the agencies have defined equivalent limits on the "brake energy fraction" that can be recovered by a hybrid system during each type of test.

Engine Testing of Post-transmission Hybrids

Manufacturers may certify post-transmission hybrids with hardware-in-the-loop testing using a powertrain (or "powerpack") 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" (Draft RIA[13], page 3-32). The FTP engine test cycle is not suitable for post-transmission powerpack testing. For this testing configuration, the GEM test cycles (Transient, 55 mph Cruise, and 65 mph Cruise) must be utilized.

12 This formula is for the EPA program. There is an equivalent formula with fuel use units for the NHTSA program.

13 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).

References

International Council on Clean Transportation (2009). Evaluation of Vehicle Simulation Tools. (http://www.theicct.org/pubs/Ricardo_Simulation_2009.pdf)

International Council on Clean Transportation (2009). Reducing Heavy-Duty Long-Haul Combination Truck Fuel Consumption and CO_2 Emissions. (http://www.theicct.org/pubs/HDVemissions_oct09.pdf)

National Academy of Science (2010) Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles. The National Academy Press. Washington, D.C. (http://www.nap.edu/catalog.php?record_id=12845).

Northeast States Center for a Clean Air Future (NESCCAF); International Council on Clean Transportation (ICCT); Southwest Research Institute (SwRI); and TIAX, LLC (2009) Reducing Heavy-Duty Long Haul Combination Truck Fuel Consumption and CO_2 Emissions. (http://www.theicct.org/2009/10/reducing-hdv-emissions/).

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).

US EPA and NHTSA (2011) Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles. (http://www.gpo.gov/fdsys/pkg/FR-2011-09-15/pdf/2011-20740.pdf).

US EPA and NHTSA (2011) Regulatory Impact Analysis: Final 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/documents/420r11901.pdf).