Improvements for Heavy-Duty Engine and Vehicle Test Procedures

Response to Comments

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Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Introduction

The Environmental Protection Agency ("EPA") published a supplemental Notice of Proposed Rulemaking ("NPRM") on June 29, 2021 (86 FR 34189) to propose changes to the test procedures for heavy-duty engines and vehicles to improve accuracy through additional amendments for certain aspects of the modeling parameters in the Greenhouse gas Emissions Model ("GEM").

This action amends the regulations that implement our air pollutant emission standards for heavy-duty engines and vehicles. The amendments in this final rule include corrections, clarifications, additional flexibilities, and adjustment factors to the GEM compliance tool for heavy-duty vehicles. These amendments modify the existing test procedures for heavy-duty highway engines and vehicles and apply to the measurement of CO_2 emissions.

This Response to Comments contains a detailed summary of the comments we received on the supplemental NPRM as well as our analysis and response to the comments. The supplemental Final Rulemaking ("FRM") published in the Federal Register includes the final regulations resulting from this rulemaking, along with further description and rationale for our conclusions.

List of Commenters

Commenter	Docket ID
Anonymous public comment	EPA-HQ-OAR-2019-0307-0101
REV Group, Inc.	EPA-HQ-OAR-2019-0307-0102
Allison Transmission, Inc.	EPA-HQ-OAR-2019-0307-0103
Truck and Engine Manufacturers Association ("EMA")	EPA-HQ-OAR-2019-0307-0104

List of Acronyms

Acronym	Definition
CFR	Code of Federal Regulations
CO_2	Carbon Dioxide
EPA	Environmental Protection Agency
FEL	Family Emission Limit
FR	Federal Register
FRM	Final Rulemaking
GEM	Greenhouse Gas Emissions Model
MY	Model Year
MPH	Miles-per-hour
NPRM	Notice of Proposed Rulemaking
V	Version (e.g., "V3.8" means GEM version 3.8)

1.1 General Support or Opposition

Comment	Response
From: Anonymous public comment The improvements to the greenhouse gas emissions model (GEM) seems to be the right direction to go when assessing the CO_2 standards for heavy-duty vehicles. By taking the existing test procedures and making modifications to the way CO_2 measurements are measured, the model will better be able to capture how efficiently fuel is being used. The GEM model is a tool that will help determine fuel efficiency and the changes in the 3.7 model will make all the difference. In the 3.8 model the changes to the torque inputs and the adjustments to the idle fueling and the input value for neutral coasting are both that will be necessary to upgrade the model to where it needs to be.	The comment generally affirms the proposed rule.

1.2 Use of GEM 3.5.1 for Model Year 2021

Comment	Response
From: EMA GHG Phase 2 rule became effective with model year ("MY") 2021 and, since that MY has begun, it may not be feasible for manufacturers to utilize GEM V3.8 for certification and compliance to the rule. We therefore support the proposal in the SNPRM to allow manufacturers the option of using the previous GEM version, V3.5.1, for demonstrating compliance to the GHG Phase 2 standards for MY 2021 vehicles.	We have finalized provisions intended to provide appropriate flexibility to transition to a revised version of GEM, see Section III.B. of the preamble "Allowable version of GEM for certification and compliance" for more details.

1.3 Concerns with GEM 3.5.1 and GEM 3.8 for Custom Chassis Applications

Comment	Response
From: REV Group, Inc. The subject NPRM proposes to make corrections and add adjustment factors to the EPA Greenhouse Gas Emissions Model (GEM) to improve this compliance tool for heavy-duty vehicles while more closely matching the outputs produced by the original GEM version 3.0 that was used to establish the CO_2 standards for model years 2021 and later in the 2016 Heavy-duty Phase 2 Final Rule. REV Group business units utilized the provisions in 40 CFR 1037.105(h) for custom chassis certification in the other bus and emergency vehicle categories and prepared MY21certification applications using GEM V3.0. However, when these business units subsequently ran the same configurations using GEM 3.5.1, FEL results were an average of 3.6% higher than GEM 3.0. When the business units ran the same configurations using GEM 3.8, FEL results were an average of 3.8% higher than GEM 3.0. REV Group requests that EPA staff look into this issue and add adjustment factors for the custom chassis other bus and emergency vehicle categories to GEM 3.8 that would result in achieving the stated intent of this NPRM	We agree with the comment that GEM 3.5.1 gives different results for custom chassis vehicles than with GEM 3.0, and we have made multiple changes to GEM that are included in GEM 4.0 to align the custom chassis results with the results from GEM 3.0. The first of these changes was to align the default engine fuel maps used for custom chassis vehicles between the two version of GEM. The second change that was made was including adjustment factors in GEM 4.0 to more closely match the outputs produced by the same vehicle configurations when using the original GEM version 3.0 (GEM 3.0 was used in the 2016 Heavy-duty Phase 2 Final Rule to establish the CO_2 standards for model years 2021 and later.)
From: Allison Transmission Inc. Regarding EPA's improvement to correct how GEM adjusts the idle fueling of the transient cycle, Allison is concerned that EPA did not achieve the outcome that they expected for the Custom Chassis category. For this improvement, EPA used correction factors to adjust the FEL scores in GEM 3.8. Allison's understanding is that the goal is to adjust FEL scores to be closer to GEM 3.0 values. Allison staff analyzed the results using GEM 3.8 with the correction factors and found that the results in Custom Chassis category were unfavorable. The unfavorable outcome was especially noticeable in the Refuse and Other Bus applications and even resulted in an adverse impact in the School Bus application. The Refuse and Other Bus FEL values were only slightly improved. The School Bus FEL values were worse. Please refer to plots in Appendix A.	

1.4 Concerns with GEM 3.8 Adjustment Factors

Comment	Response
From: Allison Transmission Inc. As Allison has stated in earlier comments of October 1, 2015, transit buses are disadvantaged in GEM because transit buses operate in urban areas and have a duty cycle of frequent starts and stops, with no 65 mph operation and very limited 55 mph operation so the current vocational test cycle does not represent how they operate. And, we are learning from transit bus OEM customers that it is challenging to determine a compliance path. The Custom Chassis option was supposed to offer flexibility for specialty OEMs. Now, further compounding the challenge is the unexpected outcome of the proposed correction factors. Allison recommends that EPA re-evaluate the GEM 3.8 fix using correction factors, especially for the Custom Chassis category. Additionally, Allison recommends EPA consider a special category in GEM for transit buses.	We recognize that GEM utilizes a fixed set of drive cycles and limited number of duty cycle weights. The Urban weighting of 90% ARB Transient and 10% 55 mph cruise is not too far off the operation described. The custom chassis "other bus" category uses the same weighting factors that are used in the Urban category. The included Adjustment Factors in GEM 4.0, that are described in Section III of the Preamble, were determined so that the outputs of GEM 4.0 more closely match the outputs produced by the original GEM version 3.0 (GEM 3.0 was used to establish the vocational and custom chassis CO_2 standards for model years 2021 and later in the 2016 Heavy-duty Phase 2 Final Rule.) Therefore, the results from GEM 4.0 for transit buses should be comparable to the same vehicles run in GEM 3.0.

1.5 Improving the accuracy of GEM 3.8

Comment	Response
From: EMA GEM is required to model CO_2 emissions to show compliance with the vehicle standards in the Greenhouse Gas ("GHG") Phase 2 rule, and the SNPRM proposes GEM improvements and adjustment factors for GEM results. The SNPRM proposes to incorporate the changes in a new version of GEM, V3.8. We appreciate the collaborative approach the Agency has taken toward improving GEM and offer these comments in that same constructive spirit. GEM is a sophisticated compliance tool that models the CO_2 emissions and fuel consumption of a vehicle over the speeds and loads in prescribed duty cycles. GEM also must accurately simulate real-world operation of a vehicle and accurately assess the impacts of different engine and vehicle fuel-saving technologies. Since trucking fleets place a high value on fuel consumption performance when purchasing a new commercial vehicle, the technologies that manufacturers develop must perform effectively in-use and show an equivalent benefit in GEM. Otherwise, there would be a disconnect between the real-world performance of fuel-saving technologies and technologies that show a CO_2 and fuel consumption benefit in GEM. Accordingly, we support EPA's efforts to refine GEM, and we believe that incorporating the following proposed changes in GEM V3.8 will enhance the accuracy of the model • Changed limits on engine input to allow small negative torque inputs. • Corrected how GEM adjusts the idle fueling of the transient cycle by using the same idle duration time both for subtracting the idle fuel rate from the transient cycle average engine fuel map and for adding back in the simulated idle fuel rate. • Added an option for vocational vehicles to input a value for neutral coasting in GEM and amend the related test procedure in 40 CFR 1037.520(j)(1). • Corrected manual and automated manual transmissions to perform clutched upshifts for Heavy HDV.	We agree with all of the changes to GEM that EMA suggested in their comments to improve the accuracy of the model. These changes are incorporated in GEM 4.0 and are described in Section III.A. of the Preamble.

1.6 Adjustment Factors

Comment	Response
From: EMA ***Adjustment Factor Calculations*** The SNPRM proposes adjustment factors to the GEM V3.8 results to "ensure that these changes to GEM do not change the effective stringency of the GHG Phase 2 CO_2 standards." See, *id.* at 34,192. ThSe SNPRM proposes that manufacturers apply the adjustment factors to their unrounded GEM V3.8 outputs. However, the process EPA used to determine the proposed adjustment factors included a minor mathematical flaw that negatively affected the results of the calculations. Even though the SNPRM proposes applying the adjustment factors to unrounded GEM V3.8 outputs, and the adjustment factors are carried out to four decimal places, the Agency calculated the adjustment factors using GEM results rounded to the nearest whole number for vocational vehicles and the nearest tenth for tractors. We believe that calculating the adjustment factors using unrounded GEM results would yield more accurate adjustment factors. Accordingly, EPA should recalculate all the proposed adjustment factors using unrounded GEM results and include those more accurate adjustment factors in Table 10 of 40 C.F.R. § 1037.520.	We agree with the comment to calculate adjustment factors from unrounded GEM results. The adjustment factors included in GEM 4.0 have been determined from unrounded results.

Comment	Response
From: EMA ***Applying the Adjustment Factors*** The SNPRM proposes that manufacturers first produce GEM outputs using V3.8 and then modify those results by applying the adjustment factors. Such a two-step process would be resource intensive and wasteful. Moreover, the SNPRM proposes that each manufacturer apply one of the 33 different adjustment factors to each of the multitude of GEM outputs it produces, with the 33 adjustment factors changing with each of the three stringency steps in the rule. Such an after-the-fact application of the myriad and changing adjustment factors is sure to lead to errors. Instead of that burdensome and error-prone approach, EPA should incorporate the adjustment factors into the GEM programming so the computer model will apply the proper adjustment factor before producing a result.	We agree with the comment to include adjustment factors in GEM. GEM 4.0 includes the adjustment factors and applies them to the unrounded composite GEM result before outputting the "Default FEL CO_2 Emissions".
From: EMA ***Adjustment Factors for Tractors with Automatic Transmissions*** As stated before, we endorse the proposal to correct GEM V3.8 programing for clutched upshifts for tractors with manual and automated manual transmissions. The performance of tractors with those transmissions in GEM V3.8 will more closely match real-world operation, with the adjustment factors appropriately increasing the GEM output to align with the GHG Phase 2 stringency values. However, the GEM modification for clutched upshifts does not affect a small but significant number of tractors that are built with automatic transmissions, because those transmissions do not benefit from the clutched upshift change due to their unique design. Thus, the adjustment factors inappropriately increase the GEM V3.8 outputs for those tractors. To correct that error, EPA should set the adjustment factors to zero for tractors with automatic transmissions.	We agree with the comment that the adjustment factor for tractors with automatic transmissions should be set to zero and have included this in GEM 4.0.

1.7 Features of GEM 3.8

Comment	Response
From: EMA ***Input Files Generated with Prior GEM Versions*** GEM V3.8 will not run properly with a fuel map, a transmission power loss map, or a rear axle power loss map that was generated using a prior version of GEM. Reproducing all component input maps using GEM V3.8 would consume tremendous resources and produce nearly identical maps. To avoid unnecessarily wasting time and resources, EPA should modify the GEM V3.8 programing to fully accept component input maps produced with prior versions of GEM. Additionally, EPA must only audit component input maps using the same version of GEM that the manufacturer used to produce the map.	We agree with the comment that GEM should allow input files from previous versions of GEM as long as the inputs are the same. GEM 4.0 allows inputs that were created for prior versions of GEM as long as the input file includes all the inputs needed for GEM 4.0. We agree that EPA will only audit component inputs for fuel maps using the same version of GEM that the manufacturer used to create the input.
From: EMA ***Steady-State Fuel Map Inconsistency*** GEM V3.8 correctly removes from the default steady-state fuel maps points that are below 105% of the maximum speed and 120% of the maximum torque. However, the regulatory text in 40 C.F.R. § 1036.535(d)(2) calls for removing points that are below 115% of the maximum speed and 115% of the maximum torque. EPA should correct the regulatory text.	We agree with the comment that GEM correctly removes from default steady-state fuel map points and as discussed in Section IV of the Preamble we have removed this requirement from 40 CFR 1036.535. We have finalized the removal of the text from 40 CFR 1036.535 because the default fuel maps are now included in GEM starting with version 3.5.1, so the only reason for keeping the regulatory text would be to note what GEM does.
From: EMA ***Transmission Cost Map Error*** GEM V3.8 includes a programming error that affects the generation of transmission cost maps. To correct the error, EPA should revise GEM V3.8 to use between 6 and 70 points to determine whether a default steady-state fuel map is needed for the transmission cost map.	We agree with the comment that GEM can incorrectly generate a transmission cost map in circumstances where only the idle portion of the fuel map is input into GEM and have changed how GEM determines what data is used to determine the transmission cost map in GEM 4.0 to address this issue. If 25 or fewer points are input, a default map will be used to determine the transmission cost map, otherwise the cost map will be constructed from the provided steady state points. We chose 25 or fewer points because 25 is above the upper limit of points needed to define the engine fuel map at idle,

	but below the number of points needed for the complete engine fuel map.
Comment	**Response**
From: EMA *Drive Idle Fueling Interpolation Error* The interpolation of drive- idle fueling in GEM V3.8 is inappropriately impacted by the surrounding default steady-state fuel map points when the option of using three cycle-average fuel maps is utilized. To correct the error, EPA should modify GEM V3.8 to only use measured drive-idle fuel map points for the interpolation of drive- idle fuel consumption. That is, GEM should not merge measured drive-idle fuel map points with default steady-state fuel map points.	We agree with the comment, and have made changes included in GEM 4.0 to not merge measured drive-idle fuel map points with default steady-state fuel map points. When a default map is required, it is used for simulation and the idle data is used in the post process calculations.
From: EMA *Cycle-Average Fuel Map Regression Error* GEM V3.8 uses Regression Method 7 to determine fueling during the 55 and 65 MPH cruise duty cycles in cycle-average fuel maps. However, that planar regression is not accurate. EPA should modify GEM to use Regression Method 13 instead. Please note that GEM V3.8 should continue to use Regression Method 7 to determine fueling during the transient duty cycle in cycle-average fuel maps.	We agree with the comment that regression Model 7 is not accurate for all engines for the 55 and 65 mph cruise duty cycles and have changed the regression model in GEM 4.0 for the cycle average cruise cycles as described in Section III of the Preamble. The regression model used is not Method 13 because Method 13 requires more data points to prevent overfitting of the model. The Method finalized is more accurate than 7 and 13 and works when the fuel maps for the 55mph and 65mph cruise cycles are combined. By combining the 55mph and 65mph fuel maps, the number of test points available to fit the model double without requiring additional testing.
From: EMA *Engine Speed Tolerance Error* The engine speed tolerance is too sensitive in GEM V3.8. Specifically, GEM will report an error for engine idle speed when slight testing variations impact the speed. For example, if an engine's lowest measured idle speed is 700.08 RPM, GEM will report an error when attempting to	We agree with the comment and have changed the idle speed tolerance in GEM 4.0 as described in Section III of the Preamble.

simulate 700 RPM. EPA should modify GEM V3.8 to include a reasonable tolerance for engine speeds.

1.8 Powertrain Test

Comment	Response
From: EMA ***Idle Reduction in Powertrain Test*** The benefit of automatic engine shutdown idle reduction technology is not fully realized during a powertrain test. Additionally, realizing benefits for neutral idle and stop-start technologies requires testing with the features enabled, which may lead to significant file proliferation to cover multiple combinations of idle reduction technologies. To ensure the full benefits of idle reduction technologies, and to reduce the number of powertrain input files, EPA should modify GEM V3.8 to allow manufacturers the option of directly identifying those features.	We agree with the comment to include in GEM the ability to recognize idle shutdown technologies when the powertrain test method is used to generate the fuel maps. As described in Section III of the Preamble we have included in GEM 4.0 changes that will allow automatic engine shutdown and stop-start to be selected in the vehicle input file instead of requiring these technologies to be captured in the powertrain fuel maps.
From: Allison Transmission Inc. As we look ahead to using GEM for Powertrain Certification, Allison suggests that EPA consider an enhancement of the GEM Technology Improvement section. Today, GEM's Technology Improvement section provides a Yes/No entry for Neutral Idle. For Powertrain Certification, however, an entry of "Yes" in the Neutral Idle field simply allows a trivial computation using "Drive Idle". Allison recommends that for Powertrain Certification, that "Yes" in the Neutral Idle field runs the same or similar Neutral Idle computation as the one used for stand-alone components. This enhancement would provide an option for the certifier to use a default computation when the collection of powertrain data is overly costly and burdensome.	We understand the comment as a request to include in GEM the ability to recognize if the vehicle includes Neutral Idle technology with a Yes/No entry when the powertrain test method is used to generate the fuel maps. To allow this, GEM would have to make an assumption about the load from the transmission on the engine when neutral idle is enabled and disabled. To do this in a representative way, GEM would need additional inputs, which may require additional test procedures. For these reasons, with GEM 4.0 we have not enabled the ability to select Neutral Idle with a Yes/No entry at this time.