POLICY UPDATE

JUNE 2015

UNITED STATES EFFICIENCY AND GREENHOUSE GAS EMISSION REGULATIONS FOR MODEL YEAR 2018-2027 HEAVY-DUTY VEHICLES, ENGINES, AND TRAILERS

ICCT **POLICY UPDATES** SUMMARIZE REGULATORY AND OTHER DEVELOPMENTS RELATED TO CLEAN TRANSPORTATION WORLDWIDE.

On June 19, 2015, the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) jointly proposed new standards to reduce the fuel consumption and greenhouse gas emissions of new heavy-duty vehicles, tractors, trailers, and engines. The new Phase 2 regulations would be implemented from model years 2018 to 2027, building upon initial standards that cover model years 2014 to 2018. This policy update provides a summary of some key aspects of the proposed rules. The final Phase 2 rules are expected in 2016.

In structure the proposed Phase 2 regulation is similar to Phase 1, with performance standards that promote diverse efficiency technologies across dozens of categories of medium- and heavy-duty vehicles. Efficiency improvements from Phases 1 and 2 together would deliver CO_2 and fuel consumption reductions of about 20%–30% for heavy-duty pickups and vans, 20% for vocational vehicles, and 30%–45% for tractor-trailers (compared with model year 2010 technology). Under the agencies' preferred "Alternative 3" proposal, these per-vehicle benefits would phase in through model year 2027. Under the agencies' more stringent "Alternative 4," the same new requirements would be phased in two to three years earlier. The associated deployment of the new truck technologies would deliver fuel savings that greatly exceed their upfront costs. The payback periods for truck owners would be within two years for tractor-trailers, within three years for pickups and vans, and about five years on average for vocational vehicles. The impact of the Phase 1 and 2 standards together would result in over one million barrels per day of oil savings from 2035–2050.

INTRODUCTION

Heavy-duty vehicles, including tractor-trailers, work trucks, and buses, consumed over three million barrels of oil equivalent per day in the United States in 2014. Table 1 summarizes how heavy-duty vehicles, while they total a relatively small number of vehicles, represent a substantial fraction of transportation energy use. Heavy-duty

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION vehicles account for 7% of road vehicles and about 30% of U.S. road energy use. In the absence of new regulations, heavy-duty vehicle fuel use is projected to increase by over one third to almost four million barrels per day in 2040. In contrast to light-duty automobiles, heavy-duty vehicles in the United States have not seen significant fuel economy changes in decades and were regulated for efficiency for the first time in model year 2014. The new standards regulate the efficiency and carbon dioxide (CO_2) emissions of over one million new heavy-duty vehicles per year. Among the heavy-duty vehicle types, the lightest heavy-duty pickup-and-van category represents most of the sales, whereas the heaviest Class 7-8 category, typically combination tractor-trailers, accounts for roughly 70% of the fuel use.

Table 1. Summary of basic statistics for vehicles in the United States in 2014

Vehicle class	Typical vehicle types	Fuel use 2014 (mBOE/day)	Vehicle population (million)	Vehicle sales (million)	New vehicle fuel economy (miles per gallon)
Light-duty vehicles (< 8,501 lb)	Cars, sport utility vehicles, minivans, pickups	7.4	226.6	15.24	24
Light heavy duty Class 2b–3 (8,501–14,000 lb)	Commercial full-size pickups and vans	0.5	9.2	0.68	13
Medium heavy duty Class 4–6 (14,001–26,000 lb)	Urban delivery, box, bucket trucks	0.3	2.0	0.15	8
Heavy duty Class 7–8 (> 26,000 lb)	Combination tractor-trailers	2.2	5.1	0.26	6

Based on US EIA Annual Energy Outlook 2015 (http://www.eia.gov/forecasts/aeo/); mBOE/day = million barrels of oil equivalent per day; weights provided are Gross Vehicle Weight Rating.

REGULATORY REQUIREMENTS

The Phase 1 heavy-duty vehicle program included regulatory standards for tractors, heavy-duty pickups and vans, vocational vehicles, and engines. The overall structure of the program remains generally the same under Phase 2, but the proposed standards add one major new category, trailers. The new standards would further reduce fuel consumption and CO_2 emissions of engines *per brake-horsepower-hour*; tractors, trailers, and vocational vehicles *per ton-mile*; and heavy-duty pickups and vans *per mile*. The sections below briefly summarize the requirements of the new standards and several notable changes in the Phase 2 standards in each of the five areas.
The basis for this summary of the standards is the agencies' preferred "Alternative 3" proposal; however, it is noted that the agencies also discuss other alternatives including an "Alternative 4," which would advance the timing of the rule by two to three years (i.e., 2027 standards would shift forward to model year 2024 or 2025). It must be emphasized that the text below is a greatly condensed summary of a complex rulemaking, and the full details and supporting information are available here: http://www.epa.gov/oms/climate/regs-heavy-duty.htm. In addition, more resources and web links are provided at the end of this update.

ENGINES

The Phase 2 proposal would retain the use of separate engine standards to increase the efficiency of engines certified for light-, medium-, and heavy-heavy-duty vehicles. The proposed rules include discrete steps from the existing 2017 standards, to 2021, 2024, and 2027. Table 2 summarizes the existing standards for model year 2017 and the proposed Phase 2 standards for 2027, as measured in grams CO_2 per engine brake-horsepower-hour. As shown, Phase 1 would reduce diesel (compression ignition) engines' fuel use by 5%–9%, Phase 2 would bring a further 4% reduction for diesel engines, and together the standards would result in an approximate 9%–12% fuel consumption reduction from 2010 baseline engines by model year 2027. Gasoline (spark ignition) engines' fuel use would be reduced by 5% during Phase 1, but no further efficiency gains are required for Phase 2.

Table 2. Summary of proposed engine standard requirements

Vehicle type		Engine class	Standard (g CO_2 / bhp-hr)			Percent CO_2 reduction		
			Baseline (2010)	Phase 1 (2017)	Phase 2 (2027)	Phase 1 only	Phase 2 only	Phase 1+2
Spark ignition			660	627	627	-5%	0%	-5%
Compression ignition	Vocational	Light	630	576	553	-9%	-4%	-12%
		Medium	630	576	553	-9%	-4%	-12%
		Heavy	584	555	533	-5%	-4%	-9%
	Tractor	Medium	518	487	466	-6%	-4%	-10%
		Heavy	490	460	441	-6%	-4%	-10%

Spark ignited engines and compression-ignition vocational engines are tested under the heavy-duty Federal Test Procedure (FTP) cycle while compression ignition tractor engines are tested under the Supplemental Emission Test (SET).

For context, these proposed Phase 2 engine standards requiring a 4% CO_2 reduction from 2017–2027 engines represent less than half of the technology potential that has been shown to be available in the rules' time frame. Cummins, the engine manufacturer with the most heavy-duty engine sales in the United States, estimated that the potential beyond Phase 1 is 9%–15%.[1] In addition, independent engine technology research indicates the potential for 18%–20% fuel consumption reduction from a 2010 baseline.[2] The agencies' analysis indicates that the predominant technology pathway for compliance with the standards will include the following technologies: friction reduction, reduced parasitic loads, variable valve timing, and improvements in the exhaust gas recirculation, combustion, and fuel injection systems. In addition, the agencies projected that up to 10% of heavy-duty engines could have turbocompounding and 15% of the engines could have waste heat recovery by 2027. Overall, the engine technologies to comply with the standards are projected to increase average technology costs by approximately $1,700 for tractor engines and $400–$500 for vocational engines between model years 2017 and 2027.

COMBINATION TRACTORS

Among heavy-duty vehicles, Class 7 and 8 tractors consume the most fuel—over 70% of fuel used by heavy-duty vehicles in the United States in 2014[3]—and generally have the most available technology to reduce their fuel use. The proposed second phase of the

1 Eckerle, W (2015). Engine Technologies for GHG and Low NO_x. http://www.arb.ca.gov/msprog/onroad/caphase2ghg/presentations/2_7_wayne_e_cummins.pdf

2 Thiruvengadam, A., et al (2014) Heavy-duty vehicle diesel engine efficiency evaluation and energy audit. http://www.theicct.org/heavy-duty-vehicle-diesel-engineefficiency-evaluation-and-energy-audit

3 US Energy Information Administration (2015). Annual Energy Outlook 2015. http://www.eia.gov/forecasts/aeo/

heavy-duty standards would require the widespread application of available powertrain and road load efficiency technologies across the Class 7–8 tractor fleet to meet new standards from model year 2018 through 2027. Combination tractors had some of the largest required percent improvements in the first phase of the standards, with a 9%–23% reduction in grams CO_2 per ton-mile from a 2010 baseline to model year 2017 across the nine categories.

Table 3 summarizes the CO_2 reduction requirements for Class 7 and 8 tractors of varying roof height (i.e., low, mid, high) and cab type (i.e., day or sleeper). The Phase 2 standards include one new category, "heavy-haul" tractors, which are differentiated by their higher weight capacity[4] and tend to have higher maximum power and different transmission configurations. The proposed standards include three discrete steps beyond 2017—for 2021, 2024, and 2027. Only the final 2027 requirements are shown in Table 3. As shown in the table, the newly proposed Phase 2 standards would reduce CO_2 emissions per ton-mile of freight moved by 11% (heavy-haul) to 24% (sleeper cab, high roof, Class 8) from model years 2017 to 2027. The associated model year 2027 fuel economy of these standards, under the assumed payloads, would be approximately 7.0 to 9.4 miles per gallon for Class 7–8 combination tractors.

Table 3. Summary of proposed combination tractor model year 2027 requirements

Tractor class	Type	Standard (g CO_2 / ton-mile)[a]		Fuel economy (miles per gallon)		Percent change 2017–2027	
		Reference (2017)	Proposed (2027)	Reference (2017)	Proposed (2027)	CO_2	Fuel economy
Class 7	Low roof	107	87	7.6	9.4	-19%	23%
	Mid roof	118	96	6.9	8.5	-19%	23%
	High roof	121	96	6.7	8.5	-21%	27%
Class 8 (day)	Low roof	86	70	6.2	7.7	-19%	23%
	Mid roof	93	76	5.8	7.0	-18%	22%
	High roof	95	76	5.6	7.0	-20%	25%
Class 8 (sleeper)	Low roof	79	62	6.7	8.6	-22%	28%
	Mid roof	87	69	6.1	7.8	-21%	27%
	High roof	88	67	6.1	8.0	-24%	32%
Heavy haul		57	51	4.2	4.6	-11%	12%

[a] Include assumed 25,000 lb (Class 7) and 38,000 lb (Class 8), 86,000 lb (heavy haul) payload; Equivalent NHTSA fuel consumption standards in gallon/1,000 ton-mile are based on 10,180 gram CO_2 per gallon diesel; Assumes tractors are pulling standard trailer, therefore trailer improvements are excluded.

These CO_2 reductions would primarily be from engine efficiency improvements resulting from the engine standards (as discussed above), advanced automatic transmissions, lower rolling resistance tractor tires, improved tractor aerodynamics, anti-idle devices, and additional driveline and accessory technologies being increasingly adopted across the Class 7 and 8 fleet. The agencies project that the new standards will raise the average cost of these tractors by approximately $9,500 (heavy haul) to $12,800 (Class 8, high-roof sleeper). The average payback period, when accounting for the vehicle owner fuel savings from the efficiency technologies, is

4 "Heavy-haul" category is defined as tractors with Gross Combined Weight Rating of over 120,000 lb.

within two years. These efficiency and CO_2 improvements and costs include the engine technology discussed above but exclude trailer technologies discussed below.

TRAILERS

The new heavy-duty vehicle program includes a new set of regulatory standards to promote the efficiency attributes of trailers that are typically hauled by Class 7 and 8 tractors. This program builds upon California's fleet requirements[5] and the voluntary U.S. EPA SmartWay program,[6] and acknowledges the increasing availability of low-cost efficiency improvements in the marketplace.[7] The proposal includes new requirements for the manufacturers of the trailers, including technologies that lower the trailer aerodynamic drag and rolling resistance of trailer tires.

The standards for box-type trailers use a system of aerodynamic bins numbered I through VIII, under which new trailer models would be certified. The higher-number bins represent greater levels of CO_2 reduction, up to 13%. The performance standard requires greater deployment of trailers performing at the higher aerodynamic bins over time. Similarly, the standards establish tire rolling resistance Levels 1 and 2, associated with a CO_2 reduction up to 3%. Manufacturers also receive credit for up to a 1.5% CO_2 reduction for automatic tire-pressure inflation systems. In addition, the agencies identify 11 common lightweight components that will be credited with approximately 1% CO_2 reduction per 1,000 pounds of weight reduction. For every three pounds of trailer weight reduction, one pound of additional payload is applied in the certification process to acknowledge the resulting lower CO_2 per ton-mile.

Table 4 summarizes the typical technologies expected to be deployed to meet the required average CO_2 emission reduction levels for 2027 for each of the 10 categories. The standards are performance-based, allowing trailer manufacturers to increasingly deploy some combination of aerodynamic devices from 2018 through 2027 to meet the standards. Aerodynamic Bin VI, an advanced aerodynamic drag package that is similar to the SmartWay Elite designation, could become quite common on long box 2027 trailers. The proposed rules include discrete steps for 2021, 2024, and 2027. By 2027, new long box trailers are expected to deliver approximately 9% lower CO_2 emission per ton-mile, while other trailer types would deliver 3%–4% lower CO_2. The proposed standards are estimated to cost an additional $1,400 for long box trailers, $1,300 for short box and refrigerated trailers, and $700 for non-box trailers in model year 2027.

5 California Air Resources Board. Tractor-Trailer Greenhouse Gas Regulation http://www.arb.ca.gov/msprog/truckstop/trailers/ttghg_regorder.pdf
6 US Environmental Protection Agency. SmartWay. http://www.epa.gov/smartway/index.htm
7 Sharpe and Roeth (2014). Costs and adoption rates of fuel-saving technologies for trailers in the North American on-road freight sector. http://www.theicct.org/costs-and-adoption-rates-fuel-saving-trailer-technologies

Table 4. Summary of trailer requirements for model year 2027

Trailer type	Typical 2027 technologies to meet performance standards	Standard (g CO_2 / ton-mile)[a]	Fuel economy (mpg)	Percent CO_2 reduction
Reference	Aerodynamic drag CdA = 6–6.2 m^2 (Bin I) Tire rolling resistance 6.0 kg/ton No automatic tire inflation system	85–87 (long) 147–151 (short)	6.2–6.3 (long) 6.7–6.9 (short)	0%
Long dry box	Aerodynamic improvements (Bins V–VII) Low rolling resistance tires (Level 2) Automatic tire inflation system	77	7.0	9%
Short dry box	Aerodynamic improvements (Bins II–IV) Low rolling resistance tires (Level 2) Automatic tire inflation system	140	7.3	5%
Long refrigerated box	Aerodynamic improvements (Bins V–VII) Low rolling resistance tires (Level 2) Automatic tire inflation system	80	6.7	8%
Short refrigerated box	Aerodynamic improvements (Bins II–IV) Low rolling resistance tires (Level 2) Automatic tire inflation system	144	7.1	5%
Partial aero long dry box	Aerodynamic improvements (Bins IV–VI) Low rolling resistance tires (Level 2) Automatic tire inflation system	79	6.8	7%
Partial aero short dry box	Aerodynamic improvements (Bins II–III) Low rolling resistance tires (Level 2) Automatic tire inflation system	141	7.2	4%
Partial aero long refrigerated box	Aerodynamic improvements (Bins IV–VI) Low rolling resistance tires (Level 2) Automatic tire inflation system	81	6.6	7%
Partial aero short refrigerated box	Aerodynamic improvements (Bins II–III) Low rolling resistance tires (Level 2) Automatic tire inflation system	144	7.1	5%
Non-aero box trailers	Low rolling resistance tires (Level 2) Automatic tire inflation system			3%–4%
Non-box	Low rolling resistance tires (Level 2) Automatic tire inflation system			3%–4%

[a] Includes assumed 20,000 lb (short van) and 38,000 lb (long van) in payload; Equivalent NHTSA fuel consumption standards in gallon/1,000 ton-mile are based on 10,180 gram CO_2 per gallon diesel; Assumes trailers are pulled by a standard tractor.

Because the new advanced trailers would be deployed simultaneously with the new required tractor efficiency improvements through 2027, their combined impact would be greater than shown above. The combined effect of the average 2027 trailer improvements for a long dry box van trailer (i.e., 9%) with the required efficiency increase on a 2027 high-roof, sleeper cab Class 8 tractor (i.e., from Table 3) would increase its fuel economy from 8.0 mpg to 8.8 mpg. For context, recent vehicle simulation modeling[8] and an associated technology cost assessment[9] indicated that it would be feasible to achieve greater than 10 mpg with cost-effective efficiency technologies in these tractor-trailers.

8 Delgado and Lutsey (2015). Advanced tractor-trailer efficiency technology potential in the 2020–2030 timeframe. http://www.theicct.org/us-tractor-trailer-efficiency-technology

9 Meszler et al (2015). Cost effectiveness of advanced efficiency technologies for long-haul tractor-trailers in the 2020–2030 timeframe. http://www.theicct.org/us-tractor-trailer-tech-cost-effectiveness

VOCATIONAL VEHICLES

The vocational vehicle category captures those heavy-duty vehicles that are not in the tractor category (above) or heavy-duty pickup and van category (below). These diverse vocational trucks include urban delivery vans, bucket trucks, refuse haulers, and many other vehicle types. Because of their greatly varied duty cycles and diverse highway driving patterns, some of the technologies mentioned above are not as widely applicable in this category. The adopted first phase of the standards required that vocational vehicles reduce their CO_2 emissions by 5%–9% by model year 2017, via engine and tire improvements. The original regulation had three general categories to split these vehicles by light (Class 2b–5), medium (Class 6–7), and heavy (Class 8) vehicles. The proposed Phase 2 standards, enabled by more sophisticated certification modeling, further subdivide the vocational vehicle standards according to duty cycle.

Table 5 summarizes the proposed new standards for 2027 vocational vehicles. The proposal includes 18 separate CO_2 standards. These are separated according to gasoline and diesel-fueled vehicles, three weight classes (light, medium, and heavy), and three duty cycles (regional, multi-purpose, and urban). The CO_2 emissions and fuel use for the three duty cycles are measured with different weightings of four test cycles, which are described further below. The proposed standards would require an additional 10%–13% CO_2 reduction from gasoline vocational vehicles and a 14%–15% CO_2 reduction from diesel vocational vehicles from model year 2017 through model year 2027.

Table 5. Summary of vocational vehicle requirements for model year 2027

Duty cycle	Standard (g CO_2 / ton-mile)[a]		Fuel economy (miles per gallon)		Percent CO_2 reduction 2017–2027	
	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline
Light urban	272	299	13.1	10.4	14%	10%
Light multi-purpose	280	308	12.8	10.1	14%	10%
Light regional	292	321	12.2	9.7	14%	10%
Medium urban	172	189	10.6	8.4	14%	11%
Medium multi-purpose	174	191	10.4	8.3	14%	11%
Medium regional	170	187	10.7	8.5	15%	11%
Heavy urban	182	196	7.5	6.0	14%	13%
Heavy multi-purpose	183	198	7.4	6.0	14%	12%
Heavy regional	174	188	7.8	6.3	14%	12%

[a] Include assumed payloads of 5,700 lb (light heavy duty), 11,200 lb (medium heavy duty), and 15,000 lb (heavy heavy-duty); Equivalent NHTSA fuel consumption standards in gallon/1,000 ton-mile are based on 10,180 gram CO_2 per gallon diesel and 8,887 gram CO_2 per gallon gasoline; Standards are based on the weighting of four drive cycles.

The agencies project that compliance with these Phase 2 standards would result from widespread use of lower rolling resistance tires, engine efficiency improvements (for diesel engines only, as discussed above), transmission improvements including integrated engine-transmission approaches, and idle reduction technology. In addition, the agencies project that there could be up to 10% penetration of hybrid technology in this truck category. Overall the average incremental per-vehicle technology cost among the 18 categories varied, from approximately $1,400 up to $7,400, in the categories that are expected to see more hybridization. These vehicles are typically owned for much longer time periods than other vehicle classes, and the average payback period in the segment was estimated to be 5 years.

HEAVY-DUTY PICKUPS AND VANS

The heavy-duty pickup and van category includes those vehicles of gross vehicle weight rating from 8,501 to 14,000 lb that are not regulated under the light-duty vehicle regulations. This category, with approximately 0.6 to 1 million sales per year, represents the majority of all medium- and heavy-duty vehicle sales and approximately 15% of these vehicles' fuel use annually.[10] The first phase of standards was projected to reduce pickup and van CO_2 and fuel use by 10% (for gasoline) and 15% (for diesel) by model year 2018. After a period of no change in regulatory stringency during 2018–2020, the proposed second phase would continue with increasingly stringent standards from model year 2021 through 2027.

The proposed new standards, as in the first phase, utilize a *work factor* to index more stringent requirements to lesser truck work functionality, and lower stringency to higher work functionality. Figure 1 illustrates the work factor-based regulatory CO_2 targets. The figure shows the work factor-to-CO_2-target functions that determine the regulatory requirements for each model year. The regulatory targets for each manufacturer in each model year are dependent upon its fleet's sales-weighted work factor, which is based on the payload capacity, the towing capacity, and whether the trucks have four-wheel drive. As shown by the two sets of regulatory target lines, gasoline and diesel vehicles are subject to separate standards. Generally, gasoline models have lower towing and payload capacity and are therefore lower on the work factor scale (3,000–5,000 lb work factor, versus typically 5,000–7,000 lb for diesel) and have more stringent standards. The figure shows the agencies' projected average work factor and CO_2 emission levels for gasoline and diesel trucks for model years 2014, 2018, and 2027

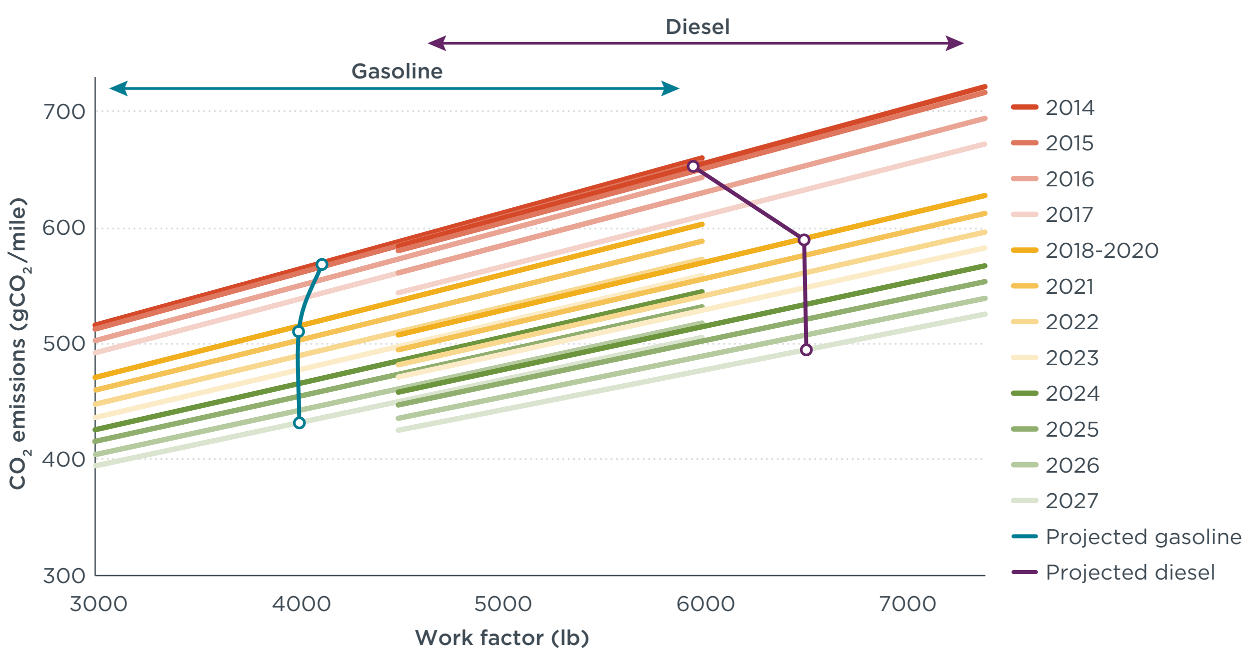

Figure 1. Heavy-duty pickup and van work factor-based CO_2 regulatory targets and agencies' projected average CO_2 for gasoline and diesel pickups and vans

10 US Energy Information Administration (2015). Annual Energy Outlook 2015. http://www.eia.gov/forecasts/aeo/

Based on the agencies' projected compliance, the gasoline and diesel heavy-duty pickup and van fleets each see a CO_2 reduction of 24% from 2014 (the first year of standards) through 2027. From only the Phase 2 standards, the gasoline and diesel heavy-duty pickups and vans would see a 16% reduction in CO_2 in 2021–2027, for a 2.5% per model year CO_2 reduction for new vehicles over that period. The proposed Phase 2 standards would result in an average increase in new gasoline and diesel vehicles' fuel economy from approximately 16 mpg in 2014 to 21 mpg in 2027. For context, the recent light-duty vehicle regulation would require a 45% reduction in CO_2 from 2012 through 2025, for an approximate 4.5% CO_2 reduction per year.[11] In addition, a recent assessment indicated that heavy-duty pickups and vans could adopt technologies similar to their full-size light-duty pickup and van counterparts and meet similarly technology-forcing standards.[12]

The agencies projected that the efficiency technologies that would become more widespread to comply with the proposed standards would include engine, transmission, and road load technologies. The prominent technologies expected across the new-vehicle fleet include engine friction reduction, low friction lubricants, low rolling resistance tires, 8-speed transmissions, aerodynamic drag reduction, electric power steering, and improved accessories. Other technologies that the agencies anticipate would see less widespread deployment include variable valve timing and lift, cylinder deactivation, turbocharging, and direct injection (which are mainly expected on heavy-duty vans). The agencies also projected an 8% market share for hybrids in setting the proposed targets. The projected average cost impact for the proposed pickup and van standards is approximately $1,000 per vehicle. Considering the resulting average fuel savings, the associated technology is expected to deliver a payback period within 3 years.

OTHER REGULATORY DETAILS

The proposed Phase 2 regulation largely adopts the structure and protocols of the Phase 1 regulation. Some differences are noted here.

A key part of the compliance process is handled through the U.S. EPA-developed Greenhouse Gas Emission Model (GEM), which is a physics-based simulation model that quantifies the CO_2 emissions and fuel consumption rates of each tractor and vocational vehicle. The tool incorporates hundreds of permutations of the various vehicle attributes (e.g., vehicle type, weight, transmission, aerodynamics, tire rolling resistance) for each make and model.

The new version of GEM (i.e., Phase 2 GEM) has been substantially upgraded to better estimate real-world impacts and capture the impacts of more efficiency technologies. Improved accuracy results from the incorporation of more detailed manufacturer-specific data related to engine and drivetrain specifications. Improvements from engine efficiency technologies are incorporated via manufacturer-specific steady-state "engine maps" that index fuel consumption to engine torque and speed, instead of the generic default engine maps that were used in the first phase. Manufacturers have the ability to utilize default transmission information within the model as well

11 U.S. EPA (2015). Regulations & Standards: Light-Duty. http://www.epa.gov/oms/climate/regs-light-duty.htm
12 Lutsey, N. (2015). Regulatory considerations for advancing commercial pickup and van efficiency technology in the United States. http://www.theicct.org/us-commercial-pickups-vans-efficiency-technology

as to submit new data on transmission performance. With more detailed input on transmissions, including drive axles and gear ratio information, the regulation now allows for subdividing the vocational space into three additional operational-based subcategories, as described above.

Many of the applicable vehicle and engine test cycles are carried through to Phase 2, but there are several additions and modifications. For tractor engines, the 13-mode Supplemental Emissions Test cycle remains; however, the weighting of the 13 test points has shifted more toward the lower engine speed points to reflect where more real-world tractor engine operation occurs. For vocational engine regulatory testing, the heavy-duty Federal Test Procedure cycle remains. The vehicle test cycles (ARB Transient, 55 mph, 65 mph) remain in Phase 2; however, road grade has now been included in the heavy-duty tractor and vocational vehicle testing within the 65 mph and 55 mph test cycles to better incorporate real-world load, engine, and transmission fluctuations. In addition, a fourth cycle for idling is introduced for vocational vehicles. The vocational vehicles utilize different weightings of the ARB Transient, 55 mph, 65 mph, and Idle cycles for the three different operational duty cycles (regional, multi-purpose, and urban). The heavy-duty pickups and vans continue to use the light-duty Federal Test Procedure and the Highway Federal Economy Test.

The Phase 2 proposal also addresses several aspects of natural gas vehicles and engines, their relative emission impacts, and emission-reduction technologies. The proposal includes standards related to emissions from the engine crankcase and liquefied natural gas (LNG) boil-off, two of the largest sources of on-vehicle methane emissions. EPA is proposing to require that all natural gas engines have closed crankcases to limit the current practice, where crankcase emissions are released to the atmosphere. In addition, EPA is proposing standards that would mandate a five-day hold time for on-vehicle LNG tanks to reduce LNG boil-off emissions.

The proposed useful life requirements for maintaining the certified CO_2 emission and fuel consumption levels remain as in the adopted Phase 1 regulation for the following vehicle categories. For Class 6–7 vehicles and medium heavy-duty engines, the useful life requirements are applicable up to 10 years and 185,000 miles. For Class 8 vehicles the standards apply up to 10 years and 435,000 miles. Changes to useful life designations include Class 2b—5 engines and vehicles (changed from 10 years and 110,000 miles to 15 years and 150,000 miles) as well as commercial pickup and vans (changed from 11 years and 120,000 miles to 15 years and 150,000 miles).[13] The civil penalties for violating the standards remain the same, with EPA and NHTSA having the authority to assess penalties of up to $37,500 for each noncomplying vehicle or engine.

SUMMARY OF PROPOSED BENEFITS

Figure 2 summarizes the reduction in CO_2 emissions from a nominal 2010 baseline, including the percent improvements from the adopted Phase 1 regulation and the proposed Phase 2 regulation. The figure shows nine particular vehicle types, among at least 46 separately regulated vehicle subcategories that reflect the diverse uses, duty cycles, requirements, and technology availability within the heavy-duty vehicle segment.

13 Corrected 6.30.2015. The original version of this update incorrectly stated that useful life requirements for Class 2b–5 vehicles and engines would remain unchanged from Phase 1.

Efficiency improvements from Phases 1 and 2 together would deliver CO_2 and fuel consumption reductions of about 20%–30% for heavy-duty pickups and vans, 20% for vocational vehicles, and about 30%–45% for Class 7–8 tractors-trailers. The figure shows how there is a 2018–2020 period of regulatory stability between the phases, and how many of the regulatory categories move in discrete steps for 2021, 2024, and 2027. The figure shows the agencies preferred Alternative 3 proposal. Under the agencies' more stringent Alternative 4, the same new requirements would generally be phased in three years earlier, by 2024, for each vehicle category (with the exception of pickups and vans, which would phase in two years earlier, by 2025).

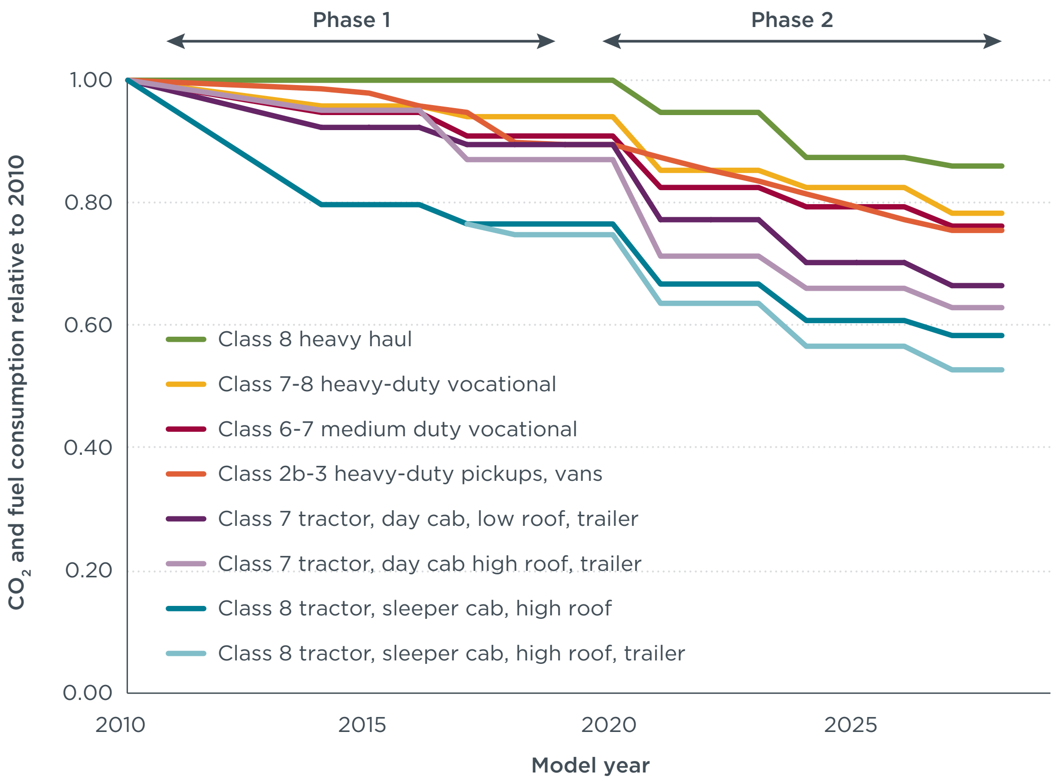

Figure 2. Summary of CO_2 and fuel consumption reduction from adopted Phase 1 and proposed Phase 2 heavy-duty vehicle standards for selected vehicle categories

Table 6 summarizes the main impacts of the adopted Phase 1 and proposed Phase 2 standards. The table includes the per-unit CO_2 impact in the final year of the standards, the estimated technology costs, the fleet-wide fuel use and CO_2 reduction impacts, and the total estimated costs and benefits. As shown there are many similarities, as the proposed Phase 2 would largely be a continuation of the adopted regulatory structure with increasing stringency from 2018 through 2027. New truck technologies would deliver fuel savings that greatly exceed the upfront costs in both phases of the regulation. In addition, both offer attractive payback periods. The payback periods for truck owners are within two years for tractor-trailers, within three years for pickups and vans, and about five years on average for vocational vehicles for the Phase 2 proposal. The impact of the Phase 1 and 2 standards together would result in over one million barrels per day of oil savings from 2035–2050.

Table 6. Summary of basic details for first phase and second phase

		Phase 1	Proposed Phase 2
Proposal		2010	2015
Final rule (expected)		2011	(2016)
Model years		2014–2018	2018–2027
Percent CO_2 reduction	**Combination tractors (Class 7 and 8)**	9%–23%	11%–24%
	Trailers	-	3%–9%
	Vocational vehicles (Class 2b-8)	5%–9%	10%–15%
	Heavy-duty pickups and vans (Class 2b and 3)	10%–15%	16%
	Engine	5%–6%	0%–4%
Vehicle technology cost	**Combination tractors (Class 7 and 8)**	$6,215	$11,680
	Trailers	-	$1,170
	Vocational vehicles	$378	$3,380
	Heavy-duty pickups and vans (Class 2b and 3)	$1,048	$1,340
Average payback period[a]	**Combination tractors (Class 7 and 8)**	1	2
	Vocational vehicles	1	5
	Heavy-duty pickups and vans (Class 2b and 3)	2	3
Energy and climate impact	**Greenhouse gas emission reduction by calendar year (million metric ton CO_2)**	76 (2030) 108 (2050)	127 (2035) 183 (2050)
	Fuel reduction by calendar year (million gallons per year)	6.0 (2030) 8.7 (2050)	9.3 (2035) 13.4 (2050)
	Greenhouse gas reduction over regulated vehicle lifetimes (million metric ton CO_2 equivalent)	273	961
	Fuel reduction over regulated vehicle lifetimes (billion gallons)	22	75
Monetary impact[b]	**Fuel savings (billion)**	$50	$170
	Other benefits (billion)	$7	$99
	Total costs (billion)	$8	$25
	Overall benefit-to-cost ratio	7:1	10:1

[a] Years after technology purchase in which cumulative fuel savings are greater than the additional initial technology cost.
[b] Based on 3% discount rate; "Other benefits" include value of health and monetized CO_2 benefit.

There are several notable differences from Phase 1 to Phase 2. The new standards would regulate trailers for the first time, and include longer phase-in periods and lead-time for technology deployment. By the time of the expected Phase 2 final rule adoption in 2016, there will be 11 years of lead-time for the 2027 standards. In contrast, with the Phase 1 adoption in 2011 for 2018 standards, there were seven years of lead-time. In addition, the proposed Phase 2 program is expected to bring greater benefits than the Phase 1 program—at least 50% greater calendar year benefits, and over three times the cumulative benefits over the regulated vehicle lifetimes. The programs have similar estimated benefit-to-cost ratios.

As mentioned, the above summary of the proposal is almost exclusively focused on the agencies' preferred Alternative 3. The agencies also assess an Alternative 4, which would achieve the same per-vehicle CO_2-reduction performance as the proposed standards, but two to three years earlier. The agencies point out that Alternative 4 has the potential to be the maximum feasible and appropriate alternative. Over the lifetime of the regulated 2018–2029 vehicles, Alternative 4 would offer 13% greater greenhouse gas benefit (an additional 125 million tons CO_2), yield 13% greater fuel savings (an additional 9.5 billion gallons of fuel), provide $23 billion in additional fuel savings to truck owners, deliver $9.6 billion in additional climate and health benefits, and cost about $8 billion more in additional technology costs, as compared to the agencies' preferred Alternative 3.

INTERNATIONAL CONTEXT

The developments discussed above regarding the proposed Phase 2 U.S. heavy-duty vehicle regulation for model years 2018–2027 are relevant to a number of other governments that are deliberating similar efficiency policies. Table 7 summarizes the timeline for the implementation of adopted heavy-duty efficiency and CO_2 regulations, as well as for other major markets that have conducted initial steps to collect data and consider potential regulation. In 2015, the heavy-duty vehicle efficiency regulations implemented in Japan, the United States, Canada, and China markets cover approximately one third of global heavy-duty vehicle sales. The European Union, India, Mexico, and South Korea are at various stages in their processes of developing heavy-duty efficiency standards. Considering the global nature of heavy-duty engine and vehicle technology manufacturers, each regulation gains from collaboration, data sharing, and aligned provisions. This is especially important throughout the rulemaking process, when key technology, vehicle simulation, test protocol, and compliance details are being finalized for at least 10 years into the future, as in this case of the U.S. heavy-duty vehicle regulation.

Table 7. Estimated implementation timeline for heavy-duty vehicle efficiency standards

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Japan				Phase 1					Phase 2					
U.S.			Phase 1					Phase 2						
Canada			Phase 1					Phase 2						
China	Phase 1		Phase 2						Phase 3					
EU						Monitoring, reporting			Phase 1					
India							Phase 1							
Mexico						Phase 1								
S.Korea							Phase 1							

Hashed areas represent unconfirmed projections of the ICCT.

US PHASE 2 REGULATION RESOURCES

Further regulatory and technical support information is available online at these addresses:

- General U.S. EPA page: http://www.epa.gov/oms/climate/regs-heavy-duty.htm
- General NHTSA page: http://www.nhtsa.gov/fuel-economy
- Proposal: http://www.epa.gov/oms/climate/documents/hd-ghg-fr-notice.pdf
- Regulatory Impact Analysis: http://www.epa.gov/oms/climate/documents/420d15900.pdf
- Greenhouse Gas Emission Model (GEM): http://www.epa.gov/oms/climate/gem.htm
- NHTSA supporting research page: http://www.nhtsa.gov/Laws+&+Regulations/CAFE+-+Fuel+Economy/supporting-phase-2-proposal
- Docket (NHTSA-2014-0132, EPA–HQ–OAR–2014-0827): http://www.regulations.gov

ADDITIONAL HEAVY-DUTY VEHICLE RESOURCES

The following is a list of papers and briefings produced by the International Council on Clean Transportation in 2013–2015 on topics that relate to the U.S. heavy-duty vehicle Phase 2 rulemaking, such as technology availability, technology cost, and regulatory design.

Tractor-trailers: Engine efficiency, technology availability, technology simulation, payback period in the 2020–2030 time frame

- Delgado, O., Lutsey, N. (2015). Advanced tractor-trailer efficiency technology potential in the 2020–2030 timeframe. http://www.theicct.org/us-tractor-trailer-efficiency-technology. April.
- Meszler, D., Lutsey, N., Delgado, O. (2015). Cost effectiveness of advanced efficiency technologies for long-haul tractor-trailers in the 2020–2030 timeframe. http://www.theicct.org/us-tractor-trailer-tech-cost-effectiveness. April.
- Thiruvengadam, A., Pradhan, S., Thiruvengadam, P., Besch, M., Carder, D., Delgado, O. (2014) Heavy-duty vehicle diesel engine efficiency evaluation and energy audit. http://www.theicct.org/heavy-duty-vehicle-diesel-engineefficiency-evaluation-and-energy-audit.
- Delgado, O., Lutsey, N. (2014). The U.S. SuperTruck Program: Expediting development of advanced HDV efficiency technologies. http://www.theicct.org/us-supertruck-program-expediting-development-advanced-hdv-efficiency-technologies. June.
- Lutsey, N., Langer, T., Khan, S. (2014). Stakeholder workshop report on tractor-trailer efficiency technology in the 2015-2030 timeframe. http://www.theicct.org/stakeholder-workshop-report-tractor-trailer-efficiency-technology-2015-2030. August.

Trailers: Market, regulatory design, technology, cost

- Sharpe, B., Delgado, O., Lutsey, N. (2014). Benefit-cost analysis of integrating trailers into heavy-duty vehicle efficiency regulation. http://www.theicct.org/integrating-trailers-hdv-regulation-benefit-cost-analysis. July.
- Sharpe, B. (2014). Recommendations for regulatory design, testing, and certification for integrating trailers into the Phase 2 U.S. heavy-duty vehicle fuel efficiency and greenhouse gas regulation. http://www.theicct.org/integrating-trailers-us-phase-2-hdv-efficiency-rule. February.

- Sharpe, B., Roeth, M. (2014). Costs and adoption rates of fuel-saving technologies for trailers in the North American on-road freight sector. http://www.theicct.org/costs-and-adoption-rates-fuel-saving-trailer-technologies. February.
- Sharpe, B., Clark, N., Lowell, D. (2013). Trailer technologies for increased heavy-duty vehicle efficiency. http://www.theicct.org/trailer-technologies-increased-hdv-efficiency. June.

Regulatory design: Structure, simulation modeling

- Sharpe, B., Delgado, O., Muncrief, R. (2014). Comparative assessment of heavy-duty vehicle regulatory design options for U.S. greenhouse gas and efficiency regulation. http://www.theicct.org/us-phase2-hdv-regulation-design-options. October.
- Franco, V., Delgado, O., Muncrief, R. (2015). Heavy-duty vehicle fuel-efficiency simulation: A comparison of US and EU tools. http://www.theicct.org/heavy-duty-vehicle-fuel-efficiency-simulation-comparison-us-and-eu-tools. May.

Heavy-duty pickups and vans

- Lutsey, N. (2015). Regulatory considerations for advancing commercial pickup and van efficiency technology in the United States. http://www.theicct.org/us-commercial-pickups-vans-efficiency-technology. April.

Market barriers: Technology availability, credible information, uncertain payback time

- Roeth, M., Kircher, D., Smith, J., Swim, R. (2013). Barriers to the increased adoption of fuel efficiency technologies in the North American on-road freight sector. http://www.theicct.org/hdv-technology-market-barriers-north-america. July.

International context for heavy-duty vehicle regulation

- Kodjak, D. (2015). Policies to reduce fuel consumption, air pollution, and carbon emissions from vehicles in G20 nations. http://theicct.org/policies-reduce-fuel-consumption-air-pollution-and-carbon-emissions-vehicles-g20-nations. June.
- Kodjak, D., Sharpe, B., Delgado, O. (2015). Evolution of heavy-duty vehicle fuel efficiency policies in major markets. Mitigation and Adaptation Strategies for Global Change 20: 755–775. http://link.springer.com/article/10.1007%2Fs11027-015-9632-5.
- Langer, T., Khan, S. (2013). International Alignment of Fuel Efficiency Standards for Heavy-Duty Vehicles. http://www.theicct.org/international-alignment-fuel-efficiency-standards-heavy-duty-vehicles.