Peer-review Comments and EPA Responses: Speciation and Toxic Emissions from On road Vehicles, and Particulate Matter Emissions from Light-Duty Gasoline Vehicles in MOVES201X

December 2020

Peer review is an important element in ensuring the quality and integrity of the MOVES model. Peer review for MOVES updates was carried out under procedures described in the EPA Peer Review Handbook.[1] A contractor managed the peer review process, selecting qualified independent experts and arranging for letter reviews. This document lists the comments received from peer reviewers on selected sections from a September 2017 version of following reports. At that time, the draft MOVES3 model was known as MOVES201X.

1) Speciation of Total Organic Gas and Particulate Matter Emissions from Onroad Vehicles in MOVES 201X
    - Chapter 3 Organic Gas Aggregations
    - Chapter 4 Chemical Mechanism (CM) Speciation (Pages 21 and 24)
    - Section 5.1. $PM_{2.5}$ Speciation Calculations. Step 8 (Page 32-33)

2) Air Toxic Emissions from Onroad Vehicles in MOVES201X
    - Updates made for 2007+ diesel engine emission rates within the following sections:
        - Section 3.1.2 (Volatile Organic Compounds)
        - Section 3.2.2 (Polycyclic Aromatic Hydrocarbons)
        - Section 3.3. Metals

3) Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES201X
    - Section 1.4 Exhaust Emission Rates for Start operation
    - Section 2.2 Particulate-Matter Emission Rates for Model Year 2004 and Later Vehicles

4) Emission Adjustments for Temperature, Humidity, Air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES201X
    - Section 2.3.2. PM Running-Exhaust Temperature Effects

As explained in the charge letter, the peer-reviewers were given five general questions to consider in their review, as well as one specific question on the ACES Phase II Speciation Report. Dr. Yanowitz provided sequential comments on each of the reports, and Dr. Karavalakis provided comments in response to each of the general comments for each report. The EPA questions were retained in the comments from Dr. Karavalakis in this document. EPA questions to the reviewers are listed in bold; EPA response to the comments is in italic. Reviewer comments on minor formatting issues and typos are omitted. The peer-reviewed report, charge

questions to the peer-reviewers and as-received peer-review comments, and other associated peer-review materials are located on EPA's science inventory webpage[2].

In response to the peer-review comments, we have made updates to the following MOVES3 technical reports.

1) Speciation of Total Organic Gas and Particulate Matter Emissions from Onroad Vehicles in MOVES3[3]
2) Air Toxic Emissions from Onroad Vehicles in MOVES3[4]
3) Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES3[5]
4) Emission Adjustments for Temperature, Humidity, Air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES3[6]

Many of the updates documented in this report were also made to a draft version of MOVES3 that was used for preliminary analysis on EPA's Cleaner Trucks Initiative (CTI). The updates made to the draft MOVES3 version used for the CTI analysis from MOVES2014b will be documented in separate MOVES reports.

Note the section, table, and figure references made by the peer-reviewers refer to the September 2017 version of the report and may no longer be consistent with the updated reports.

General Comments

Dr. Janet Yanowitz:

This update continues EPA's refinement of the MOVES model. Not only is the MOVES program used for airshed modeling, its documentation is used by many for determining the likely impacts of individual changes in fuel and vehicle technology and operation.

One ongoing concern is the lack of documentation on the accuracy of the various input values. Often parameters are presented with numerous significant digits, clearly far beyond the accuracy of the source data, if only because of the limited number of vehicles tested. I understand that there is little to be gained by truncating these values for the purposes of the model, but I would propose that in future work EPA consider procedures for estimating and presenting the uncertainty of each parameter. The model could then be tested with a range (say plus or minus one standard deviation) of potential values of each parameter to determine the parameters most in need of further refinement. More importantly, if the model is using values that are no more than guesses, than the results are similarly compromised and not appropriate as the basis for policy decisions. In order to maintain trust in the model it is necessary to ensure that all of the results are based on data that is adequate to determine the stated results. Finally, as I noted above, the documentation is frequently used independently of the model and an understanding of the uncertainty would be valuable for those purposes.

Response: We have reviewed and updated the data presented in the speciation and air toxics reports to be reported to three to four significant digits.
We have added more discussion of uncertainty in the individual technical reports

including Section 1 of the Air Toxics Report and Section 1.3 in the Speciation report.

Another addition to allow better understanding of the model is to compare estimates from the most recent past model (MOVES2014) with the newly proposed estimates such as in Figure 2-29 in Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES 201X. Before and after figures provide a ready way for readers to predict the impact of changes without needing to run the entire model or review past model documentation.

Response: Given the complexity of MOVES documentation, we have chosen to focus on the current model in our documentation, rather than detailing comparisons to past versions. For future model updates, we will consider the usefulness of documenting the change in the model updates to assist in conveying our uncertainty of the new rates.

One general stylistic comment would be to include captions for tables and figures that provide a more complete explanation of the contents, particularly in the case of those figures/tables which are presenting an intermediate stage in the process of determining final emission rates. Figures/tables can readily be taken out of context and it should be made clear when further adjustments are still required. For example Figures 2-31 and 2-32[a] in Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES 201X have similar captions and yet one has been adjusted for deterioration rate while the other has not.

Response: We updated the discussion and clarification to the MOVES3 light-duty exhaust report to clarify how and at which stage in the analysis we adjusted the PM rates to account for deterioration, including:

- *Adding text to the Dataset Description Section to specify that we assumed that the studies used for the MY 2004+ rates represent age zero emission rates in MOVES*
- *Adding Vehicle Age to the 4.2.6 subsection title "Calculation of Fleet-Average PM Emission Rates by Model Year, Vehicle Age, and PM component," and the 4.2.6.3 subsection "Calculating Rates by Model Year, Vehicle Age, and PM Component" to clarify at which stage the age effects are applied to the zero-mile rates*
- *Adding text to Section 4.2.6.3 that discuss how PM emission rates are derived from the pre-2004 rates in a way that maintains the original deterioration trend. We also include references to Section 4.1.2.3 where the original deterioration factors are derived for the pre-2004 vehicles.*
- *Adding the Age 0 to Figures 4-26 through Figure 4-29, to specify that these figures refer to age 0 rates.*
- *We did not change the captions on Figure 4-31 and Figure 4-32[a] because they both present emission rates adjusted for deterioration. The other documented changes make this clearer.*

[a] Figures 2-31 and 2-32 in the draft report for peer-review are and now Figure 4-31 and 4-32 in the MOVES3 report

- *In addition, we have reviewed all the table and figure headings in the peer-review material, to clarify whether the values represent measurement data, intermediate inputs or final MOVES inputs (See changes with respect to the light-duty exhaust report figure and table headings discussed in the comments to that report.*

Speciation of Total Organic Gas and Particulate Matter Emissions from Onroad Vehicles in MOVES 201X

Dr. Janet Yanowitz:

Chapter 3

Table 3-1. I appreciate this table for clarifying the meaning of these terms as they are used in the MOVES model. These terms are used elsewhere in the sections which I reviewed. Please ensure that wherever they are used they have the meaning listed in this table and I would suggest that you do not use other terms to mean the same thing. For example, Section 1.4 of Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES 201X uses the terms HC and THC, I believe interchangeably, but it is not clear that either or both refer to FID-HC, as the term is used in this table. Similarly, the term VOC is used in Section 3.1.2 of Air Toxic Emissions from Onroad Vehicles in MOVES201X - please confirm that is calculated in this section as you do in this table: FID-HC minus methane, ethane and acetone. I ask this because I have seen many cases in the scientific literature in which VOCs are assumed to include every organic compound.

Response: We added a column in Table 3-1 to include the acronym for each, specifically using the term THC for total hydrocarbons, and we added a glossary term for hydrocarbons (HC) separate from THC in Section 2. Speciation Glossary. Also, see the EPA Response to comments in the light-duty exhaust report regarding the use of THC and HC in that report.

Further, we updated the text in the definition of VOC in the air toxics report to be consistent with text in the speciation report to make clear that the usages are the same. There are footnotes in the light-duty report that clarify any deviations to this VOC definition. For example, in Section 2.1.1 there are two footnotes that clarify that "VOC is typically calculated as NMOG – ethane – acetone, but for this purpose, acetone was considered negligible, and was not subtracted."

Table 3.2. Profile Nos. 8754, 8769, 8770, 8878, 8934 for evaporative emissions of ethanol containing fuels. I would expect that the NMOG/NMHC and VOC/NMHC ratios would change depending on the vapor pressure of the fuel. Assuming a fixed ethanol content, the vapor pressure of the ethanol is relatively constant and the vapor pressure of the blendstock changes. Thus at high vapor pressures I would expect relatively more THC in comparison to ethanol in the vapors. E85 and E70 evaporative emissions (Profile No. 8934) are also impacted by vapor pressure, although to a lesser extent because there is a smaller amount of hydrocarbon. The

methods in SAE Paper No. 2007-01-4006 can be adapted to estimate the mole fraction of ethanol in the vapor phase, given the RVP and ethanol content of the blend.

Response: Profiles 8769 and 8770 are used to speciate permeation emissions. In the CRC E-77-2/2b/2c studies[7,8,9] we saw that on average for the sixteen vehicles tested there was not an RVP effect on permeation emissions, but a significant effect on permeation emissions from ethanol content. Because there is no significant change total permeation emissions with RVP, we also assume there is no significant change on the composition (e.g. VOC/NMOG) of the permeation emissions.

Profile 8754, used for vapor venting, leaks and spillage processes in MOVES, was developed from data collected in the early 1990's as part of the Auto/Oil test program. We are unaware of more recent data which could be used to represent these emission processes. Clearly, use of data this old introduces significant uncertainty, since fuel delivery, fuel formulations and emission control systems have changed significantly since then. It might be possible to adjust these profiles for RVP using SAE Paper No. 2007-01-4006, but it may be more worthwhile to develop an entirely new profile.

In the CRC E-77-2/2b/2c studies there was an observed effect found for both RVP and ethanol in the diurnal emissions data largely due to the vapor venting breakthrough emissions which were vented outside of the SHED using special procedures as defined in the individual study reports. We agree with the reviewer that there is likely an accompanying effect of RVP on vapor venting speciation, and both RVP and ethanol content should be considered as factors when developing updated vapor venting profiles in future test programs.

Profile 8870 and 8871 are speciation profiles for headspace emissions. Note - we assume Dr. Yanowitz intended to refer to profile 8870 (gasoline headspace vapor) instead of 8878 (which is not a mobile source profile used by MOVES). Due to limited resources we have not been able to evaluate the feasibility of adjusting those values based on SAE Paper No. 2007-01-4006, and whether the emissions impact would merit the additional complexity in developing new emission profiles. As noted in the updated report, we can consider accounting for RVP in future speciation test programs.

We believe that updating profile 8934 (used for E70 and E85 evaporative emissions) to account for different RVP blends is lower priority to evaluate given the small volume of E85 currently used.

Table 3.2 Profile Nos. 8870 and 8871 for the headspace of ethanol containing fuels. NMOG/NMHC and VOC/NMHC ratios of 1 implies that all of the organics in the headspace are hydrocarbon. However, according to the same paper cited above there is always at least some ethanol in the headspace.

Response: You are correct. The NMOG/NMHC and VOC/NMHC were both erroneously entered as 1.0 for profiles 8870 and 8871. We have updated the values in the Table 3-2 and in the MOVES3 database to account for the measured ethanol mass in the speciation profiles (1.037 for both NMOG/NMHC and VOC/NMHC from profile 8870, and 1.175 for both NMOG/NMHC and VOC/NMHC from profile 8871).

Section 3.1.2.1, p. 17. You write "The NMOG/NMHC ratio we estimated was 1.0312...." Table 3-4 Profile No. 8756 has a NMOG/NMHC ratio of 1.038.

Response: We updated the text in the section (now Section 3.3) to state 1.038, to be consistent with the value in Table 3-4 and the value used in MOVES.

Chapter 4 (pp. 21 and 24)

No comment.

Section 5.1 (step 8, p. 33)

No comment

Dr. Georgios Karavalakis:

Does the presentation describe the selected data sources sufficiently to allow the reader to form a general view of the quantity, quality and representativeness of data used in the analysis? Are you able to recommend alternate data sources that might better allow the model to estimate national or regional default values?

The document is well written, well structured, and contains comprehensive information. It certainly represents a significant improvement over the previous MOVES versions. I am particular satisfied that in MOVES201X the ratios of CH4/THC, NMOG/NMHC, and VOC/NMHC were calculated based on profiles from the SPECIATE database. On the other hand, I was particularly concerned about how representative and realistic MOVES201X might be since all these information derived essentially from one (1) testing campaign (EPAct program). This could be a major critique for the MOVES201X model in terms of the representativeness of the data used. Essentially, the estimations for the national and/or regional values of the model came from older technology Tier 2 LDVs equipped with port fuel injection (PFI) engines. The model fails to capture the emissions from newer technology LDVs equipped with gasoline direct injection (GDI) engines. This is major concern about the representability of MOVES201X, since GDI vehicles are dynamically penetrating the US market, with a prognosticated market share of up to 97% by 2025.

Response: We agree that developing speciation profiles from modern LDVs equipped with gasoline direct injection is a priority for future updates to the SPECIATE database and to MOVES. The need for updated speciation profiles for GDI vehicles

is discussed in the context for $PM_{2.5}$ in Appendix E.1 but would also be true for TOG speciation profiles.

For the CNG vehicles, the analysis is focusing only on transit buses. The model fails to capture vehicles of different vocations, such as trucks and waste haulers.

Response: The speciation and toxics analysis for CNG vehicles was conducted for MOVES2014, which only had the capability to model CNG use in transit buses. MOVES3 allows modeling of a wider range of CNG for heavy-duty vehicles. However, developing separate speciation values for CNG vehicles used as trucks and waste haulers has been a lower priority for several reasons: 1) it is reasonable to assume that speciated values from CNG transit buses can apply to all heavy-duty CNG vehicles 2) CNG vehicles are a minor contributor to total onroad NMOG emissions in the national inventory, and 3) we are not aware of a significant body of test data from which the speciated and toxics values could be derived for other heavy-duty CNG vehicles.

It is not clear to this reviewer as to whether the ACES Phase 1 profile is used for all current diesel sources, including LDVs. If this is the case, perhaps EPA should reconsider and include studies conducted on diesel light-duty passenger cars and trucks, such as the CRC AVFL-17b program.

Response: We clarified in the text in Section 3.2 that we apply the ACES Phase 1 profile to all 2007-2009 light-duty and heavy-duty diesel vehicles. Table 3-2 also explains that Profile 8775 applies to both light-duty and heavy-duty diesel vehicles. We have not prioritized updating light-duty diesel speciation profiles in MOVES or the SPECIATE database due to the very small emission inventory contribution of TOG emissions from light-duty diesels in the United States. In addition, we discuss the uncertainty of applying heavy-duty diesel speciation profiles to light-duty diesel vehicles in Section 1.3 (Data Uncertainty and Limitations)

Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made by EPA while developing the model inputs? Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

The description of the methods is well written and adequate. The reader has enough details to understand the steps taken and details behind them made by EPA. I find the examples for tables and figures adequate.

No Response Needed

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics? Are you able to suggest or recommend alternate approaches that might

better achieve the goal of developing accurate and representative model inputs? In making recommendations please distinguish between instances involving reasonable disagreement in adoption of methods as opposed to instances where you conclude that current methods involve specific technical errors?

The methods and procedures are technically appropriate and well described. I have reviewed the mathematical formulations and statistics and appear to be sound.

No Response Needed

Where EPA has concluded that applicable data is meager or unavailable, and consequently has made assumptions to frame approaches and arrive at solutions, do you agree that the assumptions are appropriate and reasonable? If not, and you are able to do so, please suggest alternative assumptions that might lead to more reasonable or accurate model inputs.

With few exceptions, the assumptions made by EPA are appropriate and reasonable. MOVES201X has limitations that need to be addressed. For example, the results of ACES Phase 1 program cannot be used to represent light-duty diesel passenger cars and trucks. For more accurate model inputs, MOVES201X should utilize data from studies employed diesel LDVs.

Response: As stated above, we made this assumption for simplicity due to the small contribution of light-duty diesels to TOG emissions in the national fleet. We may reconsider this decision in future versions of MOVES.

Are the resulting model inputs appropriate and, to the best of your knowledge and experience, reasonably consistent with physical and chemical processes involved in mobile source emissions, formation and control? Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

I believe the resulting model inputs are appropriate and generally consistent with the body of data and published literature. Overall, the model seems to be well specified and much more comprehensive than previous versions. To the best of my knowledge, much of the design used for MOVES201X is well articulated in this draft documented, which will help the reader understand how the model was developed.

No Response Needed

Specific Charge Question on ACES Phase II Speciation Profile

As discussed in the Speciation and Air Toxic Emissions reports, EPA developed a TOG speciation profile from ACES Phase II, using the data collected on the 16-hour transient cycle, and an average of the data collected from the three tested engines. The TOG speciation profile from ACES Phase II has zero percent methane, as opposed to 58 percent methane in the ACES

Phase I profile used to represent 2007-2009 heavy-duty trucks. Other inconsistencies were also noted between the speciation profiles. For example, benzene was not detected (ND) (from which we then assumed benzene=0), while ethanol comprises over 3% of the TOG emissions, due to one of the three engines in ACES Phase II reporting over 8% ethanol in the VOC emissions.

We are proposing to use the ACES Phase II profile as the source of toxics and for developing chemical mechanism species for air quality modeling. Do you have any recommendations regarding the use of the ACES Phase II TOG Profile in MOVES? Do you think it should be corrected/updated based on engineering judgment or test data collected from other 2010+ diesel engines? How should we consider correcting the profile data to accurately represent 2010+ diesel exhaust?

Dr. Janet Yanowitz:

This issue is to some degree addressed above, where I expressed skepticism on the number of significant digits with which the data from this study was presented.

Before making any specific recommendations I would propose the following analysis: There were several compounds which were not detected in 2010+ MY emissions which were detected in 2007 MY emissions and perhaps vice versa; calculate changes in emissions rates between the two sets of data only after replacing the non-detects with one half of the method detection rate. Then consider each of the compounds within its group of similar compounds - say all alkanes, or all PAHs - are there consistent trends in the emission rate changes for all of the compounds within each groups of similar compounds? Consistent trends suggest that individual emissions data is reasonably accurate, while big variability suggests that the data for individual compounds is not accurate. Consider also how close individual emissions results are to the method detection limit. If the measurements are very close to the detection limit you might only trust the analytical value to be accurate within a factor of 2 to 10. If all this suggests that the data is reasonably accurate then trust the results and use the data as is.

If these results suggest that the results for individual compounds are not accurate enough than one possibility which EPA might wish to consider is to calculate the percentage reduction in total organics between 2007 MY and 2010+ MY data and then use that value as a multiplier for individual organics to estimate the amount of toxics emitted in 2010+ MY. They could refine this further by using a single value for groups of compounds (alkanes, PAHs etc.). There are values for this in the ACES Phase II CRC report, Table ES-2.

I am not aware of any other comparable studies of 2010+ MY diesel emissions, but a literature search should be conducted to see if any other comparable data is available that can help refine this estimate.

Response:

We conducted the recommended analysis to compare the measured organic compounds from ACES Phase 1 (MY 2007-2009) and Phase 2 (MY 2010+) by groups of compounds, and by individual compounds. A summary of this analysis was

added to Appendix D of the MOVES3 Speciation Report.[3]

As stated in Appendix D, there was inconsistency in emission changes among individual compounds in all chemical groups. The inconsistent pattern of hydrocarbon measurements suggests that there are potential significant uncertainties in the measurements. Despite the uncertainties of the ACES Phase 2 profile, it is still our best speciation profile to characterize modern heavy-duty exhaust. We decided to use the ACES Phase 2 profile, with a few additional adjustments as discussed below to characterize total organic gaseous emissions in MOVES.

We did not apply a percent reductions between the 2007-2009 and 2010+ emission rates, because we are developing speciation profiles, which are percentages of the total organic emissions. This approach would essentially be to use ACES Phase 1 for all MY 2007 and later vehicles. We also did not adjust the ACES Phase 1 profile by groups of compounds, because of the differences in groups of compounds between the ACES Phase 1 profile could be driven by one or two compounds, and we thought it would introduce more uncertainty to adjust the Phase 1 profile using the summarized results from Phase 2, as compared to using the Phase 2 individual speciation results.

We did not attempt to impute minimum values in the cases where the species were not detected in one of the profiles. Our speciation profiles consist of the weight percentage of total organic emissions for each detected species as opposed to an absolute emissions value (in mg/mi or similar unit); therefore, it is not straightforward to apply a below detection limit value to not measured species.

As discussed in Appendix D in the Speciation Report[3]*, we did adjust the ACES Phase 2 speciation profile. We created a new profile (95335a) from 95335 where the mass fractions for the alcohol species are set to zero and we re-weighted the remaining non-alcohol species.*

In addition, we conducted a literature review of methane fractions of hydrocarbon emissions from MY 2010 and later heavy-duty diesel vehicles as discussed in the new Section 3.6 of the MOVES3 Speciation Report. We found several studies reporting consistent methane emissions that were measured above the detection limit, and the average value from these studies were used for the methane fraction, rather than the ACES Phase 2 values. Unfortunately, most of these studies had limited speciation data (e.g. only THC and methane) and could not be used to evaluate the ACES Phase 2 measurements for other organic gas species.

Due to the uncertainties of the Phase 2 profile, the report recommends further work to improve the confidence of speciation of exhaust from modern heavy-duty diesel engines, including from engines with aged and deteriorated aftertreatment systems.

Dr. Georgios Karavalakis:

I am not entirely convinced that for a non-detected value an assumption should be made to be zeroed out. I would leave this value as 'not detected' instead of assuming it is zero.

While it is reasonable that benzene was low or even not detected from newer trucks, I cannot see any obvious formation pathways for ethanol emissions. I would assume that ethanol could be an artifact of the measurement during sampling or more likely an artifact of the measurement during the analysis in the lab (contamination). I would therefore use my engineering judgement and exclude ethanol from the analysis from the current model.

Response: Currently, "not detected" is not a MOVES input or output. For inventory modeling purposes, non-detects are treated as zero. We agree that ethanol and other alcohols are likely contaminants and have removed them from a revised ACES Phase 2 speciation profile.

See the following text added to Appendix D in the MOVES3 Speciation Report.[3]

Within SPECIATE profile 95335, the mass fraction of three alcohol species, ethyl alcohol (ethanol), isopropyl alcohol (2-propanol), methyl alcohol (methanol), sum to 7% of the total TOG emissions. We do not believe these alcohol species are produced in modern heavy-duty exhaust; instead they are likely an artifact of measurement during sampling or analysis in the laboratory. With agreement from one of the 2017 peer-reviewers we created a new profile (95335a) from 95335 where the mass fractions for the alcohol species are set to zero and we re-weighted the remaining non-alcohol species.

As discussed in the previous comment, we updated the methane fraction in MOVES3, which were measured below the detection limit in the ACES Phase 2 program, this is discussed in Section 3.6 of the MOVES3 Speciation Report.

Air Toxic Emissions from Onroad Vehicles in MOVES201X

Dr. Janet Yanowitz:

3.1.2

Table 54. Here is an example where the number of significant digits is misleading. 0.0 is the value used for "not detected" in numerous places in the table. While reasonable for purposes of the model as there is no difference between 0.0 or 0.00000 as input to a computer, in this table it implies that the measurement was only made to a limit of detection of 10% (0.1) of the entire mass of VOC which I think is unlikely considering the other measurements. On the other hand, directly above the table you note that there is considerable measurement uncertainty - suggesting that it is the other measurements, taken in many cases to five digits past the decimal point

(0.001%) that are not be trusted. You also note that the PAH emissions were uncorrected for background concentrations. Depending on the location of the test site these can be significant.

I can understand the EPA perspective that they are only inputting the most accurate number possible given the data available, but perhaps if the reader could evaluate the uncertainty, it would be clear whether projections based on these numbers were trustworthy and appropriate as the basis for policy decisions. If the results are not appropriate for policy decisions then they do not belong in the model.

Response: All toxic ratios and values directly based on measurement data are now limited to four significant figures or less in the technical report so as not to overly convey precision in the data, including this table (now Table 3-2 in the MOVES3 report). However, in some cases model fit parameters (such as intercept values) are reported to more significant figures so users can reproduce the MOVES values. We have added text to the introduction of the MOVES3 air toxic report[4] to specify that the number of significant figures does not necessarily reflect the uncertainty of the emissions. Additional uncertainty is introduced when we apply emission measurements from the available test programs to represent national fleet-average emissions.

In the case of measurements that are not measured or below the detection limit, they are listed as a non-detect (ND) measurements but are modeled as zero in MOVES. We have updated the toxic data for diesel dioxins (Table 3-7) and CNG VOC (Table 4-1) to present these values as ND rather than zeroes. For PAH values that are zero due to our EPA calculations due to zero-phase fractions, we added footnotes to clarify the values that are zero.

3.2.2

Table 56 - same comment as above, plus recommend that you note that PAH/VOC is for the gas phase and PAH/OC2.5 is for the particulate phase.

Response: All PAH values in the table (now Table 3-4) are limited to three significant figures so that they do not overly convey precision. However, as discussed above, the number of significant figures should not be used to determine the uncertainty of the values. In the case of the PAH values, we multiplied the measured PAHs values by the phase-fractions, which introduces additional uncertainty as is noted in the diesel PAH section (Section 3.2).

We have updated the column headers in Table 3-4 (and similar tables in the report in the gasoline and CNG sections) to note that the gaseous phase is the PAH/VOC fractions and the particulate phase are the PAH/OC2.5 for all the PAH factors provided in the toxics report.

Table 57 - same comment as for Table 54

Response: All values are limited to four digits past the decimal point or less in this

table (Table 3-5) and other tables in the report.

Table 58 - same comment as for Table 54

Response: All values limited to two significant figures in this table (now Table 3-6).

Dr. Georgios Karavalakis

Does the presentation describe the selected data sources sufficiently to allow the reader to form a general view of the quantity, quality and representativeness of data used in the analysis? Are you able to recommend alternate data sources that might better allow the model to estimate national or regional default values?

This section is well written and adequately organized. EPA did a good job in categorizing the data of toxic fractions for pre-2007 diesel engines and for newer engines.

No Response Needed

For partitioning factors for diesel PAH emissions, I do see some limitations of MOVES201X, since the bulk of data came from a limited number of engines and of older technology.

Response: We added text in this section (Section 3.2) to acknowledge this limitation: "We note that we introduce additional uncertainty when we apply the phase-partitioning derived from two pre-2007 technology vehicles to the 2007+ diesel engines."

At the beginning of section 3.2.2, there is statement about the change in PAH composition with diesel HDVs manufactured in 2007 and later. Could you please elaborate as to how PAH composition changes with newer engines?

Response: We added the text to the beginning of Section 3.2 (PAH from Diesel) in the MOVES3 air toxic report.

*"PAH emissions from diesel vehicles can be formed by combustion as well as post-combustion in the engine and aftertreatment systems.**Error! Bookmark not defined.** We have developed separate PAH emission rates for pre-2007 diesel, 2007-2009 diesel, and 2010+ diesel to represent the different combustion and aftertreatment strategies as discussed in the following subsections."*

We added additional text at the beginning the discussion of Section 3.2.2 (2007+ diesel PAH) that discussed control and formation of PAHs in oxidation catalysts used in 2007+ diesel aftertreatment configurations, including citing relevant studies. (See response to Dr. Karavalakis's last comment of this report).

We also added text to the end of the Section 3.2.2 (2007+ diesel PAH) mentioning that the PAH fractions of VOC and PM are generally lower with the 2007 and 2010

engines:

"The 2007 and later engines have lower gaseous PAH fractions than the pre-2007 engines with the exception of naphthalene, and phenanthrene, and most of the particulate phase PAHs. The 2010 and later engines emissions technologies facilitate further reductions in PAHs and have significantly lower fractions of all gaseous and particle-phase PAH emission rates than the 2007-2009 emission rates, with the exception of benzo(a)anthracene."

Why didn't the toxic fractions differentiated by emission process?

Response: *In general, the test procedures did not allow us to develop toxic fractions that varied for starts and running. We added clarifying text as follows to the MOVES3 air toxic report[4]:*

- *For gasoline vehicles, we added text to Section 2.1 Vehicles Operating on Fuel Blends Containing 0-20 percent Ethanol, that states "Because the PAH measurements from the LA-92 cycle include both start and running emissions, we use the same VOC fractions for both start and running PAH emissions."*
- *We also added text to Section 2.2.1 (PAHs for gasoline vehicles on low ethanol blends) explaining that we adjusted the PAH/PM2.5 fraction by the fraction of OC measured in the start (42.6 percent) and running emission processes (55.7 percent) to produce PAH/OC2.5 emission fractions. Because OC/PM fractions differ for start and running, we have separate PAH/OC toxic fractions for start and running."*
- *For diesel vehicles, we added the following statement to the Section 3.1 Volatile Organic Compounds "For each model year group, the toxic fractions were developed from test cycles that included both running and start exhaust emissions and the same toxic fractions."*
- *We also specified in the Section 3.1.1 (Pre-2007 Diesel VOC) that for the VOC fractions developed from the CRC E-75 database. "A single set of toxic fractions were developed from the measurements from different test cycles, with no differentiation between cycles with start emissions and running emissions only."*
- *In Section 3.1.2 (2007+ Diesel VOC), we discussed "We made use of data from the 16-hour transient cycle which is composed of FTP and CARB 5-Mode cycles, developed specifically to gain sufficient mass of toxics emitted at low concentrations, and to capture diesel particulate filter regeneration events."*
- *In the Section 3.2.1 (PAH Pre-2007 Diesel) we clarified, "PAH fractions for pre-2007 diesel engines were calculated using results from the E-75 database. A single set of PAH /VOC fractions were derived for the E-75 database that represent both start and running exhaust. For the particulate phase, a single fraction was first calculated with respect to total PM2.5, and then converted to a fraction of total OC2.5 using estimates of OC as a*

fraction of total PM2.5. Note that the OC/PM fractions differed by emissions process, thus for MOVES we obtained with separate PAH/OC2.5 fractions applied for start, running and extended-idle emissions."

- *In Section 3.2.2 (PAH 2007+ Diesel) we clarified: "The 16-hour drive cycle used in the ACES studies comprises multiple driving modes and is used to represent both start and running exhaust in MOVES."*
- *In Secton 4.2 (PAH CNG), we clarified that the VOC and PAH fractions are applied to both start and exhaust emission rates.*

Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made by EPA while developing the model inputs? Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

Overall, the methods and procedures were well described and defined.

Was the measurement uncertainty for the gaseous air toxics taken into account? If the measurement uncertainty for some toxics is considerably great, how is the model affected? What is the accuracy of the model?

Response: In the introduction of the MOVES3 air toxic report, we added a qualitative discussion of measurement uncertainty, and noted that the uncertainties in emission estimates may be substantial. We do not have a quantitative estimate of the uncertainty or accuracy of the model estimates.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics? Are you able to suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs? In making recommendations please distinguish between instances involving reasonable disagreement in adoption of methods as opposed to instances where you conclude that current methods involve specific technical errors?

The methods and approaches are technically sound. The assumptions followed for the hexavalent chromium estimations appear to be sound.

No Response Needed

Where EPA has concluded that applicable data is meager or unavailable, and consequently has made assumptions to frame approaches and arrive at solutions, do you agree that the assumptions are appropriate and reasonable? If not, and you are able to do so, please suggest alternative assumptions that might lead to more reasonable or accurate model inputs.

For this section, the amount of data is quite comprehensive and all the assumptions made by EPA are appropriate.

No Response Needed

Are the resulting model inputs appropriate and, to the best of your knowledge and experience, reasonably consistent with physical and chemical processes involved in mobile source emissions, formation and control? Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

The resulting model inputs described in this document are appropriate. What might be missing from MOVES201X are the nitrated PAH emissions that can be formed de novo in the DPF/SCR system through nitration reactions. From toxicity and human exposure standpoints, some of these species (i.e., 1-nitropyrene) should be included in the model.

Response: We added the following statement to the Introduction (Section 1) of the MOVES3 air toxic report about why nitrated PAH are not included in MOVES:
"*MOVES estimates the sixteen PAHs (**Error! Reference source not found.**Table 1-2) that are included in the National Emissions Inventory (NEI), which does not include nitrated PAHs."*

We added the following text to Section 3.2.2:
"Advanced emission controls used in 2007 and later model year diesel including diesel vehicles particulate filters, diesel oxidation catalysts, and selective catalytic reduction (SCR) catalysts and ammonia oxidation catalysts can reduce or facilitate the formation of individual PAHs. PAHs are destroyed through oxidation by diesel oxidation catalysts, catalyzed-diesel particulate filters and NO2 present in the aftertreatment that is produced by the diesel particulate filter but controlled by the SCR Modern aftertreatment systems can also facilitate the formation of individual PAH. For example, Liu et al. 2015 measured an increase in nitrated PAHs emissions in some tests configurations of a nonroad diesel engine with oxidation catalyst + SCR aftertreatment systems compared to a baseline case with no diesel aftertreatment system."

Exhaust Emission Rates for Light-Duty On-road Vehicles in MOVES201X

Dr. Janet Yanowitz:

Section 1.4

Throughout - the terms HC and THC are used, I believe interchangeably. If this is true I would suggest you use only one term and that it be however you refer to pollutantID1 for clarity.

Response: We have added the following statement to the Section 2.2 of the Background Section in the MOVES3 light-duty exhaust report.[5]

"MOVES estimates other organic gas aggregations as ratios from the THC emission rates, including methane (CH4), non-methane hydrocarbons (NMHC), volatile organic compounds (VOC), total organic gases (TOG), and non-methane organic gases (NMOG). The definitions and methods for estimating these other organic gas aggregations are documented in the MOVES speciation report. THC emissions are intended to include all hydrocarbon emissions and are operationally defined as measurements made with a flame ionization detector. In this report we also use the term hydrocarbons (HC) emissions to refer specifically to emissions of compounds of carbon and hydrogen (regardless of the measurement method), and more generally, to other measures of organic gases that are primarily composed of hydrocarbons, including NMHC and NMOG."

Additionally, we have updated the terms to refer to THC when it refers to emission rates for pollutantID 1 in MOVES, as well as measurements from a flame ionization detector (FID). In other places we have left the term hydrocarbons when we are referring to hydrocarbons more generally.

1.4 - second paragraph - Excess fuel is not the only reason for "start emissions". Another reason for "start emissions" is the temperature of the catalytic converter. It does not work effectively until it heats up. To further explain why excess fuel leads to excess emissions you might wish to explain that the catalytic converter is designed to operated optimally at stoichiometric air/fuel ratio. At the lower air/fuel ratio, the catalytic converter is less efficient at controlling HC and CO emissions.

Response: We have added language to this paragraph to describe the role of these additional factors in the formation of start emissions.

Table 1-26 Suggest that you add the word "adjusted" to the title to clarify that it is not just Bag1-Bag3

Response: We have added the term "adjusted" to the title to clarify this point. In any case, the application of the adjustment is implicit in the term "Cold-start," as used in Equation 1-42 (Now Equation 3-47)[b].

Line 6 - how do you adapt MY 1994-1999 sample results when this section only goes to MY 1995?

Response: The reviewer's comment is well taken. The sentence in the draft report was no longer relevant as written and has been revised to reflect the fact that the model-year group spans 1990-1995.

Table 1-28 - Table 1-28 and Table 1-25 seem to be talking about cold start emissions for the same group of cars (MY 1995 and earlier). If so please add "MY 1995 and earlier" to the title of this table.

Response: We have added the label "MY 1995 and earlier" to the title of the tables

(now Table 3-49 and Table 3-51).

Table 1-28 - what I think you are saying here is that the cold start HC emissions after a 3 minute soak are 5.1 percent of the cold start emissions of 720 minute soak; and for an 18 minute soak the cold start emissions are roughly 26.9 percent of the cold start emissions of a 720 minute soak. In Equation 1-42 is based on the same relationship although only between the cold start emissions of a 10 minute soak and the 720 minute soak. Not sure if this is obvious so I show below how I get this by restating Equation 1-42 as follows:

Bag1 - total emissions after 720 minute soak

Bag3 - total emissions after 10 minute soak

and to this we add another variable: the unmeasured (i.e. hypothetical) emissions after a soak of 0 minutes - let's call this Bag0.

Cold Start Emissions = Bag1 - Bag0

Cold Start Emissions after 10 minute soak = Bag3-Bag0

(Bag1- Bag 0) = (Bag1 - Bag3)/(1-A)

(1-A)*(Bag1-Bag0) = Bag1 - Bag3

Bag1-Bag0-A(Bag1-Bag0) = Bag1-Bag3

A(Bag1-Bag0)=Bag3-Bag0

A(Cold Start Emissions after 720 minute soak)=Cold Start Emissions after 10 minute soak

Response: We agree that Equation 1-42[b] (Now Equation 3-47) describes the difference between the 720-minute and 10-minute soak periods, as these are the periods that apply to the cold-start and hot-start phases of the Federal Test Procedure, i.e., Bag 1 and Bag 3, respectively. The fractions for the 3-minute and 18-minute soak periods were estimated by evaluating piece-wise regression equations relating start emissions to soak time at these times, which represent the midpoints of the respective operating modes.

Table 1-25 says that for a catalyst equipped vehicle HC emissions after a 10 minute soak are 12.09 percent of those after the 720 minute soak, i.e. the "A" value is .1209. This is roughly what you would get interpolating between the values for the 3 and 18 minute soak in Table 1-28, in which the adjustment (A) values are 0.051 and 0.269, respectively. Similarly for CO. However it does not work for NOx: Table 1-28 the adjustment (A) values for cold start NOx emissions for 3

[b] In the most recent revision of the report, for MOVES3, Eqn 1-42, Table 1-25 and Table 1-28 are Eqn 3-47, Table 3-49 and Table 3-51, respectively.

and 18 minute soaks are 0.093 and 0.347 but in Table 1-25 for a 10 minute soak the adjustment (A) value is .39366. Perhaps there is an explanation for this discrepancy, however I think you need to explain and make sure you have calculated these values correctly.

Response: The adjustment in Equation 1-42 (Now Equation 3-47) and the associated values in Table 1-25 (Now Table 3-49)1 are not the same as the adjustment in Table 1-28 (now Table 3-51). As explained in detail in the MOBILE6 report,[10] the first set of adjustments are derived directly from CARB data, while the second have been further adjusted to account for EPA data on hot and cold starts. This further adjustment is larger for NOx than for the other pollutants.

Figure 1-43. It is interesting that NOx emissions are highest for the cold starts after intermediate length soaks. The FTP includes one very long soak (i.e. the start of Bag 1) and one short soak (start of Bag 3). Thus it does not capture this effect of increased emissions in vehicle certification testing. If EPA finds that intermediate soaks are common and producing significant emissions, then it will need to consider including intermediate soaks in its standard certification test procedure as currently available sophisticated engine controls are capable of controlling operating conditions to minimize this issue. As long as intermediate soaks are not part of the test procedure, OEMs will have not have motivation to control these emissions.

Response: As an inventory model, MOVES attempts to represent on-road emissions as they occur in the "real world," reflecting the effects of applicable emissions standards. The reviewer suggests that EPA modify regulations and associated test procedures. This suggestion is beyond the scope of this review.

Figures 1-43, 1-45 and 1-46. It does not appear that cold start conditions have plateaued at 720 minutes. In the future you will need to add longer cold soaks to the experimental test conditions.

Response: We believe that the reviewer was referring to Figures 1-47, 1-48 and 1-49, (now Figures 3-83, 3-85, and 3-86 in the MOVES3 report) In the figures, these values are assigned to a nominal soak time of 12 hours. In fact, many of the test results were measured after soak periods longer than 12 hours, i.e., it was practical to measure the "cold-start" early in the morning following an overnight soak. In any case, we assume that 12 hours is long enough to allow the engine to cool to ambient temperature, beyond which point additional time would have no additional effect on the "cold-start" emissions.

1.4.3.2 Line 13. https://www.fhwa.dot.gov/policyinformation/statistics/2013/vm1.cfm has more accurate data on the average rate of mileage accumulation per vehicle. It is higher than 10,000 miles per year.

Response: We agree that the initial estimate of 10,000 miles/year was low. For the most recent update, we repeated the calculations for MY 1990 and later with a revised estimate of 12,500 miles/year as clarified in Section 3.9.3.3.1 of the MOVES3 light-duty report.

Section 2.2

2.2.1 Line 10-11. Add reference for the Kansas City study.

Response: A reference for the Kansas City study was added into the section (now Section 4.2.1).

2.2.2 Lines 17-25 and Table 2-7. In Section 2.3.2 of Emission Adjustments for Temperature, Humidity, air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES201X you conclude that the "significant PM running temperature effect detected for Bag 2" in the LA92 test cycle is "due to the short duration and relatively mild accelerations of the cold-start phase of the LA92 cycle, which is only 310 seconds in length. We note that the PM temperature effect was much larger at the beginning of Bag 2 than at the end." This suggests that at least in cold temperatures there are "start emission" effects in Bag 2. Do you find that for the room temperature starts considered in this section that there is any difference between the start and the end of the cycle for the same operating modes? If some "start emission" effects spill over into Bag 2 in the LA92 test cycle, this would also suggest that the "start emission" effects measured as Bag 1 - Bag 3 would also be underestimated in LA92. Did you find any significant differences in the "start emissions" between FTP and LA92?

Response: As we only analyzed filter masses, we could not determine if spillover start emissions were measured. We did not observe significant differences between FTP and LA92 starts.

Table 2-9. Make it clear that the first row of numbers are superseded by the second row - perhaps call first row "unadjusted scaling factor from new data (Table 2-8)" and second row "scaling factor from new data adjusted based on additional historical data"

Response: The row descriptions in the table (now Table 4-8) were updated to improve clarity, and refer to the unadjusted scaling values from the previous table (now Table 4-7)

2.2.6.2 Line 26 - you refer to "the combined curves", however the description above refers only to the sigmoid fit curve to the original data. Please describe how the other curve was generated.

Response: The combined curve pairs the pre-2016 data with the fitted post-2016 sigmoidal fit. The description in the text in Section 4.2.6 in the MOVES3 report has been updated to help clarify this.

2.2.6.3 Equation 2-7 This equation for the entire fleet needs to be changed to account for the different scaling parameters and different populations of LDVs and LDTs.

Response: the emission rates were calculated separately for each regClass in the model (LDV, LDT) using the same equation. We clarified in the MOVES3 report that this equation (now Equation 4-7) was applied "for each regClass."

Figures 2-26, 2-27, 2-28 and 2-31 - Suggest adding "-not adjusted for phase-in of Tier 3 standards" to end of caption for each table

Response: The suggested text was added to the end of the captions for Figure 4-26, 4-27, and 4-28 in the MOVES3 light-duty exhaust report. Figure 4-31, on the other hand, represents the final rates including the adjustments and was not updated.

Figure 2-29 - Suggest adding to the caption "Base Rate is prior to adjustment for phase-in of Tier 3 standards."

Response: The recommended clarifying text was added to the caption (now Figure 4-29) .

The MOVES2014 PM emission rates and the new PM emission rates for 201X for the model years 2004 - 2015 differ by more than a factor of 2. It is quite useful to compare current and past estimates as you do here, as it gives the reader some idea of the uncertainty surrounding these estimates and I think the EPA should consider adding this type of graph to every section of the report. It would be useful to explain why you think this significant change occurred and consider if a similar uncertainty surrounds this new modeling effort.

Response: We added a new section (4.3 Comparing Light-Duty PM Emission Rates Between Pre-2004 and 2004-and-later model years) that discusses reasons for the large differences observed in the pre-2004 and 2004 and later model years. We also discuss the relative confidence we have in both the pre-2004 and 2004 and later model year emission rates.
See our response to Dr. Yanowitz's comment in the General comments about adding documentation and comparisons to previous model inputs.

Dr. Georgios Karavalakis

Does the presentation describe the selected data sources sufficiently to allow the reader to form a general view of the quantity, quality, and representativeness of data used in the analysis? Are you able to recommend alternate data sources that might better allow the model to estimate national or regional default values?

This section is well written, well organized with sufficient quantity and quality of data used in the analysis. The analysis successfully included the cold-start emissions and implemented a correction factor A for different emissions. Why EPA didn't apply this correction factor for NMHC and CH4 emissions?

Response: We added a paragraph in the Section 2.2 that describes that methane, NMHC, and other organic gas aggregations are estimated from the THC emission rates in MOVES.

EPA did a good job in emphasizing mileage accumulation and odometer readings.

No Response Needed

EPA went into great efforts to emphasize on GDI PM emissions. It is also useful that fuel type and composition were also considered in the analysis.

No Response Needed

I am concerned that the model fails to capture PM emissions from GDI vehicles with different injection architectures (wall-guided versus spray-guided) that are generally significantly different.

Response: Not enough data of both injection types were available to differentiate between them for this update. A sentence to this effect was added to the last paragraph of Section 4.2.1.

Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made by EPA while developing the model inputs? Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

The description of analytic methods and procedures is very detailed and comprehensive. There are several examples throughout the document explaining the steps taken by EPA in the development of the model. The tables and figures are sufficient, providing detail and clear information to the reader.

No Response Needed

For the PEMS work, EPA should comment on the PEMS limitations, including measurements variability and repeatability. EPA should have done a PEMS correlation study in the lab mimicking the real-world testing.

Response: Following release of the draft inputs, we completed an additional analysis that combined the PEMS measurements acquired by EPA with a larger set of dynamometer results collected by the California Air Resources Board, measured on the Unified cycle. The inclusion of the additional data resulted in a substantial increase in sample size. In the revised report (for MOVES3), the entire dataset is presented graphically, after averaging by vehicle and soak period. These plots give a clear depiction of the degree of the inter-vehicle variability present in the data for all three pollutants. In addition, they serve as a de-facto comparison of the PEMS data to similar laboratory data. On the whole, it is clear that the repeatability for the PEMS data is adequate for use in estimating start emissions.

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics, and statistics? Are you able to suggest or recommend alternate approaches that might

better achieve the goal of developing accurate and representative model inputs? In making recommendations, please distinguish between instances involving reasonable disagreement in adoption of methods as opposed to instances where you conclude that current methods involve specific technical errors.

I have reviewed the methods and procedures and the mathematics. They all appear to be technically sound and are described in reasonable detail.

No Response Needed

Where EPA has concluded that applicable data is meager or unavailable, and consequently has made assumptions to frame approaches and arrive at solutions, do you agree that the assumptions are appropriate and reasonable? If not, and you are able to do so, please suggest alternative assumptions that might lead to more reasonable or accurate model inputs.

The assumptions made to determine GDI truck scaling factors are both reasonable and appropriate. No Response Needed

Are the resulting model inputs appropriate and, to the best of your knowledge and experience, reasonably consistent with physical and chemical processes involved in mobile source emissions, formation, and control? Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

I believe the resulting model inputs are appropriate and generally consistent with the body of data and published literature. Overall, the model seems to be well specified and much more comprehensive than previous versions. To the best of my knowledge, much of the design used for MOVES201X is well articulated in this draft documented, which will help the reader understand how the model was developed.

No Response Needed

Emission Adjustments for Temperature, Humidity, Air Conditioning, and Inspection and Maintenance for On-road Vehicles in MOVES201X

Dr. Janet Yanowitz

Section 2.3.2. Second paragraph - MSAT-2 (Mobile Source Air Toxics) rules apply to fuels, so vehicles cannot be MSAT-2 compliant.

Response: We updated the discussion of the MSAT-2 rule in Section 2.1 in the MOVES3 adjustments report[6] with additional text stating the updated emission standard on the FTP, and explanations of the MSAT-2 terminology, and citations to the MSAT and MSAT-2 rulemakings.

Table 2-11 - third study is a tunnel study - this type of study cannot be used to tease out small differences in gasoline PM2.5 tailpipe emissions between winter and summer. The authors did not attempt this for good reason. There can be significant differences in the PM on the roadway between summer and winter unrelated to gasoline tailpipe emissions such as the application of salt. Gasoline tailpipe PM emissions are only a small part of the total PM measured. EPA's Chemical Mass Balance (CMB) model used in this analysis does not differentiate between tire wear emissions and gasoline vehicle tailpipe emissions because they have a similar chemical profile. For all these reasons this study is not applicable to drawing a conclusion one way or the other on the effect of temperature on small changes in running PM2.5 emissions from gasoline vehicles and should be removed.

Response: In summarizing the tunnel study in the table (now Table 2-12), we updated the text to specify that the gasoline tailpipe emissions are estimated to be the primary contributor to the $PM_{2.5}$ (EC + OC) emissions, and that EC and OC emissions are reduced in the winter compared to the summer. In addition, we have added text that discusses that the winter tests had comparable or larger PM measurements of inorganic ions and metals (including Na and Cl) presumably due to road salt in the winter.

We agree that the study should not be used to determine the effect of small changes in running $PM_{2.5}$ emissions. However, MOVES2014 has a large temperature effect on running $PM_{2.5}$ emissions (emissions increase 10X between 72F and 0 F).

We also updated the text to clarify that the studies evaluated in the literature review were not conducted to specifically to evaluate a temperature effect in PM emissions, but they were studies that could be used to evaluate if a significant temperature effect exists: "For MOVES3, we conducted a literature review from other studies that conducted measurements particulate matter emissions from gasoline vehicles including model years before 2004 at different ambient temperatures."

Dr. Georgios Karavalakis

Does the presentation describe the selected data sources sufficiently to allow the reader to form a general view of the quantity, quality and representativeness of data used in the analysis? Are you able to recommend alternate data sources that might better allow the model to estimate national or regional default values?

The analysis conducted for the PM running emissions and exhaust temperature effects is well done. I believe that EPA did well to remove the temperature effect for Tier 2 vehicle in MOVES2014 and it was also an appropriate approach removing the running temperature effect for PM emissions from MOVES201X. It appears that EPA did a thorough literature search on the available data and reached on a reasonable conclusion for the current model.

No Response Needed

Is the description of analytic methods and procedures clear and detailed enough to allow the reader to develop an adequate understanding of the steps taken and assumptions made by EPA while developing the model inputs? Are examples selected for tables and figures well-chosen and effective in improving the reader's understanding of approaches and methods?

This section is clear and concise with enough details for the reader to understand the steps taken by EPA to remove the running temperature effect for PM emissions from the current model.

No Response Needed

Are the methods and procedures employed technically appropriate and reasonable, with respect to the relevant disciplines, including physics, chemistry, engineering, mathematics and statistics? Are you able to suggest or recommend alternate approaches that might better achieve the goal of developing accurate and representative model inputs? In making recommendations please distinguish between instances involving reasonable disagreement in adoption of methods as opposed to instances where you conclude that current methods involve specific technical errors.

While all methods and procedures employed for this task were technically appropriate and reasonable, I would suggest to keep monitor the future published data on PM running emissions and temperature effects from GDI vehicles. I consider this more of a reality check to make sure the temperature has no effect on PM running emissions and what was observed in KCVES was indeed an artifact of the measurement.

Response: We added text to clarify that the OTAQ cold temperature program included GDI vehicles, however the GDI vehicles were excluded from the evaluation of the gasoline PM start temperature effects (Section 2.2), and included in the evaluation of the gasoline PM running temperature effects (Section 2.3). We added cross-references to Appendix B which displays that 2 of the 9 vehicles in the OTAQ light-duty gasoline 2012 cold temperature program were GDI vehicles. We have listed the importance of evaluating temperature effects from additional data on modern GDI vehicle technologies in Section 2.7 "Conclusions and Future Research" at the end of the Temperature Adjustments Section: "Incorporating data on the impact of temperature effects on new technology vehicles, including Tier 3 gasoline direct injection, stop-start technologies and hybrid technologies."

Where EPA has concluded that applicable data is meager or unavailable and consequently has made assumptions to frame approaches and arrive at solutions, do you agree that the assumptions are appropriate and reasonable? If not, and you are able to do so, please suggest alternative assumptions that might lead to more reasonable or accurate model inputs.

Based on the available data EPA used, the conclusions and assumptions derived in section are all reasonable and scientifically accurate.

No Response Needed

Are the resulting model inputs appropriate and, to the best of your knowledge and experience, reasonably consistent with physical and chemical processes involved in mobile source emissions, formation and control? Are the resulting model inputs empirically consistent with the body of data and literature with which you are familiar?

The resulting model inputs are appropriate and in-line with the literature.

No Response Needed

References

---

[1] 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.

[2] USEPA (2017). *Speciation and Toxic Emissions from Onroad Vehicles, and Particulate Matter Emissions from Light-Duty Gasoline Vehicles in MOVES201X - Draft Report*. Draft report and peer-review documents. Record ID 328810. EPA Science Inventory. September 2017. https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=328810.

[3] USEPA (2020). *Speciation of Total Organic Gas and Particulate Matter Emissions from Onroad Vehicles in MOVES3*. EPA-420-R-20-021. Office of Transportation and Air Quality. US Environmental Protection Agency. Ann Arbor, MI. November 2020. https://www.epa.gov/moves/moves-technical-reports.

[4] USEPA (2020). *Air Toxic Emissions from Onroad Vehicles in MOVES3*. EPA-420-R-20-022. 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). *Exhaust Emission Rates for Light-Duty Onroad Vehicles in MOVES3*. EPA-420-R-20-019. Office of Transportation and Air Quality. US Environmental Protection Agency. Ann Arbor, MI. November 2020. https://www.epa.gov/moves/moves-technical-reports.

[6] USEPA (2020). *Emission Adjustments for Temperature, Humidity, Air Conditioning, and Inspection and Maintenance for Onroad Vehicles in MOVES3*. EPA-420-R-20-013. Office of Transportation and Air Quality. US Environmental Protection Agency. Ann Arbor, MI. November 2020. https://www.epa.gov/moves/moves-technical-reports.

[7] Harold M. Haskew and Thomas F. Liberty. *CRC E-77-2 Enhanced Evaporative Emission Vehicles*. http://www.crcao.com/reports/recentstudies2010/E-77-2/E-77-2_Final_ Report March_2010.pdf, March 2010.

[8] Harold M. Haskew and Thomas F. Liberty. *CRC E-77-2b Evaporative Emissions From In-use Vehicles: Test Fleet Expansion*. http://www.epa.gov/otaq/emission-factors-research/ 420r10025.pdf, October 2010.

[9] Harold M. Haskew and Thomas F. Liberty. *CRC E-77-2c Study to Determine Evaporative Emission Breakdown, Including Permeation Effects and Diurnal Emissions Using E20 Fuels on Aging Enhanced Evaporative Emissions Certified Vehicles*. http://www.crcao.com/reports/recentstudies2011/E-77-2c/E-77-2c%20Final% 20Report%20for%20sure%201-28-11.pdf, December 2010.

[10] USEPA (2001). Determination of Start Emissions as a Function of Mileage and Soak time for 1981-1993 Model-year Light-Duty Vehicles. EPA420-R-01-058 (M6.STE.003). Office of Transportation and Air Quality Assessment and Standards Division, Ann Arbor, MI. November, 2001.