EPA Response to Comments from the 2019 External Peer Review of Draft Reports for EPA's MOtor Vehicle Emissions Simulator (MOVES) Version: MOVES_CTI_NPRM

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Introduction

In 2019, EPA contracted external peer review of two draft reports for proposed updates made to a draft version of EPA's MOtor Vehicle Emissions Simulator (MOVES) Version: MOVES_CTI_NPRM. CTI_NPRM stands for the Cleaner Trucks Initiative, Notice of Proposed Rulemaking. The MOVES_CTI_NPRM version of MOVES was used to estimate the emission reductions projected from the preliminary analysis of the Cleaner Trucks Initiative. The development of MOVES3 followed the development of the draft MOVES_CTI_NPRM version. MOVES3 is the next official public version of MOVES, replacing the last public version, MOVES2014b.

The charge to the peer reviewers asked them to provide comments on updated sections in two reports: "Exhaust Emission Rates for Heavy-Duty Onroad Vehicles in MOVES_CTI_NPRM[1]," and "Population and Activity of Onroad Vehicles in MOVES_CTI_NPRM[2]." Peer review for the exhaust emission rates for heavy-duty vehicles inputs for MOVES was carried out under procedures described in the EPA Peer Review Handbook.[3] More information on the peer review process, the selection of peer reviewers, and the specific charge to the peer reviewers is available in the contractor's final report, along with a compilation of the peer review comments available on EPA's Science Inventory Webpage.[1,2]

This document briefly summarizes the peer review comments and details EPA's responses. In general, the EPA responses only refer to MOVES_CTI_NPRM, in which case any updates made to MOVES_CTI_NPRM are also updated in MOVES3. However, in several cases, we were able to do more to address peer-review suggestions in MOVES3 than in MOVES CTI NPRM due to timing (the deadline for MOVES_CTI_NPRM preceded MOVES3 by many months). In cases where we made further changes to MOVES3, we explain how MOVES_CTI_NPRM and MOVES3 differ.

The both the updated MOVES_CTI_NPRM and MOVES3 reports will be made available on the EPA's Science Inventory Webpage. The MOVES3 reports are also available on the MOVES webpage.[4,5]

Response to Comments from Mr. Dana Lowell

In general, Mr. Lowell agreed that the data, assumptions and analysis described in the material that he reviewed was reasonable and appropriate. However, there were several areas where he made suggestions for improving the documentation, analysis and data.

Heavy Duty Emission Rates

Energy Rates-

"To calculate energy rates for MY2010 – 2013, why did EPA not analyze only a subset of the available HDUIT data to include only the MY2010-2013 vehicles, instead of using the entire data set, in which 10% of vehicles were MY2014-2015?"

For the CTI NPRM, as mention in the text, because the MY 2010-2013 vehicles represented 90% of the data, we thought it was permissible to include the small number of MY 2014 vehicles to calculate the energy rates so that the data used to estimate the energy rates and the criteria pollutant rates (HC, CO, and NOx) were consistent. We have added this rationale to the main text of the MOVES_CTI_NPRM heavy-duty exhaust report in Section 2.1.4.3.

For MOVES3, we have addressed this issue by divided the HDIUT between MY 2010-2013 and MY 2014+ vehicles, because at the time of the MOVES3 analysis we had larger sample size that we deemed sufficient to divide the vehicles into two different model year groups. This is discussed in Section 2.1.4.2 and 2.1.4.3 of the MOVES3 report.

F-scale

"In general, the process used to choose fscales seems reasonable. In particular, the final results are well supported by the resulting CO2 emission rates. My only comment is that the logic behind the preferred time distribution of data among OP modes was not explained – is there data to support that the distribution resulting from the chosen fscales is representative of real-world experience?"

We added additional text to our discussion in Appendix G to clarify our methods and logic used to select the f_{scale}. We added text to clarify that the CO_2 emission rates are used as the final factor in determining the f_{scale}. We also clarified our logic in using the CO_2 rates, in that "our objective is to select the f_{scale} that yields the most aggressive operation in the highest operating modes while still providing sufficiently robust estimates of the emission rates."

We agree that it is useful to compare the resulting operating mode distributions from the chosen f_{scale} with real-world data. We have added a comparison of the operating mode distributions estimated from the HDIUT and from estimates of in-use driving using MOVES for each heavy-duty regulatory class to Appendix G. We also mention in the report that additional could be done to compare the operating mode distributions from real-world data sets.

Gasoline rates analysis

(RE: Is EPA's current approach more reasonable or should EPA use the one chassis-certified vehicle to represent emission rates for the entire fleet of chassis-certified vehicles (regClass LHD2b3)? *"Data in Table 3-19 indicates that PM emissions were comparable from all three vehicles, but equivalent data on NOx, CO, and THC is not provided. It would help to justify EPA's chosen approach if they could state or show that emissions from the chassis-certified vehicle were similar to emissions from the other vehicles."*

We added a comparison of the emission rates of THC, CO, and NOx between the three MY 2015-2017 heavy-duty gasoline vehicles in the Appendix (Appendix H.2 of the MOVES_CTI_NPRM report, and Appendix I.2 in the MOVES3 report). In addition, we added text to the Section 3.1.1.3 discussing why we combined the chassis and engine-certified vehicles together.

(Step 2) "Significant differences are observed between the vehicles, however no consistent differences were noted across operating modes and pollutants between the two engine-certified vehicles and the chassis-certified vehicle."

(Step 4) "Ideally, the emission rates for each regulatory class (LHD2b3, LHD45, MHD, and HHD) would be estimated from test data collected from vehicles from each respective regulatory class, or estimated separately from the engine-certified (LHD45 and heavier) and chassis-certified vehicles (LHD2b3). However, due to the small sample size (including only one LHD2b3 vehicle), we decided to use a weighted average using the sales volumes from each of the three vehicles to estimate the emission rates for each heavy-duty gasoline regulatory class."

Population and Activity

Single Unit Truck Activity

In Section 12, Lowell questions the assumption that a large fraction of SourceType 52 (Single-Unit Short Haul) trucks are parcel delivery (and thus have very high trips per day) and suggests that we find other evidence to check this assumption. Specifically, he suggests using an Information Collection Request to OEMs or IHS data on the number of trucks registered to parcel delivery companies.

EPA updated the discussion in Appendix J of the population and activity report to clarify that we do not have IHS registration data resolved to individual companies which would allow us to calculate the fraction of trucks registered to parcel delivery companies.

As discussed in Section 12.2, we intend to update the activity (including starts per day) from other instrumented truck data sets. This can help evaluate the start activity obtained from the parcel delivery trucks collected in the Fleet DNA database, as well as identify other trucks.

While Lowell suggests using an Information Collection Request (ICR) to collect data on the number of trucks used for parcel delivery, we do not think this is a good use of EPA resources at this time because the burden on delivery companies to provide standardized, relevant, reliable data could be quite high, the workload to prepare such a request is high and the timeline to process such a request is long.

Bus Source Mass

In Section 15, Lowell questions the algorithm for estimating source mass of MHD and HHD buses and suggests we calculate mass considering the mile-weighted average passenger load (8.5 passengers) rather than the midpoint between curb-weight and fully-loaded weight.

EPA agrees that the algorithm used to estimate the average mass of MHD and HHD buses could be improved using average passenger load instead of the midpoint between curb-weight and fully-loaded weight. In addition to the average value suggested by the reviewer, EPA notes that the National Transit Database may have useful data related to determining the mile-weighted average passenger load for these buses. While this is unlikely to have a significant impact on fleet emissions, EPA will consider including this improvement in future versions of MOVES.

Starts/Age

In Section 12, Lowell questions the assumption that trips/day declines with mileage. He thinks it is "equally plausible" that older vehicles are preferentially used for short trips. He suggests we calculate starts/age from the Verizon data.

We will consider conducting an analysis of starts per day by vehicle age in the future. One reason we have not yet prioritized conducting an analysis of starts by vehicle age from the Verizon data set is that the Verizon data only includes vehicles back to model year 1996 (or 20-year-old vehicles). The current method using mileage accumulation rates allows us to estimate the starts per vehicle for the full range of vehicle ages in MOVES (age 0 to 30).

We updated the MOVES_CTI_NPRM report to clarify that the Verizon dataset includes vehicles back to model year 1996 vehicles, which is also the first year manufacturers were required to equip all vehicles with on-board diagnostic (OBD) systems.

In addition, for heavy-duty vehicles, we do not have an activity data set with a sufficient sample size across vehicle ages for estimating the effects of aging on vehicle activity.

In MOVES_CTI_NPRM, the only source type that had a constant mileage accumulation rate was school buses. In other words, we assumed that new school buses traveled the same amount of miles per year as when they are thirty years old. This assumption is inconsistent from all other source types, and with all other data we have on vehicles from other source types. In MOVES3, we used the relative mileage accumulation rates from transit buses to estimate the relative mileage accumulation rates for school buses.

In MOVES3, we also updated the starts per day by vehicle age to be consistent with the updated RMAR for school buses. In addition, the starts per day by vehicle age for the heavy-duty source types were based on the RMAR used in MOVES2014b, rather than the RMAR in CTI_NPRM. Tthe starts per day by vehicle in MOVES3 were updated to be consistent with the same RMAR values used in MOVES3.

Glider Populations

For Section 5, Lowell questions whether the glider population assumptions are consistent with planned EPA rulemaking on gliders. "EPA should update their estimate of annual glider production for 2018 and subsequent years to reflect the revised final glider rules under development, or categorically state that the 2011 restrictions will be maintained in the forthcoming rulemaking."

In November 2017, EPA published a proposal to repeal emission requirements for glider vehicles, glider engines and glider kits.[6] However, at this writing, that proposed rule has not been finalized. Because MOVES is intended to model only final regulations, it is not appropriate at this time for MOVES to incorporate the impacts of the proposed repeal. However, we do hope to update these glider sales estimates as more data becomes available. Such changes could have an important impact on emissions, especially for particulate matter.

Note that we updated the glider population in MOVES3 compared to the initial estimates in MOVES_CTI_NPRM. This is based on an updated number of glider manufactures with reported sales data as documented in Section 5.2.6.

Hotelling Mode Distributions

"The proposed hoteling activity distributions - especially assumed future adoption rates for APUs and auxiliary battery/AC systems (Table 11-2) - are significantly less certain and should be the focus of future updates."

We agree that future updates based on measurements would be much preferable to projections. We have added the following text following Table 11-2. "Future MOVES updates could utilize instrumented truck and APU usage measurements to replace these projections."

Response to Comments from Dr. Arvind Thiruvengadam

In general, Dr. Thiruvengadam agreed that the data, assumptions and analysis described in the material that he reviewed was reasonable and appropriate. However, there were several areas where he made suggestions for improving the documentation, analysis and data.

Heavy Duty Emission Rates

F-scale

Regarding Section 2.1.1.4.9, Thiruvengadam states, "The reviewer understands that the choice of fscale could over populate or under populate these high-power op-modes, however, I believe some additional clarity is needed on what the basis or the need to fill these op-modes." Dr. Thiruvengadam also suggest using other datasets to support our conclusions on the f-scale analysis.

> Mr. Dana Lowell had a similar comment. As discussed in our earlier reply, we added additional text to our discussion in Appendix G (both CTI_NPRM and MOVES3 heavy-duty reports) to clarify our methods and logic used to select the f_{scale}. We added text to clarify that the CO_2 emission rates are used as the final factor in determining the f_{scale}. We also clarified our logic in using the CO2 rates, in that "our objective is to select the f_{scale} that yields the most aggressive operation in the highest operating modes while still providing sufficiently robust estimates of the emission rates." We agree that it is useful to compare the resulting operating mode distributions from the chosen f_{scale} with real-world data. We have added a comparison of the operating mode distributions estimated from the HDIUT and from estimates of in-use driving using MOVES for each of the three evaluated heavy-duty regulatory classes. The comparison supported our rationale for selecting f_{scale} as we discussed in the updated text added to the report.
>
> "As shown, the distributions are similar between the HDIU data set and national MOVES runs, with most of the data occurring at idle and the operating modes above 50 mph (opModeID 33-40). One notable difference is for a national scale run MOVES estimates a higher percentage of activity in the highest power, high speed operating mode bins. Given that the HDIUT data set is expected to under-represent high power operation due to steep grades, high speeds, and heavy-pay loads (e.g. multiple trailers, over-weight trailers) compared to the in-use fleet. This comparison supports our logic to select the f_{scale} that only includes the most aggressive operation from the HDIUT data set into the highest MOVES operating mode bins. "
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> We also mention in the report that additional work could be done to compare the operating mode distributions from real-world data sets.

Diesel CO rates

Regarding Section 2.1.3.2, Thiruvengadam states, "The CO emissions rate presented in this report does seem high compared to results observed during real-world testing". He suggests that PEMS could estimate inaccurate CO compared to laboratory analyzers, because PEMS "are subject to drift issues.".

> We added a comparison of MOVES rates with road-side testing to Section 2.1.5 in response to this comment. We added this text to the section on CO rates in Section 2.1.3.2
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> "In Section 2.1.5, we demonstrated that the fleet-average heavy-duty CO emission rate estimates from MOVES compare well with two fleet-average measurement campaigns

conducted in 2015 and 2017, which increased our confidence that the CO emission rates measured from HDIUT are reasonable."

We also plotted average CO emission rates by model year in g/mile in Section 2.1.3.4, to demonstrate that the relationship of the 2010+ model years to earlier model years. The figures show that the HHD CO emissions rates are comparable in magnitude to the pre-2007 model year emission rates, whereas the CO emission rates for MHD and LHD vehicles has significantly decreased from the pre-2007 MY emission rates. These results emphasize comparatively low CO emission rates in emission rates in the model year 2007-2009 emission rates in comparison to the other model years. In the future, we plan to conduct model year specific comparisons to emission rates from remote sensing data, to evaluate and potentially update model year trends from those data.

CNG emission studies

In Section 4.2.2.3 Thiruvengadam shared three studies conducted by West Virginia University (WVU), and an on-going study conducted by CE-CERT and WVU that could be used to inform 2007+ emission rates.

Due to limited resources we are not prioritizing re-analyzing the age zero CNG emission rates for model year 2007 and later, since the current rates from the HDIU are deemed adequate. The suggested studies could be valuable for future updates, especially for pollutants such as NH_3 and N_2O which are not tested in the HDIU program.

CNG deterioration

Regarding Section 4.1.2.2 Thiruvengadam states, "Deterioration rates of CNG vehicles is an important parameter. The use of gasoline vehicle deterioration rates for CNG vehicles may not be appropriate for all vocations. Results from the 22 vehicle AQMD study has shown that transit buses and refuse haulers show higher rate of deterioration compared to Class7-8 tractor applications. CNG vehicles exhibit duty-cycle based aging which is not a function of years. The aging results in higher NOx and PM emissions. Data showing the deterioration effect of same vehicle over a long period is probably not available, however a comparison of vehicles with same model years with different engine hours accumulated or miles accumulated could exhibit the deterioration trend. Limited data pointing towards this trend is available in the 22-vehicle study, but a more in-depth analysis will be available at the end of the on-going AQMD funded study."

We agree that the deterioration rates of CNG vehicles are an important parameter. In addition to the studies you suggested, we are also interested in evaluating the use of remote sensing data to inform deterioration rates for heavy-duty vehicles, including heavy-duty gasoline and CNG fueled vehicles. Remote sensing measurements can measure hundreds to thousands of vehicles, which is important for estimating robust fleet-average deterioration factors. We suggest first evaluating these remote sensing data sources before initiating an update to the CNG deterioration factors in MOVES.

Population and Activity

Glider Populations

Thiruvengadam questions the use of 2014 sales numbers for 2017. He suggests back-calculating the glider vehicle population from remote sensing data.

> We have revised this section of the report to clarify that we mean "sales" rather than populations. In the absence of real-world counts, we believe it is appropriate to assume the maximum number of gliders allowed by law, i.e. the 2014 sales estimate.
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> While we would like to confirm these sales estimates with real world data, we do not believe that remote sensing data would be useful for this purpose; we don't believe it can adequately distinguish gliders from other high emitters such as trucks that have been subject to tampering or poor maintenance.

Extended Idle Activity

Thiruvengadam "believes that California clean-idle requirements might underestimate idle running of vehicles in other parts of the country. Trucks not registered in California may not have auto idle shut-off enabled and as a result may exhibit a longer idle activity."

> We have added the following text to Section 10.3.1 of the population and activity report:
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> "However, as presented in the NREL project report, truck idling and start activity was observed to be largely a function of the truck vocation, rather than the US state of operation. Likely a larger sample size of vehicles across vocations and states would be needed to elucidate geographic differences in truck activity."
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> And the following footnote:
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> "For example, California has a regulation prohibiting idling for more than five minutes for vehicles that are not California clean idle certified. However, other states, counties and cities also have idling regulations. In addition, most recent heavy-duty vehicles are California clean-idle certified. For example, all fourteen of the MY 2008 and later heavy heavy-duty tractors tested for extended idling emission rates (produced from four major engine manufacturers) were all clean idle certified."
>
> The number of US states that the trucks are operated in is presented in Table 10-3. We added a footnote to this table "The number of trucks operating in each US state is listed in the NREL project report"

He later suggests that, "Fleet surveys could potentially give clarity to the fraction of fleets that use relief drivers or use APUs for hoteling loads."

> Fleet surveys are a good suggestion. However, EPA staff are not aware of existing studies that address these questions. Nor do we have the resources to implement such a survey.

Starts

Thirunvengadam says that it's reasonable to assume constant starts/mile because the Verizon data shows that starts/day decrease with vehicle age.

As discussed in response to Mr. Dana Lowell's comment on start rates by vehicle age, we have not conducted an analysis of starts per day by vehicle age from the Verizon dataset.

We updated the text in Section 12.1.2 to clarify this point. We also updated Table 12-1 and Figure 12-1 to clarify that the reduction in starts per day per vehicle was conducted using the MOVES mileage accumulation rates, and not developed from the Verizon data set alone.

Also, see our response to Mr. Dana Lowell's comment on additional updates we made to MOVES3 start per vehicle rates.

Thirunvengadam suggests that we add additional starts operating modes between 120 and 360 minutes, based on Verizon-type data.

Updating MOVES to account for finer resolution start operating mode bins would be a substantial effort because it would require both new emission rate data and start activity data to be estimated at the finer operating mode bins. This could be considered if we had data demonstrating that the start emission rate is strongly non-linear during this soak length rangeand adding additional resolution would substantially improve our start estimates. However, the current MOVES_CTI_NPRM hot-start emission rates vs. soak time documented in the light-duty and heavy-duty appear to be rather linear for the area between 120 and 360 minutes.

Thirunvengadam says "WVU is working with EMA on a telemetry data collection for 100 HD vehicles of long-haul, construction and delivery applications. Although the data may not be publicly available, the telemetry data recorded will be a rich dataset to strengthen and improve estimates of start and soak time."

If EMA makes the telemetry data and methodology available to EPA, we can consider incorporating it into future versions of MOVES.

Thirunvengadam suggests that California data may be biased to more frequent starts and shorter soak times due to heavy traffic and engine shut-off. He suggests that OEMs might have data that is more representative of national activity.

As explained above in our response to the question on California Clean Idle, we have added the following text to Section 10.3.1 of the Population and Activity report:

> "However, as presented in the NREL project report, truck idling and start activity was observed to be largely a function of the truck vocation, rather than the US state of operation. Likely a larger sample size of vehicles across vocations and states would be needed to elucidate geographic differences in truck activity."

Thirunvengadam suggests that we request fleets register with EPA and share data with us or leverage economic incentive programs like California's Carl Moyer program to get vocation data.

Current U.S. laws and regulations do not allow EPA to require fleet registration. While we may be able to leverage other programs to obtain data, such as EPA's SmartWay Program, we are concerned that they may not be fully representative of in-use activity, particularly of smaller fleets.

References

[1] USEPA (2019). *Exhaust Emission Rates of Heavy-Duty Onroad Vehicles in MOVES_CTI_NPRM - Draft Report*. Draft report and peer-review documents. Record ID 347135. EPA Science Inventory. December 2019. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=347135.

[2] USEPA (2019). *Population and Activity of Onroad Vehicles in MOVES_CTI_NPRM - Draft Report*. Draft report and peer-review documents. EPA Science Inventory. December 2019. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=347136.

[3] USEPA (2015). *U.S. Environmental Protection Agency Peer Review Handbook*. EPA/100/B-15/001. Prepared for the U.S. Environmental Protection Agency under the direction of the EPA Peer Review Advisory Group. Washington, D.C. 20460. October 2015. https://www.epa.gov/sites/production/files/2020-08/documents/epa_peer_review_handbook_4th_edition.pdf.

[4] USEPA (2020). *Exhaust Emission Rates of Heavy-Duty Onroad Vehicles in MOVES3*. EPA-420-R-20-018. Office of Transportation and Air Quality. US Environmental Protection Agency. Ann Arbor, MI. November 2020. https://www.epa.gov/moves/moves-technical-reports.

[5] USEPA (2020). *Population and Activity of Onroad Vehicles in MOVES3*. EPA-420-R-20-023. Office of Transportation and Air Quality. US Environmental Protection Agency. Ann Arbor, MI. November 2020. https://www.epa.gov/moves/moves-technical-reports.

[6] 82 FR 53442, November 16, 2017. https://www.govinfo.gov/content/pkg/FR-2017-11-16/pdf/2017-24884.pdf