POLICY UPDATE

AUGUST 2016

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 August 16, 2016, the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) jointly published the final rulemaking[1] to reduce the fuel consumption and greenhouse gas emissions from new heavy-duty vehicles, tractor trucks, trailers, and engines. The new Phase 2 regulations will be implemented from model years 2018 to 2027, building upon the initial Phase 1 standards that cover model years 2014 to 2018. This rulemaking finalizes the standards that were proposed in June 2015.

This policy update provides a brief summary of some key aspects of the regulation. For a more in-depth discussion of technology potential, test procedures, and regulatory design, please see the ICCT's policy update[2] for the Phase 2 proposal. In addition, the final section of this policy update provides a number of Phase 2-releated resources and lists all of the ICCT research that was developed in support of this regulatory development process.

REGULATORY REQUIREMENTS

The structure of the Phase 2 regulation is similar to Phase 1, with regulatory standards for tractors, commercial pickups and vans, vocational vehicles, and the engines used in tractors and vocational vehicles. In addition, the Phase 2 rule incorporates one new major category: trailers. Table 1 and Figure 1 below summarize the requirements of the new standards in each of these five areas.

The Phase 2 regulation retains the use of separate engine standards to increase the efficiency of engines certified for light-, medium-, and heavy-heavy-duty vehicles. As shown in Table 1, Phase 1 reduces diesel (compression ignition) engines' fuel use by 5%–9%, Phase 2 brings a further 5% reduction for diesel engines, and together the

1 https://www3.epa.gov/otaq/climate/regs-heavy-duty.htm
2 http://www.theicct.org/us-phase2-hdv-efficiency-ghg-regulations-policy-update

THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION standards will result in an approximate 9%–12% fuel consumption reduction from 2010 baseline engines by model year 2027. 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. Overall, the engine technologies necessary to comply with the standards are projected to increase average technology costs by approximately $1,600 for tractor engines and $400–$500 for vocational engines between model years 2017 and 2027. In addition, new to the final rule, the agencies are including an optional engine provision whereby manufacturers can opt for slightly relaxed standards for model years 2024 to 2026 by achieving the model year 2021 standards a year early in model year 2020. Under this provision, the model year 2027 standard is unchanged, but any credits generated for model years 2018 and 2019 can be extended through model year 2030.

For tractor trucks, the Phase 2 standards require CO_2 emission reductions per ton-mile of freight moved by 15% (heavy-haul) to 27% (sleeper cab, high roof, Class 8) from model years 2017 to 2027. 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 $10,000 (heavy haul) to $13,700 (Class 8, high-roof sleeper), which includes the additional engine costs cited above. The average payback period, when accounting for the vehicle owner fuel savings from the efficiency technologies, is within two years.

In addition to tractors, the Phase 2 program includes a new set of regulatory standards to promote the efficiency attributes of commercial trailers. These standards build upon California's fleet requirements[3] and the voluntary U.S. EPA SmartWay program,[4] and acknowledges the increasing availability of low-cost efficiency improvements in the marketplace.[5] The rule 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 require the various combinations of aerodynamic devices, tire rolling resistance technologies, and automatic inflation systems, depending on the type and length of trailer. The standards are estimated to impose an additional $1,400 on long box trailers, $1,200 for short box and refrigerated trailers, and $400 for non-box trailers in model year 2027.

The vocational truck category includes urban delivery vans, bucket trucks, refuse haulers, and many other vehicle types. Because of their greatly varied duty cycles and diverse driving patterns, the agencies have segmented vocational vehicles by weight and mission profile. As such, the rule includes 18 separate CO_2 standards, which are defined according to fuel type (diesel and gasoline), three weight classes (light,

3 California Air Resources Board. Tractor-Trailer Greenhouse Gas Regulation http://www.arb.ca.gov/msprog/truckstop/trailers/ttghg_regorder.pdf

4 US Environmental Protection Agency. SmartWay. http://www.epa.gov/smartway/index.htm

5 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

medium, and heavy), and three duty cycles (urban, multi-purpose, and regional). The standards require a 10%–18% CO_2 reduction from gasoline vocational vehicles and a 12%–24% CO_2 reduction from diesel vocational vehicles from model year 2017 through model year 2027. Overall, the average incremental per-vehicle technology cost among the 18 categories varies from approximately $1,500 up to $5,700, for the categories that are expected to see increased hybridization. First owners of vocational vehicles typically keep these vehicles for much longer time periods than tractor trucks, and the average payback period in the segment is estimated to be four years.

The commercial pickup and van category includes those vehicles of gross vehicle weight rating from 8,501 to 14,000 lbs. that are not regulated under the light-duty vehicle regulations. The 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. The gasoline and diesel commercial pickups and vans are required to achieve a 16% reduction in CO_2 in 2021–2027, for a 2.5% annual CO_2 reduction for new vehicles over that period. The projected average cost impact for the proposed pickup and van standards is approximately $1,300 per vehicle. Considering the resulting average fuel savings, the associated technology is expected to deliver a payback period within three years.

Table 1. Phase 2 requirements* for engines, tractors, trailers, and vocational vehicles

Class	Type	Baseline: Phase 1 2017		Final rule 2027		Final rule: percent change 2017–2027	
		$g\ CO_2$ / bhp-hr		$g\ CO_2$ / bhp-hr			
Compression ignition engine	TRACTOR (MD)	481		457		-5%	
	TRACTOR (HD)	455		432		-5%	
	VOCATIONAL (LD)	576		552		-4%	
	VOCATIONAL (MD)	558		535		-4%	
	VOCATIONAL (HD)	525		503		-4%	
Spark ignition engine		627		627		0%	
		$g\ CO_2$ / ton-mile	mpg	$g\ CO_2$ / ton-mile	mpg	CO_2	Fuel economy
Class 7 tractor	LOW ROOF	119.1	6.8	96.2	8.5	-19%	24%
	MID ROOF	127.2	6.4	103.4	7.9	-19%	23%
	HIGH ROOF	129.7	6.3	100.0	8.1	-23%	30%
Class 8 tractor (day)	LOW ROOF	91.3	5.9	73.4	7.3	-20%	24%
	MID ROOF	96.6	5.5	78.0	6.9	-19%	24%
	HIGH ROOF	98.2	5.5	75.7	7.1	-23%	30%
Class 8 tractor (sleeper)	LOW ROOF	84.0	6.4	64.1	8.4	-24%	31%
	MID ROOF	90.2	5.9	69.6	7.7	-23%	30%
	HIGH ROOF	87.8	6.1	64.3	8.3	-27%	37%
Heavy haul tractor		57	4.2	48.3	4.6	-15%	12%
Long box trailers	DRY VAN	83.2	6.4	75.7	7.1	-9%	10%
	REFRIGERATED VAN	84.9	6.3	77.4	6.9	-9%	10%
Short box trailers	DRY VAN	126.5	8.0	119.3	8.5	-6%	6%
	REFRIGERATED VAN	130.3	7.8	123.1	8.3	-6%	6%
Non-aero box trailers		-	-	-	-	-3 to -4%	3 to 4%
Non-box trailers		-	-	-	-	-3 to -4%	3 to 4%
		$g\ CO_2$ / ton-mile		$g\ CO_2$ / ton-mile		$g\ CO_2$ / ton-mile	
		Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline
Light heavy-duty	URBAN	482	502	367	413	-24%	-18%
	MULTI-PURPOSE	420	441	330	372	-21%	-16%
	REGIONAL	334	357	291	319	-13%	-11%
Medium heavy-duty	URBAN	332	354	258	297	-22%	-16%
	MULTI-PURPOSE	294	314	235	268	-20%	-15%
	REGIONAL	249	275	218	247	-12%	-10%
Heavy heavy-duty	URBAN	338	354	269	297	-20%	-16%
	MULTI-PURPOSE	287	314	230	268	-20%	-15%
	REGIONAL	220	275	189	247	-14%	-10%

* Equivalent NHTSA fuel consumption standards in gallon/1,000 ton-mile are based on 10,180 gram CO2 per gallon diesel

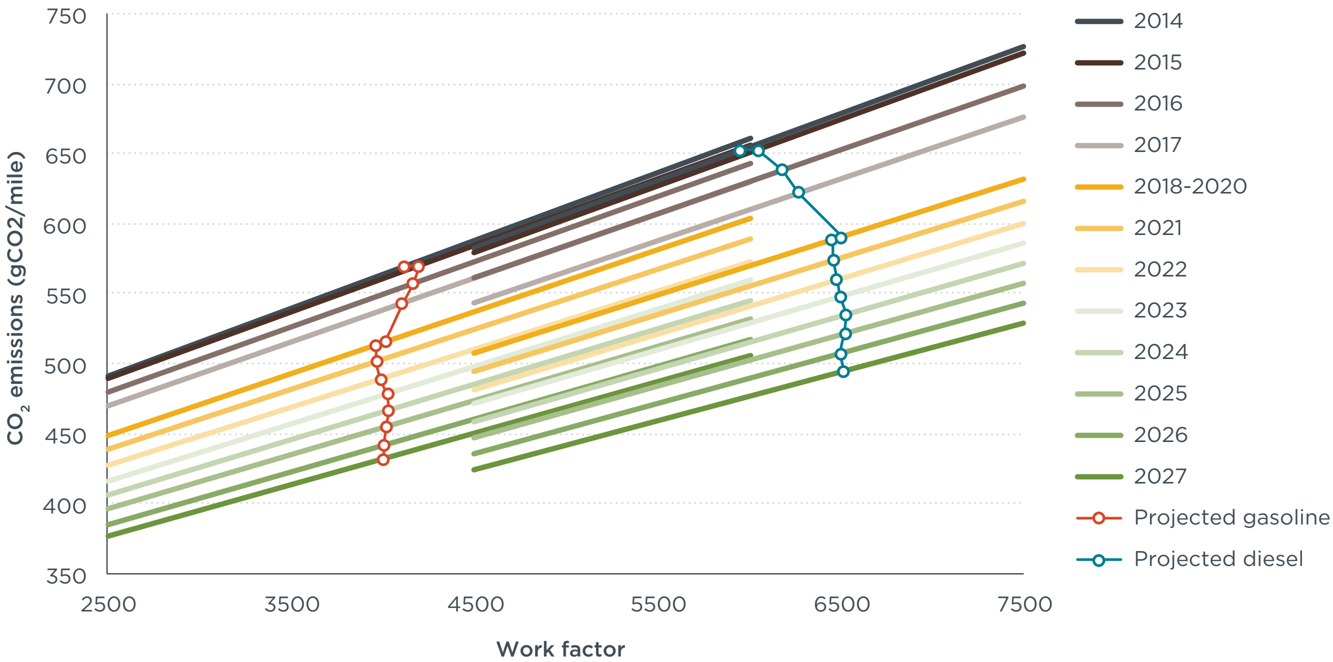

Figure 1. Commercial pickup and van work factor-based CO_2 regulatory targets and agencies' estimated average CO_2 for gasoline and diesel pickups and vans

SUMMARY OF PROPOSED BENEFITS

Table 2 summarizes the main impacts of the Phase 1 and 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 Phase 2 rule is largely a continuation of the adopted regulatory structure with increasing stringency from 2018 through 2027. New truck technologies will 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 four years on average for vocational vehicles for the Phase 2 proposal. The impact of the Phase 1 and 2 standards together will result in over $200 billion in net savings to commercial vehicle fleets and society at large.

Table 2. Summary of basic details for first phase and second phase

		Phase 1	Phase 2
Proposal		2010	2015
Final rule		2011	2016
Model years		2014–2018	2018–2027
Percent CO_2 reduction	**Combination tractors (Class 7 and 8)**	9%–23%	12%–27%
	Trailers	-	3%–9%
	Vocational vehicles (Class 2b-8)	5%–9%	10%–24%
	Commercial pickups and vans (Class 2b and 3)	10%–15%	16%
	Engines	5%–6%	0%–5%
Vehicle technology cost[a]	**Combination tractors (Class 7 and 8)**	$6,215	$12,300
	Trailers	-	$1,100
	Vocational vehicles	$378	$2,700
	Commercial pickups and vans (Class 2b and 3)	$1,048	$1,350
Average payback period[b]	**Combination tractors (Class 7 and 8)**	1	2
	Vocational vehicles	1	4
	Commercial 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)	139 (2040) 167 (2050)
	Fuel reduction by calendar year (billion gallons per year)	6.0 (2030) 8.7 (2050)	10.2 (2040) 12.3 (2050)
	Greenhouse gas reduction over regulated vehicle lifetimes (million metric ton CO_2 equivalent)	273	1,098
	Fuel reduction over regulated vehicle lifetimes (billion gallons)	22	82
Monetary impact[c]	**Fuel savings (billion)**	$50	$169
	Other benefits (billion)	$7	$88
	Total costs (billion)	$8	$29
	Overall benefit-to-cost ratio	7:1	8:1

[a] For tractors and vocational vehicles, these values include the additional costs related to engines.
[b] Years after technology purchase in which cumulative fuel savings are greater than the additional initial technology cost
[c] Based on 3% discount rate; "Other benefits" include value of health and monetized CO_2 benefit.

INTERNATIONAL CONTEXT

The developments discussed above regarding the Phase 2 U.S. heavy-duty vehicle regulation for model years 2018–2027 are relevant to a number of other governments around the world that are deliberating similar efficiency policies. Table 3 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 together 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. Recently, the European Commission announced[6] that it will commence a formal regulatory process to establish efficiency standards for heavy-duty trucks and buses. China has its own process moving forward to finalize its proposed Phase 3 standards[7] that would reduce fuel consumption by up to 27% from 2012 trucks. 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 3. 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.

6 http://ec.europa.eu/transport/themes/strategies/news/doc/2016-07-20-decarbonisation/com(2016)501_en.pdf
7 http://www.theicct.org/china-stage-3-fuel-consumption-standard-commercial-HDVs

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
- Draft Regulatory Impact Analysis: http://www.epa.gov/oms/climate/documents/420d15900.pdf
- Final rule: https://www3.epa.gov/otaq/climate/documents/2016-08-ghg-hd-final-rule-phase2-preamble.pdf
- Final Regulatory Impact Analysis: https://www3.epa.gov/otaq/climate/documents/420r16900.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
- NHTSA Final Environmental Impact Statement: http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/MDHD2-Final-EIS.pdf
- 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 from 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.

Commercial 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.

Muncrief, R., Sharpe, B. (2015) Overview of the heavy-duty vehicle market and CO2 emissions in the European Union. http://www.theicct.org/overview-heavy-duty-vehicle-market-and-co2-emissions-european-union. December.

Delgado, O. (2016) Stage 3 China fuel consumption standard for commercial heavy-duty vehicles. http://www.theicct.org/china-stage-3-fuel-consumption-standard-commercial-HDVs. July.