American Council for an Energy-Efficient Economy
529 14th Street, N. W., Suite 600 Washington, D.C. 20045 202.507.4000 202.429.2248 www.aceee.org

To:
Air and Radiation Docket and Information Center,
Environmental Protection Agency, Mail code: 28221T,
1200 Pennsylvania Ave. N.W., Washington, DC 20460

Docket Management Facility, M–30,
U.S. Department of Transportation,
West Building, Ground Floor, Rm. W12–140,
1200 New Jersey Avenue S.E., Washington, DC 20590

From:
Therese Langer and Siddiq Khan, American Council for an Energy-Efficient Economy (ACEEE)

Re: Docket ID Nos. NHTSA-2014-0132 and EPA-HQ-OAR-2014-0827

Date: October 1, 2015

Attached please find the comments of the American Council for an Energy-Efficient Economy (ACEEE) on EPA and NHTSA's Proposed Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Phase 2.

ACEEE, a nonprofit, 501(c)(3) organization, acts as a catalyst to advance energy efficiency policies, programs, technologies, investments, and behaviors. We believe that the United States can harness the full potential of energy efficiency to achieve greater economic prosperity, energy security, and environmental protection for all its people. ACEEE carries out its mission by:

- Conducting in-depth technical and policy analyses
- Advising policymakers and program managers
- Working collaboratively with businesses, government officials, public interest groups, and other organizations
- Convening conferences and workshops, primarily for energy efficiency professionals
- Assisting and encouraging traditional and new media to cover energy efficiency policy and technology issues
- Educating consumers and businesses through our reports, books, conference proceedings, press activities, and websites

ACEEE was founded in 1980 by leading researchers in the energy field.

We appreciate this opportunity to provide comment on the agencies' proposal. Unless otherwise indicated, page references in the comments that follow refer to the proposed rule as it appeared in the Federal Register on July 13, 2015 (FR Vol. 80, No. 133).

# ACEEE Comments on EPA and NHTSA's Proposed Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Phase 2

**Docket ID Nos. NHTSA-2014-0132 and EPA-HQ-OAR-2014-0827**

**Therese Langer, Ph.D. and Siddiq Khan, Ph.D.**
**October 1, 2015**

# Table of Contents

## Overview

The adoption of the first-ever greenhouse gas emissions and fuel efficiency standards for heavy-duty vehicles and engines in 2011 (called 'Phase 1' hereafter) was a historic step in reducing emissions and oil consumption from the transportation sector. The proposed Phase 2 standards, built on the success of the Phase 1 program, would provide substantial gains in fuel efficiency for heavy-duty vehicles by 2027, provide continuity and certainty to the manufacturers, deliver savings at the pump to truck owners and operators, and reduce freight costs. The heavy-duty fuel efficiency program is also a key element of the President's climate action plan.

The Phase 1 program helped to establish the leadership of U.S. manufacturers and suppliers in certain advanced truck technologies in a global market, and we expect the Phase 2 program to further strengthen that position. The Phase 2 program also offers the potential of new jobs in the design and production of new vehicle technologies.

ACEEE applauds the agencies' excellent work in developing the Phase 2 standards. The scope of the Phase 1 program was necessarily constrained by multiple factors, limiting what could be accomplished. The proposed rule Phase 2 improves upon the existing Phase 1 program in several fundamental ways, including:

- **Full vehicle integration.** The proposal takes very important steps toward making the standards full-vehicle standards. In Phase 2, tractor and vocational vehicle certification levels will reflect the efficiency of the engine sold with the vehicle, rather than a default engine, and how that engine operates in the vehicle. Transmission efficiency, which allows for several additional percentage points savings, will be recognized and credited for the first time. Integration of engine and transmission can be captured through a powertrain test, an important option introduced in the proposal. The greenhouse gas emissions model (GEM), which is used to calculate vehicles' fuel efficiency, will become more sophisticated and allow many more technologies to contribute to certified fuel efficiency. The vehicle certification protocols will promote integration of engine, transmission, and vehicle components.
- **Inclusion of trailers.** The addition of trailers to the program is crucial, because known, affordable trailer aerodynamic and tire technologies can deliver almost 10% fuel savings for tractor-trailers.
- **Further vocational vehicle segments and more realistic test cycles**. The more extensive segmentation of vocational vehicles and the accompanying cycle re-weightings will better reflect these vehicles' operating characteristics. Test cycles will match vehicles' real-world duty cycles much better than they do in the Phase 1 program, especially with the addition of an idle cycle. Inclusion of road grade on the 55- and 65-mph steady-state cycles in Phase 2 will better reflect real-world driving. Reweighting operating points for tractor truck engine certification to reflect today's lower real-world operating speeds is another positive step.

Facilitated by these advances in the program, the proposed Phase 2 standards would bring very substantial further reductions in fuel efficiency and GHG emissions by 2027. At the same time, ACEEE believes that the final standards could and should be stronger than the proposed standards.

**The proposed 2027 standards – and more – can cost-effectively and feasibly be achieved by model year 2024.**

As discussed in detail below, the fuel consumption reduction achieved by 2027 in the preferred alternative (Alternative 3) can and should be reached or exceeded by 2024. However, the agencies' compliance package for Alternative 4 represents only one pathway to reach those reductions, and it is unlikely to be the lowest cost option to do so. In particular, we find that an overall fuel consumption reduction of 24% relative to 2017 levels could be achieved cost-effectively in 2024 without the use of advanced technologies, as described later in these comments.

The single most important shortcoming of the proposal is the weakness of the tractor truck engine standard. However, standards for all engine and vehicle classes have room for improvement.

**Standards in 2027 must drive advanced technologies.**

If the program is extended to 2027, those standards must go well beyond what is currently proposed to meet the agencies' requirements for appropriate and maximum feasible standards. A crucial function of motor vehicle emissions standards is to promote the further development and accelerate the deployment of promising technologies whose pathway to market acceptance is less clear. EPA has the authority to set technology-forcing standards under the Clean Air Act; it is especially important that the agency exercise that authority in a rule, such as this one, that has a long time horizon.

The proposed rule recognizes this, and includes technologies such as advanced aerodynamics and vocational hybrids in the compliance scenario for this reason. However, given that the proposed standards can be met without drawing on those technologies, it is necessary to substantially strengthen the 2027 standards to ensure the program does in fact promote the development of these and other advanced technologies and point the way to further, major gains for heavy-duty vehicles.

## Vehicle Simulation, Engine Standards and Test Procedures

#### Greenhouse Gas Emissions Model (GEM) outputs

As in the Phase 1, the output files of the GEM executable distributed with the Phase 2 proposal display only the composite fuel consumption and emissions results and not the individual cycle results. Basing the fuel efficiency standard on a weighted average of cycle-specific fuel consumption results makes sense. However, there is no justification for not providing these cycle-specific results to the GEM user, for whom the individual cycle results clearly constitute valuable information about vehicle performance.

Furthermore, the individual cycle results for each model should be reported in a publicly accessible electronic database. The variation in duty cycles experienced by heavy-duty vehicles, even within a vehicle category, is among the challenges to creating a sound and equitable program of standards. Knowing how vehicles compare on individual cycles can be much more valuable information than the composite results for some purchasers, especially those for whom the relevant duty cycle involves much more or much less transient and idle operation than is reflected in the weighting assumed for purposes of the standards.

*Recommendation: GEM outputs*

- The GEM executable should be revised to report sufficient fuel efficiency performance data to permit buyers to assess fuel consumption over customized duty cycles. In particular, outputs should include fuel efficiency results over each discrete test cycle.

#### Chassis testing of tractor and vocational vehicles

ACEEE supports the agencies' proposal that tractor and vocational vehicle manufacturers annually chassis test some of their production vehicles over the GEM cycles to verify that relative reductions simulated in GEM are being achieved in actual production (p. 40190). ACEEE in its 2011 report recommended physical testing (road, track, or chassis dynamometer) for a basic set of well-defined vehicle configurations.[1] The results of these tests should be public information.

Such a requirement can benefit the heavy-duty vehicle program greatly by:

1. Helping to make further changes to the GEM model that will improve its accuracy in projecting real-world effectiveness of fuel efficiency technology packages, and
2. Generating extensive data on vehicle performance that could be used by researchers to evaluate the program.

*Recommendation: Chassis testing requirements*

- Finalize the requirement that manufacturers provide results from annual chassis testing of a small number of vehicles.
- Provide the results of this testing to the public in a usable format.

#### Powertrain testing

ACEEE strongly supports the inclusion of an option to test tractors and vocational vehicles using a powertrain test (p.40179). Given the very substantial benefits to be gained from the integration of engine and transmission, it is important that the efficiency benefits of such integration be not only recognized but factored into the stringency of the standards, especially for vocational vehicles.

Needless to say, this option will not help to incentivize engine-transmission integration unless powertrain testing can demonstrate the efficiency benefit of the integration. If the integrated powertrain does not achieve better results on the powertrain test than it – or a less efficient powertrain – achieves in GEM testing, the powertrain option will serve no purpose. Transmission loss in present GEM is conservative and efficiency gain from transmission is generous than powertrain testing. It is important that the agencies keep this issue in mind as they determine how the GEM executable handles the various transmissions types.

*Recommendation: Powertrain testing*

- Calibrate GEM treatment of transmission efficiency to yield result that can be compared to results of powertrain testing.

[1] Khan and Langer. 2011. "Heavy-Duty Vehicle Fuel Efficiency and Greenhouse Gas Emissions: The 2014-2019 Standards and a Pathway to the Next Phase." ACEEE Research Report T113. http://aceee.org/research-report/t113.

### Cycle-average approach to engine performance

For purposes of representing the engine in GEM, i.e. for certifying tractor and vocational vehicle fuel consumption levels, manufacturers must provide a 140-point steady-state engine map showing fueling rates. However, the agencies request comment on an alternative procedure for representing engine performance, both for input to GEM and for engine certification, using "cycle average maps" (RIA p.3-80). The agencies note that this alternative could be the procedure finalized in the Phase 2 rule.

The rationale for this alternative is two-fold. First, some engine manufacturers believe that the engine fueling map constitutes confidential business information and would prefer not to divulge it to the OEMs, as the proposal would require. Second, the alternative procedure can capture transient performance of the engine, which is an important factor in engine fuel consumption.

Given that some OEMs have indicated their willingness to provide engine maps, we are not sympathetic to the concern regarding engine CBI. However, we strongly support the agencies' efforts to capture engines' transient performance in testing, which will both improve the agreement between certified and real-world performance and enable the standard to promote technologies that reduce fuel consumption in transient operation.

Agency test data indicates that, when tested over a cycle that includes transient operation, engines consume from 3 to 7% more fuel than would be calculated from modeling the engine based on a steady-state fuel map. Cycle–based engine testing would create an incentive for the adoption of transient controls that minimize this fuel consumption, especially if the standards were tightened to reflect this opportunity for additional fuel consumption reduction.

*Recommendation: Cycle-average approach to engine performance*

- Continue to develop and refine the proposed cycle-average approach to engine testing. Should this approach be adopted, greater efficiency should be required of engines to drive the adoption of transient controls.

### Separate engine standards

ACEEE has supported maintaining standards for tractor and vocational truck engines in Phase 2. The primary reason for such standards in our view is to set out direct, multiyear targets for engine performance sufficient to promote substantial, sustained investment in engine efficiency. So long as the only signal to improve engine efficiency is filtered through the lens of whole vehicle efficiency, there will remain uncertainly about how much of the improvement will fall to the engine. This is especially problematic for engines not produced by vehicle OEMs, which play a prominent role in the U.S. market.

The 4.2% engine efficiency improvement over the 2017 standard proposed by the agencies for 2027 represents such a modest gain as to undermine the argument for the engine standard. An engine standard that achieves 10% fuel consumption reduction by 2027, which we recommend in these comments, has a much clearer justification. Other rationales cited for engine standards include ensuring that criteria pollutant and greenhouse gas emissions for engines remain linked, so that these two types of emissions can be brought down in tandem. However, given the proposed changes to the weighting of the test point in the supplemental emissions test (SET) cycle for engines and the possibility that engine certification will move to a drive-cycle-based approach, the link between GHG and criteria pollutant testing may be in jeopardy even assuming the separate engine standard is maintained. EPA should consider adjustments to the criteria emissions program at the earliest opportunity to address this issue and ensure that reductions in one set of pollutant emissions do not come at the expense of reductions in the other.

*Recommendations: Separate engine standards*

- Maintain separate engine standards in Phase 2, as proposed, but require substantially greater improvements in fuel efficiency.
- Adjust the criteria pollutant emissions program for engines as needed to ensure that both these emissions and GHG emissions decline in tandem.

#### Engine standards for tractor trucks

Revised weighting of SET cycle test points; baseline engine efficiency

The agencies propose to change the weighting of the SET cycle test points in the Phase 2. The re-weighting would result in a higher percent (33% higher) of time spent at low engine speed points (A and B speeds) than is reflected in the current SET (p. 40192). This increase in the weights of A and B speeds means greater weight to points of low brake-specific fuel consumption and consequently show lower overall cycle fuel consumption than results from current SET weightings.

ACEEE supports this revised weighting for SET, because it better represents the real-world operation of today's long-haul trucks. In a presentation in 2014, the Daimler Truck North America (DTNA) shared data on the operating points of a 2010 model year DD15 heavy-duty diesel engine in on-road testing. The majority of the data points for that truck were clustered around A and B speeds and rarely reached C speeds in its operation. Volvo Group, in another presentation, presented the on-road engine operation of about 600 line-haul trucks covering 82 million miles, where these trucks spent most of their time under 1500 rpm engine speed. Note that most of these trucks are rated at 1800 rpm or more.[2] Therefore, increasing the weighting of A and B points of the SET cycle and reducing the weighting of C points in the Phase 2 certification protocol is appropriate.

The engines that operate at lower speeds in the real world typically will be more efficient as a result. To the extent that these engines become prevalent prior to the start of Phase 2, however, these are gains achieved in Phase 1 or before, and they should be reflected in the Phase 2 baseline. With this baseline adjustment, it will be clear that the proposed Phase 2 tractor engine standard would achieve even less than the stated 4% fuel consumption reduction, clearly not an adequate improvement for the decade from 2017 to 2027.

*Recommendation: Revision of tractor engine baseline*

- Adjust the 2017 tractor engine baselines to reflect the reweighting of SET points.

Stringency of the tractor engine standard

The Phase 2 proposal calls for only 4.2% efficiency gains for tractor truck engines by 2027 (p. 40197). In fact, given that the Phase 2 baseline efficiency level does not reflect the engine cycle test points' new weighting, as discussed above, the actual improvement the proposal represents is even less than 4%. In

[2] 2013 Diesel Truck Index

terms both of the importance of greater engine efficiency and the technologies available to increase that efficiency, the proposal is far too timid.

Both the overall and the annual rate of improvement for medium and heavy heavy-duty engines in Phase 2 are lower than those in Phase 1, as shown in table 1. Phase 1 is being implemented in six years, from 2011-2017, while Phase 2 would be implemented over ten years, from 2017-2027. The Phase 1 rule, adopted in 2011, mandates some improvement from its pre-Phase 1 baseline in 2014, the first year of compliance. The Phase 2 rule also mandates some improvement in 2021, the first year of compliance, from the 2017 baseline.

Table 1: Comparison of rates of fuel consumption reduction from diesel engine standards in Phase 1 and Phase 2 (proposed)

| | Phase 1 reduction | Phase 2 reduction |
|---|---|---|
| Engines for tractor trucks | 6.1% | 4.2% |
| Annual Reduction | 1.0% | 0.4% |
| Engine for vocational vehicles | 6.8% | 4.0% |
| Annual reduction | 1.2% | 0.4% |

Improved combustion, engine airflow improvement, friction and parasitic loss reduction, and waste heat recovery are the major technologies in the agencies' Phase 2 package. The agencies understate the benefits of these technologies in three ways:

1. the effectiveness numbers for some of the technologies are low;
2. the penetration levels for some technologies, especially waste heat recovery, are low;
3. the agencies apply an unexplained discounting of the benefits of engine technologies when they are combined, which lowers the effectiveness of the package.

Consequently, the increase in tractor engine efficiency called for in the proposal is much too small. These issues will be discussed in the following paragraphs, leading to our recommendations regarding the stringency of Phase 2 standards for heavy-duty diesel engines used in tractor trucks.

Engine technology effectiveness

The Phase 2 engine package draws on research done by Southwest Research Institute (SwRI).[3] However, the agencies sometimes use lower effectiveness values than SwRI finds, without offering a justification. First and foremost is the case of engine friction reduction. The SwRI study considered potential friction reduction from any component needed for engine operation, including engine piston, ring, liners, bearings, valve train, and gear train. It also considered reduced friction from variable speed oil and water pumps, from reduced-power fuel pumps, and by using low viscosity engine oil. While the SwRI study estimated more than 4% fuel consumption reduction from friction reduction, the agencies estimated 1.4% reduction from engine friction and parasitic reduction.

Improvement in combustion and control is another area where the agencies underestimated effectiveness. The agencies estimated 1% improvement from combustion and control, while Cummins

[3] Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #1
NHTSA report no. DOT HS 812 146, June 2015, Submitted to the Phase 2 rule docket

Inc. has estimated 4% thermal efficiency improvement, or almost 8% fuel efficiency improvement, beyond Phase 1 from combustion, air-handling, and after-treatment improvement.[4] Similarly, industry sources have indicated 2% and 1% minimum fuel savings from combustion and engine controls, respectively.[5]

Additional fuel consumption reduction is possible from waste heat recovery (WHR) in the form of either turbocompounding or Rankine cycle. Volvo reported 2 to 4% fuel savings from turbocompounding in line haul applications (p. 40196), yet the agencies assumed only 1.8%.[6] In Phase 1 the agencies reported 2.5% to 5% fuel savings from mechanical turbocompounding[7]. Similarly, while the agencies assume 3.6% fuel savings for Rankine Cycle over the SET, the SwRI study estimated 4.4% fuel savings over a weighted average of transient, 55 mph and 65 mph cycles. The benefits of Rankine cycle would not accrue on the transient cycle, so one would not expect the fuel savings on the SET to be lower than the weighted SwRI results. Furthermore, Cummins Inc., in a recent presentation to the Air Resources Board, claimed 4.5% average fuel savings from Rankine cycle in their SuperTruck project.[8]

Engine technology penetration

The Phase 2 proposal estimates 100% penetration of all engine technologies in the 2027 timeframe except engine downsizing, turbocompounding and Rankine cycle. More than 40 percent of all energy loss in an engine is lost as heat to the exhaust and engine coolant (p. 40196). Therefore, manufacturers are actively pursuing WHR in at least one form. Hence we believe the agencies' estimate of 15% penetration for Rankine cycle and 10% penetration for turbocompounding in Phase 2 are far too low. Both turbocompounding and Rankine cycle are suitable for the steady-speed operation that is typical in line haul operation. Furthermore, turbocompounding is part of the Phase 1 package for 2017 model year engines, so 10% penetration in next ten years is an overly conservative estimate. Two major manufacturers, Daimler Truck North America and Volvo, are likely to use this technology before 2020 (p. 40196). Cummins Inc., another major engine manufacturer, has invested in Rankine cycle and used it in their SuperTruck program. Therefore, we believe it is more appropriate to expect all line haul tractor trucks (62% of all tractor trucks) to take advantage of one of these two WHR technologies in the Phase 2 timeframe.

Overlapping benefits

After calculating the combined benefits of engine technologies using a multiplicative approach, the agencies appear to have applied a further 15% discount to the benefits to account for overlapping benefits of the technologies. We agree that the percent fuel savings realized by a given technology may be lower when the technology is used with another technology, and this issue should be addressed in estimating combined benefits. However, no explanation is offered for how the 15% figure was arrived at, and this value does not appear to be justified in this case.

---

[4] http://aceee.org/files/pdf/conferences/workshop/heavy-duty/salemme-cummins.pdf

[5] Stakeholder workshop report on tractor trailer efficiency technologies, 2015-2030, http://aceee.org/files/pdf/conferences/workshop/heavy-duty/hdv-workshop-report.pdf

[6] Test cycles may not be comparable.

[7] p. 57205, Federal Register /Vol. 76, No. 179/September 15, 2011

[8] http://www.arb.ca.gov/msprog/onroad/caphase2ghg/presentations/2_7_wayne_e_cummins.pdf

Any attempt to quantify such overlaps in benefits should be based on considerations specific to the technologies to be combined. For example, the effectiveness of a waste heat recovery will be lower in combination with technologies that reduce the amount of waste heat available. However, we are unaware of other overlapping benefits among the particular technologies in the agency engine package.

Using the above-mentioned effectiveness and penetration of these technologies, we estimate that the fuel consumption of tractor track engines can be reduced by 9% and 10% in 2024 and 2027, respectively. Table 2 summarizes the potential engine efficiency improvements for 2027 model year and compares with the proposed standards. Table A1 in the Appendix shows the corresponding comparison for model year 2024.

Table 2: Engine Stringency in 2027

| Technology | Phase 2 proposal (p. 40197) | | | ACEEE recommended effectiveness | ACEEE recommended penetration | MY 2027 weighted estimate |
|---|---|---|---|---|---|---|
| | FC reduction | Penetration in 2027 | Weighted reduction | | | |
| Improved combustion and control | 1.1% | 100% | 1.1% | 5.0% | 100% | 3.0% |
| Engine friction/parasitic reduction | 1.4% | 100% | 1.4% | 4.2% | 100% | 4.2% |
| Aftertreatment improvement | 0.6% | 100% | 0.6% | 0.6% | 100% | 0.6% |
| Engine downsizing | 0.3% | 30% | 0.1% | 4%[9] | N/A | N/A |
| EGR/airflow/turbo improvement | 1.1% | 100% | 1.1% | 1.7% | 100% | 1.7% |
| WHR (Turbo compounding) | 1.8% | 10% | 0.2% | 3.0% | 31% | 0.9% |
| WHR (Rankine cycle) | 3.6% | 15% | 0.5% | 4.5% | 31% | 1.4% |
| Reduction for overlapping benefits | | | 15% | | | 9% |
| Total reduction | | | 4.2% | | | 10.3% |

*Recommendation: Stringency of engine standard for tractor trucks*

- Any discounting of the benefits of technology packages to account for overlapping benefits should be based on the specifics of the technologies in the packages.
- The standards for tractor track engines should require reductions of at least 9% in 2024 and 10% in 2027, rather than the much lower levels called for in the proposal.

#### Standards for vocational vehicle engines

### Diesel engines

The agencies' Phase 2 technology package for diesel engines used in vocational applications is similar to that of diesel engines used in tractor trucks, except that the WHR technologies are not included. This is appropriate, considering that these technologies are suitable for steady-state operation, whereas vocational vehicles mostly operate in a transient duty cycle. However, the agencies' estimates of effectiveness and penetration of other technologies are conservative in our estimation. SwRI estimates

[9] http://energy.gov/sites/prod/files/2014/03/f8/deer12_sisken.pdf

that friction reduction can provide almost 4% fuel savings while combustion improvements can provide at least 2% fuel savings, as we have discussed in the previous section. Model-based control is a promising technology, especially for the transient engine operation typical in vocational vehicles. Improvements in computing power and speed would make it possible to use much more sophisticated algorithms that are more predictive than today's controls (p. 40195). We used the agencies' penetration in our estimate, even though their estimate was very low. This technology has a cost of less than $100 but provides at least 2% fuel saving benefits, so its penetration would be expected to exceed the agencies' estimate of 40% in 2027 timeframe.

The agencies also appear to assume an overlapping of benefits for vocational engine technologies, without providing a justification. We did not include such a factor. In our calculation, diesel engines for vocational vehicles can attain 7% and 8% fuel savings beyond Phase 1 levels in 2024 and 2027, respectively. Table 3 outlines the agency package and our estimate for vocational vehicles in 2024 and 2027.

Table 3: Diesel engine stringency for vocational vehicles in 2024 and 2027

| Technology | Phase 2 proposal (p. 40198) | | | | | ACEEE estimate FC benefit | 2024 weighted estimate | 2027 weighted estimate |
|---|---|---|---|---|---|---|---|---|
| | FC benefit | Penetration in 2024 | Penetration in 2027 | 2024 Weighted reduction | 2027 Weighted reduction | | | |
| Model based control | 2.0% | 30% | 40% | 0.6% | 0.8% | 2.0% | 0.6% | 0.8% |
| Engine friction/parasitic reduction | 1.5% | 90% | 100% | 1.3% | 1.5% | 3.8% | 3.4% | 3.8% |
| Combustion optimization | 1.0% | 90% | 100% | 0.9% | 2.0% | 2.0% | 1.8% | 2.0% |
| EGR/Air/VVT/ Turbo | 1.0% | 90% | 100% | 0.9% | 1.0% | 1.0% | 0.9% | 1.0% |
| Aftertreatment improvement | 0.5% | 90% | 100% | 0.5% | 0.5% | 0.5% | 0.5% | 0.5% |
| Overlapping benefits | 15% | | | | | N/A | | |
| Total reduction | | | | 3.5% | 4.0% | | 7.0% | 7.9% |

## Gasoline engines

The gasoline engines used in vocational vehicles are developed for heavy-duty pickup trucks and vans primarily, but are also sold for use in vocational vehicles (p. 57180). For this reason, the agencies evaluated these engines in parallel with heavy-duty gasoline pickup engines in Phase 1 and based their estimate of improvement potential on technologies such as gasoline direct injection, friction reduction, and variable valve timing.[10] Under the Phase 1 program, fuel consumption of the HD gasoline pickups and vans will decline by 10.8%, of which the agencies estimates almost half could come from engine technologies. Therefore, the 5% fuel consumption reduction required of vocational gasoline engines in Phase 1 was reasonable.

[10] p. 57171, Federal Register /Vol. 76, No. 179/September 15, 2011

In the Phase 2 proposal, fuel consumption of HD gasoline pickups and vans would decline by 16.2%, of which 6-7% would be contributed by engine technologies, including further friction reduction, variable valve lift/actuation, cylinder deactivation, and turbo downsizing. It is highly likely that these technologies will also be used in vocational engines, since they use the same design platform. Using these engine technologies, vocational gasoline engines can achieve at least 6% reductions in Phase 2.

*Recommendations: Standards for vocational vehicle engines*

- Require at least 6% reduction in fuel consumption for gasoline engines in vocational applications in 2027 to reflect the availability of further friction reduction, turbo downsizing, and variable valve lift/actuation.
- Strengthen the proposed standards for diesel engines used in vocational vehicles by 3% in 2024 and 4% in 2027.

## Tractor trucks

#### Road grade in GEM certification

ACEEE supports the agencies' proposal to include road grade in the constant speed cycles used in vehicle certification. Significant road grade is common much of the country. Driving through the grade demands more power from the engine and hence increases fuel consumption.

The grade profile discussed in the proposal was developed by Southwest Research Institute on a 12.5 mile stretch of restricted-access highway during on-road tests. The agencies have requested comment on related work done by the National Renewable Energy Laboratory (NREL). We agree with NREL's concern that a cycle that requires constant speeds (55-mph and 65-mph) on positive and negative grades misrepresents the real-world operation of MD/HD trucks, because there is a strong correlation between road grade and average speed for these vehicles[11,12]. The agencies should address this issue before adopting the Phase 2 rule.

#### Tractor aerodynamics

In the agencies' compliance package for the 2027 tractor standard, the average CdA value for a high roof sleeper cab (CdA=5.3) is 14.5% lower than the 2017 baseline value, a reduction of 1.6% per year from the 2017 baseline. This value falls between Bins IV and V, as shown below in figure 1.

[11] Khan, A.S., and Clark, N.N., *"An Empirical Approach in Determining the Effect of Road Grade on Fuel Consumption from Transit Buses,"* SAE International Journal of Commercial Vehicle, Vol. 3, No. 1, pp. 164-180, December 2010

[12] EPA GHG Certification of Medium- and Heavy-Duty Vehicles: Development of Road Grade Profiles Representative of US Controlled Access Highways. NREL/TP-5400-63853, May 2015

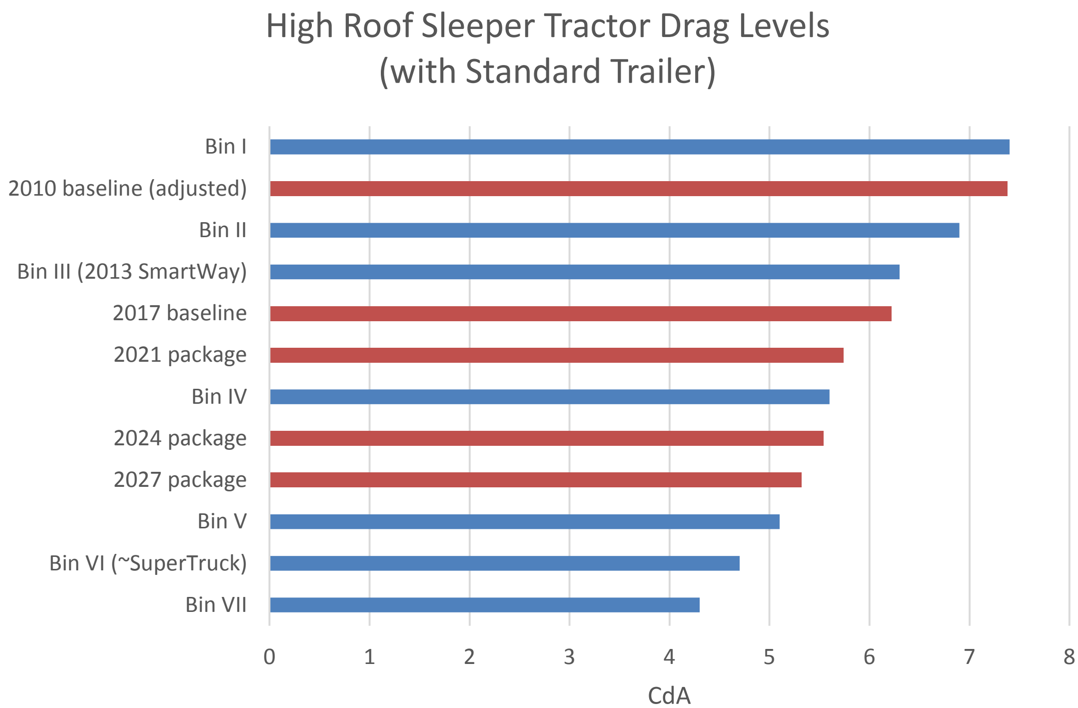


**Figure 1: Comparison of high roof sleeper cab CdA levels for bins and proposed standards compliance packages**

The agencies note: "Since the development of the Phase 1 rules, the manufacturers have continued to invest in aerodynamic improvements for tractors. This continued evolution of aerodynamic performance, both in production and in the research stage as part of the SuperTruck program, has consequently led the agencies to propose two additional aerodynamic technology bins (Bins VI and VII) for high roof tractors. These two new bins would further segment the Phase 1 aerodynamic Bin V to recognize the difference in advanced aerodynamic technologies and designs" (p.40246). It is therefore important that the standards promote these advances by moving tractor aerodynamics well into the new bins. The 2027 compliance package for a high roof sleeper cab assumes a 25% penetration of these higher aerodynamic bins, but an average that falls short of achieving Bin V. This suggests that the aerodynamic package for the standards is well within reach of the manufacturers over the next decade.

Measurement issues

We support the agencies' proposal to shift to wind-averaged drag in the calculation of CdA. This step is necessary to capture the benefits of certain aerodynamic improvements whose primary function is to reduce drag with non-zero yaw. Such devices can provide substantial real-world savings, so the standards should promote their adoption.

We take this opportunity to comment on an adjustment EPA proposes to the Phase 1 measurement of Cd. Phase 1 does not call for the measurement of wind-averaged drag but offers manufacturers the option of using wind-averaged drag, together with a downward adjustment factor, to estimate Cd for compliance purposes. Due to an error in the agencies' specified adjustment factor, however, manufacturers using this option are currently generating unwarranted fuel efficiency and GHG credits. The discrepancy is significant. In order not to lose benefits of the program through the application of credits that do not correspond to real-world savings, the agencies should as soon as possible correct the factor applied to wind-averaged drag to generate Cd values for Phase 1 compliance.

*Recommendations: Tractor aero measurement issues*

- Include wind-averaged drag, as proposed, in the final measurement protocol for tractor CdA measurement.
- At the earliest opportunity, correct the factor applied to wind-averaged drag to generate Cd values for Phase 1 compliance.

#### Standard trailer for tractor certification

The agencies seek comment on the proposed Phase 2 standard trailer configuration (p.40245). While the agencies' decision to use a more aerodynamic trailer as the standard trailer than in Phase 1 is welcome, the proposed improvement is not sufficient. The wind tunnel testing results shown in Table 3-10 of the RIA indicates that the addition of a skirt to a trailer achieves a delta CdA of approximately 0.5 on a high roof sleeper. This suggests that the proposed Phase 2 standard trailer is a Bin IV trailer ("advanced skirt or tail," according to the characterization in RIA Table 2-70).[13] However, by the time the standard trailer is updated in 2021, the agencies' compliance package assumes an average delta CdA = 0.66, considerably better than that of the new standard trailer. By 2027, the compliance package has average delta CdA = 1.1. To the extent that the tractor manufacturers seek to design tractors to tow the more aerodynamic trailers coming into the market over the course of Phase 2, keeping the standard trailer static could be counterproductive. In fact, it does not seem realistic to expect that all tractors would necessarily admit testing with a standard trailer, as advanced aerodynamic designs call for more dramatic changes in cab shape.

We recommend that, at a minimum, tractor OEMs be given the option of testing with a trailer more advanced than the proposed standard trailer. This option would help to promote the integration of tractor and trailer, which represents an enormous opportunity for savings in the longer term. Volvo's SuperTruck project reports that it has already achieved approximately 6% drag reduction from "co-optimization" of tractor and trailer and anticipates additional drag reductions of over 10% from "integrated design."[14] Major gains in tractor-trailer efficiency through improved aerodynamics will eventually allow these trucks to far surpass the 2027 standards. In discussing the Peterbilt SuperTruck project, which is said to have achieved a 25% gain in fuel economy through aerodynamic improvements, the agencies observe: "This effort represents the first step in the evolution of improving the aerodynamic efficiency of tractor-trailer by radically redesigning today's tractor-trailer combination, as a wholly integrated system rather each component, tractor and trailer, independently." (RIA p.2-23) The RIA (p.2-24) also discusses Lawrence Livermore National Laboratory's advanced aerodynamic research, which developed a prototype tractor-trailer designed to achieve 50 percent reduction in aerodynamic drag.

While the standards perhaps should not anticipate that that transition will occur by 2027, Phase 2 should facilitate the transition by promoting full tractor-trailer integration. The current requirement

[13] The agencies should clarify whether the proposed Phase 2 standard trailer is in fact a Bin 3 trailer.
[14] Amar 2014. DOE Annual Merit Review. (http://energy.gov/sites/prod/files/2014/07/f17/vss081_amar_2014_o.pdf.

that tractors be tested using a standard box trailer cannot recognize integration and therefore cannot promote it.

Allowing manufacturers to test their tractors with advanced trailers would yield results reflecting the aerodynamic gains of both tractor and trailer, as well as their integration. To prevent double counting of the drag reductions provided solely by the more advanced trailer under this option, the result of testing would need to be corrected using a “delta CdA” approach, as is discussed in the proposal in connection with trailer aero. Specifically, a manufacturer could assign tractor X to a given bin if CdA of tractor X with aerodynamic trailer + delta CdA of aerodynamic trailer met the bin threshold. Note that the value of second term in this expression would be available from compliance testing for the aerodynamic trailer, so this approach would not increase the test burden on the tractor manufacturer.

While tractor X might not always be paired with an aerodynamic trailer in operation and thus might not realize the calculated benefit (just as any tractor might operate with a trailer less aerodynamic than the standard box trailer), manufacturers and purchasers of advanced tractors presumably would seek to ensure that the correct pairings were made as a matter of course. As the agencies note, “tractor-trailer pairings are almost always optimized.” (p.40245) Furthermore, the value of a meaningful incentive to accelerate the aerodynamic integration of tractors and trailers likely outweighs potential costs in fuel savings of mismatched tractors and trailers. However, if the possibility of unrealized benefits poses an obstacle to allowing certification with an advanced trailer, the agencies could require that tractors so certified be used only with advanced trailers and that this requirement be indicated on the tractor label.

It should be noted that trailer manufacturers are already given the latitude to test with any tractor of Bin III or better:

> In order to maintain a minimal level of performance, we are proposing that tractors used in trailer aerodynamic tests meet Phase 2 Bin III or better tractor requirements (see Section III.D.). We believe the majority of tractors in the U.S. trucking fleet will be Bin III or better in the timeframe of this rulemaking, and trailer manufacturers have the option to choose higher performing tractors in later years as tractor technology improves. (p. 40280)

Tractor manufacturers should be accorded this flexibility as well. While allowing such flexibility on the tractor side, as well as for the trailer, might appear to invite double counting of tractor-trailer integration benefits that is not the case. If the trailer manufacturer has already taken credit for integration through this mechanism, that trailer’s delta CdA will have been elevated as a result. Hence the (upward) correction of the tractor’s CdA will be greater, and the tractor OEM will gain no integration credits in this situation.

*Recommendation: Standard trailer for tractor certification*

- To promote integration of aerodynamically advanced tractors and trailers, provide manufacturers the option to test tractors with advanced trailers; correct the test result appropriately to account for the benefit provided by the trailer alone.

## Trailers

#### Van trailer aerodynamics

For 53’ van trailers, we find the proposed standards to be well within the technical capabilities of the industry. The required average reduction in drag in 2027 is delta CdA = 1.1, only marginally higher than the Bin VI (SmartWay Elite) value of delta CdA=1.0. The agencies state: “To date, SmartWay has verified over 70 technologies, including nine packages from five manufacturers that have received the Elite designation.” (p.40254) Whether or not the mix of bins will include more advanced trailers as the agencies assume in their compliance packages, reaching an average aerodynamic performance twelve years hence that matches that of multiple packages being produced today is a reasonable, and perhaps overly lenient, requirement of the industry.

To put the agencies’ overall aerodynamic targets for long-haul combination trucks with dry vans in perspective, Daimler reported a 54% reduction in drag for its SuperTruck.[15] By comparison, the agencies’ compliance package for 2027 contains tractor and trailer aerodynamic parameters resulting in a 41% reduction in drag (CdA =4.2) from the (adjusted) 2010 baseline level of CdA=7.4. Thus, the 2027 targets do not even require the industry to match levels of improvement being demonstrated today.

#### Short and non-box trailers

The proposal requires 4.8% and 4.6% fuel consumption reduction in 2027 from short dry vans and short reefers, respectively. The agencies projected 2027 adoption of 95% Level II tires and automatic tire inflation (ATI) can provide almost 3% fuel savings, more than half of the 2027 target. At the same time, based on industry effectiveness estimates[16] and the agencies’ bin adoption assumptions (30%, 60% and 10% for Bin II, III, and IV, respectively), these short trailers can achieve 4.4% fuel savings in 2027. Thus the 2027 requirements can be nearly met with aero technologies alone. Hence the total potential for fuel consumption from improvements in short trailers exceeds the proposed standard by more than 50%, and we would encourage the agencies to strengthen the 2027 requirements in order to drive advanced aero technologies for these trailers. With regard to non-box trailers, the proposed standards for 2027 would require improvement only in tires. We urge the agencies to consider adopting basic aero devices for non-box trailers in this timeframe.

#### Standard tractor for trailer certification

The Phase 2 proposal would permit manufacturers to test their trailers with tractors meeting Phase 2 Bin III or better (p. 40280). This will allow trailer manufacturers to gain credit for integration with tractors as both tractor and trailer aerodynamics evolve. Above we recommend that tractor manufacturers be given a comparable flexibility in their choice of test trailer while noting that a trailer already certified to a higher delta CdA by virtue of such integration would negate any integration benefits on the tractor side. This is appropriate, since double counted of integration benefits cannot be permitted. However, tractor manufacturers may be far more likely than trailer manufacturers to

[15] Daimler Truck NA 2014 DOE Merit Review Presentation (http://energy.gov/eere/vehicles/downloads/vehicle-technologies-office-merit-review-2014-class-8-truck-freight ).

[16] http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf (P. III-4)

pursue the development of integrated tractor-trailer aerodynamic designs, so the availability of an integration credit on the trailer side does not diminish the need for such a credit on the tractor side.

*Recommendations: Trailers*

- Consider strengthening the trailer standards for 2027 in order to increase the adoption of advanced aero technologies for both long and short dry vans and reefers.
- Promote aero technologies for non-box trailers by revising the 2027 standards.

## Vocational vehicles

#### New duty cycle and cycle weighting

The Phase 1 rule's segmentation of vocational trucks is based on weight class only and does not reflect vehicle use. Inadequate segmentation of vocational vehicle prevented the Phase 1 standards from promoting technologies that provide major benefits for only a subset of vocational duty cycles. ACEEE applauds the agencies' segmentation of vocational vehicles into nine subcategories in Phase 2, reflecting both weight and usage profile, together with the appropriate reweighting of cycles to capture these usage profiles.

We also support the agencies' proposal to include an idle cycle in vocational vehicle certification. The three cycles used in the Phase 1 program could not properly represent the operation of certain vocational vehicles in the real-world. Many vocational vehicles, including urban buses have average speed less than 10 miles per hour. Consequently, the transient cycle, with 15 mph average speed, and 55-mph and 65-mph constant speed cycles could not reproduce the appropriate average speed. Inclusion of an idle cycle will resolve this problem in Phase 2.

#### Stringency

ACEEE strongly supports the inclusion of a modest number of hybrid vehicle in the compliance package for the vocational vehicle standards. Many vocational vehicles spend a significant amount of time in idling and in stop-and-go operation, making them suitable candidates for hybridization. While we agree with the agencies' estimate of 22-25% improvement from hybridization using the powertrain test (p. 40297), we would like to see consideration and adoption of electric power-take-off (e-PTO) hybrids for certain vocational segments. These e-PTO technologies can provide more than 10-14% additional savings, provided they are accommodated with a hybrid-PTO test procedure, since their benefits cannot be captured in a powertrain test.

The agencies' estimate of 5% efficiency improvement, on average, from transmission integration (p. 40296), irrespective of transmission types, is too low. Such a blanket assumption fails to distinguish among the different transmission architectures and thus does not promote the most efficient technologies.

*Recommendations: Vocational vehicles*

- Consider including e-PTO hybrids in the compliance package for appropriate vocational segments. This would support a stronger vocational vehicle standard for 2027.
- Assign technology-specific effectiveness values for transmission and integration.

## Heavy-duty pickups and vans

Heavy-duty gasoline and diesel pickups and vans will reduce their fuel consumption by 16% each in 2027 relative to the 2018 standards (p. 40338). Figure 2 uses the data in the rule docket for MY 2014[17] heavy-duty pickups and vans to display the distribution of models relative to the Phase 1 standards for 2014 and 2018. Two observations from the data relevant to the discussion below are: 1) work factor is a far better predictor of fuel efficiency for pickups than for vans; and 2) at present, diesel vehicles approach 2018 targets, while gasoline vehicles are approximately at 2014 target levels.

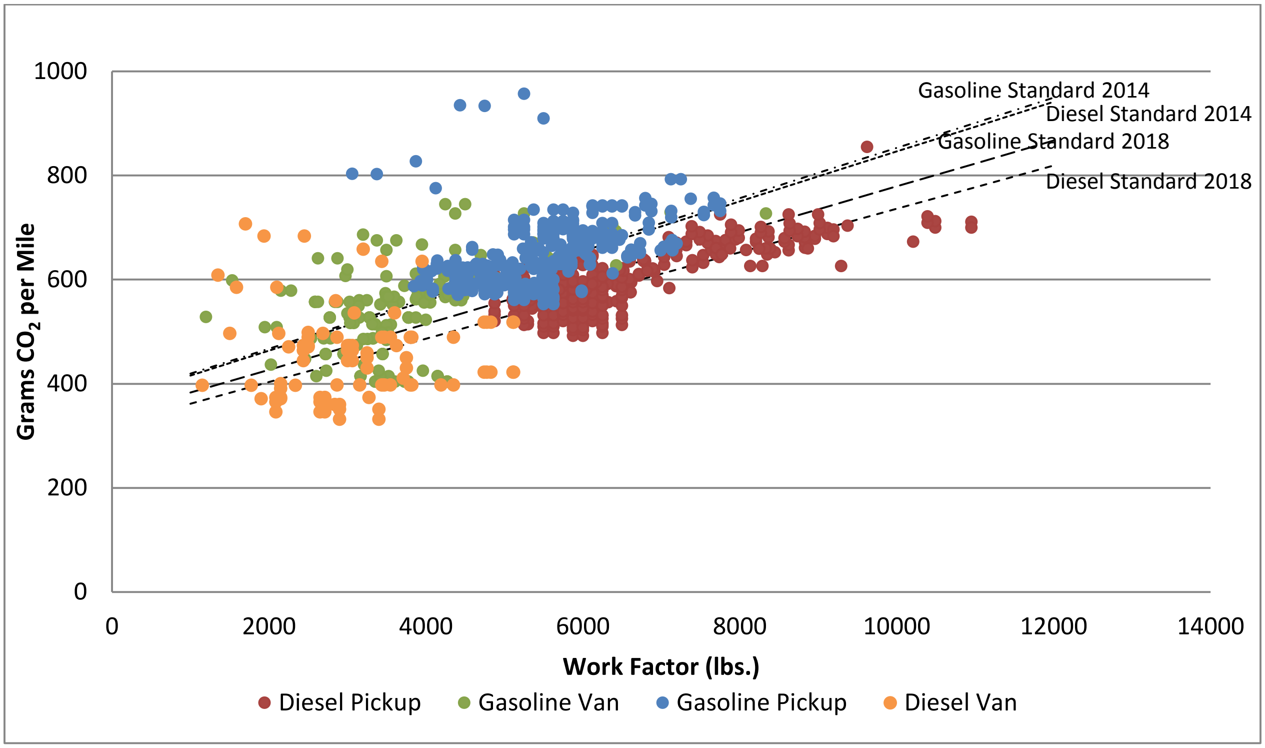


Figure 2: $CO_2$ vs. work factor for MY2014 heavy-duty pickups and vans

#### Work factor

The rule defines work factor from payload and towing capacities which involves three weight parameters including gross vehicle weight rating (GVWR), gross combined weight rating (GCWR) and curb weight. Definitions of these three weight parameters, provided in the rule, involve manufacturer discretion. This leeway could weaken the standards, in effect. For example, two manufacturers recently claimed 150 to 250 lbs. additional payload in model year 2015 pickups by lowering vehicle curb weight[18]. Adding 250 lbs. to the payload would increase a vehicle's work factor by 188 lbs. This in turn would lessen the fuel consumption/$CO_2$ emissions reduction required in 2018 by 8.3 grams per mile, or 11 to 20%, depending on the work factor of the vehicle. Hence it is important that the agencies better define these weight parameters.

[17] Market-data_2014-10-28_CBI_2b3_MY2014_PB-3606. Rule docket.

[18] http://www.autonews.com/article/20140804/OEM/308049927/ford-gm-play-with-numbers-for-bragging-rights.

When manufacturers can increase work factor at little cost and get benefit in fuel consumption, work-factor-based standards will incentivize such increases. This is an undesirable result that will reduce the benefits of the proposed standards. The agencies proposals to address this problem (p. 40336) are welcome. In particular, changing the shape of the standard curve for both gasoline and diesel vehicles to be flatter at higher work factors warrants further consideration. We also support the agencies' consideration of adopting different work factor formulas for pickups and vans, especially in light of the very poor correlation between work factor and $CO_2$ emissions for vans, as shown in figure 2.

*Recommendations: Work factor*

- The agencies should better define GVWR, GCWR, and curb weights in order to reduce manufacturers' discretion in determining these weights.
- For the final rule, adopt a mechanism to minimize the incentive the proposed standards provide to increase work factor.

#### Standards for gasoline pickups and vans

The Phase 2 gasoline engine package draws primarily on research done by Southwest Research Institute (SwRI).[19] SwRI evaluated a host of technologies that were deemed suitable for the Phase 2 timeframe. Engine technologies for gasoline pickups include cylinder deactivation, variable valve actuation/lift, and friction reduction. Vehicle and transmission technologies include 8-speed transmission with high efficiency gearbox, aero drag reduction, low rolling resistance tires, mass reduction, accessory improvement, low drag brakes, and hybrids.

There is room for substantial improvement in the agencies' gasoline package, both in technology effectiveness and in technology penetration. The agencies sometimes use lower effectiveness values than SwRI finds, without providing justification. For example, agency effectiveness numbers for cylinder deactivation, variable valve lift and turbodownsizing were much lower than the SwRI estimates. The agencies assumed 22% penetration of cylinder deactivation and variable valve lift, which is conservative. Considering the expected adoption of these technologies in light-duty vehicles and considering the Phase 2 timeframe, we assume 50% penetration of these technologies in 2027.

A major shortcoming of the agency package is the absence of turbodownsizing for gasoline pickups, although they used this technology for gasoline vans. Downsized, turbocharged engines offer a major opportunity to improve gasoline vehicle fuel efficiency. SwRI compared a 6.2-liter V-8 gasoline engine to a simulated downsized 3.5-liter V-6 and found 16% fuel savings. The National Academy of Sciences (NAS) study found turbocharged downsizing benefits in the range of 10–14%. Downsized, turbocharged engines played a major role in the agencies' compliance scenario for the light-duty fuel efficiency standards for model years 2017–25; the LD rule found 12.3% savings for 33% downsizing with turbocharging.[20] A gasoline engine largely can retain its performance when downsized and turbocharged, but fuel savings benefits may be reduced or eliminated at high load operation, including towing. This technology is therefore especially suitable for vehicles not regularly employed in heavy towing.  We assumed that at least 10% of pickups will adopt turbodownsizing in 2027 timeframe.

---

[19] Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #1. NHTSA report no. DOT HS 812 146, June 2015. Submitted to the Phase 2 rule docket.

[20] "Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy Standards." Final Rule. *Federal Register* 77 (199). October 15, 2012

The agencies did not consider cooled exhaust gas recirculation for gasoline pickups. Cooled EGR can reduce the fuel consumption of both direct-injected and port-injected gasoline engines by reducing pumping losses, mitigating knock, cooling the exhaust, and eliminating the need for fuel enrichment.[21] SwRI found 3.7% savings from cooled EGR. We assumed this technology only for pickups and vans with turbocharged, downsized engines.

Inclusion of hybrids in the agency package (10% for pickups, 6% for vans) is a positive step. The agency estimate of 6% potential hybrid penetration for vans is likely too low, given that most of these vehicles have urban and vocational-like operation.

In light of the above discussion, the standards for gasoline pickups and vans should reflect:

- Increased penetration of cylinder deactivation and variable valve timing. Use these technologies for at least 50% of pickups.
- Increased the penetration of GDI and turbodownsizing to at least 10% of pickups and use cooled EGR for all downsized pickups and vans.
- The existing hybrid assumption (10% and 6% for pickups and vans by 2027)

Tables 4 and 5 compare technology effectiveness and penetration, respectively, for the agency package (Table VI-5, p. 40356) and in our estimate.

**Table 4: Comparison of technology effectiveness**

| Gas Pickups and Vans in 2027 | EPA effectiveness | ACEEE effectiveness |
|---|---|---|
| Low friction lubricants and reduced friction | 1.6% | 1.6% |
| Cylinder Deactivation | 3.7% | 7.7%/2.1%* |
| Variable valve timing/lift | 2.5% | 6.7%/2.8%* |
| GDI | 0.5% | 0.5% |
| Turbodownsized engines | 8.0% | 12.3% |
| Cooled EGR | 3.0% | 3.7% |
| 8-speed transmission | 5.0% | 5.0% |
| Low RR tires | 1.1% | 1.1% |
| Aero drag reduction (10%) | 0.7% | 0.7% |
| Mass reduction (10%) | 3.0% | 3.0% |
| Electric power steering | 1.0% | 1.0% |
| Improved accessories level-I&II | 1.9% | 1.9% |
| Low drag brakes | 0.4% | 0.4% |
| Stop/Start engine system | 1.1% | 4.0% |
| Mild hybrid | 3.2% | 3.2% |
| Strong hybrid | 17.2% | 17.2% |

* When used in downsized engines

[21] "Cool and Clean: Cooled EGR Improves Fuel Economy and Emissions in Gasoline Engines." *Technology Today* (Summer): 10-13. http://www.swri.org/3pubs/ttoday/Summer10/PDFs/Clean-and-Cool.pdf

**Table 5: Comparison of 2027 technology penetration for gasoline pickups and vans for the agency package (Table VI-8, p. 40359) and in ACEEE's estimate**

| Gas Pickups and Vans in 2027 | Agency penetration for pickups | Agency penetration for vans | ACEEE penetration for pickups | ACEEE penetration for vans |
|---|---|---|---|---|
| Low friction lub and reduced friction | 100% | 100% | 100% | 100% |
| Cylinder Deac | 22% | 19% | 40% | 19% |
| Variable valve timing/lift | 22% | 82% | 40% | 82% |
| GDI | 0% | 63% | 10% | 63% |
| Turbodownsized engines | 0% | 63% | 10% | 63% |
| Cooled EGR | 0% | 0% | 10% | 63% |
| 8-speed transmission | 98% | 92% | 100% | 92% |
| Low RR tires | 100% | 92% | 100% | 92% |
| Aero drag reduction (10%) | 100% | 100% | 100% | 100% |
| Mass reduction (5%) | 100% | 100% | 100% | 100% |
| Electric power steering | 100% | 49% | 100% | 100% |
| Improved accessories level-I&II | 100% | 87% | 100% | 100% |
| Low drag brakes | 100% | 45% | 100% | 100% |
| Strong hybrid | 9.9% | 6% | 10% | 6% |

The estimate of overall fuel consumption reductions needs to account for possible overlaps in benefits. For engine and transmission technologies, there is a risk of double-counting benefits when more than one technology in a package addresses the same efficiency losses. A recent ACEEE report discusses the overlapping of benefits for gasoline pickups and vans engine and transmission technologies and develops a correction factor of 23%.[22] Using a multiplicative approach to combining technology benefits, and applying the adjustment for overlapping of benefits, we estimate that the technologies considered above, when applied at the revised penetration rates shown in table 5, provide a 22% average reduction in fuel consumption for gasoline vehicles and vans relative to Phase 1 level, as shown in table 6.

**Table 6: Fuel consumption reduction for gasoline pickups and vans in 2027**

| Fuel consumption reduction for gasoline pickups and vans in 2027 | Agency estimate | ACEEE estimate |
|---|---|---|
| Gasoline pickups and vans | 16.2% | 25.3% |
| Correction for overlapping benefits (23% engine and transmission technologies) | N/A | 4.0% |
| Overall reduction in 2027 | 16.2% | 22.2% |
| Additional improvement beyond the agency package | | 7.2% |

[22] Khan and Langer. 2015. "Fuel Efficiency and Greenhouse Gas Emissions Standards for Heavy-Duty Pickups and Vans: Phase 2." ACEEE research report T1501. **http://aceee.org/research-report/t1501**

This increment in gasoline pickups and vans will promote the integrity of the pickup market in two ways: it will reduce the fuel economy gap between these pickups and full-size light-duty pickups; and it will help reduce the efficiency gap between heavy-duty gasoline and diesel vehicles. Heavy-duty gasoline pickups, according to the Phase 2 proposal, will attain 19.5 miles per gallon (mpg), on average, in 2025 while contemporary LD pickups will average 32.5 mpg in 2025,[23] as shown in table 7. That is, LD pickups will have more than 50% higher fuel economy than HD gasoline pickups and vans will achieve in 2025. Heavy duty pickups and full-size light duty pickups often use similar engine, vehicle, and transmission technologies and are tested on the same test cycles with same cycle weighting for certification,[24] but at different weights. When light-duty fuel economy is corrected for the difference in test weights, the discrepancy is still 43%. Any gap between fuel economy requirements for LD and HD pickups for which there is no engineering rationale could produce distortions in the pickup market, shifting sales toward the heavier vehicles.

Table 7: Average fuel economy (mpg) for LD and HD pickups and vans under existing and proposed standards

| Vehicle type | 2014 | 2016 | 2018 | 2025 |
|---|---|---|---|---|
| Class 2b and 3 HD gasoline pickups and vans (average) | 15.6 | 16.1 | 17.2 | 19.5 |
| Class 2a large LD trucks (footprint 66 sq. ft.)* | 23.1 | 24.7 | 24.7 | 32.5 |

*Tested at different test weight than HD vehicles.

Reducing the gap between gasoline and diesel efficiency requirements would also be a step forward for the heavy-duty pickup and van standards. Given that the work factor parameter has been specifically designed to capture the utility of these vehicles as it relates to fuel efficiency, gasoline and diesel vehicles should in principle be subject to the same, performance-based standard for $CO_2$.[25] As shown in Figure 2, there is a substantial difference at present in the performance of gasoline and diesel vehicles, which presents challenges for the adoption of a fuel-neutral standard at this time. However, reducing the gap between the diesel and gasoline standards by strengthening the gasoline standard, would help to address this problem.

#### Standards for diesel pickups and vans

The agencies' technology package for diesel pickups and vans uses the same vehicle and transmission technologies as the gasoline package. Their engine package is not fully explained. The Phase 2 proposal says: "Diesel engines in the HD pickup and van segment are expected to have several improvements in their base design in the 2021–2027 timeframe. These improvements include items such as improved combustion management, optimal turbocharger design, and improved thermal management" (p. 40352). The diesel engine technology evaluation, however, estimates savings from friction reduction, turbo efficiency improvement, and engine downsizing.

---

[23] Light-Duty Vehicle Greenhouse Gas Emissions Standards and Corporate Average Fuel Economy Standards." Final Rule. *Federal Register* 77 (199). October 15.

[24] "Final Rulemaking to Establish Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engine and Vehicles." EPA-420-R-11-901. http://www.epa.gov/oms/climate/documents/420r11901.pdf.

[25] The standards for gallons per 100 miles would continue to differ, due to the difference in energy content of the two fuels.

Although the agencies made a more conservative estimate of the potential for friction reduction than the estimate from SwRI, estimates of effectiveness for turbo efficiency improvement and diesel engine downsizing were the same as SwRI estimates. However, the agencies assume zero penetration of engine downsizing for pickups. While the majority of these pickups may carry substantial loads and need high towing capacities, some have low payload and towing capacities, and would be candidates for engine downsizing. In the case of diesel vans, engine downsizing is already occurring. Some manufacturers are providing this option, and its penetration is likely to increase overtime. We estimate 10% penetration of engine downsizing for pickups and 30% penetration for vans in 2027. We also assume 6% penetration of hybrids in vans, similar to gasoline vans.

After accounting for the losses from overlapping of benefits for these vehicles, we estimate overall fuel consumption reductions of 18% reduction for diesel pickups and vans beyond Phase 1 in 2027, an additional 1.6% improvement from the agency estimate. Table 8 outlines the proposal and our estimate for Phase 2.

Table 8: Fuel consumption reduction for diesel pickups and vans in 2027

| Fuel consumption reduction for diesel pickups and vans in 2027 | Agency estimate | ACEEE estimate |
|---|---|---|
| Diesel pickups and vans | 16.3% | 20.0% |
| Loss from overlapping of benefits (23% for engine and transmission technologies) | N/A | 2.9% |
| Overall reduction in 2027 | 16.3% | 17.6% |
| Additional improvement beyond the agency package | | 1.6% |

*Recommendation: Stringency of standards for heavy-duty pickups and vans*

- Increase the 2027 targets for gasoline pickups and vans by 7% to reflect the adoption of advanced technologies.
- Consider downsizing for diesel pickups with low work factor and vans, and increase the 2027 targets by 2%.

#### Labeling

The absence of a consumer fuel efficiency label for heavy-duty pickups and vans is a serious shortcoming of the program that should be remedied as soon as possible. In response to Phase 1 comments to this effect, EPA and DOT committed to "consider this issue as we begin work on the next phase of regulations, as we recognize that a consumer label can play an important role in reducing fuel consumption and GHG emissions" (76 Fed. Reg. (Sept. 15, 2011) at 57119). A subsequent letter from NHTSA Administrator David Strickland to Senator Dianne Feinstein stated: "We are currently working to include the consideration of fuel economy labels for large pickup trucks and commercial vans as part of the second phase of fuel efficiency and greenhouse gas standards for heavy-duty vehicles." Despite this, the agencies have not addressed this issue at all in the Phase 2 proposal.

Any consumer product regulated for fuel efficiency should be labeled for fuel efficiency. In the case of HD pickups and vans, the success of the standards depends on manufacturers' addition of incremental technologies to save fuel. These technologies will typically increase the cost of the vehicle, and manufacturers will need to figure out how to recover that cost. The absence of a label or any other publicly available information stating the fuel efficiency of the vehicle at the time of sale means the consumer is in effect cut out of the market for efficiency. While this might not create a problem where the standard is applied as an efficiency threshold, standards that manufacturers meet on an average basis will only work properly when coupled with a market that values efficiency and allocates efficiency based on its comparative importance relative to other vehicle requirements.

While establishing a vehicle label is not a simple process, we believe it would be well worth the resources required. The general approach should be similar to light-duty vehicle labeling and could perhaps be carried out as a revision to that rule. While there are issues of duty cycle, test protocols, and comparability to be addressed, these are largely issues that would need to have been addressed in any case to establish a sound fuel efficiency program for these vehicles.

Absent a consumer label, the agencies should make certification data readily available to the public. This data should be available at a single location on the internet and should be available for all vehicles prior to their availability for sale. While we understand the limitations of the certified fuel efficiency vis-à-vis performance in the real world, the certification data would at least permit comparisons of these vehicles within their regulatory class.

*Recommendations: Labeling and data availability to the public*

- The final Phase 2 rule should commit the agencies to conducting a subsequent rulemaking for the labeling of heavy-duty pickups and vans and set out a timetable for the label rulemaking.
- Prior to the implementation of a labeling requirement for HD pickups and vans, certification values should be made publicly available for any vehicle model before it can be sold.

## Greenhouse Gas and Fuel Consumption Impacts

#### Baseline

The agencies request comment on their choice of baseline scenario (p.40166). To analyze the benefits of the proposed standards, the agencies compare the expected outcomes of the standards to those of two distinct baseline scenarios: the less dynamic baseline and the more dynamic baseline. The less dynamic baseline represents a reasonable attempt to incorporate the effects of existing policies (California Air Resources Board's Tractor-Trailer Greenhouse Gas regulation and EPA's SmartWay Transport Partnership) on box trailers' adoption of aerodynamic technologies and low rolling resistance tires (RIA p.5-12). However, the more dynamic baseline relies on the assumption that pickups and vans and tractor technologies that pay back within the first six months of ownership will be taken up in the market (p.40492 and RIA p.5-12). This is an arbitrary assumption.

In general, assumptions regarding the trajectory of fuel efficiency in the absence of standards are necessarily highly speculative, given the many complex factors that can produce rising or falling fuel efficiency over time. The agencies' assumption in earlier fuel efficiency rulemakings of constant fuel efficiency in the baseline scenario best maintains the transparency of the analysis.

*Recommendation: Baseline*

- Assume flat fuel efficiency in the baseline scenario unless there is strong evidence that another assumption is more plausible. Alternative baseline assumptions are appropriate for a sensitivity analysis.

#### Rebound

Also pertinent to the estimate of benefits of the proposed standards are the assumptions made about the rebound effect associated with the standards, and in particular the extent to which better fuel efficiency results in more miles traveled by the regulated vehicles. The agencies maintain the assumptions of 10% rebound for heavy-duty pickups and vans, 15% for vocational vehicles, and 5% for combination trucks using in the Phase 1 rule. Absent further evidence, the agencies' current estimates are reasonable. In particular, the 10% rebound assumption that has been used in the light-duty vehicle fuel economy rulemakings is the best starting point for heavy-duty pickups and vans. With regard to the other vehicle categories, however, it should be noted that the working paper by Energy and Environmental Research Associates that the agencies placed in the docket concludes: "The results suggest that in recent decades, fuel price elasticities for U.S. trucking VMT (combination and single-unit trucks) and fuel consumption (combination trucks) are near zero or not statistically different than zero."

This and other relevant work warrant further consideration for the final rule.

*Recommendation: Rebound*

- Consider newly available research on the effects of improved fuel efficiency on heavy-duty vehicle driving behavior to determine whether the rebound values used in the proposal should be retained in the final rule.

## Other Issues

#### Acceleration of Standards to 2024 and ensuring 2027 standards promote adoption of advanced technology

As noted above, ACEEE finds that the overall stringency of the standards proposed in Alternative 4, and more, is readily achievable. That is, the fuel consumption reduction achieved by 2027 in the preferred alternative (Alternative 3), can and should be reached or exceeded by 2024.

The majority of improvements beyond Phase 1 would come from fuel consumption reduction in tractor trailers, followed by heavy-duty pickups and vans, and vocational vehicles. Table 9 replicates the agencies' proposed improvement for heavy-duty vehicles and engines and the overall reductions in 2024 and 2027.

Table 9: Phase 2 proposed reductions for heavy-duty vehicles and engines in 2024 and 2027

| Vehicle/engine class | % Fuel consumption | Fuel consumption reduction in 2024 beyond Phase 1 | Fuel consumption reduction in 2027 beyond Phase 1 |
|---|---|---|---|
| Tractor truck engine | 66% | 3.7% | 4.2% |
| High roof sleeper cab | | 24.4% | 28.8% |

| | | | |
|---|---|---|---|
| Day cabs | | 18.3% | 23.0% |
| Total tractor trucks including trailers | | 22.2% | 26.7% |
| Vocational engine | 19% | 2.5% | 4.0% |
| Vocational vehicle | | 9.8% | 13.6% |
| 2b/3 gasoline | 15% | 11.9% | 16.2% |
| 2b/3 diesel | | 11.9% | 16.3% |
| Total from 2b/3 | | 11.9% | 16.3% |
| Overall reductions beyond Phase 1 | | 19.6% | 23.5% |

Greater reductions can be achieved in all vehicle and engine classes, however, even without accelerating or increasing reliance on advanced technologies such as waste heat recovery (Rankine cycle/turbocompounding), hybrids, or advanced aerodynamics. By adopting higher effectiveness values from the SwRI study for some incremental engine, transmission, and vehicle technologies, as explained in the previous sections, we can achieve 26% and 31% reductions in overall fuel consumption in 2024 and 2027, respectively, substantially more than the 23.5% reduction from the proposed 2027 standard.

Moreover, given concerns that have been raised about the cost, performance and/or durability of some advanced technologies, it is worth noting that similar results can be achieved in 2024 without any adoption of waste heat recovery, advanced aero for tractors and trailers, level 3 tires, start/stop systems or strong hybrids. If we exclude these technologies from our 2024 package and keep the agency penetration rates for all other technologies, we can still attain 24% reduction in 2024, as shown in table 10. This shows that the manufacturers can comply with stronger standards than those proposed with existing technologies in the market.

**Table 10: Potential reductions for heavy-duty vehicles in 2024 with no advanced technologies**

| Vehicle/engine class | Fuel consumption reduction in 2024 beyond Phase 1 |
|---|---|
| Tractor truck engine | 8.4% |
| High roof sleeper cab | 29.8% |
| Day cabs | 29.5% |
| Total tractor trucks including trailers | 29.2% |
| Vocational engine | 5.8% |
| Vocational vehicle | 16.3% |
| 2b/3 gasoline | 12.7% |
| 2b/3 diesel | 12.8% |
| Total from 2b/3 | 12.8% |
| Overall reduction beyond Phase 1 | 24.1% |

However, it is important that the standards in fact help to draw new technology into the market, especially if they are set out to 2027. The package mentioned above, delivering an overall fuel consumption reduction of 31% in 2027 using the agencies' assumptions for adoption and effectiveness of advanced technologies would be an appropriate target for that year.

Figure 3 shows the fuel consumption reductions in 2024 or 2027 for the three scenarios discussed, and compares them with the Phase 2 proposal for 2027.

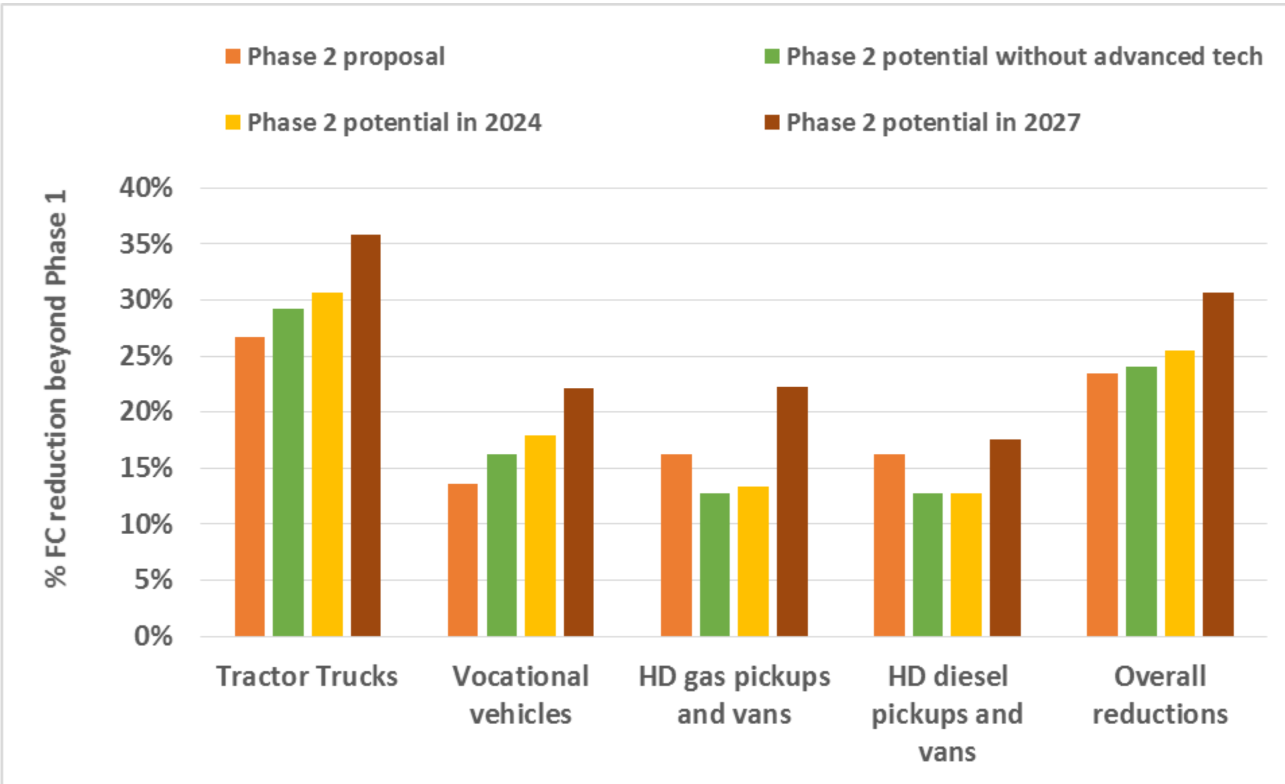


Figure 3: Comparison of the Phase 2 proposal and ACEEE analyses of potential fuel consumption reduction in 2024 and 2027

*Recommendation: Acceleration of standards to 2024*

- Adopt standards for 2024 that are comparable or superior in fuel consumption reductions to the 2027 standards.
- For 2027, adopt technology-forcing standards that will help drive advanced technologies into the market and reduce overall fuel consumption by 31% beyond Phase 1 levels.

#### Glider Kits

ACEEE fully supports EPA's proposal to establish GHG and criteria emissions standards for engines in glider kits and NHTSA's proposal to include glider kits under its Phase 2 standards. The Phase 2 proposal will allow only engines that have been certified to meet current standards to be installed in new glider vehicles (p.40174). The agencies have observed sharp increase in glider kit production (p.40529) recently, which suggests that gliders are being used more and more as a loophole to avoid purchasing engines that meet 2010 EPA emission standards, and potentially to avoid NHTSA safety regulations[26]. These vehicles, unless regulated, will emit significantly higher NOx and PM emissions than from equivalent vehicles being produced with new engines.

[26] http://www3.epa.gov/otaq/climate/documents/420f15904.pdf

*Recommendation: Glider Kits*

- Adopt standards for Glider vehicles in order to prevent them from using older engines with high criteria emissions.

#### Data collection and dissemination

Heavy-duty vehicle data

Sound practices for the collection and dissemination of data are essential to the effective evaluation of the heavy-duty vehicle fuel efficiency and greenhouse gas emissions program. Data from the program should also greatly enhance understanding of heavy-duty vehicles and vehicle markets in the U.S. The lack of specifications of engine and transmission associated with a given vehicle, which is major gap in data collection in Phase 1, will be filled in Phase 2, now that vehicle certification uses actual power train specifications rather than default values as inputs to GEM. It is important that this information, along with all other GEM inputs and outputs, be made available to the public.

The agencies should make available in a timely fashion other data and information arising from the program as well, relating to individual vehicle and engine model certification, manufacturer compliance, and performance of the industry as a whole. Key information would include the contents of certification applications for engines and vehicles, and annual compliance reports showing each manufacturer's status and usage of special credit provisions and credit balances. In the final rule, the agencies should commit to regular publications summarizing trends in the heavy-duty vehicle market, as EPA stated it would "make every effort to do" in its response to comments on the Phase 1 rule.[27] A 2013 ACEEE working paper on heavy-duty vehicle fuel efficiency data[28] set out in detail our concerns and recommendations in this area. Many remain relevant to the current proposal and are reiterated in the recommendations that follow.

CAFE data collection

NHTSA proposes (p.40540) changes to the way that manufacturers report CAFE data to the agency. NHTSA should take this opportunity to add the footprint of each vehicle to the model-by-model information required of the manufacturers. Moreover, footprint data together with fuel economy data for each model should be publically available. Given that footprint is the attribute on which the light-duty CAFE standards are based, analysts and others seeking to understand how the standards are working need this detailed information. Moreover, it is hard understand how the agencies could directly verify the accuracy of manufacturers' calculations of their fleets' compliance without having footprint data for individual models.

*Recommendations: Data collection and dissemination*

- Post all data collected in rule implementation that is not Confidential Business Information on the web in a timely fashion and in a form conducive to analysis. Posted data should include the information in certification applications for engines and vehicles and include all GEM inputs and outputs. The data should be made available in a

[27] Environmental Protection Agency. 2011a. Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: EPA Response to Comments Document for Joint Rulemaking. EPA-420-R-11-004. August.

[28] Langer, T. 2013. "Heavy-Duty Vehicle Fuel Efficiency Data in the United States." ACEEE. http://aceee.org/white-paper/heavy-duty-data.

database that is updated frequently so that key properties of engines and vehicles can be referenced as these products enter the market. Sales volumes at the most disaggregate level available should be added to the database as early as possible.

- In annual compliance reports for the heavy-duty rule, report on each manufacturer's use of special provisions (e.g., early credits, alternative engine certification, advanced and innovative technology credits), application of credit carry-forward/carry-back, and credit balance. Understanding the details of how manufacturers are complying with the standards, including their use of rule flexibilities, will provide insight into how the rule may be influencing the vehicle market and how rule design might be improved.
- Produce an annual report on trends in heavy-duty vehicle technology, carbon dioxide emissions, and fuel economy. An annual heavy-duty vehicle trends report is necessary to track the directions of a rapidly evolving market for fuel efficiency technology. The report should present the agencies' findings regarding the key fuel efficiency trends in the heavy-duty vehicle market with respect to vehicle and engine types, technologies, and manufacturers. Where relevant data on individual models or manufacturers is unavailable in the public online database, present that information in the least aggregated form compatible with CBI policy.
- Consolidate analysis and reporting of data on heavy-duty pickups and vans with light-duty reporting. Include these vehicles in the agencies' light-duty databases and in EPA's annual Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends report.
- (CAFE) Require manufacturers to include model-by-model footprint data when submitting fuel economy information for CAFE compliance. This model-level data should be made available to the public along with fuel economy and vehicle specifications, as well as sales volumes.

## Conclusions

ACEEE strongly supports EPA and NHTSA's work to establish Phase 2 greenhouse gas and fuel efficiency standards for heavy-duty vehicles and engines. The proposed rule, built on the success of the first phase, represents another important step toward major reductions in fuel consumption and greenhouse gas emissions of the heavy-duty sector. We recommend that the agencies strengthen the proposed rule in several areas to ensure that the Phase 2 program achieves maximum economic and environmental benefits.

## Appendix

Table A1: Engine stringency in 2024

| Technology | Phase 2 proposal (p. 40197) | | | ACEEE recommended effectiveness | ACEEE recommended penetration | MY 2024 weighted estimate |
|---|---|---|---|---|---|---|
| | FC reduction | Penetration in 2024 | Weighted reduction | | | |
| Improved combustion and control | 1.1% | 95% | 1.1% | 3.0% | 95% | 2.9% |
| Engine friction/parasitic reduction | 1.4% | 95% | 1.3% | 4.2% | 95% | 4.0% |
| Aftertreatment improvement | 0.6% | 95% | 0.6% | 0.6% | 95% | 0.6% |
| Engine downsizing | 0.3% | 20% | 0.1% | N/A | N/A | |
| EGR/airflow/turbo improvement | 1.1% | 95% | 1.1% | 1.7% | 95% | 1.6% |
| WHR (Turbo compounding) | 1.8% | 10% | 0.2% | 3.0% | 15% | 0.5% |
| WHR (Rankine cycle) | 3.6% | 5% | 0.2% | 4.5% | 15% | 0.7% |
| Dis-synergy factor | | | 15% | | | 5% |
| Total reduction | | | 3.7% | | | 9.3% |