Matthew Rodriquez
Secretary for
Environmental Protection

Air Resources Board

Mary D. Nichols, Chair
1001 I Street • P.O. Box 2815
Sacramento, California 95812 • www.arb.ca.gov

Edmund G. Brown Jr.
Governor

October 1, 2015

Administrator Gina McCarthy
U.S. Environmental Protection Agency
Air and Radiation Docket and Information Center, Mail Code: 28221T
1200 Pennsylvania Avenue, NW
Washington, DC 20460
Docket No. EPA–HQ–OAR–2014–0827

Administrator Mark R. Rosekind
U.S. Department of Transportation
National Highway Traffic Safety Administration
Docket Management Facility, M-30
1200 New Jersey Avenue, SE
Washington, DC 20590
Docket No. NHTSA-2014-0132

Dear Administrators McCarthy and Rosekind:

The California Air Resources Board (CARB) appreciates the opportunity to provide comments on the Notice of Proposed Rulemaking for the U.S. Environmental Protection Agency's (U.S. EPA) and the National Highway Traffic Safety Administration's (NHTSA) Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2, as published in the Federal Register on July 13, 2015.

Over the past two years, CARB staff has worked closely with the staff of U.S. EPA and NHTSA to develop the technical analyses intended to inform the stringencies of the federal Phase 2 proposal. We commend and appreciate your agencies' significant efforts to build on the success of current Phase 1 standards for the purpose of establishing a strong, national Phase 2 program, particularly one that will support California in achieving its unique climate and petroleum reduction targets.

After a thorough assessment by CARB's Phase 2 team of scientists and engineers, we have concluded, unfortunately, that the proposal falls short of the program needed in California. This should come as no surprise in light of my testimony at the August 18th federal hearing on the proposal in Long Beach, California. At that time, CARB staff was midway through its technical deep dive into the proposal. With that process complete, I

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now offer our detailed recommendations, which are attached, to strengthen the program and to accelerate opportunities to achieve climate benefits nationwide.

Overall, CARB believes the proposed federal Phase 2 rule misses opportunities to maximize greenhouse gas reductions and spur development of critical advanced technologies that can provide early climate benefit. These are especially important to California in meeting our 2030 greenhouse gas and petroleum use reduction goals. As proposed, the federal rule would provide less than half of the reductions needed for California to meet its 2030 targets. Furthermore, the proposal lacks any acknowledgement of the need for future national heavy-duty engine standards to reduce emissions of oxides of nitrogen (NOx), and, in fact, lacks adequate safeguards to protect against NOx increases in some heavy-duty vehicle applications, as noted in our more detailed comments.

While CARB's attached comments include significantly more detail and breadth than I provide here, I do want to highlight a few specific recommendations and areas for improvement.

1. **Strengthen the overall proposal and adopt the Alternative 4 timeline in order to deliver greater climate benefits earlier**

CARB strongly recommends that the federal agencies strengthen the overall proposal and adopt the Alternative 4 timeline, rather than adopt the proposed Alternative 3. While the two alternatives are nearly identical in terms of technological feasibility and payback periods for fuel efficient technologies, Alternative 4 accelerates full program phase-in by three years, from 2027 to 2024, and as discussed below, can be strengthened in overall stringency.

By 2030, Alternative 4 as proposed would provide about four million metric tons more cumulative greenhouse gas benefits in California than Alternative 3, and together with Phase 1 would reduce petroleum use from the medium- and heavy-duty sector by about 22 percent. Yet, this still is not enough, and even more needs to be done to strengthen the federal Phase 2 proposal, such as including an increase in the engine-only standard, as described in our next recommendation. Overall, a strengthened Alternative 4 would provide an important step toward reaching Governor Brown's climate goals and 50 percent petroleum reduction target for the transportation sector.

2. Increase stringency of the proposal, via tighter engine-only standards and consideration of all appropriate technologies

As proposed, the Phase 2 tractor and vocational engine standards are expected to achieve only a modest 4 percent fuel efficiency improvement beyond what the current Phase 1 program requires. CARB staff recommends that the tractor engine standard stringency be increased to achieve at least a seven percent reduction in carbon dioxide emissions versus a model year 2017 baseline engine, in conjunction with a corresponding increase in the whole vehicle standards, to levels that capitalize on the full emission reduction potential of efficiency improving technologies. Recent work by the Southwest Research Institute, the U.S. Department of Energy's SuperTruck teams, and Cummins, the largest manufacturer of heavy-duty truck engines, all indicate the feasibility of engine greenhouse gas reductions in the Phase 2 timeframe at levels more than twice the levels being proposed.

Additional areas in which the proposal misses opportunities to maximize climate benefits include the lack of consideration of aerodynamic improvements and electrified accessories for vocational vehicles, tighter standards for pickup trucks and vans and trailers, and limitations on the global warming potential of air conditioning refrigerants.

3. Include a greater reliance on advanced technologies

The Phase 2 proposal lacks sufficient stringency to drive market development of battery electric or fuel cell electric technologies. The proposal assumes only a modest level of hybrid technology and no use of battery electric or fuel cell electric technology, is generally pessimistic on the future of battery electric and fuel cell electric vehicles, and, in fact, eliminates the advanced technology credits included in the Phase 1 program that were intended to encourage development of these technologies. This is contradictory to CARB's position that the early deployment of advanced technologies is the foundation of California's pathway to achieving both its climate and air quality targets.

Furthermore, without any significant reliance on advanced technologies built into the proposed standards, CARB estimates that projected increases in truck activity will completely overtake projected greenhouse gas reductions by 2043 (with respect to the 2010 baseline), resulting in greenhouse gas levels from medium- and heavy-duty trucks in 2050 that are about six percent higher than 2010 levels. To actually offset the expected activity growth, advanced, near-zero emission technologies must be a significant part of the long-term solution.

4. Address projected diesel PM increases due to the increase use of auxiliary power units

The proposal encourages manufacturers to increase the use of auxiliary power units (APUs) to reduce idling. While CARB supports reducing such unnecessary idling, U.S. EPA estimates that this action could increase diesel particulate matter emissions throughout the rest of the country by nearly 10 percent, thus exacerbating public health issues associated with exposure to toxic diesel particulate matter. This is one of the largest public health problems tackled by CARB in recent decades, and even after an extensive control program in California, diesel particulate matter remains responsible for about 60 percent of the known risk from toxic air contaminants. As such, CARB supports the development of a federal rule that requires diesel particulate filters on APUs, concurrent with the Phase 2 program, similar to requirements already in place in California.

5. Commit to future NOx control

California needs dramatic further reductions in NOx emissions beyond what our current programs will achieve by 2031 to attain health-based standards for ozone and fine particulate matter. Reaching these attainment levels in California's South Coast Air Basin will require an approximate 70 percent reduction in NOx from today's levels by 2023, and an overall 80 percent reduction in NOx by 2031. CARB expected the proposal to include a commitment from U.S. EPA to begin efforts to develop lower, mandatory NOx standards for heavy-duty engines and vehicles. Federal action is especially needed for the largest heavy-duty trucks that frequently cross state lines and therefore cannot be effectively regulated by California alone. CARB will begin development of lower, mandatory NOx engine standards in 2017, and will also petition U.S. EPA to establish lower, federal NOx engine standards. If U.S. EPA fails to initiate a timely rulemaking, CARB will continue with its efforts to establish a California-only standard.

6. Address the potential for an increase in emissions from improperly designed hybrid systems and from the use of non-road engines

CARB previously submitted to U.S. EPA comments requesting a supplemental NOx check to safeguard against NOx increases from improperly designed heavy-duty hybrid systems; the current proposal does not address this issue or incorporate CARB's recommendations. At a minimum, CARB recommends that the proposal specify the consequences for NOx emissions increases identified during powertrain testing of hybrid systems, such as prohibiting manufacturers from counting high-NOx hybrid vehicles towards Phase 2 fleet averages.

In addition, CARB strongly urges U.S. EPA and NHTSA to include appropriate safeguards to protect against possible criteria pollutant increases associated with allowing non-road engines to be used in on-road heavy-duty hybrid systems.

CARB has appreciated the opportunity to work collaboratively with both U.S. EPA and NHTSA in developing the federal Phase 2 proposal. My hope is that U.S. EPA and NHTSA will seriously consider our comments in the spirit they are provided: as an opportunity for our agencies to continue our collaborative efforts to finalize a strong, national Phase 2 program that maintains this country's global leadership role in addressing climate change.

Without such a national program, it is ultimately CARB's responsibility to ensure the Phase 2 standards assist California in meeting its climate and petroleum reduction goals, and, therefore, may consider California-only elements as part of CARB staff's Phase 2 proposal expected in the mid-2017 timeframe.

Again, thank you for the opportunity to provide comments. If you have any questions regarding our comments, please contact me or Mr. Michael Carter, Chief of the Mobile Source Regulatory Development Branch, at (626) 575-6632, or via email at Michael.Carter@arb.ca.gov.

Sincerely,

Mary D. Nichols
Chair

Attachment

cc: See next page

cc: Mr. Richard W. Corey
Executive Officer

Dr. Alberto Ayala
Deputy Executive Officer

Mr. Erik White, Chief
Mobile Source Control Division

Mr. Michael Carter, Chief
Mobile Source Regulatory Development Branch
Mobile Source Control Division

Ms. Kim Heroy-Rogalski, Manager
Strategic Planning and Development Section
Mobile Source Control Division

Mr. Stephan Lemieux, Manager
On-Road Heavy-Duty Diesel Section
Mobile Source Control Division

ATTACHMENT

California Air Resources Board's (CARB) Specific Comments on Greenhouse Gas Emissions (GHG) Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, Phase 2 Proposed Rules

CARB staff appreciates this opportunity to comment on U.S. Environmental Protection Agency's (U.S. EPA) and the National Highway Traffic Safety Administration's (NHTSA) proposed Phase 2 Heavy-Duty Program that establishes both GHG emission standards and fuel efficiency standards for new heavy-duty vehicles, the engines that power such motor vehicles, and trailers hauled by combination tractors.

CARB staff has comments related to many aspects of the proposed Phase 2 rules which are presented below and organized as follows:

- California's need for GHG reductions – background on the legislative and executive drivers for swift action to reduce GHGs in California;
- Summary of CARB's work on Phase 2 – summary of CARB staff's work with U.S. EPA and NHTSA during development of the proposed Phase 2 standards;
- CARB recommendations on stringency –
    1. Benefits of Alternative 4 for California
    2. Legal Authority to Adopt Alternative 4
    3. Tractor and Vocational Engine Standards
    4. Class 7 and 8 Combination Tractor Vehicle Standards
    5. Vocational Vehicle Standards
    6. Class 2b/3 Pickups and Van Standards
    7. Trailer Standards;
- Comments on proposed Phase 2 provisions – credit provisions, hybrid vehicle provisions, battery electric vehicle (BEV) provisions, and how fuel cell electric vehicles (FCEV) are characterized;
- Comments on proposed compliance, certification, and enforcement provisions - on-board diagnostics (OBD), labelling, test procedures, the GHG emission model (GEM), and the use of non-road engines;
- Comments on other proposed amendments – baseline scenario, gliders, tire-related comments, refrigerant –related comments, solar control, vehicle speed limiter (VSL), and in-use standards;
- Comments on the described impact on fuel consumption, GHG emissions, and climate change, including how natural gas vehicles are accounted for, and emission benefit estimates;

- Comments on non-GHG emissions and their associated effects, such as oxides of nitrogen (NOx) and particulate matter (PM), including our recommendation that Phase 2 include requirements to control toxic diesel PM emissions from auxiliary power units (APUs), the use of which Phase 2 is expected to increase;
- Comments on estimated cost and economic impacts; and
- Comments on definitions and miscellaneous topics.

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California's Need for GHG Reductions

Support Comment

Affected document(s): GHG Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, Phase 2 (Phase 2 Proposed Rules)

Affected pages: 40149-40150

Comment – California's need for GHG reductions

As a leader in climate action, California is committed not only to reducing GHG emissions, but also to advancing the principle that economic prosperity and environmental sustainability go hand-in-hand. The release of the latest edition of the California Greenhouse Gas Emission Inventory in late June 2015 shows that total GHG emissions in California fell by 1.5 million metric tons (MMT) in 2013 from 2012, even while the economy grew 2 percent, a rate greater than the national average.[1] These trends convincingly demonstrate that California can grow its economy, continue to fight climate change, and remain on a sustainable trajectory towards a clean energy future. This recent success, however, does not relieve California of its responsibility to implement even more ambitious measures to significantly reduce GHG emissions.

In fact, California has in place a unique set of directives to expand upon our success in reducing climate emissions and to transform the State's transportation system. These directives require California to:

- Reduce GHG emissions to 1990 levels by 2020;
- Reduce GHG emissions 40 percent from 1990 levels by 2030;
- Reduce GHG emissions 80 percent from 1990 levels by 2050;
- Reduce petroleum use in cars and trucks by up to 50 percent by 2030;

[1] (CARB, 2015a) California Air Resources Board, "California Greenhouse Gas Emissions for 2000 to 2013 – Trends of Emissions and Other Indicators," 2015, <http://www.arb.ca.gov/cc/inventory/pubs/reports/ghg_inventory_trends_00-13.pdf> and "California greenhouse gas inventory shows state is on track to achieve 2020 AB 32 target," June 30, 2015, <http://www.arb.ca.gov/newsrel/newsrelease.php?id=740>.

- Produce at least 50 percent of electricity from renewable sources by 2030; and
- Develop and implement a plan to reduce emissions of short-lived climate pollutants, including black carbon.

Most recently on July 8, 2015, at the Climate Summit of Americas in Toronto, Canada, California Governor Edmund G. Brown, Jr. used his keynote remarks to urge other states and provinces to join with California in the fight against climate change in an effort to spur more aggressive action at the national level. California has already joined the growing lists of states and provinces from around the world in a first-of-its-kind agreement, called the "Under 2 MOU," to limit global warming to less than 2 degrees Celsius. This MOU provides a template for nations to follow as work continues toward an international agreement at the United Nations Climate Change Conference in Paris later this year.

CARB staff recognizes that the federal Phase 2 standards presented in the Notice of Proposed Rulemaking (NPRM) will play a crucial role in California's integrated and comprehensive strategy to further reduce GHG emissions. CARB staff estimates indicate the NPRM proposal, coupled with the federal Phase 1 standards already in place, would reduce California trucking sector GHG emissions 31 percent by 2050 compared to baseline 2010 levels.

With successful policies already in place, California has started down the road to delivering significant GHG reductions through the deployment and use of zero-emission vehicle technologies, cleaner low carbon fuels, more renewable energy, and ongoing improvements in system-wide efficiencies. The additional GHG reductions resulting from the federal Phase 2 standards represent an important "down payment" that will increase momentum in meeting our ambitious climate goals, particularly for the 2030 petroleum reduction target, thus facilitating the decarbonization of California's economy and energy sources.

While every major economic sector in the State will play a role in this effort, the medium- and heavy-duty transportation sector provides key opportunities to advance progress in stabilizing climate emissions and improving freight efficiency. For example, CARB's Assembly Bill 32 (the California Global Warming Solutions Act of 2006) Scoping Plan Update includes more stringent Phase 2 GHG standards as one of the many strategies to assist in meeting California's climate goals.[2] The Phase 2 standards are also identified as a measure in CARB's *Sustainable Freight: Pathways to Zero and Near-Zero Emissions – Discussion Document,* which details CARB's efforts, along with other State of California transportation and energy agencies, to develop a comprehensive and integrated proposed plan for a sustainable State freight system.[3]

California's committed leadership in reducing GHG emissions also extends to short-lived climate pollutants, which have been shown to account for 30-40 percent of global warming to date. The relative potency of methane, black carbon, fluorinated gases, and tropospheric ozone can be tens, hundreds, and up to thousands of times greater than that of CO2. The effects of short-lived climate pollutants are especially strong in the near-term: their impact on global warming more than doubles to almost 40 percent of California's Greenhouse Gas Emission Inventory when "global warming potentials" are computed over 20 years, instead of 100 years.[4]

To address these climate pollutants, CARB has led a collaborative process with other State agencies and local air districts to develop California's comprehensive and aggressive Short-Lived Climate Pollutant Reduction Strategy, as directed by Senate Bill 605 (Lara; Chapter 523, Statutes of 2014). With the release of the draft strategy on September 30, 2015, this effort engages the scientific and legislative communities to identify additional strategies the State will take to build upon existing programs to further reduce these GHGs for an immediate beneficial impact on climate change.

To access the Short-Lived Climate Pollutant Reduction Strategy and additional information on California's research projects and activities related to reducing short-term climate pollutants, please see: http://www.arb.ca.gov/cc/shortlived/shortlived.htm.

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[2] (CARB, 2014a) California Air Resources Board, "First Update to the Climate Change Scoping Plan," May 2014, <http://www.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf>.

[3] (CARB, 2015b) California Air Resources Board, "Sustainable Freight – Pathway to Zero and Near-Zero Emissions," April 2015, <http://www.arb.ca.gov/gmp/sfti/sustainable-freight-pathways-to-zero-and-near-zero-emissions-discussion-document.pdf>.

[4] (CARB, 2014b) California Air Resources Board, "Reducing Short-Lived Climate Pollutants in California," September 2014, <http://arb.ca.gov/cc/shortlived/slcp_booklet.pdf>.

Summary of CARB's Work on Phase 2

<u>Neutral/Provide Additional Information Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40141-40142, 40145-40146

Comment – Process/summary of CARB's work on Phase 2

As the only state in the nation with authority under the Clean Air Act (CAA) to develop its own motor vehicle emission standards, California strives to harmonize its standards with the federal standards as much as possible to achieve a comprehensive, unified national program, while ensuring that California's needs for emission reductions are met.

Over the past two years, CARB staff has closely coordinated with U.S. EPA and NHTSA to develop the technical analyses that inform the stringency of the proposed federal Phase 2 standards. CARB staff would support a harmonized national program, provided it is sufficiently stringent to meet California's significant need to reduce climate emissions from the trucking sector. While CARB staff is fully committed to continuing to work with U.S. EPA and NHTSA to strengthen the federal proposal, we are also prepared to introduce a California proposal that includes elements that move beyond the NPRM proposal if necessary to address California's unique climate needs. Detailed comments addressing specific areas in the NPRM proposal that CARB staff recommends strengthening are included in this submittal package.

In addition to its diligent coordination efforts with U.S. EPA and NHTSA, CARB staff also engaged in complementary research efforts and activities to inform evaluation of the federal Phase 2 proposal, as well as possible development of more stringent California-only elements. These activities and research efforts are summarized below.

<u>Technology Assessments</u>

CARB staff has developed technology assessments for a variety of mobile source categories, including trucks and buses, and fuels. While not all the assessments have yet been released for public comment, each assessment evaluates the current state and projected development of technologies and fuels, and staff presented draft findings from each of the assessments at workshops in September 2014.[5] For each technology, the assessment includes its description, its suitability in different applications, current and anticipated costs at widespread deployment (where available), and emissions levels.

In June 2015, the Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency was released for public comment. This draft assessment identifies engine and vehicle technologies that can reduce fuel consumption and GHG emissions from class 2b through class 8 heavy-duty vehicles with a gross vehicle weight rating (GVWR) of greater than 8,500 pounds (lbs). The technologies discussed in the assessment are the same as or similar to those evaluated by U.S. EPA and NHTSA as part of the federal Phase 2 regulatory development process. The Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency may be accessed from CARB's web page at: http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf.

In developing the assessments, CARB staff conducted an extensive literature search of current, emerging, and advanced technologies using published reports, research studies, and conversations with technology experts. CARB staff also recognizes that both U.S. EPA and NHTSA have sponsored new research in support of the proposed Phase 2 standards, and is using this publically available research to reevaluate the fuel consumption reduction potential of the technologies discussed in the Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency.

Aerodynamic Drag Reduction Technologies Testing for Heavy-Duty Vocational Vehicles and Trailer Configurations

Various aerodynamic drag reduction technologies have been assessed and proven to reduce fuel consumption, particularly for vehicles that operate at higher speeds. To further reduce fuel consumption in the heavy-duty vehicle vocational sector, CARB staff evaluated potential opportunities to use aerodynamic technologies in the vocational vehicle sector that are already in use in the long-haul tractor trailer sector. Through literature reviews and stakeholder discussions, CARB staff realized the dearth of data available on aerodynamic technology utilization on vocational vehicles.

[5] (CARB, 2014c) California Air Resources Board, Technology and Fuels Assessments Workshop Presentations, September 2014, <http://www.arb.ca.gov/msprog/tech/presentation.htm>

To help fill this data gap, CARB funded a study through the National Renewable Energy Laboratory (NREL), in close coordination with U.S. EPA, to evaluate the fuel consumption reduction potential of various aerodynamic technologies on heavy-duty vocational vehicles and pup trailers. In this study, CARB contracted NREL to perform coastdown and on-road test runs, with and without aerodynamic devices such as skirts, front fairings, and wheel covers, on vocational vehicles. Testing on vocational vehicles is complete, and the results are discussed further in Comment – Vocational Aerodynamics: Credits for aerodynamic devices on vocational box trucks (page 44 of this document).

To assist U.S. EPA in its testing and data-gathering efforts, CARB also funded NREL to quantify the fuel consumption reduction potential of aerodynamic technologies on pup trailers. As of September 2015, this testing is underway but not yet complete. The pup trailer testing component consists of five coastdown test configurations: 1) baseline: tractor, two pups, no aerodynamic improvements; 2) trailer side skirts on front trailer only; 3) trailer side skirts on rear trailer only; 4) trailer side skirts on both trailers; and 5) trailer side skirts on both trailers and an advanced trailer tail on the rear trailer only.

CARB staff is submitting a draft report with the test results on the completed vocational vehicle testing, prepared by NREL, with its formal comments on the proposed Phase 2 provisions for vocational aerodynamics. As discussed further in Comment – Vocational Aerodynamics: Credits for aerodynamic devices on vocational box trucks (page 44 of this document), the testing results demonstrate that aerodynamic technologies could provide fuel consumption reduction benefits in vocational vehicles under many operating conditions.

California Phase 2 Symposium

On April 22, 2015, CARB staff hosted a symposium to discuss California's coordination efforts with U.S. EPA and NHTSA to develop the proposed federal Phase 2 standards. Representatives from environmental government agencies, engine manufacturers, component suppliers, environmental policy and technical research organizations, and trucking fleets participated in panel discussions to present the latest information on heavy-duty engine and vehicle technology options, including their associated emission reduction potential and costs, expected for use in the post-2020 timeframe to reduce fuel consumption and improve tractor-trailer efficiency.

At the symposium, CARB staff discussed the magnitude of GHG reductions still needed in California to achieve its climate goals, how the proposed Phase 2 standards fit within California's overall strategy to achieve those goals, and the critical need to ensure that California maintains its progress in reducing NOx emissions while further reducing GHG emissions.

Overall, the symposium provided participants opportunities to share and discuss their diverse perspectives. CARB staff highly values the symposium presentations and resulting dialogues and used the materials to help inform its evaluation of the proposed federal Phase 2 standards. The symposium presentations may be accessed from CARB's web page at: http://www.arb.ca.gov/msprog/onroad/caphase2ghg/presentations/caphase2ghg_symposium_presentations.htm. CARB staff will also use the materials as it develops its own Phase 2 program, expected in 2017.

CARB Recommendations on Stringency

Comments on Proposed Final GHG and Fuel Consumption Standards for Heavy-Duty Engines and Vehicles and on Feasibility Assessments and Conclusions

Overall Benefits of Alternative 4 in California

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40397 - 40406

Comment – GHG emissions reductions of proposed regulation in California

CARB staff consulted with both U.S. EPA and NHTSA throughout the development of the proposed federal Phase 2 Heavy-Duty Program and fully recognizes the potential benefits that would result should CARB harmonize California's future Phase 2 GHG regulation with the proposed Phase 2 rulemaking, namely, nationwide consistency for engine and vehicle manufacturers.

However, as explained in further detail below, CARB staff believes that U.S. EPA and NHTSA's proposed adoption of emission standards corresponding to "Alternative 3" does not adequately serve California's needs to reduce both greenhouse gas emissions and petroleum usage from heavy-duty vehicles, and therefore urges its federal partners to adopt the emission standards corresponding to the "Alternative 4" option.

We recommend Alternative 4 be the preferred standard across all vehicle categories – tractors, (see comment on page 30), vocational vehicles (see comment on page 36), pickups and heavy-duty vehicles (see comment on page 52) and trailers (see comment on page 57), and in fact in several instances recommend tightening the final stringency also. We recommend tighter standards for tractor and vocational engines as well. In general, CARB staff believes that the NPRM is overly pessimistic about the outlook for the implementation of advanced technologies such as BEVs and FCEVs, as well as the ability of engine and truck manufacturers to engineer solutions that are needed to meet global GHG goals. Generally, CARB staff believes that U.S. EPA and NHTSA should be more willing to push the technology envelope, and have confidence in the ability of industry to meet far reaching environmental goals. As discussed at length in other comments, we believe that more stringent standards for both compression ignition and spark-ignited engines and vehicles are appropriate and could be met in a cost-effective manner. Our recommended reinstitution of Advanced Technology Credits would make Alternative 4 even more attractive and attainable. The projected balances of Phase 1 credits, discussed further below, supports our belief that the engine and truck industry can and will do its part to curb global GHG emissions if more stringent standards are set.

The benefits of adopting the Alternative 4 standards across all vehicle categories are critical to California for meeting our GHG and petroleum reduction targets for 2030 and 2050.[6] Alternative 4 standards would result in an additional 4 MMT carbon dioxide (CO_2) benefit by 2030 in California which is equivalent to removing about 3,300 class 8 long-haul tractor-trailers off the road.[7] This reduction would be a critical first step towards California meeting its goal of reducing petroleum use by 50 percent in 2030.

Adopting Alternative 4 standards across all vehicle categories would also result in the Phase 2 program being fully phased in by 2024 (by 2025 for pickups and vans), three years earlier than if Alternative 3 standards are adopted. This would allow manufacturers to take action on reducing NOx emissions from the heavy-duty vehicles addressed in this rulemaking in a timelier manner. This is especially important since heavy-duty vehicles are responsible today for one-third of California's NOx emissions. The South Coast Air Basin will need nearly a 90 percent reduction in heavy-duty vehicle NOx emissions by 2031 from 2010 levels to attain the 2008 National Ambient Air Quality Standards (NAAQS) for ozone. Additionally, on November 25, 2014, U.S. EPA issued a proposal to strengthen the ozone NAAQS. If a change to the ozone NAAQS is finalized, California and other areas of the country will need to identify and implement measures to reduce NOx as needed to complement federal emission reduction measures.

<u>Alternative 4 vs. Alternative 3 Emission Benefits</u>

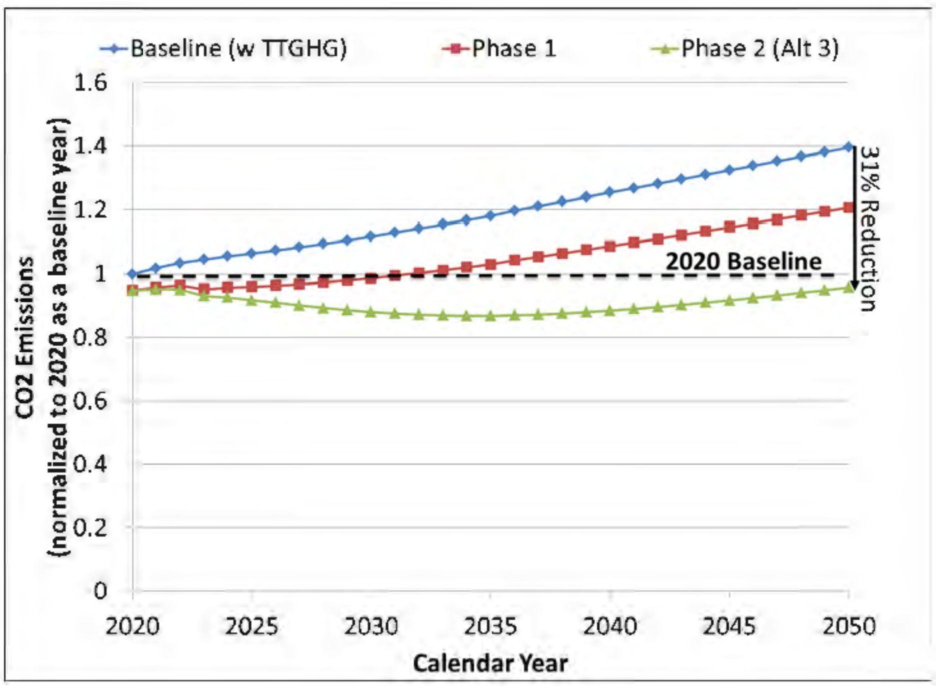
This comment provides an overview of the emissions benefits from the proposed regulation in California. Trucking operations in California differ substantially from the national average. Trucks that are operated primarily in California are retained by fleets

[6] Assembly Bill 32: Reduce GHG emissions to 1990 levels by 2020.; Executive order B-32-15: Reduce GHG Emissions to 40 percent below 1990 levels by 2030; Executive order S-21-09: Reduce GHG emissions to 80 percent below 1990 levels by 2050; Governer Brown's inaugural address: Reduce petroleum use in cars and trucks in California by up to 50 percent by 2030

[7] Assuming tractor meets baseline emission level of 88 g CO_2/ton-mile; payload of 38,000 lbs; travels 120,000 miles/year over 6 year period (2024 to 2030).

longer than the national average.[8] In addition, the California trucking market is segmented, with national, regional and local fleets all competing in different segments of the goods movement economy; and hence it has a lower fraction of long-haul freight truck traffic as compared to national truck activity.[9] This leads to a different vehicle fleet mix, vehicle age, and vehicle miles traveled (VMT) profiles than the national average. California's emissions model, EMFAC2014 (v1.0.7), reflects these California-specific factors, and is used to estimate the GHG emissions impact of the proposed rule as applied to medium and heavy-duty vehicles operating in California.

Figure 1: Statewide On-Road GHG Emissions (Normalized to 2020 as a Baseline year) from Phase 2 Regulated Vehicles: without Regulation (Baseline including CARB Tractor-Trailer Regulation), with the Phase 1 Regulation, and with the Alternative 3 of Phase 2 Regulation



Using the model year (MY) specific percent reductions in CO_2 emission rates, staff assessed the emissions impact of the proposed regulation under both alternative 3 and 4 scenarios. Figure 1 shows the impact of the Phase 1 and Phase 2 (Alternative 3)

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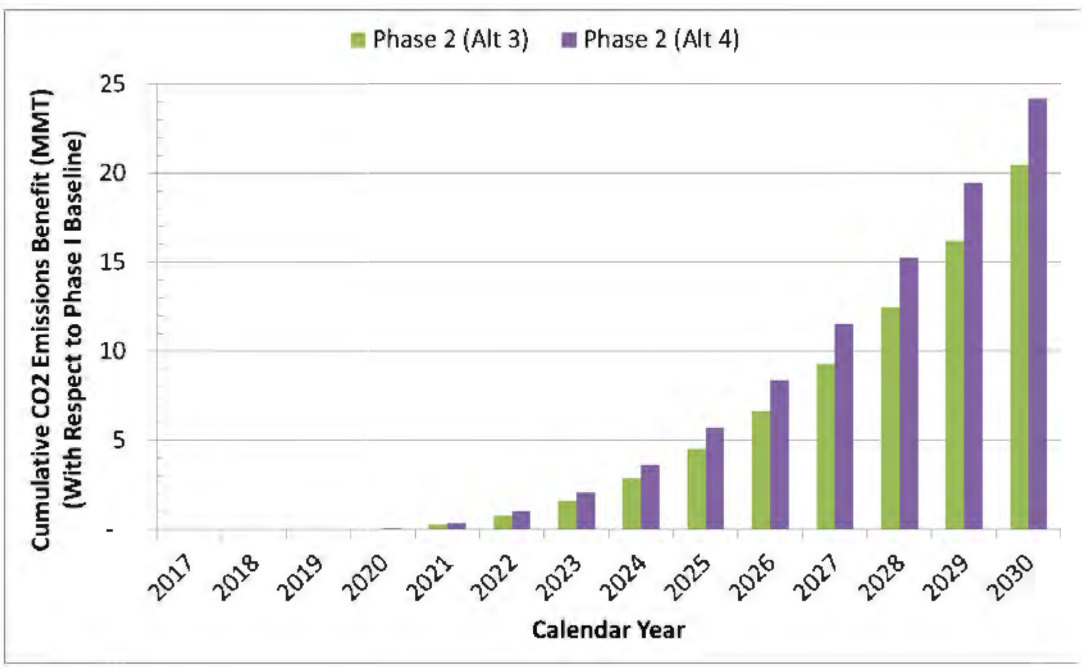
[8] United States Census Bureau, "Vehicle Inventory and Use Survey (2002)," available at: http://www.census.gov/svsd/www/vius/products.html.
[9] Id.

regulations on GHG emissions from affected vehicles.[10] Results show a combined reduction of ~31percent in GHG emissions by 2050. Furthermore, staff analysis shows that as compared to alternative 3, alternative 4 would achieve an additional 4 MMT cumulative benefit in CO_2 emissions by 2030 (Figure 2). If Alternative 4 is adopted, Phase 1 and 2 together would achieve approximately a 22 percent reduction in petroleum use from the medium- and heavy-duty sector in 2030. This reduction would be a first step towards reaching the California Governor's goal of up to a 50 percent reduction in petroleum use by 2030. As shown in Figure 1, due to the relatively fast growth of freight activity in California and at California ports (which handle roughly 40 percent of the nation's freight flow), GHG emissions from the regulated trucks will start increasing in 2035. Therefore, achieving California's mid- and long-term climate change targets will require additional steps such as broader use of renewable fuels, increasing use of zero-emission technologies, and increasing operational efficiencies.

Figure 2: Statewide Cumulative On-Road CO_2 Emissions Benefit from the Alternative 3 and Alternative 4 of Phase 2 Regulation



[10] The affected EMFAC vehicle categories by Phase 1 and 2 regulations are heavy-duty trucks and buses exceeding 8,500 pounds GVWR.

Legal Authority to Adopt Alternative 4

Legal Authority

Alternative 4 is consistent with U.S. EPA's authority to promulgate GHG emission standards under the federal CAA, and with NHTSA's authority to promulgate fuel efficiency standards under the Energy Independence and Security Act (EISA).

Alternative 4 is Consistent with U.S. EPA's Statutory Authority

U.S. EPA is promulgating the proposed Phase 2 greenhouse gas emission standards pursuant to the statutory authority of Title II of the federal CAA, and specifically sections 202(a)(1) and (2), sections 202(d), 203-209, 216, and 301 (42 U.S.C. 7521 (a)(1) and (2), 7521(d), 7522-7543, 7550, and 7601).

Alternative 4 is consistent with the statutory provisions applicable to U.S. EPA's determination of the requisite lead time requirements associated with the proposed greenhouse gas emission standards. CAA section 202(a)(2) [42 U.S.C.§ 7521(a)(2)] provides that "[a]ny regulation prescribed under paragraph (1) of this subsection (and any revision thereof) shall take effect after such period as the Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period."

Courts interpreting section 202(a) of the CAA have recognized that Congress intended U.S. EPA to rely upon projected future developments and advances in pollution control technology in establishing emission standards, and expected U.S. EPA to "press for the development and application of improved technology rather than be limited by that which exists today." *Natural Resources Defense Council v. U.S. EPA*, 655 F.2d 318, 328 (D.C. Cir. 1981) (*NRDC*). The NRDC court noted that a longer lead time "gives the U.S. EPA greater scope for confidence that theoretical solutions will be translated successfully into mechanical realizations",[11] and further stated that "the presence of substantial lead time for development before manufacturers will have to commit themselves to mass production of a chosen prototype gives the agency greater leeway to modify its standards if the actual future course of technology diverges from expectation." (Id.) The court concluded:

[11] *Id.* at 329.

> "We think that the U.S. EPA will have demonstrated the reasonableness of its basis for prediction if it answers any theoretical objections to the [projected control technology], identifies the major steps necessary in refinement of the [projected control technology], and offers plausible reasons for believing that each of those steps can be completed in the time available."[12]

In this NPRM, U.S. EPA and NHTSA have set forth a broad range of compliance strategies and technologies that they anticipate engine and vehicle manufacturers will utilize in order to comply with the emission standards associated with both Alternatives 3 and 4. Such compliance strategies and technologies vary from well-established control technologies that are currently widely available (essentially "off-the-shelf" technologies) to control technologies that are only utilized in certain industry segments or that will likely require substantial development before they will be commercially available on a widespread basis throughout the industry (e.g., Rankine-cycle engines and strong hybrid pickups and vans).

As demonstrated below, CARB staff believes that for each regulated category of engines and vehicles, U.S. EPA and NHTSA have identified specific technologies that will be commercially available and that will enable manufacturers to comply with the proposed emission standards within the time frames associated with Alternative 4.

In *NRDC*, the court upheld U.S. EPA's PM standards for MY 2005 light-duty diesel vehicles that U.S. EPA had promulgated in 2000. The court stated:

> "Given this time frame, we feel there is substantial room for deference to the EPA's expertise in projecting the likely course of development. The essential question in this case is the pace of that development, and absent a revolution in the study of industry, defense of such a projection can never possess the inescapable logic of a mathematical deduction."[12]

In this rulemaking action, Alternative 4 provides manufacturers of heavy-duty engines and heavy-duty vehicles approximately *eight years of lead-time* to develop and apply technologies needed to comply with the most stringent greenhouse emission standards. This time frame is 60 percent longer than the time frame considered by the *NRDC* court, and in light of the extensive information discussed in this NPRM regarding the numerous control technologies that manufacturers are anticipated to utilize to comply

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[12] *Id.* at 331-32. *Accord*, *Husqvarna AB v. Environmental Protection Agency*, 254 F.3d 195, 201 (D.C. Cir. 2001) and *National Petrochemical & Refiners Association v. Environmental Protection Agency*, 287 F.3d 1130, 1136 (D.C. Cir. 2002).

with the proposed standards, their capability of reducing GHG emissions, current states of development, and identification of the major steps needed to refine those technologies for implementation in MY 2024 engines and vehicles, it is clear that Alternative 4 is consistent with the lead time requirements of section 202(a)(2) of the CAA (42 U.S.C. 7521 (a)(2)).

CAA section 202(a)(2) also requires U.S. EPA to consider the cost of compliance of regulations promulgated pursuant to the authority of CAA section 202(a). "Any regulation prescribed under paragraph (1) of this subsection (and any revision thereof) shall take effect after such period as the Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period."

In *Motor and Equip. Mfrs Assoc. v. EPA,* 627 F.2d 1095 (D.C. Cir. 1979), (*MEMA I*), the court addressed the cost of compliance issue in reviewing a challenge to U.S. EPA's issuance of a waiver to California. The court found:

> Section 202's "cost of compliance" concern, juxtaposed as it is with the requirement that the Administrator provide the requisite lead time to allow technological developments, refers to the economic costs of motor vehicle emission standards and accompanying enforcement. See S. Rep. No. 1922, 89th Cong., 1st Sess. 5-8 (1965); H.R. Rep. No. 728 90th Cong., 1st Sess. 23 (1967), U.S. Code Cong. & Admin. News 1967, p. 1938. It relates to the timing of a particular emission control regulation rather than to its social implications. Congress wanted to avoid undue economic disruption in the automotive manufacturing industry and also sought to avoid doubling or tripling the cost of motor vehicles to purchasers. It therefore requires that emission control regulations be technologically feasible within economic parameters. Therein lies the intent of the "cost of compliance" requirement. (*MEMA I*, 627 F.2d at 1118.)

U.S. EPA and NHTSA have extensively discussed in the NPRM the projected costs of compliance for the proposed emission standards, as set forth in both Alternative 3 and Alternative 4. Although the incremental costs for emission standards under Alternative 4 are generally higher than the corresponding costs for emission standards under Alternative 3, the incremental costs associated with Alternative 4 only constitute a fraction of the base costs of new engines and vehicles, and most importantly, are more than offset by the reduced fuel consumption costs within time frames of 2 to 6 years. These cost-related factors demonstrate that the emission standards associated with

Alternative 4 are technologically feasible, considering the cost of compliance within the lead time provided.

Alternative 4 is Consistent with NHTSA's Statutory Authority

NHTSA is promulgating the proposed fuel efficiency standards pursuant to the statutory authority of the EISA, which amends the Energy Policy and Conservation Act (EPCA) of 1975. Specifically, section 102 of EISA (49 USC section 32902(k)(2)) authorizes NHTSA to implement "a commercial medium- and heavy-duty on-highway vehicle and work truck fuel efficiency improvement program designed to achieve the maximum feasible improvement, and [to] adopt and implement appropriate test methods, measurement metrics, fuel economy standards, and compliance and enforcement protocols that are appropriate, cost-effective, and technologically feasible for commercial medium- and heavy-duty on-highway vehicles and work trucks."

The fuel efficiency standards that correspond to the GHG emission standards associated with Alternative 4 are consistent with section 32902(k)(2) of EISA. In the Phase 1 rulemaking, NHTSA stated that it has the discretion to balance the factors specified in section 32902(k)(2) of EISA "in a way that is technology-forcing … but not in a way that requires the application of technology which will not be available in the lead time provided by the rule, or which is not cost-effective, or is cost-prohibitive …"[13]

As demonstrated above, Alternative 4 is consistent with the statutory provisions of section 202(a)(2) of the CAA regarding adequate lead times and costs of compliance associated with the proposed greenhouse gas emission standards. To the extent that NHTSA's considerations of lead times and compliance costs for the technologies needed to comply with fuel efficiency standards are consistent with the lead time and cost of compliance factors that U.S. EPA considered in developing the GHG emission standards associated with Alternative 4, the corresponding fuel efficiency standards are arguably consistent with the factors specified in section 32902(k)(2), and are consistent with NHTSA's statutory directive to achieve the maximum feasible improvement in fuel efficiency standards from commercial medium- and heavy-duty on-highway vehicles and work trucks.

[13] Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, U.S. EPA Response to Comments, Document for Joint Rulemaking, p. 5-17, EPA-420-R-11-004, August 2011.

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: **40546**

Comment - Interpretation that 49 U.S.C. 32919(a) does not extend to commercial medium- and heavy-duty on-highway vehicles and work trucks

NHTSA states that in the Phase 1 rulemaking it concluded that EPCA's express preemption provision of 49 U.S.C. 32919(a) (which expressly preempts any State or local government from adopting or enforcing a law or regulation related to fuel economy standards or average fuel economy standards for automobiles covered by an average fuel economy standard under 49 U.S.C. Chapter 329) does not extend to the fuel efficiency standards established in the Phase 1 rulemaking because commercial medium- and heavy-duty on-highway vehicles and work trucks are not ''automobiles,'' as defined in 49 U.S.C. 32901(a)(3). NHTSA states that it is reiterating that conclusion for the proposed Phase 2 standards.

CARB staff concurs with NHTSA's reasoning and conclusion that 49 U.S.C. 32919(a) does not extend to the fuel efficiency standards established under the Phase 1 rulemaking or to the proposed fuel efficiency standards established under the Phase 2 rulemaking.

Tractor and Vocational Engine Standards

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40182

Comment – Separate engine and vehicle standards

The NPRM requests comment on the choice to maintain separate engine and vehicle standards.

CARB staff strongly agrees with U.S. EPA and NHTSA's choice to maintain separate engine standards for the following reasons.

- Engine standards directly address the source of GHG emissions and ensure some efficiency improvements at the engine level will be achieved over the useful life of the vehicle. Without an engine standard, some vehicle manufacturers could elect to rely more heavily on vehicle technologies to meet emission standards. These technologies may prove to be less effective at reducing emissions as the vehicles' vocation changes over time. For example, line-haul tractors with aerodynamic technologies would see less of a benefit from the aerodynamic technologies if placed into local-haul service by a second owner.
- Separate engine standards based on the direct measurement of GHG emissions from engines can be directly verified for compliance using existing engine test protocols: U.S. EPA's heavy-duty engine ramped-modal Supplemental Emission Test (SET) and heavy-duty engine transient emissions test, i.e., the Federal Test procedure (FTP).
- The SET and FTP would continue to be used to certify heavy-duty engines to GHG emission standards, as well as the criteria pollutant emission standards. This provides a direct link between the GHG emission measurement and NOx emission measurement methods for certification.

<u>Oppose/ Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40159-40160, 40584

Comment – Proposed GHG emission standards for spark-ignited engines

Under these paragraphs in 40 CFR1036.108 a)(1)(i) and (ii), CO_2 standards for 2016 and later spark-ignited engines remain at the Phase 1 levels of 627 grams per horsepower-hour (g/hp-hr), while compression ignition (and others deemed to be compression ignition in this section) have allowable CO_2 limits that decline over time. U.S. EPA and NHTSA's reasoning is that the volume of gasoline engines is relatively low in these vehicle classes, so reduction requirements will have few benefits to offset the research investment costs. CARB staff believes that some of the technology developed to reduce GHG emissions in the light-duty sector should be transferrable to the medium- and heavy-duty sectors and recommends that declining GHG standards for spark-ignited engines be set based on these technologies. CARB staff believes that such GHG reductions for Phase 2 spark-ignited engines are cost-effective. The NPRM does request comment on reducing the Phase 1 CO_2 standard for spark-ignited gasoline engines by 1 percent to 621 g/hp-hr, based on the use of advanced friction reduction technology. CARB staff supports requiring more stringent standards for gasoline engines, and, at a minimum, supports the proposal in the NPRM to limit CO_2 emissions for Phase 2 spark-ignited gasoline engines to no more than 621 g/hp-hr.

The NPRM further requests comment on whether *not* requiring more stringent standards for gasoline engines would create an incentive for purchasers who would otherwise choose a diesel engine to instead choose a gasoline engine. CARB staff believes that, all other things being equal, such a switch could well occur. To avoid unintended incentives, CARB staff suggests that Phase 2 gasoline engines be required to meet reduced emission standards beyond the 621 g/hp-hr previously mentioned, the compliance with which would require similar investments and/or have a similar compliance cost as is anticipated for the compression ignition engines and vehicles. Because gasoline vehicles are currently cheaper than diesel, it is particularly important to avoid further incentives for buyers to choose less efficient, gasoline vehicles.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40194-40197

Comment – Stringency of the engine standards for heavy-duty tractors

The NPRM requests comment on the proposal to increase the stringency of the compression ignition tractor engine standards. CARB staff strongly supports U.S. EPA and NHTSA's decision to increase the stringency of the compression ignition engine standards. The Phase 1 regulation established engine standards that were easily achieved using "off-the-shelf" technologies. With the Phase 2 regulation, U.S. EPA and NHTSA committed to establish more stringent engine standards that force the introduction of new and advanced cost-effective engine technologies. CARB staff supports that effort, and in fact believes the engine standards should be made more stringent than either the preferred Alternative 3 standards or the Alternative 4 standards. As discussed further below, CARB staff recommends that when fully implemented, the tractor engine standard stringency should be increased from 4.2 percent to 7.1 percent, and that full implementation should happen by MY 2024.

As shown in Table II-6 of the NPRM (included below), U.S. EPA and NHTSA's preferred Alternative 3 would result in standards for MY 2027 diesel engines that require a 4.2 percent reduction in CO_2 emissions versus a 2017 baseline engine. Also proposed are interim standards for MY 2021 and MY 2024, requiring reductions in CO_2 emissions of 1.5 to 3.7 percent better than a 2017 baseline. The proposed standards were determined by taking the SET weighted reduction for each technology, weighting it by the estimated market penetration, calculating a weighted average for the entire suite of technologies, and then applying a "dis-synergy factor" to the weighted average. Dis-synergy factors were used to make adjustments accounting for the potential that some combinations of technologies may result in CO_2 reductions less than that indicated by the calculated weighted average. The dis-synergy factor applied to the 2021 weighted average was 0.75. The dis-synergy factor applied to the 2024 and 2027 weighted averages was 0.85.

TABLE II–6—PROJECTED TRACTOR ENGINE TECHNOLOGIES AND REDUCTION

SET mode	SET weighted reduction (%) 2020–2027	Market penetration (2021) %	Market penetration (2024) %	Market penetration (2027) %
Turbo compound with clutch	1.8	5	10	10
WHR (Rankine cycle)	3.6	1	5	15
Parasitic/Friction (Cyl Kits, pumps, FIE), lubrication	1.4	45	95	100
Aftertreatment (lower dP)	0.6	45	95	100
EGR/Intake & exhaust manifolds/Turbo/VVT/Ports	1.1	45	95	100
Combustion/FI/Control	1.1	45	95	100
Downsizing	0.3	10	20	30
Weighted reduction (%)	....	1.5	3.7	4.2

CARB staff urges U.S. EPA and NHTSA to increase the stringency of the standards in consideration of the following concerns:

The estimated emission reductions used as the basis of Alternative 3 are overly conservative. A number of sources lead CARB to conclude that the SET weighted reductions that serve as the basis of the preferred Alternative 3 standards should be made more stringent, as listed below:

- The estimated emission benefits of the Phase 2 engine standards from a 2010 baseline engine are significantly less than the potential cited in a number of published technical assessments. There are a number of published studies that estimated the potential reduction from the application of engine technologies on

2010 and pre-2010 engine technologies, and the estimated emission benefits of the Phase 2 engine standards from a 2010 baseline engine are significantly less than the potential cited in these assessments. The GHG emission rate of a 2010 baseline engine, 490 g/bhp-hr, was defined by U.S. EPA and NHTSA when developing the Phase 1 tractor engine standard. The proposed Phase 2 tractor engine standard for 2027 is 441 g/bhp-hr and represents a 10 percent reduction from a 2010 baseline engine, which is much less than what has been estimated as technically feasible in the following reports.

- CARB's recently released technology assessment for engine and vehicle efficiency estimates that tractor engines can achieve up to 34 percent reduction in fuel use/GHG emissions from a 2010 baseline through the application of fuel saving technologies within the Phase 2 timeframe.[14]
- U.S. Department of Energy's Supertruck Program demonstrated engine efficiency improvements up to 22 percent from a 2009 baseline engine. Technologies demonstrated included waste heat recovery (WHR) systems using the Rankine cycle.[15]
- At the 2013 Society of Automotive Engineers (SAE) Commercial Vehicle Engineering Congress, Donald W. Stanton, Cummins Inc., presented a lecture entitled, "Systematic Development of Highly Efficient and Clean Engines to Meet Future Commercial Vehicle Greenhouse Gas Regulations." Dr. Stanton estimated that over 20 percent reduction in GHG emissions is possible through the application of engine technologies in the Phase 2 timeframe.[16]
- The International Council on Clean Transportation (ICCT) research study on advanced tractor-trailer efficiency technologies estimated that up to 21.5 percent fuel consumption reduction from a 2010 baseline engine is possible in the 2020 to 2030 timeframe with the application of advanced engine technologies and WHR (Rankine).[17]

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[14] (CARB, 2015c) California Air Resources Board, "Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency," June 2015, <http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf>.

[15] (Delgado and Lutsey, 2014) Delgado, O., Lutsey, N., The U.S. SuperTruck Program: Expediting the development of advanced heavy-duty efficiency technologies, June 2014, <http://www.theicct.org/us-supertruck-program-expediting-development-advanced-hdv-efficiency-technologies>.

[16] (Stanton, 2013) Donald W. Stanton, "Systematic Development of Highly Efficient and Clean Engines to Meet Future Commercial Vehicle Greenhouse Gas Regulations," Cummins Inc., 2013 Society Automotive Engineers Commercial Vehicle Engineering Congress, 2013.

[17] (Delgado and Lutsey, 2015) Delgado, O., Lutsey, N., Advanced Tractor-Trailer Efficiency Technology Potential in the 2020 2030 Timeframe, April 2015, <http://www.theicct.org/us-tractor-trailer-efficiency-technology>

- The SET weighted reductions are overly conservative. Cummins and SwRI, have conducted independent technical analyses assessing the potential reductions resulting from the application of engine technologies. Both analyses assumed the baseline engine was a Phase 1 compliant engine. The Cummins analysis was over the SET certification cycle; the SwRI analysis was over the drive cycles used by GEM.
    - Cummins has indicated that tractor engines can achieve a 9 to 15 percent fuel savings from a 2017 baseline engine in the 2020 to 2030 timeframe.
    - Southwest Research Institute (SwRI) completed a study for NHTSA to inform the development of the Phase 2 standards that concluded that tractor engine fuel consumption could be reduced 4 to 10 percent from a baseline 2019 engine compliant with the Phase 1 standards.[18]

Two of the above referenced sources, Cummins and SwRI, provided specific information relating the potential reductions from a Phase 1 compliant engine over either the SET certification cycle or the drive cycles used by GEM. The information they provided and how it compares to the proposed tractor engine standard is discussed in further detail below.

Cummins

At the April 22, 2015, CARB Symposium on Phase 2 GHG Emission Standards for Heavy-Duty Vehicles, Dr. Wayne Eckerle, Vice President of Corporate Research and Technology for Cummins Inc., presented Cummins' perspective on the potential for reduction of CO_2 from tractor engines in the 2020 to 2030 timeframe. Dr. Eckerle stated that CO_2 emission reductions of 9 to 15 percent from a 2017 baseline engine are achievable through improvements in combustion and air handling, friction and parasitics, heat transfer management, and WHR (Rankine cycle). These reductions were estimated over the SET certification cycle using the current mode weightings. The SET weighted reductions from Table II-6 for a tractor engine that employs WHR in the 2020 to 2027 timeframe are presented in Table 1. The total reduction of CO_2 emissions from the application of the suite of technologies is 6.7 percent. This includes the application of a dis-synergy factor of 0.85. WHR (Rankine cycle) was included since the Cummins engine employs that technology. Turbocompounding was not included

[18] (Reinhart, 2015) Reinhart, T., Commercial Medium- and Heavy-Duty Truck Fuel Efficiency Technology Study – Report #2. Draft, <http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Draft-SwRI-MDHD-FE-TechReport2_DocketVersion.pdf>.

since it is unlikely that a manufacturer would install two WHR technologies on the same engine.

Table 1: SET Weighted Tractor Engine Emission Reductions from Suite of Technologies under Proposed Phase 2 Stringency (U.S. EPA & NHTSA)

Technology	**SET weighted reduction 2020-2027**
WHR (Rankine cycle)	3.6%
Parasitic/Friction, lubrication	1.4%
Aftertreatment (lower dP)	0.6%
Exhaust Gas Recirculation (EGR)/Intake & exhaust manifolds/Turbo/Variable Valve Train (VVT)/Ports	1.1%
Combustion/FI/Control	1.1%
Downsizing	0.3%
TOTAL	6.7%

The 6.7 percent reduction represents the projected emission reduction from a single tractor engine that uses WHR (Rankine cycle) and not turbocompounding. The 4.2 percent reduction for MY 2027 (Table II-6 in the NPRM) represents the percent emission reduction from a fleet of tractor engines taking into account the projected market penetration of each technology. CARB staff believes comparing the 6.7 percent reduction to the 9 to 15 percent reduction represents an “apples-to-apples” comparison of what U.S EPA and NHTSA, and Cummins believe is achievable in the 2020 to 2030 timeframe. So it is clear that U.S. EPA and NHTSA’s 6.7 percent is much lower than what Cummins has publicly stated is achievable in the Phase 2 timeframe.

Outside of WHR (Rankine cycle), Cummins has not published any information regarding the percent reduction potential associated with the individual engine technologies that contribute to the total 9 to 15 percent reduction estimate. Regarding WHR (Rankine cycle), Cummins estimates that a 4 to 5 percent emission reduction is achievable in the 2020 timeframe. Cummins is currently in its fourth generation WHR (Rankine cycle) system design and plans to implement end-user testing by late 2015, and has stated that production of a WHR (Rankine cycle) is possible by 2020.

Given the information provided by Cummins regarding the potential for CO_2 emission reductions, CARB staff strongly urges U.S. EPA and NHTSA to reevaluate the projected SET weighted reductions it used to determine the proposed tractor engine standards. Comparing the 3.6 percent reduction U.S. EPA and NHTSA projected for WHR (Rankine cycle) to the Cummins estimate of 4 to 5 percent, and U.S. EPA's overall percent reduction of 6.7 percent to the Cummins estimate of 9 to 15 percent, suggests that the proposed SET weighted reductions in the 2020-2027 timeframe are overly conservative and should be made more stringent.

SwRI Report

To inform the development of the Phase 2 standard, the SwRI conducted research assessing the effectiveness of potential GHG emission reducing technologies for the Phase 2 timeframe. Engine models were created and calibrated using available experimental data. Each engine model was exercised over five cycles that included the three Phase 1 GEM cycles, i.e., 55 miles per hour (mph) steady-state cruise, 65 mph steady-state cruise, and the CARB urban cycle.

Based on the technologies studied, SwRI concluded that there is the potential to improve long-haul truck engine fuel consumption and GHG emissions by 8 to 10 percent over the Phase 1 baseline. This would require the use of WHR (Rankine cycle). The study also indicated that fuel savings and GHG emissions using friction reduction and down speeding could result in reductions in the 4 to 7 percent range.

To more directly compare the results of the SwRI study to the proposed Phase 2 engine standards, staff compared the SET weighted reductions assumed by U.S. EPA and NHTSA in setting the engine standard (as shown in Table 1), to the SwRI simulation results from the drive cycles used in GEM. Staff believes directly comparing the percent reduction from the SET to the percent reduction from the weighted GEM cycles is appropriate since U.S. EPA and NHTSA concluded that tractor engine technologies will improve engines and tractors proportionally, even though the separate engine and vehicle certification test procedures have different duty cycles (page 40199 of the NPRM). Table 2 shows the simulation results for two technology packages modeled in the SwRI study. Technology package 1 (referred to as "DD15 Technology Package 2" in the SwRI report) includes aggressive friction reduction and downspeeding, but does not include WHR (Rankine cycle). Technology package 2 (referred to as DD15 Technology Package 3f in the SwRI report) includes technology package 1 with WHR (Rankine cycle). These simulation results were estimated using the same three test cycles used in GEM. Staff then weighted the results in accordance with the GEM drive cycle weightings for sleeper-cab tractor trailers and day-cab tractor-trailers, as shown in Table 3. The percent reductions represent the reductions from a Phase 1 compliant baseline engine at 100 percent payload (46,040 lbs).

Table 2: SwRI Study: Percent GHG Emission Reductions from Engine Technologies

Technology Combination	Test Cycle		
	CARB	**55 MPH**	**65 MPH**
Tech Package 1 (No WHR)	6.6%	4.4%	4.9%
Tech Package 2 (with WHR)	6.6%	10%	11%

Table 3: SwRI Percent GHG Emission Reductions Weighted in Accordance with the Phase 2 GEM Drive Cycle Weightings

Technology Combination	Sleeper-cab (5% CARB/ 9% 55/ 86% 65)	Day-cab (19% CARB/ 17% 55/ 64% 65)
Tech Package 1 (No WHR)	4.9%	5.1%
Tech Package 2 (with WHR)	10.7%	10.0%

As shown in Table 3, based on the SwRI study, the percent reduction in GHG emissions is estimated to range from 10.0 to 10.7 percent with WHR (Rankine cycle) and 4.9 to 5.1 percent without it. Comparing this to U.S. EPA and NHTSA's overall percent reduction of 6.7 percent with WHR (Rankine cycle) and 3.8 percent without WHR (Rankine cycle) suggests that the proposed SET weighted reductions in the 2020-2027 timeframe are overly conservative and should be made more stringent.

<u>The dis-synergy factors used to establish the final standards are unnecessary given the conservative nature of the proposed standards.</u>

U.S. EPA and NHTSA applied dis-synergy factors of 0.75 for MY 2021 and 0.85 for MYs 2024 and 2027. These factors are based on U.S. EPA and NHTSA staff's engineering judgment and are meant to account for the potential dis-synergy of engine technologies. For example, friction reduction technologies reduce waste heat produced by the engine. This, in turn, could reduce the effectiveness of WHR (Rankine cycle) to some degree. The dis-synergy factor is intended account for this loss of effectiveness. CARB staff understands the rationale behind the application of dis-synergy factors, but believes they are unnecessary given 1) the conservativeness of the SET weighted reductions that serve as the basis for preferred Alternative 3 standards and 2) the equation[19] used to calculate the benefit of multiple combined technologies does not simply add the percent effectiveness of each technology, but accounts for the interaction between technologies and potential loss of effectiveness.as technologies are combined. As noted previously, Cummins stated that CO_2 emission reductions of 9 to 15 percent from a 2017 baseline engine are achievable. The 9 to 15 percent estimate incorporates the anticipated dis-synergy when combining engine technologies. Removing the application 0.85 dis-synergy factor from U.S. EPA and NHTSA's calculation of the 2027 standard would raise the percent reduction of the standard from 4.2 percent to 4.8 percent. This is much less then what CARB believes is achievable, but would be a step in the right direction.

Suggested Tractor Engine Stringency

In consideration of the information presented above and additional information as noted below, CARB recommends U.S. EPA and NHTSA reevaluate the stringency of the tractor engine standards for preferred Alternative 3. Specifically, CARB suggests U.S. EPA and NHTSA make the following changes to the assumptions used in setting the standards:

- Increase the percent reduction associated with "Parasitic/friction, lubrication" from 1.4 percent to 3.3 percent. Parasitic/friction, lubrication improvements were included in the technology package 1 discussed above. The SwRI study also evaluated the benefit of these improvements separately (referred to as DD15 Technology Package 1 in the SwRI report). The GEM drive cycle weighted average of the SwRI results ranged from 3.2 percent benefit for sleeper-cab tractor trailers to 3.4 for day-cab tractor-trailers.
- Remove the dis-synergy factor from standard setting calculation.
- Increase the 2024 penetration rate assumptions to those proposed in 2027. This more aggressive implementation schedule is consistent with our

[19] $\%GHG\ reduction_{package}=100[1-(1-\{\%GHG_{tech\ 1}/100\})(1-\{\%GHG_{tech\ 2}/100\})\ldots(1-\{\%GHG_{tech\ N}/100\})]$

recommendation to adopt the Alternative 4 implementation schedule for all engine and vehicle categories.

- Combine the WHR turbocompounding and Rankine cycle categories into one WHR category and increase the percent reduction associated with WHR to 4.5 percent. CARB staff is suggesting that for standard setting purposes the WHR SET reduction should reflect the percent reduction potential from the most effective technology, which would be 4.5 percent from WHR (Rankine cycle). The market penetration values used to set the standard would be the combined existing Alternative 3 percentages for turbocompounding and Rankine cycle technologies. Thus the market penetration for the engines that are projected to utilize WHR systems (either turbocompounding or Rankine cycle) remains unchanged from the original U.S. EPA proposal. But, the higher SET reduction associated with WHR would drive more to install WHR Rankine cycle systems. CARB is confident that manufacturers will have WHR Rankine cycle systems tested and production-ready to meet the MY 2024 standard. WHR Rankine cycle technology was developed and implemented as part of the Supertruck program. A fourth generation design of this technology is currently being developed for tractor applications by Cummins. End-user testing of this system is planned for late 2015. Production is possible as early as 2020. This should be be sufficient leadtime to develop reliable and compliant engines for MY 2024.

Table 4 below illustrates the impact the suggested changes would have on the stringency of the proposed tractor engine standards.

Table 4: Projected Market Penetration of the Proposed Tractor Engine Technologies

Technology	SET Weighted reduction	Market Penetration (2021)	Market Penetration (2024)	Market Penetration (2027)
WHR System (combination of Rankine cycle and Turbocompounding)	4.5%	6%	25%	Same as 2024 Standard
Parasitic/friction, lubrication	3.3%	45%	100%	
Aftertreatment (lower dP)	0.6%	45%	100%	
EGR/Intake and Exhaust manifolds/Turbo/VVT/Ports	1.1%	45%	100%	

Technology	SET Weighted reduction	Market Penetration (2021)	Market Penetration (2024)	Market Penetration (2027)
Combustion/FI/Control	1.1%	45%	100%	
Downsizing	0.3%	10%	30%	
Weighted Reduction		**3.0%**	**7.1%**	

To summarize, as shown in Table 4, CARB recommends that when fully implemented, the tractor engine standard stringency should be increased from 4.2 percent to 7.1 percent, and that full implementation should happen three years earlier than indicated in the preferred Alternative 3, moved from 2027 to 2024. This more aggressive implementation schedule is consistent with our recommendation to adopt the Alternative 4 implementation schedule for all engine and vehicle categories.

<u>Impact of More Stringent Tractor Engine Standards on Alternative 4 Tractor Vehicle Standards</u>

If U.S. EPA and NHTSA adopt more stringent tractor engine standards, the corresponding tractor vehicle standards should also be made more stringent. Table 5 shows the fuel consumption reductions for the tractor engine and vehicle standards fully implemented by MY 2024. As discussed above we are suggesting that U.S. EPA and NHTSA adopt the Alternative 4 implementation schedule for tractor engine standards; the same holds true for tractor vehicle standards. Therefore, full implementation is shown as occurring by MY 2024 and not 2027 as prescribed by U.S. EPA and NHTSA's preferred Alternative 3.

Table 5: Projected Phase 2 Improvements for Tractors

	MY 2024 Tractor Engine Standard Reduction	MY 2024 Tractor Vehicle Standard Reduction
Proposed Standard % Reductions	4.2%	18%-24%
CARB Suggested More Stringent Standard % Reductions	7.1%	21%-27%

As shown, CARB is suggesting that U.S. EPA and NHTSA adopt more stringent tractor engine standards that would result in an additional 3 percent reduction when fully implemented by MY 2024. This would result in a corresponding additional 3 percent reduction in the tractor vehicle standard.

<u>Oppose/Requested Change Comment</u>

Affected Document(s): Phase 2 Proposed Rules

Affected Pages: 40197-40198

Comment - Feasibility of vocational vehicle engine standards

CARB staff strongly recommends strengthening the proposed vocational engine standard from the proposed 4.0 percent reduction in CO_2 emissions beyond Phase 1 to 4.3 percent. For compression ignition engines fitted into vocational vehicles, the NPRM proposes an engine standard that achieves 4.0 percent reduction in CO_2 emissions beyond the Phase 1 standard. This proposed engine standard was derived assuming certain SET weighted reductions for applicable technologies, along with a certain penetration for each technology. Table 6 shows the projected emission reductions from the SET weighted reductions for vocational engine technologies listed in the NPRM. Without accounting for penetration, the vocational engine reductions amount to a 6.0 percent improvement for MY 2027 (in other words, 6.0 percent reduction could be achieved if the described technologies had penetration of 100 percent; with the technology penetrations assumed, the technologies' 6.0 percent potential improvement achieves an overall 4.0 percent reduction for vocational compression-ignition engines in total). Cummins, the largest manufacturer of heavy-duty truck engines, has publically stated a vocational engine emission improvement of 5 to 11 percent in the Phase 2 timeframe is feasible. U.S. EPA and NHTSA are currently proposing a vocational engine standard consistent with the lowest end of Cummins' projections.

In addition, in deriving the proposed standard, U.S. EPA and NHTSA applied a dis-synergy factor of 0.85. CARB staff does not believe that the dis-synergy factor adjustment is necessary for two reasons. One, manufacturers already account for dissynergistic effects between various technologies when predicting future engine improvements. Therefore, U.S. EPA is, in essence, double discounting when applying in their own dis-synergy factor. Two, the proposed vocational engine standard for vocational engines is already conservative; therefore, CARB staff believes the application of a dis-synergy factor is unnecessary. CARB staff strongly urges U.S. EPA and NHTSA to improve the vocational engine standard. Overall, CARB staff believes that the proposed Phase 2 emission standard for vocational vehicles under both Alternative 3 and Alternative 4 is overly conservative and leaves emission benefits “on the table.”

Table 6: SET Weighted Reductions from Vocational Engine Suite of Technologies (U.S. EPA & NHTSA)

Technology	SET weighted reduction 2020-2027
Model based control [20]	2.0%
Parasitic Friction	1.5%
EGR/Air/VVT/Turbo[21]	1.0%
Improved Aftertreatment	0.5%
Improved Combustion	1.0%
TOTAL	6.0%

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected Document(s): Phase 2 Proposed Rules

Affected Pages: 40192

Comment - Proposed reweighting of SET modes

The NPRM requests comment on the reweighting of SET modes. CARB staff agrees with U.S. EPA and NHTSA that the current 23 percent weighting of “C Speed” in the SET Cycle will not adequately represent typically real world driving conditions seen in future heavy-duty applications. Therefore, CARB staff supports the reweighting of the SET cycle as proposed to increase the importance of the A Speed engine applications, while decreasing the application of C Speed engine modes.

[20] See page 40195 of the NPRM for more details of the technology
[21] See page 40195 to 40196 of the NPRM for more details of the technology

Class 7 and 8 Combination Tractor Vehicle Standards

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40211, 40236-40241

Comment – CARB strongly prefers proposed Alternative 4 Phase 2 Heavy-Duty Combination Tractor Emission Standards

The NPRM requests comments on the proposed alternatives, with special interest in Alternatives 3 and 4. In total, the NPRM considers five alternatives as summarized in Table II-22 of the NPRM, shown below:

TABLE III–22—SUMMARY OF ALTERNATIVES CONSIDERED FOR THE PROPOSED RULEMAKING

Alternative 1	No action alternative
Alternative 2	Less Stringent than the Proposed Alternative applying off-the-shelf technologies.
Alternative 3 (Proposed Alternative)	Proposed Alternative fully phased-in by 2027 MY.
Alternative 4	Alternative that pulls ahead the proposed 2027 MY standards to 2024 MY.
Alternative 5	Alternative based on very high market adoption of advanced technologies.

For tractors as with all vehicle categories, Alternative 1 is the no action alternative. Alternative 2 would base the standards on the application of off-the-shelf technologies, which is the same approach taken in Phase 1. Alternative 3 is U.S. EPA and NHTSA's preferred alternative. Alternative 4 is identical in stringency to Alternative 3, but its implementation schedule is accelerated by three years (i.e., from 2027 to 2024). Alternative 5 is the most aggressive alternative, requiring the highest market adoption rate of more advanced technologies amongst the five alternatives. CARB strongly prefers Alternative 4 standards over Alternative 3 standards over all vehicle categories including tractors.

For a compliant Phase 2 tractor, U.S. EPA and NHTSA estimate that Alternative 3 standards would achieve up to 24 percent reduction in CO_2 emissions compared to a Phase 1 tractor at a cost of approximately $13,000 per vehicle. Alternative 4 achieves the same percent reduction in CO_2 emissions and fuel consumption compared to a Phase 1 tractor, but does it three years earlier, at a per vehicle cost of approximately $14,000 per vehicle (i.e., $1,000 more per vehicle than Alternative 3).

Alternative 4 is technologically feasible and will result in more emission and fuel consumption reductions from heavy-duty tractors in MYs 2021 through 2026. The increased cost due to the accelerated implementation is minimal – about $1,000 per vehicle as estimated by U.S. EPA and NHTSA. The improved fuel efficiencies resulting from either alternative would decrease fuel use, which equates to fuel savings that would eventually offset the upfront cost of the required technologies. U.S. EPA and NHTSA estimate the payback period for tractor and trailers for both Alternative 3 and 4 is similar at about 2 years.

When looking more broadly at not only tractors, but also tractor engines and the trailers they pull, Alternative 4 achieves greater emission benefits and greater net societal benefits, than Alternative 3. As summarized in Table 7, Alternative 4 for tractors, tractor engines, and trailers would cumulatively achieve 75.7 more MMT CO_2 reductions nationally than Alternative 3 for MYs 2018 through 2029 vehicles. This additional reduction would occur with a $16.7 billion greater net benefit in the U.S.

Table 7: Tractor-Trailer Alternative 3 and 4 Comparison (U.S. Benefits through MY 2029)

	Alternative 3	Alternative 4	Difference
CO_2 reduction [MMT]	816.4	892.1	75.7
Net Social Benefit [$billion]	202.0	218.7	16.7

(from the NPRM, Tables X-1 and X-5, 3% discount rate, baseline 1a)

In addition, the increases in tractor engine technology application rates from Alternative 3 to Alternative 4 are not overly aggressive and should not negatively impact reliability. The Alternative 3 and Alternative 4 standards are based on the application of the same emission control technologies. The difference between the two standards is the assumed adoption rate of each technology in 2024. Table 8 shows the Alternative 3 and Alternative 4 adoption rates for the standard setting tractor engine technologies.

Table 8: Comparison of Alternative 3 and Alternative 4 2024 Technology Penetration Rates for Tractor Engines

Technology	Alternative 3 Market Penetration in 2024	Alternative 4 Market Penetration in 2024
Turbocompounding with clutch	10%	10%
WHR (Rankine cycle)	5%	15%
Parasitic/Friction	95%	100%
Aftertreatment	95%	100%
EGR/Intake and exhaust manifolds/Turbo/VVT/Ports	95%	100%
Combustion Control	95%	100%
Downsizing	20%	30%

As shown in Table 8, there is no increase in market penetration for turbocompunding, and only a 5 percent increase for parasitic and friction reduction, aftertreatment improvements, EGR and Intake improvements, and combustion control. CARB staff does not believe an additional 5 percent increase in market penetration – from 95 percent to 100 percent - should result in any additional reliability concerns amongst engine manufacturers. Further, the Alternative 3 2024 market penetration rate for WHR was only 5 percent. A fourth generation design WHR system is currently being developed for tractor applications by Cummins. End-user testing of this system is planned for late 2015. Production is possible as early as 2020. This should be sufficient leadtime to develop reliable and compliant engines.

The tractor vehicle technologies used to set the tractor standards varied by class of tractor (class 7/8), type of tractor cab (day cab or sleeper cab), and height of roof (low roof, mid roof or high roof). Table 9 shows the Alternative 3 and Alternative 4 technology adoption rates for class 8 high roof sleeper cab tractors. The conclusions drawn from comparing these adoption rates of these tractors can be applied to all tractor types addressed by the standards.

Table 9: Comparison of Alternative 3 and Alternative 4 2024 Technology Penetration Rates for Class 8 Sleeper Cab Tractors

Technology	Alternative 3 Market Penetration in 2024	Alternative 4 Market Penetration in 2024
	Aerodynamics	
Bin I	0%	0%
Bin II	0%	0%
Bin III	30%	20%
Bin IV	30%	20%
Bin V	25%	35%
Bin VI	13%	20%
Bin VII	2%	5%
	Steer Tires	
Base	5%	5%
Level 1	50%	20%
Level 2	30%	50%
Level 3	15%	25%
	Drive tires	
Base	5%	5%
Level 1	50%	20%
Level 2	30%	50%
Level 3	15%	25%
	Extended Idle Reduction	
APU	90%	90%
	Transmission Type	
Manual	20%	10%
AMT	50%	50%
Auto	20%	30%
Dual Clutch	10%	10%
	Driveline	
Axle Lubricant	40%	40%
6x2 or 4x2 Axle	60%	60%
Downspeed	40%	60%
Direct Drive	50%	50%
	Accesory Improvements	
A/C	20%	30%

Technology	Alternative 3 Market Penetration in 2024	Alternative 4 Market Penetration in 2024
Electric Access	20%	30%
	Other Technologies	
Predictive Cruise	40%	40%
ATIS	40%	40%

As shown in Table 9, there is no increase in market penetration between Alternative 3 and Alternative 4 for extended idle reduction, predictive cruise control, automatic tire inflation systems (ATIS), axle lubricant technologies, 6x2 axle or 4x2 axle technologies, direct drive technologies, and dual clutch transmissions .

The market penetration rates for aerodynamic technologies and low rolling resistance (LRR) tires show a decrease in the penetration rates for technologies that are equivalent to SmartWay and SmartWay Elite technologies and a higher penetration of more advanced aerodynamic treatments and LRR tire materials and designs. Currently, aerodynamic technologies are dominated by existing, widely-used fairings and more aerodynamic shapes of the tractor body itself. Bin II represents currently available SmartWay aerodynamic technologies. Bin V through VII tractors incorporate more advanced technologies which are currently in the prototype stage of development, such as advanced gap reduction, rearview cameras to replace mirrors, wheel system streamlining, and advanced body designs. To the extent that these advanced designs use existing technologies in new and innovative ways (i.e., rearview cameras) concerns over reliabilty are minimal. For the steer and drive tire technologies, level 1 represents rolling resistance equivalent to today's SmartWay tires. Level 2 represents the best in class rolling resistance tires available today. Level 3 represents a 25 percent improvement over level 2 which should be achievable in the 2024 timeframe. Should more complex systems or advanced materials require more reliability testing prior to MY 2024 tractor production date deadlines, higher applications of one or more of the other proven technologies from the other categories (i.e., level 2 LRR tires, predictive cruise, ATIS, etc.) can be used to meet the 2024 Alternative 4 standards.

For transmissions, the market penetrations decrease for manual transmissions and increase for automatic transmissions when comparing Alternative 3 to Alternative 4. This change is reflected in the increase in the application of downspeeding, since advanced transmissions enable downspeeding. With the exception of dual clutch transmission technology, automated manual transmission and automatic transmission technology is mature and should not result in reliability concerns associated with its application in MY 2024 tractors.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40217

Comment – Extended idle reduction approach to day cab tractors

The NPRM requests comment on the applicability of the idle test cycle to day cab tractors.

Day cab tractors often idle while cargo is loaded or unloaded, as well as during the frequent stops that are inherent with driving in urban traffic conditions near cargo destinations. To recognize idle reduction technologies that reduce workday idling, U.S. EPA and NHTSA have developed a new idle-only duty cycle that is proposed to be used in GEM for vocational vehicles only, because these types of vehicles spend more time at idle than tractors. However, U.S. EPA and NHTSA request comment on whether they should extend this vocational vehicle idle reduction approach to day cab tractors.

CARB staff believes U.S. EPA and NHTSA should extend the idle provision to day cab tractors. Currently, limited numbers of specific types of day-cab tractors (e.g., low-roof bottle delivery tractors) may be reclassified as vocational tractors. These reclassified tractors can take advantage of the vocational vehicle idle reduction approach. See 40 CFR 1037.630. By extending the workday idle provisions to all day-cab tractors, manufacturers would have some incentive to install neutral idle or stop-start systems on mid-roof and high roof day-cabs. Although the first user may not see significant emission reductions from these technologies, many of the high roof and mid roof day cab tractors are used in port and drayage applications in their second life – where start-stop and neutral idle technologies could result in significant emission reductions as these trucks travel in and out of ports and rail yard facilities.

Extending the idle provision to day cab tractors would require U.S. EPA and NHTSA to set a fixed GEM composite cycle weighting factor at a value representative of the time spent at idle for a typical day cab tractor. For vocational vehicles in the regional category, the idle cycle weighting factor is 10 percent. U.S. EPA and NHTSA suggest 5 percent may be the appropriate value. Initial reaction is that the factor will probably be between 5 and 10 percent. CARB staff would like to work with U.S. EPA and NHTSA staff to determine the appropriate value for the day cab factor.

Vocational Vehicle Standards

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40304

Comment - Emission credits for electrified accessories for vocational vehicles

U.S. EPA and NHTSA have not included electrified accessories as a component of the GEM model for vocational vehicles and instead propose to only allow manufacturers to apply for off-cycle credits for the technology. CARB staff sees electrified accessories as a viable technology to improve emissions in the vocational sector and believes it should be included in the overall stringency standards and GEM model. As stated in the NPRM, electrified accessories can result in a 2 to 4 percent fuel consumption benefit in vocational applications. CARB's recently released report on heavy-duty drivetrain and vehicle efficiency[22] backs these findings up, suggesting a 1 to 3 percent benefit from electrified accessories. This technology is feasible as it has already been demonstrated in various applications. With the long lead time of the Phase 2 regulation, CARB staff believes that the production volumes for electrified accessories can substantially increase if pushed by regulatory action, raising the production volumes and significantly lowering the costs, which will make this technology a cost-effective approach to reduce CO_2 emissions.

U.S. EPA and NHTSA are proposing vocational stringencies of 16 percent fuel consumption improvement by 2027. Electrified accessories could allow the proposed stringencies to be significantly tightened in certain vocational applications and should be included in the final rule. By only allowing off-cycle credits for electrified accessories, U.S. EPA and NHTSA are leaving out fuel reduction benefits from a technology that will be readily available in the Phase 2 timeframe.

[22] (CARB, 2015c) California Air resources Board, "Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency," June 2015, <http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf>.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules; Draft Regulatory Impact Analysis: Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles - Phase 2 Proposed Rule (RIA)

Affected pages: NPRM 40253, 40159, 40331, 40300-4; RIA 11-59 to 11-61

Comment – Current and future status of all BEV; standards should assume some use of all EVs

In the NPRM, U.S. EPA and NHTSA confirm that BEVs have advantages over their conventionally-fueled counterparts in terms of efficiency, torque, regenerative braking opportunities, and low noise characteristics, but also notes that they are limited by weight, range, and cost. Because of the high cost and developing nature of this technology, U.S. EPA and NHTSA do not project that fully electric vocational vehicles will be widely commercially available in the time frame of the proposed rules, and the proposed standards are not based on any level of adoption of this technology. Yet U.S. EPA and NHTSA do indeed project some use of these technologies as is noted "While the agencies have not premised the proposed Heavy-Duty Phase 2 tractor standards on hybrid powertrains, FCEVs, or BEVs, we also foresee some limited use of these technologies in 2021 and beyond." (page 40253 of the NPRM) In acknowledging the projected use of BEVs but not including their use in setting appropriate emission standards, U.S. EPA is leaving potential emission benefits on the table. CARB staff believes that the GHG standards should incorporate limited penetration rates for these advanced technologies, particularly for vocational vehicles.

While CARB staff agrees with U.S. EPA and NHTSA's assessment of the advantages and limitations of current medium- and heavy-duty EVs, CARB staff is significantly more optimistic about the potential penetration of BEVs into the market during the Phase 2 timeframe. CARB staff believes that the current status of heavy-duty zero-emission vehicles is more advanced than U.S. EPA and NHTSA project. In the NPRM, U.S. EPA and NHTSA state "[W]e have not found any all-electric heavy-duty vehicles that have certified by 2014. As we look into the future, we project very limited adoption of all-EVs into the market." (page 40159 of the NPRM) "In our assessment, we have observed that the few all-electric heavy duty vocational vehicles that have been certified are being produced in very small volumes in MY2014." (page 40331 of the NPRM) "[T]he agencies do not project fully electric vocational vehicles to be widely commercially available in the time frame of the proposed rules. For this reason, the agencies have not based the proposed Phase 2 standards on adoption of full-electric vocational vehicles." (page 40304 of the NPRM) CARB staff believes these assessments are not as optimistic as the status of the technology indicates.

In our medium- and heavy-duty BEV technology assessment, CARB staff investigated the current status of the technology. We specifically looked at transit bus applications, school bus applications, medium-duty trucks and shuttle buses (8,501-14,000 lbs GVWR and heavy-duty trucks (>14,000 lbs GVWR). We found that battery all-electric transit buses are commercially available, with over 2,600 of battery all-electric buses worldwide. New orders are placed regularly. Urban transit buses are an ideal application for battery all-electric heavy-duty vehicles because they operate on fixed routes of normally short distances, perform frequent stop and start driving which is needed for regenerative braking, maintain low average speeds which helps to preserve the battery power, and return to a general base or facility at the end of the day which enables overnight charging. Electric transit buses are currently available from BYD, New Flyer, and Proterra, while Nova's new electric bus model is in demonstration. CARB is developing advanced transit fleet requirements, which will be predicated on the widespread use of electric transit buses. CARB staff believes that the Phase 2 GHG standards should assume the penetration of electric transit buses into the nationwide fleet.

School buses are not yet as commercially available as transit buses. The TransTech SSTe type A school bus is available for purchase, however, and Lion, a Canadian company, has recently released the eLion type C school bus. Electric school buses have the potential for significant market penetration in the next 5 to 10 years, well within the timeframe of the Phase 2 GHG regulations. CARB has funded three electric school bus demonstrations to date, starting in fiscal year 2011/12 and those projects have been completed, with buses now transporting children daily. The final reports from these projects are posted on CARB's Air Quality Improvement Program (AQIP) Advanced Technology Demonstration Project webpage at: http://www.arb.ca.gov/msprog/aqip/demo.htm.

There are hundreds of BEVs in the medium-duty (8,501-14,000 lbs GVWR) vocational category already operating on California's roads; such vehicles are in the early commercialization stage. Vehicles in this category are being utilized in an optimal duty cycle for BEVs, urban delivery, and have CARB incentives to promote adoption. For example, to reduce the incremental costs of zero-emission vehicles, CARB has been providing financial incentives to fleets statewide through programs such as California's Hybrid and Zero-Emission Truck and Bus Voucher Incentives Project (HVIP). Since HVIP's launch in 2010, CARB has provided over $10 million to funding nearly 400 heavy-duty BEVs.[23] CARB staff expects widespread penetration of BEVs into some parts of the market place in the next 5 to 10 years. Therefore, CARB staff believes it would be appropriate to assume some market penetration of BEVs in this class in the timeframe of the Phase 2 GHG regulations.

Expanding BEV technology into additional applications in the heavy-duty truck segment (other than buses) will require further developments in battery technology and lower vehicle component costs overall. It is not expected that BEVs will penetrate into the long-haul trucking market in the next several decades without significant advances in battery energy density and BEV recharging technologies. CARB staff agrees it is reasonable to presume no significant market penetration in the regulatory timeframe for long haul class 7 and 8 tractors. There are electric drayage trucks in demonstration phases, as well as electric refuse trucks, but CARB staff agrees it is likely that commercial BEV penetration in these applications will be limited during the next decade.

However, CARB staff believes it is appropriate to push technology development. Electric vocational vehicles have been demonstrated effectively; stringent emission requirements would further promote their use. CARB staff encourages U.S. EPA and NHTSA to continue to evaluate appropriate different technologies and approaches that can achieve substantial emission reductions. Over the past decade, heavy duty fleets have made substantial investments to adopt modern, lower-emitting vehicles. Today, as noted above, zero-emission vehicles such as battery electric and fuel cell electric buses are in the early commercialization phase. Demonstrations are underway across the State in a wide array of heavy-duty applications including drayage trucks, delivery trucks, and school buses. State incentives are in place that are encouraging the development and adoption of these technologies, increasing production volumes, fostering innovation, and reducing costs. For more information, please see CARB's battery and fuel cell electric technology assessment that is currently in development and will be posted at http://www.arb.ca.gov/msprog/tech/report.htm when available.

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[23] California Air Resources Board, "Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project." See http://www.arb.ca.gov/msprog/aqip/hvip.htm.

While CARB staff acknowledges that the present populations of medium- and heavy-duty vocational BEVs are low, these numbers are expected to increase significantly in the Phase 2 timeframe. For example, CARB staff plans to propose purchase zero-emission requirements for last-mile delivery vehicles in 2020, which will significantly increase demand for these vehicles. Yet U.S. EPA and NHTSA's proposed emission standards are not based on the inclusion of any zero-emission vehicles under either Alternative 3 or the more accelerated Alternative 4. To assume no penetration in the selected Alternative does not reflect market trends and results in a loss of potential GHG emission reductions by setting the emission standard less stringent than would be appropriate with the inclusion of these vehicles. CARB staff notes that even with the higher upfront capital cost of EVs, the anticipated savings in operation and maintenance costs allows payback of the initial investment and significant market penetration for medium- and heavy-duty vehicles operating in an "optimum" BEV duty cycle (defined routes, lots of starts and stops, high idle time, and lower average speeds) can occur in the Phase 2 timeframe. Therefore, CARB staff recommends that U.S. EPA and NHTSA set emission standards that are based on the inclusion of an electric vocational vehicle penetration rate of at least 1 percent, which is a third of the rate projected for Alternative 5 in the NPRM.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40308

Comment - Vocational vehicle stringency across subcategories

CARB staff recommends that U.S. EPA and NHTSA re-examine the weighting procedure used to set equivalent standards for the three subcategories of vocational vehicles in the NPRM. CARB staff agrees it is important to set the standards so manufacturers do not have an incentive to purposely "misclassify" their vehicles. However, CARB staff is concerned that the method described on page 40308 of the NPRM may inadvertently present just such an incentive.

In the example on page 40308, the NPRM explains that for one technology that would provide a 5 percent benefit for regional vehicles, 7 percent for multipurpose vehicles, and 8 percent for urban vehicles, when setting the proposed standards, they weighted the reductions and assumed 6.6 percent benefit for all three subcategories. CARB staff is concerned that a manufacturer using such a technology would have an incentive to classify their vehicle as urban (to show an 8 percent benefit) even if their vehicle actually would fit more appropriately in the regional or multipurpose subcategories (where the device would show only a 5 to 7 percent benefit). CARB staff encourages U.S. EPA and NHTSA to re-examine whether it may be more appropriate to set differing standards for the differing vocational vehicle subcategories, to remove this potential incentive for misclassification.

Oppose/Requested Change Comments

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40295

Comment - Feasibility of proposed vocational vehicle stringency standards

CARB staff recommends that Alternative 4 be chosen, with the regulation proposing standards out to MY 2024 vehicles. CARB staff believes the proposed rule in its current framework is conservative and leaves obtainable emission benefits on the table. CARB staff does not believe that the current stringencies require the additional three years of lead time that is proposed in Alternate 3. Multiple manufacturers have made it clear to CARB staff that the proposed stringencies can easily be met in the MY 2024 compliance time frame. In the current Alternative 3 framework, most technologies do not see significant changes in penetration from MY 2024 to MY 2027. CARB staff notes that stop-start and transmission market penetrations are significantly affected by a switch from Alternative 3 to Alternative 4. However, these technologies are either already starting to penetrate the vocational marketplace or have prototypes and demonstrations in place as of today; therefore, CARB staff views the nine years of lead time until 2024 as ample time to meet the penetration goals that U.S. EPA and NHTSA have proposed.

CARB staff believes that Alternative 4 for vocational vehicles is feasible and superior to Alternative 3 for the following reasons:

- **Alternative 4 achieves greater emission benefits and greater net societal benefits than Alternative 3.** As summarized in Table 10 below, Alternative 4 for vocational vehicles would achieve 33.5 more total MMT CO_2 reductions and a $5.2 billion greater total societal benefit nationally through MY 2029.
- **The projected payback period for Alternative 4 is still acceptable and within the same year as the projected payback period for Alternative 3.**

Table 10: Heavy-Duty Vocational Vehicle Alternative 3 and 4 Comparison (U.S. Benefits through MY 2029)

	Alternative 3	Alternative 4	Difference
CO_2 reduction* [MMT]	110.3	143.8	33.5
Net Social Benefit [$billion]**	21.7	26.9	5.2

(*from the NPRM, Table X-5; **from the NPRM, Table X-1)

In addition to recommending the Alternative 4 timing for the final rule, CARB staff is also proposing that U.S. EPA and NHTSA strengthen the final vocational vehicle stringency standards of the proposed rule. As mentioned elsewhere in our comments, CARB staff notes that viable technologies such as regional/multipurpose vocational aerodynamics and electrified accessories should be included in the final rule stringency standards. Additionally, CARB staff proposes that the engine standard be strengthened (as previously discussed) by removing the dis-synergy factor and that a small percentage (1 to 2 percent) of zero-emission (battery electric and fuel cell electric) vehicles be required in the vocational marketplace. Table 11 breaks down the stringency changes that CARB staff recommends.

Table 11: CARB Staff's Recommended Additional Stringencies for Alternative 4

Technology	MY 2024 Percent CO_2 Benefit	Penetration
Regional Aerodynamics(*)	3.5%	90%
Multipurpose Aerodynamics(*)	1%	50%
Electrified Accessories	3.0%	50%
Improved Engine Standard(**)	4.3%	N/A
Zero-Emission Technology	100%	1%

* The NPRM divides vocational vehicles into 3 subcategories: urban, multipurpose, and regional. For this stringency calculation, each subcategory was estimated to account for 33 percent of vocational fleet.
** Removal of dis-synergy factor results in a 0.3 percent improvement in the engine standard. Penetration rates of various engine technologies already included in the 4.3 percent value.

Research done at NREL shows that improved aerodynamics on vocational vehicles can result in significant fuel consumption reductions as high as 8 percent during cruise cycles.[24] CARB staff recommends that a value of 3.5 percent be included in the vehicle stringency for regional vocational vehicles and 1 percent for multipurpose vocational vehicles due to aerodynamic devices. These values are in line with the observed fuel consumption benefit that front fairings and skirts achieved on the Urban Dynamometer Driving Schedule (UDDS) test cycle and CARB staff transient test during the NREL study, cycles similar to that of what Phase 2 proposes to use to simulate regional and multipurpose vocational vehicles, respectively. CARB staff notes that the vocational subcategory contains a vast range of regional and multipurpose vehicles and that while most regional vehicles will benefit from these technologies, not all vehicles (such as urban vocational) will be able to take advantage of the improved fuel efficiency of improved aerodynamics. Based on this fact and the research done at NREL, CARB staff believes that almost all regional vocational vehicles can benefit from aerodynamics, whereas only about half of the multipurpose subcategory can benefit from the aerodynamic devices, and is recommending penetration rates of 90 percent for regional vehicles and 50 percent for multipurpose vehicles. Vocational aerodynamic improvements are discussed further below under the comment entitled “Vocational aerodynamics: credit for aerodynamic devices on vocational box trucks.”

Electrified accessories can also reduce fuel consumption. The NPRM and CARB’s Technology Assessment[25] notes that electrified accessories can deliver a 1 to 3 percent fuel consumption benefit in vocational applications; however, U.S. EPA and NHTSA are currently only allowing off-cycle credits for this technology. As U.S. EPA and NHTSA’s Phase 1 rule did not consider electrified accessories either, this full 1 to 3 percent benefit can be obtained in the Phase 2 rulemaking. CARB staff recommends a fuel consumption benefit of 2 percent be applied to electrified accessories. CARB staff also notes that not every vocational application will be suited to best use this technology, therefore, CARB staff recommends a conservative penetration rate of 50 percent in the final MY stringency. An additional 0.3 percent emission benefit can be gained by removing the dis-synergy factor from the vocational engine standard. As stated in other comments, CARB staff believes the dis-synergy factor is unnecessary.

Furthermore, as noted previously, a 1 percent penetration for zero-emission vocational vehicles in 2024 is reasonable, given that, as detailed above, zero-emission vocational

[24] (NREL, 2015a) National Renewable Energy Laboratory, “Aerodynamic Drag Reduction Technologies Testing for Heavy-Duty Vocational Vehicles – Preliminary Results,” July 2015. See Attachment 1 for the Draft Report.
[25] (CARB, 2015c) California Air Resources Board, “Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency,” June 2015, <http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf>

vehicles are already on the road in California (9 years ahead of 2024), and all-electric transit buses and delivery vehicles are in the early commercialization stage. Given the long lead time of the Phase 2 regulation, CARB staff believes it is reasonable to include zero-emission advanced technology vehicles in setting the stringency of the standards.

The NPRM proposes an overall 16 percent CO_2 emission benefit for the final MY vocational vehicles. The additional stringencies recommended by CARB staff result in additional incremental CO_2 benefits of about 2.5 percent for vocational vehicles. CARB staff therefore recommends U.S. EPA and NHTSA pursue Alternative 4 with a final stringency level of approximately 18.5 percent for vocational vehicles.[26]

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40186-40187, 40303-40304; RIA 2-134 to 2-135

Comment – Vocational aerodynamics: credits for aerodynamic devices on vocational box trucks

The NPRM requests comment on the approach to provide credits for aerodynamic devices on vocational box trucks. The Phase 1 standards did not address the aerodynamic characteristics of vocational vehicles; instead, vocational vehicles were assumed in the GEM model to have default aerodynamic characteristics, and manufacturers did not have the opportunity to obtain credits for installation of aerodynamic devices on vocational vehicles. The Phase 2 proposal still includes only default aerodynamic characteristics for vocational vehicles in GEM, but does allow manufacturers to apply for credit for some aerodynamic improvements to some vocational vehicles.

CARB staff appreciates and supports U.S. EPA and NHTSA offering vocational aerodynamic credits to manufacturers in Phase 2; however, we recommend the proposed Phase 2 standards be modified to include actual aerodynamic characteristics for the vocational vehicles that travel most at high speeds (the regional and multipurpose subcategories), and we recommend aerodynamic improvements for these

[26] (CARB, 2015c) California Air Resources Board, “Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency,” June 2015, <http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf>
(NREL, 2015a) National Renewable Energy Laboratory Aerodynamic Drag Reduction Technologies Testing for Heavy-Duty Vocational Vehicles – Preliminary Results, July 2015. See Attachment 1 for the Draft Report.

vocational vehicles be included when setting the Phase 2 standards. CARB funded work to support Phase 2 development assessing various aerodynamic drag reduction technologies and proving their ability to reduce fuel consumption. Aerodynamic devices such as skirts and fairings are readily available in the marketplace for vocational vehicles; hence, there is no issue of technological feasibility. Not including potential aerodynamic improvements for these vocational vehicles, which spend much of their operation at high speeds where aerodynamics are important, represents a significant missed opportunity. As discussed further below, aerodynamic improvements to regional vocational vehicles could yield up to an 8 percent CO_2 and fuel consumption reduction on some duty cycles, and 6 percent in real world operation. Considering that U.S. EPA and NHTSA took into account improvements such as low friction axle lubricants that get only a 0.5 percent benefit when setting the proposed standards, it seems inappropriate to ignore potential aerodynamic improvements in standard setting.

If U.S. EPA and NHTSA are unwilling to modify the Phase 2 standards for regional and multipurpose vocational vehicles to include aerodynamic improvements, at a minimum, CARB staff recommends allowing generation of aerodynamic improvement credits more broadly than proposed. As the proposal is currently structured, such credits are allowed only in extremely narrow circumstances and CARB staff believes the credits would offer little if any incentive for manufacturers to actually pursue such aerodynamic improvements.

The discussion below provides information on the following topics:

- Availability of aerodynamic improvements for vocational vehicles;
- Data on potential fuel consumption reductions achievable via use of aerodynamic improvements;
- Potential additional Phase 2 GHG reductions if vocational aerodynamics were included; and
- Why vocational aerodynamic credits should be offered more broadly than proposed.

<u>Availability of aerodynamic improvements for vocational vehicles</u>

The aerodynamics of vocational vehicles can be improved either through changes to the shape of the vehicle during manufacture or through addition of aerodynamic devices such as skirts after manufacture.

As CARB staff has shared with U.S. EPA, at least one heavy-duty vocational truck manufacturer, Ford Motor Company (Ford), the second largest U.S. manufacturer of class 3 trucks, is interested in improving aerodynamics of vocational vehicles. Ford has investigated potential drag reduction and fuel consumption reduction achievable via improvements to some of their customers' vocational box trucks and has shared that data with U.S. EPA and CARB staff.

CARB staff also gathered information regarding aerodynamic devices and their applicability to vocational vehicles through literature reviews and stakeholder discussions. We contacted vocational aerodynamic technology manufacturers, including Deflecktor, Freightwing, Ridge Corporation, SOLUS, Vorblade, Wabash Composites, Air Flow Deflector, Nose Cone, Laydon Composites, Fleet Engineers, Transtex, etc. Most of them produce devices, specifically skirts, for use on trailers. However, many indicated their devices could be customized to fit on vocational vehicles, and some have sold devices for use on these types of vehicles. For example, Freightwing and Ridge Corporation, who sell side skirts for box trucks intended to achieve a 2 to 4 percent reduction in fuel use, indicate their skirts can be used on any box truck as long as equipment underneath, such as storage boxes, lifts, etc., does not interfere and there is adequate space between axles.

We also contacted vocational fleets, including Waste Management, Aramark, Cintas, U-haul, and Pepsi/Frito Lay, to learn about their experience in using trucks with aerodynamic controls. Some had purchased vocational trucks with aerodynamic controls for their fleets. For example, Pepsi/Frito Lay reported that in the field their aerodynamic improvements had given them 1 to 1.5 percent fuel savings. In its class 3 Sprinter truck design, Frito Lay changed the box geometry, added side skirts, and a front lip. In its class 6 trucks, it installed nose cones.

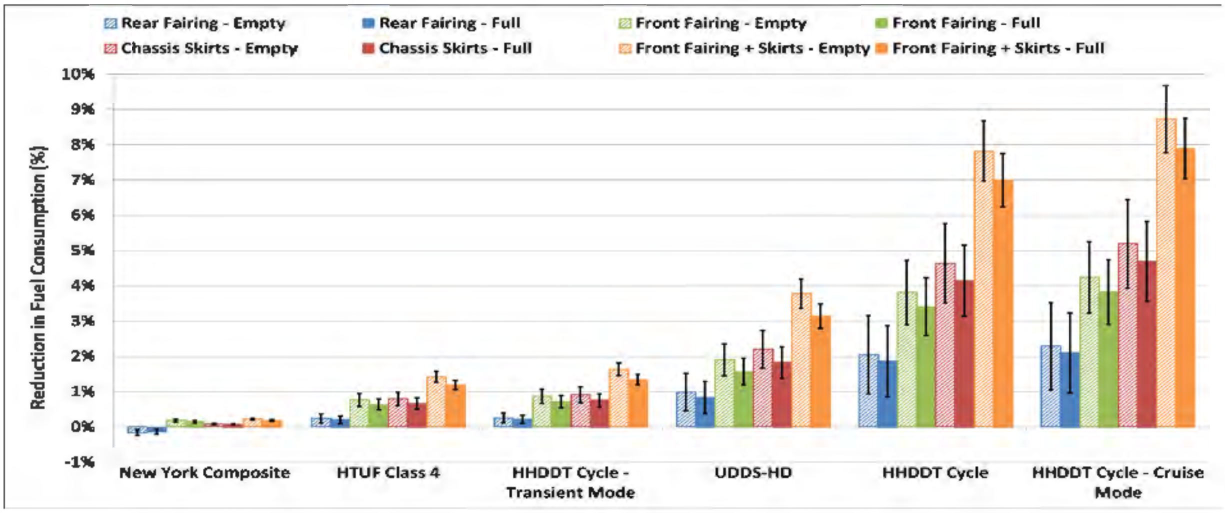
Data on potential fuel consumption reductions achievable via use of aerodynamic improvements

CARB staff gathered available data on the drag and fuel consumption reductions achievable via aerodynamic improvements to vocational vehicles. For example, we obtained data from Auto Research Center, a research facility in Indianapolis that provides various test services including but not limited to wind tunnel testing and computational fluid dynamics. Auto Research Center met with us and discussed their current fuel economy efforts specific to vehicle aerodynamics. Auto Research Center tested an aerodynamic technologies package that included various aerodynamic devices such as side skirts, fairings, and others for a class 5 box truck. The box truck was tested in a wind tunnel with data recorded at yaw angles of 0, 3, and 6 degrees. The resulting percentage fuel economy savings at 55 mph were 2.5 percent with top fairing, 1.3 percent with side skirts, 0.5 percent with wheel covers, and 2.2 percent with smooth underfloor. We shared this data with U.S. EPA staff in June 2015.

After gathering available data, we concluded there was a paucity of data concerning the effectiveness of aerodynamic technologies for vocational vehicles. To help fill the gap, CARB contracted with U.S. Department of Energy's NREL to perform coastdown and on-road test runs with and without aerodynamic devices such as skirts, front and rear fairings, and wheel covers to quantify their potential benefits for class 6 and class 4 box trucks. A report describing NREL's findings is attached. The most important findings are summarized below:

- All devices except wheel covers showed a benefit: There were six coastdown test configurations: 1) baseline, no aerodynamic device, 2) wheel covers, 3) front fairing, 4) chassis skirts, 5) front fairing and skirts, and 6) front fairing and skirts and wheel covers. All test configurations, except adding just wheel covers, indicated a statistically significant change in total road load force in the 45–68 mph range. Front fairings and chassis skirts were the most effect devices tested, with both showing improvements on the order of 6 percent individually for total road load force. When front fairings and skirts were tested together, the improvement increased to 8 to 10 percent.
- Emission benefits up to 8 percent, depending on duty cycle: To determine the significance of their aerodynamic devices in real world operation of vocational vehicles, NREL applied their test results to a variety of test cycles commonly used for vocational vehicles. As shown in the chart below, for vocational cycles that contain a significant portion of high speed driving, the potential benefits of aerodynamic devices can be significant, up to 8 percent.

Figure 3: Simulated Drive Cycle Fuel Consumption Results



CARB staff appreciates that U.S. EPA and NHTSA referenced the data from CARB and NREL testing in the Phase 2 proposal. We encourage U.S. EPA and NHTSA to utilize other vocational aerodynamic data that they have obtained from other sources (e.g., Ford and Auto Research Center data), which will help particularly in the class 3 to 5 categories.

The potential emission reductions from use of aerodynamic devices on vocational vehicles are significant and – in CARB staff's opinion – too large to ignore in Phase 2. To estimate the potential impact of vocational aerodynamics on actual vocational vehicle emissions, we made an estimate of this impact in two ways. First, we used actual duty cycle data from NREL's Fleet DNA (a database of commercial fleet vehicle operating data) for 553 days of driving data from 36 delivery trucks and, as shown in Table 12 below, and detailed in the attached spreadsheets, found that these trucks could achieve more than a 5 percent reduction in fuel consumption via use of aerodynamic devices.[27]

[27] See Attachment 2 for Use of Aerodynamic Devices for Actual Vocational Trucks in NREL Fleet DNA Database Spreadsheet.

Table 12: Potential Fuel Consumption Reductions via Use of Aerodynamic Devices for Actual Vocational Trucks in NREL Fleet DNA Database

	Chassis Skirt	Front Fairing	Rear Fairing	Front Fairing and Chassis Skirt
Fuel Consumption Reduction through use of Aerodynamic Devices	2.8-3.3%	2.7-3.7%	1.5-2.1%	5.6%

Next, we modeled potential reductions for vocational vehicles modeled in CARB's EMFAC database. Using duty cycles for medium heavy-duty out-of-state and instate trucks with GVWR less than or equal to 26,000 lbs, we arrived at similar results to those for the NREL fleet DNA data, potential fuel consumption reductions of about 6 percent.[28] Given that the total reductions from vocational vehicles for the proposed Phase 2 program are only 16 percent, ignoring potential fuel consumption and emission reductions of 6 percent is clearly a significant and regrettable missed opportunity.

<u>Why vocational aerodynamic credits should be offered more broadly than proposed</u>

U.S. EPA and NHTSA have proposed that credits for aerodynamic improvements be available to manufacturers only of trucks whose configuration and dimensions are essentially identical to those CARB and NREL tested and only for aerodynamic devices of identical weight to those tested. U.S. EPA and NHTSA neglected to consider other relevant data submitted to them during development of the Phase 2 standards (including data from Ford and Auto Research Center, mentioned above).

In addition, the proposed method is overly restrictive and will inappropriately limit the vehicles that could receive any credit for using vocational devices to ones essentially identical to the two trucks CARB and NREL tested. We believe this restriction would make the aerodynamic credit provisions unlikely to be used widely, or at all, by vocational vehicle manufacturers. We also believe this restriction ignores the physical reality that devices such as skirts are likely to provide fuel economy benefits for trucks of a variety of frontal areas, lengths, and shapes. Although as discussed above CARB staff recommends that aerodynamic improvements be included when setting the standards for vocational vehicles and in GEM, should U.S. EPA and NHTSA decline to

[28] See Attachment 3 for Potential Fuel Consumption Reductions via Use of Aerodynamic Devices for Medium-Heavy Duty Vehicles in CARB's EMFAC 2014 Database.

do that, at minimum, we recommend allowing credit for all class 3 to 7 straight trucks with a van or box shaped body.

CARB staff believes the data available show convincingly that aerodynamic devices can reduce fuel consumption and GHG emissions from vocational vehicles and believes credit for such devices should be offered more broadly, not just to trucks identical to the two we tested. Especially given the diversity of vocational vehicles offered in the market, it would not be feasible to perform testing on every possible vehicle, coupled with every aerodynamic device, nor would such testing be a good use of scarce public agency resources. NREL concluded, "… as long as the box sits above the rear wheels without a wheel well, there will likely be a spot for chassis skirts, and as long as the box extends above the front cab, there will likely be an opportunity for a front fairing. These devices may vary in size and aerodynamic benefit for different platforms, but the benefit likely has a closer tie to vehicle shape and body style rather than a specific weight class or dimension."[29]

Elsewhere in the Phase 2 rulemaking, U.S. EPA and NHTSA use similar logic to what we are proposing to justify how aerodynamic data for 53-foot dry vans can be translated to vans and box trailers in lengths different than 53 feet (page 40261 of the NPRM and 40 CFR 1037.501(g)). Putting aerodynamic devices (i.e., skirts) on vocational trucks is similar to putting skirts on trailers, and hence it is unclear why U.S. EPA and NHTSA did not apply this same logic to vocational aerodynamics.

CARB staff also believes U.S. EPA and NHTSA are overly restrictive in limiting credit to devices of equivalent weight to those tested. We recommend allowing credit for aerodynamic devices of differing weights because their weight varies for various types of vehicles and brands of devices. We recommend that U.S. EPA and NHTSA follow an approach for vocational aerodynamic devices similar to the approach they describe on pages 40280 to 40281 of the published NPRM for trailer aerodynamic devices. Under that approach, device manufacturers could certify their aerodynamic devices, then chassis manufacturers, including secondary manufacturers, can install the aerodynamic devices and obtain credits without having to retest for every individual vehicle. The approach also lays out the procedures for combining the effects of several devices.

To facilitate application of the test data available to a broader variety of vehicles, we recommend U.S. EPA and NHTSA consider use of a percent delta coefficient of drag x

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[29] (NREL, 2015a) National Renewable Energy Laboratory, "Aerodynamic Drag Reduction Technologies Testing for Heavy-Duty Vocational Vehicles – Preliminary Results," July 2015, page 10. See Attachment 1 for the Draft Report.

area (CdA) instead of a flat CdA. CARB staff recommends using a ratio approach by applying a percent CdA change, not an m^2 CdA. For example, if we tested a vocational truck and found that a skirt could reduce CdA 6 percent, then a smaller or bigger truck could apply that same percent change to their CdA. We encourage U.S. EPA and NHTSA to consider this ratio approach.

Support Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40287-40288

Comment - Assignment of vocational subcategories

The NPRM requests comment on the assignment of vocational chassis to regulatory categories. CARB staff supports U.S. EPA and NHTSA's assignment of regulatory subcategories for vocational vehicles. We recognize the broad range of uses in the vocational sector which dictates the use of many different test cycles to fully encompass all of the vocational duty cycles. However, there is also a need for simplicity in regulating vocational manufacturers to reduce unnecessary burden on both manufacturers and regulators. The proposal of nine subcategories for the vocational sector addresses and balances these two competing factors. The proposal to allow manufacturers to request a different duty cycle would provide necessary flexibility for those vocational vehicles that are not properly accounted for by these simplified subcategories.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40292-40294

Comment - Emergency vehicle provisions

CARB staff understands the unique nature and uses of emergency vehicles and supports the proposal's provisions to allow emergency vehicles to certify to less stringent standards with reduced compliance procedures than for other vocational vehicles. California Statute and many of CARB staff's in-use regulations similarly have special provisions for emergency vehicles. CARB staff also understands that current idle reduction technologies applicable to the Phase 2 vocational standards may not be sufficient to power all of the on-board electronics required by emergency vehicles.

Therefore, CARB supports proposed emergency vehicle standards that do not require the use of specific idle reduction technologies.

Additionally, because the proposed compliance method for emergency vehicles is simplified compared to that of other Phase 2 vocational vehicles, emergency vehicle manufacturers would not follow the otherwise applicable Phase 2 approach of entering an engine map into GEM. Instead, CARB staff supports the proposed equation-based compliance approach using a Phase 1-style GEM interface with a default engine simulated in GEM is appropriate for the emergency vehicle category.

Class 2b/3 Pickup and Van Standards

Oppose/Requested Change Comment

Affected document: Phase 2 Proposed Rules

Affected pages: 40334-40390

Comment - Proposed heavy-duty pickups and vans (class 2b/3) standards should be strengthened

The NPRM solicits comment on Alternative 4 for heavy-duty pickups and vans, which would result in approximately the same Phase 2 program stringency increase of about 16 percent compared to Phase 1 but would do so two years earlier, in MY 2025 rather than in MY 2027. Alternative 4 would require CO_2 reductions of 3.5 percent per year from 2021 to 2025, whereas Alternative 3 would require CO_2 reductions of 2.5 percent per year from 2021 to 2027. We encourage U.S. EPA and NHTSA to accept Alternative 4 rather than Alternative 3 for heavy-duty pickups and van.

CARB staff believes that Alternative 4 for heavy-duty pickups and vans is technologically feasible, cost-effective, and superior to Alternative 3 for the following reasons:

> **Alternative 4 achieves greater emission benefits and greater net societal benefits than Alternative 3.** As summarized in Table 13, Alternative 4 for heavy-duty pickups and vans would achieve an additional 21 MMT of CO_2 reductions and $2.3 billion in societal benefits in the U.S.

Table 13: Heavy-duty Pickups and Van Alternative 3 and 4 Comparison (U.S. Benefits through MY 2029)

	Alternative 3	**Alternative 4**	**Difference**
CO_2 reduction [MMT]	118	139	21
Net Social Benefit [$billion]	23.4	25.7	2.3

(from the NPRM, Table VI-6, versus flat baseline)

- **The projected payback period for Alternative 4 is still acceptable and only a few months longer than the projected payback period for Alternative 3.** Alternative 4 is projected to pay back in 34 months versus 26 months for Alternative 3 (or 34 months versus 31 months if a dynamic baseline is used), and hence adds only 3 to 8 months to the expected payback period. Both alternatives pay back in the third year of ownership which is still expected to be well within the period vehicles are owned by the first buyer.

- **Alternative 4 is significantly less stringent than the standards light-duty pickup trucks will be meeting in the same timeframe**. Heavy-duty pickups and vans are very similar to light-duty pickup trucks but have higher load and towing capacity requirements. Both groups of vehicles are manufactured by many of the same manufacturers (Ford, General Motors, and Fiat/Chrysler) and utilize comparable engine and vehicle technologies. For this reason, both groups would have similar routes to achieving GHG emission reductions. Furthermore, continuing availability of advanced technology credits (see page 69) would provide additional technology flexibility to manufacturers in achieving reductions beyond alternative 3. For light-duty pickups, U.S. EPA and NHTSA have set GHG emission standards that would reduce emissions by 3.5 percent per year from MYs 2017-2021 and 5 percent per year from MYs 2022-2025. For a typical light-duty pickup, the resulting CO_2 standard would be 203 grams per mile (g/mi) by 2025.

  Alternative 4 would require a 3.5 percent per year improvement in CO_2 emission reductions from MYs 2021-2025 and result in an average CO_2 standard of 458 g/mi in 2025. Even under Alternative 4, the standard for heavy-duty pickups and vans would be more than double the allowable CO_2 emissions for light-duty trucks in the same time period.

<u>Oppose/Requested Change Comment</u>

Affected document: Phase 2 Proposed Rules

Affected pages: 40341

Comment - The test weight bins should be changed in order to allow for more realistic testing of heavy-duty pickups and vans due to mass reduction

CARB staff believes weight reduction can be a cost-effective technology that can achieve significant CO_2 reductions. A prime example of the effectiveness of this technology is the recently redesigned F150 which makes extensive use of aluminum. In fact, all manufacturers are expected to incorporate vehicle weight reduction across their light-duty fleet (where emission test weight (ETW) bins are significantly smaller) in response to the 2017-2025 GHG requirements. As currently structured, the ETW bins for class 2b and 3 vehicles (500 lbs) tend to discourage the use of this technology since significant weight reduction is required before any benefit can be demonstrated over the applicable emission test cycles. Narrowing the ETW bins could encourage early implementation of vehicle weight reduction across a vehicle product line as well as providing manufacturers with increased flexibility in using weight reduction as part of their technology portfolio. Another benefit of reducing ETW bins is that the test results would more accurately reflect vehicle GHG emissions. Accordingly, CARB staff recommends restructuring the compliance process to encourage vehicle weight reduction by reducing the applicable ETW bins to 125 pound increments.

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40334-40335, 40389-40390, proposed 40 CFR 1037.621

Comment – The heavy-duty pickups and vans technology list should include battery electric or fuel cell electric technology, hybridization of diesel engines and dieselization

CARB staff has significant concerns regarding the following assertion:

> As discussed in Section I, the agencies request comment on the proposed approach for the advanced technology multipliers for heavy-duty pickups and

> vans as well as the other heavy-duty sectors, including comments on whether or not the credits should be extended to later model years for more advanced technologies such as EVs and fuel cell vehicles. These technologies are not projected to be part of the technology path used by manufacturers to meet the proposed Phase 2 standards for heavy-duty pickups and vans. (page 40389 of the NPRM)

A large population of heavy-duty pickups and vans are used as last-mile delivery vehicles that return to a yard or terminal on a daily basis. Last-mile delivery vehicles will be ideal candidates for zero-emission technologies, especially fuel cell electric technology. With this understanding, CARB staff is considering regulations that will incentivize and/or mandate zero-emission technologies in the heavy-duty sector within the Phase 2 timeframe. Specifically heavy-duty pickups and vans, especially in last-mile delivery applications, is an area that CARB staff considers fertile for greater adoption of zero-emission technologies in the near-term. CARB staff believes that the federal Phase 2 standard is important to incentivize early adoption and deployment of zero-emission technologies in this category.

The NPRM requests comment on the proposed technology list that would be used by manufacturers to comply with the heavy-duty pickup and van standard. CARB staff recommends that the list include battery electric and fuel cell electric technologies.

The list of technologies should also include hybrid diesel technologies as CARB staff believes strong hybrids in the heavy-duty pickup and van sector will be widely available in the 2025 timeframe. Currently, XL Hybrids and Crosspoint Kinetics have commercially-available hybrid systems for both new purchases and existing vehicle conversions.

XL Hybrids currently has hybrid systems for box trucks (Ford E-350/E-450 cutaway, Ford E-450 strip chassis), Reach walk-in commercial vans (Isuzu/Utilimaster), cargo vans and passenger wagons (Chevy Express 2500/3500, GMC Savana 2500/3500, Ford E-150/E-250/E-350, Ford Transit), shuttle buses (Ford E-350/E-450 cutaway, Ford E-450 strip chassis, GM 3500/4500 cutaway (available September 2015)), and commercial stripped chassis (F59 super duty) for walk-in van fleets.

Crosspoint Kinetics currently has hybrid systems for a variety of new class 3-7 trucks and buses, including a retrofit option for existing vehicles. Their systems have been tested and approved at Altoona and have been certified by the Federal Transit Administration.

CARB staff believes that if there is a projected demand created by regulatory Phase 2 (Alternative 4) requirements, these two companies, and likely other companies, would make additional hybrid systems available for the targeted heavy-duty truck and van sector. Since the basic hybrid system designs from XL Hybrids and Crosspoint Kinetics have been proven in actual fleet operations, additional demands for their products would lower the price of hybrid technologies due to increased production. The technology could also be more economically designed for other vehicle platforms, creating additional growth and development for hybrids in general.

Furthermore, U.S. EPA and NHTSA's own modeling on the projected level of hybridization penetration necessary by 2030 to comply with the different regulatory alternatives showed that for two companies (Daimler and Nissan), no hybridization is necessary to comply with Alternative 4 (Tables VI-25, page 40378 of the NPRM, and VI-26, page 40378-40379 of the NPRM, respectively). Another company, Fiat/Chrysler needs only 3 percent hybridization penetration to comply with Alternative 4 (Table VI-24, page 40376-40377 of the NPRM) and Ford needs to have 14 percent hybridization penetration to meet Alternative 4 requirements (Table VI-23, page 40375-40376 of the NPRM). Of the major manufacturers, only GM would need to have a significant level of hybridization penetration at 79 percent to comply with Alternative 4 (Table VI-22, page 40375 of the NPRM). This lends further support for the feasibility for Alternative 4, which CARB staff recommends.

Trailer Standards

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules; Redline/Strikeout of EPA Proposed Regulatory Text Relative to Current CFR (Redline Document)

Affected pages: NPRM 40253 - 40285; Redline Document: 137-138

Comment – Compliance requirements for trailers, trailer classification systems; Add aero requirements for non-box trailers; Change 50-foot demarcation to 47-feet; Remove belly boxes from the list of work-performing devices that inhibit the use of aerodynamic devices

The NPRM includes U.S. EPA and NHTSA's proposal to regulate greenhouse gas emissions associated with trailers for the first time. The regulation will affect most trailers designed for use on highways. The proposed regulation requires that all affected trailers use LRR tires and ATIS, and that most box van trailers also use aerodynamic technologies.

Although most aerodynamic technologies developed up until now have been designed for box van trailers, other trailer types, such as tanker trailers and flatbed trailers also stand to gain appreciable fuel economy benefits from these technologies. In wind tunnel testing conducted at the Auto Research Center in conjunction with Freight Wing, adding side skirts to a flatbed trailer reduced its wind-average drag coefficient by 8 to 9 percent at 50 mph, equivalent to a fuel savings of 3.5 to 4 percent at 50 mph, with larger savings possible at higher speeds.[30] Manufacturers are working on developing technologies for these trailers. For example, Wabash has already released its DuraPlate Tanker AeroSkirt product. CARB staff believes that there are significant benefits from the use of aerodynamic equipment on non-box trailer types, especially for longer non-drop-deck flatbed trailers (greater than 50 feet in length). For this reason, CARB staff recommends that U.S. EPA and NHTSA consider adding aerodynamic equipment requirements on certain non-box trailers. For example, as part of Alternative 4, longer non-drop-deck flatbed trailers should start with a 5 percent adoption rate of Bin III technology by the 2021 MY, increasing to 15 percent by the 2024 MY. CARB staff believes that this standard for long non-drop-deck flatbed trailers is feasible given the relatively low adoption rate of 5 percent combined with the extra lead time by starting

[30] See Attachment 5 for Freight Wing ARC Wind Tunnel Flatbed Testing Summary Results.

the requirements in 2021, three years after aerodynamic equipment requirements will have taken effect for box van trailers.

In addition to distinguishing between box van trailers and non-box trailers, the proposed regulation also subdivides box van trailers into nine subcategories, each with different standards. The division of box van trailers is based on whether the trailer is a dry or refrigerated van, whether it is long (over 50 feet) or short (50 feet and below), and whether positions where aerodynamic equipment are typically installed are occupied by a work-performing device. CARB staff is supportive of this classification system to determine the stringency of the requirements to which a trailer is subjected since it recognizes the fact that there is a greater availability of aerodynamic technologies designed for long box van trailers and also takes into account the presence of work-performing devices that may partially restrict the installation of aerodynamic devices. However, CARB staff recommends two changes to this classification system.
First, CARB staff believes that the 50-foot demarcation should be changed to a 47-foot demarcation to account for the fact that 48-foot trailers are much more similar to 53-foot trailers than they are to 28-foot trailers in terms of length and available aerodynamic technologies; and 28-foot trailers are typically used in tandem, limiting their ability to use rear aerodynamic technologies, unlike with 48-foot trailers. 48-foot dry van trailers constitute nearly 6 percent[31] of the dry van trailer population. Hence, including 48-foot van trailers in the long box van trailer category, which essentially lowers the standard for these trailers by 42 to 45 percent, can lower overall emissions attributed to long and short dry box van trailers by about 2.5 percent, a significant amount.

Second, U.S. EPA and NHTSA should remove belly boxes from the list of work-performing devices that inhibit the use of aerodynamic devices where the belly box is located. The NPRM defines "non-aero" and "partial-aero" trailers as trailers that have at least one of the work-performing features listed in paragraph (a)(1)(i) of the proposed 40 CFR 1037.107 in the redline version of U.S. EPA regulation. By including belly boxes on the list of work-performing devices, it is possible that certain fleets may exploit this as a loophole by specifying a small belly box in their trailer order instead of having side aerodynamic equipment installed. From CARB's experience in implementing the Tractor-Trailer GHG Regulation, we know it is feasible to install a modified trailer skirt around the belly box. A wind tunnel testing project conducted jointly by Kentucky Trailer

[31] (ICCT, 2014) The International Council on Clean Transportation, "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," February 2014, <http://www.theicct.org/sites/default/files/publications/ICCT_trailer-test-procedure_20140218.pdf>.

and Freight Wing at Auto Research Center showed that adding a modified trailer skirt around the belly box actually resulted in increases in fuel savings compared to the same trailer with unmodified trailer skirts and no belly box.[32] As a result, CARB has modified its "Implementation Guidance for the Tractor-Trailer GHG Regulation"[33] to allow the addition of a modified trailer skirt, as a CARB pre-approved modification, around a belly box. Pre-approval is based on testing demonstrating that a particular modification increases the wind averaged coefficient of drag (Cdw) by no more than 10 percent of the difference between the Cdw of the zero equipment baseline and the Cdw of the same trailer with the skirt. CARB staff has not experienced any difficulties implementing this provision, and recommends that U.S. EPA and NHTSA remove belly boxes from the list of work-performing devices that inhibit the installation of an aerodynamic device at the location where the belly box is located. Instead, U.S. EPA and NHTSA should identify belly boxes as a work performing feature that may require the installation of an aerodynamic device modified according to predetermined guidelines to be fitted around the belly box. This may require the preparation of an aerodynamic modification guidance document similar to that of CARB.

The proposed rule requires the use of LRR tires for all trailer types. The LRR tire requirement for short and long box type trailers begins with an 85 percent adoption rate of Level 1 tires, which have a coefficient rolling resistance of 5.1 (kilograms per ton) kg/ton, equivalent to today's SmartWay-verified tire models, with the remaining 15 percent using the baseline tires with a coefficient of rolling resistance of 6.0 kg/ton. CARB staff believes that the adoption rate for Level 1 tires can be increased to at least 95 percent given that industry has already had years of experience with U.S. EPA's SmartWay program and that the Truck Trailer Manufacturers Association stated in a October 16, 2014 letter to U.S. EPA informing them that SmartWay-verified LRR tires are now standard with new trailers. Furthermore, U.S. EPA and NHTSA propose a 100 percent Level 1 tire adoption rate for non-box trailers and non-aero trailers, indicating that it should be possible for box-type trailers to meet a higher adoption rate as well.

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[32] See Attachment 6 for Auto Research Center, Class Eight Semi Truck Aerodynamic Fuel Economy Component Test, 2011.

[33] (CARB, 2012) California Air Resources Board, "Implementation Guidance for the Tractor-Trailer GHG Regulation," October 2012, <http://arb.ca.gov/cc/hdghg/documents/modaeroguidev1.pdf>.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40253 - 40285

Comment – Stringency of trailer standard, alternative 4 recommended

The NPRM also requests comments on whether Alternative 3 or Alternative 4 should be the preferred alternative. Both alternatives provide a gradual increase in the adoption rates of aerodynamic technologies, leading to the same final stringency, except that Alternative 4 arrives at the final stringency three years earlier. The main difference in the implementation of the two alternatives is the second phase of standards, which occurs during the 2021 MY. Under Alternative 4, the adoption rates specified in Alternative 3’s second phase is skipped so that Alternative 3's 2024 standards take effect in 2021, and Alternative 3's 2027 standards take effect in 2024.

Since most of the requirements for trailer aerodynamic equipment can be met with technology that is already available, the difference in cost from accelerating the adoption of these technologies by three years would be low. Table I-11 in the NPRM provides the costs of the technology needed on a baseline trailer to comply with the Phase 2 regulation, under Alternatives 3 and 4 and is provided here for reference.

TABLE I–11—PER VEHICLE COSTS RELATIVE TO BASELINE 1a

	3 Proposed standards			4	
	MY 2021	MY 2024	MY 2027	MY 2021	MY 2024
Per Vehicle Cost ($)[a] Trailers	900	1,010	1,170	1,080	1,230

Note:

[a] Per vehicle costs include new engine and vehicle technology only; costs associated with increased insurance, taxes and maintenance are included in the payback period values.

As indicated in the table, the added cost per trailer to meet Alternative 3 MY 2024 standards is $1010 (2012 dollars); whereas the cost to meet the Alternative 4 MY 2021 standards (the equivalent of the MY 2024 Alternative 3 standards) is $1080 (2012 dollars), a difference of $70, or 6.9 percent. Similarly, the difference in cost to meet the final stringency requirements of the two alternatives is $60, or 5.1 percent.

The differences in compliance cost should then be viewed in terms of their effect on the payback period, since the adoption of Alternative 4 requires more aerodynamic trailers sooner, leading to greater fuel savings earlier. The NPRM provides the results of analyzing the payback periods of the two alternatives, and have determined that choosing Alternative 4 over Alternative 3 results in negligible impacts on the payback periods, with both alternatives having payback periods of 2 years, as shown below in the NPRM's Table I-12.

TABLE I–12—PAYBACK PERIODS FOR MY2027 VEHICLES UNDER THE PROPOSED STANDARDS AND FOR MY2024 VEHICLES UNDER ALTERNATIVE 4 RELATIVE TO BASELINE 1a

[Payback occurs in the year shown; using 7% discounting]

	Proposed standards	Alternative 4
Tractors/Trailers	2nd	2nd

While Tables I-11 and I-12 show that there is a negligible impact on the economics of fleets that operate trailers, it is also important to compare the impacts of the two alternatives in terms of the overall costs and benefits of the regulation as well. Table X-1 and X-3 in the NPRM provide a comparison of the net costs and benefits of the two alternatives for the tractor-trailer vehicle as a whole, in which trailer benefits play a major part. Under both the 3 percent discount rate and the 7 percent discount rate assumptions, Alternative 4 provides a greater net benefit, after subtracting out the costs, over the 2018 to 2029 timeframe.

Table 14: Summary of Tables X-1 and X-3 for Tractor-Trailers (values in $billion)

	Alt 3 (3% Discount)	**Alt 4 (3% Discount)**	**Alt 3 (7% Discount)**	**Alt 4 (7% Discount)**
Benefit	217.5	236.7	130.0	142.2
Cost	15.5	18.1	10.3	12.1
Net Benefit	202.0	218.6	119.7	130.1

Upon examining the cost-benefit analysis provided in the NPRM and differences in stringency between the two alternatives, and drawing upon CARB's experience in implementing its Tractor Trailer GHG Regulation, CARB staff recommends Alternative 4. Under Alternative 4, by 2021, 65 percent of long box van trailers (defined in the NPRM as those over 50 feet) would employ Bin V aerodynamic technology, which is equivalent to SmartWay Elite levels, which became effective in 2014. CARB staff believes it is reasonable to assume 65 percent penetration of such technology by 2021, which will be five years after the adoption of the proposed Phase 2 regulation and seven years after SmartWay Elite levels became effective. In addition to recommending Alternative 4, CARB staff also recommends two modifications to the stringency levels. First, given that Bins I through VII can all be attained using existing technology, CARB staff believes that the final phase of standards should incorporate some adoption of Bin VIII, which represents as yet undeveloped technology. Having seen how quickly aerodynamic technology has evolved since the SmartWay's launch in 2004, CARB staff believes that these technologies will continue to evolve at a rapid pace for the next nine years, when the final phase of standards in Alternative 4 takes effect. As such, CARB staff recommends that the stringencies of Alternative 4 for long box dry van trailers should be modified to include some adoption of Bin VIII technology trailers, such as 10 percent Bin V, 45 percent Bin VI, 40 percent Bin VII, and 5 percent Bin VIII, by 2024. Using the compliance equation given in the proposed 40 CFR 1037.515 in the redline version of the regulation, this modification reduces the final standard by a further 0.24 grams of CO_2 per ton-mile. CARB staff believes that it is important to include at least a nominal adoption rate of Bin VIII technologies in order to move beyond off-the-shelf technology and push for further development of aerodynamic technologies. In the event that such technology is still unavailable by the 2024 MY, the 5 percent adoption rate is low enough such that manufacturers would still be able to meet the stringency by slightly adjusting the percent adoption rates between Bins V and VII.

Another recommended modification relates to the final stringencies of long box refrigerated van trailers. From the RIA, the trailer-to-tractor ratio of refrigerated vans (2:1) is lower than that of dry vans (3:1), which means that a refrigerated van trailer is typically used on the road more than dry van trailers. Because of the higher use experienced by refrigerated van trailers, investments in aerodynamic equipment for refrigerated trailers can generate faster, and larger, returns on investment. In addition, because of the higher base cost of a refrigerated trailer (roughly twice as much as a dry van trailer[34]), the incremental cost of the required aerodynamic equipment would be a much smaller percentage of the base cost of a refrigerated van trailer than it would be for a dry van trailer. For these reasons, CARB staff believes that the final stringency level (applicable to MY 2024 under Alternative 4) of long box refrigerated van trailers should be adjusted so that the combined adoption of Bins VI and VII should match or exceed that of long box dry van trailers. For example, the Alternative 4 MY 2024 long

[34] (ICCT, 2013) The International Council on Clean Transportation, “Trailer technologies for increased heavy-duty vehicle efficiency - Technical, market, and policy considerations,” June 2013, <http://www.theicct.org/sites/default/files/publications/ICCT_HDVtrailertechs_20130702.pdf>.

box refrigerated van trailer adoption rates should be as follows: 10 percent Bin V, 60 percent Bin VI, and 30 percent Bin VII. Using the compliance equation from the proposed 40 CFR 1037.515 in the redline version of the regulation, this modification reduces the final standard by a further 0.41 grams of CO_2 per ton-mile.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: NPRM 40278 – 40279; RIA 2-161 to 2-162

Comment –Exclusively using zero-yaw testing for trailer aerodynamic performance

U.S. EPA and NHTSA are proposing to determine the delta CdA for trailer aerodynamics using only the zero-yaw (or head-on wind) values for coefficient of drag. U.S. EPA and NHTSA are not proposing a reference method (i.e., the coastdown procedure in the tractor program). Instead, they are proposing to allow manufacturers to perform any of the proposed test procedures (e.g. coastdown, constant-speed, wind tunnel, computational fluid dynamics (CFD)) to establish a delta CdA. Since the proposed coastdown and constant speed procedures include wind restrictions, U.S. EPA and NHTSA are proposing to only accept the zero-yaw values from aerodynamic evaluation techniques that are capable of measuring drag at multiple yaw angles (e.g., wind tunnels and CFD) to allow cross-method comparison and certification.

CARB staff is concerned that using only the delta of the zero-yaw values to determine the delta CdA for trailer aerodynamics may not accurately reflect the aerodynamic benefit from improved trailer aerodynamics. U.S. EPA and NHTSA recognize that the benefits of aerodynamic devices for trailers can be better seen when measured considering multiple yaw angles. This is illustrated in Figure 22 from the RIA (shown below - Figure 4). The wind- average results were calculated at 55 mph vehicle speeds, consistent with the procedures in 40 CFR 1037.810. The wind-averaged analysis consistently results in a larger improvement (i.e., delta CdA) than the zero-yaw results.

Therefore, CARB staff is recommending that U.S. EPA and NHTSA reestablish the performance bins and resulting proposed trailer standards based on wind-averaged drag results. Making this change is critical if the trailer standards are to reflect real-world gains in fuel efficiency and GHG reduction. In the real world, it is unreasonable to assume that tractor-trailers always travel when winds are coming straight at the vehicle. If the test method does not reflect wind-averaged drag, manufacturers run the danger of developing aerodynamic products that result in meeting standards that result in minimal or no benefit in real-world conditions. The opposite could also be true, where a technology that shows minimal benefit under zero yaw analysis can show measurable benefit when wind-averaging over multiple yaw angles are considered. This is illustrated in Figure 22 (shown below - Figure 4) for the gap fairing technology tested.

CARB staff agrees with U.S. EPA and NHTSA decision to not require a reference test method, in order to reduce the test burden for manufacturers and allow them to choose an appropriate test method for their need and resources. However, the test method used must be capable of measuring wind-averaged drag. Wind tunnel testing and CFD are two viable methods. The use of reduced scale wind tunnel testing to evaluate the wind-averaged drag of aerodynamic technologies is common practice amongst trailer manufacturers. Several such manufacturers have submitted wind tunnel test results to CARB staff in accordance with requirements of California's Tractor-Trailer GHG Regulation.

Figure 4: Comparison of Zero Yaw and Wind-Averaged Drag Results[35]

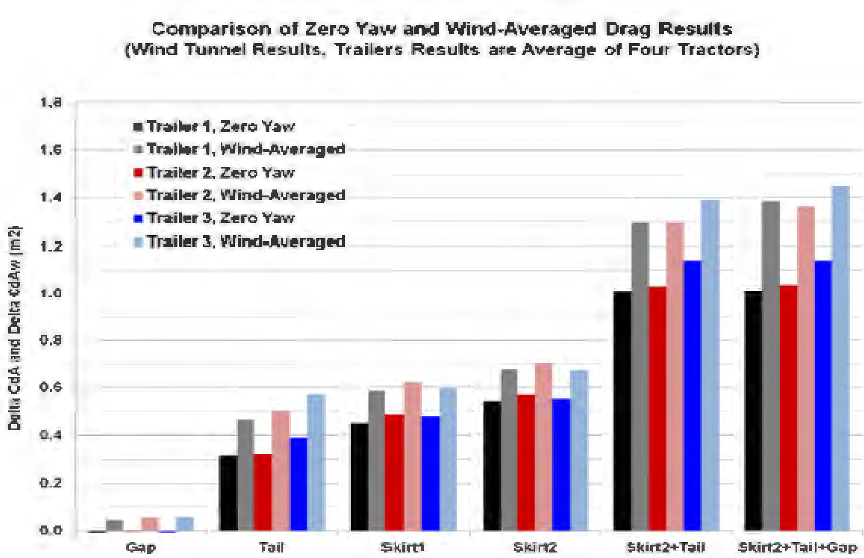

Figure 2-22 Comparison of Zero Yaw and Wind-Averaged Drag Results

[35] Figure 22 from the RIA, page 2-162

Comments on Proposed Phase 2 Provisions

Credits

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40252

Comment –Tractor- off-cycle technology credits, penetration rate

The NPRM requests comment on providing credit for off-cycle innovative technologies.

We agree with the concept of providing such credits, as credits can be an incentive for innovation. For example, such credits could support continued innovation in connected vehicle technologies such as platooning. The proposed Phase 2 standards were developed including benefits for predictive cruise control, a type of connected vehicle technology, and CARB staff supports allowing off-cycle credits for other connected vehicle technologies such as platooning. As discussed further in CARB's Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency,[36] platooning is being tested in Southern California and can yield fuel consumption reductions of 10 to 21 percent.

We also agree with the proposed removal of some types of off-cycle credits allowed in Phase 1 in light of Phase 2 GEM accounting directly for some of the Phase 1 innovative off-cycle strategies.

The NPRM proposes requiring A to B testing on a chassis dynamometer to demonstrate the effectiveness of off-cycle technologies. CARB staff suggests caution in using A to B testing on a chassis dynamometer or by using portable emissions measurement systems (PEMS) to quantify sub percentage point efficiency gains. Care must be taken when the expected change is on the same order of magnitude as the test-to-test repeatability of the test method used.

[36] (CARB, 2015c) California Air Resources Board, "Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency," June 2015, <http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf >.

Support Comment/Request Clarification

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40596

Comment – Off-cycle credits and adjustments

CARB staff supports the requirements in 40 CFR 1036.610 (c), (e), and (f) that sufficient technological descriptions and data be required to allow adjustment of emission results for off-cycle credits, as well as the demonstration of the durability of the off-cycle technology. This section allows the use of the approved adjustments to be retained through the 2020 MY but that new approval will be required for MY 2021. CARB staff recommends clarification of whether approval for MY 2021 and beyond must be renewed annually or whether that approval will continue for similar off-cycle approaches as had been previously allowed under Phase 1 of the GHG regulations. CARB staff believes the latter approach would be appropriate.

Oppose/Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rule, RIA

Affected pages: 40156-40157, 40206, 40251-40252, 40329, 40342, 40388, 40564; RIA 2-113

Comment – Use of banked Phase 1 credits in Phase 2 program / Credit adjustment factors

The NPRM indicates that "positive market reception to Phase 1 technologies could lead to manufacturers accumulating credit surpluses that could be quite large at the beginning of the Phase 2 program" (pages 40157 and 40251 of the NPRM). The NPRM does not attempt to quantify the level of projected banked credits that could be available at the end of Phase 1. However, U.S. EPA and NHTSA believe, even at this early stage of Phase 1 implementation, that substantial credits will be available that will impact Phase 2 cost, technology readiness, and other key variables. The NPRM provides almost no analysis of, nor accounting for, the potential implications of a large number of banked Phase 1 credits. A large number of Phase 1 credits means that manufacturers have adopted CO_2 reducing technologies much faster than originally anticipated. However, the NPRM baseline scenarios do not recognize that a large number of banked credits reflect technology advancement beyond Phase 1 standards:

> "In each of these proposed baseline configurations, the agencies have not applied any vehicle-level fuel saving or emission reduction technology beyond what is required to meet the Phase 1 standards. NHTSA and EPA reviewed available information regarding the likelihood that manufacturers of vocational vehicles would apply technology beyond what is required for Phase 1, and we concluded that the best approach was to analyze a reference case that maintains technology performance at the Phase 1 level." (page 2-113 of the RIA).

U.S. EPA and NHTSA propose that these credits be fully carried over into the Phase 2 regulations, without discounting. CARB staff has several concerns with this approach:

1) Allowing banked Phase 1 credits in the Phase 2 program reduces the efficacy of the Phase 2 program and delays technology development progress. Generation of large volumes of credits in the Phase 1 program indicates that technology has progressed faster than anticipated during the Phase 1 rulemaking. This faster Phase 1 progress should not justify reduced progress during Phase 2. CARB staff believes sunsetting these credits with the Phase 1 program would still provide manufacturers the opportunity to utilize these credits during Phase 1 (although some manufacturers may not), while maintaining the technological momentum needed to cost-effectively meet more aggressive Phase 2 standards. CARB staff believes that, at most, the life of remaining Phase 1 credits should be limited to no more than three years or with MY 2020, whichever is sooner, such that they would be sunsetted after MY 2020.

2) The cost and benefit assessments in the NPRM did not account for the potential of large quantities of banked Phase 1 credits in either of the "baseline" scenarios. If manufacturers have banked large numbers of credits at the beginning of the Phase 2 program, this suggests that the baseline for purposes of cost-benefit and feasibility analysis at the beginning of Phase 2 should reflect Phase 1 plus the technology advancement associated with the large numbers of banked credits. A large number of credits at the end of Phase 1 suggests the trajectory of technology advancement may be more rapid than utilized for baseline scenario modeling, and a more dynamic baseline may be appropriate.

3) Not only does the NPRM not discount the Phase 1 credits when carrying them over into Phase 2, it actually adjusts these credits upwards, reflecting an increase in the proposed useful life definition. CARB staff recommends against use of these proposed adjustment factors. U.S. EPA and NHTSA base the calculation of credits on factors such as the emission level compared to the standard and the useful life. Some of the useful life values in Phase 1 were substantially shorter than the actual typical useful life; U.S. EPA and NHTSA have proposed to increase the useful life period for these classes of vehicles. As a consequence of this increase, U.S. EPA and NHTSA propose to apply an adjustment factor relating the old useful life to the new useful life. U.S. EPA and NHTSA assert that CO_2 deterioration is relatively flat and thus, one can presume that the certified CO_2 levels will indeed continue to be met over the longer useful life. While CARB staff agrees that it is appropriate to adjust the useful life upwards to more closely represent the actual useful life, if the credit is multiplied by the ratio of new "actual" useful life to Phase 1 (shorter) useful life, an additional fractional credit will be generated for a benefit that already exists. Because this change in the useful life reflects a recognition of the actual useful life, rather than an increase in the anticipated useful life, CARB staff believes that it is not appropriate to apply a credit adjustment factor to these credits. Allowing the Phase 1 credits to be adjusted upward based on a new extended useful life, as proposed, would take benefits achieved by the Phase 1 program and -- instead of allowing them to benefit the environment -- would allow them to be used to reduce the potential benefits of the proposed Phase 2 program.

CARB supports the use of ABT to enable manufacturers to meet Phase 1 and Phase 2 standards in the most efficient and cost-effective way. However, allowing excess Phase 1 credits into the Phase 2 program could result in slower technology advances than anticipated in the NPRM. CARB encourages U.S. EPA and NHTSA to consider sunsetting banked Phase 1 credits in the Phase 2 program to lock in the faster than anticipated technology adoption anticipated from Phase 1. CARB staff specifically suggests that the Phase 1 credits, which currently expire after 5 years, be set to expire in three years or with MY 2020, whichever is sooner. CARB staff further recommends that Phase 1 credits not be adjusted upwards to reflect the change in the useful life to more properly approximate actual useful life. Finally, CARB staff suggests a more dynamic baseline than U.S. EPA and NHTSA are proposing may be appropriate if U.S. EPA and NHTSA are correct in presuming the accumulation of large numbers of Phase 1 credits.

Manufacturers are demonstrating their ability to utilize ABT to cost-effectively meet and exceed existing GHG standards. If U.S. EPA disagrees with CARB's recommendation and maintains its proposal to allow Phase 1 credits in Phase 2, a significant number of Phase 1 credits in the early years of Phase 2 provides greater justification for adopting Alternative 4 over Alternative 3 (as is CARB staff's recommendation discussed elsewhere in this comment package).

Support Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40158-40160, 40163-40164, 40205, 40253, 40331, 40348, 40388-40389, 40435, 40564, 40652

Comment – Termination of the advanced technology multiplier for Rankine engines and class 2b-6 hybrids

The NPRM requests comment on the proposed termination of the advanced technology multiplier. CARB staff agrees that it is appropriate to terminate the advanced technology multiplier for Rankine cycle WHR at this point, since the standards proposed for Phase 2 presume some use of this technology. In addition, hybrids for class 2b through 6 trucks are also reasonably developed at this point, and the vocational vehicle standards were set assuming some penetration of hybrids. Thus, it would be appropriate to terminate the multiplier for these classes of hybrids as well. However, CARB staff believes that the advanced technology multiplier should be continued for class 7/8 hybrids as well as BEVs and FCEVs, as discussed in the following comment.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules; Redlined Document

Affected pages: NPRM 40158, 40253, 40331, 40388-40389, 40563-40564; 40 CFR 1037.615

Comment – Advanced technology credits

Effective with the 2021 MY, U.S. EPA and NHTSA propose eliminating all Advanced Technology Credits (1.5 multiplier) that were included in the Phase 1 GHG regulations to promote early implementation of advanced technologies. The Phase 2 standards anticipate the use of hybrids and Rankine cycle technology, for which advanced technology credits were previously allowed, as part of the technology path used by manufacturers to meet the proposed Phase 2 standards. U.S. EPA and NHTSA believe that the Phase 2 standards alone should provide sufficient incentive to continue to develop these and other advanced technologies. U.S. EPA and NHTSA welcome comments on the need for advanced technology credits for BEVs and FCEVs in Phase 2, including information on why an incentive in this time frame may be warranted, recognizing that the incentive would result in reduced benefits in terms of CO_2 emissions and fuel use due to the Phase 2 program. CARB staff agrees that there is no further need for advanced technology credits for class 2b through 6 hybrids and Rankine cycle technology, but believes that these credits provide a further impetus to manufacturers to manufacture other technologies such as BEVs and FCEVs, and that the furtherance of this technology development will, over time, offset the temporary reduction in benefits attendant with the use of a multiplier credit. To minimize the potential emissions impact, the incentive could be phased out at a certain manufacturer volume or with a certain MY. Advanced technology credits, as they relate to class 7 and 8 vehicles, are discussed in the following comment.

Oppose (Comment on Topic Where NPRM Requests Comment)

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40158-40160, 40163-40164, 40205, 40219, 40253, 40331, 40348, 40388-40389, 40435, 40564, 40652

Comment – Reinstate advanced technology multiplier for class 7/8 hybrids, BEVs, and FCEVs

The Phase 1 GHG regulation included an advanced technology multiplier to create an incentive for the adoption and early introduction of advanced technologies, namely, Rankine cycle technology, hybrids, BEVs, and FCEVs. According to U.S. EPA and NHTSA, the advanced technology incentives were "intended to promote the commercialization of technologies that have the potential to provide substantially better GHG emissions and fuel consumption if they were able to overcome major near-term market barriers" (page 40389 of the NPRM). CARB staff believes such incentives are needed, especially given the magnitude of California's GHG emission reduction goals. Accelerated deployment of hybrid and zero-emission trucks and buses is critical for California to meet its air quality, climate and petroleum reduction goals. We anticipate these technologies will be increasingly critical nationally in the years ahead as federal ozone standards become more stringent and the impacts of climate change continue to manifest themselves.

Thus, CARB staff believes that the advanced technology multiplier should be continued for BEVs and FCEVs in all classes and for full hybrids in class 7 and 8 tractor and regional vocational applications, for the reasons discussed below. In addition to maintaining the advanced technology multiplier, CARB staff encourages U.S. EPA and NHTSA to look for other creative ways in the context of the Phase 2 standards to encourage the development of these critical advanced technologies.

- Proposed standards are not based on these technologies. 40 CFR 1036.615 (k)(7) of the Phase 2 proposal limits the advanced technology multiplier to Phase 1 vehicles, based on the premise that the Phase 2 standards presume the use of Rankine engines, as well as some hybrids. However, hybrid technologies for class 7 and 8 long haul tractor applications, as well as heavy heavy-duty hybrid technologies for regional vocational applications, were not assumed to have any penetration when setting the proposed Phase 2 standards. Hybrid technologies for such applications are still not fully developed and the costs of available hybrid technologies for these applications are still high. In addition, because U.S. EPA and NHTSA anticipate very limited use of BEVs and FCEVs and did not include any anticipated use of these advanced technologies when setting the emission standards proposed in the NPRM, it is appropriate to continue to offer the advanced technology multiplier to accelerate their development and adoption.
- These technologies are potential game-changers and are worth the potential small emission disbenefit. These multipliers would reduce some of the benefits from the rule because manufacturers could use the advanced technology credits in lieu of reducing emissions. For example, a 1 ton emission reduction from using advanced technologies would allow a manufacturer to avoid 1.5 tons in emission reductions they would otherwise need to achieve from traditional vehicles. However, CARB staff expects this reduction in benefits to be insignificant, even under an extremely optimistic penetration scenario for advanced technologies in the Phase 2 timeframe.[37] Also, in the long term, the reduction in benefits would be worthwhile due to the anticipated support for development of advanced technologies. A footnote in the NRPM (page 40389 of the NPRM) expresses U.S. EPA and NHTSA's

[37] CARB staff estimates if 3 percent of all vehicles covered by the Phase 2 standards received advanced technology credits for model year 2027 and later (for example if 3 percent were battery or fuel cell electric), emissions will be increased by about 0.5 MMT in California as a result of the multiplier. This would reduce projected Phase 2 benefits by about 3% in 2050.

opinion when applying multipliers for advanced technology in the light-duty vehicle fleet for MYs 2017 to 2021: It is "worthwhile to forego modest additional emissions reductions and fuel consumption improvements in the near-term in order to lay the foundation for the potential for much larger 'game changing' GHG and oil consumption reductions in the longer term." U.S. EPA and NHTSA believe it was appropriate to provide multipliers in the light-duty vehicle fleet; BEV development and penetration for the light-duty vehicle fleet is at a much more advanced commercial level than BEVs for the medium- and heavy-duty fleet, with many light-duty vehicle models available in a variety of configurations with ever-increasing consumer acceptance. It is therefore even more appropriate to allow these credits to continue for the medium- and heavy-duty fleet.

- <u>These technologies currently have substantial incremental costs, which advanced technology credits could help bring down</u>. These advanced technologies currently have higher initial costs compared to diesel or gasoline approaches due to low production volumes and higher manufacturer costs. For instance, incremental costs for vehicles using battery electric approaches is estimated at up to about $90,000 for a medium-duty vehicle (8,501 to 14,000 lbs GVWR), and substantially more for a vehicle in the heavier classes. Maintaining the 1.5 multiplier would help these technologies transition from prototype and small scale production to assembly line production, thereby reducing vehicle costs. By further encouraging early sales of these technologies, the multiplier would help drive down production cost and help zero-emission technologies become more cost-competitive.
- <u>Advanced technology credits would promote research, development and production of advanced technologies and eventual transfer of these technologies to other applications</u>: These multipliers promote the investment by manufacturers in advanced technologies. Further encouraging development and deployment of plug-in hybrid and zero-emission truck and bus technology would help accelerate the rate of these technologies transfer to other applications, such as off-road equipment and marine vessels.
- <u>Advanced technology credits would accelerate consumer acceptance:</u> One of the barriers to commercialization of plug-in hybrid and zero-emission trucks and buses is consumer reluctance to purchase unfamiliar technologies. The "energy paradox" identified in the NPRM (page 40435 of the NPRM) – whereby many readily available technologies that appear to offer cost-effective fuel efficiency benefits have not been widely adopted – is particularly difficult to overcome for the most advanced technologies such as hybrids and zero-emission vehicles. As the NPRM notes, there are numerous potential causes for the energy paradox, including behavioral

rigidity among vehicle operators, imperfect information in the new and resale vehicle markets, and inherent distrust of new technologies. California has experienced these consumer acceptance challenges as we begin our transition to zero- and near-zero-emission technologies. These challenges, where the market does not act rationally to enable cost-effective technologies, underscore the need not only for robust federal standards to help bring these technologies to market, but potentially also for additional strategies to overcome initial consumer resistance to the most advanced technologies.

The advanced technology multiplier provides an incentive for manufacturers to continue to develop BEVs and FCEVs in all class 2b through 8 categories, as well as hybrid technologies for the class 7 and 8 long haul tractor and regional vocational applications. CARB staff believes that continuing the advanced technology multiplier is an important part of promoting these technologies that, in the long term, offer a key approach to significant reduction of GHG emissions. In addition to the supply-level incentive that these credits support, CARB staff has and will continue to incentivize these technologies as well at the consumer level (demand incentive) through the use of its voucher programs, incentive funds, and other types of consumer based credits to promote demand. These programs provide funds to partially offset the incremental costs of advanced technology heavy-duty vehicles compared to equivalent conventional vehicles. CARB has planned rulemakings that will promote substantial requirements for zero-emission transit buses as well as promote advanced technologies for last mile delivery applications and airport shuttles. These planned rulemakings are part of CARB's Sustainable Freight Transport Initiative.

By continuing to allow advanced technology credits for these technologies in the Phase 2 rule, the synergy between the Phase 2 rule and California's incentive and regulatory programs for heavy-duty technologies could push further acceleration of advanced technologies development. To minimize the potential emissions impact, the incentive could be phased out at a certain manufacturer volume such as two percent of vehicles produced in that class or application. We encourage U.S. EPA and NHTSA to maintain the 1.5 multiplier for these critical technologies.

The status of hybrid, battery electric, and fuel cell electric technologies is presented through technology assessment reports, which will be posted at http://www.arb.ca.gov/msprog/tech/report.htm when available. These technology assessments support our belief that these technologies are on the cusp of major potential deployment, which the continued use of the advanced technology multiplier will support.

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40598-40602

Comment – Retirement of emission reduction credits

CARB staff recommends U.S. EPA and NHTSA consider the inclusion of a mechanism within the proposed Phase 2 rulemaking for manufacturers to quantify and then voluntarily forego/retire emission reduction credits (particularly for hybrid heavy-duty engines) in a way that is simple, real, transparent, and enforceable. CARB staff is currently developing innovative technology regulatory requirements that could allow hybrid engine, vehicle and/or driveline manufacturers to meet more flexible CARB OBD and other certification requirements to facilitate market launch of key hybrid truck and bus technologies. The innovative technology regulations could also provide more limited certification flexibility for other innovative engine technologies, such as WHR, that have the ability to achieve even greater CO_2 emission reductions. CARB staff anticipates that the innovative technology regulations could require manufacturers opting to receive this flexibility to demonstrate that the applicable hybrid or other innovative technology be surplus to all applicable rules, regulations, or other requirements. Further detailed discussion on these issues follows.

CARB staff is exploring how a potential innovative technology surplus emission reduction compliance demonstration might be conducted in a transparent and efficient way. One potential approach might be to allow manufacturers to generate emission reduction credits from the hybrid or other innovative technology as part of their federal Phase 2 compliance demonstration, and then require the manufacturer to forego/retire these credits as part of their possible Phase 2 ABT reporting. This report would then be shared with CARB as part of the demonstration that the hybrid technology receiving certification flexibility via the innovative technology regulation is surplus to any Phase 2 requirement. The accounting involved with generation, quantification, and retirement of the applicable emission reduction credits would be critical for CARB to determine that the hybrid engines opting to participate in the innovative technology regulation are surplus to Phase 2. Such a mechanism could mirror the approach taken in the NPRM, 40 CFR 1039.710(h), which allows for quantification and retirement of emission reduction credits generated by off-road engines. We believe credit for hybrid engines not participating in the Innovative Technology Regulation should continue to be allowed.

Another potential approach might be to allow manufacturers to voluntarily designate their credits to a third party, such as CARB (or other public agencies). Such an approach would provide CARB staff with assurance that a banked credit is permanently retired.

Without a reporting mechanism to ensure a technology is (and remains) surplus to the proposed Phase 2 requirements in each compliance MY, a potential Innovative Technology Regulation may need to require manufacturers to supplement any adopted federal Phase 2 compliance demonstrations with a California-specific Phase 2 compliance demonstration (with and without the hybrid or other technology, weighted as appropriate by its anticipated California sales volume). Even in such circumstances, however, it may be challenging for CARB staff to track whether a manufacturer utilizes the "surplus" reduction associated with the hybrid or other technology in future year federal compliance demonstrations. A formal mechanism for manufacturers to demonstrate compliance with any adopted federal Phase 2 standard, generate the appropriate emission reduction credits associated with a specific technology, and then permanently forego/retire those credits could help align a potential CARB Innovative Technology Regulation with any adopted federal Phase 2 program, and provide a simple, real, transparent and enforceable mechanism to encourage key technologies in California that go beyond proposed Phase 2 standards. CARB staff looks forward to discussing such a potential approach with U.S. EPA and NHTSA over the coming months as CARB, U.S. EPA and NHTSA consider the adoption of these potential rulemakings.

Hybrid Vehicle Provisions

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40190

Comment – Powertrain testing

The NPRM requests comment on “if the generic powertrains should be modified according to specific aspects of the actual powertrain. For example using the engine’s rated power to scale the generic engine’s torque curve.” For hybrid technologies, CARB staff recommends that U.S. EPA and NHTSA consider the effect of the hybrid system, e.g., the work performed by the electric motor, on the generic engine’s torque curve. Because the electric motor is sharing some of the vehicle load requirements, the engine torque map will be altered from its designed targets for similar total power requirement, at least for some operating regimes. If this is not properly accounted for by the powertrain testing procedures, inaccurate fuel economy and emissions test data may likely result.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40296-40298

Comment – Hybrid powertrain test/potential hybrid NOx increases

The NPRM is proposing to allow a single powertrain test for hybrid vehicles. Instead of A to B testing as required for hybrids in Phase 1, manufacturers would be required to conduct powertrain testing solely on the hybrid system and the test results would be used as inputs for GEM for simulation. CARB staff has significant concerns on the possible NOx increases of improperly designed heavy-duty hybrid systems, especially in light of U.S. EPA and NHTSA's current proposed provisions allowing the use of downsized engines and non-road engines in on-road heavy-duty hybrid vehicles.

The NPRM requests comment on CARB's letter recommending that U.S. EPA consider including supplemental NOx testing of hybrids. The published version of the Phase 2 proposal does not contain the supplemental check for NOx emissions as recommended in the aforementioned CARB letter. Literature data point to possible increases in NOx emissions from heavy-duty hybrid vehicles if the hybrid system wasn't properly designed and integrated and/or if the hybrid vehicles were placed in vocations with mismatched duty cycles. As an example, a recent NREL study of hybrid trucks (funded by CARB) shows the average NOx emissions level from a hybrid class 5 parcel delivery step van was 111 percent higher than the NOx emissions from a similar conventional step van when tested on a chassis dynamometer.[38] CARB staff continues to believe that this is an important issue for heavy-duty hybrid vehicles and should not be ignored, and continues to support requiring supplemental NOx testing of hybrids.

Although the Phase 2 proposal requires hybrid powertrain testing to record NOx emissions from the hybrid system, there are no provisions for addressing situations where the results show elevated NOx emissions levels. Since no penalties are specified for such a situation, manufacturers may have incentive to exploit a CO_2/NOx trade-off and optimize the hybrid system for fuel economy at the detriment of NOx emissions.

At a minimum, if the recommended supplemental check for NOx emissions is not required for every hybrid, CARB staff recommends that U.S. EPA and NHTSA specify in the Phase 2 standards the consequence for elevated NOx detected during the required hybrid powertrain testing. Possible consequences could include not allowing hybrid systems with elevated NOx to be certified under Phase 2 and/or requiring follow-up supplemental A to B testing if powertrain testing indicates elevated NOx emissions. CARB staff would be happy to work with U.S. EPA to develop the appropriate NOx emissions thresholds for hybrid powertrain testing to identify elevated NOx emissions.

If U.S. EPA and NHTSA ultimately decline to include the recommended supplemental check for NOx emissions (as described above) in the final Phase 2 rulemaking, CARB staff recommends an alternative approach. As an option, U.S. EPA and NHTSA could offer advanced technology credits to encourage manufacturers to perform the supplemental check for NOx emissions. Such credits could be offered to manufacturers who submit data showing hybrid NOx levels the same or lower than a conventional vehicle using supplemental A to B testing. CARB staff believes that these extra credits would provide incentives for hybrid manufacturers to produce hybrids without elevated NOx emissions.

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[38] (NREL, 2015b) National Renewable Energy Laboratory, "Data Collection, Testing, and Analysis of Hybrid Electric Trucks and Buses Operating in California Fleets - Final Report," page 35, June 2015, <http://www.nrel.gov/docs/fy15osti/62009.pdf>.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40325-40326

Comment – Useful life and in-use standards for hybrids

The NPRM "requests comment on the possibility of mismatched engine and vehicle useful-life values and on any possible implications this may have for manufacturers' ability to design, certify, produce and sell their engines and vehicles." (page 40326 of the NPRM). The NPRM notes that "This could lead to a situation where the engine and the vehicle are subject to emission standards over different useful-life periods." However, the NPRM suggests that "While such a mismatch in useful life values could be confusing, we don't believe it poses any particular policy problem that we need to address." CARB staff believes that the mismatching in engine and vehicle classes is a significant issue that needs to be fully addressed. All heavy-duty engines that are certified for sale have to comply with warranty requirements, which apply to the proper functioning and performance of emission-related components over the warranty period. The useful life requirements for heavy-duty vehicles of different classes are shown in the table below.

Table 15: The Useful Life Requirements for Different Heavy-Duty Vehicle Classes

Heavy-Duty Vehicle Class	Useful Life (Years)	Useful Life (Miles)
Light Heavy-Duty	10	110,000
Medium Heavy-Duty	10	185,000
Heavy Heavy-Duty	10	435,000 (or 22,000 hrs)

As can be seen from the table above, the useful period for a lighter vehicle class is much less than the emission warranty period for a heavier vehicle (i.e., 435,000 vs. 110,000 miles). If a light heavy-duty engine is used in a heavy heavy-duty vehicle, as in using a downsized engine in a hybrid vehicle, there is a disconnect between the two different sets of useful life requirements, a difference of 325,000 miles. The purchaser of a heavy heavy-duty vehicle is protected by regulations that provide 435,000 miles of emissions warranty if the vehicle has a heavy heavy-duty engine installed. However, if a light heavy-duty engine was installed in the same vehicle, the manufacturer of that engine is only liable for 110,000 miles of emissions warranty. Since the light heavy-duty engine and its emission-related components were designed to achieve the required target of 110,000 miles, it is highly uncertain whether it could continue to meet the certified emission standards if it is operated well beyond its useful life. As such, the purchaser of the vehicle would not be protected to the extent provided by the regulations. In addition, since the emissions performance of the light heavy-duty engine are only warranted for up to 110,000 miles, its installation in a heavy heavy-duty vehicle when being operated beyond that mileage is subject to potential emissions increases without recourse for corrective action.

Another significant issue is engine durability. Heavy-duty engines are designed and manufactured for an acceptable period of use, separate from the emissions warranty useful life. A heavy-duty engine in an over-the-road tractor application is expected by fleet operators to have an operating life of one million miles. A light or medium heavy-duty engine, if installed in that vocational application, is not expected to be able to last that long and may need to be replaced with a new engine some number of times over the life of the vehicle. This would result in an additional cost that may not be anticipated by the purchaser, and may not have been accounted for in the cost analysis of the NPRM, if the NPRM is assuming a certain level of engine downsizing penetration into the heavy heavy-duty vehicle application.

CARB staff believes that these are significant issues that need to be addressed in the Phase 2 rulemaking. One possible approach that was used by CARB in the Interim Certification Procedures for Heavy-Duty Hybrid Vehicles was the requirement that the hybrid vehicles, with or without engine downsizing, have to comply with the same useful life requirements as for the conventional diesel engine that would have been normally used in the same intended vehicle class.

Oppose/Requested Change Comment

Affected documents(s): Phase 2 Proposed Rule

Affected pages: 40522-40523, 40651, proposed 40 CFR 1037.605

Comment - Use of non-road engines in on-road vehicles

The NPRM requests comment on the “technical and regulatory issues surrounding the use of engines from chassis-certified vehicles in certain heavy-duty vehicles” and “on all aspects of this program to create alternate motor-vehicle emission standards that allow certified non-road engines to be used in the identified types of heavy-duty highway vehicles.” CARB generally supports U.S. EPA and NHTSA’s desire to facilitate the certification of innovative technologies that reduce GHG emissions, recognizes why U.S. EPA and NHTSA are considering allowing non-road engine use in hybrids, and lauds U.S. EPA and NHTSA's seeking to encourage development of hybrid technology. In fact, CARB staff is considering provisions in its proposed Innovative Technology Regulation that would similarly allow limited use of non-road engines in on-road heavy-duty hybrids, but only in well-defined, limited situations (more detail on the Innovative Technology Regulation is at http://www.arb.ca.gov/msprog/itr/itr.htm).[39] As discussed further below, CARB staff believes that certain safeguards must be incorporated in 40 CFR 1037.605 to ensure that the provisions for innovation do not inadvertently allow abuse and unintended emission increases.

From a technical perspective, the proposal to allow the use of downsized engines, including non-road engines, in on-road hybrid vehicles is justifiable. The combustion engine that is sized for use in a specific heavy-duty vehicle class is, in some cases, oversized, when installed in a hybrid vehicle in the same vehicle class. This is due to the sharing of the vehicle power load requirements by the electric motor in a hybrid system. The result is the combustion engine is occasionally being forced to operate in non-optimal regions of its torque map, which could lead to reduced engine efficiency and increased criteria pollutant emissions, as we have observed in a recent CARB-funded study conducted by NREL (available on our website at http://www.arb.ca.gov/msprog/aqip/hybrid_test.htm). We also agree that, if properly structured, using non-road downsized engines has the potential to reduce both fuel consumption and emissions in hybrid vehicles.

Using non-road engines in a hybrid vehicle makes the most sense in series hybrid configurations where the primary purpose of the combustion engine is to provide power to charge the batteries that are used to propel the vehicle. The combustion engine in a series hybrid configuration can then be operated in a narrow region where it is most efficient and where its emissions can be more effectively controlled. CARB staff recommends against allowing the use of non-road engines in parallel hybrid applications due to the larger range of engine operating parameters that must be controlled in order to minimize criteria pollutant emissions.

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[39] CARB held its first public workshop on the Proposed Regulation to Provide Certification and Aftermarket Conversion Flexibility for Innovative Medium- and Heavy-Duty Engine and Vehicle Emission Reduction Technologies (Innovative Technology Regulation) in March 2015, and is conducting on-going public work group meetings with interested stakeholders to craft this proposed regulation.

CARB staff recommends that U.S. EPA and NHTSA be cognizant of the fact that non-road engines are generally higher emitting than on-road engines, are certified to higher emission standards with less stringent useful life and durability requirements, and often, unlike on-road engines, are certified without a DPF. For example, the NOx and PM emission standards (40 CFR part 1039) for compression ignition non-road engines for 56 kW (75 hp) to 560 kW (750 hp) are 0.40 grams per kilowatt-hour (g/kW-hr) (~0.3 grams per brake horsepower-hour (g/bhp-hr)) and 0.02 g/kW-hr (~0.015 g/bhp-hr), respectively. In comparison, the current NOx and PM emissions standards for on-road heavy-duty diesel engines are 0.20 g/bhp-hr and 0.01 g/bhp-hr, respectively. Contrasting the useful life requirements for on-road heavy-duty engines of 435,000 miles or 22,000 hours with the useful life for >=37kW non-road engines of 8,000 hours, or 5,000 hours for lower powered non-road engines (Table 4, 40 CFR 1039.101), the large differences in the required useful life for on-road and non-road engines, and the attendant effects on warranty provisions, could give rise to durability issues that we believe are significant. Hence, their use should only be allowed in the narrow circumstances where an appropriate on-road engine is not available to facilitate the use of an advanced technology.

CARB staff is also cognizant of the potential for abuse when flexibility provisions are worded too broadly and hence suggests that some restrictions be added to the provision to prevent inappropriate use of non-road engines in on-road vehicles, such as use of a non-road engine to power an on-road truck that is also connected to a small electric assist battery. CARB staff recommends the Phase 2 regulations include several safeguards to prevent the unintended use of non-road engines in on-road vehicles more broadly than intended.

We recommend the following safeguards:

- First, the scope of applicability should be clarified in 40 CFR 1037.605(a)(1) such that the provisions are restricted to engines in vehicles with hybrid powertrains used <u>exclusively</u> to charge batteries and, by extension, not to vehicles with engines that can also directly propel the drive train as in a parallel hybrid electric vehicle. In other words, the provisions should be restricted to series hybrids only.
- Second, the provisions should be limited to vehicles with significant zero-emission range (for example, 35 miles zero-emission range).
- Third, the non-road engine must meet a 0.01 g/bhp-hr PM standard and be equipped with a DPF.

- Fourth, non-road compression ignition engines with maximum engine power less than 56 kW should not be allowed. We realize that such a prohibition has been proposed for incorporation in 40 CFR 86.007-11(g) of the criteria pollutant standard setting part for highway vehicles, but CARB staff recommends that similar language also be explicated in 40 CFR1037.605 of the GHG standard setting part itself, not just referenced as proposed, to avoid any confusion regarding the provisions applicability. Accordingly, CARB staff recommends that this concern be addressed via the inclusion of a qualifying phrase in the applicability portion of 40 CFR 1037.605, such as "… and the engines have maximum engine power ratings equal to or greater than 56 kW." (see underscored text in paragraph (a) of CARB staff's revised regulatory text on page 118 below).

With these safeguards incorporated, CARB staff would support the proposed Phase 2 provisions allowing use of non-road engines for on-road series hybrids.

Oppose/Requested Change Comment

Affected documents(s): Phase 2 Proposed Rule

Affected pages: 40522-40523, 40651, proposed 40 CFR 1037.605

Comment - OBD flexibility for specialty heavy-duty vehicles

CARB staff understands some manufacturers of hybrid engines and drivelines have had challenges meeting existing certification requirements, particularly for engine, driveline, and vehicle OBD. U.S. EPA and NHTSA's proposal would allow up to 1,000 hybrid engines and vehicles per manufacturer per year to meet significantly reduced OBD requirements, in order to help enable these technologies to come to market sooner. While we agree with the intent of this proposal, we are concerned it would enable hybrid engine, driveline, and vehicle manufacturers to sell a potentially unlimited number of vehicles with almost no diagnostic capabilities over a period of years, as long as each manufacturer's annual volume stays below 1,000. This approach could also provide an incentive for manufacturers to plan for low annual hybrid sales without ever having to invest in developing diagnostics capabilities.

OBD is critical to not only ensure that vehicle after-treatment and other controls are working properly in-use, but also to address potential engine and driveline integration issues that can result in increased NOx emissions. While CARB staff concurs that integrating a fully functional diagnostic system into a vehicle utilizing an alternate standard engine may be challenging at first, the benefits of beginning the process early are worthwhile. Access to real-time/real-world data can only improve compatibility and accelerate refinements that will result in cleaner vehicles and more reliable diagnostic systems in the near term.

CARB staff encourages U.S. EPA and NHTSA to set a sunset mechanism for the reduced OBD requirements that reflects the number of vehicles or amount of time needed for the hybrid truck market to launch. The NPRM suggests a few potential approaches to identifying an appropriate sunset mechanism.[40] CARB staff suggests U.S. EPA and NHTSA explore a sunset for the proposed hybrid certification flexibility, potentially based on phasing in full OBD requirements once 5,000 to 10,000 unit volumes per manufacturer have been produced. U.S. EPA and NHTSA could initially require engine manufacturers diagnostics (EMD) systems for manufacturers wishing to sell only a small number of engines annually and increase to full OBD requirements as a manufacturer applies to sell more engines. While such a sunset mechanism may or may not be triggered within the Phase 2 implementation timeframe, it would send an important signal to hybrid technology manufacturers that as the technology matures, they must plan for eventual OBD compliance. Without such a sunset mechanism, the 1,000 annual volume limit for reduced OBD may mean hybrid manufacturers never develop effective OBD systems.

As mentioned previously, California is developing a proposed Innovative Technology Regulation intended to provide hybrid medium- and heavy-duty engines, drivelines and vehicles with more flexible diagnostics and other certification requirements at time of market launch, ramping up to full OBD over time. CARB staff looks forward to continued coordination with U.S. EPA and NHTSA in developing the proposed Innovative Technology Regulation and in aligning it with the proposed federal program to provide heavy-duty hybrids with OBD flexibility where appropriate.

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[40] The “learning cost reduction curve” identified on pages 40439 and 40440 of the NPRM describes the reduction in unit production cost as a function of accumulated production volume. U.S. EPA has estimated that this results in an approximately 20 percent reduction in cost per every doubling in volume or, by proxy, in the third and then fifth year of production following introduction. After the fifth year following introduction, costs would decline much more slowly (at approximately two percent per year for five years then by one percent per year for the five years after that). The NPRM also indicates that a 5,000 to 10,000 unit volume per hybrid driveline manufacturer may represent a solid sales foundation that would indicate a manufacturer could justify OBD development from a resources standpoint.

BEV Provisions

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): RIA

Affected pages: 3-16 to 3-17

Comment – Modification of the minimum and maximum allowable test vehicle accumulated mileage for BEVs and plug-in hybrid electric vehicles (PHEV)

CARB staff agrees that it would be appropriate to increase the maximum allowable test vehicle accumulated mileage for BEVs and PHEVs. *Note that this proposed modification does not appear to be included in the NPRM or redlined regulatory language, only in the RIA.*

<u>Oppose/Requested Change Comment</u>

Affected document(s): RIA

Affected pages: 2-135 to 2-136, 2-199 to 2-204, 2-243 to 2-444, 11-59 to 11-61

Comment –Feasibility and costs for medium- and heavy-duty BEVs

While a BEV does not require an engine, exhaust system, or emission controls, it does require the addition of other components such as an electric motor, various electronics, and a battery pack. Of these, the battery pack comprises the vast majority of the cost. Because of the battery pack, BEVs currently have a substantial net incremental cost. The incremental cost is the cost of the BEV over and above the cost of a comparable conventionally-fueled vehicle. U.S. EPA and NHTSA present the incremental costs (2012 dollar) of EVs, and projects how it anticipates these costs will change in the foreseeable future.

While U.S. EPA and NHTSA's anticipated cost reduction approach on the part of the balance-of-components seems reasonable, CARB staff believes that significantly greater cost reductions will be realized in the future due to declining battery costs. Over the last several years, battery costs have declined substantially, and ongoing efforts on the part of academia and industry continue to reduce costs through materials changes, manufacturing improvements, and cost reductions associated with increased volumes, and are projected to continue to do so. CARB staff believes that U.S. EPA and NHTSA's cost projections overestimate the likely costs of these vehicles in the post 2020 timeframe because of the significant reductions in anticipated battery costs.

CARB staff believes that medium- and heavy-duty BEVs have a significant role to play in the near future, especially for vehicles operating in the optimal duty cycle identified for BEVs (defined routes, lots of starts and stops, high idle time, and lower average speeds). A variety of medium- and heavy-duty BEVs are now available for purchase, including shuttle buses, school buses, and transit buses, and demonstration vehicles are in use in drayage, garbage collection, and other applications. While CARB staff agrees that BEVs are not yet suitable for long-haul trucking, more localized urban opportunities for BEVs abound. CARB staff is currently pursuing battery electric and fuel cell electric requirements for buses and last mile delivery trucks, and will continue to pursue the maximum feasible BEV penetration in other applications. For more information, please see CARB's battery and fuel cell electric technology assessment, which will be posted at http://www.arb.ca.gov/msprog/tech/report.htm when available.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40303-40304

Comment – Electric truck deployment projections

CARB disagrees with US EPA and NHTSA's comment that electric trucks will not be widely commercially available in the timeframe of the proposed rule, particularly with respect to urban and miscellaneous vocational vehicles. U.S. EPA and NHTSA cite cost as one of the key factors in this determination. While CARB staff agrees that higher up-front capital costs will be a significant deterrent to zero emission truck and bus deployment in the coming decade, California is taking steps to address this challenge.

California must meet several air quality, climate, and petroleum reduction targets in the 2030 timeframe that will require a broad transformation of our light-, medium- and heavy-duty fleets to utilize zero- and near-zero-emission technologies. In recognition that this transformation will not come simply or cheaply, California is investing hundreds of millions of dollars annually to develop and deploy zero-emission vehicle technologies. Plug-in hybrid and zero-emission passenger car sales in our State have increased dramatically in the past five years, from a few hundred in 2010 to over 200,000 sold as of mid-2015. California Governor Jerry Brown's Executive Order B-16-2012 sets a target of deploying 1.5 million zero-emission vehicles by 2025, including zero-emission trucks and buses, and California's Zero-Emission Vehicle Action Plan identifies implementation strategies and milestones for achieving this goal.

While the heavy-duty sector will be much more challenging than the light-duty sector, we are implementing key strategies needed to shift trucks and buses to utilize hybrid and zero-emission technology where practical. California's Sustainable Freight Transport Initiative: Pathways to Zero- and Near-Zero Emissions Discussion Document recognizes that in order to meet our public health mandates, climate goals, and economic needs, the transition to a less-polluting, more efficient, modern freight transport system is a preeminent policy objective for the State of California – and will continue to be so for several decades to come. It will require us to make steady and continual progress in moving both domestic and international cargo in California more efficiently, with zero emissions everywhere feasible, and near-zero emissions with renewable fuels.

California Senate Bill 1204 (Lara, Chapter 524, Statutes of 2014) establishes the California Clean Truck, Bus and Off-Road Vehicles and Equipment Technology Program to fund development, demonstration, pre-commercial pilot, and early commercial deployment of zero- and near-zero-emission technologies. In June 2015, CARB approved a $350 million funding plan for fiscal year 2015-16 utilizing GHG Reduction Fund and AQIP monies. The GHG Reduction Fund provides an ongoing source of funding which California can invest in zero- and near-zero-emission transportation solutions. Previous year's investments have resulted in over 2,000 hybrid and zero-emission heavy-duty vehicles now deployed in California, mostly in delivery truck vocations.

We believe the NPRM should recognize California's critical need for, and commitment to, accelerated deployment of zero-emission heavy-duty vehicle technologies. We anticipate California will address capital cost and other barriers to zero-emission truck and bus deployment through a robust strategy portfolio of targeted incentives, complementary regulations, and other approaches. CARB staff believes that zero-emission trucks and buses will likely begin to be widely commercially available in California in the Phase 2 timeframe, particular in urban and local delivery vocations.

Given that California represents about ten percent of the nation's truck and bus market, this is not an insignificant development, even in the context of a federal Phase 2 program.

Other States and localities are also recognizing the need for zero-emission truck and bus technologies to meet more stringent eight-hour ozone standards and local air quality and health goals. New York State and the City of Chicago, for example, have followed California's lead by implementing similar funding programs to accelerate deployment of zero-emission truck and bus technologies. While we expect California will lead the nation in making zero-emission truck and bus technologies a reality, we also anticipate, much like other states have "opted in" to California's light-duty passenger car zero-emission vehicle program, our heavy-duty zero-emission vehicle program and strategies may also be a model for other states. We recommend that U.S. EPA and NHTSA recognize California's needs for, and commitment to, deployment of zero-emission heavy-duty vehicles in the 2025 to 2030 timeframe, with the expectation for significant zero-emission truck and bus deployment in the urban vocational and miscellaneous vehicle vocations.

Support/Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40159, 40331, 40389, 40616, 40750-40751

Comment – Upstream emissions/deemed zero language for BEVs

Like the Phase 1 standards, Phase 2 standards are based on tailpipe emissions. Because the expected penetration of BEVs is low, U.S. EPA and NHTSA propose to continue to treat BEVs as if they have zero emissions of CO_2, methane, and nitrous oxide (N_2O) without accounting for upstream emissions from charging. The NPRM specifically requests comment on this continued use of deemed zero language for EVs. While there are clearly emissions associated with power production to charge medium- and heavy-duty EVs, emissions associated with producing a kW of power are declining, and medium- and heavy-duty BEVs currently comprise a small portion of the fleet that the emissions associated with charging the vehicles is comparatively insignificant.

The 2017 to 2025 MY light-duty vehicle GHG rule includes a cap whereby upstream emissions would be counted after a certain volume of sales is reached. U.S. EPA and

NHTSA believe such a cap is not needed for medium- and heavy-duty BEVs due to their anticipated low likelihood of significant production volumes in the Phase 2 timeframe. CARB staff agrees such a cap need not be included in this regulation at this time. CARB staff believes a different regulatory structure for the likely small number of anticipated vehicles would put an extra burden on manufacturers and would not result in significant emission reductions.

FCEV Characterization

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40253, proposed 40 CFR 1037.621

Comment – Limited use of fuel cell electric technologies in 2021 and beyond

CARB staff believes the NPRM is overly pessimistic regarding the future of heavy-duty FCEVs. CARB believes that zero-emission technologies will be able to demonstrate greater applications, range, durability, and reliability by 2021. CARB staff is currently developing a fuel cell electric technology assessment, which will be posted at http://www.arb.ca.gov/msprog/tech/report.htm when available. In developing the fuel cell electric technology assessment, CARB staff has concluded heavy-duty FCEVs have the potential to become a prime candidate for zero-emission transportation, especially for vehicle types that travel long distances. It is reasonable to expect that fuel cell electric technology will likely be transferred to other heavy-duty applications in the near future, which will help foster broader commercialization.

Fuel cell electric buses are already in the early commercialization stage today and have demonstrated robust service records. As detailed in Attachment 4 – Active and Planned Fuel Cell Electric Vehicles Demonstrations,[41] various demonstrations of heavy-duty FCEVs have been funded through federal, state, and local programs. Fuel cell electric transit buses have been demonstrated worldwide over the last two decades, with promising results.[42] Currently, there are 24 (of which 18 are in California) demonstrated fuel cell electric buses and 22 (of which 8 are in California) planned demonstrations fuel

[41] See Attachment 4 for Active and Planned Fuel Cell Electric Vehicles Demonstrations.
[42] (NREL, 2015c) Eudy, Leslie, and Matthew Post, "Zero Emission Bay Area (ZEBA) Fuel Cell Bus Demonstration Results: Fourth Report," National Renewable Energy Laboratory, July 2015, <http://www.nrel.gov/docs/fy15osti/63719.pdf>.

cell electric buses in the U.S.[43] In addition, there are 45 (of which 22 are in California) fuel cell electric trucks that are currently being demonstrated or are planned to be demonstrated in the U.S.[44] To encourage further development of fuel cell electric technology in other heavy-duty on-road applications, a number of agencies including the U.S. Department of Energy, California Energy Commission, and South Coast Air Quality Management District have recently and are currently funding heavy-duty fuel cell electric demonstration projects, including demonstrations involving electric drayage trucks. CARB will make available approximately $25 million for near-zero- and zero-emission drayage trucks and at least $25 million for zero-emission trucks and buses in 2015. By 2021, CARB staff expects heavy-duty FCEVs will be in commercial or pre-commercial phases, depending on the vocation. However, as new technology is often more expensive, it is important to provide adequate incentives to the market at the early stage. In California, we have and will be utilizing a variety of financial incentives along with regulatory programs. We urge U.S. EPA and NHTSA to consider a similar strategy to increase the volume of heavy-duty FCEVs, reduce their cost, and establish corridor fueling networks. CARB is interested in working collaboratively with U.S. EPA and NHTSA on this effort.

Oppose/Requested Change Comment

Affected document(s): RIA

Affected pages: 2-39

Comment –Excess weight associated with fuel cell

CARB staff has significant concerns regarding the following assertion:

> Hybrid powertrains, fuel cells and auxiliary power would not only present complex packaging and weight issues, they would further increase the need for reductions in the weight of the body, chassis, and powertrain components in order to maintain vehicle functionality.

CARB staff disagrees with the statement made in the RIA that fuel cells present complex packaging and weight issues. With regard to packaging, the stack power density for a heavy-duty proton exchange membrane fuel cell (PEMFC) system (commonly used in on-road vehicles) ranges between 1,500 and 1,800 watts per liter

[43] See Attachment 4 for Active and Planned Fuel Cell Electric Vehicles Demonstrations.
[44] Id

(W/L) and the system power density is 200 to 300 W/L. The system specific power for heavy-duty PEMFCs is similar to conventional engines. For instance, a Cummins ISB 6.7 diesel engine that is used in hybrid transit buses is rated at 209 kW and with a system weight of 616 kg has a system specific power of 339 watts per kilogram (W/kg), falling in the range of a heavy-duty fuel cell system. The stack and system specific power and density are equivalent to commercial conventional engine products. Therefore, the volume and weight of a fuel cell system does not pose a "complex packaging and weight issue" for heavy-duty vehicles, nor does it compromise the vehicle's functionality.

The additional weight of FCEVs is not actually associated with the fuel cell engine. It is the electrified components that are used in hybrid electric vehicles, BEVs, and FCEVs that have some additional weight. Also, similar to compressed natural gas (CNG) vehicles, on-board hydrogen storage tanks weigh more than diesel tanks. CARB staff anticipates that weight reductions in both electrical components and hydrogen storage tanks are feasible within the Phase 2 timeframe and that heavy-duty FCEVs should not be discounted merely on a near-term assessment of weight.

Comments on Proposed Compliance, Certification, and Enforcement Provisions

OBD

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40526, 40552-40554, 40580, 40710-40712; RIA 3-2; proposed 40 CFR 86.004-28, 40 CFR 1033.535, 40 CFR 1065.680

Comment – Adjustment factors for infrequent regeneration events

CARB staff supports the proposed use of adjustment factors for correction of CO_2 emission results and fuel consumption from infrequent regeneration events from heavy-duty engines equipped with exhaust aftertreatment. However, CARB staff has concerns regarding the continued use of the methodology for calculation of infrequent regeneration adjustment factors (IRAFs) as specified in 40 CFR 1065.680.

The primary concern stems from the application of the adjustment factors to discount both FTP and heavy-duty SET emissions. Instead, the adjustment factors should be applied in such a way as to apply the discounted FTP regeneration emissions to the SET regeneration emissions. In addition, staff believes that adjustment factors should be developed separately for each engine family. Due to the concerns with manufacturers inappropriately calculating adjustment factors, staff does not recommend allowing carry-across of adjustment factors from one engine family to another.

Specifically regarding the application of IRAFs to FTP and SET emissions, staff understands that heavy-duty manufacturers have been calculating adjustment factors based on a U.S. EPA guidance document (REF CISD-06-22 HD-HWY). The concept in this document is to allow an offset in regeneration emissions from city-type driving to highway-type driving. CARB staff believes the example provided in this guidance document is flawed in that it applies discounted adjustment factors for both the FTP and SET cycles. In this example, the regeneration emissions were not applied to the SET. A true offset would seek to balance the emissions between city and highway driving. That is, if the regeneration emissions were offset from the FTP then the balance would be added to the SET; not subtracted, as done in the guidance document. This becomes more evident in the calculation of the new frequency factors, F, in the RIA's example.

The FTP regeneration frequency is decreased from 0.2 to 0.06; however, the SET frequency is also decreased from 0.05 to 0.035. This double discounting in frequency is not reasonable and does not follow our understanding of in-use regeneration frequency. Instead, there should be a composite frequency, F’, that resides between the individual cycle frequencies (i.e., 0.05 < F’ < 0.2).

CARB staff suggests that U.S. EPA and NHTSA develop a representative composite frequency that takes into account the SET and FTP frequencies similar to the example equation below. Using the data provided in U.S. EPA guidance document, an equation to offset emissions with in-use driving averaged at 30 percent city (FTP-like driving) and 70 percent highway (SET-like driving) would be as follows:

$F' = F_{ftp} * offset + F_{set} * (1 - offset)$
$F' = 0.20*0.3 + 0.05 * (1 - 0.3) = 0.095$
Where offset = percent city driving

The new frequency, F’, would be used for both FTP and SET calculations of upward adjustment factors.

The table below includes the calculation of F’ for the full spectrum of percent city driving.

Table 16: Calculation of F’ for the Full Spectrum of Percent City Driving

City Driving	F-ftp	F-set	F'
0	0.20	0.05	0.05
10%	0.20	0.05	0.065
20%	0.20	0.05	0.08
30%	0.20	0.05	0.095
40%	0.20	0.05	0.11
50%	0.20	0.05	0.125
60%	0.20	0.05	0.14
70%	0.20	0.05	0.155
80%	0.20	0.05	0.17
90%	0.20	0.05	0.185
100%	0.20	0.05	0.20

Further, CARB staff recommends utilizing existing standardized data stream parameters or developing new ones that characterize regeneration frequency on in-use engines (e.g., average regeneration frequency as a function of integrated fuel consumed, integrated work, positive kinetic energy) to complement analysis and conclusions made at the time of certification. For example, 2013 and newer MY diesel vehicles support in-use regeneration information through scan tool output. Vehicles using the SAE Standard J1939 protocol must support either SPN 5827 – 'Aftertreatment 1 Average Distance Between Active DPF Regenerations', or SPN 5454 – 'Aftertreatment 1 Diesel Particulate Filter Average Time Between Active Regenerations.' Vehicles using the SAE Standard J1979 protocol must support PID $8B which includes both 'average time between regens' and 'average distance between regens.'

Using these in-use data, a manufacturer can calculate an in-use regeneration frequency. Also, U.S. EPA and NHTSA can use these data for verification and compliance of the manufacturer's reported regeneration adjustment factors. The example below shows how the in-use data might be used to confirm reported adjustment factors:

$$F = \frac{distance\ to\ complete\ Regen}{distance\ to\ comlete\ Regen + avg.\ dist.\ between\ Regens}$$

A similar equation can be developed using a time basis:

$$F = \frac{time\ to\ complete\ Regen}{time\ to\ comlete\ Regen + avg.\ time\ between\ Regens}$$

In closing, CARB staff strongly suggests that U.S. EPA and NHTSA revise the IRAF calculation methodology to accurately account for infrequent regeneration emissions on both FTP and SET test cycles.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40511; RIA 13-37, 13-41

Comment – Liquid natural gas (LNG) boil-off warning systems

The NPRM requests comment on the feasibility and appropriateness of a regulatory requirement that LNG-fueled vehicles include a warning system that would notify a driver of a pending boil-off event as one means of reducing the frequency of such events in an effort to limit methane releases to the atmosphere. U.S. EPA and NHTSA have suggested a warning light that would be illuminated once tank pressure exceeded a threshold in addition to an audible, periodic chime. In addition, the RIA notes that the components used as inputs to the boil-off warning system would be required to be monitored by OBD, and the number of boil-off events tracked and reported. CARB staff agrees that it seems valuable to have both a driver notification (so the operator can take action to prevent or mitigate a boil off) and tracking of boil offs that actually occur to help quantify the occurrences and guide development future requirements. However, CARB staff would like to note that tracking the history of boil-off events and the methods used for boil-off would require new communication messages to be defined in both SAE Standards J1939 and J1979 if the information is to be downloaded via scan tool. Because these data are currently not standardized, CARB staff suggests a simpler near term approach such as requiring installation of a dedicated light that would illuminate if the undesired boil-off to the atmosphere event occurred. This light could be designed to only be cleared by a dealership technician. Additionally, the light could provide the same information as the scan tool messages without implementation of new scan tool messages by blinking at key-on engine-off to indicate the exact number of undesired boil-off events that occurred on the vehicle since the memory was last cleared. As the necessary standardization required to obtain boil-off event information is developed, both driver notification and event tracking via OBD could be implemented.

Note that if boil offs generally only occur when the vehicle is parked, a warning system would have to be active when the operator has shut down the vehicle. This means either the engine control module (or some other module on the vehicle) has to be kept alive during the vehicle shutdown period or some type of hardware (e.g., latching pressure-based, mechanical switches) has to be incorporated to sense the overpressure condition during the shutdown period. Both of these are feasible and have been done in OBD system implementations. However, it is not clear what the benefit is if the operator is not near the vehicle and is unable to respond.

<u>Oppose/Requested Change Comment</u>

Affected document(s): RIA

Affected pages: 13-41

Comment – Methane leak detection

While CARB staff supports the use of OBD to detect and provide a warning for when methane leaks from the CNG or LNG fuel system occur, staff is not certain if an actual methane leak check is required under the current requirements, or if rationality and functionality of sensors and components is required, or both. If a leak detection monitor is required, staff suggests that the leak size or leak rate be clearly defined. Additionally, it is important to note that simple rationality and functionality of sensors and components, which is what is required by comprehensive component monitoring, do not inherently indicate leaks in the system. A full system check would be required in order to ensure detection of CNG or LNG fuel system leaks. While feasibility of leak detection has not been determined, tank pressure profiles should follow predictable behavior and provide the basis for a monitoring strategy. In reality, the operator might notice a leak in many instances due to odor or a change in fuel level disproportionate to driving before the diagnostic system has adequate time to identify the leak and store a fault code.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40523

Comment – Alternate emission standards for specialty heavy-duty vehicles

The NRPM requests comments on the technical and regulatory issues of heavy-duty vehicles that use an engine from a smaller vehicle that is already covered by chassis-based certification under 40 CFR part 86, subpart S. For these vehicles, it is proposed that alternate standards would apply to the engine certification-based emission standards and certification requirements while all vehicle-based requirements for evaporative and greenhouse gas emissions would continue to apply as specified in the regulation.

While an engine from a chassis certified vehicle may fulfill the charging demands of a series heavy-duty hybrid, tailpipe emissions, evaporative emissions and OBD performance may be significantly compromised when the engine is used in heavy-duty hybrid applications. In the hybrid application, the engine would likely be commanded to operate at optimal efficiency speed-load points, which could be conditions that do not have optimized emissions control on the chassis cycles (e.g., sustained high load on a gasoline engine might result in enrichment for catalyst over temperature protection; it may also result in inadequate canister purging). Further, the OBD system would be calibrated to yield good OBD performance under duty cycles typically encountered by the chassis certified vehicles, which may be significantly different than the duty cycle experienced in the hybrid. A likely consequence is that diagnostics simply won't experience the conditions necessary to execute (e.g., if the monitor in the chassis certified application is designed to detect malfunctions when the engine is idling and the engine is not idled in the hybrid application, the malfunction won't be detected). A less likely yet plausible concern is that monitors will make non robust decisions (i.e., the diagnostic will indicate a malfunction is present when there isn't one). Another consequence is that the correlation between emission levels and malfunction detection will be upset (e.g., malfunctions may likely be detected at much higher emission levels because the engine operates at higher duty cycles on average). These examples highlight the need to recalibrate the emission control system and OBD system to ensure good performance in the heavy-duty hybrid application. This can be difficult to achieve by the heavy-duty vehicle manufacturer wishing to design a heavy-duty hybrid if the vehicle manufacturer does not have the intimate knowledge of and ability to reprogram the original engine computer with a custom calibration.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40523-40524

Comment – OBD for heavy-duty vehicles

The NRPM requests comment on the proposal to change U.S. EPA and NHTSA regulation to simply require manufacturers to meet the California OBD requirements. Given that, as U.S. EPA and NHTSA state, manufacturers in almost all cases certify based on the California regulations and procedures today, CARB staff generally supports this proposal. However, because California OBD requirements are in some cases more stringent than federal OBD requirements, it is important to note that some vehicles and engines currently certified through U.S. EPA and NHTSA alone as federal certifications may not be able to comply with California requirements without significant improvements to their OBD systems. If a manufacturer seeks certification of previous federal only system in California, CARB staff will require necessary improvements, which could be a significant increase in workload for the applicant and staff and could consequently increase certification timing for all applicants, depending on the additional volume of certifications. Additionally, staff has some questions regarding those situations in which U.S. EPA and NHTSA would continue to reserve the right to certify vehicles or engines as “Federal Only” certifications. Specifically, if U.S. EPA and NHTSA desire to maintain special situations it must be made clear that the vehicle is not certified to the California OBD regulation by CARB and the OBD compliance parameter identification (PID) from the scan tool (PID $1C in SAE Standard J1979) would need to report that it is a federal vehicle, even if U.S. EPA and NHTSA used the California requirements as the basis for their certification. Also, it is not clear whether U.S. EPA and NHTSA would select separate engine families for demonstration under 40 CFR 1971.1 (i) that are independent and addition to the families selected by CARB.

Labelling

<u>Support Comment</u>

Affected document: Phase 2 Proposed Rules

Affected pages: NPRM 40282, proposed 40 CFR 1037.135

Comment – Requirements for emission control labels for trailers

CARB staff supports the proposal that emission control system identifiers be included on trailer labels. Having the emission control system identifiers on the emission control label is a simple and effective way of verifying that a vehicle is in a certified configuration, and is the most commonly used method of making a compliance determination during a vehicle inspection. CARB staff does recommend that an additional requirement be included to make labels readily visible to the average person (for example, amend 40 CFR 1037.135(b) to include: "Attached in a location where the label will be readily visible to the average person after the vehicle manufacture is complete.")

<u>Oppose/Requested Change Comment</u>

Affected document: Phase 2 Proposed Rules

Affected pages: NPRM 40250-40251, 40327, proposed 40 CFR 1037.135

Comment – Requirements for emission control labels for tractors and vocational vehicles

CARB staff has significant concerns regarding the proposed removal of the requirements directing manufacturers to list the emission control system identifiers on the emission control labels for tractors and vocational vehicles certified to the Phase 2 standards. Specifically, CARB staff recommends leaving 40 CFR 1037.135(c)(6) as it currently reads, and not including the additional statement that "Phase 2 tractors and Phase 2 vocational vehicles (other than those certified to standards for emergency vehicles) may omit this information." Having the emission control system identifiers on the emission control label is a simple and effective way of verifying that a vehicle is in a certified configuration, and is the most commonly used method of making a compliance determination during a vehicle inspection. Relying solely on an electronic method of identifying vehicles would limit vehicle inspections to areas where a sufficient internet connection could be obtained in order to access an online database, and is therefore not the most practical and efficient way of determining a vehicle's compliance in all situations. For these reasons, CARB staff recommends that emission control identifiers continue to be listed on the emission control labels along with an electronic method of identifying vehicles similar to the label shown in Figure 5 below. If it is not practical to require that all emission control identifiers be listed, then CARB staff recommends at a minimum requiring that all visible components be listed. CARB staff also recommends that an additional requirement be included to make labels readily visible to the average person (for example, amend 40 CFR 1037.135(b) to include: "Attached in a location where the label will be readily visible to the average person after the vehicle manufacture is complete.")

Figure 5: Heavy-Duty Diesel Engine Emissions Control Label

Fig. 1: This is a photograph of a heavy-duty diesel engine Emissions Control Label containing both a list of emission control identifiers, and a barcode that can be used to electronically identify the vehicle.

Oppose/Requested Change Comment

Affected document: Phase 2 Proposed Rules

Affected pages: NPRM 40390

Comment – Consumer label requirements for pickups and vans

In 2011, U.S. EPA and NHTSA signed a final rule on requirements for window labels for new MY 2013 and later light-duty vehicles sold in the U.S. Such window labels provide fuel efficiency and environmental impact information to vehicle buyers, enabling them to make more informed choices and potentially buy more fuel efficient, lower GHG emitting vehicles. On page 57119 of the Phase 1 rule,[45] U.S. EPA and NHTSA committed to consider requiring similar window labels for heavy-duty pickups and vans (Class 2b and 3 vehicles) as part of the Phase 2 proposal. However, the NPRM does not include such window label requirements.

CARB staff encourages U.S. EPA and NHTSA to develop consumer label requirements for pickup and vans in Phase 2. Having window labels for heavy pickup and vans would give buyers of such vehicles better, more complete information to consider when purchasing new vehicles. It would also increase the likelihood that the more efficient, lower GHG emitting vehicles required by the proposed Phase 2 standards are embraced by consumers.

[45] Page 57119 of the Phase 1 Rule "As we did not propose a consumer label for heavy-duty pickups and vans in this action and have not appropriately engaged the public in developing such a label, we are not prepared to finalize a consumer-based label in this action. However, we do intend 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." (Federal Register / Vol. 76, No. 179, Sept. 15, 2011).

Test Procedures

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40178-40179

Comment – Chassis dynamometer test procedure

The NPRM requests comment on whether a chassis dynamometer test procedure should be required in lieu of the proposed vehicle simulation approach. CARB staff supports chassis testing for vehicles that are already emissions certified on chassis dynamometers and provisions for similar vehicles that can also be tested using widely available chassis dynamometer testing resources, as proposed in the NPRM. These are the lighter end of the heavy-duty vehicle range.

The NPRM's proposed chassis dynamometer testing requirements will expand the data set of chassis dynamometer emissions measurements, which will help provide data needed to evaluate vehicle integration success. CARB staff believes chassis dynamometer testing is critical for assessing engine, powertrain, and vehicle integration effects on GHG emission levels. For its own testing needs, CARB staff is committed to developing a robust in-house test program by aggressively working to expand its heavy-duty chassis dynamometer testing capacity for the comparison of chassis data with simulation, PEMS, and engine/powertrain test data.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40179

Comment – Powertrain testing requirement

The NPRM requests comment on whether U.S. EPA and NHTSA should require powertrain testing more broadly. CARB staff supports the proposed use of powertrain testing, and also supports future further exploration of powertrain and powerpack testing for certification use. The demands on the GEM simulation will be reduced as more of the engine/transmission interaction is demonstrated by physical operation in test cells. In this fashion, the detailed engine/transmission interaction behavior will be directly captured rather than being potentially ignored by simplifying assumptions in the GEM model.

CARB staff anticipates that growth in powertrain testing will act to encourage collaborative information exchange between engine, transmission, and hybrid powertrain development groups. Maximization of the anticipated GHG savings from advanced powertrains cannot be realized without engine, transmission and hybrid powertrain development groups affecting the designs of each other's products. CARB staff sees adoption of a powertrain testing pathway for certification as a possible incentive in this collaborative direction.

Neutral/Provide Additional Information Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40179-40180

Comment – Engine-only testing over the GEM duty cycle approach

CARB staff generally supports the NPRM's proposal for vehicle simulation and engine testing and is interested in the extent to which engine-only testing can help capture the transient behavior that is lost in a steady state fueling map simulation approach. This capture of transient behavior could yield more robust results for vocational applications that are characterized by hard acceleration and by stop-and-go driving patterns.

As has been noted, the simulation burden for correctly capturing transmission behavior is non-trivial even with access to the proprietary control algorithms. CARB staff anticipates that engine/transmission interactions will continue to develop in both sophistication and prevalence as powertrain development groups seek to maximize efficiency and minimize GHG emissions. This increased complexity is likely to make high fidelity transmission modelling increasingly difficult over time. The advantages of engine-only testing to augment the GEM model inputs could be viewed as a partial step toward eventual use of powertrain and powerpack testing inputs in the GEM model.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40180-40181

Comment – Full vehicle simulation approach (advantages and disadvantages)

The NPRM requests comment on the proposed approach for full vehicle simulation. CARB staff generally supports the proposed full vehicle simulation approach, and is in favor of GEM including additional subsystems to provide manufacturers greater design flexibility and incentivize the development of vehicles that fully realize the GHG benefits of well-integrated systems.

Additionally, the NPRM requests comment on whether the Phase 2 full vehicle simulation proposal, which potentially requires engine manufacturers to disclose proprietary engine performance information to vehicle manufacturers long before production, would enable the "reverse engineering" of engine manufacturers' intellectual property, and if so, what steps U.S. EPA and NHTSA could take to address this issue. While CARB staff recognizes that this proposed approach will likely require engine manufacturers to disclose more detailed engine design and performance information early in production cycles, certainly earlier than currently occurs, CARB staff believes this will be a positive development that will facilitate better engine, component, and vehicle integration necessary for achieving maximum, cost-effective fuel efficiency improvements and GHG benefits.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40190

Comment – Powertrain testing in GEM (generic powertrain modification, transmission gear ratio scaling)

The NPRM requests comment on whether the generic powertrains should be modified according to specific aspects of the actual powertrain, for example by using the engine's rated power to scale the generic engine's torque curve. CARB staff believes the generic powertrains should be modified with actual powertrain data and support the proposed efforts to include further experimental data into the GEM simulation. The interpolation of powertrain test CO_2 data for advanced powertrains allows the real behavior of the powertrain control algorithms and actuator responses to more fully manifest in the GEM evaluation while also minimizing testing burden and avoiding the need to divulge detailed proprietary powertrain control algorithms.

CARB staff support gear ratio scaling as it is in line with including all trivially available powertrain parameters in the GEM simulations.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40190-40191, 40251

Comment – Annual production vehicle testing for comparison to GEM requirement, chassis dynamometer testing (cost and efficacy)

The NPRM requests comment on the proposed testing requirement for annual production vehicle testing. CARB staff supports requiring annual production vehicle testing, but wants to encourage sufficient chassis testing across the variety of vehicle types to verify that the GEM model remains robust over time in the face of shifting vehicle and engine technologies. CARB staff also prefers that the range of technologies be represented rather than just those technologies present on the highest volume vehicle models. Restriction to only the highest volume models could blind this GEM evaluation to a large aggregate fraction of vehicle sales that will never individually rise to the popularity level necessary to qualify for chassis testing under the current vehicle selection criteria. CARB staff prefers there be some representation of non-highest-seller vehicles.

The “configuration” language is ambiguous. This GEM evaluation would be best served by spreading the sparse testing across five vehicle configurations that differ from each other as much as possible (transmission type and gearing, engine size, axle ratios, etc.) while selecting from widely used configurations. CARB staff seeks to avoid a situation where the meaning of a “configuration” is interpreted so strictly that all 12 most popular configurations, from which a manufacturer is allowed to select, may be essentially the same configuration with near trivial differences from GEM or actual GHG perspectives.

To address the concerns above, CARB staff recommends amending the regulatory language as described below:

> **§ 1037.665 In-use tractor testing**.
> perform in-use testing as described in this section.
> (a) The following test requirements apply beginning in MY 2021:
> 1 or more models that you project to ~~be among~~ **represent the diversity of** your 12 highest-selling vehicle configurations for the given year.

This tractor based GEM evaluation avoids the vehicles most likely to stress the GEM model's assumptions. Particularly avoided are vocational vehicles in heavily transient applications such as urban buses and solid waste collection vehicles, and vehicles with complex engine/transmission interactions such as advanced powertrain hybrids. CARB staff sees widespread deployment of electrified vocational vehicles (including hybrids) as central to meeting our GHG reduction goals thus lending importance to planning for their inclusion in future GEM model evaluations. CARB staff would prefer to see some representation of vocational and other non-tractor heavy-duty vehicle categories where the GEM model assumptions may not hold as well as for classic tractor vehicles.

The NPRM requests comment on the costs and efficacy of the requirement for manufacturers to annually chassis test three sleeper cab tractors and two day cab tractors and submit these data and GEM results. CARB staff feels that this testing requirement for comparison to the GEM model gathered from across the heavy-duty vehicle market is important for maintaining confidence in the certification simulation method as vehicle technology evolves. The limited amount of annual testing per manufacturer appears financially and operationally manageable while also providing an aggregate industry-wide dataset needed for evaluating correlation of actual emissions with GEM simulation results trends.

The financial burden and operational limitation of available facilities are both eased by the relaxation of emissions measurement equipment specifications from those typical of engine emissions certification test cells. This allows any transient heavy-duty chassis dynamometer to be used by temporary placement of a PEMS unit next to it.

CARB staff agrees that for the purposes of this GEM evaluation the reduced instrumentation requirements of Subpart J are an acceptable cost savings and open many more potential chassis testing sites for consideration.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40265

Comment – The use of Class 8 tractors for compliance simulation as well as performance testing

The NPRM requests comment on the use of class 8 tractors when tractor-trailer combinations are used for compliance simulation as well as performance testing. We agree with the expediency of standardizing use of the class 8 tractors for determining trailer compliance even though the tractors pulling some trailer categories include a small portion of class 7 tractors. This approach will simplify compliance, and the differences between the results for a class 8 tractor pulling a trailer and a class 7 tractor pulling that same trailer are relatively minor. We recommend that this assumption be revisited if class 7 tractors grow in popularity or if the class 7 vs. class 8 tractor difference for tested trailers becomes significantly different due to evolving technology.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40278-40279

Comment – A to B testing for trailer aerodynamic performance - the issue of varying performance for devices across the range of short van lengths, full credit for aerodynamic improvement

The NPRM requests comment on approaches to address the issue of varying performance for devices across the range of short van lengths. CARB staff supports U.S. EPA and NHTSA's proposed grouping approach.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40279-40280

Comment – Trailer aerodynamic compliance testing; pros and cons of exclusive use of zero-yaw data, allowing the use of wind-averaged results for compliance, strategy, supporting data

The NPRM requests comment regarding the pros and cons of exclusive use of zero-yaw data from trailer aerodynamic testing. CARB staff believes that there are advantages of using zero-yaw data. The primary advantage is that zero-yaw data is more reproducible than non-zero-yaw (multiple yaw angles) data. If U.S. EPA and NHTSA provide the option of using either zero-yaw or multiple yaw angle data, the same yaw angle must be chosen for both A and B cases to properly attribute aerodynamic benefits.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): RIA

Affected pages: 3-16

Comment – Making the constant speed test procedure the reference aerodynamic method

The RIA requests comment whether the constant speed test procedure should be the reference aerodynamic method. CARB staff believes the constant speed test procedure should not be made the reference method until it can be demonstrated to be superior to the coastdown type methods. The constant speed test procedure requires invasive and costly vehicle modifications in preparation for testing. Namely it requires installation of physical torque meters in either multiple wheel hub positions or in a custom driveshaft location. Nevertheless, while CARB staff believes it is pre-mature at this time to deviate from the accepted industry practice of the coastdown method, we also believe the constant speed procedure holds merit as a potential alternative to the coastdown method. CARB staff looks forward to working with U.S. EPA and NHTSA to examine the full potential and applicability of the constant speed procedure.

Comment on Topic Where NPRM Requests Comment

Affected document(s): RIA

Affected pages: 3-79 to 3-80

Comment – Hybrid charge sustaining operation - FTP or "City" Test and HFET or "Highway" Test: modifying the minimum and maximum allowable test vehicle accumulated mileage for both BEVs and PHEVs

The RIA requests comment on modifying the minimum and maximum allowable test vehicle accumulated mileage for both BEVs and PHEVs. CARB staff agrees with SAE's test validity criterion of a 1 percent limit on net State of Charge compared to fuel energy. CARB staff agrees minimum and maximum test vehicle allowable mileage should have flexibility to account for unique usage and wear accumulation in plug-in and BEV vehicles. CARB staff recommends that deviations from the standard requirements be contingent on the certifying manufacturer submitting an engineering justification and the agency's subsequent approval.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40519-40520

Comment – Proposed evaporative emissions testing provisions for LNG vehicles

The NPRM requests comment on all aspects of the proposed provisions for LNG vehicles.

CARB staff supports regulatory action encouraging long hold times before boil off emissions are emitted, but suggests clarifying the requirements. The draft Phase 2 regulatory language states, "Liquefied natural gas vehicles must meet the requirements in Section 4.2 of SAE J2343 (incorporated by reference in § 1037.810), which specifies that vehicles meet a five-day hold time after a refueling event before the fuel reaches the point of venting to relieve pressure."

SAE Standard J2343 states the following regarding LNG venting and tank design: "Vehicle LNG Tanks shall have a design hold time (build pressure without relieving) of 5 days after being filled net full and at the highest point in the design filling temperature/pressure range." (Section 4.2 of SAE Standard J2343)

The SAE Standard J2343 covers the test initial conditions adequately: 1) fill level and 2) thermal energy in the tank as expressed in either temperature or pressure of the fuel, and the draft Phase 2 regulatory language specifies that the vehicle must remain parked away from direct sun with ambient temperatures between (20 and 30) degree Celsius throughout the measurement procedure.

However, the SAE Standard J2343 does not give detail about how fill level, thermal energy in tank, or venting would be measured. For example, the fuel flow rate threshold or minimum fuel mass emission that defines a venting event needs to be specified.

CARB staff recommends specifying the required measurement techniques for determining hold time.

There is also need for durability requirements for LNG tanks. At present the NPRM proposal is for 5 days for new vehicles only with no restriction on subsequent degradation of vacuum insulated tanks. A minimum durability of the insulation is imperative to controlling boil off emissions over the life of the vehicle. CARB staff recommends the following language be added: "vehicle mounted LNG tank insulation shall continue to meet SAE Standard J2343 hold time standards through the emissions warranty period of the vehicle."

<u>Neutral/Provide Additional Information Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40287-40288

Comment – Proposed composite test cycle weightings (in percent) for vocational vehicles

The Composite Test Cycle is weighted based on the CARB transient cycle, 55 mph cruise with road grade cycle, and 65 mph cruise with road grade cycle. The idling portion is already included in those three cycles. But in the NPRM's Table V-2, it appears that idling is additional to the three cycles. And if the percentages in each row in Table V-2 are added up, they sum to higher than 100 percent. For example, under urban conditions, the table indicates 94 percent CARB transient, 6 percent 55 mph cruise, and 20 percent idle. CARB staff recommends clarification on how these percentages will be used.

GEM

<u>Neutral/Provide Additional Information Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40182-40191, 57464; RIA 4-1 to 4-38

Comment – Overall Phase 2 GEM

The GEM was developed by U.S. EPA for demonstrating compliance with U.S. EPA's GHG emissions and NHTSA's fuel consumption vehicle standards, applicable to class 7 and 8 combination tractors, trailers, and class 2b-8 vocational vehicles. In Phase 1 GEM, most of the simulation parameters were predefined and there were only very limited number of user input parameters. The proposed Phase 2 GEM (GEM P2v1.0) was substantially improved to better model real-world impacts of various fuel efficiency technologies. GEM P2 allows more user input simulation parameters including engine-specific fuel maps, transmissions, and drive axle ratios, which will increase accuracy. The model was validated using approximately 130 vehicle variants, using both chassis and powertrain dynamometer tests.

CARB staff commends U.S. EPA for taking significant steps to improve the model.

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA; Executable Version of GEM P2v1.0; and GEM User Manual

Affected pages: NPRM 40182-40191, 57464; RIA 4-1 to 4-38; GEM User Manual 1-48

Comment – Phase 2 GEM improvements

CARB staff has evaluated and run GEM P2v1.0 and has several suggestions and recommends for clarification:

While GEM for Phase 1 included a graphical user interface (GUI), GEM P2v1.0 does not. CARB staff still prefers GUI for data input. We believe that GUI makes it easy for users to select or input data without the need to see behind the scenes information. We understand that GUIs are not simple to make or upgrade. However, we encourage U.S. EPA to develop a GUI for GEM P2 that can integrate the added Phase 2 technology information.

In the GEM user manual, it is not clear on how to input or edit parameters. We recommend adding clarification regarding how to create new input files and how to use the 'Sample Input Files'.

The proposed GEM was generally designed for diesel engines. We recommend that natural gas engines be treated separately in GEM because their specifications are significantly different from the diesel engines. Please see page 148 for detailed comments on natural gas requirements.

In the future, we encourage U.S. EPA to consider linking GEM to the VERIFY database to make analysis of GHG and criteria pollutant data more convenient.

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA; Executable Version of GEM P2v1.0; and GEM User Manual

Affected pages: NPRM 40182-40191, 57464; RIA 4-1 to 4-38; GEM User Manual 1-48

Comment – Phase 2 GEM technologies included

We appreciate U.S. EPA and NHTSA including additional technologies such as low friction axle lubricant in GEM P2's pull-down menus that were not included in GEM for Phase 1. We recommend U.S. EPA and NHTSA also add to GEM P2 potential aerodynamic improvements and electrified accessories for vocational vehicles and solar control for heavy-duty pickups and vans in the pull-down menu as well. We believe that both technologies must be considered in the overall stringency to further improve emissions in the vocational sector.

Please see detailed comments on vocational vehicles, vocational aerodynamics, and BEVs on pages 36, 44, and 84 respectively.

As described further in our VSL comment on page 143, we recommend that U.S. EPA reconsider offering credit for VSLs and remove them from the GEM P2 pull-down menus.

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40326-40327

Comment- Potential for manufacturers to choose a specific vocational duty cycle for GEM simulation

The NPRM requests comment on allowing vocational vehicle manufacturers to request a different duty cycle versus allowing them to select a test cycle without any need for U.S. EPA or NHTSA approval. CARB staff supports U.S. EPA and NHTSA's proposal for assigning vocational vehicle test cycles through the designated formulas, while still allowing manufacturers to petition to use an alternative. CARB staff does not support allowing manufacturers complete freedom in choosing a test cycle. CARB staff believes that this freedom could lead manufacturers to test on cycles that are not applicable to the duty cycle of the vehicle in an effort to meet less stringent emission standards. The proposed mechanism of allowing manufacturers to petition for use of an alternative test method means that manufacturers must show proof that the vehicle they are certifying meets the criteria for the specific test cycle. Although slightly more burdensome for regulators, CARB staff believes the requirement of a petition to test on an alternative cycle will keep manufacturers from trying to circumvent the emission standards and is the best approach to take.

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40192, 40587, 40592-40593, 40751

Comment – Fuel map requirements

U.S. EPA and NHTSA are proposing that engine manufacturers must certify fuel maps as part of their certification to engine standards, except in cases where they certify based on powertrain testing, and that engine manufacturers be required to provide these fuel maps to vehicle manufacturers beginning with MY 2020 engines, since MY 2020 engines may be used in MY 2021 vehicles. Vehicle manufacturers may not develop their own fuel maps for engines they do not manufacturer. For Phase 2, GEM will allow the input of engines-specific fuel maps, which will increase accuracy. CARB staff supports these requirements as stated.

Non-Road Engines and Vehicles

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40534, 40682, proposed 40 CFR 1039.110

Comment – Recording reductant use and other diagnostic functions

CARB staff conceptually supports U.S. EPA and NHTSA's proposal requiring non-road compression ignition engine manufacturers to incorporate OBD that monitor selective catalytic reduction (SCR) reductant levels and quality, and alert the equipment operator when those levels and quality are out of specification. Advanced notification of compromised or low levels of reductant will help to ensure proper SCR operation in-use, and should help minimize occurrences of the engine entering a derated mode of operation per existing SCR inducement strategies.

CARB staff understands that this proposal is not meant to replace SCR inducement policies, but rather to complement them with additional detection capability in an uncomplicated manner. While we generally prefer simple and straightforward approaches as well, diagnostics need the proper balance between simplicity and utility. As such, CARB staff recommends that extra rigor be introduced in 40 CFR1039.110 to enhance monitoring effectiveness and compatibility. CARB's "On-Board Diagnostic System Requirements for 2010 and Subsequent Model-Year Heavy-Duty Engines" in Title 13 of the California Code of Regulations (CCR), Section 1971.1, contain reductant level/quality monitoring provisions that could serve as guidelines for a more robust federal mechanism.

At a minimum, CARB staff recommends that U.S. EPA and NHTSA adopt standardized fault codes (e.g., SAE Standard J1939 or controller area network (CAN) based), monitoring conditions, malfunction criteria, and fault processing protocols to ensure reasonable and reliable diagnostic system monitoring frequency and malfunction detection performance. Precautions such as these will help ensure that issues related to reductant quality and replenishment are detected and addressed in a timely manner, and will undoubtedly prove useful should matters of in-use compliance and enforcement come into question. For example, there are no timeframes for detection specified in the proposed language; therefore, a manufacturer could theoretically only monitor once per month (or even less frequently) rendering the diagnostic virtually useless. Therefore, we recommend U.S. EPA and NHTSA to clearly define a minimum performance metric such that the monitoring strategy provides detection capability several times per tank fill of reductant, or continuously for the parts of the diagnostic that rely on electrical continuity or out of range type checking. Standardization may also create opportunities for innovative control approaches by third party developers who might otherwise not have access to proprietary diagnostics.

Additionally, CARB staff recommends that U.S. EPA and NHTSA revise the reductant quality monitoring exemption in 40 CFR 1039.110(a) for vehicles that already possess a diagnostic NOx sensor. The problem with the provision is that it requires a NOx sensor to be present with the capability to monitor reductant quality, but does not necessarily require the sensor to monitor reductant quality in any meaningful way. We recommend that a qualifying statement be appended to the language to address this limitation (see underscored text in paragraph (a) of CARB staff's revised regulatory text below).

CARB staff also recommends the same degree of standardization and robustness mentioned above for any emission-related diagnostic strategy employed per the provisions of 40 CFR1039.110(b). Taking the time to standardize diagnostic practices now will save valuable resources in the future when more comprehensive OBD requirements are adopted for the non-road compression ignition category. For reference, 40 CFR1039.110(b) contains the following language:

"§1039.110 Recording reductant use and other diagnostic functions.

(a) Engines equipped with SCR systems using a reductant other than the engine's fuel must have a diagnostic system that monitors reductant quality and tank levels and alert operators to the need to refill the reductant tank before it is empty, or to replace the reductant if it does not meet your concentration specifications. Unless we approve other alerts, use a warning lamp or an audible alarm. You do not need to separately monitor reductant quality if you include an exhaust NOx sensor (or other sensor) that allows you to determine inadequate reductant quality <u>and alert operators when the condition that is indicative of inadequate reductant quality is present</u>. However, tank level must be monitored in all cases.

(b) You may equip your engine with other diagnostic features. If you do, they must be designed to allow us to read and interpret the codes. Note that § 1039.205 requires you to provide us any information needed to read, record, and interpret all the information broadcast by an engine's onboard computers and electronic control units."

Neutral/Provide Additional Information Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40683, proposed 40 CFR 1039.135(d)

Comment – Allowing optional content on the emission control label for non-road compression ignition engines

Although CARB staff recognizes that this particular provision merely allows manufacturers to incorporate features on the label that can be used to identify counterfeit labels (which CARB staff supports in principle), CARB staff recommends that U.S. EPA and NHTSA include a provision requiring the case-by-case approval of all manufacturer specific content on the label or any content not specifically identified in the regulations, prior to issuing a Certificate of Conformity. U.S. EPA and NHTSA should retain the right to reject any content that could have unintended consequences regardless of whether or not that content meets the general criteria for the optional label content. In particular, staff is concerned that too much information on the label could be a source of confusion to the end user or to enforcement inspectors in the field. For example, a manufacturer might want to use the labelling provisions of 40 CFR 1039.135(d)(1) to identify an ABT engine, that was originally certified to a family emission limit (FEL) consistent with Tier 3 emission levels, as being compliant with the more stringent Tier 4 emission levels. While this identification may not be inaccurate, it could create a situation for California's in-use programs in which fleet owners mistakenly purchase these ABT engines believing that they fulfill the owners' requirements for upgrading the "emissions average" of their fleets. Such a situation could negatively impact both the effectiveness of CARB's in-use programs and the fleet owners' costs should penalties be assessed. Other situations could be problematic, such as the inclusion of bar codes or Quick Response® (QR) type matrix codes on the emission control label that would redirect to a manufacturer supported webpage over which U.S. EPA and NHTSA have no control, or which a manufacturer may decide to no longer support at a future date. CARB staff does not have a comparable allowance for optional label content for off-road compression ignition engines, as the CAA prohibits

California from regulating farm and construction equipment under 175 hp; therefore, we must rely on U.S. EPA and NHTSA to protect California's interests in this matter.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40687; proposed 40 CFR 1039.701(h)

Comment – Foregoing emission credits; Expiration of credits

CARB staff fully supports the provisions in 40 CFR 1039.701(h) that allow manufacturers to voluntarily waive their rights to use banked emission credits. CARB staff's only recommendation for amending this proposal is that U.S. EPA and NHTSA should clarify that manufacturers choosing not to generate credits for an engine family certified to a FEL more stringent than the applicable standard, as described in 40 CFR 1039.701(h)(2), are permanently bound by that choice and cannot later decide to claim credits for that engine family retroactively in a subsequent MY.

On a separate but related topic, CARB staff recommends that U.S. EPA and NHTSA adopt provisions to set a reasonable timeframe for the compulsory expiration of Tier 4 non-road compression ignition emission credits, and codify the terms for expiration in 40 CFR 1039.740. California is a participant in the federal ABT program and is therefore dependent on U.S. EPA and NHTSA for action regarding this request. Our concern is the delay in the full implementation of engines in California equipped with advanced exhaust aftertreatment controls for both PM and NOx. More manufacturers than anticipated are certifying off-road compression ignition engine families in California to Tier 4 final standards without simultaneously employing both PM and NOx aftertreatment devices, and this is due in part, we believe, to manufacturers' use of banked emission credits. We recognize that other factors may contribute to this situation as well, but addressing the expiration of emission credits would help California to more quickly achieve its much needed PM and NOx emission reduction goals.

<u>Oppose/Requested Change Comment</u>

Affected documents(s): Phase 2 Proposed Rule

Affected pages: 40522-40523, 40651, proposed 40 CFR 1037.605

Comment - Exemption from on-road engine criteria pollutant standard for engines in vehicles with maximum speed at or below 45 mph

CARB staff recommends that the scope of the provisions be narrowed such that they do not apply universally to all vehicles with maximum speed at or below 45mph. The need to exempt engines solely on the basis of maximum speed is unclear and has not been thoroughly explained or justified in the preamble. Furthermore, the use of an engine to directly propel a vehicle on the highway, even at less than 45mph, would necessitate the use of a highway certified engine per U.S. EPA and NHTSA's own preamble arguments regarding the representativeness of duty-cycle operation. CARB would not be opposed to relief for specific applications in this category should the need for relief be justifiably explained, but as the provision stands now it seems to have more potential to create new business opportunities that rely on the use of less stringent engines than it does to drive innovation to reduce emissions.

<u>Oppose/Requested Change Comment</u>

Affected documents(s): Phase 2 Proposed Rule

Affected pages: 40522-40523, 40651; 40 CFR 1037.605

Comment - Exemption of amphibious and speed-limited vehicles

The proposed classification of amphibious and speed-limited vehicles utilizing alternate emission standards as, "exempt from the requirements for greenhouse gases" would make it extremely difficult, if not impossible, to enforce violations of these provisions should they occur. This would be especially true for individual states, such as California, which would only have the emissions labels and nationwide end-of-year production reports as the sole means of differentiating compliant vs. non-compliant vehicles within their borders. Although U.S. EPA and NHTSA propose to limit these exempted vehicles to no more than 200 federal units per manufacturer per MY, there are no guarantees that these engines will end up distributed evenly with respect to each of the 50 states. In fact, states with either coastal access or numerous accessible waterways, such as California, will probably receive disproportionately larger numbers of amphibious vehicles than will other states that lack such features. Furthermore, trying to hold manufacturers accountable to any standard is often untenable when vehicles and engines are considered exempt from regulation. CARB staff believes the potential for abusing this provision is significant and recommends that U.S. EPA and NHTSA address the issue by requiring manufacturers using these provisions to be granted an "abridged" form of a Certificate of Conformity prior to the introduction of their engines into commerce. This would greatly facilitate the in-use tracking and identifying of improper applications of the provision. As a template, U.S. EPA and NHTSA might consider adopting an abridged Certificate of Conformity similar to the abridged Executive Order that California grants for off-road compression-ignition engine families certified under the relief provisions in the Transition Program for Equipment Manufacturers in California (13 CCR 2423 (h)).

CARB staff's suggested revisions to 40 CFR1037.605 based on the comments above are indicated below in strikeout/underline format.

§1037.605 Installing engines certified to alternate standards for specialty vehicles.
(a) General provisions. This section allows vehicle manufacturers to introduce into U.S. commerce certain new motor vehicles if the installed engines are certified to alternate emission standards that are equivalent to standards that apply for non-road engines under 40 CFR part 1039 that have maximum engine power ratings equal to or greater than 56 kW or part 1048. See 40 CFR 86.007-11(g) and 40 CFR 86.008-10(g). The provisions of this section apply for the following types of vehicles:
(1) Vehicles with a hybrid powertrain in which the engine provides energy exclusively for the Rechargeable Energy Storage System.
(2) Amphibious vehicles.
~~(3) Vehicles with maximum speed at or below 45 miles per hour. If your vehicle is speed limited to meet this specification by reducing maximum speed below what is otherwise possible, this speed limitation must be programmed into the engine or vehicle's electronic control module in a way that is tamper-proof. If your vehicles are not inherently limited to a maximum speed at or below 45 miles per hour, they may qualify under this paragraph (a)(3) only if we approve your design to limit maximum speed as being tamper-proof in advance.~~

(b) Notification and reporting requirements. Send the Designated Compliance Officer written notification describing your plans before using the provisions of this section. In addition, by February 28 of each calendar year (or less often if we tell you), send the Designated Compliance Officer a report with all the following information:

(1) Identify your full corporate name, address, and telephone number.

(2) List the vehicle and engine models for which you used this exemption in the previous year and identify the total number of vehicles.

(c) Production limits. You may produce up to 1,000 hybrid vehicles and up to 200 amphibious vehicles, under this section in a given MY. This includes vehicles produced by affiliated companies. If you exceed this limit, the ~~exemption~~ provision is void for the number of vehicles that exceed the limit for the MY. ~~For the purpose of this paragraph (c), we will include all vehicles labeled or otherwise identified as exempt under this section.~~ You must apply for and be granted an “abridged” Certificate of Conformity per the instructions in §1037.201(c)([*to be determined*]) to use the provisions of this section.

(d) Vehicle standards. Hybrid vehicles using the provisions of this section remain subject to all other requirements of this part 1037. For example, you must use GEM in conjunction with powertrain testing to demonstrate compliance with emission standards under subpart B of this part. Vehicles qualifying under paragraph (a)(2) or (a)(3) of this section ~~are exempt from the requirements of this part, except as specified in this section; these vehicles~~ must include a label as specified in §1037.135(a) with the information from §1037.135(c)(1) and (2) and the following statement: “THIS [amphibious vehicle or speed-limited vehicle] IS ~~EXEMPT FROM GREENHOUSE GAS STANDARDS~~ CERTIFIED UNDER THE SPECIAL ALLOWANCES OF 40 CFR 1037.605.

Comments on Other Proposed Amendments

Baseline Scenario

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40166, 40489-40492

Comment – Flat vs. dynamic baseline scenario

The NPRM requests comment regarding which alternative baseline scenario is most appropriate (flat baseline scenario vs. dynamic baseline scenario). Historically, for modeling and emission projection purposes, CARB staff assumes manufacturers would not go beyond regulations' requirements except where we have data that shows otherwise. CARB staff does not have data that suggests that manufacturers, in the absence of further, stricter standards, would make vehicles more fuel efficient than required by the Phase 1 standards. As a result, our EMFAC 2014 emissions inventory database does not project fuel economy improvements or CO_2 emission rate reductions beyond what is required by Phase 1, and CARB staff has been using a flat baseline for our Phase 2 emissions analysis. In the absence of certainty regarding how manufacturers would behave if no Phase 2 program were adopted, CARB staff believes the approach taken in the NPRM and RIA to examine both a less dynamic and more dynamic baseline is valid and reasonable.

Gliders

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40125, 40215, 40528-40530

Comment – Gliders: Proposed amendment to U.S. EPA and NHTSA vehicle and engine standards

CARB staff supports U.S. EPA's proposal to end Phase 1 provisions in 40 CFR part 1037 that: a) allow used, remanufactured or rebuilt engines certified to pre-Phase 1 emission standards to be installed in glider kits; and b) exempt glider kits and glider vehicles[46] produced by small businesses from the requirement to obtain a *vehicle* certificate[47] for GHG emissions compliance. Since the adoption of the federal 2007/2010 emission standards for PM and NOx, glider sales have significantly increased, and the Phase 1 provisions affecting glider kit and glider vehicle production did not inhibit the accelerated growth in the glider market.

U.S. EPA believes, and CARB staff concurs, that the proposed changes in the Phase 2 rulemaking are necessary to curb the nearly 10-fold increase[48] in the sale of glider vehicles with older engines (used, remanufactured, or rebuilt), and the associated increase in emissions that has occurred since the implementation of the 2007/2010 NOx and PM standards. While criteria pollutant increases due to the sale of glider vehicles with older engines is somewhat constrained in California as a result of CARB's Truck and Bus Regulation, which required the installation of DPFs on heavier trucks (GVWR over 26,000 lbs) starting in 2012, and engine upgrades to at least 2010 NOx and PM emission levels starting in 2015 for lighter trucks (with GVWR under 26,000 lbs), CARB

[46] "Glider kit" typically refers to a chassis and cab assembly produced by a manufacturer without a new engine, transmission, or rear axle. "Glider vehicle" or "glider" typically refers to the completed assembly of the glider kit with a used, remanufactured, or rebuilt engine, a transmission, and/or rear axle. U.S. EPA considers "glider kits" to be incomplete motor vehicles, and, under the Clean Air Act, has the authority to regulate incomplete motor vehicles, including unmotorized chassis.

[47] Under Phase 1, U.S. EPA requires glider kits and gliders to obtain a *vehicle* certificate, except those produced by small businesses. The engine installed in the glider kit is not required to certify to the Phase 1 engine standards. Thus, depending on the size of the business producing the glider kit or glider vehicle, some are exempt from the requirement to obtain a Phase 1 vehicle certificate prior to introduction into commerce as a new vehicle.

[48] (U.S. EPA, 2015) "Frequently Asked Questions about Heavy-Duty Glider Vehicles and Glider Kits."

staff supports U.S. EPA 's proposal to limit the production and sale of glider vehicles with older, higher-emitting engines for the nationwide protection of human health and the environment and to close potential enforcement loopholes.

Glider kits and glider vehicles are currently exempt from NHTSA's Phase 1 fuel consumption standards. Unlike U.S. EPA, NHTSA defines glider kits as motor vehicle equipment, not as motor vehicles, and therefore is only considering the inclusion of completed glider vehicles in its proposed Phase 2 requirements which will be similar in effect to U.S. EPA's proposal, including special provisions for small business manufacturers. NHTSA is seeking comments from the glider industry regarding its intent to include glider vehicles in its Phase 2 requirements. CARB staff supports NHTSA's intent to apply Phase 2 requirements to completed glider vehicles and strongly encourages it to develop provisions that align, to the extent possible, with U.S. EPA's proposed requirements.

Tire-Related Comments

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40243, 40517

Comment – Tire testing and the need for a reference machine for calibration of truck tire characterization equipment

The NPRM proposes to carry over tire testing provisions adopted in International Organization for Standardization (ISO) 28580 for the Phase 1 program into Phase 2. CARB staff supports this proposal.

The NPRM also requests comment on the need to develop a reference machine for calibration of truck tire characterization equipment, and on whether tire test facilities are interested in and willing to commit to developing a reference machine. CARB staff supports this effort to consider the need for a reference machine to ensure accurate correlations of coefficient of rolling resistance (Crr) measurements within the tire industry. CARB staff believes this effort is critical to ensuring reliable comparisons between tire models and manufacturers, and is pertinent to providing rolling resistance data to assist consumers in purchasing replacement tires with Crr levels equivalent to original equipment manufacturer (OEM) tires.

One of the findings in the National Academy of Sciences (NAS) Committee on Technologies and Approaches for Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles, Phase Two, interim report was that tire Crr measurements need to be precise, given the relatively modest fuel savings achieved with LRR tires. Further, while the ISO 28580 test procedure has received high grades from the tire industry, there is not yet a robust cross-correlation for machines used in commercial tire testing. Based on this finding, the NAS Committee recommended that NHTSA, supported by U.S. EPA, implement a mechanism for obtaining accurate tire rolling resistance data, including establishing a tire alignment laboratory and mandating the use of that laboratory.[49]

Based on public comment during Phase 1 development and to address the NAS Committee's specific recommendation to establish a tire alignment laboratory, U.S. EPA and NHTSA evaluated test data from U.S. EPA's Phase 1 tire test program conducted at two independent tire test labs, Standards Testing Lab (STL) and Smithers-Rapra (Smithers), and concluded that any lab-to-lab variation between STL and Smithers has little effect on measured rolling resistance values.[50] As such, U.S. EPA and NHTSA consider STL or Smithers as acceptable for use as the reference test laboratory in correlating results of tire testing performed by vehicle manufacturers intended for use as GEM inputs. The Phase 2 proposal, however, does not go so far as to require vehicle manufacturers to use a reference laboratory, and instead carries over the provisions from Phase 1 that allow vehicle manufacturers to also perform their own testing or obtain test results from the tire manufacturer or another third party.

Given the proposal's lack of a provision mandating the use of a reference laboratory, CARB staff believes it is important that NHTSA and U.S. EPA work with the tire test industry in developing a reference machine.

[49] (NAS, 2014) The National Academies of Sciences, "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase 2, First Report," Washington, D.C. National Research Council, The National Academies Press, 2014.
[50] Summary of test results is described in U.S. EPA Heavy-Duty Tire Evaluation Memorandum by L. Joseph Bachman, July 18, 2011.

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40518

Comment – Develop rolling resistance performance standard for replacement tires

The Phase 2 proposal continues the Phase 1 requirement for GEM inputs for steer tire and drive tire rolling resistance. As with the Phase 1 program, the Phase 2 proposal contains no mechanism to ensure that rolling resistance of replacement tires is the same as the OEM tires simulated during GEM vehicle certification, even though vehicle tires will likely be replaced at the discretion of the vehicle owner at multiple points over the actual lifetime mileage of the vehicle. For example, U.S. EPA and NHTSA estimate a tire replacement interval of about 200,000 miles for tractors (page 7-36 of the RIA). For a class 8 tractor, the regulatory useful life in regards to GHG emissions is 10 years/435,000 miles (page 40215 of the NPRM) but this mileage value is considerably less than the actual lifetime mileage for a class 8 truck. Without a mechanism to ensure replacement tires have Crr values equivalent to OEM tires, there is no assurance a vehicle will maintain its allowable GHG vehicle emission levels demonstrated through GEM.

As such, CARB staff strongly supports the NAS Committee recommendation[51] for NHTSA, in coordination with U.S. EPA, to quantify the rolling resistance of new tires, especially those sold as replacements, and to adopt a regulation establishing a LRR performance standard for all new tires designed for tractors and trailers (if additional cost-effective fuel savings can be achieved), and encourages NHTSA to act as expeditiously as possible.

[51] (NAS, 2014) The National Academies of Sciences, “Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase 2, First Report,” Washington, D.C. National Research Council, The National Academies Press, 2014.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40517

Comment – Publication of tire Crr levels and development of tire Crr database

The NPRM states that U.S. EPA and NHTSA are considering publishing Crr levels from GHG and fuel efficiency program compliance data (which is submitted by vehicle manufacturers, not by tire manufacturers), although the data could vary for a given tire model among vehicle manufacturer submissions or lag when tires are redesigned. CARB staff supports this as a first step in providing buyers information on Crr levels for the universe of tires utilized under the Phase 2 program in order to facilitate tire replacements with equivalent Crr levels.

Nonetheless, U.S. EPA and NHTSA cite the data limitations described above as the rationale for not proposing to establish a public database containing heavy-duty vehicle tire LRR information at this time. While CARB staff acknowledges this concern, the NAS Committee recommends,[52] and CARB staff strongly encourages, that U.S. EPA and NHTSA develop a mechanism to maintain accurate information on LRR levels in a public database (or other web-based medium). Commercial tires are not sidewall labeled with Crr values, or another standardized metric, to assist truck owners in purchasing replacement tires with Crr values equivalent to the OEM tires, or to assist vehicle builders with tire selection based on their fuel savings benefits. The NPRM itself acknowledges the inability of vehicle buyers to obtain reliable information on the fuel savings, reliability, and maintenance costs of technologies that improve fuel efficiency (page 40436 of the NPRM). For the near-term, CARB staff believes that a public database is necessary to provide truck owners and vehicle builders with access to accurate information on tire LRR and fuel savings benefits associated with Crr values.

For the longer-term, CARB staff recommends that NHTSA coordinate with the tire industry to develop standardized sidewall labeling parameters that include Crr values, or

[52] (NAS, 2014) The National Academies of Sciences, "Reducing the Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase 2, First Report," Washington, D.C. National Research Council, The National Academies Press, 2014.

other standardized accepted metrics for determining Crr values, and undertake a rulemaking to require such sidewall labeling.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40187, 40218, 40261-40262, 40264; RIA 2-28 to 2-29, 2-163 to 2-165

Comment – Tire pressure monitoring system

The NPRM requests comment on whether they should assign a fixed credit in fuel consumption and CO_2 emissions for tire pressure monitoring systems, and if so, what would be an appropriate assigned fixed value. Maintaining properly inflated tires can extend tire life, save fuel, and improve safety, so CARB staff generally supports the use of systems that assist in the maintenance of properly inflated tires. However, CARB staff strongly supports U.S. EPA and NHTSA not providing credit for tire pressure monitoring systems for heavy-duty tractors and trailers. Unlike ATISs, tire pressure monitoring systems only monitor pressure and alert the driver regarding the variance between the recommended target pressure and the actual measured pressure in the tire. Tire pressure monitoring systems require action from the drivers to reinflate the affected tire(s), hence the benefit of such systems is dependent on driver behavior. Because there is no guarantee what action, if any, drivers will take in response to tire pressure monitoring systems, CARB staff recommends no credit for such systems in Phase 2.

In the Tire Pressure Systems – Confidence Report dated August 2013, the North American Council for Freight Efficiency (NACFE) indicated that ATISs are more common than tire pressure monitoring systems by a ratio of about four to one for trailers. The ATIS is designed to monitor and continually adjust the level of pressurized air in tires, automatically keeping tires properly inflated even while the vehicle is in motion. CARB staff concurs with U.S. EPA and NHTSA's proposal to provide credit in GEM for the installation of ATISs on tractors and trailers. This system was included in CARB's evaluation of vehicle efficiency technologies for heavy-duty vehicles that would result in improved fuel consumption and reductions in GHG emissions. For more information on ATIS, please refer to CARB's Draft Technology Assessment: Engine/Powerplant and Drivetrain Optimization and Vehicle Efficiency, June 2015 at: http://www.arb.ca.gov/msprog/tech/techreport/epdo_ve_tech_report.pdf.

<u>Oppose/Requested Change Comment</u>

Affected Document(s): Phase 2 proposed Rules

Affected Pages: 40292-40294

Comment - Emergency vehicle tire provisions

The Phase 2 proposal for emergency vehicles allows emergency vehicles to continue to use tires meeting only Phase 1-level Crr performance. While CARB staff understands the unique functionality, performance, and reliability criteria applicable to emergency vehicles, it also believes that as tires with Phase 2-level Crr values become more readily available in the market place and at a lower cost, emergency vehicle manufacturers will be able to overcome remaining technical challenges associated with the use of lower-rolling resistance tires in the emergency vehicle sector, particularly in the latter years of the Phase 2 program. As such, CARB staff proposes U.S. EPA and NHTSA to consider provisions, utilizing a phase-in approach, to require the use of tires meeting lower Crr levels than required by Phase 1, in the emergency vehicle sector.

Heavy-duty Refrigerant Issues

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40171-40173, 40343-40344, 40562, 40613

Comment – Not appropriate to allow manufacturers to be "deemed to comply" with Air Conditioning (AC) leakage standard by using an alternative refrigerant

U.S. EPA and NHTSA are proposing to allow a manufacturer to be "deemed to comply" with the leakage standard by using a lower global warming potential (GWP) alternative refrigerant.

Although CARB supports the promotion of the development and use of lower-GWP refrigerants for heavy-duty vehicle air conditioning, CARB staff has significant concerns regarding the proposed "deemed to comply" provisions, because CARB staff believes that maintaining a low leak rate is important, regardless of the refrigerant in use, for the reasons discussed below.

First, having a low leak rate helps realize the full direct refrigerant emission benefits of a transition to a low-GWP refrigerant by reducing the need for AC service, and hence reducing the potential for consumers to recharge their low-GWP AC systems with hydrofluorocarbon (HFC)-134a (a high-GWP refrigerant), as HFO-1234yf (a low-GWP refrigerant) is more expensive than HFC-134a. Due to similar thermodynamic properties between HFO-1234yf and HFC-134a, it is possible that an HFO-1234yf AC system can have satisfactory performance when recharged with HFC-134a. A leak-tight system will reduce this possibility, simply because the AC system is less likely to need recharging.

Second, having a low leak rate also reduces the possibility of loss of cooling performance and energy efficiency due to undercharging. Experimental and modeling studies have shown that as an AC system loses refrigerant charge, its cooling performance generally decreases, and its energy efficiency (Coefficient of Performance, or COP) first remains constant or increases slightly, then decreases markedly after the charge drops below a certain level, usually about half the nominal charge.[53] When significant charge loss occurs, vehicle drivers or operators would have to either endure compromised performance and efficiency, or have the AC recharged, in many cases more frequently than necessary, hence incurring emissions and cost associated with service. The most efficient and cost-effective means to tackle the undercharging issue is to use better refrigerant containment technologies to make the AC leak rate low.

Therefore, having a low leak rate complements using a low-GWP refrigerant, and ensures that the optimal benefits of the use of a low-GWP refrigerant would be achieved. Such rationale also applies to light-duty vehicle AC systems, and formed the basis for a “high-leak disincentive” term in the AC leakage credit provisions in the U.S. EPA GHG emission standard for MY 2017-2025 light-duty vehicles.

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[53] (Clodic, 2006) Clodic, D., Refrigerant MAC leakage, new evidences from the Armines / ACEA study. IEA Workshop, Cooling Car with Less Fuel. Paris, France, October 23 – 23, 2006.
(Prölss et al., 2006) Prölss, K., Schmitz, G., Limperich, D., Braun, M., Influence of refrigerant charge variation on the performance of an automotive refrigeration system. Proceedings of the 2006 International Refrigeration and Air Conditioning Conference at Purdue. West Lafayette, Indiana, USA, July 17 - 20, 2006.
(Huyghe, 2011) Huyghe, E. P., Impact of low refrigerant charge on energy consumption of the MAC system. SAE Automotive Refrigerant System Efficiency Symposium. Scottsdale, Arizona, USA, September 27 – 29, 2011.

CARB staff further believes that retaining a leakage standard separate from a low-GWP requirement is necessary to maintain low leak rates. Such a separate leakage standard would apply to existing manufacturers to ensure that they continue to use good refrigerant containment technologies after the Phase 1 implementation period ends. The leakage standard would also apply to new entrants to the market to hold them to the same requirements. A "deemed to comply" provision would result in the use of either low-leak technologies or low-GWP refrigerants, but likely not both, hence losing the benefits that can only be realized when a leakage standard and a low-GWP requirement work in tandem.

Therefore, CARB staff recommends that U.S. EPA and NHTSA not include such a "deemed to comply" mechanism, but rather develop a provisional requirement for the use of low-GWP refrigerants (see CARB comment regarding alternative refrigerants) while retaining the leakage standard.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40212-40213

Comment – Approved low-GWP refrigerants for heavy-duty vehicles

The NPRM states that currently, there are no low-GWP refrigerants approved for the heavy-duty vehicle sector. This appears to be a misstatement. Two low-GWP refrigerants, R-744 (CO_2) and HFC-152a have been approved for motor vehicle air conditioning systems, including those for heavy-duty vehicles. (In addition, HFO-1234yf is SNAP approved for light-duty use and Chemours is applying for SNAP approval for this low-GWP refrigerant for heavy-duty use.)

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40328-40329

Comment – No existing test procedures or facilities to measure AC leak rate for vocational vehicles

The NPRM states that U.S. EPA and NHTSA are not proposing a specific in-use standard for leakage, because neither test procedures nor facilities exist to measure refrigerant leakage from a vehicle's air conditioning system.

While existing test procedures (SAE Standard J2763 and J2762) could be used to assess refrigerant leakage, such procedures are time consuming and costly, and thus impractical. Therefore, CARB is not opposed to U.S. EPA and NHTSA's position of not proposing an in-use standard for leakage at this time.

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40564-40565, 40617

Comment – Information required for AC leakage standard certification

To show compliance with the AC leakage standard, U.S. EPA and NHTSA are only requiring the manufacturer to provide refrigerant leak rates, describe the type of refrigerant, and identify the refrigerant capacity of the air conditioning systems.

CARB staff believes more information ought to be required to afford U.S. EPA and NHTSA the opportunity to verify the leakage calculation and to track technological development. CARB staff recommends that U.S. EPA and NHTSA require the following information from the manufacturer: the calculation that leads to the refrigerant leak rate estimates, and specifications of the system components with sufficient detail to allow reproduction of the calculation. This level of detail is consistent with the information that

CARB staff requires light-duty manufacturers to report under the AC credit provisions in its “Advanced Clean Cars” programs for light-duty vehicles.

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40212-40213, 40292, 40301-40302; RIA 2-133 to 2-134

Comment – Extension of AC leakage standard to vocational vehicles

U.S. EPA and NHTSA are proposing to retain the AC leakage standard adopted in the Phase 1 program. U.S. EPA and NHTSA are also proposing extending the AC leakage standard to class 2b-8 vocational vehicles, which were excluded from the leakage standard in Phase 1.

CARB staff supports the proposal to continue the AC leakage standard adopted in the Phase 1 program. CARB staff believes that the leak rate limits in the Phase 1 program are at appropriate levels that balance technical feasibility and emission reduction goals. CARB staff further supports the proposal to extend the AC leakage standard to class 2b-8 vocational vehicles, because the main obstacles (complexity in building process and potentially different entities other than chassis manufacturers involved in production and installation) identified during Phase 1 regulation development have been resolved with new information received during Phase 2 rulemaking process. CARB staff further believes that it is appropriate to set the leak rate limits for vocational vehicles at the same levels as for other tractors, heavy-duty pick-up trucks and vans, due to the substantial similarity of the AC systems for these vehicle classifications.

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40613

Comment – Emission-related warranty covers components whose failure would increase a vehicle's emissions of air conditioning refrigerants

U.S. EPA and NHTSA are proposing that the emission-related warranty cover components whose failure would increase a vehicle's emissions of AC refrigerants.

CARB staff supports this proposal. Although most refrigerant emissions occur as refrigerant gradually leaks through fittings, connection, and seals, and permeates through hoses ("regular leakage"), sudden failure of AC components may lead to the loss of the entirety or a significant portion of the refrigerant charge in a short period of time ("irregular loss"). Requiring that the emission-related warranty cover those components not only provides a venue to restore the system back to working order when component failure occurs, but also promotes the use of technologies more durable and less prone to failure, hence helping to prevent failure and reduce emissions at the design level.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40171-40173

Comment – Include requirement for low-GWP refrigerants once commercially available

The NPRM requests comment on industry development and other aspects of low-GWP refrigerants for heavy-duty vehicles. CARB staff supports U.S. EPA and NHTSA's intent to consider and evaluate alternative, low-GWP, refrigerants for use in heavy-duty AC systems. Using low-GWP refrigerants would significantly reduce the climate impact from the direct refrigerant emissions from heavy-duty vehicles. R-744 (CO_2) and HFC-152a have already been approved by U.S. EPA Significant New Alternatives Policy

(SNAP) program for use in all (including heavy-duty) AC applications. One chemical manufacturer, Chemours, is preparing an application to U.S. EPA SNAP program to qualify HFO-1234yf (another low-GWP refrigerant which is SNAP approved for light-duty use) for heavy-duty applications. In general, however, industry development and adoption of low-GWP refrigerants in heavy-duty subsectors has been relatively slow compared to light-duty applications, despite the substantial similarity between the AC systems for light-duty and for heavy-duty.

CARB staff believes that regulatory requirements or incentives can motivate those research and development activities, and speed up the transition to low-GWP refrigerants for heavy-duty applications. Therefore, CARB staff is considering developing regulations to prohibit the use of high-GWP refrigerants for these applications, as a part of CARB strategies to reduce short-lived climate pollutants. For the same reason, CARB staff urges U.S. EPA and NHTSA to expedite the review and determination process for the upcoming HFO-1234yf SNAP application for heavy-duty. Furthermore, CARB staff recommends that U.S. EPA and NHTSA include in the Phase 2 standards a requirement of using low-GWP refrigerants, starting as early as legally and technologically possible. (For example: “Starting in Model Year 2021, or the model year commencing four years after this provision is promulgated, or the model year commencing three years after a low-GWP refrigerant for this end-use becomes commercially available, whichever comes last, the GWP of Motor Vehicle AC refrigerants used by manufacturers in new heavy-duty vehicles be equal to or less than 150. Being ‘Commercially Available’ in this provision means having been approved for the concerned end-use by the SNAP program, having been determined to be acceptable for adoption by at least one vehicle manufacturer, and being produced at commercial quantities. This provision must stay in effect till the end of the current regulation, and no less than three model years.” The three-year lead time is based on a stakeholder (Honeywell) comment on CARB Short-Lived Climate Pollutant Concept Paper that manufacturers would need two to three years to implement a transition to a low-GWP alternative once the refrigerant has been evaluated.

Neutral/Provide Additional Information Comment

Affected document(s): RIA

Affected pages: 5-26 to 5-28

Comment – Calculation of HFC emissions

U.S. EPA and NHTSA are proposing to estimate refrigerant emissions from heavy-duty vehicles using the same emission rates for light-duty vehicles assumed in the Vintaging Model, consistent with the methodology in U.S. EPA and NHTSA's heavy-duty Phase 1 GHG regulation.

Heavy-duty vehicles are primarily used for commercial or industrial purposes, as opposed to light-duty vehicles, typically used for commuting or pleasure. For this reason, heavy-duty vehicles, and hence, their AC systems, operate much longer than light-duty vehicles. Longer operation of the AC systems leads to higher annual refrigerant leakage and may accelerate aging-related deterioration of refrigerant containment. Therefore, CARB staff encourages U.S. EPA and NHTSA to continue to evaluate refrigerant emission rates for heavy-duty vehicles, in order to improve the understanding of refrigerant emissions for this sector. CARB staff is willing to provide assistance in this regard.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40258-40259

Comment – Non-CO_2 GHG emissions from trailers

The NPRM requests comment on the issue of HFCs refrigerant leakage from transport refrigeration units (TRU). U.S. EPA and NHTSA believe TRU refrigerant leakage is insignificant because they contend that trailer TRU owners have a strong incentive to limit this leakage in order to maintain the operability of the trailer's refrigeration unit and avoid financial liability for damage to perishable freight due to failure to maintain the agreed-upon temperature and humidity conditions. Also, U.S. EPA and NHTSA believe that refrigerated van units represent a relatively small fraction of new trailers. U.S. EPA and NHTSA also asked for data on typical TRU charge capacity and the frequency of HFC leakage.

Overall, CARB staff believes U.S. EPA and NHTSA are underestimating potential refrigerant leakage from TRUs. CARB staff recommends, as discussed further below, that 1) U.S. EPA and NHTSA establish an HFC refrigerant usage monitoring program for TRUs to inform future “cause and contribute findings” and decisions to regulate refrigerants used in TRUs, and 2) U.S. EPA and NHTSA provide incentive funding for zero- and near-zero-emission transport refrigerators, such as cryogenic transport refrigerators.

CARB staff believes U.S. EPA and NHTSA may be overly optimistic when it comes to TRU owners proactively preventing and repairing refrigerant leaks. That may be partially true for the first generation owners, but many TRUs receive less maintenance as they age and their second, third, or fourth generation owners are not financially able to pay for repairs. CARB staff believes that for a considerable number of TRU owners, repairs and maintenance issues are typically addressed only when there is a performance issue with the TRU. Excluding TRUs from leakage requirements shifts the responsibility for these systems to the users, leaving manufacturers free to develop systems that may be more prone to leakage. TRU manufacturers should be held accountable for manufacturing quality products that are not prone to leakage. CARB staff is not aware of any tracking programs for HFC usage to recharge leaky TRU systems or determine leakage frequency; but, those types of programs should be considered to provide the data that is needed to assess the impact on climate change due to TRU refrigerant leakage.

TRU models that use open-drive refrigeration compressors are more susceptible to shaft seal leakage as they age. Many TRU models still use open-drive refrigeration compressors. Hermetically sealed refrigeration compressors do not have shaft seal refrigerant leakage issues because the electric drive motor is enclosed inside a housing with the refrigeration compressor. Unfortunately, hermetically sealed refrigeration compressors have not been incorporated into all TRU platforms. When used in conjunction with more energy efficient scroll compressors, GHG emissions are greatly reduced through a combination of lower fossil fuel use and the elimination of high-GWP refrigerant leakage from shaft seals.

A quick review of current, on-line TRU specification sheets revealed refrigerant charge capacities are 13 to 16 lbs per trailer TRU. Previous to 2013, when both of the major TRU manufacturers re-designed and optimized their trailer TRU platforms, refrigerant charges averaged about 20 lbs per unit. This value is consistent with the value reported in Table S4 (page S8) of the *Supporting Information Document* for the article titled “High Global Warming Potential F-Gas Emissions in California: Comparison of Ambient-based verses Inventory-Based Emission Estimates, and Implications of Refined Estimates” by Glenn Gallagher, et al.[54] This document also includes average annual leakage rates for TRUs (18.3 percent). The data sources and methodology for TRU refrigerant emissions are explained on pages S19-S21.

ACT Research estimates there are over 370,000 refrigerated trailers in the U.S. in 2015 and the average fleet age is 5.63 years.[55] This means that the total TRU refrigerant charge in the U.S. subject to potential leakage could range from 2,405 short tons to 3,700 short tons.

Refrigerant emissions may be small compared to some other commercial and industrial sectors, but significant emission reductions in this sector can be achieved by adopting lower GWP refrigerants. CARB staff believes it is hard to rationalize refrigerant leaks on the basis of small sector numbers when the GWP is so high for currently used TRU refrigerants (R-404A, used in trailer TRUs, has a GWP of 3,922) and near “drop-in” refrigerants, such as R-452A, has a GWP of 2,141.

Refrigerant R-452A is a blend of the hydrofluoro-olefin (HFO) R-1234yf that has a very low-GWP of 4 and higher GWP HFCs. Blends with greater R-1234yf cause reduced refrigeration capacity. Lost capacity could be offset by improvements in refrigeration system efficiency (requiring less energy) and more thermally efficient insulated cargo vans (requiring less refrigeration capacity). Integrated designs that balance these effects and produce net improvements in total equivalent warming impact are needed.

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[54] (Gallagher et al., 2014) Gallagher et al., “Supporting Information - High Global Warming Potential F-Gas Emissions in California: Comparison of Ambient-based verses Inventory-Based Emission Estimates, and Implications of Refined Estimates,” *Environmental Science & Technology*. Available for download at: http://pubs.acs.org/doi/suppl/10.1021/es403447v.

[55] (ACT, 2014) Kenny Vieth (ACT Research), personal communication with Rodney Hill (California Air Resources Board), November 24, 2014, at ACT Research Co., LLC, U.S. Trailer Model, Reefer Van Population Outputs, 2014.

In the long-term, natural refrigerants, such as CO_2, may become viable if associated energy use rates can be reduced through continued design optimization. CO_2 systems have been demonstrated in Europe for refrigerated shipping containers but industry has been slow to adopt them because costs are still high as a result of low production numbers and economies of scale. Incentive programs are needed to encourage adoption of existing CO_2 refrigerant systems for shipping containers and to develop CO_2 refrigerant systems for higher ambient temperature conditions and larger capacity systems needed for 53 foot trailer TRU applications.

Cryogenic transport refrigerators also offer an alternative to vapor compression refrigeration systems that use high-GWP refrigerants. A cryogenic fluid, such as liquid nitrogen, liquid CO_2 or liquid air, is used to provide cooling to the cargo space. There are some GHG emissions associated with the production of these cryogenic fluids. For liquid nitrogen, the most common type of cryogenic transport refrigerator, well-to-wheel (WTW) GHG emission reductions are 50 to 60 percent less than a conventional TRU. This technology, as well as other zero- and near-zero-emission technologies, is discussed in CARB's *Technology Assessment: Transport Refrigerators*.[56]

In addition to establishing an HFC refrigerant usage monitoring program and providing incentive funding for zero- and near-zero-emission transport refrigerators, CARB staff also recommends that U.S. EPA use its SNAP program to phase out high-GWP refrigerants, such as R404A, as soon as it determines that viable alternative are available.

<u>Support Comment</u>

Affected document(s): Proposed Rules Phase 2; RIA

Affected pages: RIA page 7 of 9

Comment – Refrigerated Trailer Problems

CARB staff agrees with U.S. EPA and NHTSA's statements: "Over time, refrigerated trailers can also develop problems that interfere with their ability to keep freight temperature-controlled. For example the insulating material inside a refrigerated

[56] (CARB, 2015d) California Air Resources Board, "Technology Assessment: Transport Refrigerators," August 2015, <http://www.arb.ca.gov/msprog/tech/techreport/tru_07292015.pdf>.

trailer's walls can gradually lose its thermal capabilities due to aging or damage from forklift punctures. The door seals on a refrigerated trailer can also become damaged or loose with age, which greatly affects the insulating characteristics of the trailer."

The refrigerated transport industry is well aware of the thermal performance degradation that insulated trailers go through as a result of blowing agent outgassing, moisture intrusion, insulation breakdown caused by road-induced vibration and panel flexing, forklift damage, tree side-swiping damage, and other normal wear-and-tear. Low permeability barriers can be used to slow down outgassing. Aluminum and stainless steel sheets, various types of polymeric films, laminated foil/plastic films, metalized films, fiberglass, glass mat, and composite liners are offered as options to prevent damage and subsequent moisture intrusion. Great Dane has published charts that show up to 40 percent degradation of insulation performance over several years and much slower degradation when various options are used to conserve insulation performance.

There are no standards in the U.S. to ensure all refrigerated trailers meet minimum thermal performance standards when they are new. There are also no standards in the U.S. that measure thermal performance as an insulated trailer ages to ensure they are retired or delegated to less demanding service when thermal performance degrades. As this performance degrades, energy efficiency is compromised and TRU engines must run harder and longer to maintain temperature set points, resulting in greater GHG emissions. Market forces drive the thermal efficiency of refrigerated trailer designs in the U.S.

CARB staff encourages U.S. EPA and NHTSA to look at the regulatory requirements that must be met in Europe regarding refrigerated van insulation. The 26 members of the European Union and 23 other European, former Soviet Union, North African and Middle Eastern counties have signed on as contracting parties to the United Nations Economic Commission for Europe's (UNECE) standards under the *Agreement on the International Carriage of Perishable Foodstuffs and on Special Equipment to be Used on Such Carriage (ATP)*. ATP requires testing and certification of the insulation and cooling capacity of refrigerated transport equipment, and provides for separate testing of TRUs. France, Italy, Russia, and Spain apply ATP standards to domestic transportation within their borders. Although the U.S. is a contracting party to ATP, the U.S. made a declaration under article 10 of the International Carriage of Perishable

Foodstuffs Act of 1982 and the implementing regulations at title 7 Code of Federal Registration (CFR) 3300, resulting in ATP standards being voluntary in the U.S.

Under the ATP, samples of new-model insulated vans are tested to ensure they meet the appropriate overall heat transfer coefficient standard (K-value). Passing models are certified for six years. Certification of insulated vans may be renewed at six year intervals by inspecting and/or testing a sample of aged insulated vans to determine if they still meet the ATP K-value standard.

In addition, market forces are at work in Europe, because diesel fuel typically costs two to three times more than U.S. fuel due to differences in government subsidies, taxes, and other influences. Greater thermal efficiency in truck and trailer vans makes legal and economic sense in the Europe, so insulation is generally thicker there (side walls are typically about four inches thick compared to two inches thick in the U.S.)

The high cost of diesel fuel, the above-mentioned thermal efficiency standards, and greater prevalence of noise ordinances have also made European refrigerated fleets more open to trying new or alternative transport refrigeration technologies. For example, there is greater use of cryogenic transport refrigerators, all-electric, and hybrid electric TRUs with various range extender strategies in Europe.

CARB staff recommends U.S. EPA and NHTSA continue to evaluate appropriate technologies and approaches that can achieve substantial emission reductions for TRUs and insulated trailers. CARB's *Technology Assessment: Transport Refrigerators*[57] provides information on zero- and near-zero-emission technologies and includes a discussion on energy efficiency for refrigeration systems and thermal efficiency for insulated cargo vans. Incentive programs are needed to transition these technologies to commercial readiness so they can be included in later phases of GHG rules.

[57] (CARB, 2015d) California Air Resources Board, "Technology Assessment: Transport Refrigerators," August 2015, <http://www.arb.ca.gov/msprog/tech/techreport/tru_07292015.pdf>.

Solar Control

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40389-40390
Comment – Available credit for solar control for heavy-duty pickups and vans

For heavy-duty pickups and vans (class 2b/3), the NPRM requests comment on establishing a pre-defined technology menu list for off-cycle emissions, including solar control (see table VI-33, page 40390 of the NPRM). U.S. EPA and NHTSA consider these vehicles to be analogous to light-duty vehicles, since they use the same chassis test procedure. To determine the appropriate default level of credits for these heavier vehicles, the NPRM requests comments with supporting heavy-duty pickup- and van-specific data and analysis that would provide a substantive basis for appropriate adjustments to the credits levels. As with the light-duty vehicle program, U.S. EPA and NHTSA would also consider including a cap on credits generated under the pre-defined list. Such a cap addresses issues of uncertainty regarding the level of credits automatically assigned to each technology.

CARB staff believes it is appropriate to include solar control in the pre-defined technology menu list for heavy-duty pickups and vans along with a preapproved credit. Credits for solar control are largely about reducing the heat build-up in parked vehicles, reducing the need to idle to stay comfortable, and reducing the load on the engine from operating the AC, since AC use generally reduces fuel economy. Class 2b/3 vehicles likely spend less of the workday parked than do light-duty vehicles although they probably do spend part of the work day parked with the engine off. They likely spend more time idling than light-duty vehicles, some of which time could be reduced if there was less need for comfort idling. The balance of the workday is spent in motion. Solar control has a benefit during driving operations as well, although the fuel economy of vehicles with larger engines are less affected by the use of an AC than are light-duty vehicles with smaller engines. The value established for light-duty trucks of 3.9 g CO_2/mile could be used. However, CARB staff believes it would be appropriate to reduce this value by the assumed contribution from the backlite, since work vehicles often do not have substantial if any backlites. CARB staff assumed, based on an overview of the literature for its Cool Car proposal,[58] that 30 percent of the solar energy enters the vehicle through the backlite. Therefore, CARB suggests a pre-approved credit of 2.7 g CO_2/mile for the 2b-3 sector. Manufacturers who believed that this underestimates the value that solar controls provide to their vehicle model could provide appropriate test data to substantiate a request for a greater off-cycle credit.

Neutral/Provide Additional Information Comment

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40252, 40330; RIA 2-47

Comment – Inclusion of solar control as an off-cycle credit for class 4-8 vehicles

The flexibility provisions for class 4-8 vehicles include off-cycle credit provisions. Several technological approaches have been identified that would seem to merit inclusion, whether incorporated as a line-item in GEM or through available off-cycle credits. Solar controls are not specifically listed as they are for class 2b/3, but the RIA clearly states (page 2-47 of the RIA) they could be considered for credits if the effectiveness can be suitably demonstrated. CARB believes this is a reasonable approach. Because of the uncertainties surrounding estimates of effectiveness of solar control approaches in the heavy-duty fleet, it is appropriate to require demonstration of benefit in a specific case before granting credits for vehicles in these vehicle classes. See CARB docket letter dated December 3, 2014[59] for a thorough discussion of issues involved in determining appropriate solar control credits for heavy-duty vehicles.

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[58] (CARB, 2009) California Air Resources Board, "Staff Report: Initial Statement of Reasons for Rulemaking - Cool Car Standards and Test Procedures,", May 8, 2009, <http://www.arb.ca.gov/regact/2009/coolcars09/coolcarsisor.pdf>.

[59] See http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2014-0827-0035 for our comment regarding solar load.

Neutral/Provide Additional Information Comment

Affected document(s): RIA

Affected pages: 2-47

Comment – Solar control clarification

The RIA includes some incorrect statements, as described further below. First, the RIA states, “Solar control glazing reflects some of the solar energy from the glass.” The implication of this sentence is that solar control glazing is synonymous with solar reflective glazing. However, in fact, solar control glazing includes both solar absorbing glazing and solar reflective glazing. The RIA states, “CARB found that most heavy-duty trucks today use solar absorbing glass.” The Enhanced Protective Glass Automotive Association (not CARB) has indicated that new trucks are typically provided with solar absorbing glazing (total solar transmission of around 60 percent, compared to 88 percent for clear glass). Note also that the statement applies to original glazing and may not be true for replacement glazing.

U.S. EPA and NHTSA further note they are “not proposing [solar control paint and glazing] as part of heavy-duty Phase 2, but these types of technologies could be considered under the innovative technology program.” CARB believes it is appropriate to retain the flexibility to consider solar control credits where such controls are shown to reduce overall GHG emissions and agrees that it is appropriate to require demonstration of quantified benefits before credit is granted for class 4-8 vehicles. See CARB docket letter dated December 3, 2014 for a thorough discussion of issues involved in determining appropriate solar control credits for heavy-duty vehicles.

VSL

<u>Neutral/Provide Additional Information Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40224; RIA 2-42

Comment – VSL Benefit

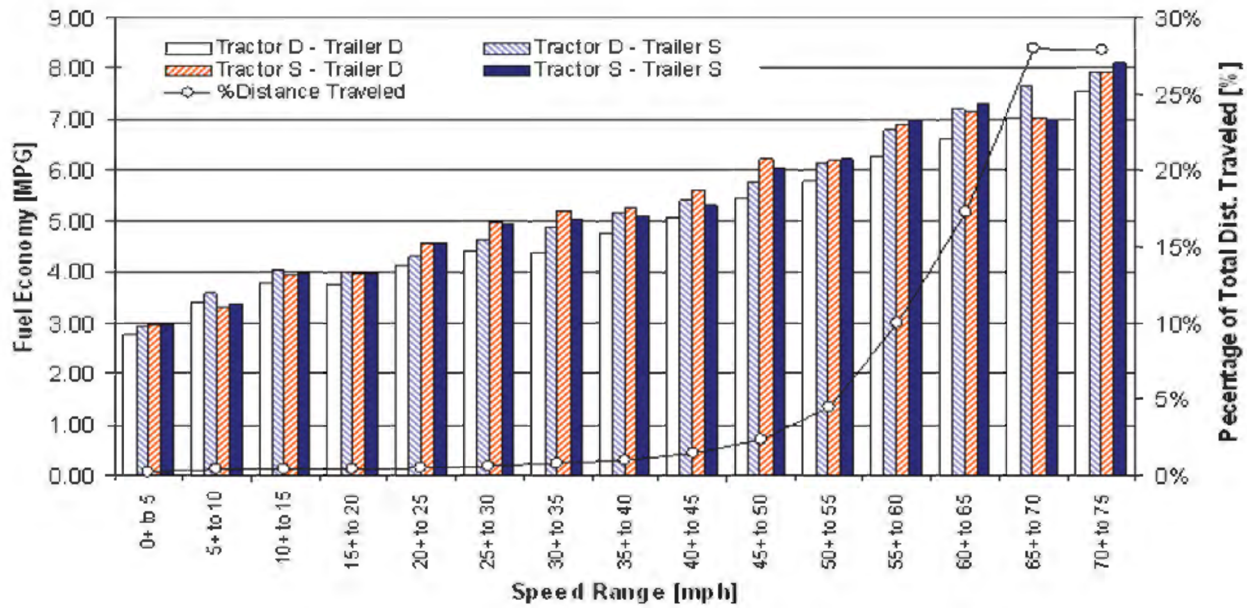
According to the NPRM, VSLs were not considered when setting the proposed Phase 2 standards; however, U.S. EPA and NHTSA propose to allow use of VSL as a technology to meet the proposed standards. The NPRM proposes that manufacturers would receive credit for installing tamper-proof VSLs with maximum drive cycle speeds set at 65 mph; the draft GEM appears to offer up to 22 percent credit for use of VSL.

CARB staff recommends not giving any credit for VSLs at this time because available data do not fully support whether VSLs result in real-world fuel consumption and CO_2 reductions. In addition to the concerns regarding possible tampering of VSLs when in use, which the NPRM mentions, the data are still inconclusive as to whether VSLs can provide real-world fuel benefits, especially for modern trucks.[60] In fact, CO_2 emissions were shown to decrease as vehicles' speed increase (improved fuel economy at higher speeds) in Oak Ridge National Laboratory's (ORNL) Transportation Energy Data Book (Table 5.11, Fuel Economy for Class 8 Trucks as a Function of Speed and Tractor-Trailer Tire Combination, and Figure 5.3 (shown below – Figure 6), Class 8 Trucks Fuel Economy as a Function of Speed and Tractor-Trailer Tire Combination and Percentage of Total Distance Traveled as a Function of Speed, available at http://cta.ornl.gov/data/chapter5.shtml).

[60] See Attachment 7 for California Air Resources Board's Portable Emissions Measurement System's Data on 2010 Standard Trucks – Carbon Dioxide Emission Rate vs. Speed.

Figure 6: Class 8 Truck Fuel Economy as a Function of Speed and Tractor-Trailer Tire Combination and Percentage of Total Distance Traveled as a Function of Speed[61]

NOT ADJUSTED FOR TERRAIN: See note below.



Note: D = Dual tire. S = Single (wide) tire.
These data were not adjusted to account for the effects of terrain. The increase in fuel economy for speeds above 70 mph is likely due to the vehicle achieving high speeds while traveling down slope. Therefore, this increase in fuel economy is not expected to be characteristic of all travel at these higher speeds.

The data presented above indicates there may be no benefit through use of VSLs or even possibly a dis-benefit; hence, CARB staff recommends no credit in GEM for VSLs.

The issue of whether and what credit to offer for VSLs is timely and important because tamper-proof VSLs may soon be required in the U.S. by federal regulation. In 2006, the American Trucking Association (ATA), Road Safe America and a group of motor carriers petitioned NHTSA to initiate rulemaking to require vehicle manufacturers to install a device to limit the speed of trucks with a GVWR greater than 26,000 lbs to no more than 68 mph. The petitions were based on a desire to reduce the number and

[61] (ORNL, 2008) Capps, Gary, Oscar Franzese, Bill Knee, M.B. Lascurain, and Pedro Otaduy. "Class-8 Heavy Truck Duty Cycle Project Final Report," ORNL/TM-2008/122, Oak Ridge National Laboratory, Oak Ridge, TN, December 2008.

severity of crashes involving large trucks.[62] NHTSA in 2011 agreed to consider a rule requiring speed limiters and has stated they intend to propose such a rule later this year (http://www.regulations.gov/#!documentDetail;D=NHTSA-2007-26851-3854).[63] As a result, VSLs are likely to be widely utilized in heavy-duty truck fleets in the near future; thus, the issue of understanding whether or not VSLs have an emissions benefit and not offering too much credit for them in GEM is imperative.

Before offering any credit for VSLs, CARB staff suggests that U.S. EPA and NHTSA should thoroughly evaluate whether they would result in real-world CO_2 and fuel consumption benefits. CARB staff is willing to offer our help in this evaluation if needed.

If U.S. EPA and NHTSA decide to give credit in Phase 2 GEMs for VSLs, VSL benefit should also be included in premising the proposed standards. If credit for use of VSLs is granted without considering them when setting stringency, use of VSLs will only reduce use of other technologically feasible technologies that were included when setting stringency, without providing further benefit.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40224

Comment – VSL credit in GEM

The NPRM proposes that manufacturers would receive credit for installing tamper-proof VSLs with maximum drive cycle speed set at 65 mph or less (the minimum VSL value input in GEM is set at 45 mph). The draft GEM model appears to offer up to 22 percent credit for use of VSL,[64] which is unreasonably high. In addition, as mentioned in the above comment, whether or not use of VSL will provide emissions benefit is still an open question. Thus, CARB staff strongly suggests U.S. EPA and NHTSA remove the

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[62] (NACFE, 2011) North American Council for Freight Efficiency, "Speed Limiters Save Money and Fuel without Significant Productivity Loss," February, 2011, <http://nacfe.org/wp-content/uploads/2011/04/NACFE-ER-1003-Speed-Limiters-Mar-2011.pdf>, accessed on July 9, 2015.

[63] (NHTSA, 2011) Federal Motor Vehicle Safety Standards: Engine Control Module Speed Limiter Device, Federal Register Notice, January 3, 2011, <http://www.regulations.gov/#!documentDetail;D=NHTSA-2007-26851-3854>, accessed on July 30, 2015.

[64] This is estimated based on GEM results for sample GEM input file of tractor. The specified tractor configuration (350 hp with AMT transmission) was run with four scenarios (no VSL - baseline, 45 mph speed limit VSL, 55 mph speed limit VSL, and 65 mph speed limit VSL). Projected CO_2 emissions for each scenario were used to calculate percent CO_2 reduction from baseline (no VSL use) (22%, 11%, and 0.01% CO_2 reduction for VSL set at 45 mph, 55 mph, and 65 mph, respectively).

credit offered for use of VSL in GEM, pending confirmation of the actual fuel consumption and CO_2 benefits VSLs achieve in the real world.

Comment on Topic Where NPRM Requests Comment

Affected document: Phase 2 Proposed Rules

Affected pages: 40250

Comment – Participation of owners in VSLs' emissions credit transactions

The NPRM requests comment on potential means by which truck owners that use VSLs could directly participate in Phase 2 emission credit transactions. It is not clear what fleet owners would do with Phase 2 credits and allowing fleet owners to garner such credits would unnecessarily complicate implementation and enforcement of the Phase 2 program. As a result, CARB staff recommends not including owners in emission credit transactions for VSL installation.

In-Use Standards

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40206, 40 CFR Part 1036

Comment – Appropriateness of useful life adjustment factor

The NPRM requests comment on the useful life adjustment factor allowance.

Consistent with Section 202(a)(1) and 202(d) of the CAA, for Phase 1, U.S. EPA established in-use standards for heavy-duty engines. Based on their assessment of testing variability and other relevant factors, U.S. EPA established in-use standards by adding a 3 percent adjustment factor to the full useful life emissions and fuel consumption results measured in U.S. EPA certification process to address measurement variability inherent in comparing results among different laboratories and different engines. See 40 CFR part 1036. U.S. EPA and NHTSA are not proposing to change this for Phase 2, but request comment on whether this allowance is still necessary.

CARB staff believes that the current 3 percent adjustment factor should be removed. An emission standard inherently already accounts for measurement variability due to different laboratories and engines being tested. While the 3 percent in-use factor was allowed for Phase 1 vehicles since the Phase 1 standards were new, this in-use factor should not be necessary for Phase 2 vehicles. Historically, CARB typically does allow an in-use factor when phasing in new standards that force new technology. Many manufacturers have already implemented the technologies that will be required to meet the proposed Phase 2 standards.

In conclusion, CARB staff encourages U.S. EPA and NHTSA to not apply the proposed 3 percent adjustment factor to the in-use emission standard.

Neutral/Provide Additional Info Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: **40557, 40572**

Comment – Not-to-Exceed (NTE) Standards

There may be opportunities to fold in-use compliance testing for CO_2 and N_2O into the NTE protocol currently in place for criteria pollutants. This could provide greater assurance of in-use compliance, and provide manufacturers an efficient way to demonstrate in-use compliance for greenhouse gas and criteria pollutants simultaneously. When U.S. EPA and NHTSA next consider changes to the NOx standards and NTE requirements, CARB staff recommends considering adding in-use testing of CO_2 and N_2O. A manufacturer could conduct NTE testing and determine in-use compliance for the entire suite of pollutants (GHG as well as other criteria pollutants).

CARB staff also suggests that tracking of vehicle weight and speed with engine CO_2/N_2O emissions could be used as a tool to determine overall vehicle performance. This information could be used as a GEM correction/correlation tool going forward.

Comment on Impact on Fuel Consumption, GHG Emissions, and Climate Change

Natural Gas

<u>Neutral/Provide Additional Information Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40159, 40389, 40503-40509; RIA 13-1 to 13-42

Comment – Phase 2 standards apply exclusively at the vehicle tailpipe and do not reflect lifecycle emissions

CARB staff understands the reasoning behind U.S.EPA and NHTSA's proposal to apply Phase 2 standards exclusively at the vehicle tailpipe (rather than reflecting full lifecycle emissions), in order to better harmonize the fuel efficiency and GHG emission standards. CARB staff also appreciates the inclusion of a lifecycle analysis for natural gas and diesel trucks, even though the proposed standards are tailpipe only, as it illustrates the relative GHG benefits of different vehicle/fuel combinations and the potential reduction in the tailpipe GHG benefits of CNG due to methane leakage during refueling or LNG boil-off as the vehicle sits idle.

CARB staff suggests including BEVs and FCEVs in the lifecycle analysis. Those technologies are extremely efficient at utilizing energy for motive power and the lifecycle results are compelling. GVWR are expected to produce significantly less GHG emissions than similar MY conventional diesel fueled trucks on a WTW basis.

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40171, 40502-40503

Comment – Natural gas engines must meet the Phase 2 diesel or gasoline tailpipe CO_2 standards

According to the NPRM, natural gas engines must meet the Phase 2 diesel or gasoline standards (depending on the service application) and fuel consumption is then calculated according to their tailpipe CO_2 emissions. This would likely create a small balanced incentive for natural gas use. A natural gas vehicle that achieves approximately the same fuel efficiency as a diesel powered vehicle would emit 20 percent less CO_2; a natural gas vehicle with the same fuel efficiency as a gasoline vehicle would emit 30 percent less CO_2.[65]

CARB staff believes that future natural gas engines, if certified to one of CARB's optional NOx standards and operated on renewable natural gas,[66] would reduce both NOx and GHG emissions. Many stakeholders are advocating for broad use of natural gas vehicles in California, particularly in the South Coast Air Basin and other areas that need near-term NOx reductions to meet federal ozone ambient air quality standards.

However, as shown in U.S. EPA and NHTSA's lifecycle analysis, if methane emissions from the vehicle and from upstream production and distribution are not well controlled (for example, boil-off from LNG vehicles that are parked for multiple days), natural gas engines have the potential to actually increase GHG emissions. It is important to strengthen natural gas engine and vehicle requirements to ensure we maximize the benefits of the cleaner fuel as well as the most efficient vehicle technology. CARB staff will continue to work with U.S. EPA and NHTSA as well as engine and vehicle manufacturers to require the use of efficient engine and vehicle technology, reduce NOx emissions, and minimize fugitive methane emissions. Additional comments on requirements are also included.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40512

Comment – Lifecycle emissions incorporated into the certification level

Based on U.S. EPA and NHTSA's lifecycle analysis, the impact of leaks and other methane emissions that occur upstream of the vehicle can potentially be large enough to more than offset the CO_2 benefit of natural gas vehicles as measured at the vehicle tailpipe. U.S. EPA and NHTSA are considering separate action to control these upstream emissions. U.S. EPA and NHTSA are concerned that the high-GWP of methane makes even small leaks of natural gas of concern. The NPRM requests

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[65] This is because natural gas has lower carbon content than either diesel or gasoline.
[66] See http://www.arb.ca.gov/msprog/onroad/cert/mdehdehdv/2016/cummins_mhdd_a0210630_8d9_0d20-0d01_ng.pdf and http://www.arb.ca.gov/msprog/onroad/cert/mdehdehdv/2016/cummins_ub_a0210629_8d9_0d20-0d01_ng.pdf for Cummins natural gas certification on 8.9L engines to 0.02 g/bhp-hr NOx standard, September 2015.

comment on whether it would be appropriate to adjust the tailpipe GHG emission standard for natural gas vehicles to reflect the relative lifecycle emissions relative to diesel.

U.S. EPA and NHTSA state that if, for example, they were to determine that the lifecycle climate impacts of natural gas vehicles were 150 percent of the tailpipe GHG emissions, while the lifecycle climate impacts of diesel vehicles were 135 percent of the tailpipe GHG emissions, they could approximate the relative climate impacts by setting the natural gas tailpipe emission standard 10 percent lower than the diesel tailpipe standard. U.S. EPA and NHTSA state “We recognize that there is significant uncertainty in assessing these relative climate impacts, and that they could change as new production methods and/or regulations go into effect. Thus commenters supporting making such an adjustment are encouraged to address this uncertainty. Commenters are also encouraged to address how such an adjustment for GHG emissions would impact the closely coordinated EPA and NHTSA heavy-duty Phase 2 program including how a potential adjustment for upstream methane emissions for natural gas fueled vehicles would impact the coordination of EPA GHG regulations with the NHTSA fuel consumption regulations.”

CARB staff believes that future natural gas engines, if certified to one of CARB’s optional NOx standards and operated on renewable fuels, have the potential to reduce both NOx and GHGs and provide needed near term reductions. To ensure those reductions are realized, it is important to strengthen natural gas engine and vehicle requirements to maximize the benefits of the cleaner fuel as well as the most efficient vehicle technology. CARB staff believes it is appropriate to have separate standards for natural gas engines and also important that actions be taken to minimize methane emissions from both the vehicle and the upstream natural gas production and distribution system. Steps to minimize emissions from the vehicle should include requiring a closed crankcase, limiting boil-off from LNG vehicles, and limiting tailpipe methane and N_2O. Additional comments on requirements are also included.

As for adjusting tailpipe standards to account for upstream emissions, the ICCT in their “Assessment of Heavy-Duty Natural Gas Vehicle Emissions: Implications and Policy Recommendations”, July 2015, recommends an approach that would phase-in the inclusion of upstream emissions in the certification for natural gas heavy-duty vehicles. CARB supports phasing-in inclusion of upstream emissions in the certification for natural gas heavy-duty vehicles.

<u>Oppose/Requested Change Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40506

Comment – Tailpipe standards for natural gas vehicles

U.S. EPA and NHTSA state: "For 2014 and later OEM compression ignition natural gas trucks or natural gas conversions of 2014 and later diesel trucks, the trucks must meet a 0.1 g/bhp-hr methane emission standard in the case of a larger truck engine tested with an engine dynamometer, and a 0.05 g/mi methane emission standard in the case of smaller trucks tested on a chassis dynamometer. For spark-ignited engines, the standards take effect in 2016. Natural gas truck manufacturers are allowed to offset methane emissions exceeding the methane emission standard by converting the methane emission exceedances into CO_2 equivalent emissions and using CO_2 credits. For the initial natural gas engine certifications that U.S. EPA received for 2014, the truck manufacturers chose to continue to emit high levels of methane (around 2 g/bhp-hr) and use CO_2 credits to offset those emissions. We don't know if this practice of will continue in the future; however, for evaluating the lifecycle impacts of natural gas heavy-duty trucks, the 2014 and later natural gas heavy-duty trucks may in fact have an emissions profile more like the pre-2014 trucks and not like the 2014 and later trucks."

CARB staff suggests that U.S. EPA and NHTSA investigate the feasibility of more stringent tailpipe standards for methane and N_2O. Considering the high-GWP of methane, a 0.1 g/bhp-hr methane standard is equivalent to 4 to 8 percent of the proposed CO_2 standards, depending on vehicle and vocation types. CARB staff also suggests that U.S. EPA and NHTSA consider eliminating or at least phasing out the use of CO_2 credits in lieu of compliance with tailpipe methane standards.

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40187, 40249-40250, 40325

Comment – Reflecting weight decreases for lightweight components, and weight increases for natural gas fuel tanks versus gasoline or diesel tanks

CARB staff supports the Phase 2 proposal to give weight reduction credit for the use of lightweight components, and a weight increase (i.e., negative credit) for natural gas vehicles to reflect the increased weight of natural gas fuel tanks versus gasoline or diesel tanks. The weight reductions or increases translate into decreased or increased CO_2 emissions in GEM. The weight increases would be 600 lbs for a compression ignition LNG tractor, 525 lbs for a spark-ignited CNG tractor, and 900 lbs for a compression ignition CNG tractor; those same weight increases would also apply to vocational vehicles. The weight reductions (credits) for lighter components range from 4 lbs to 588 lbs.

Neutral/Provide Additional Information Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40504

Comment – More efficient natural gas storage

The NPRM states that an adsorbent for natural gas (ANG), called metal organic framework (MOF) for storing CNG, has been developed and is being tested for large scale use. The substance stores the same quantity of natural gas in a smaller volume at the same pressure (about 60 percent of the energy density of diesel fuel), or stores the same density of natural gas at a lower pressure.

CARB staff believes there is potential in the both adsorbent technology as well as conformable tanks. CARB staff suggests that to the extent that those technologies contribute to lighter weight tanks in the future, U.S. EPA and NHTSA should consider either revising the natural gas weight “penalties” or allow the manufacturers to get credit under the off-cycle technology credits (formerly referred to as “innovative technologies”).

Support Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40187, 40249-40250, 40325

Comment – Natural gas engines and vehicles certifying according to intended service class

CARB staff supports the Phase 2 proposal to require any natural gas engine qualifying as a medium heavy-duty (19,500 to 33,000 lbs GVWR) or heavy heavy-duty (over 33,000 lbs GVWR) natural gas engine to be subject to all the emission standards (GHG and criteria pollutant) and other requirements, including the longer useful life and warranty provisions, that apply to compression ignition engines.

CARB supports the proposal to require medium heavy-duty and heavy heavy-duty engines to meet compression ignition requirements (useful life, warranty, not-to-exceed limits, criteria pollutant standards) because they are more stringent and protective of air quality compared to the comparable spark-ignited requirements.

CARB believes there are some 6.8 to 9 liter natural gas engines (produced by BAF, Greenkraft, Impco, Landi Renzo, and Power Solutions) that are currently being certified to the Otto-cycle requirements that may be offered in the future in medium heavy- and even heavy heavy-duty vehicle configurations, and thus could ultimately be impacted by the proposed requirements. Many of these natural gas “converters” offer vehicles primarily in the light heavy-duty classes, and there is some possibility that with the additional requirements they may no longer choose to offer medium heavy-duty and heavy heavy-duty natural gas vehicles. However, this should have minimal market impact as Cummins is already certifying their spark-ignited natural gas engines to the compression ignition requirements.

Support Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40208, 40510

Comment – Closed crankcase requirement for natural gas engines

CARB staff supports the Phase 2 proposal to require closed crankcases for all natural gas engines, including those subject to compression ignition standards. An open crankcase has historically been allowed for diesel-fueled engines, as recirculating those crankcase emissions with their high PM levels could potentially foul turbochargers and aftercooler heat exchangers. Natural gas vehicles have low PM emissions, and requiring a closed crankcase is appropriate. The European Union standard currently compels the use of closed crankcase ventilation systems, and Cummins ISL G Euro V engines already have closed crankcase ventilation.

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40510-40512, 40519-40520, 40609

Comment – Proposal to require 5-day hold time for LNG vehicles

CARB supports the Phase 2 proposal to require a 5-day hold time for LNG vehicles, to reduce the potential for an LNG boil-off event. Manufacturers would have to follow current industry recommended practice, SAE Standard J2343 for 5-day hold time to limit boil-off emissions from LNG vehicles. Boil-off events occur when a LNG truck is parked or driven very little, the fuel vaporizes, and the pressure inside the tank increases to a maximum of 230 pounds per square inch (psi) and a safety release valve releases the methane gas to vent excess pressure. As estimated in U.S. EPA and NHTSA's lifecycle analysis, each boil-off event has the potential to release from 3 to 9 gallons of LNG for each boil off event, depending on the fill level of the LNG tank. And because methane has a global warming potential that is 25 times higher (assessed over 100 years) than CO_2, that equates to 132,000 to 140,000 grams of CO_2 equivalent emissions. CARB staff concurs that the venting characteristics inherent in LNG vehicles are an emissions concern, and recommends adoption of this requirement. CARB staff believes this is a good step towards limiting the release of methane from natural gas fueled vehicles, and that this will better standardize the requirements. CARB may consider similar requirements in the future.

The NPRM also requests comments on other potential requirements to control LNG boil-off emissions. These include control technologies like methane canisters, a methane burner, a catalyst to convert the methane to CO_2, an on-board monitoring requirements to track boil-off events, and other ways to reduce emissions from LNG refueling. CARB staff has not made final determinations on the efficacy of those technologies at this time, but will further investigate their effectiveness.

Neutral/Provide Additional Information Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40503-40509

Comment – Supplemental and clarifying information regarding WTW analysis of CNG and LNG and comparison to CARB results.

CARB staff has four main comments regarding the WTW analysis presented in the NPRM:

1. **The analysis should use GREET's U.S. diesel result, and should identify the version of GREET used.** U.S. EPA and NHTSA use a 2005 NETL analysis to determine the carbon intensity of U.S. diesel. Given that a version of Argonne National Laboratory's GREET model was used for the majority of U.S. EPA and NHTSA's WTW natural gas analysis, CARB staff recommends using the result from the same version of GREET for diesel. If they are based on a different baseline, the results should not be expressed in percent reduction from diesel; it would be preferable to use the same U.S. diesel baseline, or just report the carbon intensity directly.[67] Also, the NPRM does not identify the version of the GREET model used in U.S. EPA and NHTSA's WTW analysis of natural gas fuels (first mention of the use of the GREET model occurs on page 40404). Argonne National Laboratory releases an update nearly every year and 2013-2014 versions included changes to natural gas systems, so it is important to note the model year.

2. **USEPA accurately portrays CARB's August 2014 WTW analysis, but we would like to share some updated information based on our work since then.** On page 40508-40509, the NPRM presents draft results from CARB's August 2014 WTW analysis. CARB staff has since finalized its estimates of WTW carbon intensity for CNG and LNG: without adjusting for natural gas vehicle fuel economy, the carbon intensity of CARB's North American natural gas

[67] CARB staff finds the WTW emissions of California ULSD to be 102 g CO_2e/MJ, approximately 9 gCO_2e/MJ higher than the value U.S. EPA uses to represent the WTW emissions of average U.S. diesel (approximately 93 gCO_2e/MJ or 98,000 g/MMBtu, which we estimate from Figure 13-2 of the RIA). This lack of common baseline confounds the comparison between the NPRM's and CARB's results for natural gas fuels.

to CNG pathway is 78.36 gCO_2e/MJ, or 76.82 percent of CARB-ULSD WTW emissions and the carbon intensity of CARB's North American natural gas to LNG pathway is 84.55 gCO_2e/MJ, or 82.89 percent of CARB- Ultra Low Sulfur Diesel (ULSD) WTW emissions.

3. **U.S. EPA and NHTSA's WTW analysis results in the NPRM are similar to CARB's and where they differ, the differences are primarily due to unique California circumstances.** CARB staff agrees that the U.S. EPA and NHTSA's results "are very similar to those estimated by CARB and when there are differences, the differences are as expected."

   CARB staff believes that the carbon intensity of CNG determined by U.S. EPA and NHTSA is lower than the result in CARB's analysis primarily because the transmission distance from Western U.S. natural gas sources to end users in California is greater than the national average.

   CARB staff estimates the carbon intensity of LNG to be lower than U.S. EPA and NHTSA's analysis, due to the following factors:
   - CARB staff assumes a typical liquefaction stage thermal efficiency of 90 percent (resulting in 8.44 gCO_2e/MJ for the liquefaction stage), rather than 80 percent (which would result in 18.29 gCO_2e/MJ using California grid electricity), reflecting an assumption that most LNG used in California is produced at large centralized facilities. Under the LCFS, each LNG producer must demonstrate the actual efficiency, meaning some individual LNG pathways will result in higher WTW emissions than given in CARB's illustrative scenario;
   - CARB staff does not quantify any venting from the refueling or the vehicle operation stages due to lack of data, but does not disagree with the sensitivity analysis used by U.S. EPA and NHTSA; and
   - There may be differences in the mode and distance of LNG transport; the U.S. EPA and NHTSA document does not provide sufficient information to determine the transportation and distribution assumptions or their resulting impacts.

4. **CARB staff does not recommend U.S. EPA and NHTSA rely on the U.C. Davis study referenced on page 40509 of the NPRM, as we believe that study is flawed.**[68] The U.C. Davis study used GREET 2014 to explore the role of natural gas in the U.S. trucking industry, and reported that:

   (A) CNG has higher WTW GHG emissions than LNG, and
   (B) CNG and LNG have higher WTW GHG emissions relative to diesel when used in spark-ignited engines (with EER=0.9).

CARB staff disagrees with this analysis and finds that under most scenarios, when a methane GWP of 25 is used, both CNG and LNG have a life cycle GHG benefit over diesel. CARB staff believes the UC Davis report reached incorrect conclusions due to using flawed assumptions, including inappropriately using default transport parameters in GREET 2014 (which tend to reduce assumed LNG transport emissions), incorrect assumptions regarding the efficiency of LNG-fueled heavy-duty pilot ignition engines, and not quantifying losses from the LNG vehicle tanks, among others.

Oppose/Requested Change Comment

Affected document(s): RIA

Affected pages: 13-1 to 13-23

Comment – Supplemental and clarifying information regarding CARB analysis

There is a misprint/typo on page 13-22:

> For the CARB emissions estimates, we used the estimates made for what it terms purposes" using the 2013 version of the CARB GREET model as published in August, 2014.

[68] (Jaffe, 2015) Jaffe, Amy Myers, "Exploring the role of Natural Gas in U.S. Trucking," NextSTEPS Program, UC Davis Institute of Transportation Studies, February 18, 2015.

CARB staff believes this should read:

> For the CARB emissions estimates, we used the estimates made for what it terms "illustrative purposes" using the ~~2013~~ draft version of the CA-GREET2.0 model as published in August, 2014.

Regarding the statement comparing CARB and U.S. EPA results on page 13-22, "CARB estimates that CNG engines emit 76 percent of the CO_2eq emissions as a diesel truck, while our analysis estimates that CNG engines emit 81 percent of the CO_2eq emissions as a diesel truck," the "percent of diesel emissions" basis does not provide a direct comparison of the CNG results, as CARB and U.S. EPA do not use the same diesel emissions as baseline. In the CA-GREET2.0 analysis, CARB-ULSD was determined to have a carbon intensity of 102.01 gCO_2e/MJ, while U.S. EPA and NHTSA appear to use approximately 93 gCO_2e/MJ as a baseline (98,000 g/MMBtu, estimated from Figure 13-2 of the RIA).

While CARB staff does not object to the value used as a diesel baseline (this value is meant to reflect the national average WTW emissions of diesel fuel and CARB staff can provide no insight on the accuracy of results outside of California), we suggest that CNG, LNG and diesel should be compared using the same model in order to obtain the most robust results. Given that a version of Argonne National Laboratory's GREET model was used for the majority of U.S. EPA and NHTSA's WTW natural gas analysis, we recommend using the result from the same version of GREET for diesel.

The parameters used to determine methane leakage, LNG boil-off, process energy demand, and the impacts of these inputs are presented clearly and comprehensively; however, the NPRM do not provide information on the transportation and distribution assumptions or resulting impacts modeled for the CNG or LNG pathways. These transport modes and distances are a major driver of the difference between the GREET and CA-GREET2.0 model results. If default transport parameters from GREET 2014 were used in U.S. EPA and NHTSA's analysis, the following table provides a breakdown and contrast of the differences in the two models.

Table 17: GREET vs. CA-FREET Model

Life Cycle Stage	Default GREET 2014 North American NG to CNG pathway: Input/Assumptions	Impact g CO2e/MJ	Default CA-GREET2.0 North American NG to CNG pathway: Input/Assumptions	Impact g CO2e/MJ	
Pipeline Transmission & Distribution - *pipeline energy intensity = 1,641 Btu/ton-mile*	750 miles from production and processing facility to refueling station	2.87	1000 miles from Western U.S. sources of NG production and processing facilities to refueling stations in California	3.83	CNG
Pipeline Transmission Leakage - *distance-dependent leakage factor*	Transmission and Storage Methane Venting and Leakage factor = 81.189 g CH4/MMBtu NG/680 miles, adjusted to 750 miles	2.12	GREET 2014 leakage factor x (1000 mi/680 mi)	2.83	CNG
Pipeline Distribution Leakage - *constant leakage factor*	Pipeline distribution to refueling stations (leakage factor = 63.635 g CH4/MMBtu NG)	1.51	Pipeline distribution to refueling stations (GREET 2014 leakage factor)	1.51	CNG
Total T&D		**6.50**		**8.17**	CNG
	Default GREET 2014 North American NG to LNG pathway: Input/Assumptions	**Impact g CO2e/MJ**	**Default CA-GREET2.0 North American NG to LNG pathway: Input/Assumptions**	**Impact g CO2e/MJ**	
Pipeline Transmission & Distribution - *pipeline energy intensity = 1,641 Btu/ton-mile*	50 miles from production and processing facility to a liquefaction plant.	0.19	1000 miles from Western U.S. sources of NG production and processing facilities to liquefaction facility in California	3.83	LNG
Pipeline Transmission Leakage - *distance-dependent leakage factor*	Transmission and Storage Methane Venting and Leakage factor, adjusted to 50 miles	0.14	GREET 2014 leakage factor x (1000 mi/680 mi)	2.83	LNG
Pipeline Distribution Leakage - *constant leakage factor*	No pipeline distribution; this pathway assumes liquefaction plants are located on main Transmission pipeline	0	No pipeline distribution; this pathway assumes liquefaction plants are located on main Transmission pipeline	0	LNG
Other Transport modes	LNG 50% by Barge (520 miles), 50% by Rail (800 miles), and distribution via diesel truck (30 miles)	0.82	LNG distribution via diesel truck (50 miles)	0.37	LNG
T&D Boil-off with 80% recovery	0.1% loss per day for 2.7 days of T&D	0.28	0.1% loss per day for 0.1 days of T&D	0.01	LNG
Storage Boil-off with 80% recovery	0.1% loss per day for cummulative 8 days of Storage (at terminal and refueling station; not included here are emissions from an additional 5 days of storage at the liquefaction plant)	0.83	0.1% loss per day for cummulative 8 days of Storage (at terminal and refueling station; not included here are emissions from an additional 5 days of storage at the liquefaction plant)	0.83	LNG
Total T&D		**2.25**		**7.87**	LNG
	GREET 2014		CA-GREET2.0		

Emission Benefits Estimates

Neutral Comment to Provide Additional Information

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40216, 40220, 40225, 40226, 40227, 40238, 40393 – 40394, 40412

Comment – NOx benefits from the extended use of APUs appear overestimated

According to page 40219 of the NPRM, to date, manufacturers are meeting the 2014 MY GHG standards without the use of automatic engine shutdown (AES) systems or APUs. U.S. EPA and NHTSA assume an APU/AES technology adoption rate of 90 percent for 2024+ MY class 7 and 8 tractors (page 40393 – 40394 of the NPRM). Given that manufacturers complied with Phase 1 without using APUs, CARB staff believes a 90 percent adoption rate may be too high.

Additionally, CARB's engine certification database shows that almost all of the 2014 MY engines which are sold in California (especially in class 8) are certified (as 50-State families) to the California clean idle engine requirements of 30 grams/hour NOx at idle. Following U.S. EPA and NHTSA's projection of increased use of APUs during extended idling in combination tractors, the NPRM claims 34 percent NOx emissions reduction in year 2050 (page 40412 of the NPRM). Considering that APUs emit only a slightly lower NOx emissions than CA clean idle certified engines (because they are certified to CA clean idle requirements), such a high reduction in tailpipe NOx emissions (i.e., 34 percent) is not expected.

Therefore, CARB staff encourages U.S. EPA and NHTSA to:

1. Re-evaluate the projected level of AES/APU systems that will be used by manufacturers to comply with the requirements of the proposed regulation and;
2. Provide more information on the methodology and assumptions used to estimate the NOx emission benefits associated with this regulation.
3. Update the NOx emission benefit estimates to account for the current prevalence of clean idle certified engines.

<u>Neutral Comment to Provide Additional Information</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40397 - 40406

Comment – GHG emissions reductions

According to Table VII-13 of the NPRM, the annual downstream GHG emissions impact of the proposed regulation (preferred Alternative 3 vs. Alternative 1a baseline using Analysis Method A) in year 2050 is reported as ~134.9 MMT CO_2eq (at the national level). In order to compare these federal emissions reductions estimates to a California-specific analysis, it is necessary to have estimates of the baseline emissions (baseline Alternatives 1a and 1b). However, the NPRM does not provide baseline information.

Therefore, CARB staff encourages U.S. EPA and NHTSA to either provide estimates of GHG emissions (in MMT CO_2eq) for baseline scenarios (Alternatives 1a and 1b), or report the benefits as a percent reduction from the baseline emissions similar to those provided in Section VIII of the NPRM for non-GHG emissions (e.g. Table VIII-7).

Comment on Non-GHG Emissions and their Associated Effects

NOx

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40149-40150

Comment – NOx reductions from heavy-duty vehicles are crucial to California's air quality goals

In the NPRM, U.S. EPA and NHTSA rightly noted California's unique challenge to attain the ozone and PM NAAQS in many regions of the state. In particular, California's South Coast Air Basin and San Joaquin Valley Air Basin, the nation's only two "Extreme" ozone non-attainment areas, require significant reductions in NO_X and volatile organic gases to reach state air quality goals. Since heavy-duty vehicles currently emit approximately one-third of the state's NO_X emissions, measures to reduce emissions from such vehicles are crucial for California. California needs dramatic further reductions in NOx emissions beyond what our current programs will achieve by 2031 to attain health-based standards for ozone and fine PM. Reaching these attainment levels in California's South Coast Air Basin will require an approximate 70 percent reduction in NOx from today's levels by 2023, and an overall 80 percent reduction in NOx by 2031. To make matters more challenging, U.S. EPA and NHTSA are revising the NAAQSs (due to be finalized by December, 2015). These new NAAQSs, which are more stringent than existing ones, will require even greater NO_X emission reductions. This means that heavy-duty NO_X emission reduction strategies must begin now and in parallel with GHG emission reduction strategies.

California's compelling need for emission reductions necessitates further actions now, despite the past significant achievements of U.S. EPA and CARB efforts to reduce heavy-duty vehicle emissions. CARB's *Sustainable Freight Pathways to Zero and Near-Zero Discussion Document* (Discussion Document)[69] describes actions to identify and prioritize potential immediate and near-term measures and strategies to reduce criteria pollutants and GHG emissions from all vehicle/equipment sectors that move

[69] (CARB, 2015b) California Air Resources Board, "Sustainable Freight – Pathway to Zero and Near-Zero Emissions," April 2015, <http://www.arb.ca.gov/gmp/sfti/sustainable-freight-pathways-to-zero-and-near-zero-emissions-discussion-document.pdf>.

freight in California to assist in meeting both the State's air quality attainment and climate needs.

For the trucking sector, these strategies and measures include expanded enforcement efforts and financial incentive opportunities, reduced opacity limits for filter-equipped trucks, enhanced certification and warranty requirements to ensure low in-use emissions, increased flexibility for manufacturers in certifying advanced innovative truck engine and vehicle systems, and California Phase 2 GHG requirements, which may be more stringent than federal Phase 2 requirements, depending on the stringency of the final federal rule. The Discussion Document also calls for CARB to petition U.S. EPA to develop mandatory, NOx standards (which is discussed in more detail later in this comment).

The CAA gives California independent authority to adopt its own heavy-duty vehicle and engine standards, which it has utilized on numerous occasions to achieve additional emission reductions as compared to the federal standards. However, the regulated industry has consistently preferred a single, national program, rather than a more stringent California-only standard. California recognizes this, and is committed to working with U.S. EPA and NHTSA to address heavy-duty truck NOx emissions. This is especially important for out of state trucks; of the one million heavy-duty vehicles that operate in California, approximately 60 percent of trucks operating in California were originally purchased in states outside of California. CARB is prepared to utilize its authority to develop California-only mandatory, lower NOx standards if U.S. EPA fails to take timely action in developing federal standards.

Although the NPRM claims some reductions in NOx emissions are expected due to the Phase 2 program (due to use of APUs instead of idling),[70] CARB staff believes these emission reductions are overstated. Because nearly all of today's engines already meet clean idle requirements which limit NOx at idle to 30 grams/hour, switching to APU use is not expected to appreciably reduce NOx emissions and hence Phase 2 is not expected to significantly reduce tailpipe NOx emissions. Instead, because the NPRM does not incorporate CARB's recommendation for a supplemental NOx check for heavy-duty hybrids[71] and proposes overly broad use of dirtier off-road engines in on-road vehicles, CARB staff instead is concerned that Phase 2 may result in overall NOx emissions to increase; recent work at NREL funded by CARB shows that heavy-duty

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[70] Table VIII-20 in the Phase 2 Proposed Rule estimates 426,610 tons/yr downstream NOx reductions nationwide in 2050 due to Phase 2.
[71] See http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2014-0827-0036 for our comment regarding the need for a supplemental NOx check for hybrids.

hybrids can have NOx emissions more than three times those of comparable diesel vehicles.[72]

As CARB staff has worked with U.S. EPA and NHTSA over the past several years on the Phase 2 program, we have repeatedly requested that U.S. EPA and NHTSA consider opportunities in the Phase 2 rulemaking to encourage further NOx emission reductions, prevent inadvertent NOx increases, and lay the groundwork for swift federal action to reduce NOx from heavy-duty trucks. However, these requests have not been addressed in the NPRM.

CARB staff was anticipating the inclusion in the NPRM of a discussion on the need for federal action on future NOx control and a commitment from U.S. EPA and NHTSA to begin development on lower, mandatory NOx standards for heavy-duty engines and vehicles. Unfortunately, the proposal included no such commitment.

In parallel with completion of the Phase 2 rulemaking, CARB staff recommends that U.S. EPA and NHTSA pursue a joint rulemaking effort to reduce the NOx emission standard for heavy-duty engine certification. The current emission standards for heavy-duty engines, the 2010 emission standards, were promulgated in 2001, which was 14 years ago. Since that time, engine manufacturers have made significant progress in improving the conversion efficiency of NO_X aftertreatment technologies and in reducing emissions from engines. The next phase of NO_X emission standards may be achieved with advanced engine controls and advanced aftertreatment technologies, leading to a significantly lower NOx emission standard than the 2010 standards.[73]

CARB staff will begin development of lower, mandatory NOx engine standards in 2017, and also plans to petition U.S. EPA to establish lower, federal NOx engine standards. If U.S. EPA fails to initiate its rulemaking by 2017, CARB will continue with its efforts to establish a California-only standard. A lower NOx standard that reduces emissions from all trucks operating in California is critical to meeting 2031 air quality goals.

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[72] (NREL, 2015b) National Renewable Energy Laboratory, "Data Collection, Testing, and Analysis of Hybrid Electric Trucks and Buses Operating in California Fleets - Final Report," June 2015, <http://www.nrel.gov/docs/fy15osti/62009.pdf>.

[73] (CARB, 2015e) California Air Resources Board, "Draft Technology Assessment: Lower NOx Heavy-Duty Diesel Engines," September 2015, <http://www.arb.ca.gov/msprog/tech/techreport/diesel_tech_report.pdf>.

CARB staff has already begun work to lay the technical foundation for a lower NOx emission standard for new heavy-duty engines. CARB has funded SwRI for a $1.6 million project to investigate advanced technologies to reduce NOx emissions by 90 percent from today's U.S. EPA and CARB heavy-duty engine standards. The engine technology package must continue to meet all applicable standards for hydrocarbons, carbon monoxide, and PM, including, and GHG emissions.

In this research contract, SwRI is evaluating enhanced aftertreatment technology choices, aftertreatment configurations, catalyst optimizations, urea dosing strategies, engine tuning, and engine management practices for two heavy-duty engines: one natural gas engine with a three-way catalyst; and one diesel engine with a DPF and SCR. The target NOx emission rate for this project over the heavy-duty FTP is 0.02 g/bhp-hr.

SwRI will characterize the emission performance of the two stock engines using procedures following Title 40, Code of Federal Regulations, Part 1065, determine stock engine characteristics for cold starts, hot starts, normal operation, and low-load-low-temperature operation, and will determine possible engine control strategies. Based on the engine performance and possible engine control strategies, SwRI will select candidate aftertreatment technologies and engine control strategies for screening. The candidate emission reduction strategies will be screened using low-cost exhaust emission sources and test benches. The best performing technology packages and strategies will be identified and their performance will be measured on engine dynamometer over the heavy-duty FTP, World Harmonized Transient Cycle, ramped mode cycle, extended Idle, and three low-load-low-temperature cycles derived from the Orange County Transit Authority bus cycle, New York bus cycle, and CARB Creep cycle.

The screening process is currently progressing and it is showing promising results towards achieving the 0.02 g/bhp-hour NOx for both natural gas and diesel engines.[74] This research contract is expected to be completed by the end of 2016.

To further reduce NO_X emissions, CARB also adopted optional low-NO_X standards in late 2013 that are 50 percent, 75 percent, and 90 percent lower than the current NO_X standard of 0.20 g/bhp-hr. The optional low-NO_X standards were developed to encourage engine manufacturers to develop new technologies and also to provide them

[74] See Attachment 8 for Southwest Research Institute, ARB Low NOx Program Advisory Group Update, August 2015; and see http://www.arb.ca.gov/research/veh-emissions/low-nox/low-nox.htm for more information of this study.

with a mechanism to optionally certify engines to lower NO_X standards. Certification to these lower optional standards could enable trucks equipped with certified lower NO_X engines to become eligible for incentive funding. CARB's incentive funding programs have been updated to include incentives to encourage the development and certification of lower NO_X heavy-duty engines. In response to these actions, Cummins Westport Inc. (CWI) announced in May 2015 that it achieved a 0.02 g/bhp-hr NO_X emission level on its 8.9 liter ISL G spark-ignited natural gas engine, and was starting field testing in California. In September 2015, CARB issued Executive Orders for the 8.9 liter ISL engine certified to the 0.02 g/bhp-hr optional NOx standard for use in medium heavy-duty and urban bus applications.

As discussed previously on California's need for GHG reductions, another consideration for the adoption of lower NOx emission standards is its simultaneous implementation with the proposed Phase 2 GHG standards. The proposed Phase 2 Alternative 3 does not become fully implemented until the 2027 MY. A more stringent Alternative 4 would be fully implemented by the 2024 MY, which would allow earlier action on NOx, without the need for manufacturers to implement both rulemakings simultaneously. As a result, the need for timely NOx reductions lends additional support for U.S. EPA and NHTSA to choose Alternative 4 over Alternative 3.

In light of California's and certain other states' pressing needs for NO_X emission reductions to achieve the proposed more stringent NAAQS standards, CARB staff urges U.S. EPA and NHTSA to thoroughly describe the need for lower federal NO_X emission standards for new heavy-duty engines in the Phase 2 rulemaking package and to initiate a parallel effort to adopt such standards as quickly as possible.

PM

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40211, 40213-40124, 40126-40127, 40219, 40223-40224, 40416-40418

Comment – Need to control PM emissions from APUs to prevent Phase 2 causing PM increases

The NPRM requests comment on the need and appropriateness to further reduce PM emissions from APUs. The Phase 1 regulations included provisions to use extended idle reduction technologies as a compliance path to meet the GHG standards for sleeper cab tractors. In developing the Phase 1 GHG standards, U.S. EPA and NHTSA assumed that manufactures would install diesel-fueled APUs on all of the sleeper cab tractors to meet the Phase 1 GHG standards. Because the federal emission standards for APUs are less stringent than those for on-road heavy-duty engines, it was estimated that compliance with the Phase 1 standards using APUs as a compliance option would increase PM emissions by approximately 8 percent in 2030. Concerned about this potential increase in PM emissions, CARB and other stakeholders recommended that U.S. EPA and NHTSA regulate PM emissions from diesel-fueled APUs in the Phase 1 rulemaking.[75] However, U.S. EPA and NHTSA chose not to take action on APUs because such action was outside the scope of the Phase 1 rulemaking.

To date, CARB staff is not aware of any tractor manufacturers using APUs as a technology option to meet the Phase 1 GHG standards. Nonetheless, U.S. EPA and NHTSA are proposing the use of extended idle reduction technologies as a compliance option to meet the proposed Phase 2 standards. Moreover, like in Phase 1, the proposed rule does not require PM control from APUs. Thus, U.S. EPA and NHTSA's inventory estimates project that compliance with the Phase 2 standards would increase federal PM emissions from heavy-duty trucks by approximately 10 percent in 2050 mainly due to PM increases from APUs. The NPRM requests comments on the need and appropriateness to further control PM emissions from APUs, taking into account cost, safety, noise, and energy factors. Although, as noted above, CARB staff believes the projection of APU use in the NPRM may be too high and hence the actual PM increases may be lower than projected, CARB staff is concerned about any such PM increases and believes they should be eliminated.

In the Phase 2 NPRM, U.S. EPA and NHTSA rightly note that CARB, recognizing the excess PM emissions from APUs, requires APUs that operate in California to control PM emissions by either installing a DPF that is Level 3 (85 percent filtration efficiency) verified or must have the APU exhaust routed to the truck's exhaust system upstream of the truck's DPF. To comply with California's requirements, several APU and DPF manufacturers have verified Level 3 DPFs for use with APUs. Commercially available today, verified DPFs for use with APUs include Thermo King's Electric Regenerative DPF for use with their TriPac APU, Impco Ecotrans Technologies' ClearSky DPF for use with their Comfort Pro APU, and Proventia's Electronically Heated DPF for use with the

[75]See http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2010-0162-2354 for Phase 1 Comment submitted CARB and for comments by others "EPA Response to Comments, EPA-420-R-11-004, August 2011, Pages 136-140 http://www.epa.gov/otaq/climate/regs-heavy-duty.htm.

Thermo King TriPac APU. APUs are typically equipped with diesel-fueled off-road engines with power ratings less than 25 hp. The verified DPFs are available as factory installed on APUs or as APU retrofits. As of December 31, 2014, approximately 7,000 APUs equipped with CARB verified DPFs have been sold nationwide. These technologies have been in use now for the last 5 to 7 years and during this period, CARB has not received any complaints from end users related to DPF performance, safety, reliability, or noise issues that would make these devices impractical to use on APUs. Thus, there are no technical feasibility issues that would hinder U.S. EPA and NHTSA from requiring additional PM controls on APUs.

Based on price quotes provided by the three manufacturers, the average incremental cost of a verified DPF for an APU is approximately $2,500. This cost estimate for an APU engine rated at less than 25 hp is relatively high compared to the $580 DPF incremental cost estimate for a 150 hp off-road engine that U.S. EPA cites in the NPRM. The higher cost quoted by the three manufacturers for these DPFs is due to the low sales volume of APUs with verified DPFs since the requirements only apply to California as opposed to being a nationwide requirement. Also, since DPFs are not required on APUs installed on trucks equipped with 2006 or older MY engines, California does not prohibit the purchase and installation of non-DPF equipped APUs. It only restricts their operation within the state if installed on trucks equipped with 2007 or subsequent MY engines. Thus, many trucking companies that purchase APUs do not purchase the DPF. CARB staff expects if the requirements are applied nationally, the sales volume will increase and consequently the incremental cost will drop significantly, most likely to levels even below the $580 DPF cost estimate for a 150 hp engine that U.S. EPA and NHTSA cite in the NPRM.

In 1998, CARB identified diesel PM as a toxic air contaminant. In 2012, the International Agency for Research on Cancer, which is part of the World Health Organization, also classified diesel engine exhaust as carcinogenic to humans.[76] Numerous studies have shown diesel PM's adverse effects on human respiratory and cardiovascular systems and its contribution to increased morbidity and mortality. Further details regarding diesel PM health effects is available on CARB's website at http://www.arb.ca.gov/research/diesel/diesel-health.htm.

The health risk posed by diesel PM is one of the largest public health problems tackled by CARB in recent decades, and even after an extensive control program including a

[76] IARC: Diesel Engine Exhaust Carcinogenic, http://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf

series of air toxic control measures in California (see for example the mobile source measures listed at http://www.arb.ca.gov/toxics/atcm/atcm.htm), diesel PM remains responsible for 60 percent of the known risk for air contaminants. Hence, controlling diesel PM remains a huge priority for CARB. Diesel PM also contains black carbon, which is a powerful short-lived climate pollutant, so even beyond the toxicity reasons for controlling diesel PM, there are climate reasons as well. The PM 2.5 increases projected for the Phase 2 regulation are very significant – an increase of 1,631 tons and 2,257 tons of nationwide PM 2.5 in 2035 and 2050,[77] respectively. To put those emission increases in perspective, they are greater than the entire projected reductions of 1,058 tons statewide diesel PM in 2023 from CARB's Truck and Bus Regulation.[78] While this issue does not significantly affect California because CARB already requires DPFs on APUs, CARB staff supports adopting similar requirements at the federal level concurrent with the Phase 2 program.

Overall, CARB staff strongly urges U.S. EPA and NHTSA to regulate PM emissions from APUs in this rulemaking since the technology is commercially available, trucking businesses are currently using it, and it is cost-effective. It does not make sense to pursue CO_2 emissions reductions at the expense of increased toxic diesel PM emissions.

[77] Phase 2 Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium and Heavy-Duty Engines and Vehicles; Notice of Proposed Rulemaking; 40 CFR 1036; 40 CFR 1037; 40 CFR 86; http://www.regulations.gov/#!documentDetail;D=EPA-HQ-OAR-2014-0827-0002.

[78] (CARB, 2014d) California Air Resources Board, "Staff Report: Initial Statement of Reasons for Proposed Rulemaking – Proposed Amendments to the Truck and Bus Regulation," page 33, March 2014, <http://www.arb.ca.gov/regact/2014/truckbus14/tb14isor.pdf>.

Comments on Estimated Cost, Economic, and Other Impacts

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40434-40489

Comment – Scope of costs and benefits

The NPRM requests comment on whether any costs or benefits are omitted from the analysis. CARB staff supports the inclusion of all quantifiable impacts of reductions in GHG and non-GHG pollutants. Specifically, CARB staff suggests the inclusion of ecosystem benefits from reduced non-GHG pollutants including those to crops as outlined in Murphy et al. (1999). Changes in fugitive emissions from altered driving patterns on paved roads may also impact agriculture and ecosystem health. These impacts should be included in the analysis to the extent that they can be quantified.[79]

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40434-40438

Comment – Energy efficiency gap

The NPRM requests comment on the slow adoption of cost-effective technologies for reducing fuel consumption. CARB staff supports the hypothesis that the end-users are not adopting readily available, cost-effective energy efficiency technologies because they do not have full information regarding their costs and benefits (this economic situation is known as the "energy efficiency gap" or "energy paradox"). CARB staff also recognizes that in the highly diverse and specialized heavy-duty vehicle sector, no manufacturer wants to be the first to be absorb high upfront research and development costs for new technologies that other manufacturers will subsequently utilize at lower costs (the "first-mover disadvantage"). Overall, CARB staff agrees these issues necessitate further research in order to better understand the heavy-duty vehicle sector and to identify potential strategies and mechanisms to speed the adoption of fuel efficient technologies.

[79] (Murphy et al., 1999) Murphy, J.J., M.A. Delucchi, D.R. McCubbin, and H.J. Kim, "The cost of crop damage caused by ozone air pollution from motor vehicles," Journal of Environmental Management: 55, 273-289.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40446-40453; RIA 2-199 to 2-284

Comment – Maintenance costs

The NPRM requests comment on the estimation of maintenance costs for hybrid electric vehicles. CARB staff supports the inclusion of all maintenance costs across vehicle technologies. Maintenance costs of hybrid buses [80] and small fleets of hybrid delivery vans[81] have been estimated as part of several recent research projects. In addition, changes in electricity expenditures associated with BEVs should also be included in the estimation of fuel costs for advanced technology vehicles. In other words, the costs and savings resulting from changes in electricity consumption, not just savings based on the decreased use of liquid fuels, must be incorporated into the fuel cost savings calculation.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40438-40453; RIA 2-191 to 2-199,

Comment – Indirect cost estimates

The NPRM requests comment on the estimation of indirect costs. CARB staff supports the use of indirect cost multipliers over retail price equivalent multipliers to capture the difference in research costs associated with varying technology complexities.

[80] (Callaghan and Lynch, 2005) Callaghan, L. and Lynch, S., “Analysis of electric drive technologies for transit applications: battery-electric, hybrid-electric, and fuel cells. U.S. Department of Transportation,” Final Report: FTA-MA-26-7100-05.1, 1-54.

[81] (Lammert, 2009) Lammert, M, “Twelve-Month evaluation of UPS diesel hybrid electric delivery vans,” NREL Technical Report: NREL/TP-540-44134, 1-38.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules RIA

Affected pages: 40448-40453; RIA 8-10 to 8-114

Comment – Rebound effect

The NPRM requests comment on the assumptions related to the rebound effect for heavy-duty vehicles. CARB staff believes further research is needed in this area. Emerging research from Winebreak et al. (2015) on fuel price elasticity in the U.S. combination trucking sector suggests fuel price inelasticity of demand for vehicles miles traveled and fuel consumption.[82] This result implies that existing estimates of the rebound effect in the combination trucking sector could be overstated and calls for additional analysis. CARB staff suggests that, when feasible, short-run and long-run rebound effects should be estimated separately as research suggests the response to changes in efficiency varies over time.[83]

In addition, CARB staff recommends additional research on the indirect and economy-wide portions of the rebound effect. Freight system interactions, fuel surcharges, and changes in capacity may impact the direct rebound effect in the heavy-duty sector, resulting in compensating changes outside of fuel consumption.[84] The price elasticity of energy demand may be preferred over the use of the price elasticity of VMT in the heavy-duty sector.

The RIA cites Guerrero (2014), which simulates the California freight network and concludes that the rebound effect could offset 40 to 50 percent of vehicle efficiency emission reductions.[85] CARB staff does not support the findings of Guerrero (2014) in

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[82] (Winebreak et al., 2015) Winebreak, J. J., Green, E.H, Comer, B., Li, C., Froman, S., and Shelby,M., "Fuel price elasticities in the U.S. combination trucking sector," Transportation Research Part D: 38,166-177.

[83] (Dahl, 2012) Dahl, C.A., "Measuring global gasoline and diesel price and income elasticities," Energy Policy: 41, 2-13.

(De Borger and Mulalic, 2012) De Borger, B., Mulalic, I., "The determinants of fuel use in the trucking industry – volume, fleet characteristics and the rebound effect," Transportation Policy: 24, 284-295.

(Winebreak et al., 2012) Winebreak, J.J, Green, E.H., Comer, B., Froman, S., "Estimating the direct rebound effect for on-road freight transportation," Energy Policy: 48. 252-259.

[84] (Winebreak et al., 2015) Winebreak, J. J., Green, E.H, Comer, B., Li, C., Froman, S., and Shelby,M., "Fuel price elasticities in the U.S. combination trucking sector," Transportation Research Part D: 38,166-177.

[85] (Guerrero, 2014) Guerrero, S.E., "Modeling fuel saving investments and fleet management in the trucking industry: the impact of shipment performance on GHG emissions," Transportation Research Part E: 68, 178-196.

assessing the relationship between fuel saving technology and the management of vehicle fleets. Guerrero (2014) estimates the rebound effect of long-haul trips only, which is not representative of the entire heavy-duty vehicle feet. The analysis fails to account for existing market failures that currently are impediments to the adoption of cost-effective fuel saving technology, resulting in potential overestimation of the rebound effect with optimal adoption of fuel saving technology. Guerrero (2014) is based on a commodity flow data and not heavy-duty vehicle activity, which is more representative of the sector and utilized in Winebreak (2015).

CARB staff appreciates the use of sensitivity analysis in regards to the rebound effect and suggests additional sensitivity cases to incorporate varying discount rates, and additional estimates of indirect and economy-wide rebound, when feasible.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed Rules RIA

Affected pages: 40457-40470; RIA-8-1 to 8-144

Comment – Social cost of non-CO_2 GHGs

The NPRM requests comment on the inclusion of non-CO_2 GHGs in the estimated benefits of the proposed rulemaking. CARB staff supports the use of directly modeled peer-reviewed estimates of the social cost of all GHGs over the GWP approach but is concerned about consistency if not all GHGs are directly modelled. Currently, there is no proposed research to directly model the social cost of HFC-134a for example, which will result in biased estimation as the GWP-based approximation has been shown to underestimate climate benefits relative to direct modeling. CARB staff suggests that there is a need for additional research on the social cost of non-CO_2 GHGs such as black carbon including harmonization with the social cost of CO_2.

Comment on Topic Where NPRM Requests Comment

Affected document(s): RIA

Affected pages: RIA 8-1 to 8-144

Comment – Economic value of reduction in criteria pollutants

The NPRM requests comment on the economic valuation of reductions in criteria pollutants resulting from the proposed rulemaking. CARB staff supports the inclusion of criteria pollutant emission reductions as well as consideration of the impacts on toxic air contaminants such as diesel PM. CARB staff also suggests the impact of local pollutants be based on source-specific estimates of marginal damage.[86] CARB staff supports continued full-scale air quality modeling for the final rulemaking to capture local variability.

Comment on Topic Where NPRM Requests Comment

Affected document(s): Phase 2 Proposed RIA

Affected pages: 40465-40472; RIA 8-72 to 8-87

Comment – Energy security analysis

The NPRM requests comment on the estimation of energy security benefits of the proposed rulemaking. CARB staff supports the estimation of energy security benefits and suggests that the benefit to national defense be included in the estimation. The National Research Council (2013) estimates that inclusion of the impact to national defense could impact the estimation of energy security benefit by 25 percent. CARB staff recommends additional analysis to determine methodologies to incorporate the impact of national defense in the analysis of energy security.[87]

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[86] (Muller and Mendelsohn, 2009) Muller, N.Z. and Mendelsohn, R., “Efficient pollution regulation: getting the prices right,” American Economic Review: 99(5), 1714-39.
(Muller and Mendelsohn, 2012) Muller, N.Z. and Mendelsohn, R., “Efficient pollution regulation: getting the prices right: reply,” American Economic Review: 102(1), 608-12.

[87] (NAS, 2013) National Research Council, “Transitions to alternative vehicles and fuels,” The National Academies Press: Washington, D.C.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules; RIA

Affected pages: NPRM 40472-40486; RIA 8-61 to 8-89

Comment – Accidents, congestion, and noise

The NPRM requests comment on the input metrics used in the analysis of accidents, congestion, and noise. CARB staff supports the holistic inclusion of these inputs and suggests that the inputs related to congestion, accidents, and noise be consistent with any anticipated changes in vehicle usage, including VMT, mode switching, and route modification, due to the rebound effect of the proposed rulemaking. Any modification to the rebound effect from continued research should be reflected in the estimation of accidents, congestion, noise, and increased travel.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40155

Comment – Lead time

The NPRM requests comment on the lead time for the proposed rulemaking and market disruption. CARB staff suggests that U.S. EPA and NHTSA conduct additional research on the market impact of the proposed rulemaking, including an ex post (retrospective) analysis of the market impacts resulting from existing GHG and criteria pollutant engine and vehicle regulations.

<u>Comment on Topic Where NPRM Requests Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40161

Comment – Small business impacts

The NPRM requests comment on additional provisions for small businesses. In California, small businesses play an important role in the economic vitality of the state, representing 3.5 million businesses and 50 percent of the private-sector labor force. CARB staff supports additional research on the impact of the proposed rulemaking on small businesses, specifically in regards to potential impacts on employment.

Comment on Definitions and Miscellaneous Topics

Support Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40558, 40573, 40602

Comment – CARB Staff Supports Improved Definitions

The CARB staff supports U.S. EPA and NHTSA's proposed addition of, and clarification to, definitions throughout the proposed language, specifically in 40 CFR 86.1803-01, the addition of definitions for a cab-complete vehicle, an incomplete vehicle, transmission type, the addition of automated manual and continuously variable transmissions to the list of basic transmission types (page 40573 of the NPRM). Also, in 40 CFR 1036.801 (page 40602 of the NPRM), CARB staff supports the clarification that a dual fuel engine can include 2 or more fuels as long as it does not operate on a continuous mixture of those 2+ fuels, and the expanded definition of manufacturer to include those who assemble an engine, vehicle, or piece of equipment.

Oppose/Requested Change Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40602, 40661

Comment – Definitions

The definition of compression ignition in 40 CFR1036.801 has been expanded to include gas turbines and "certain" spark-ignited engines. CARB staff believes it would be appropriate to either state here which spark-ignited engines are to be treated like compression ignition and subject to the requirements of compression ignition or to provide a reference to the appropriate section so describing, which would appear to be 40 CFR1036.140. 40 CFR 1036.140 (a) states that medium heavy-duty and heavy heavy-duty engines that do not run on gasoline must meet compression ignition standards, even if they are spark-ignited engines. Gasoline-fueled (including dual fuel) medium heavy-duty and heavy heavy-duty meet spark-ignited standards. Light heavy-duty spark-ignited engines meet spark-ignited requirements regardless of fuel. Thus, CARB staff suggests the following modification to the definition of compression ignition in 40 CFR 1036.801:

> *Compression ignition* means relating to a type of reciprocating, internal-combustion engine that is not a spark-ignited engine. Note that 40 CFR 1036.1 also deems gas turbine engines and other engines to be compression-ignition engines. Note also that certain spark-ignited engines are subject to the requirements for compression-ignition engines, specifically, per 40 CFR1036.140(a), medium heavy-duty and heavy heavy-duty engines that do not operate on gasoline, even if they are spark-ignited engines.

The definition of basic vehicle frontal area in 40 CFR 1037.801 (page 40661 of the NPRM) would be enhanced by an illustration. The language states that "basic vehicle frontal area means the area enclosed by the geometric projection of the basic vehicle along the longitudinal axis onto a plane perpendicular to the longitudinal axis of the vehicle, including tires but excluding mirrors and air reflectors."

<u>Support Comment</u>

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40553, 40559-40561, 40585, 40611, 40652-40654

Comment – Miscellaneous support

The CARB staff supports the addition of DPF filters to the list of items that require a regular maintenance interval of 50,000 miles/1500 hours (40 CFR 86.004-25 (b)(4)(i)).

The CARB staff supports the language added to 40 CFR 86.1819-14 clarifying that the CO_2 standards must be met over the full useful life. CARB staff supports the addition of language setting broad applicability and pulling out specific further requirements. This approach by U.S. EPA and NHTSA will close potential loopholes for engines/vehicles that are difficult to fit into existing language.

The CARB staff supports the lengthening of the useful lives of class 2b through 8 engines and vehicles to more properly reflect their actual use. For non-medium-duty passenger vehicle heavy-duty vehicles, the emissions standards in 40 CFR 86.1819 apply for the currently defined useful life of 11 years, 120,000 miles though MY 2020, then increase to 150,000 miles/15 years with MY 2021 and beyond. Under 40 CFR 1036.108 (d), a 150,000 mile/15 year useful life over which compliance must continue is also specified (page 40585 of the NPRM). CARB staff supports the increased useful life for vocational class 2b through 5 vehicles from 110,000 miles/10 years to 150,000 miles/15 years as specified in 40 CFR 1037.105 (e)(1).

The CARB staff supports the approach delineated in 40 CFR 1037.620-622 which defines the responsibility for each entity involved in an engine/vehicle with multiple manufacturers. This clearly defined approach will make it evident which party is responsible for every facet of the engine/vehicle.

Neutral/Provide Additional Information Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40610, 40654, 40587

Comment – Editorial corrections

CARB staff notes that while Table 2 in 40 CFR1037.105 (page 40610 of the NPRM) is correctly identified in paragraph 2, it appears that its title is incorrect. CARB staff believes that the table should be titled as shown in strike out and insertion below:

> Section 1037.105 Exhaust emission standards for CO_2 for vocational vehicles (b) (2) Model year 2024 through 2026 vehicles are subject to CO_2 standards corresponding to the selected subcategories as shown in the following table:
>
> TABLE 2 OF § 1037.105 – PHASE 2 CO_2 STANDARDS FOR MODEL YEAR 2024 ~~AND LATER~~ THROUGH 2026 VOCATIONAL VEHICLES

CARB staff further believes that 40 CFR1037.622 (page 40654 of the NPRM, paragraph (5)) should use “site” instead of “cite” (“[T]he secondary manufacturer must identify the regulatory ~~cite~~ site identifying the applicable exemption instead of a valid family name when ordering engines from the original vehicle manufacturer.”).

40 CFR1036.150 (e) Alternate phase-in standards (page 40587 of the NPRM) states “[w]here a manufacturer certifies all of its model year 2013 compression-ignition engines within a given primary intended service class to the applicable alternate standards of this paragraph (e), its compression ignition engines within that primary intended service class are subject to the standards of this paragraph (e) for model years 2013 through 2016.” Then follows an untitled table, the last line of which is labeled “Model Years 2016 and later”, and provides standards of 576 g/hp-hr for light heavy-duty and medium heavy-duty engines, and 555 g/hp-hr for heavy-duty diesel engines. CARB staff believes this last line of the table should be labeled “Model Years 2016 through 2020.” The presumably unintended implication in this table as written is that if a manufacturer follows this alternate phase-in schedule, the manufacturer may continue to certify engines to the same standard after 2016 and throughout Phase 2.

Requested Clarification

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40161, 40285, 40545, 40563, 40586

Comment – Small Manufacturer Provisions

Small manufacturers were exempt from Phase 1 GHG rules, but must comply with Phase 2, under a delayed schedule. The small manufacturer delays apply to engine manufacturers (page 40161 of the NPRM), trailer manufacturers (page 40285 of the NPRM), and small engine converters (page 40545 of the NPRM). Alternate fuel engines, defined as those fueled with any fuel other than gasoline, E85, or diesel, have an additional year to comply with each new standard. CARB staff supports the inclusion of small manufacturers into Phase 2 of the GHG regulations. CARB staff recommends clarification on whether this alternate fuel delay noted in 40 CFR1036.150 (d) and 86.1819 – 14 (j) (5) is in addition to the small manufacturer delay (resulting in a delay of up to 2 years for an alternative fuel engine manufactured by a small manufacturer), and whether the alternative fuel delay is available to manufacturers who are not small manufacturers.

Neutral/Provide Additional Info Comment

Affected document(s): Phase 2 Proposed Rules

Affected pages: 40175

Comment - Manufacturer data submittal

The NPRM discusses ways to streamline the submittal of manufacturer data, avoid unnecessary duplication, and allow timely access to the data by both U.S. EPA and NHTSA, for example by allowing manufacturers to submit compliance data to U.S. EPA's VERIFY database system for use by both U.S. EPA and NHTSA. When CARB staff proposes its California's Phase 2 regulations, we will seek ways to similarly allow CARB staff timely access to Phase 2 compliance data, potentially by requiring all manufacturers who wish to certify in California to submit data to CARB simultaneous with submittal to U.S. EPA and NHTSA. CARB staff looks forward to finding the most efficient way to allow this access.

California Air Resources Board's Comments on Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, Phase 2 Proposed Rules

REFERENCE DOCUMENTS

Attachment 1

Aerodynamic Drag Reduction Technologies Testing for Heavy- Duty Vocational Vehicles—Preliminary Results

National Renewable Energy Laboratory

Aerodynamic Drag Reduction Technologies Testing for Heavy-Duty Vocational Vehicles—Preliminary Results

Adam Ragatz and Matthew Thornton

National Renewable Energy Laboratory

Produced under direction of California Air Resources Board (CARB) by the National Renewable Energy Laboratory (NREL) under Work for Others Agreement number FIA-11-1763 and Task No WW4A.1007.

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Technical Report
NREL/TP-5400-64610
July 2015

Contract No. DE-AC36-08GO28308

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National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

Technical Report
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Contract No. DE-AC36-08GO28308

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Acknowledgments

This work was generously supported by the California Air Resources Board under agreement number 11-600, National Renewable Energy Laboratory contract number FIA-11-1763.

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List of Acronyms

AMT	Automated Manual Transmission
CARB	California Air Resources Board
CI	Confidence Interval
GPS	Global Positioning System
Hz	Hertz
mph	Miles per Hour
NREL	National Renewable Energy Laboratory
STP	Standard Temperature and Pressure

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Project Background and Objective

The National Renewable Energy Laboratory (NREL) under California Air Resources Board (CARB) Agreement Number 11-600, NREL Contract Number FIA-11-1763, has performed a series of coastdown and constant-speed on-highway tests on heavy-duty vocational vehicles with and without aerodynamic improvement devices in order to assess their performance. Various aerodynamic improvement technologies have been evaluated through the U.S. Environmental Protection Agency's SmartWay program and for compliance with the Phase 1 heavy-duty vehicle greenhouse gas standards. The vast majority of these technologies have been devices primarily intended for heavy-duty class 8 tractor-trailers, leaving a data gap regarding the potential benefits of aerodynamic improvement technologies for use on heavy-duty vocational vehicles such as box trucks. It is the intention of this current NREL study to complement previous work by the U.S. Environmental Protection Agency and explore the potential benefits of the most common aerodynamic improvement devices on box trucks using both coastdown and on-road steady-state techniques. The devices tested are not intended to include all aerodynamic devices available for vocational vehicles, but rather they are a sampling of the most common types of technologies which are currently commercially available; nor were testing funds sufficient to test all possible designs of vocational vehicles, which are extremely diverse. Instead, the testing utilized two common vocational vehicle designs, a Class 4 and a Class 6 box truck, which often operate at duty cycles with sufficient high-speed operation where aerodynamic devices could provide significant fuel savings. The overall intent of the NREL work is to estimate the expected benefits of several common types of aerodynamic devices on select vocational vehicles, as accurately as possible given limited test time and budget. All work for this project was conducted by NREL staff engineers and technicians.

Project Summary

This study focused on two accepted methods for quantifying the benefit of aerodynamic improvement technologies on vocational vehicles; the coastdown technique, and on-road constant speed fuel economy measurements. Both techniques have their advantages. Coastdowns are conducted over a wide range in speed and allow the rolling resistance and aerodynamic components of road load force to be separated. This in turn allows for the change in road load and fuel economy to be estimated at any speed, as well as over transient cycles. The on-road fuel economy measurements only supply one lumped result, applicable at the specific test speed, but are a direct measurement of fuel usage and are therefore used in this study as a second check to the observed coastdown results.

Vehicles

Test vehicles that met our specifications, shown in Table 1 below, were chosen and acquired from a local rental company for use for this project. Coastdown tests required one vehicle at a time whereas on-road testing required two vehicles, one for test and one for control, with matching specifications for each test. The two types of vehicles selected for this study were class 6 and class 4 box trucks. Both were equipped with 2010 or newer diesel engines with selective catalytic reduction and diesel exhaust fluid dosing for representative baseline fuel economy.

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Table 1. Vehicle Specifications

	Class 6 Box Truck	Class 4 Box Truck
Vehicle Descriptor		
Cab Style	Conventional	Low Cab Forward
Make / Model	Freightliner M2	Isuzu NPR HD
GVWR	26,000 lbs. (Class 6)	14,500 lbs. (Class 4)
Nominal Box Length	26 feet	16 feet
Full Vehicle Length	37 feet	23 feet
Full Vehicle Height	12 feet 10 inches	11 feet
Max Width	8 feet 6 inches	8 feet 6 inch
Minimum Ground Clearance	10 inches	5 inches
Tires	295/75R22.5	215/85R16E
Engine	Cummins ISB 6.7L (240HP)	Isuzu 5.2L Turbo Diesel (215HP)
Engine Model Year	2012	2012
Engine Family	CCEXH0408BAH	CSZXH05.23FA
Transmission	Eaton Fuller UltraShift AMT	Aisin 6-speed Automatic

Additional dimensions are shown in Appendix A.

The two types of vehicles selected for this study differ considerably in weight ratings and dimensions. However, the same "box truck" form-factor makes both of these vehicles suitable candidates for similar types of aerodynamic improvement devices. For instance, as long as the box sits above the rear wheels without a wheel well, there will likely be a spot for chassis skirts, and as long as the box extends above the front cab, there will likely be an opportunity for a front fairing. These devices may vary in size and aerodynamic benefit for different platforms, but the benefit likely has a closer tie to vehicle shape and body style rather than a specific weight class or dimension.

Aerodynamic Devices

The aerodynamic improvement devices tested in this study were not intended to be all inclusive, but rather they are a sampling of some technologies that are currently commercially available. These included chassis skirts, front and rear fairings, and wheel covers. Some technologies, such as the rear fairing, would require some redesign for the vocational market to work with common door designs and ease of actuation during frequent stops. It is the intention of this study to benchmark the potential for these devices with the understanding that further refinement may be required for specific vehicles and vocations. Table 2 shows the four aerodynamic improvement devices that were tested, the device weight, and which type of vehicle it was used with for testing.

Table 2. Aerodynamic Devices, Weight, and Corresponding Test Vehicle

Vehicle	Chassis Skirts	Front Fairing	Rear Fairing	Wheel Covers (2)
Class 6 Box Truck	X	X		X
Class 4 Box Truck			X	
Total Device Weight (lbs.)	101	34	109	5

Photos of the equipped test vehicles are shown in Figure 1. The photos on the left show the class 6 box truck with the following aerodynamic improvement devices: chassis skirts, front fairing, and wheel covers. The photos on the right show the class 4 box truck with the rear fairing. The rear fairing used during this testing was adapted from a tractor-trailer tail and plywood used for mounting is visible in the photograph. This material was not included in the device weight because it is assumed it would not be necessary if the device were designed for the medium-duty vocational market.

Figure 1. Vehicles with Aerodynamic Devices Installed. Class 6 (left), Class 4 (right), Coastdown Vehicles (top), On-Road Test and Control Vehicles (bottom)

Coastdown Testing

The procedures used for coastdown testing followed the general guidelines outlined in SAE J1263 “Road Load Measurement and Dynamometer Simulation Using Coastdown Techniques” and SAE J2263 “Road Load Measurement Using Onboard Anemometry and Coastdown Techniques” and used calculations from 40 Code of Federal Regulations (CFR), Part §1066.310 where applicable. Coastdown tests were performed by accelerating the vehicle to the desired speed, then shifting the vehicle to neutral, and allowing it to naturally coast down in speed. Test vehicles were equipped with a Garmin 18x-5Hz global positioning system (GPS) to record velocity, time, and position. Vehicles were also equipped with a controller area network (CAN) data recorder to capture the transmission neutral signal, along with several vehicle and engine parameters, for automated data processing. The coastdown test matrix is shown in Table 3.

Table 3. Coastdown Test Matrix

Vehicle	Wheel Covers (2)	Front Fairing	Chassis Skirts	Front Fairing + Chassis Skirts	Front Fairing + Skirts + Wheel Covers	Rear Fairing
Class 6 Box Truck	X	X	X	X	X	
Class 4 Box Truck						X

Testing was performed on a private stretch of road that runs parallel to the east runway at Colorado Front Range Airport. Figure 2 shows an aerial picture of the private road with the test section (~1.2 miles) highlighted in green, along with a picture from in the middle of the track looking north.

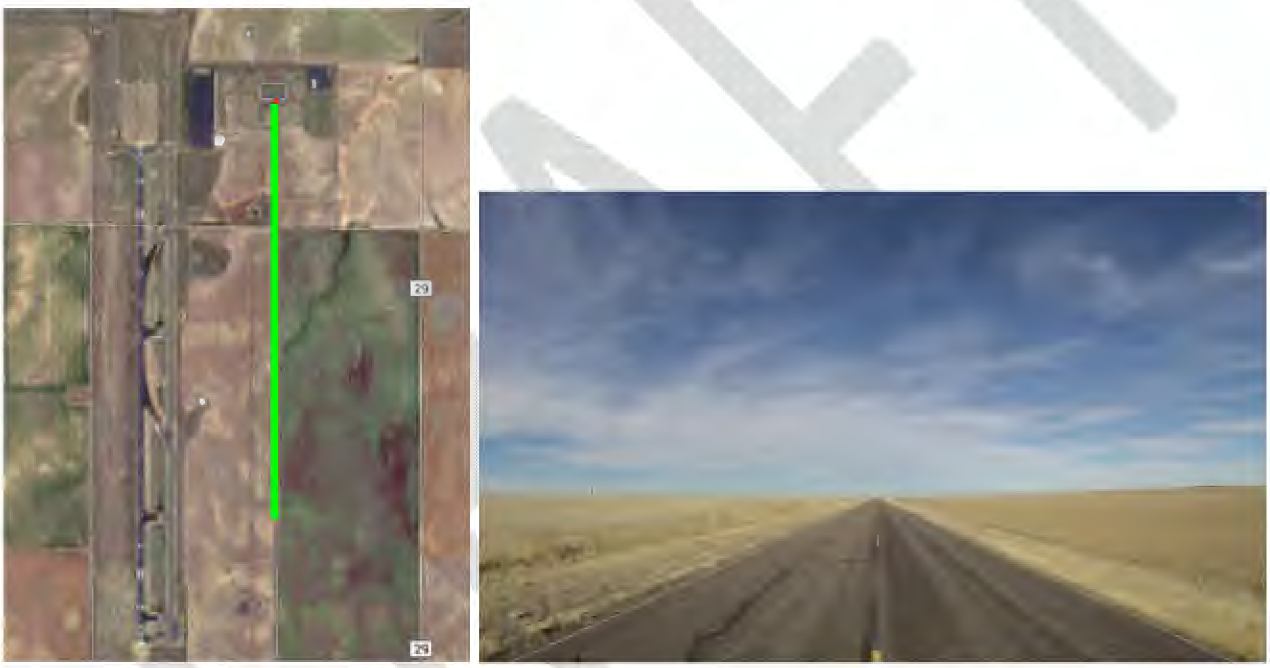

Figure 2. Coastdown Test Track

The track has a very slight grade (Figure 3), which is hard to perceive with the naked eye but has a clear effect on vehicle behavior, and the data needed to be corrected for grade during post processing. Processing code either leverages a manual land survey conducted by NREL staff or United States Geological Survey aerial light detection and ranging elevation data for correction.

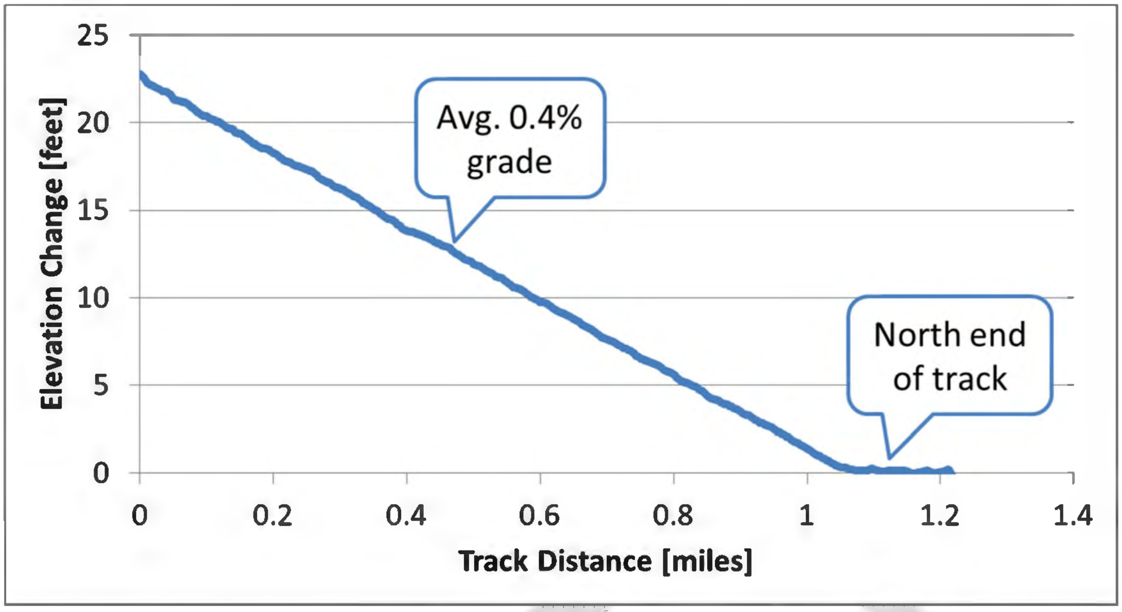

Figure 3. Coastdown Track Grade

A roadside weather station, located just east of the coastdown test track, was used to collect 1-Hz wind speed, direction, temperature, pressure, and humidity data and was used to make corrections for weather conditions per the coastdown procedure (Figure 4). The Airmar 150WX weather station also has a built-in GPS and compass, which are used to report wind direction relative to magnetic and true north regardless of sensor orientation. GPS time is used to stitch vehicle telemetry and weather results together. The weather station is mounted directly on a tripod that was adjusted to approximately half the vehicle height.

Figure 4. Roadside Weather Station, Airmar 150WX

Coastdown tests are performed in both directions; due to the track's slight grade, the northbound and southbound profiles differ. Figure 5 shows a sample of raw GPS data for 12 runs, six in each direction.

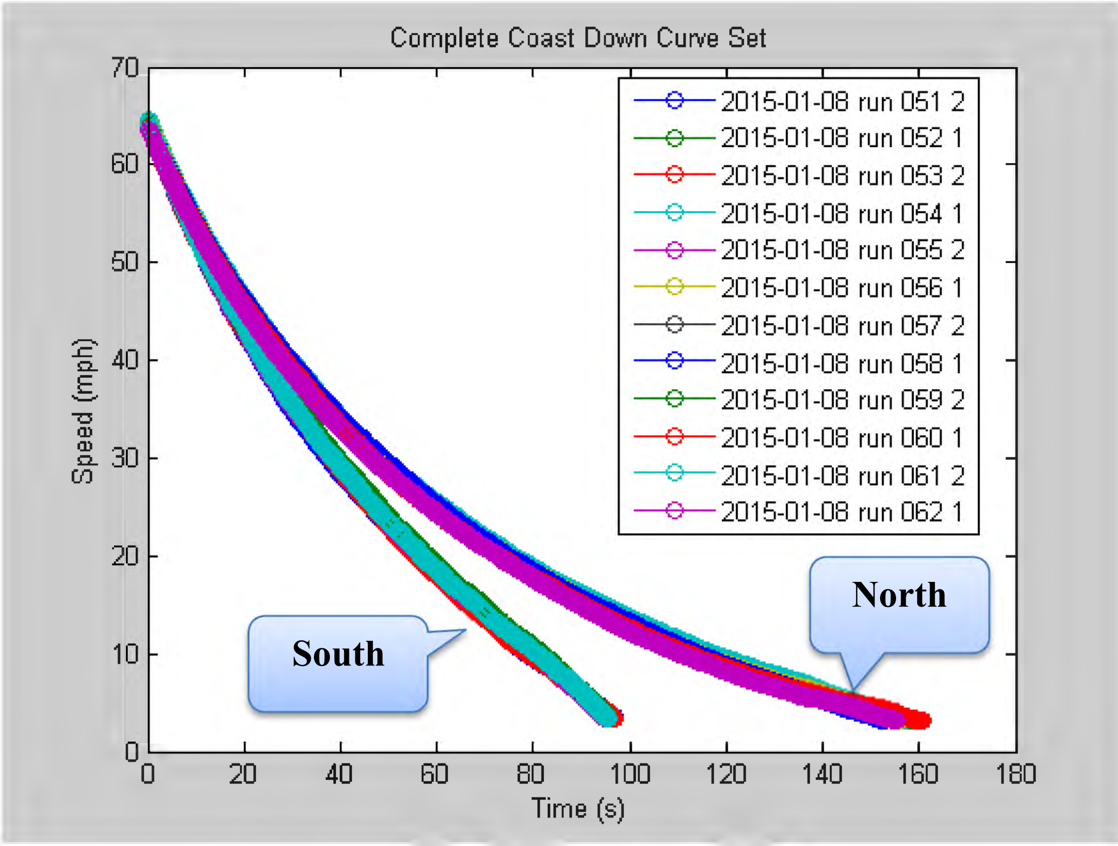

Figure 5. Raw GPS Data from 12 Coastdown Runs (six in each direction)

The following road load equation is used to describe the behavior of the vehicle:

$$F - mgx\frac{\Delta hx}{\Delta xx} = x\ mgx\quad {}^{1}/_{2}\,\rho A C_d V^{2x} \tag{1}$$

Where F is the force due to road load, m is the vehicle mass, g is the gravitational constant, $\frac{\Delta hx}{\Delta xx}$ is the road grade, μ is the coefficient of rolling resistance, ρ is the density of air, A is the cross-sectional area, C_d is the drag coefficient, and V is the velocity.

At each time step interval the total force on the vehicle can be calculated using Newton's second law of motion. Where the external forces F on an object are equal to the mass m multiplied by the acceleration a of the object:

$$Fx = xmax \tag{2}$$

$$F_i = xm_{ex}\frac{V_i - V_{i-1x}}{\Delta tx} \tag{3}$$

The effective mass (m_e) was calculated for the class 6 box truck by adding 56.7 kilograms (kg) to the measured vehicle mass for each tire making road contact. For the class 4 box truck, the ratio of rotating mass to measured vehicle mass was kept the same. After correcting for elevation change using the road grade survey, each interval point is plotted and a least-squares regression is used to determine the coefficients, as shown in Figure 6.

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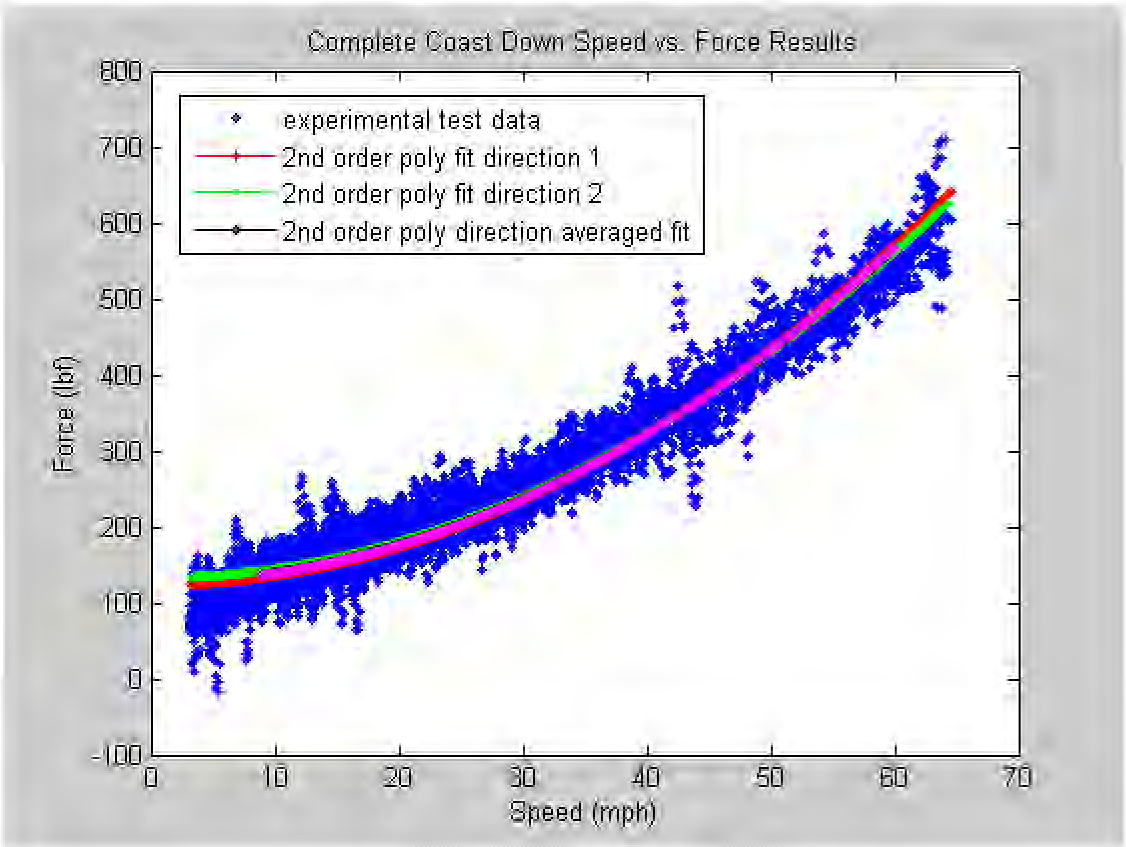


Figure 6. Example of Road Load Force vs. Vehicle Speed and Resulting Fit Curve

The least-squares regression follows the general form:

$$f(x)x=x\ Cx^{2x}\quad Bx\quad Ax \tag{4}$$

In the polynomial fit the "B" term is fixed at zero and coefficients are assigned as follows:

$$Ax=x\ \ mgx \tag{5}$$

$$Bx=x\ 0x \tag{6}$$

Switching nomenclature to match CFR§1066.310:

$$Cx=xDx=x^{1}/_{2}\ \rho AC_{dx} \tag{7}$$

The "D" term can be corrected for standard conditions as follows:

$$D_{adjx}=xDx\frac{Tx\ 98.21x}{293x\ \ P} \tag{8}$$

On-Road Testing

The procedure used for on-highway testing followed the general guidelines outlined in SAE J1526 "Joint TMC/SAE Fuel Consumption In-Service Test Procedure Type III." On-road testing was conducted on a stretch of I-70 east of Denver, Colorado (Figure 7). The test and control vehicles entered the highway 30 – 60 seconds apart in order to experience the same traffic conditions, but not interfere with each other's aerodynamics. Vehicles were accelerated until they reached the speed limiter at which point the cruise control was set and the fuel tank selector valves were switched from the main tanks to the test weigh tanks (Figure 8). Fuel consumption was accurately measured using a scale with 5-gram resolution, before and after each test run.

Figure 7. On-Road Test Section

Figure 8. Secondary Fuel Weigh Tank and Scale

The SAE J1321 "Data Analysis – Fuel Economy Improvement Testing" utility was used to calculate the nominal fuel economy improvement and corresponding confidence interval (CI) from raw fuel us data.

Results and Discussion

Coastdown road load force coefficients are shown below in Table 4 and Table 5. Coefficient A_m is a constant, independent of speed and represents the rolling resistance component of road load force. Coefficient D_{adj} is the aerodynamic component of road load force which depends on velocity squared. D_{adj} has been adjusted to standard temperature and pressure (STP). These two coefficients can be used to solve for theoretical road load force at STP, at any speed, and are how the "Road Load @ XX mph" is derived. Finally, μ and C_dA are derived by dividing out the other constants. Since the headwind / tailwind correction is derived from a roadside weather station, the vehicle and weather station do not always experience the same conditions at the exact same time. Under steady weather conditions corrected results should provide a better estimate, but under changing conditions the wind correction has the potential to introduce additional error. For this reason results are presented both with and without wind correction for comparison. The first table (Table 4) uses ground speed as the velocity component, whereas the second table (Table 5) uses ground speed plus headwind, or ground speed minus tailwind, as the velocity component. Each colored grouping of tests was completed on the same day.

Table 4. Coastdown Results without Wind Correction

Coefficients	Includes Correction for Road Grade and Adjustment to Standard Temperature and Pressure							
Test Vehicle	Aerodynamic Device(s)	A_m [N]	D_{adj} [N/mps^2]	μ	C_dA [m^2]	Road Load @ 45 mph [N]	Road Load @ 55 mph [N]	Road Load @ 68 mph [N]
Class 6 Box Truck	Baseline #1	579 ± 41	3.13 ± 0.16	0.0076 ± 0.0005	5.35 ± 0.27	1846 ± 46	2473 ± 61	3473 ± 86
Class 6 Box Truck	Wheel Covers	582 ± 49	3.17 ± 0.12	0.0076 ± 0.0006	5.42 ± 0.21	1865 ± 57	2500 ± 76	3512 ± 107
Class 6 Box Truck	Baseline #2	599 ± 61	3.41 ± 0.16	0.0079 ± 0.0008	5.83 ± 0.27	1980 ± 59	2663 ± 79	3753 ± 111
Class 6 Box Truck	Front Fairing	611 ± 35	3.11 ± 0.12	0.0081 ± 0.0005	5.32 ± 0.21	1870 ± 52	2492 ± 69	3485 ± 97
Class 6 Box Truck	Front Fairing + Skirts	558 ± 45	3.03 ± 0.11	0.0073 ± 0.0006	5.18 ± 0.19	1785 ± 42	2392 ± 56	3360 ± 79
Class 6 Box Truck	Baseline #3	620 ± 134	3.32 ± 0.34	0.0083 ± 0.0018	5.67 ± 0.57	1962 ± 67	2625 ± 89	3685 ± 125
Class 6 Box Truck	Chassis Skirts	564 ± 116	3.12 ± 0.21	0.0074 ± 0.0015	5.33 ± 0.35	1826 ± 132	2449 ± 177	3445 ± 249
Class 6 Box Truck	Front Fairing + Skirts + Covers	565 ± 99	3.04 ± 0.18	0.0074 ± 0.0013	5.2 ± 0.3	1796 ± 67	2403 ± 90	3375 ± 126
Class 4 Box Truck	Baseline #4	564 ± 15	3.09 ± 0.07	0.0128 ± 0.0003	5.29 ± 0.12	1817 ± 33	2436 ± 44	3424 ± 62
Class 4 Box Truck	Rear Fairing	555 ± 30	2.95 ± 0.11	0.0125 ± 0.0007	5.05 ± 0.2	1751 ± 67	2342 ± 89	3285 ± 125

Error estimates shown are 95% confidence intervals

Table 5. Coastdown Results with Wind Correction

Coefficients	Includes Correction for Road Grade, Headwind/Tailwind and Adjustment to Standard Temperature and Pressure Conditions							
Test Vehicle	Aerodynamic Device(s)	A_m [N]	D_{adj} [N/mps^2]	μ	C_dA [m^2]	Road Load @ 45 mph [N]	Road Load @ 55 mph [N]	Road Load @ 68 mph [N]
Class 6 Box Truck	Baseline #1	577 ± 39	3.14 ± 0.2	0.0075 ± 0.0005	5.37 ± 0.34	1847 ± 67	2475 ± 89	3477 ± 125
Class 6 Box Truck	Wheel Covers	573 ± 70	3.12 ± 0.17	0.0075 ± 0.0009	5.34 ± 0.29	1837 ± 48	2461 ± 64	3458 ± 90
Class 6 Box Truck	Baseline #2	607 ± 54	3.37 ± 0.17	0.008 ± 0.0007	5.76 ± 0.29	1971 ± 50	2645 ± 68	3721 ± 95
Class 6 Box Truck	Front Fairing	633 ± 54	3.06 ± 0.14	0.0084 ± 0.0007	5.24 ± 0.24	1873 ± 63	2486 ± 84	3464 ± 117
Class 6 Box Truck	Front Fairing + Skirts	546 ± 49	3.02 ± 0.15	0.0071 ± 0.0006	5.16 ± 0.26	1768 ± 51	2371 ± 69	3335 ± 97
Class 6 Box Truck	Baseline #3	601 ± 165	3.3 ± 0.36	0.0081 ± 0.0022	5.65 ± 0.61	1938 ± 67	2598 ± 90	3653 ± 126
Class 6 Box Truck	Chassis Skirts	537 ± 91	3.17 ± 0.21	0.007 ± 0.0012	5.42 ± 0.36	1819 ± 47	2453 ± 63	3465 ± 89
Class 6 Box Truck	Front Fairing + Skirts + Covers	557 ± 91	2.97 ± 0.25	0.0073 ± 0.0012	5.08 ± 0.42	1760 ± 62	2353 ± 84	3303 ± 117
Class 4 Box Truck	Baseline #4	560 ± 18	3.09 ± 0.12	0.0127 ± 0.0004	5.28 ± 0.2	1810 ± 52	2428 ± 70	3414 ± 99
Class 4 Box Truck	Rear Fairing	576 ± 20	2.93 ± 0.19	0.013 ± 0.0005	5.01 ± 0.32	1761 ± 85	2347 ± 113	3283 ± 158

Error estimates shown are 95% confidence intervals

Measured aerodynamic improvement for a specific device will depend on weather conditions. Some of these elements can be corrected for, as shown in Equation 8 and headwind/tailwind aerodynamic velocity correction in Table 5. However, other components such as crosswind and yaw angle are not accounted for in these corrections and may have a significant nonlinear effect which is difficult to correct for without additional data. For example, chassis skirts will demonstrate a higher advantage under high crosswind conditions. These advantages are real, but the test conditions need to be compared with average weather conditions where the device is intended to be deployed in order to understand how applicable the results will be. For this reason, average weather conditions, including wind vector components, for each test condition are shown in Table 6.

Table 6. Coastdown Average Weather Conditions

		Average Weather Conditions					
Test Vehicle	Aerodynamic Device(s)	Wind Speed [mph]	Wind N [mph]	Wind E [mph]	Air Temp [F]	Atm P [Bar]	Dew Point [F]
Class 6 Box Truck	Baseline #1	3.4	0.6	3.2	53.5	0.828	15.7
Class 6 Box Truck	Wheel Covers	3.5	1.9	1.1	56.0	0.828	13.7
Class 6 Box Truck	Baseline #2	3.8	0.6	-0.5	58.0	0.832	13.5
Class 6 Box Truck	Front Fairing	3.3	-1.0	-2.7	59.4	0.832	14.7
Class 6 Box Truck	Front Fairing + Skirts	3.4	1.5	-2.5	64.1	0.831	15.5
Class 6 Box Truck	Baseline #3	9.2	-1.0	8.8	79.1	0.836	47.3
Class 6 Box Truck	Chassis Skirts	6.7	4.5	4.0	72.3	0.836	45.6
Class 6 Box Truck	Front Fairing + Skirts + Covers	5.5	2.5	4.6	76.5	0.836	46.6
Class 4 City Van	Baseline #4	14.1	0.0	13.9	43.0	0.834	20.3
Class 4 City Van	Rear Fairing	13.7	-3.4	13.1	44.1	0.833	21.2

Using the data from the coefficients table, the observed percent change was determined by comparing the aerodynamic condition with the applicable baseline condition that day. Observed percent change for rolling resistance and aerodynamic coefficients, along with total road load are shown with and without aerodynamic velocity wind correction in Table 7 and Table 8 respectively and displayed graphically in Figures 9 and 10 respectively. A positive change indicates a reduction in drag. Similarly a negative change represents an increase in drag. Changes in road load force should have an impact on vehicle fuel economy. The relative magnitude (i.e. percent change in fuel economy for a given percent change in road load force) is discussed further in the simulation section of this report. Estimated fuel economy improvement during transient conditions over standard drive cycles are also explored further in the simulation results section.

Table 7. Observed Change without Wind Correction

Observed Change - Without Wind Correction							
Test Vehicle	Aerodynamic Device(s)	μ	C_dA	ΔC_dA [m^2]	Road Load @ 45 mph	Road Load @ 55 mph	Road Load @ 68 mph
Class 6 Box Truck	Wheel Covers	-0.5% ± 3.5%	-1.3% ± 2%	0.07 ± 0.11	-1% ± 1.2%	-1.1% ± 1.2%	-1.1% ± 1.2%
Class 6 Box Truck	Front Fairing	-1.8% ± 3.3%	8.9% ± 1.7%	-0.52 ± -0.1	5.6% ± 1.1%	6.4% ± 1.1%	7.1% ± 1.1%
Class 6 Box Truck	Chassis Skirts	10.8% ± 10.2%	6% ± 4.2%	-0.65 ± -0.45	7% ± 2.7%	6.7% ± 2.7%	6.5% ± 2.7%
Class 6 Box Truck	Front Fairing + Chassis Skirts	8.7% ± 3.8%	11.2% ± 1.7%	-0.34 ± -0.05	9.9% ± 1.1%	10.2% ± 1.1%	10.5% ± 1.1%
Class 6 Box Truck	Front Fairing + Skirts + Covers	10.8% ± 9.4%	8.3% ± 3.9%	-0.47 ± -0.22	8.5% ± 1.7%	8.4% ± 1.7%	8.4% ± 1.7%
Class 4 Box Truck	Rear Fairing	1.6% ± 1.6%	4.5% ± 1.2%	-0.24 ± -0.06	3.6% ± 1.1%	3.9% ± 1.1%	4.1% ± 1.1%

Error estimates shown are 95% confidence intervals

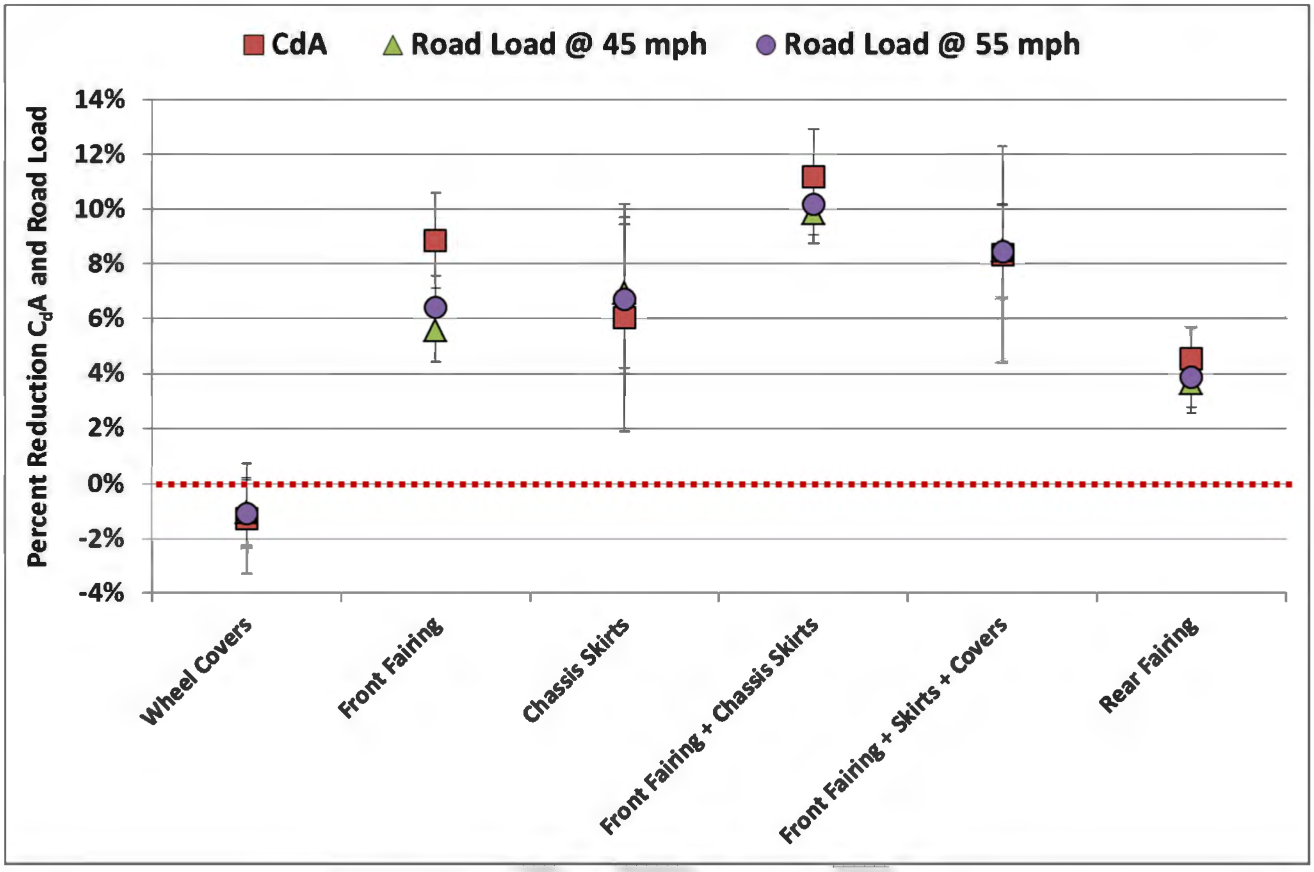


Figure 9. Observed Change without Wind Correction, Error Estimates Shown are 95% Confidence Intervals

Table 8. Observed Change with Wind Correction

Observed Change - With Wind Correction							
Test Vehicle	**Aerodynamic Device(s)**	**μ**	**C_dA**	**ΔC_dA [m^2]**	**Road Load @ 45 mph**	**Road Load @ 55 mph**	**Road Load @ 68 mph**
Class 6 Box Truck	Wheel Covers	0.6% ± 4.4%	0.5% ± 2.6%	-0.03 ± -0.14	0.6% ± 1.4%	0.6% ± 1.4%	0.6% ± 1.4%
Class 6 Box Truck	Front Fairing	-4.1% ± 3.5%	9.1% ± 1.9%	-0.53 ± -0.11	5% ± 1.2%	6% ± 1.2%	6.9% ± 1.2%
Class 6 Box Truck	Chassis Skirts	12.5% ± 11.1%	4.1% ± 4.3%	-0.6 ± -0.64	6.1% ± 1.5%	5.6% ± 1.5%	5.2% ± 1.5%
Class 6 Box Truck	Front Fairing + Chassis Skirts	11.8% ± 3.7%	10.5% ± 2%	-0.23 ± -0.04	10.3% ± 1.1%	10.4% ± 1.1%	10.4% ± 1.1%
Class 6 Box Truck	Front Fairing + Skirts + Covers	9.4% ± 10.8%	10% ± 4.6%	-0.57 ± -0.26	9.2% ± 1.7%	9.4% ± 1.7%	9.6% ± 1.7%
Class 4 Box Truck	Rear Fairing	-2.8% ± 1.2%	5.2% ± 1.9%	-0.27 ± -0.1	2.7% ± 1.5%	3.3% ± 1.5%	3.8% ± 1.5%

Error estimates shown are 95% confidence intervals

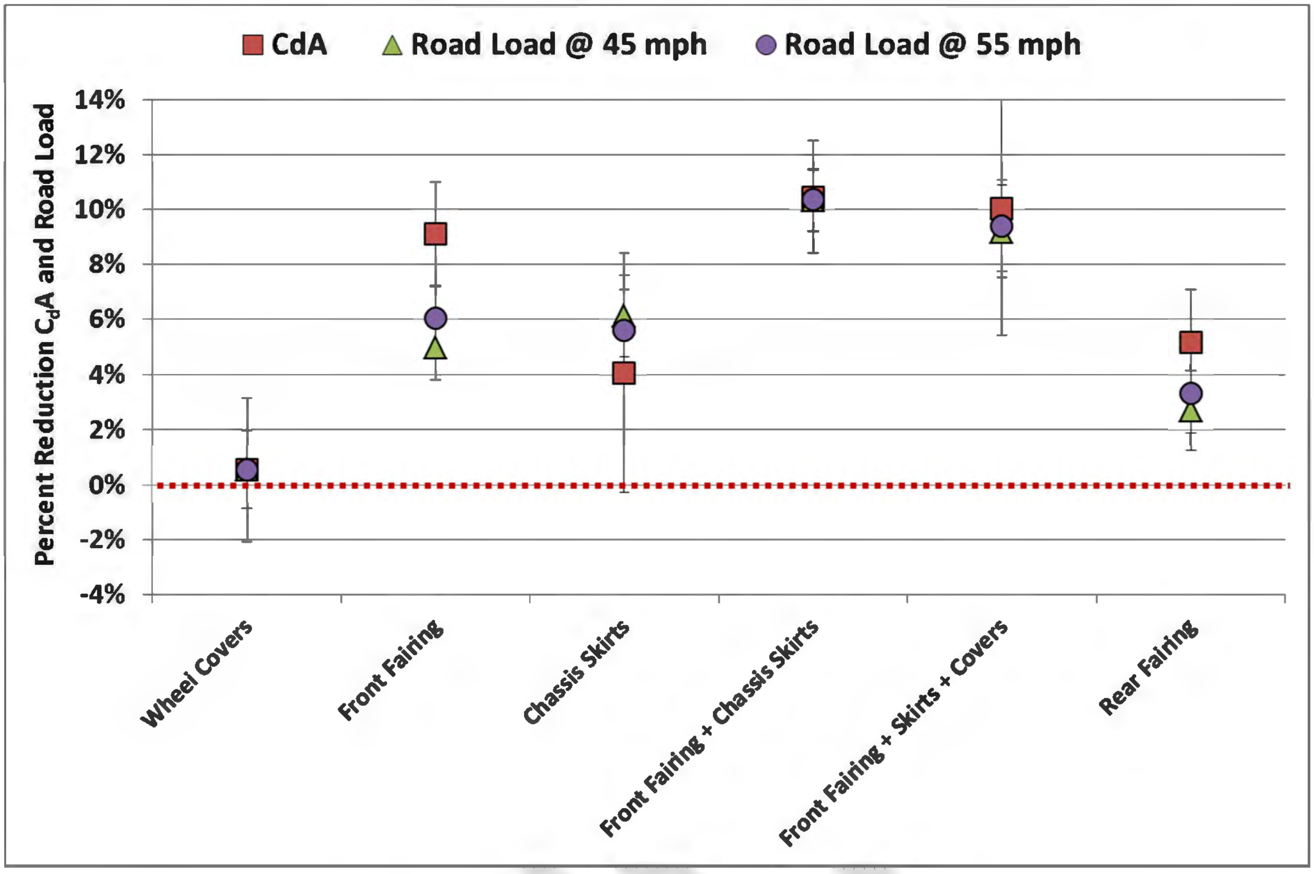


Figure 10. Observed Change with Wind Correction, Error Estimates Shown are 95% Confidence Intervals

Both with and without wind correction, there was no statistically significant difference when adding the wheel covers. All other test scenarios showed a statistically significant change in total road load force in the 45–68 mile per hour range. Both the front fairing and the chassis skirts show improvements on the order of 6% individually for total road load force. This was the highest of any individual components. When both devices are installed at the same time the improvement increases to 8%–10%, greater than either individual component, but less than the sum of the two. The relationship between these results and modeled fuel economy improvement are explored in the simulation section.

On-road testing was conducted to verify these theoretical fuel economy projections under real-world highway driving conditions. Table 9 shows results for individual testing days, all of which included a minimum of four test and four baseline runs. Combined, data such as "Skirts" is a combination of all test days (1–3). This is also shown graphically in Figure 11.

Table 9. On-Road Fuel Economy Test Results[1]

Test Vehicle	Aerodynamic Device(s)	Fuel Saved		FE Improvement		Avg Temp	Avg Wind
		Nominal	CI	Nominal	CI	F	mph
Class 6 Box Truck	Wheel Covers	0.30%	2.00%	0.30%	2.01%	66.6	7.7
Class 6 Box Truck	Front Fairing 1	3.12%	3.16%	3.23%	3.26%	59.7	10.7
Class 6 Box Truck	Front Fairing 2	4.19%	3.02%	4.37%	3.15%	53.7	6.6
Class 6 Box Truck	Front Fairing	3.59%	1.79%	3.72%	1.86%		
Class 6 Box Truck	Chassis Skirts 1	8.34%	1.78%	9.09%	1.94%	60.5	21.9
Class 6 Box Truck	Chassis Skirts 2	6.07%	3.48%	6.47%	3.70%	57.2	17.4
Class 6 Box Truck	Chassis Skirts 3	2.41%	1.40%	2.47%	1.44%	66.6	7.7
Class 6 Box Truck	Chassis Skirts	5.40%	1.64%	5.71%	1.73%		
Class 6 Box Truck	Covers+Fairing+Skirts	3.23%	2.61%	3.34%	2.69%	50.9	8.6
Class 6 Box Truck	Front Fairing + Skirts	7.66%	1.63%	8.30%	1.77%	63.1	6.6
Class 4 Box Truck	Rear Fairing	3.31%	3.26%	3.43%	3.37%		

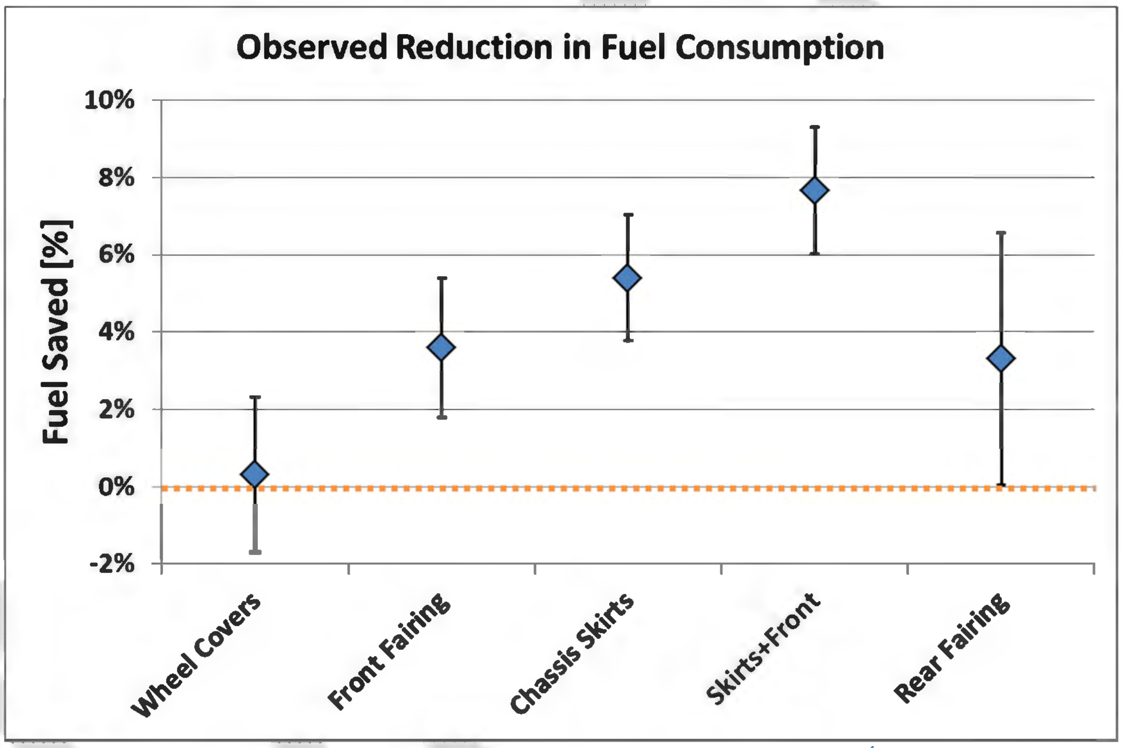


Figure 11. On-Road Fuel Consumption Test Results[1]

Wheel covers again showed no statistically significant difference from the baseline, for on-road testing as well. The measured fuel savings from front fairing, chassis skirts, a combination of both, and rear fairing, all fell in line with expectations from the theoretical road load predictions based on coastdown results. The "Front Fairing + Skirts + Covers" condition from Table 9 is suspected to be erroneous due to changing environmental conditions during testing; however, there was insufficient time to repeat this condition within our established testing window and it has been excluded from Figure 11. Chassis skirts had the most test repeats capturing a broad range of wind conditions ranging from a slight breeze to

[1] Error estimates shown are 95% confidence intervals

"Fuel Saved" was calculated as *((baseline fuel used) – (test case fuel used)) / (baseline fuel used)*

"Fuel Economy" was calculated as *((distance traveled) / (fuel used))*

"Fuel Consumption" was calculated as *((fuel used) / (distance traveled))*

"Improvement" was calculated as *((test case) – (baseline)) / (baseline)* strong and constant crosswinds. Figure 12 shows this range in fuel savings that can be realized under these different scenarios. Figure 13 shows California average wind conditions by month and hour of the day (top) and a combined histogram for wind speed year-round from 8 a.m. to 6 p.m. Wind data were supplied by the National Oceanic and Atmospheric Administration (NOAA) climate norms database and are an average of normal conditions at the Bakersfield, Los Angeles, San Diego, Sacramento, San Francisco, and Stockton airport weather stations. Looking at the California wind data alongside the chassis skirt wind dependence shows that fuel savings are going to vary throughout the day and seasonally.

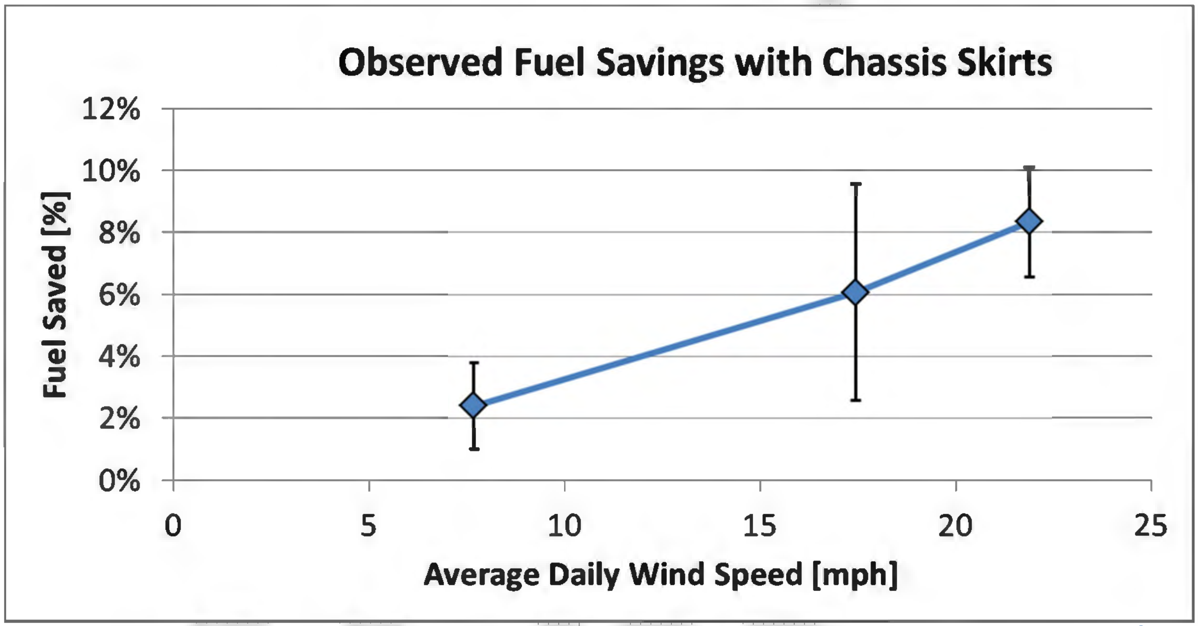


Figure 12. On-Road Fuel Savings from Chassis Skirts under Various Wind Conditions[2]

[2] Error estimates shown are 95% confidence intervals
"Fuel Saved" was calculated as *((baseline fuel used) – (test case fuel used)) / (baseline fuel used)*

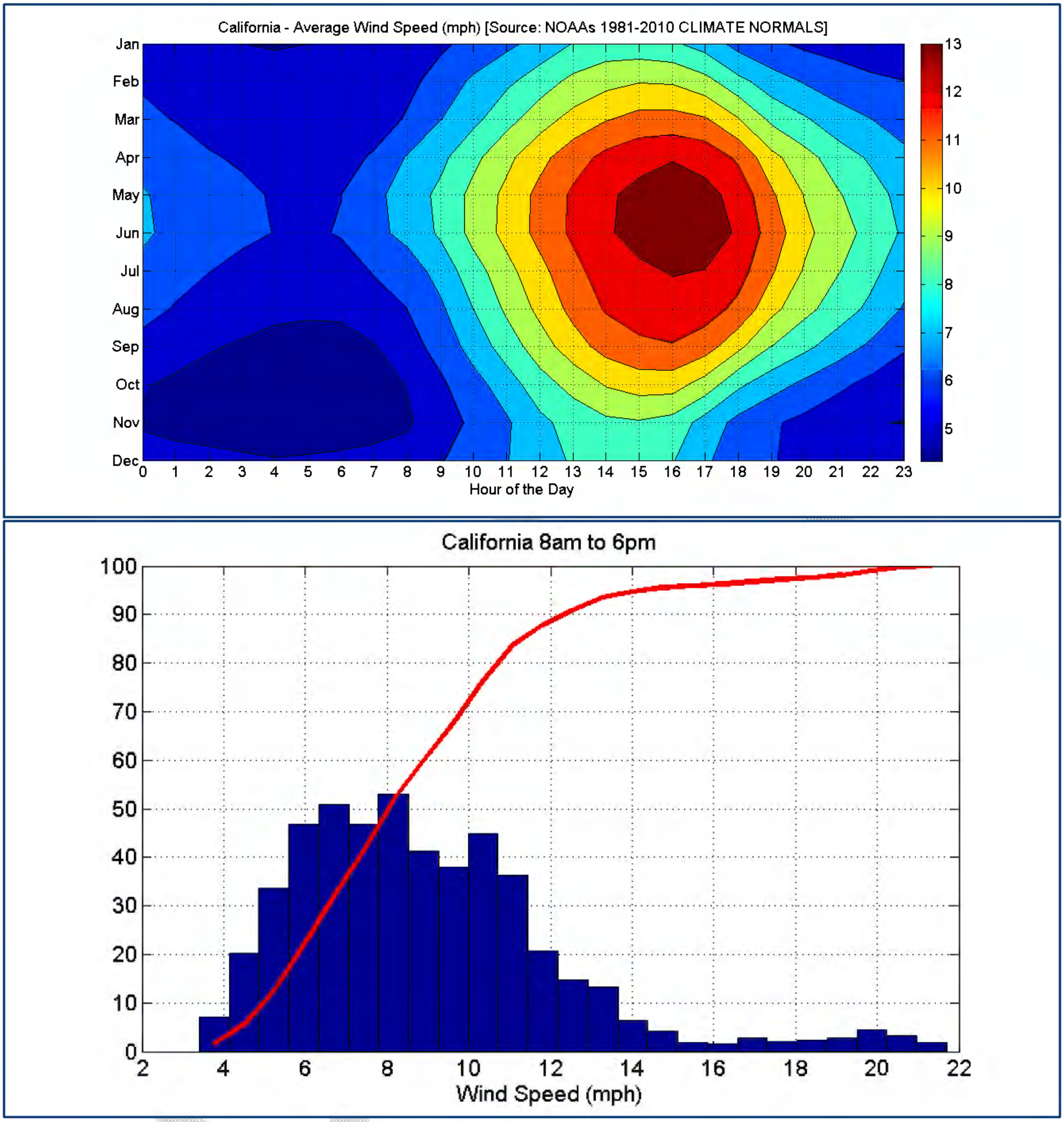


Figure 13. California Average Wind Speed

Simulation Results

For a given vehicle the simulated road load force is a function of both vehicle speed and mass. Equation 1, shown here again for reference, describes this behavior.

$$F - mgx\frac{\Delta hx}{\Delta xx} = x \;\; mgx \quad {}^{1}/_{2}\,\rho A C_d V^{2x} \qquad (1)$$

For the purposes of illustrating the dramatic effect weight can have on total road load force, a series of example coefficients have been selected. The following constants have been fixed; $\mu = 0.0062$, $g = 9.81$ m/s^2, $\rho = 1.17$ kg/m^3, and $C_d = 0.5$. The road load components from three theoretical vehicles are shown below in Figure 14. The cross-sectional area and empty/full weights selected for the class 4 and 6 vehicles are identical to the test vehicles in this study. The cross-sectional area and empty/full weights for the class 8 vehicle were selected to match that of a typical on-road tractor trailer.

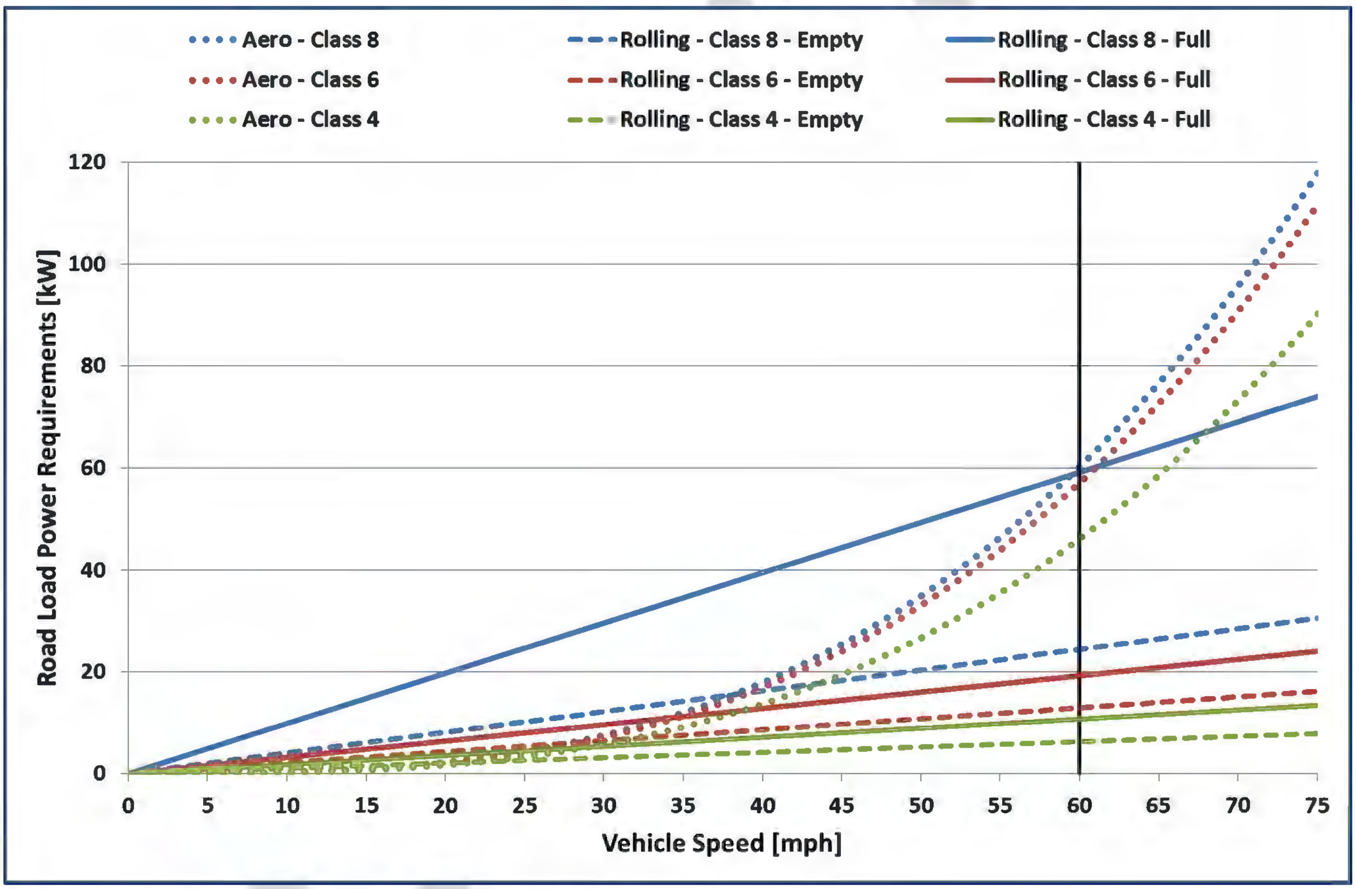


Figure 14. Theoretical Road Load Components

For a fully loaded class 8 tractor trailer traveling at 60 mph, the rolling resistance and aerodynamic resistance are nearly equal. This means a modification to the aerodynamic drag coefficient of 1% would have approximately 0.5% change to the total road load force since the components are equal and rolling resistance is unaffected. However, for a lightly loaded tractor trailer the aerodynamic component plays a greater role. For the class 6 box truck, the aerodynamics are very similar, the same width and only 8" shorter than the tractor trailer (~5% difference), but the weight is substantially different, approximately one third when both are full. Therefore, aerodynamics become even more important if those vehicles are expected to see a significant amount of highway operation. This is illustrated in Figure 15.

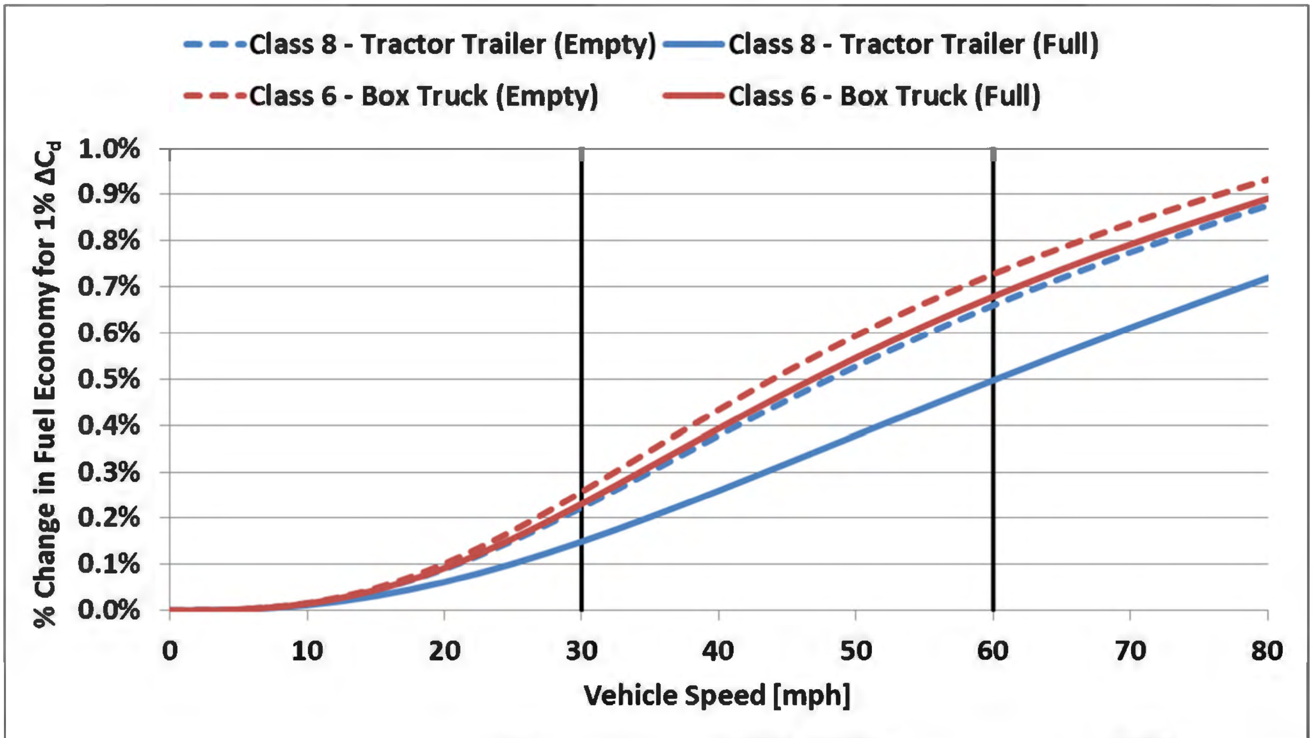
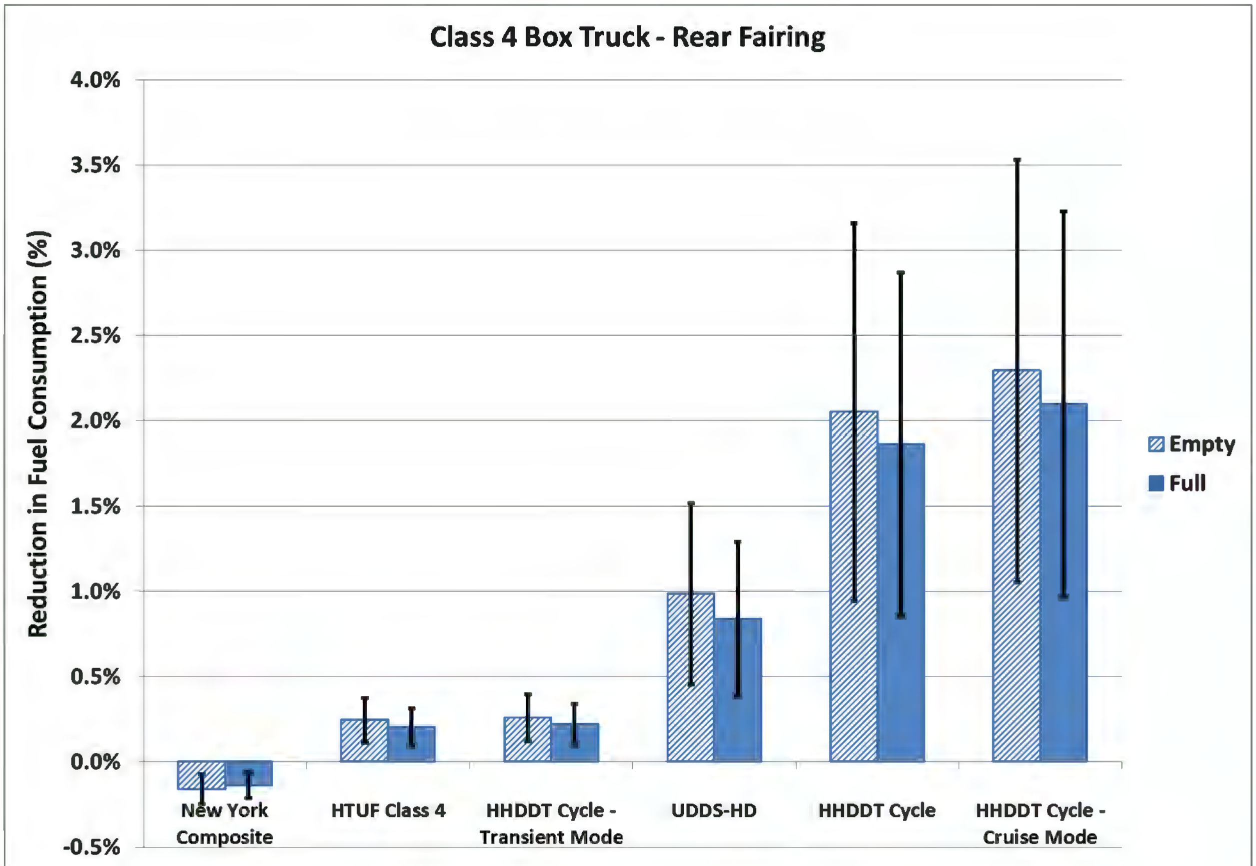


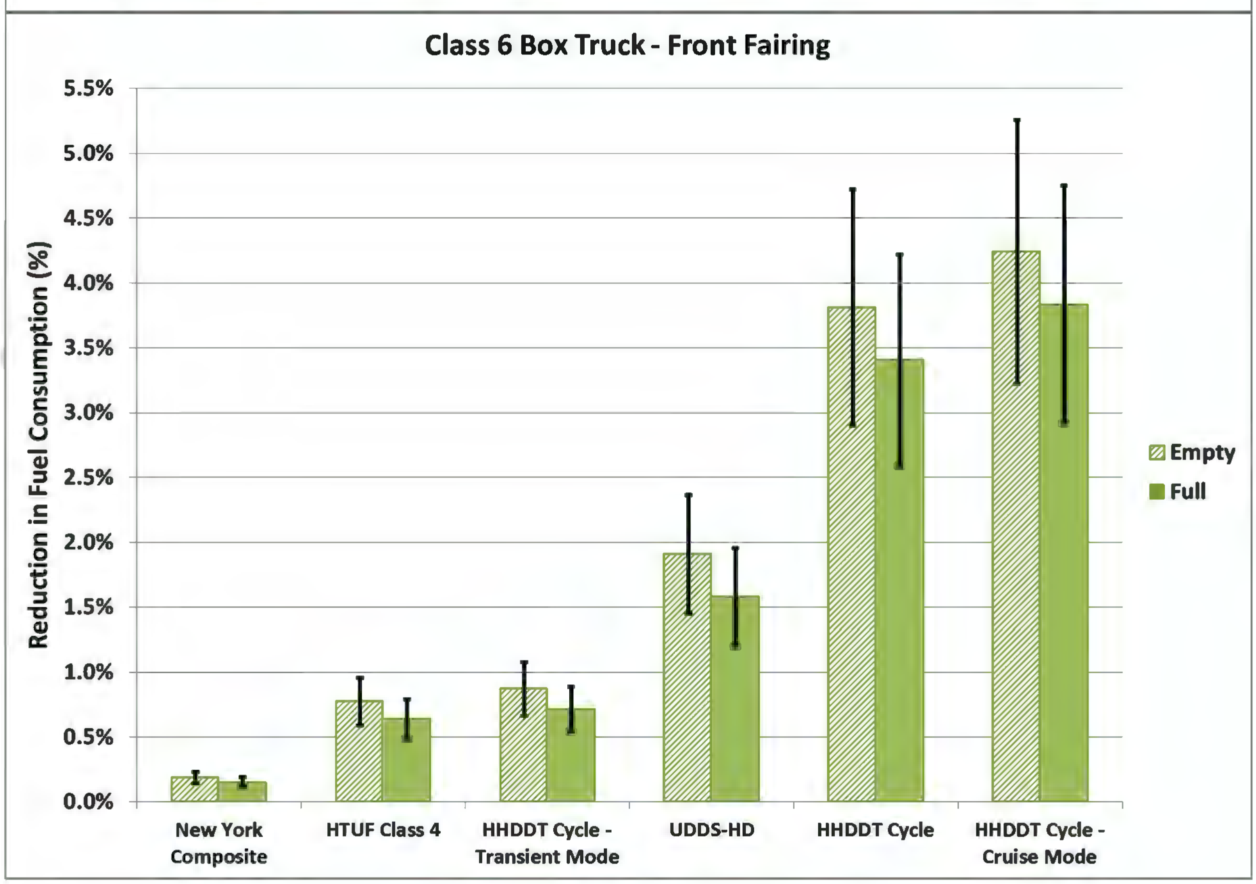
Figure 15. Percent Change in Fuel Economy[3] for a 1% change in C_d

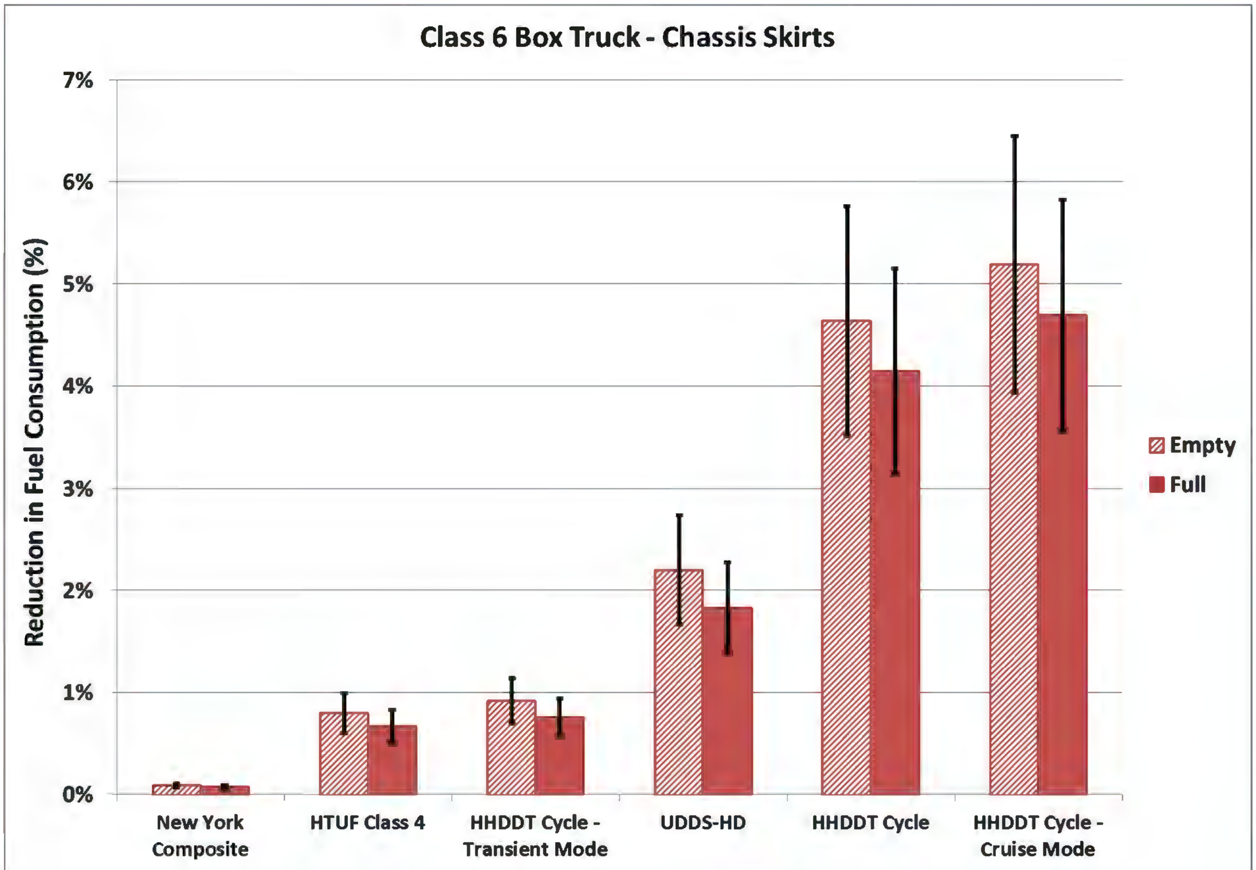
For a fully loaded class 8 tractor trailer traveling at 60 mph a 1% change in C_d is expected to result in a ~0.5% change in fuel economy. For a class 6 box truck traveling at 30 mph a 1% change in C_d is expected to result in a ~0.25% change in fuel economy. However, if that same class 6 box truck is placed in a vocation where it averages 60 mph this could result in a ~0.7% change in fuel economy. This emphasizes how important it is to pair these devices with a vehicle operating on an appropriate duty cycle to maximize fuel economy gains.

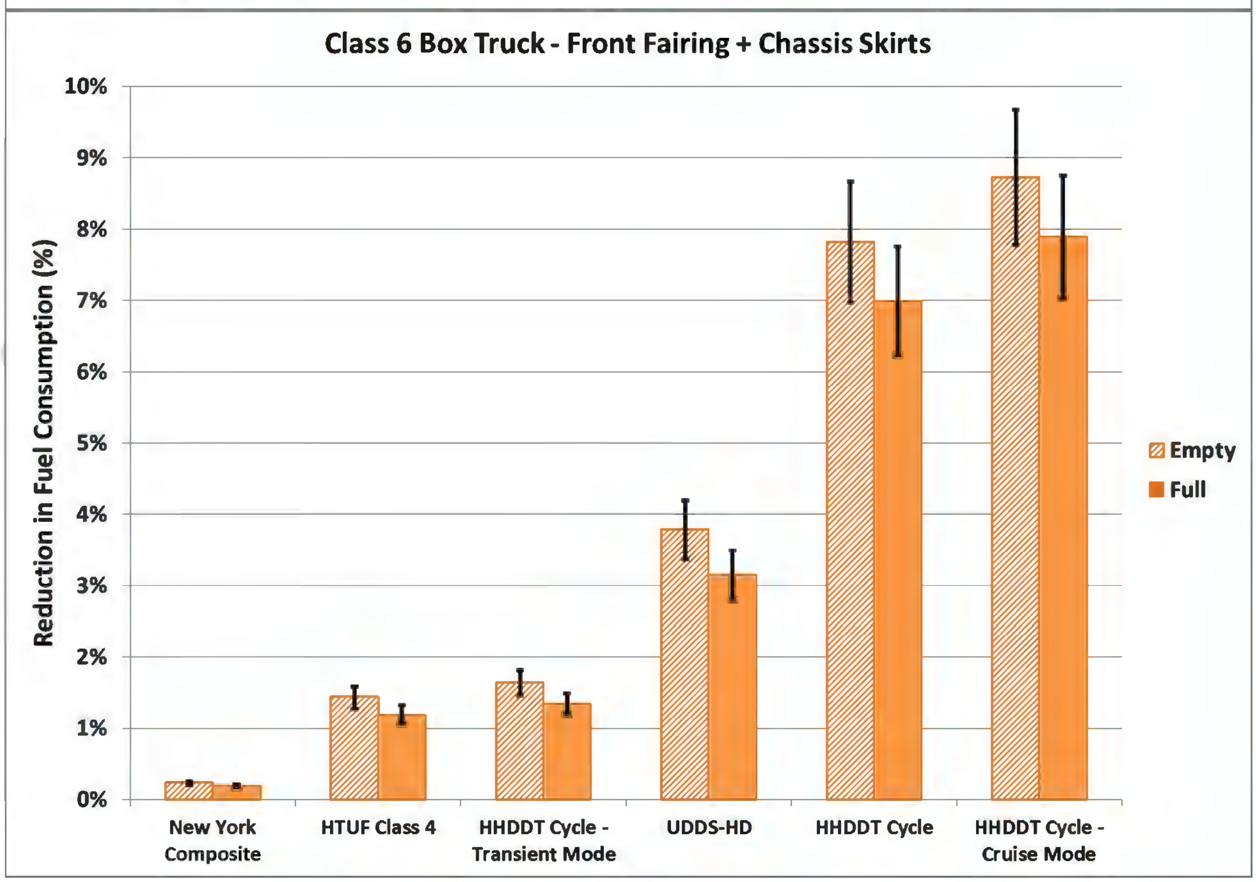
Using the coastdown results, theoretical fuel economy improvements can be predicted over steady-state conditions, and various transient drive cycles. The coastdown coefficients from Table 5 are used to populate a road load force curve. For a given drive cycle, assuming zero grade, the required force at each speed interval can be found using this curve. Some assumptions about driveline efficiency and an engine thermal efficiency curve can be used to derive instantaneous fueling requirements and eventually arrive at a full cycle fuel economy with the test device, and for the baseline condition. Figure 16 shows four test scenarios, "rear fairing," "front fairing," "chassis skirts," and "front fairing + chassis skirts" respectively, at empty weight and maximum GVWR, along with a composite graphic for comparison across devices. The combination of front fairing and chassis skirts shows the greatest advantage across all cycles. The wheel covers are not shown since the results showed no statistically significant difference. Drive cycle statistics are shown in Table 10.

[3] "Fuel Economy" was calculated as *((distance traveled) / (fuel used))*
"% Change" was calculated as *((test case) – (baseline)) / (baseline) x 100*


Class 4 Box Truck - Rear Fairing
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
-0.5%
Reduction in Fuel Consumption (%)
New York Composite
HTUF Class 4
HHDDT Cycle - Transient Mode
UDDS-HD
HHDDT Cycle
HHDDT Cycle - Cruise Mode
Empty
Full


Class 6 Box Truck - Front Fairing
5.5%
5.0%
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
1.0%
0.5%
0.0%
Reduction in Fuel Consumption (%)
New York Composite
HTUF Class 4
HHDDT Cycle - Transient Mode
UDDS-HD
HHDDT Cycle
HHDDT Cycle - Cruise Mode
Empty
Full


Class 6 Box Truck - Chassis Skirts
Reduction in Fuel Consumption (%)
7%
6%
5%
4%
3%
2%
1%
0%
Empty
Full
New York Composite
HTUF Class 4
HHDDT Cycle - Transient Mode
UDDS-HD
HHDDT Cycle
HHDDT Cycle - Cruise Mode


Class 6 Box Truck - Front Fairing + Chassis Skirts
Reduction in Fuel Consumption (%)
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
Empty
Full
New York Composite
HTUF Class 4
HHDDT Cycle - Transient Mode
UDDS-HD
HHDDT Cycle
HHDDT Cycle - Cruise Mode

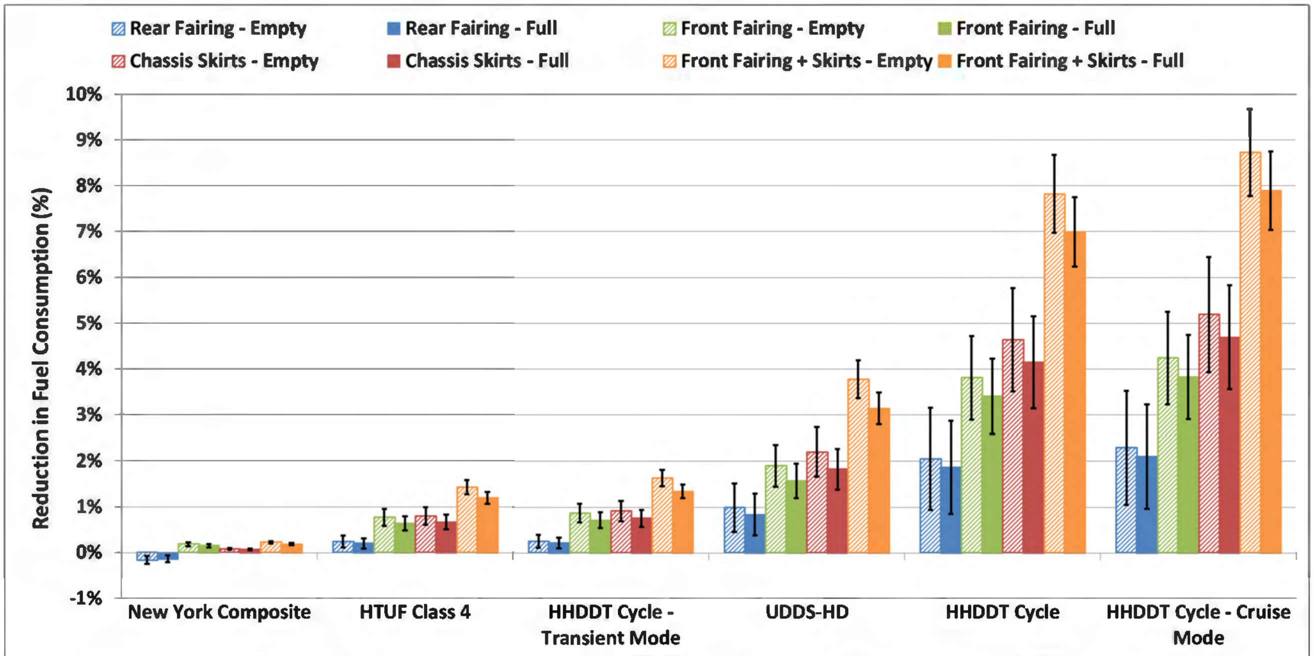


Figure 16. Simulated Drive Cycle Fuel Consumption Results[4]

Table 10. Drive Cycle Statistics

Test Cycle	Cycle Time (sec)	Total Dist (mi)	Avg Speed (mph)	Avg Driving Speed (mph)	Max Speed (mph)	KI (1/mi)	Stops	Stops/mi
New York Composite	1,029	2.5	8.8	13.1	36.0	4.3	20	8.0
HTUF Class 4	3,336	11.2	12.1	22.5	56.6	1.5	28	2.5
HHDDT Cycle - Transient Mode	668	2.9	15.3	18.2	47.5	1.4	4	1.4
UDDS-HD	1,060	5.6	18.8	28.2	58.0	0.6	14	2.5
HHDDT Cycle	2,751	25.9	33.9	37.5	59.3	0.2	10	0.4
HHDDT Cycle - Cruise Mode	2,083	23.1	39.9	43.2	59.3	0.1	6	0.3

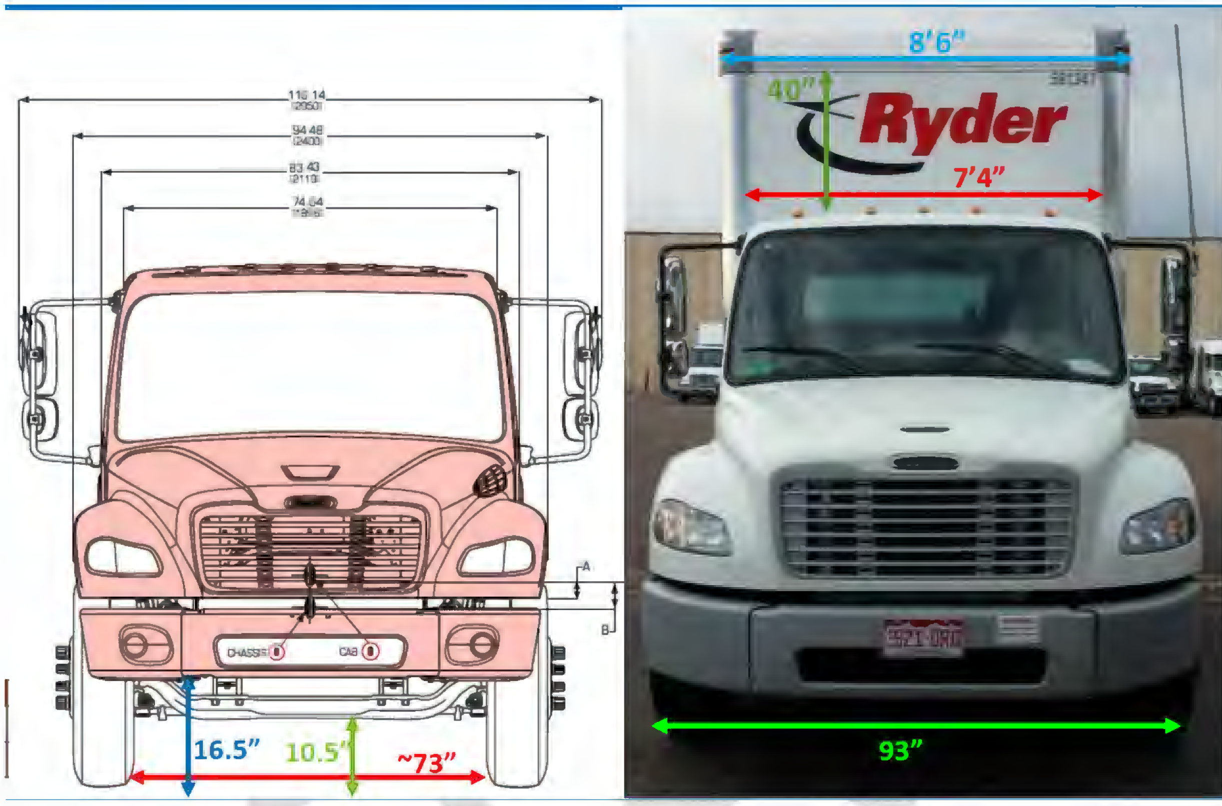
For very aggressive, low-speed cycles, the additional weight of the aerodynamic device combined with the small benefit at low speeds makes for a very small or negligible benefit. In fact, for the case of the "rear fairing" on the New York Composite test cycle the estimated benefit is actually negative, indicating the aerodynamic improvement is not sufficient to overcome the additional fuel required to carry the added weight, and thus, a vehicle equipped with this device on this cycle would actually consume more fuel. However, for cycles with significant highway contributions the benefits can be much more substantial. It is important when considering aerodynamic improvement devices for vocational vehicles, that they are paired with an appropriate drive cycle to realize the maximum benefit.

[4] Error estimates shown are 95% confidence intervals
"Fuel Consumption" was calculated as *((fuel used) / (distance traveled))*
"Reduction" was calculated as *((baseline) – (test case)) / (baseline)*

Appendix A – Additional Truck Dimensions

Class 6 Box Truck:

Dimensions - Front

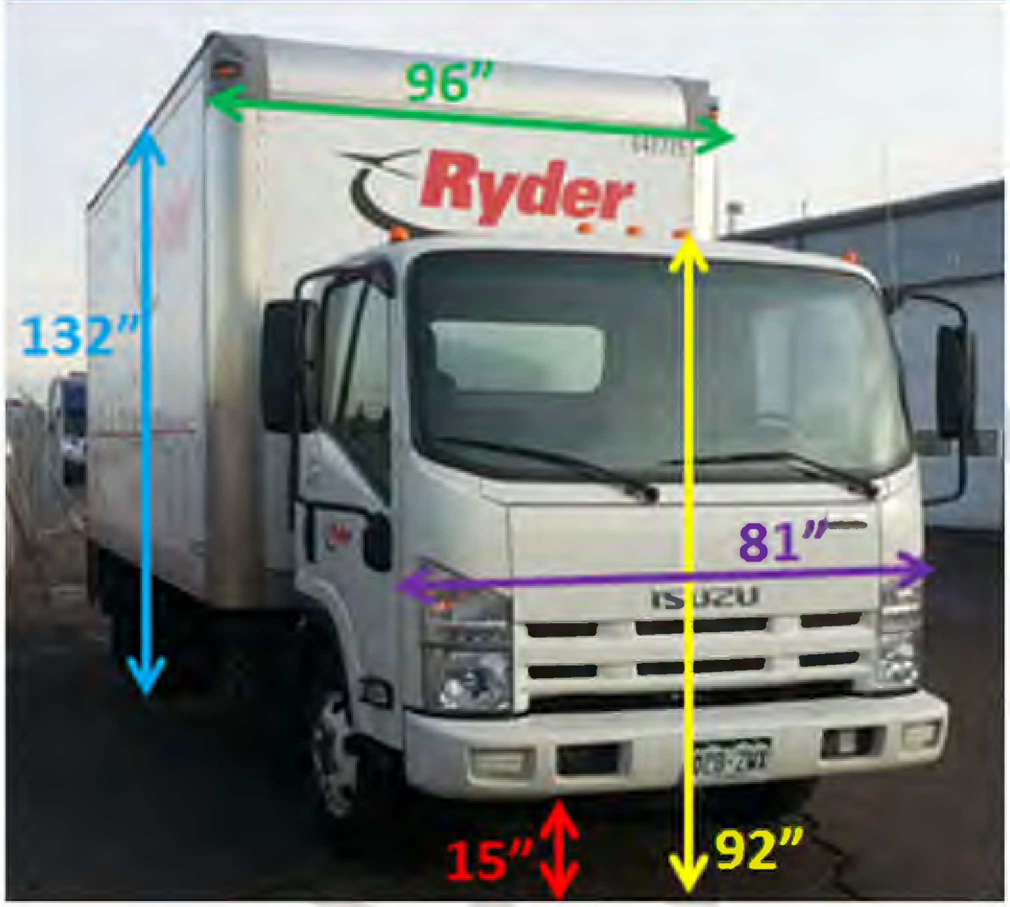


Rear Differential Height

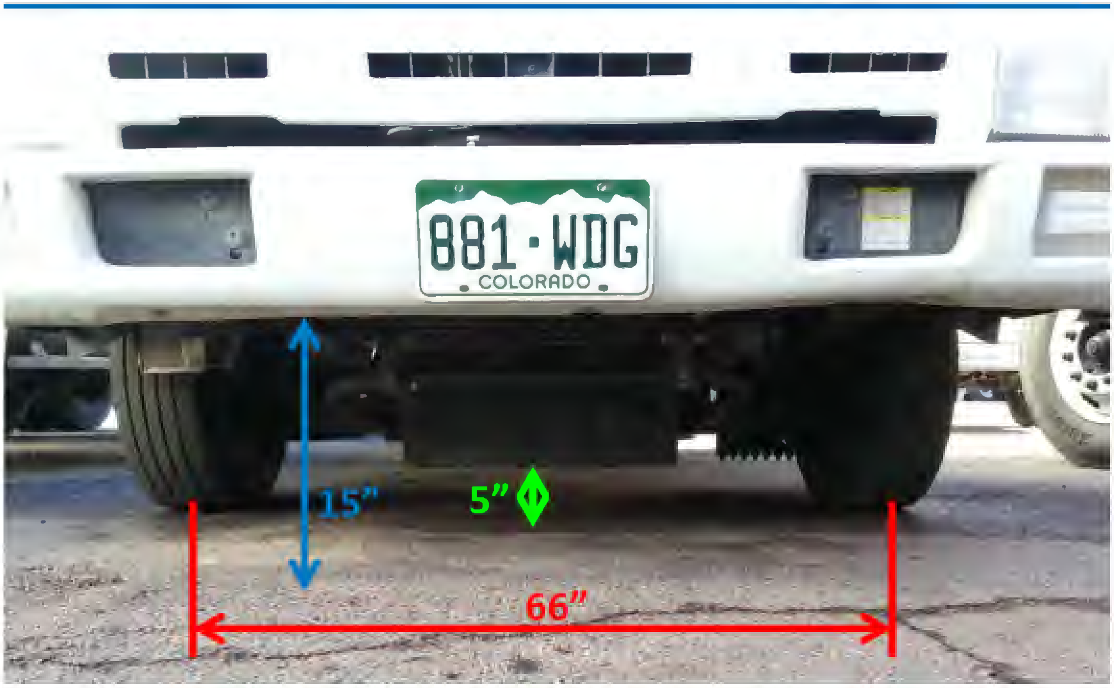
Dimensions - Side

Class 4 Box Truck:

Dimensions - Front



Dimensions – Front Ground Clearance



Attachment 2
Use of Aerodynamic Devices for Actual Vocational Trucks in NREL Fleet DNA Database Spreadsheet

Potential Fuel Consumption Reductions via Use of Aerodynamic Devices for Actual Vocational Trucks in NREL Fleet DNA Database

Fleet DNA has 553 days of driving data from 36 delivery trucks operating in the United States.

Straight Truck	Chassis Skirt (%)		Front Fairing (%)		Front Fairing + Chassis Skirt (%)		Rear Fairing (%)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Potential FCR, depending on speed*	5.20%	6.10%	5.00%	6.90%	10.30%	10.40%	2.70%	3.80%
Total Potential FCR**	**2.82%**	**3.31%**	**2.71%**	**3.74%**	**5.59%**	**5.64%**	**1.46%**	**2.06%**

*See Table 8 of the Draft National Renewable Energy Laboratory Aerodynamic Drag Reduction Technologies Testing for Heavy-Duty Vocational Vehicles – Preliminary Results (Attachment 1)
**Assumming 54.25% is the percentage distance travelling at 45 mph and above from "Straight Trucks' Vehicle Miles Traveled as Function of Speed" Table

Potential Fuel Consumption Reductions via Use of Aerodynamic Devices for Actual Vocational Trucks in NREL Fleet DNA Database

Fleet DNA has 553 days of driving data from 36 delivery trucks operating in the United States.

Straight Trucks' Vehicle Miles Traveled as Function of Speed									
Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	parcel delivery	1.46	2.29	1.56	1.18	-	-	-	11.29
straight truck	parcel delivery	1.85	1.46	1.33	1.84	0.26	-	-	11.56
straight truck	parcel delivery	2.80	2.97	2.21	3.00	0.53	-	-	22.59
straight truck	parcel delivery	2.47	5.52	3.07	1.71	0.73	-	-	23.40
straight truck	parcel delivery	1.76	2.74	2.58	0.56	-	-	-	12.04
straight truck	parcel delivery	2.33	1.68	1.49	0.73	-	-	-	11.62
straight truck	parcel delivery	2.47	1.92	3.08	1.95	0.56	-	-	22.82
straight truck	parcel delivery	3.42	3.00	3.39	1.64	-	-	-	22.58
straight truck	parcel delivery	0.67	2.11	2.45	1.07	-	-	-	11.54
straight truck	parcel delivery	1.05	0.78	2.44	1.65	0.41	-	-	11.09
straight truck	parcel delivery	1.02	1.64	3.29	0.85	-	-	-	11.43
straight truck	parcel delivery	3.32	2.92	2.21	2.17	0.15	-	-	22.75
straight truck	parcel delivery	2.10	1.12	0.59	1.12	0.16	-	-	30.26
straight truck	parcel delivery	0.50	-	-	-	-	-	-	10.90
straight truck	parcel delivery	1.35	-	-	-	-	-	-	18.98
straight truck	parcel delivery	2.08	0.71	-	-	-	-	-	18.13
straight truck	parcel delivery	0.63	-	-	-	-	-	-	12.86
straight truck	parcel delivery	6.40	2.24	1.80	1.40	0.35	-	-	30.13
straight truck	parcel delivery	0.05	-	-	-	-	-	-	10.82
straight truck	parcel delivery	0.72	-	-	-	-	-	-	10.60
straight truck	parcel delivery	0.43	-	-	-	-	-	-	10.56
straight truck	parcel delivery	0.62	-	-	-	-	-	-	10.55
straight truck	parcel delivery	1.47	0.07	-	-	-	-	-	10.54
straight truck	parcel delivery	0.92	-	-	-	-	-	-	10.60
straight truck	parcel delivery	0.62	-	-	-	-	-	-	7.45
straight truck	parcel delivery	0.31	0.34	0.12	-	-	-	-	17.56

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	parcel delivery	1.75	0.75	-	-	-	-	-	14.47
straight truck	parcel delivery	1.99	3.56	5.62	13.27	2.53	-	-	50.37
straight truck	parcel delivery	0.70	0.16	0.39	-	-	-	-	17.55
straight truck	parcel delivery	0.93	0.28	-	-	-	-	-	17.91
straight truck	parcel delivery	0.38	-	-	-	-	-	-	15.71
straight truck	parcel delivery	0.37	-	-	-	-	-	-	15.74
straight truck	parcel delivery	5.13	9.22	8.96	7.19	3.19	-	-	85.20
straight truck	parcel delivery	1.13	0.53	0.51	-	-	-	-	19.67
straight truck	parcel delivery	1.23	0.11	-	-	-	-	-	17.39
straight truck	parcel delivery	0.59	-	-	-	-	-	-	19.59
straight truck	parcel delivery	0.19	-	-	-	-	-	-	15.96
straight truck	parcel delivery	1.46	3.05	13.75	7.95	0.09	-	-	49.54
straight truck	parcel delivery	0.99	0.31	-	-	-	-	-	15.00
straight truck	parcel delivery	3.36	1.28	0.77	0.08	-	-	-	24.42
straight truck	parcel delivery	5.21	7.49	28.41	6.30	-	-	-	74.83
straight truck	parcel delivery	3.94	3.23	6.10	3.52	-	-	-	38.34
straight truck	parcel delivery	3.51	1.69	-	-	-	-	-	48.77
straight truck	parcel delivery	5.10	5.43	7.43	1.23	-	-	-	44.27
straight truck	parcel delivery	1.93	0.46	-	-	-	-	-	14.81
straight truck	parcel delivery	3.69	3.58	20.53	4.21	-	-	-	57.38
straight truck	parcel delivery	4.54	2.56	0.93	-	-	-	-	33.39
straight truck	parcel delivery	4.86	2.75	0.29	-	-	-	-	32.98
straight truck	parcel delivery	4.38	3.19	0.31	-	-	-	-	33.87
straight truck	parcel delivery	2.81	1.28	0.59	-	-	-	-	26.44
straight truck	parcel delivery	11.07	8.66	0.45	-	-	-	-	43.78
straight truck	parcel delivery	5.52	2.38	0.44	-	-	-	-	23.46
straight truck	parcel delivery	6.18	1.40	-	-	-	-	-	34.67
straight truck	parcel delivery	7.47	0.87	-	-	-	-	-	34.46
straight truck	parcel delivery	5.36	1.18	-	-	-	-	-	34.89

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	parcel delivery	6.37	0.96	-	-	-	-	-	34.02
straight truck	parcel delivery	5.15	2.19	-	-	-	-	-	34.55
straight truck	parcel delivery	6.89	2.60	-	-	-	-	-	34.28
straight truck	parcel delivery	2.58	2.99	4.62	0.95	-	-	-	21.23
straight truck	parcel delivery	6.50	1.22	-	-	-	-	-	34.68
straight truck	parcel delivery	2.55	0.57	-	-	-	-	-	11.46
straight truck	parcel delivery	4.91	2.27	2.85	0.94	-	-	-	20.95
straight truck	parcel delivery	1.03	1.48	3.80	5.80	-	-	-	20.91
straight truck	parcel delivery	2.57	1.87	4.42	0.91	-	-	-	20.97
straight truck	parcel delivery	3.10	3.15	3.88	0.78	-	-	-	20.96
straight truck	parcel delivery	0.56	1.33	1.05	0.34	-	-	-	7.22
straight truck	parcel delivery	6.37	4.01	1.90	3.55	-	-	-	36.71
straight truck	parcel delivery	5.00	2.89	1.31	2.44	-	-	-	30.96
straight truck	parcel delivery	0.09	-	-	-	-	-	-	7.56
straight truck	parcel delivery	4.42	3.29	2.87	0.44	-	-	-	30.91
straight truck	parcel delivery	4.85	4.66	1.38	0.94	0.49	-	-	30.13
straight truck	parcel delivery	5.59	6.54	1.72	-	-	-	-	30.12
straight truck	parcel delivery	0.66	1.35	0.42	-	-	-	-	6.30
straight truck	parcel delivery	0.53	0.64	0.69	0.79	2.13	-	-	6.77
straight truck	parcel delivery	4.11	5.76	1.30	0.05	-	-	-	30.93
straight truck	parcel delivery	6.56	4.50	1.59	1.05	-	-	-	30.79
straight truck	parcel delivery	4.12	5.69	2.99	0.03	-	-	-	30.19
straight truck	parcel delivery	5.34	4.88	3.38	0.56	-	-	-	31.30
straight truck	parcel delivery	1.53	0.57	-	-	-	-	-	43.80
straight truck	parcel delivery	1.28	0.17	-	-	-	-	-	35.28
straight truck	parcel delivery	1.85	0.83	-	-	-	-	-	40.99
straight truck	parcel delivery	1.28	0.19	-	-	-	-	-	38.82
straight truck	parcel delivery	1.37	0.41	-	-	-	-	-	41.92
straight truck	parcel delivery	1.15	0.51	-	-	-	-	-	34.38

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	parcel delivery	2.27	0.72	0.22	-	-	-	-	34.23
straight truck	parcel delivery	3.29	1.88	0.42	1.40	0.24	-	-	38.92
straight truck	parcel delivery	1.00	0.31	0.39	-	-	-	-	42.18
straight truck	parcel delivery	1.66	0.40	-	-	-	-	-	41.54
straight truck	parcel delivery	0.97	-	-	-	-	-	-	41.31
straight truck	parcel delivery	1.95	0.80	0.02	-	-	-	-	43.40
straight truck	parcel delivery	1.10	0.48	-	-	-	-	-	30.62
straight truck	parcel delivery	1.70	2.63	-	-	-	-	-	19.21
straight truck	parcel delivery	1.82	3.46	1.14	0.05	-	-	-	19.29
straight truck	parcel delivery	3.85	1.92	0.40	-	-	-	-	19.32
straight truck	parcel delivery	2.55	2.80	0.03	-	-	-	-	19.37
straight truck	parcel delivery	2.96	1.45	0.22	-	-	-	-	19.35
straight truck	parcel delivery	3.27	0.98	0.67	-	-	-	-	21.60
straight truck	parcel delivery	2.92	2.09	1.28	0.31	-	-	-	19.33
straight truck	parcel delivery	3.54	1.45	-	-	-	-	-	19.32
straight truck	parcel delivery	2.26	2.06	0.70	-	-	-	-	19.29
straight truck	parcel delivery	2.25	1.74	0.85	-	-	-	-	19.31
straight truck	parcel delivery	3.16	2.17	0.25	-	-	-	-	21.61
straight truck	parcel delivery	3.23	1.94	0.77	0.42	-	-	-	19.37
straight truck	parcel delivery	3.51	1.72	1.05	-	-	-	-	19.21
straight truck	parcel delivery	4.64	0.79	0.45	0.37	-	-	-	57.38
straight truck	parcel delivery	3.55	0.70	0.29	0.27	-	-	-	42.05
straight truck	parcel delivery	7.31	3.41	1.43	1.77	1.01	-	-	30.05
straight truck	parcel delivery	3.48	0.95	-	-	-	-	-	40.88
straight truck	parcel delivery	0.35	0.08	-	-	-	-	-	28.47
straight truck	parcel delivery	5.08	3.51	0.54	0.56	-	-	-	52.57
straight truck	parcel delivery	4.07	3.53	2.16	-	-	-	-	66.17
straight truck	parcel delivery	1.20	0.15	-	-	-	-	-	38.19
straight truck	parcel delivery	2.52	1.87	0.11	-	-	-	-	35.92

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	parcel delivery	4.56	1.32	0.32	-	-	-	-	62.03
straight truck	parcel delivery	0.92	1.01	0.81	1.08	0.46	-	-	16.82
straight truck	parcel delivery	8.62	4.34	5.62	5.52	3.48	-	-	81.94
straight truck	parcel delivery	5.40	1.89	0.88	1.25	0.98	-	-	64.43
straight truck	warehouse delivery	5.26	4.65	15.30	31.59	15.73	1.22	-	121.83
straight truck	warehouse delivery	3.99	6.49	13.55	25.96	10.71	2.04	-	96.34
straight truck	warehouse delivery	3.76	3.32	5.23	18.78	24.14	2.39	-	93.21
straight truck	warehouse delivery	3.48	2.67	7.79	22.52	23.96	0.51	-	93.73
straight truck	warehouse delivery	3.97	6.32	21.39	29.13	6.18	0.20	-	90.10
straight truck	warehouse delivery	2.79	4.97	6.43	3.93	1.12	-	-	62.42
straight truck	warehouse delivery	3.46	6.60	11.36	23.34	20.12	0.33	-	95.90
straight truck	warehouse delivery	2.73	6.65	14.90	13.00	0.70	-	-	69.49
straight truck	warehouse delivery	5.39	5.65	14.56	8.89	2.97	0.35	-	74.11
straight truck	warehouse delivery	3.65	7.21	16.25	25.40	26.22	6.37	-	117.70
straight truck	warehouse delivery	6.22	6.35	11.63	22.31	19.70	3.09	-	112.59
straight truck	warehouse delivery	9.71	11.11	15.46	63.73	1.94	-	-	144.94
straight truck	warehouse delivery	6.39	9.16	15.49	45.07	1.21	-	-	106.92
straight truck	warehouse delivery	12.24	13.18	16.29	44.25	0.42	-	-	123.73
straight truck	warehouse delivery	2.66	0.60	1.32	5.47	-	-	-	38.77
straight truck	warehouse delivery	11.91	13.05	13.97	51.77	1.76	-	-	139.68
straight truck	warehouse delivery	5.52	4.88	8.12	71.65	2.22	-	-	122.13
straight truck	warehouse delivery	7.44	18.52	43.00	16.05	-	-	-	104.27
straight truck	warehouse delivery	2.69	3.24	2.66	2.22	-	-	-	41.33
straight truck	warehouse delivery	4.75	2.90	8.35	3.19	-	-	-	48.86
straight truck	warehouse delivery	13.42	19.22	29.67	79.94	3.87	-	-	191.49
straight truck	warehouse delivery	12.17	8.54	11.06	63.11	1.09	-	-	126.40
straight truck	warehouse delivery	6.95	7.62	18.34	34.70	1.47	-	-	109.74
straight truck	warehouse delivery	7.73	11.57	15.52	31.60	31.57	-	-	143.74
straight truck	warehouse delivery	5.29	9.73	21.37	34.77	33.52	-	-	143.24

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	warehouse delivery	6.96	8.70	18.41	28.01	33.59	-	-	149.62
straight truck	warehouse delivery	7.52	9.28	22.83	43.61	25.48	-	-	157.77
straight truck	warehouse delivery	5.81	8.41	14.35	43.28	33.95	-	-	139.68
straight truck	warehouse delivery	6.51	7.68	10.51	19.04	11.37	-	-	90.00
straight truck	warehouse delivery	5.37	10.33	19.49	46.12	25.62	-	-	152.28
straight truck	warehouse delivery	2.46	5.10	8.12	18.44	27.27	0.10	-	94.28
straight truck	warehouse delivery	3.61	5.57	6.65	14.29	21.24	-	-	86.02
straight truck	warehouse delivery	3.64	8.80	12.27	29.26	7.42	-	-	104.95
straight truck	warehouse delivery	5.06	4.03	7.25	32.86	9.02	-	-	97.62
straight truck	warehouse delivery	4.58	15.97	13.27	0.37	-	-	-	83.39
straight truck	warehouse delivery	0.72	1.10	0.79	-	-	-	-	40.51
straight truck	warehouse delivery	2.55	3.87	4.90	27.35	9.48	-	-	74.38
straight truck	warehouse delivery	2.63	2.57	7.58	18.48	3.08	-	-	52.91
straight truck	warehouse delivery	5.16	4.91	6.42	21.67	6.83	-	-	90.13
straight truck	warehouse delivery	3.09	4.15	9.83	35.97	10.76	-	-	98.78
straight truck	warehouse delivery	2.80	2.56	5.23	21.44	6.96	-	-	85.45
straight truck	warehouse delivery	1.48	2.44	6.30	34.63	8.15	-	-	82.39
straight truck	warehouse delivery	8.10	12.50	8.40	14.12	3.86	-	-	97.86
straight truck	warehouse delivery	3.85	2.54	4.69	26.28	7.91	-	-	88.27
straight truck	warehouse delivery	4.41	11.63	12.51	3.19	-	-	-	75.12
straight truck	warehouse delivery	4.02	16.16	30.65	6.88	0.14	-	-	83.34
straight truck	warehouse delivery	9.00	6.51	12.44	17.84	5.64	-	-	94.30
straight truck	warehouse delivery	4.10	8.99	14.75	15.18	0.36	-	-	81.98
straight truck	warehouse delivery	4.89	6.09	13.40	32.56	5.48	-	-	113.48
straight truck	warehouse delivery	5.19	11.56	33.96	16.04	1.13	-	-	122.19
straight truck	warehouse delivery	5.97	16.21	12.04	1.28	-	-	-	80.47
straight truck	warehouse delivery	10.20	11.75	11.97	2.79	-	-	-	86.42
straight truck	warehouse delivery	4.46	12.54	6.88	0.19	-	-	-	56.30
straight truck	warehouse delivery	0.09	-	-	-	-	-	-	20.92

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	warehouse delivery	6.13	7.13	3.73	-	-	-	-	30.14
straight truck	warehouse delivery	5.52	8.16	6.73	8.53	1.34	-	-	77.23
straight truck	food delivery	-	-	-	-	-	-	-	9.52
straight truck	food delivery	-	-	-	-	-	-	-	9.63
straight truck	food delivery	-	-	-	-	-	-	-	9.71
straight truck	food delivery	-	-	-	-	-	-	-	12.46
straight truck	food delivery	-	-	-	-	-	-	-	10.96
straight truck	food delivery	-	-	-	-	-	-	-	9.55
straight truck	food delivery	-	-	-	-	-	-	-	9.97
straight truck	food delivery	-	-	-	-	-	-	-	9.54
straight truck	food delivery	-	-	-	-	-	-	-	10.07
straight truck	food delivery	-	-	-	-	-	-	-	9.68
straight truck	food delivery	-	-	-	-	-	-	-	10.31
straight truck	food delivery	-	-	-	-	-	-	-	9.18
straight truck	food delivery	-	-	-	-	-	-	-	9.55
straight truck	food delivery	-	-	-	-	-	-	-	10.11
straight truck	food delivery	-	-	-	-	-	-	-	10.36
straight truck	food delivery	0.08	-	-	-	-	-	-	9.85
straight truck	food delivery	-	-	-	-	-	-	-	9.73
straight truck	food delivery	-	-	-	-	-	-	-	9.44
straight truck	food delivery	-	-	-	-	-	-	-	9.58
straight truck	food delivery	-	-	-	-	-	-	-	10.10
straight truck	food delivery	-	-	-	-	-	-	-	10.07
straight truck	food delivery	-	-	-	-	-	-	-	10.01
straight truck	food delivery	-	-	-	-	-	-	-	9.66
straight truck	food delivery	-	-	-	-	-	-	-	10.31
straight truck	food delivery	-	-	-	-	-	-	-	9.11
straight truck	food delivery	-	-	-	-	-	-	-	10.04
straight truck	food delivery	-	-	-	-	-	-	-	11.67

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	-	-	-	-	-	-	-	9.36
straight truck	food delivery	2.69	2.57	4.14	6.80	3.02	-	-	41.23
straight truck	food delivery	2.45	4.02	4.57	4.05	4.94	-	-	37.89
straight truck	food delivery	1.56	2.20	6.49	4.54	3.40	-	-	31.22
straight truck	food delivery	1.00	1.70	3.43	5.67	6.37	-	-	32.27
straight truck	food delivery	2.91	1.91	2.16	5.16	5.77	-	-	30.74
straight truck	food delivery	1.91	1.04	3.79	5.15	5.68	-	-	30.37
straight truck	food delivery	1.90	2.05	4.99	3.62	6.15	-	-	29.74
straight truck	food delivery	1.74	3.96	4.62	4.74	2.72	-	-	30.98
straight truck	food delivery	1.18	2.22	8.39	4.55	0.99	-	-	31.00
straight truck	food delivery	2.72	3.57	6.04	3.52	3.75	-	-	35.38
straight truck	food delivery	0.99	1.24	5.16	6.87	3.74	-	-	33.17
straight truck	food delivery	1.15	1.66	2.90	5.64	6.30	-	-	30.45
straight truck	food delivery	2.77	2.14	5.98	3.76	3.28	-	-	30.51
straight truck	food delivery	1.73	1.41	4.12	6.36	8.30	0.08	-	36.21
straight truck	food delivery	1.63	2.07	6.77	6.19	1.67	-	-	31.17
straight truck	food delivery	2.02	3.58	3.26	7.57	1.22	-	-	31.06
straight truck	food delivery	2.05	1.41	2.39	6.84	10.03	-	-	39.64
straight truck	food delivery	1.29	1.01	2.14	7.11	6.30	-	-	30.37
straight truck	food delivery	2.16	1.67	6.28	6.80	1.83	-	-	30.56
straight truck	food delivery	2.05	2.78	6.35	6.29	1.50	-	-	30.17
straight truck	food delivery	1.59	1.74	3.52	4.75	6.64	-	-	30.44
straight truck	food delivery	0.70	0.92	3.19	9.03	3.86	-	-	31.20
straight truck	food delivery	1.74	2.47	4.86	7.45	1.72	-	-	31.23
straight truck	food delivery	1.45	1.26	1.43	5.96	8.25	-	-	31.27
straight truck	food delivery	1.50	1.58	2.28	5.86	6.56	-	-	30.47
straight truck	food delivery	1.96	2.51	3.34	5.24	4.71	-	-	30.69
straight truck	food delivery	1.46	2.88	8.12	7.10	2.10	-	-	36.33
straight truck	food delivery	0.90	2.63	5.78	4.78	3.38	-	-	31.13

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	2.63	4.27	6.33	7.65	-	-	-	38.93
straight truck	food delivery	2.69	4.90	6.66	6.18	0.09	-	-	35.44
straight truck	food delivery	3.35	4.41	4.06	10.01	0.97	-	-	41.82
straight truck	food delivery	1.91	6.13	6.66	7.52	0.80	-	-	36.48
straight truck	food delivery	0.72	2.67	6.12	11.51	1.58	-	-	35.67
straight truck	food delivery	1.51	3.53	6.38	10.23	-	-	-	37.62
straight truck	food delivery	1.63	3.18	5.46	10.95	0.58	-	-	35.97
straight truck	food delivery	1.74	6.53	7.45	3.47	0.20	-	-	40.09
straight truck	food delivery	1.84	4.35	7.54	7.74	0.38	-	-	40.26
straight truck	food delivery	3.47	5.05	3.04	4.62	2.31	-	-	35.08
straight truck	food delivery	1.74	3.73	6.40	10.42	0.82	-	-	35.70
straight truck	food delivery	0.92	4.23	8.75	7.95	0.16	-	-	34.71
straight truck	food delivery	2.45	4.51	7.19	7.84	1.36	-	-	41.81
straight truck	food delivery	1.00	4.50	6.92	7.93	2.21	-	-	36.81
straight truck	food delivery	1.78	4.24	5.22	9.67	0.33	-	-	35.91
straight truck	food delivery	1.49	4.92	5.99	9.01	0.02	-	-	35.78
straight truck	food delivery	1.57	5.55	6.69	8.18	0.71	-	-	36.69
straight truck	food delivery	0.48	2.23	6.95	12.87	-	-	-	34.77
straight truck	food delivery	0.55	3.16	10.44	7.96	0.38	-	-	36.80
straight truck	food delivery	2.92	5.42	4.58	7.89	0.44	-	-	35.28
straight truck	food delivery	2.15	5.63	6.41	11.62	0.73	-	-	42.49
straight truck	food delivery	1.60	4.47	3.73	9.70	2.23	-	-	35.90
straight truck	food delivery	1.92	3.08	7.12	8.71	-	-	-	36.07
straight truck	food delivery	1.89	6.61	4.17	7.67	1.80	-	-	35.68
straight truck	food delivery	1.28	2.47	5.51	7.96	2.91	-	-	39.98
straight truck	food delivery	2.00	4.64	8.68	4.83	-	-	-	40.64
straight truck	food delivery	3.25	5.21	9.16	3.17	-	-	-	35.95
straight truck	food delivery	3.55	3.78	17.43	0.07	-	-	-	34.43
straight truck	food delivery	0.77	2.15	21.83	-	-	-	-	51.86

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	2.87	7.47	19.27	-	-	-	-	50.28
straight truck	food delivery	1.63	5.81	14.75	-	-	-	-	26.81
straight truck	food delivery	3.20	7.22	54.80	0.49	-	-	-	81.20
straight truck	food delivery	1.22	1.32	0.84	-	-	-	-	12.08
straight truck	food delivery	1.54	2.67	13.89	-	-	-	-	34.51
straight truck	food delivery	3.09	3.08	21.81	-	-	-	-	46.46
straight truck	food delivery	1.59	2.76	17.25	-	-	-	-	40.87
straight truck	food delivery	3.37	16.37	20.12	0.29	-	-	-	51.71
straight truck	food delivery	8.33	16.45	10.59	0.20	-	-	-	51.43
straight truck	food delivery	2.67	12.75	23.99	1.17	-	-	-	54.65
straight truck	food delivery	3.35	12.07	22.18	2.09	-	-	-	51.65
straight truck	food delivery	0.85	5.99	24.92	9.39	0.07	-	-	51.56
straight truck	food delivery	0.94	3.67	21.00	15.17	0.25	-	-	51.24
straight truck	food delivery	0.83	5.88	18.96	14.39	0.80	-	-	51.14
straight truck	food delivery	1.51	5.09	13.47	17.25	3.95	-	-	51.72
straight truck	food delivery	1.16	3.79	11.41	22.33	2.94	-	-	51.57
straight truck	food delivery	2.28	4.96	11.01	17.09	0.82	-	-	51.75
straight truck	food delivery	1.39	4.58	18.56	14.41	2.63	-	-	51.46
straight truck	food delivery	2.10	4.80	24.37	8.03	0.13	-	-	51.58
straight truck	food delivery	2.95	8.82	17.93	5.86	-	-	-	51.59
straight truck	food delivery	1.75	9.27	26.47	2.17	-	-	-	51.81
straight truck	food delivery	4.06	18.87	24.87	1.45	-	-	-	67.61
straight truck	food delivery	5.19	9.62	13.11	1.49	-	-	-	51.57
straight truck	food delivery	4.70	11.36	22.40	0.44	-	-	-	54.78
straight truck	food delivery	1.64	3.44	19.17	15.92	1.16	-	-	51.70
straight truck	food delivery	1.35	4.80	25.83	8.65	-	-	-	51.57
straight truck	food delivery	2.35	5.94	17.97	13.85	0.75	-	-	51.56
straight truck	food delivery	5.55	15.28	17.89	-	-	-	-	51.91
straight truck	food delivery	3.38	15.84	17.85	0.42	-	-	-	51.50

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	3.94	18.89	16.82	-	-	-	-	51.45
straight truck	food delivery	0.53	3.80	23.27	13.51	0.09	-	-	52.07
straight truck	food delivery	1.94	5.48	25.40	7.47	-	-	-	51.54
straight truck	food delivery	4.12	10.68	20.10	0.79	-	-	-	54.78
straight truck	food delivery	4.32	17.96	16.69	-	-	-	-	51.36
straight truck	food delivery	2.87	6.16	34.62	-	-	-	-	64.44
straight truck	food delivery	3.03	13.04	28.56	-	-	-	-	60.90
straight truck	food delivery	3.10	7.02	29.69	0.02	-	-	-	55.92
straight truck	food delivery	2.24	8.39	34.85	-	-	-	-	63.15
straight truck	food delivery	2.40	7.85	23.88	-	-	-	-	59.68
straight truck	food delivery	2.76	11.09	27.21	-	-	-	-	61.48
straight truck	food delivery	1.53	5.54	26.62	-	-	-	-	55.94
straight truck	food delivery	4.76	6.79	29.36	-	-	-	-	63.38
straight truck	food delivery	2.59	10.58	32.40	-	-	-	-	64.97
straight truck	food delivery	6.80	9.66	23.56	-	-	-	-	64.63
straight truck	food delivery	4.10	4.56	33.15	0.34	-	-	-	58.48
straight truck	food delivery	3.27	7.31	31.75	0.80	-	-	-	64.22
straight truck	food delivery	3.32	6.99	28.11	-	-	-	-	57.43
straight truck	food delivery	3.48	7.80	44.64	-	-	-	-	75.42
straight truck	food delivery	3.90	13.15	27.07	-	-	-	-	69.03
straight truck	food delivery	3.39	6.46	30.22	0.22	-	-	-	59.22
straight truck	food delivery	2.99	8.20	29.30	-	-	-	-	58.31
straight truck	food delivery	3.03	6.97	30.80	0.35	-	-	-	62.68
straight truck	food delivery	3.40	7.13	41.93	0.05	-	-	-	74.23
straight truck	food delivery	4.21	7.22	36.53	-	-	-	-	65.49
straight truck	food delivery	6.47	15.73	17.21	-	-	-	-	61.40
straight truck	food delivery	2.85	5.79	24.47	-	-	-	-	52.08
straight truck	food delivery	2.77	6.46	21.08	-	-	-	-	54.61
straight truck	food delivery	1.30	9.32	12.19	1.70	-	-	-	43.24

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	2.46	6.29	10.73	0.25	-	-	-	35.85
straight truck	food delivery	0.62	4.62	6.50	7.08	3.59	-	-	43.30
straight truck	food delivery	0.57	4.03	10.10	9.37	0.18	-	-	41.49
straight truck	food delivery	1.95	7.03	11.74	4.63	-	-	-	43.61
straight truck	food delivery	1.22	3.73	15.49	1.24	-	-	-	33.31
straight truck	food delivery	1.91	7.32	12.00	3.33	-	-	-	42.83
straight truck	food delivery	2.57	8.25	11.36	2.17	-	-	-	44.48
straight truck	food delivery	0.74	1.74	8.26	9.72	1.20	-	-	38.60
straight truck	food delivery	0.62	3.06	11.68	6.80	-	-	-	38.32
straight truck	food delivery	2.73	4.55	8.17	2.24	-	-	-	45.01
straight truck	food delivery	1.02	4.29	13.39	2.96	-	-	-	35.16
straight truck	food delivery	2.88	5.04	11.22	3.38	-	-	-	41.08
straight truck	food delivery	0.96	2.84	9.54	10.17	-	-	-	45.48
straight truck	food delivery	1.06	3.78	10.43	8.50	-	-	-	41.55
straight truck	food delivery	2.35	6.33	12.06	3.06	-	-	-	44.43
straight truck	food delivery	2.22	5.53	11.88	0.88	-	-	-	33.43
straight truck	food delivery	1.40	5.50	12.55	2.28	-	-	-	37.69
straight truck	food delivery	1.75	6.14	12.72	3.50	-	-	-	43.97
straight truck	food delivery	2.88	3.40	8.15	6.08	-	-	-	45.41
straight truck	food delivery	0.83	2.13	6.76	11.80	0.16	-	-	35.31
straight truck	food delivery	3.54	7.35	12.15	1.99	-	-	-	46.03
straight truck	food delivery	2.27	6.95	11.14	0.86	-	-	-	33.10
straight truck	food delivery	2.46	7.45	8.87	1.82	-	-	-	35.55
straight truck	food delivery	2.36	2.33	7.09	3.63	0.18	-	-	35.80
straight truck	food delivery	2.38	3.67	7.41	2.57	-	-	-	35.89
straight truck	food delivery	1.65	3.11	8.37	2.31	0.02	-	-	35.67
straight truck	food delivery	2.54	7.94	17.14	6.86	0.04	-	-	61.86
straight truck	food delivery	1.88	3.19	8.43	6.72	3.54	-	-	38.69
straight truck	food delivery	3.82	2.78	8.99	1.10	-	-	-	36.07

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	3.51	3.80	7.88	1.80	0.16	-	-	35.95
straight truck	food delivery	5.01	3.80	6.59	4.73	-	-	-	48.32
straight truck	food delivery	2.94	5.22	7.05	1.73	-	-	-	35.80
straight truck	food delivery	3.89	1.37	4.80	2.90	0.13	-	-	35.67
straight truck	food delivery	2.13	4.44	5.81	2.39	0.58	-	-	38.56
straight truck	food delivery	1.51	2.37	6.29	6.66	5.05	-	-	37.32
straight truck	food delivery	2.14	2.18	9.41	3.75	-	-	-	36.17
straight truck	food delivery	2.31	3.89	7.55	1.83	-	-	-	36.44
straight truck	food delivery	2.70	2.14	7.97	4.33	-	-	-	37.00
straight truck	food delivery	1.60	2.93	5.70	4.58	0.22	-	-	35.80
straight truck	food delivery	1.66	4.53	6.33	3.42	0.40	-	-	35.65
straight truck	food delivery	1.64	2.74	6.15	11.09	1.79	-	-	37.47
straight truck	food delivery	1.84	2.04	6.52	3.94	1.17	-	-	36.65
straight truck	food delivery	2.26	1.85	6.04	4.97	1.26	-	-	37.73
straight truck	food delivery	2.18	0.98	5.19	3.66	3.28	-	-	36.67
straight truck	food delivery	1.15	1.93	5.80	11.64	3.34	-	-	41.79
straight truck	food delivery	2.05	3.25	7.36	2.39	-	-	-	35.59
straight truck	food delivery	2.36	2.97	5.62	3.88	0.20	-	-	35.69
straight truck	food delivery	0.51	2.67	10.61	8.26	0.15	-	-	37.45
straight truck	food delivery	2.94	3.05	8.42	3.04	-	-	-	36.32
straight truck	food delivery	2.42	4.85	6.06	1.58	0.33	-	-	35.95
straight truck	food delivery	1.12	3.95	6.85	1.86	-	-	-	35.79
straight truck	food delivery	2.85	1.44	9.15	7.04	-	-	-	42.69
straight truck	food delivery	4.17	1.22	6.22	7.36	0.13	-	-	41.89
straight truck	food delivery	2.92	6.54	14.06	3.85	-	-	-	52.42
straight truck	food delivery	2.35	6.48	16.63	2.48	-	-	-	52.43
straight truck	food delivery	4.03	1.02	8.38	7.75	0.36	-	-	41.32
straight truck	food delivery	5.92	6.92	14.04	8.81	0.15	-	-	68.65
straight truck	food delivery	4.08	1.35	8.02	6.68	-	-	-	42.64

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	4.29	1.86	4.12	7.41	-	-	-	41.90
straight truck	food delivery	1.27	4.10	14.88	6.97	-	-	-	52.78
straight truck	food delivery	3.45	5.80	16.98	1.22	-	-	-	52.51
straight truck	food delivery	2.42	1.72	10.10	5.23	-	-	-	41.46
straight truck	food delivery	4.85	2.39	17.19	13.99	0.11	-	-	70.13
straight truck	food delivery	4.13	3.39	8.91	2.73	-	-	-	42.00
straight truck	food delivery	1.89	4.23	13.85	8.64	0.13	-	-	53.46
straight truck	food delivery	1.66	5.42	14.64	6.00	-	-	-	52.35
straight truck	food delivery	2.28	0.97	11.23	4.96	-	-	-	41.18
straight truck	food delivery	4.13	2.74	18.52	10.63	-	-	-	68.58
straight truck	food delivery	2.69	2.16	11.33	6.56	0.02	-	-	45.80
straight truck	food delivery	4.74	2.17	7.59	3.93	-	-	-	42.25
straight truck	food delivery	2.30	4.18	16.18	6.79	0.16	-	-	53.03
straight truck	food delivery	2.81	5.83	15.74	3.65	-	-	-	52.20
straight truck	food delivery	3.26	2.46	10.66	3.42	-	-	-	41.32
straight truck	food delivery	5.39	5.16	17.18	10.91	0.07	-	-	69.59
straight truck	food delivery	3.47	2.47	8.96	5.92	-	-	-	42.54
straight truck	food delivery	2.25	1.96	5.52	12.49	10.21	-	-	49.66
straight truck	food delivery	0.68	0.28	2.53	5.33	5.53	-	-	18.10
straight truck	food delivery	0.78	0.77	1.21	5.63	4.88	-	-	26.78
straight truck	food delivery	2.03	1.75	12.61	5.68	1.57	-	-	36.05
straight truck	food delivery	4.30	3.50	3.20	5.52	0.80	-	-	38.14
straight truck	food delivery	3.96	1.10	2.42	5.52	5.99	-	-	38.90
straight truck	food delivery	2.15	2.62	5.05	12.80	9.96	-	-	49.61
straight truck	food delivery	2.44	0.62	3.12	4.96	6.37	-	-	39.23
straight truck	food delivery	2.18	1.13	2.32	5.48	5.66	-	-	40.52
straight truck	food delivery	0.55	1.03	4.91	10.85	10.34	-	-	42.78
straight truck	food delivery	1.93	1.89	7.02	4.41	1.10	-	-	38.90
straight truck	food delivery	1.19	1.79	3.30	7.15	3.97	-	-	40.38

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	4.27	1.07	2.17	6.34	7.83	-	-	40.03
straight truck	food delivery	2.38	0.60	3.08	5.91	5.57	-	-	39.29
straight truck	food delivery	2.77	0.76	3.05	6.03	7.02	-	-	40.42
straight truck	food delivery	1.63	2.86	7.99	13.33	1.75	-	-	51.12
straight truck	food delivery	2.42	2.06	3.79	8.05	2.36	-	-	40.42
straight truck	food delivery	1.87	1.74	7.47	7.71	-	-	-	40.50
straight truck	food delivery	1.02	5.17	10.84	6.16	0.24	-	-	34.76
straight truck	food delivery	2.72	4.91	1.60	1.05	0.14	-	-	31.77
straight truck	food delivery	1.81	0.76	4.90	10.27	7.61	-	-	42.15
straight truck	food delivery	2.73	1.00	2.99	7.70	3.46	-	-	39.72
straight truck	food delivery	1.19	0.16	2.50	5.59	1.73	-	-	34.36
straight truck	food delivery	2.31	2.46	5.94	6.80	1.50	-	-	40.42
straight truck	food delivery	2.52	0.53	2.84	5.93	5.68	-	-	39.32
straight truck	food delivery	2.22	3.62	3.95	10.79	12.04	-	-	49.63
straight truck	linen delivery	3.59	2.62	5.23	13.89	10.73	1.18	-	57.11
straight truck	linen delivery	3.22	3.71	5.19	14.45	9.34	0.59	-	55.00
straight truck	linen delivery	3.02	3.58	3.99	14.64	11.16	0.88	-	58.08
straight truck	linen delivery	3.61	3.51	4.07	14.60	12.32	1.13	-	52.90
straight truck	linen delivery	3.64	4.52	5.07	12.30	12.56	0.88	-	56.22
straight truck	linen delivery	2.98	3.80	3.17	16.15	11.22	1.31	-	55.89
straight truck	linen delivery	3.31	4.41	6.01	13.91	9.47	0.65	-	53.49
straight truck	linen delivery	3.82	4.50	5.38	15.78	8.29	0.22	-	59.75
straight truck	linen delivery	2.21	3.45	5.02	14.67	11.80	0.93	-	53.50
straight truck	linen delivery	3.23	4.06	5.37	13.65	11.18	0.75	-	56.71
straight truck	linen delivery	4.69	6.19	9.63	21.62	19.12	0.70	-	90.83
straight truck	linen delivery	1.17	1.47	3.02	9.46	12.96	-	-	35.54
straight truck	linen delivery	4.02	2.77	4.45	14.37	10.14	1.04	0.08	53.74
straight truck	linen delivery	5.73	5.57	5.67	17.42	13.43	1.11	-	77.70
straight truck	linen delivery	6.83	6.73	7.74	17.49	9.12	0.74	0.13	74.73

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	linen delivery	4.55	7.31	8.37	18.26	9.01	0.72	0.17	82.71
straight truck	linen delivery	9.11	11.01	11.41	9.49	2.30	0.18	-	76.22
straight truck	linen delivery	5.20	5.78	9.45	9.50	2.48	0.26	-	61.64
straight truck	linen delivery	6.46	8.44	8.51	12.02	10.87	0.76	-	71.57
straight truck	warehouse delivery	5.71	12.39	4.44	0.30	-	-	-	48.17
straight truck	warehouse delivery	5.19	7.79	5.51	3.58	0.71	-	-	52.39
straight truck	warehouse delivery	2.81	2.87	0.18	-	-	-	-	35.36
straight truck	warehouse delivery	0.88	0.98	3.10	0.50	-	-	-	44.23
straight truck	food delivery	3.31	15.14	17.67	1.68	-	-	-	52.77
straight truck	food delivery	4.09	10.93	15.73	1.89	-	-	-	51.48
straight truck	food delivery	3.42	10.61	23.97	1.72	-	-	-	51.53
straight truck	food delivery	4.36	7.56	23.01	3.01	-	-	-	51.73
straight truck	food delivery	1.63	8.19	21.11	7.90	0.18	-	-	51.61
straight truck	food delivery	1.84	5.67	23.78	9.48	0.16	-	-	51.57
straight truck	food delivery	2.33	6.72	27.60	2.36	-	-	-	51.48
straight truck	food delivery	1.97	14.56	21.56	1.95	-	-	-	51.41
straight truck	food delivery	1.82	5.50	22.49	8.11	-	-	-	51.90
straight truck	food delivery	3.02	9.07	21.85	2.84	-	-	-	51.58
straight truck	food delivery	5.05	13.05	19.52	0.13	-	-	-	51.86
straight truck	food delivery	2.69	7.30	24.68	5.27	0.04	-	-	52.14
straight truck	food delivery	1.80	3.43	20.33	13.70	0.15	-	-	51.73
straight truck	food delivery	4.32	13.10	22.63	0.84	-	-	-	51.66
straight truck	food delivery	4.67	16.95	18.86	0.15	-	-	-	51.53
straight truck	food delivery	3.92	8.85	26.67	8.20	-	-	-	64.22
straight truck	food delivery	2.44	4.48	21.20	0.82	-	-	-	43.07
straight truck	food delivery	2.65	5.19	21.76	0.39	-	-	-	44.05
straight truck	food delivery	1.39	3.95	24.21	0.44	-	-	-	42.87
straight truck	food delivery	2.63	12.76	28.71	0.22	-	-	-	66.32
straight truck	food delivery	1.46	3.64	9.68	-	-	-	-	22.82

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	5.81	15.23	34.93	0.13	-	-	-	78.83
straight truck	food delivery	1.71	2.75	25.36	0.07	-	-	-	43.71
straight truck	food delivery	0.94	4.18	25.21	-	-	-	-	43.62
straight truck	food delivery	2.10	2.39	1.49	-	-	-	-	21.47
straight truck	food delivery	3.74	1.52	1.77	-	-	-	-	21.72
straight truck	food delivery	1.03	2.04	2.95	-	-	-	-	20.44
straight truck	food delivery	4.08	1.64	0.81	-	-	-	-	20.17
straight truck	food delivery	1.88	1.90	1.66	-	-	-	-	20.16
straight truck	food delivery	2.25	1.49	2.55	-	-	-	-	20.09
straight truck	food delivery	2.07	0.84	2.92	-	-	-	-	22.14
straight truck	food delivery	3.01	8.77	10.59	1.22	-	-	-	41.49
straight truck	food delivery	2.21	4.42	9.89	6.79	0.60	-	-	41.27
straight truck	food delivery	1.58	3.05	5.51	4.97	-	-	-	37.72
straight truck	food delivery	2.43	3.98	7.70	1.38	0.11	-	-	35.63
straight truck	food delivery	1.33	2.29	8.13	11.24	2.93	-	-	41.09
straight truck	food delivery	1.21	1.25	11.04	16.38	0.31	-	-	42.48
straight truck	food delivery	0.90	2.90	14.80	8.82	2.19	-	-	42.62
straight truck	food delivery	1.25	1.61	8.54	11.56	1.42	-	-	40.72
straight truck	food delivery	1.86	4.82	8.13	8.54	0.56	-	-	41.96
straight truck	food delivery	1.53	1.86	6.24	4.68	0.51	-	-	35.75
straight truck	food delivery	1.79	4.38	17.83	10.25	0.13	-	-	61.56
straight truck	food delivery	1.18	3.20	12.90	9.80	1.87	-	-	43.06
straight truck	food delivery	1.22	2.40	15.45	11.07	0.22	-	-	42.36
straight truck	food delivery	2.06	2.15	10.13	12.07	0.85	-	-	48.70
straight truck	food delivery	1.11	1.80	9.62	11.05	1.20	-	-	41.01
straight truck	food delivery	1.97	3.66	10.84	10.49	0.42	-	-	49.14
straight truck	food delivery	1.23	3.19	5.94	11.90	9.16	-	-	49.65
straight truck	food delivery	3.09	2.49	6.82	8.35	4.96	-	-	40.33
straight truck	food delivery	2.17	3.39	7.06	5.44	0.38	-	-	40.06

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	2.35	3.46	14.00	7.07	0.15	-	-	46.82
straight truck	food delivery	1.87	0.72	3.14	9.71	7.22	-	-	40.81
straight truck	food delivery	1.88	2.39	6.03	13.11	8.68	-	-	49.68
straight truck	food delivery	1.53	1.55	5.52	11.35	8.39	-	-	46.28
straight truck	food delivery	2.14	2.48	9.39	3.60	0.79	-	-	29.80
straight truck	food delivery	0.75	2.89	3.14	3.55	6.79	-	-	29.81
straight truck	food delivery	2.17	2.38	3.76	10.79	23.56	0.06	-	61.14
straight truck	food delivery	1.68	1.43	3.29	7.65	5.09	-	-	30.45
straight truck	food delivery	1.15	1.52	3.43	7.50	4.89	-	-	30.44
straight truck	food delivery	1.87	1.49	4.87	7.46	2.95	-	-	29.82
straight truck	food delivery	1.68	2.92	9.57	6.07	0.32	-	-	36.13
straight truck	food delivery	2.06	4.90	7.71	3.43	-	-	-	29.97
straight truck	food delivery	1.56	1.67	7.30	7.53	-	-	-	29.86
straight truck	food delivery	1.95	2.57	5.56	6.48	0.87	-	-	31.31
straight truck	food delivery	0.98	1.70	6.01	8.76	-	-	-	30.92
straight truck	food delivery	1.90	2.24	7.39	5.78	-	-	-	30.87
straight truck	food delivery	1.77	1.13	5.24	10.33	0.04	-	-	29.84
straight truck	food delivery	3.94	4.15	10.61	15.96	0.97	-	-	56.80
straight truck	food delivery	1.46	2.84	3.51	9.65	0.59	-	-	33.18
straight truck	food delivery	3.51	2.92	4.60	6.16	0.24	-	-	35.29
straight truck	food delivery	5.25	4.06	4.69	3.52	0.05	-	-	39.83
straight truck	food delivery	3.64	5.25	6.04	2.80	0.05	-	-	35.15
straight truck	food delivery	2.69	4.33	6.97	4.38	-	-	-	34.88
straight truck	food delivery	1.90	2.83	7.29	11.81	0.44	-	-	36.42
straight truck	food delivery	1.46	4.61	5.98	7.49	0.20	-	-	36.10
straight truck	food delivery	4.35	4.50	8.68	4.80	0.07	-	-	40.62
straight truck	food delivery	3.36	3.12	6.52	4.15	-	-	-	39.04
straight truck	food delivery	4.63	4.85	6.30	2.32	-	-	-	39.76
straight truck	food delivery	3.73	4.70	5.47	4.21	-	-	-	48.50

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	3.96	4.24	6.35	2.98	-	-	-	39.64
straight truck	food delivery	2.58	3.58	7.54	5.91	0.07	-	-	37.55
straight truck	food delivery	2.01	2.69	7.98	6.72	-	-	-	36.36
straight truck	food delivery	2.46	3.36	9.56	2.10	-	-	-	35.35
straight truck	food delivery	5.06	2.29	5.90	4.47	-	-	-	36.00
straight truck	food delivery	1.89	3.42	8.69	2.12	-	-	-	35.03
straight truck	food delivery	-	-	-	-	-	-	-	9.93
straight truck	food delivery	-	-	-	-	-	-	-	9.28
straight truck	food delivery	-	-	-	-	-	-	-	12.99
straight truck	food delivery	-	-	-	-	-	-	-	17.57
straight truck	food delivery	-	-	-	-	-	-	-	17.73
straight truck	food delivery	-	-	-	-	-	-	-	14.18
straight truck	food delivery	-	-	-	-	-	-	-	10.97
straight truck	food delivery	-	-	-	-	-	-	-	10.63
straight truck	food delivery	-	-	-	-	-	-	-	9.27
straight truck	food delivery	-	-	-	-	-	-	-	13.18
straight truck	food delivery	-	-	-	-	-	-	-	9.23
straight truck	food delivery	-	-	-	-	-	-	-	9.84
straight truck	food delivery	-	-	-	-	-	-	-	10.11
straight truck	food delivery	-	-	-	-	-	-	-	10.22
straight truck	food delivery	-	-	-	-	-	-	-	11.38
straight truck	food delivery	1.57	2.30	19.82	-	-	-	-	40.61
straight truck	food delivery	4.74	2.17	14.51	0.26	-	-	-	39.93
straight truck	food delivery	1.68	2.39	24.73	0.12	-	-	-	44.69
straight truck	food delivery	2.12	5.11	17.88	-	-	-	-	41.50
straight truck	food delivery	2.23	2.44	25.42	-	-	-	-	46.32
straight truck	food delivery	2.43	3.58	27.38	-	-	-	-	49.68
straight truck	food delivery	2.51	1.85	14.08	-	-	-	-	39.32
straight truck	food delivery	2.36	2.25	21.89	-	-	-	-	41.73

Truck Type	Vocation	distance 45 to 50 mph	distance 50 to 55 mph	distance 55 to 60 mph	distance 60 to 65 mph	distance 65 to 70 mph	distance 70 to 75 mph	distance 75+ mph	Total Distance
straight truck	food delivery	1.70	1.93	25.44	-	-	-	-	44.88
straight truck	food delivery	2.97	6.16	9.00	-	-	-	-	34.95
straight truck	food delivery	1.38	2.23	11.33	0.29	-	-	-	33.56
straight truck	food delivery	2.20	1.76	11.79	0.79	0.11	-	-	34.03
straight truck	food delivery	0.92	2.34	11.93	0.08	-	-	-	29.87
	Total:	1,487.33	2,200.98	4,803.33	3,342.49	1,123.74	30.75	0.38	23,941.65
	Percentage of distance that delivery trucks travelling at 45mph and above (%):								54.25

Attachment 3

Potential Fuel Consumption Reductions via Use of Aerodynamic Devices for Medium-Heavy Duty Vehicles in CARB's EMFAC 2014 Database

Potential Fuel Consumption Reductions via Use of Aerodynamic Devices for Medium-Heavy Duty Vehicles in CARB's EMFAC 2014 Database

	Chassis Skirt (%)		Front Fairing (%)		Front Fairing + Chassis Skirt (%)		Rear Fairing (%)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Potential FCR, depending on speed*	5.20%	6.10%	5.00%	6.90%	10.30%	10.40%	2.70%	3.80%
Total potential FCR for Medium- heavy duty instate trucks**	2.90%	3.40%	2.79%	3.84%	5.74%	5.79%	1.50%	2.12%
Total Potential FCR for Medium- heavy out-of-state trucks***	3.09%	3.62%	2.97%	4.10%	6.11%	6.17%	1.60%	2.26%

*See Table 8 of the Draft National Renewable Energy Laboratory Aerodynamic Drag Reduction Technologies Testing for Heavy-Duty Vocational Vehicles – Preliminary Results (Attachment 1)
**Assumming 55.70% is the percentage distance travelling at 45 mph and above from "Medium-Heavy Duty Diesel Instate Trucks' Vehicle Miles Traveled as Function of Speed" Table
***Assumming 59.36% is the percentage distance travelling at 45 mph and above from "Medium-Heavy Duty Diesel Out-of-State Trucks' Vehicle Miles Traveled as Function of Speed" Table

MEDIUM-HEAVY DUTY DIESEL INSTATE TRUCKS' VEHICLE MILES TRAVELED AS FUNCTION OF SPEED

EMFAC2014 (v1.0.7) Emissions Inventory
Region Type: Statewide
Region: California
Calendar Year: 2014
Season: Annual
Vehicle Classification: EMFAC2011 Categories
Units: miles/day for VMT

Region	Calendar Year	Vehicle Class	Speed	VMT (vehicle miles traveled)
Statewide	2014	T6 instate small	5	35618.59396
Statewide	2014	T6 instate small	10	168113.3427
Statewide	2014	T6 instate small	15	239877.7315
Statewide	2014	T6 instate small	20	333206.319
Statewide	2014	T6 instate small	25	497172.3676
Statewide	2014	T6 instate small	30	656090.1952
Statewide	2014	T6 instate small	35	669323.7883
Statewide	2014	T6 instate small	40	754613.0066
Statewide	2014	T6 instate small	45	713372.2958
Statewide	2014	T6 instate small	50	742117.913
Statewide	2014	T6 instate small	55	927463.4201
Statewide	2014	T6 instate small	60	1220441.788
Statewide	2014	T6 instate small	65	536957.8169
Statewide	2014	T6 instate small	70	76624.42044
Statewide	2014	T6 instate small	75	0
Statewide	2014	T6 instate small	80	0
Statewide	2014	T6 instate small	85	0
Statewide	2014	T6 instate small	90	0
		Percentage 45mph and above		55.70%

Note: T6 instate small means Medium-Heavy Duty Diesel instate Truck with GVWR<=26000 lbs

MEDIUM-HEAVY DUTY DIESEL OUT-OF-STATE TRUCKS'S VEHICLE MILES TRAVELED AS FUNCTION OF SPEED

EMFAC2014 (v1.0.7) Emissions Inventory
Region Type: Statewide
Region: California
Calendar Year: 2014
Season: Annual
Vehicle Classification: EMFAC2011 Categories
Units: miles/day for VMT

Region	Calendar Year	Vehicle Class	Speed	VMT (vehicle miles traveled)
Statewide	2014	T6 OOS small	5	400.9294675
Statewide	2014	T6 OOS small	10	1954.592387
Statewide	2014	T6 OOS small	15	2702.416901
Statewide	2014	T6 OOS small	20	3279.502956
Statewide	2014	T6 OOS small	25	4211.773408
Statewide	2014	T6 OOS small	30	5437.230627
Statewide	2014	T6 OOS small	35	5907.688126
Statewide	2014	T6 OOS small	40	7233.799101
Statewide	2014	T6 OOS small	45	6440.767483
Statewide	2014	T6 OOS small	50	6790.837776
Statewide	2014	T6 OOS small	55	9292.983478
Statewide	2014	T6 OOS small	60	11880.06838
Statewide	2014	T6 OOS small	65	6058.964833
Statewide	2014	T6 OOS small	70	5004.622869
Statewide	2014	T6 OOS small	75	0
Statewide	2014	T6 OOS small	80	0
Statewide	2014	T6 OOS small	85	0
Statewide	2014	T6 OOS small	90	0
		Percentage 45mph and above		59.36%

Note: T6 OOS small means Medium-Heavy Duty Diesel out-of-state Truck with GVWR<=26000 lbs

Attachment 4

ACTIVE AND PLANNED FUEL CELL ELECTRIC VEHICLES DEMONSTRATIONS

Attachment 4

Active and Planned Fuel Cell Electric Vehicles Demonstrations

This attachment summarizes existing and planned fuel cell electric vehicles demonstration programs in the United States (U.S.) as of summer 2015. Various initiatives have supported demonstration of fuel cell technology in medium- and heavy-duty vehicle applications. Since 1991, over 300 fuel cell electric buses have been deployed worldwide (NREL, 2015; Fuel Cells, 2013; ARB, 2015). These demonstration programs have supported development of the technology and vehicle design. Additional information about medium- and heavy-duty fuel cell vehicle demonstrations, performance, and anticipated future applications will be included in ARB's Draft Technology Assessment: Medium- and Heavy-Duty Fuel Cell Electric Vehicles, which will be posted at http://www.arb.ca.gov/msprog/tech/report.htm.

Today, in the U.S., over twenty fuel cell electric buses with series hybrid configuration are being demonstrated. The fuel cell electric vehicle drivetrain is similar (or sometimes identical) to a conventional internal combustion hybrid drivetrain, in which the fuel cell system replaces the engine and the hydrogen tank replaces the conventional fuel tank. Their operation and performance is comparable to conventional buses (NREL, 2013). Fuel cell electric bus costs have come down substantially over the last decade, but they still remain expensive as compared to conventional vehicles. Section I below provides more information regarding transit bus demonstrations, and Section II discusses shuttle bus demonstrations.

Recent demonstration funding for medium- and heavy-duty fuel cell electric vehicles has expanded from transit buses to trucks and vans. To date, more than 40 fuel cell electric trucks, including package delivery and drayage, have been or are planned to be demonstrated in the U.S. (DOE, 2013). Performance for these vehicles will be better understood as fuel cell electric trucks are put into operation in daily service, allowing for characterization of their real world performance. The demonstration and deployment of fuel cell electric short-haul trucks and vans is essential for commercializing fuel cell technology in other on-road medium- and heavy-duty applications outside of transit service. Section III below provides more information regarding heavy-duty fuel cell electric truck demonstrations.

I. Transit Bus

This section discusses transit bus fuel cell demonstrations. Active demonstrations are discussed in subsection A. Planned demonstrations with buses not yet put into service are discussed in subsection B.

A. Active Transit Bus Demonstrations

In the U.S. today, over twenty fuel cell buses are currently in service. Table 1 lists the location and transit bus operator of active fuel cell electric bus demonstrations.

Table 1: Active fuel cell electric bus demonstrations in the U.S.

Bus Operator	Location	Total Buses
Zero Emission Bay Area (ZEBA)	San Francisco Bay Area, CA	12
SunLine Transit	Thousand Palms, CA	5
University of Delaware	Newark, DE	1
Greater New Haven Transit District	New Haven, CT	1
Birmingham-Jefferson County Transit Authority	Birmingham, AL	1
Flint Mass Transportation	Flint, MI	2
Anteater Express (UC Irvine)	Irvine, CA	1
Capital Metro	Austin, TX; Washington, DC	1
	Total	**24**

(NREL, 2015)

As part of the demonstrations listed in the table above, the National Renewable Energy Laboratory (NREL) has been tasked by Federal Transit Administration (FTA) and U.S. Department of Energy's (DOE) Fuel Cell Technologies Office to collect and analyze data on the fuel cell electric buses in service. NREL has published evaluation reports on fuel cell electric buses since 2003 and provides a public directory to these publications on its Hydrogen & Fuel Cell Research webpage (NREL, 2015). The most extensively analyzed fuel cell electric bus fleets are those of SunLine Transit and ZEBA, both of which are showing availability and durability comparable to conventional buses (NREL, 2014). A summary of the bus demonstrations listed above is described in greater detail below:

ZEBA

The ZEBA Program currently manages the largest active fuel cell dominant fuel cell electric bus fleet in the country. Alameda-Contra Costa Transit founded the program in 2006 in partnership with four major San Francisco Bay Area transit agencies: Golden Gate Transit, San Francisco Municipal Transportation Agency, San Mateo County Transit District, and Santa Clara Valley Transportation Authority. The demonstration project was a means for the participating transit agencies to comply with California Air Resources Board's Fleet Rule for Transit Agencies. The first phase of the demonstration project included three Van Hool fuel cell hybrids with a UTC Power (now under ownership of U.S. Fuel Cell) fuel cell system and hybrid electric drive system designed by ISE Corporation. The second phase of the demonstration, started in 2010, included twelve second generation buses. However, the original fuel cell systems run in the first phase of the demonstration were transferred to three of the twelve newer generation buses (NREL, 2013). An additional Van Hool fuel cell electric bus of identical configuration was transferred from the CTTRANSIT Nutmeg Project (refer below to Flint Mass Transportation*)* to the ZEBA fuel cell electric bus fleet in 2014. A thirteenth fuel cell electric bus may be added in the future.

SunLine Transit

SunLine Transit currently has five active fuel cell dominant fuel cell electric buses in its fleet in Thousand Palms, California. A New Flyer bus with a Ballard fuel cell system and hybrid electric drive system designed by ISE Corporation was put into service in 2010. The remaining four fuel cell electric buses currently operating at SunLine are the "American Fuel Cell Bus" model, which is an El Dorado National bus with a Ballard fuel cell system and BAE Systems hybrid electric drive system (NREL, 2013). These four buses were funded by different sources and delivered separately (NREL, 2013).

University of Delaware

The University of Delaware has two 22-foot battery dominant plug-in fuel cell hybrid buses in Newark. The first bus was deployed in 2007 and the second in 2009. The buses are manufactured by EBUS and use a Ballard fuel cell system and nickel-cadmium battery pack. The fuel cell electric buses are used on campus to shuttle students, as well as for academic research (University of Delaware, 2015). Currently, one of the buses is out of service, with the remaining one bus still in active service.

Greater New Haven Transit District

In 2011, Greater New Haven Transit District is operating a plug-in 22-foot battery dominant fuel cell electric bus (Connecticut, 2011a). The fuel cell electric bus uses a Ballard fuel cell system provides shuttle and paratransit service, in addition to regular revenue operations (Connecticut, 2011b). This bus is still operating in south central Connecticut (NREL, 2014).

Birmingham-Jefferson County Transit Authority

The Birmingham-Jefferson County Transit Authority is operating a 30-foot battery dominant fuel cell electric bus in Birmingham, Alabama as part of a two-year demonstration starting in 2014 (NREL, 2014). The fuel cell electric bus is using a state-of-the-art lithium titanate battery system during its first year of operation and then will use advanced lead-acid battery pack during its second year (CTE, 2015). The alternation between battery systems is to demonstrate and evaluate two different battery technologies in one application to provide an accurate and direct comparison.

Flint Mass Transportation

The first fuel cell electric bus operated by Flint Mass Transportation originally came from the demonstration of four fuel cell dominant fuel cell electric buses in Hartford, Connecticut that started in 2010 and ended in 2013 (also known at the Nutmeg fuel cell electric bus demonstration). The fuel cell electric buses are configured identically to the fuel cell electric buses for the ZEBA demonstration project. The Van Hool buses, however, were not integrated by ISE Corporation, but by the OEM itself. Only one of the four buses demonstrated was retained for transit service beyond the demonstration period by Flint Mass Transportation in Flint, Michigan. The remaining three have been transferred to three different entities. One bus was sold to North Augusta, South Carolina for demonstration purposes, one bus was shipped to California to join the ZEBA fuel cell electric bus fleet, and the last bus is being used by U.S. Hybrid for fuel cell research and development (NREL, 2013).

Flint Mass Transportation received a second fuel cell electric bus in summer of 2015 funded by the TIGGER program. The bus is an American Fuel Cell Bus model, manufactured by El Dorado National with a Ballard fuel cell system and BAE Systems hybrid electric drive system.

Anteater Express (University of California (UC), Irvine)

The student bus service at UC Irvine, the Anteater Express, is operating a fuel cell dominant "American Fuel Cell Bus," which is manufactured by El Dorado National with a Ballard fuel cell system and BAE Systems hybrid electric drive system. UC Irvine students will drive, ride and participate in research on the fuel cell bus.

Capital Metro

Capital Metro is operating a 35-foot battery dominant fuel cell electric bus with an advanced composite body. The bus was built by Proterra with a Hydrogenics fuel cell system. The battery-dominant bus is plug-in capable. The bus was first demonstrated in transit service in Columbia, SC, in collaboration with the Central Midlands Regional Transit Authority and the University of South Carolina. Following the demonstration in Columbia, the bus transitioned to Austin, TX, where it will provide a year of transit service with Capital Metro.

B. Planned Transit Bus Demonstrations Summary

There are 22 fuel cell electric buses planned for demonstration through the FTA National Fuel Cell Bus Program (NFCBP) (NREL, 2015). The table below lists the types and number of fuel cell electric buses that are going to be deployed at each location across the U.S.

Table 2: New fuel cell transit buses planned for the FTA NFCBP

Bus Operator	Location	Total Buses
Massachusetts Bay Transportation Authority	Boston, MA	1
San Francisco Municipal Transportation Agency	San Francisco, CA	1
Stark Area Regional Transit Authority	Canton, OH	7
SunLine	Thousand Palms, CA	7
Tompkins Consolidated Transit Authority	Ithaca, NY	1
Hawaii County Mass Transit Agency	Hilo, HI	2
University of Delaware	Newark, DE	2
Advanced Fuel Cell Electric Bus (60-ft articulated) - New Flyer/Siemens (NFCBP-CALSTART)*	TBD	1
	Total	**22**

*Bus Operator TBD
(NREL, 2015)

II. Shuttle Buses

Fuel cell shuttle buses have a similar vehicle platform as fuel cell electric buses. Shuttle buses essentially are shorter and carry less people than a transit bus. This section discusses shuttle bus fuel cell demonstrations. Active demonstrations are discussed in subsection A. Planned demonstrations are discussed in subsection B.

A. Active Shuttle Bus Demonstration

US Air Force Joint Base Pearl Harbor-Hickam, Hawaii

One U.S. Hybrid battery dominant H2Ride Fuel Cell Plug-In Shuttle Bus is currently operating at U.S. Air Force Joint Base Pearl Harbor-Hickam in Hawaii. The 25 passenger shuttle bus uses a 30 kW Hydrogenics fuel cell system.

B. Planned Shuttle Bus Demonstrations

Hawaii County Mass Transit Agency, Hawaii

One U.S. Hybrid battery dominant H2Ride Fuel Cell Plug-In Shuttle Bus will be delivered to the County of Hawaii Mass Transit Agency's HELE-ON Big Island for service. The vehicle is scheduled for deployment in 2015. The vehicle is identical to the shuttle bus operating at U.S. Air Force Joint Base Pearl Harbor-Hickam in Hawaii.

Hawaii County Mass Transit Agency, Hawaii

Two U.S. Hybrid battery dominant H2Ride Fuel Cell Plug-In Shuttle Buses will be delivered and operated at Volcanoes National Park in Hawaii in 2015. The vehicle is also identical to the shuttle bus operating at US Air Force Joint Base Pearl Harbor-Hickam in Hawaii.

III. Fuel Cell Electric Trucks

There are a number of fuel cell electric truck demonstrations planned in the U.S. Currently planned medium- and heavy-duty truck demonstrations are summarized in Table 3.

Table 3: Planned fuel cell electric truck demonstrations in the U.S.

Truck Operator	Vehicle Type	Location	Total Trucks
FedEx	Delivery Truck	Tennessee	20
UPS	Delivery Van	California	17
San Pedro Bay Ports	Drayage	California	5
Port of Houston	Drayage	Texas	3
		Total	**45**

The H2Cargo Fuel Cell Plug-in Step Van

The H2Cargo Fuel Cell Plug-in Step Van, funded by Hawaii Center for Advanced Transportation Technologies, will be delivered to U.S. Air Force Joint Base Pearl Harbor-Hickam in Hawaii in 2015. The Class 4 fuel cell step van (gross vehicle weight rating (GVWR) 14,000 lbs) is planned for package delivery service and cargo transportation. The vehicle includes a 30 kW Hydrogenics fuel cell system.

FedEx Delivery Vans

The U.S. DOE is providing $3 million to fund FedEx Express, Plug Power, and Smith Electric Vehicles to demonstrate 20 hydrogen fuel cell range extenders delivery trucks. Smith Electric Vehicles will add a Plug Power fuel cell to its battery electric vehicle. The vehicles will be powered by lithium-ion batteries and a 10-kilowatt Plug Power hydrogen fuel cell system. The fuel cell solution is based on Plug Power's GenDrive Series 1000 product architecture. The fuel cell will extend the range from 56 to 150 miles. These fuel cell delivery vans will be tested at FedEx facilities in Tennessee and California.

UPS Delivery Vans

UPS is in the process of receiving 17 fuel cell hybrid electric delivery vans that will be deployed in various locations throughout California. U.S. DOE partially funded the demonstration project with $3 million grant. An additional $1.1 million was provided by the California Energy Commission to support the project. South Coast Air Quality Management District (SCAQMD) also provided grant dollars to the project. In partnership with the Center for Transportation and the Environment (CTE), Hydrogenics USA, University of Texas Center for Electromechanics, battery electric vehicle provider, and Valence Technology, the project team will retrofit 17 Class 6 (GVWR 23,000 lbs.) delivery vans with fuel cell hybrid power trains and test these vehicles at distribution facilities across California. The fuel cell range extender is sized at 16 kW.

San Pedro Bay Ports Fuel Cell Electric Vehicle Demonstration Project

In partnership with SCAQMD, the purpose of the San Pedro Bay Ports fuel cell electric vehicle project is to demonstrate, collect data, and analyze zero emission technologies from BAE Systems, Transpower, Inc., and U.S. Hybrid. The total U.S. DOE investment for this demonstration project is approximately $10 million. The five fuel cell range extender drayage trucks funded are described below:

- A Class 8 battery electric drayage truck with a fuel cell range extender is to be demonstrated by CTE and BAE Systems at San Pedro Bay Ports and funded by U.S. DOE amounting to approximately $3.5 million. The platform is provided by Kenworth. The vehicle will use a 100 kW Ballard system and 100 kWh lithium-ion battery. BAE Systems and Ballard Power Systems will leverage their existing hybrid electric fuel cell propulsion system used in transit buses for use in drayage application.

- Transpower will develop two Class 8 battery electric drayage trucks with fuel cell range extenders at San Pedro Bay Ports and funded by U.S. DOE amounting to approximately $1.2 million. For a side-by-side comparison, one drayage truck will use a 30 kW Hydrogenics fuel cell system, and the other will use a 60 kW Hydrogenics fuel cell system with an identical electric drivetrain configuration. Both vehicles will have a 125 kWh lithium-ion battery pack on board.

- U.S. Hybrid is developing two Class 8 battery electric drayage trucks with fuel cell range extenders at San Pedro Bay Ports and funded by U.S. DOE amounting to approximately $1.3 million. The vehicles are to be demonstrated at San Pedro Bay Ports in partnership with SCAQMD and funded by U.S. DOE. The two vehicles will be identical; each vehicle will have an 80 kW fuel cell system and 26 kWh lithium-ion battery system installed.

Port of Houston Drayage Truck

The Houston-Galveston Area Council in partnership with Gas Technology Institute, U.S. Hybrid, Richardson Trucking, Environmental Defense Fund, and the University of Texas Center for Electromechanics, is demonstrating three fuel cell electric drayage trucks at the Port of Houston. U.S. DOE's office of Energy Efficiency and Renewable Energy is providing $3.4 million, with project partners committing more than $3 million to the three-year effort. The project is estimated to cost up to $7.6 million. U.S. Hybrid is converting three Navistar International ProStar day cab tractors (GVWR 80,000 lbs) into fuel cell electric vehicles. The vehicles will use a 320 kW fuel cell system and a 32 kWh battery energy storage system. The fuel cell drayage truck is anticipated to have a range of 200 miles and a top speed of 60 mph. Richardson Trucking will be operating the fuel cell electric vehicles at the port and reporting performance results to U.S. DOE.

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Attachment 5

FREIGHT WING ARC WIND TUNNEL FLATBED TESTING

SUMMARY RESULTS

Some information has been redacted here due to being confidential business information.

Attachment 6

AUTO RESEARCH CENTER CLASS EIGHT

SEMI TRUCK AERODYNAMIC FUEL

ECONOMY COMPONENT TEST

Some information has been redacted here due to being confidential business information.

Attachment 7

CALIFORNIA AIR RESOURCES BOARD'S (CARB)

PORTABLE EMISSIONS MEASUREMENT SYSTEMS

(PEMS) DATA ON 2010 STANDARD TRUCKS –

CARBON DIOXIDE (CO2) EMISSION RATE VS. SPEED

Some information has been redacted here due to being confidential business information.

Attachment 8

ARB LOW NOx PROGRAM

PROGRAM ADVISORY GROUP UPDATE

SOUTHWEST RESEARCH INSTITUTE

Some information has been redacted here due to being confidential business information.